



MULGA ROCK URANIUM PROJECT

RESULTS OF HYDROGEOLOGICAL INVESTIGATIONS AND NUMERICAL MODELLING, PLANNED KAKAROOK NORTH BOREFIELD

REPORT FOR VIMY RESOURCES LTD

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Appendix D - Hydrological Processes / Inland Waters Environmental Quality

D1

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

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1 INTRODUCTION

The Mulga Rock Uranium Project (MRUP) lies approximately 240km east-north-east of Kalgoorlie-Boulder in the Shire of Menzies (Figure 1). The area is remote, located on the western flank of the Great Victoria Desert, comprising series of large, generally parallel sand dunes, with inter-dunal swales and broad flat plains.

Access to the Project area is limited and is only possible using four-wheel-drive vehicles. The nearest residential town to the Project is Laverton which lies approximately 200 km to the north-west. Other regional residential communities include Pinjin Station homestead located approximately 100km to the west, Coonana Aboriginal community situated approximately 130km to the south-south-west, Kanandah Station homestead positioned approximately 150km to the south-east and the Tropicana Gold Mine lying approximately 110km to the north-east of the Project (Figure 1).

The MRUP covers approximately 102,000 hectares on granted mining tenure (primarily M39/1080 and M39/1081) within Unallocated Crown Land (UCL). It includes two distinct mining centres, Mulga Rock East (MRE) comprising the Princess and Ambassador resources and Mulga Rock West (MRW) comprising the Emperor and Shogun resources, which are approximately 20km apart (Figures 2 and 3). MRE contains over 65% of the total recoverable uranium and is of a higher grade than MRW. Mining will commence at MRE which will include the location of the processing plant. Up to 4.5 Million tonnes per annum (Mtpa) of ore will be mined using traditional open cut techniques, crushed, beneficiated and then processed at an acid leach and precipitation treatment plant to produce, on average, 1,360 tonnes of uranium oxide concentrate (UOC) per year over the life of the Project. The anticipated Life-of-Mine (LOM) is up to 16 years, based on the currently identified resource.

Other metal concentrates will be extracted using sulphide precipitation after the uranium has been removed and sold separately. These metal concentrates will not be classified as radioactive. The UOC product will be sealed in drums and transported by road from the mine site in sealed sea-containers to a suitable port (expected to be Port Adelaide) which is approved to receive and ship Class 7 materials for export.

The MRUP will require the clearing of vegetation, borefield abstraction, mine dewatering and reinjection, the creation of above-ground and in-pit overburden (non-mineralised) and tailings landforms and the construction of on-site processing facilities and associated infrastructure. Key Project infrastructure will include mine administration and workshop facilities, fuel and chemical storage depots, a diesel-fired power plant of up to 20 megawatt (MW) capacity and distribution network, a saline abstraction borefield and a saline mine water reinjection borefield with associated pipelines and power supply units, an accommodation village servicing a fly-in/fly-out workforce, an airstrip, laydown areas and other supporting ancillary infrastructure including communications systems, roads, a waste water treatment plant and solid waste landfill facilities. Transport to site for consumables, bulk materials and general supply items will be via existing public road systems linked to dedicated Project site roads, branching off the Tropicana Gold Mine access road.

At the completion of operations, the Project site will be decommissioned and rehabilitated in accordance with an approved Mine Closure Plan.

As a result, the MRUP plans to develop a borefield at Kakarook North, about 30 km north-east of the Ambassador deposit (Figure 4), to supply low-salinity water for processing ore and camp use. A supply of up to 3 GL/a (at an average of 1.8 GL/a) will be needed.

In 1990, Ramsgate Resources Limited carried out exploration for mineral sands on a series of drillhole lines in the Kakarook area. Low-salinity water was intersected in a number of the drillholes.

Vimy Resources Limited (Vimy) has drilled 52 investigation holes/monitoring bores and one test-production bore in the Kakarook North area (Fig. 5) and has delineated a southerly-trending sedimentary basin with a saturated thickness of sediments of up to 42 m over a length of about 16 km and width of 5 to 8 km. The basin is open to the north and south, although several holes drilled to the north by BP Minerals intersected similar sediments; and another basin has been indicated by drillholes to the west.

This report presents the results of geological and hydrogeological investigations in the area, as well as numerical modelling to determine the potential impacts of groundwater extraction, to support an application to the Department of Water (DoW) for a licence to take water.

2 HYDROGEOLOGICAL SETTING

2.1 CLIMATE

The MRUP is located in the Great Victoria Desert and has an arid climate with hot dry summers and cool to mild winters. The nearest long-term climate station is at Edjudina (BoM Station 012027), 170 km to the west of the planned borefield. Average rainfall data for the station (1900 to 2014) is given in Table 1.

Table 1: Average Monthly Rainfall (mm) Edjudina (BoM Station 012027)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
22.4	28.2	26.1	19.6	22.0	22.1	19.2	16.7	9.7	11.8	14.0	12.8	222.6

Most of the rain falls in irregular thunderstorm events or during the passage of the remnants of cyclones, with some frontal systems in winter. Daily rainfalls have been up to 98mm (in February). No other climate data are available for the station.

The Mulga Rock Uranium Project has had climate stations at the airstrip and at the Emperor and Shogun deposits since March 2009. A suite of climatic measurements has been made including rainfall, maximum and minimum air temperature, and pan evaporation.

Rainfall at the Mulga Rock airstrip from 2010 to November 2014 can be compared with that at Edjudina in Table 2.

Table 2: Comparison of Annual Rainfalls, Edjudina and Mulga Rock

Year	Total Rainfall (mm)	
	Edjudina	Mulga Rock
2010	222	173
2011	503	433
2012	337	129
2013	284	170
2014 to Nov.	469	160

The comparison in annual rainfall amounts over the period shown suggests that the climate at MRUP is substantially drier than at Edjudina.

Pan evaporation at the MRUP airstrip station from Dec-13 to Nov-14 was significantly lower than the average for Kalgoorlie (Luke, Burke and O'Brien, 1988), as shown in Table 3.

Table 3: Comparison between Average Pan Evaporation at Kalgoorlie and Mulga Rock (2014)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mulga Rock (2014)	306	280	225	211	150	91	81	90	140	206	255	276	2309
Kalgoorlie (Av.)	431	346	306	199	133	93	103	130	181	271	326	424	2943

In 2014, average maximum air temperatures ranged from 18.6^{o}C in June to 34.6^{o}C in January; and average minimum temperatures ranged from 1.1^{o}C in July to 18.0^{o}C in January.

2.2 GEOLOGY

The Kakarook North borefield lies within an elongated basin or graben that is at least 16 km long and 5 to 8 km wide (Fig. 5). Data obtained from holes drilled to the north by BP Minerals suggest that the basin extends a further 10 km north (holes OB86, 92 and 98 in Fig. 5). A second aquifer area has been outlined in the Kakarook (BP bore) area, south-west of the Kakarook North borefield, using data from Kakarook mineral sand exploration holes and from Bores NGW50 to 53 drilled recently by Vimy Resources. Thin, and in some places thick, aquifers extend over a larger area than shown in the figure, and some of the drillholes did not intersect the full Eocene/Cretaceous sequence, and it is likely that the basin extends further to the north than shown.

The Kakarook North bores typically intersected a thin layer of aeolian sand overlying interbedded sand, clayey sand, sandy clay, and clay, with beds generally 1m to 6m thick; interpreted by Vimy geologists to be of Miocene-Pliocene, Late Eocene, and Cretaceous in age. Grain sizes of the sand layers range from fine to very coarse and granular, and there are commonly conglomerates at the bases of the Eocene and Cretaceous strata. The sands are generally well sorted.

The Cretaceous sediments were intersected in deeper parts of both the Kakarook North and BP Bore areas and are interpreted to occupy grabens within the Proterozoic bedrock. An east–west hydrogeological cross-section through the Kakarook North borefield is shown in Figure 6, and a north–south longitudinal section through the borefield in Fig. 7. Values of total saturated sediment thickness are shown in Figure 8.

2.3 HYDROGEOLOGY

Sands and conglomerates of Eocene and Cretaceous age form a single, interconnected, semi-unconfined aquifer (at the water table) that is confined by clay beds at depth. The thickness of sand beds increases towards the centre of the basin/borefield, with a maximum total thickness of about 19m at production bore NWB3 (Fig. 9). The sands are moderately permeable, with average permeabilities of the screened sections (which include some clay and clayey beds) of 7 to 11m/d, from the pumping test results described in Section 3.

The aquifer is recharged by the infiltration of rainfall and runoff following high rainfall events. In the Kakarook North borefield, groundwater flows to the south under a low hydraulic gradient in the north increasing to 0.0042 in the south, as shown by the water-level contours in Fig. 10. The water levels in the BP bore area range from 306.4m AHD in NGW50, to 309.8 to 310.0m AHD in NGW51–53, indicating a south-easterly direction of flow. These levels and flow directions give no indication of a hydraulic connection between the BP bore area and the Kakarook North borefield, although it is possible that groundwater flows to the east from the southern end of the BP area towards the southern end of the Kakarook North area, and then continues to flow eastwards along the northern edge of a basement high that has been interpreted from aeromagnetic images.

The area and mechanism of groundwater discharge are not known; although in the BP bore area the water table is as shallow as 1.5m (NGW50) and there are gypsiferous (kopi) areas that have been identified by Vimy geologists, where groundwater discharges, or has discharged in the past, by evaporation.

The volume of groundwater in storage in sandstone beds in the area of Kakarook North that has been drilled by Vimy Resources, is calculated to be about 167GL (93 times the annual water requirement for the proposed project). There will be additional water to the north and south of that area.

2.3.1 Groundwater Quality

Groundwater in the Kakarook North borefield is slightly saline, with salinities ranging from 2,400 to 8,800mg/L TDS and mostly less than 6,000mg/L TDS (Fig. 11). The higher salinities are mostly near the edges of the basin where the aquifer is thinner, and the lower salinities are towards the centre of the basin.

The water is mildly acidic to slightly alkaline, with pH ranging from 5.0 to 7.7. It is of a sodium chloride type with moderately high sulphate concentrations (up to 1,400 mg/L). Oxidation Reduction Potential values range from 34 to 295 mV, indicating an oxidising environment; albeit, still below the approximate 600 mV (SHE) redox potential required to oxidise ferrous (Fe^{2+}) to ferric (Fe^{3+}).

Groundwater in the BP bore area ranges in salinity from 1,500 to 9,200mg/L, i.e. is of similar salinity to Kakarook North but has a wider range.

A Piper trilinear diagram of major ion composition of water from the Kakarook North bores (red symbols), BP bore area (green symbols), and south of Kakarook North (blue symbol, Fig. 12) indicates similar chemical composition in the three areas, and supports the possibility of groundwater flow to the east from the BP bore area as discussed in Section 2.3, above.

3 BORE CONSTRUCTION AND PUMPING TESTS

3.1 DRILLING AND BORE CONSTRUCTION

Vimy has drilled 52 investigation holes/monitoring bores and one test-production bore in the Kakarook North (and BP bore) area. Details of the bores are summarised in Table 4, and are described below.

The investigation/monitoring bores were drilled at 83mm diameter by Bostech Drilling Australia in 2013 and 2014 using air-core methods. They were completed with 40mm Class 9 uPVC pipe, slotted (1mm aperture) over the aquifer intervals given in Table 4.

Production bore NWB3 was drilled in February 2015 by Blue Spec Drilling, using mud-rotary methods. It was completed with 155mm Class 9 uPVC bore casing, machine-slotted (1mm aperture) from 16 to 34m and 46 to 58m depth. The annulus of the bore was packed with 1.6 to 3.2mm quartz gravel pack to 1m above the top slots, then 1.5m of bentonite, then cement grout. It was developed by airlifting and surging.

3.2 PUMPING TESTS

Bore NWB3 was test-pumped by Harrington Drilling from 6th to 9th March 2015.

The initial test was a step-rate test with four one-hour steps at 180, 305, 390 and 610 kL/d. The purpose of the test was mainly to select a suitable rate for the constant-rate test, but the results were also analysed to determine bore efficiency. The drawdown in the initial step was more than would be expected from the small drawdowns observed during the second to fourth steps – it is likely that the bore was not fully developed until the end of the first step. After correcting the data for the effects of bore development, they indicate the bore efficiency decreased from 57% in step 1 with a pumping rate of 2.1L/s, to 29% in step 4 with a pumping rate of 7.0L/s. A summary of the results is given in Appendix A.

Table 4: Summary of Bore Details

Bore	mE	mN	RLGL (m AHD)	Depth (m)	Slots (m btc)	Tot. Aqu. Thick. (m)	SWL (m bgl)	RLWL (m AHD)	TDS (mg/L)	pH	Area
Investigation/Monitoring Bores:											
NGW01	608307	6699054	327.18	35		4	13.36	313.82	3,950	6.87	Kakarook Nth
NGW02	606832	6699666	328.26	39	12-18	14	13.71	314.55	5,430	6.93	Kakarook Nth
NGW03	605301	6700306	330.93	42	18-27	16	14.85	316.08	4,050	7.57	Kakarook Nth
NGW04	603800	6700917	333.76	60	18-51	34	17.10	316.66	4,310	7.45	Kakarook Nth
NGW05	606994	6700758	329.31	39	18-61	12	13.95	315.36	6,030	6.91	Kakarook Nth
NGW06	605678	6701285	331.63	45	18-30	18	15.15	316.48	5,310	7.41	Kakarook Nth
NGW07	604378	6701799	333.72	54	23-45	27	16.84	316.88	4,090	7.73	Kakarook Nth
NGW08	606132	6703215	333.68	27	18-22	10	16.23	317.45	5,680	6.75	Kakarook Nth
NGW09	607330	6702603		24	NA	0	Dry				Kakarook Nth
NGW10	604659	6703701	335.77	39	16-31	14	18.20	317.57	4,270	7.7	Kakarook Nth
NGW11	608920	6703721		15	NA	0	Dry				Kakarook Nth
NGW12	607367	6704210		24	NA	0	Dry				Kakarook Nth
NGW13	605977	6704749	337.72	24	0-18	0	18.86	318.86			Kakarook Nth
NGW14	607570	6697670	333.22	45	19-34	6	22.31	310.91	4,780	6.94	Kakarook Nth
NGW15	606200	6698135	327.47	51	17-42	25	15.20	312.27	4,530	7.08	Kakarook Nth
NGW16	604667	6698727	330.61	60	21-48	35	16.16	314.45	4,120	7.12	Kakarook Nth
NGW17	603256	6699264	332.31	39	17-29	14	16.51	315.80	3,890	5.63	Kakarook Nth
NGW18	605616	6696707	326.56	60	22-52	40	16.53	310.03	4,590	7.48	Kakarook Nth
NGW19	604204	6697264	328.38	45	17-36	21	15.50	312.88	4,600	6.25	Kakarook Nth
NGW20	602823	6697923	327.16	33	10-20	3.5	11.94	315.22	6,280	6.9	Kakarook Nth
NGW21	603010	6695510	322.63	24	12-18	7	12.23	310.40	8,790	7.12	Kakarook Nth
NGW22	604143	6694757	328.7	51	27-39	20	21.68	307.02	4,990	6.8	Kakarook Nth
NGW23	603863	6694330	327.44	36	20-32	2	22.13	305.31	5,520	6.25	Kakarook Nth
NGW24	604021	6693287	319.06	32	18-30	0	14.47	304.59	5,440	6.15	Kakarook Nth
NGW25	602217	6696317	329.07	30	18-23	2.5	15.67	313.40	5,090	6.98	Kakarook Nth
NGW26	606059	6699977	330.41	39		18	14.51	315.91	5,320	6.45	Kakarook Nth
NGW39	604270	6707255	369.36	78	45-72	24	50.60	318.76	5,400	6.56	Kakarook Nth
NGW41	602505	6706054	360.89	99	43-91	40	42.70	318.19	4,400	7.23	Kakarook Nth
NGW42	602338	6701527	345.25	45	18-39	13	28.20	317.05	4,650	6.59	Kakarook Nth
NGW43	606112	6688383	304.27	30	12-30	4	13.70	290.57	12,600	7.33	Sth Kakarook
NGW45	608450	6693865	314.53	33	15-30	19	12.70	301.83	5,850	7.01	Kakarook Nth
NGW46	606209	6693185	315.2	33	13-31	18	11.65	303.55	4,800	6.10	Kakarook Nth
NGW47	605304	6695652	323.55	42	15-39	19.5	15.00	308.55	4,067	6.51	Kakarook Nth
NGW48	605591	6696786	327.23	57	16.5-55.5	38	16.96	310.27	5,525	6.75	Kakarook Nth
NGW49	605613	6696711	326.41	57	18-36; 45-54	39	16.44	309.97	2,400	6.87	Kakarook Nth
NGW50	597455	6686457	311.76	24	0-12	1.6	5.40	306.36	4,400	5.02	BP Bore
NGW51	595921	6688305	318.53	36	9-27	22	8.50	310.03	2,500	5.82	BP Bore
NGW52	592327	6685176	316.18	39	12-24	27	6.40	309.78	5,000	6.16	BP Bore
NGW53	591623	6685604	316.26	48	9-27; 33-42	33	6.30	309.96	ND	ND	BP Bore
Production Bore:											
NWB3	605606	6696729		61	16-34; 46-58	42	16.02		4,500		Kakarook Nth

The bore was then pumped at 600 kL/d for 48 hours. The water was discharged to a dam about 30m from the bore and was observed to rapidly infiltrate the sand in the base of the dam. Water levels were monitored in the pumped bore; in bore NGW48 located 58m NNW of NWB3; and in NGW49 located 19m SSE of NWB3. The drawdowns in all three bores followed straight-line trends on a semi-logarithmic scale for the first 1,000 minutes, typical of a laterally extensive aquifer. There was then an upward inflexion that is attributed to recirculation of the infiltrated water (Appendix A).

This demonstrates that recharge of the aquifer will occur readily following high rainfall events.

At the end of the test, water-level recovery was monitored in the bores for a period of 150 minutes (NWB3) to 937 minutes (monitoring bores).

Drawdown-time and recovery plots for the bores are included in Appendix A. They were analysed using the Jacob method and Theis recovery method to determine aquifer transmissivity (T) and storativity (S). The transmissivity values were divided by the total screened interval in NWB3 to determine average hydraulic conductivity (K) of the screened interval, which includes sand beds and interbedded clayey layers. The results are given in Table 5.

Table 5: Results of Pumping and Recovery Tests

Obs Bore	Constant Rate Test		Recovery Test		K Av. (m/d)	
	T (m^2/d)	S	T (m^2/d)	S	CR Test	Recovery
NWB3	130	ND	117	ND	8.7	7.8
NGW48	164	0.0007	171	0.00013	10.9	11.4
NGW49	108	0.0019	99	0.0017	7.2	6.6

The results suggest the aquifer is more permeable near NGW48 than NGW49. As is common in pumping tests of shallow aquifers, the aquifer initially behaves as a confined or semi-confined aquifer giving low values of storativity, particularly for the more distant monitoring bore NGW48. After weeks or months of pumping the storativity generally increases to a value more typical of an unconfined aquifer (around 0.1).

Measurements of electrical conductivity, temperature and pH were made on the pumped water at the start of the constant-rate test, and then every four hours. The results are given in Table 6 and were used to estimate salinity using a regression analysis of EC (at 25^{o}C) versus salinity derived from laboratory analyses:

TDS = 0.659 * EC – 49

Table 6: Results of Physico-Chemical Measurements made during Pumping Test

Time Since Test Start (Hrs)	EC (mS/cm)	Temp (^{o}C)	TDS (mg/L)	pH
0	10.95	22.5	7,600	5.45
4	11.04	21.7	7,800	5.61
8	11.02	20.5	8,000	5.83
12	10.91	18.6	8,200	6.07
16	10.99	19.6	8,100	5.82
20	10.85	22.5	7,500	5.37
24	10.73	23.0	7,300	5.94
28	10.71	22.4	7,400	6.00
32	10.56	19.9	7,700	6.22
36	10.49	19.5	7,700	6.20
40	10.47	19.1	7,800	6.17
44	10.60	22.3	7,400	5.86
48	10.49	23.0	7,900	5.98

The results show that the pH fluctuated during the test, but possibly increased overall. Salinities also fluctuated over a narrow range but were indicated to be slightly higher at the end of the test than at the start. This is contrary to the results of the laboratory analyses (see below).

Water samples were taken at the beginning and end of the test and were analysed by SGS laboratories (Appendix B). Salinity decreased from 6,900mg/L TDS at the start to 6,400mg/L TDS at the end. The water was of a sodium chloride type, with elevated sulphate concentrations (880–960mg/L) and boron (3.0 – 3.3mg/L). There was an anomalous copper concentration of 0.98mg/L in the initial sample, decreasing to 0.02mg/L at the end of the test. Laboratory pH values were 6.8 and 6.9.

4 NUMERICAL GROUNDWATER MODELLING

A numerical groundwater model was constructed of the Kakarook North aquifer and run to estimate the impacts of pumping the planned low-salinity water supply from the aquifer. It is based on the conceptual hydrogeological model, described below.

4.1 CONCEPTUAL MODEL

The aquifer consists of sand and minor gravel/conglomerate of Eocene and Cretaceous age that are interbedded with fine grained sediments and occupy a basin or graben within Proterozoic bedrock. The aquifer thickness and known extent is shown in Fig. 8. The aquifer is open to the north and south, and thins to zero in the east and west. A hydrogeological cross-section through the deepest part of the aquifer is shown in Fig. 6, and a north–south section in Fig. 7.

The aquifer is unconfined to semi-confined – the water table is either within the aquifer or just above it. The groundwater is recharged following high rainfall events when rainfall and runoff readily infiltrates the surface sand, and then moves down to the water table. During typical climatic periods, recharge rates are low, probably less than 1% of the average annual rainfall. The groundwater flows to the south. The water table is typically around 20m below the ground surface.

The aquifer is moderately permeable – the pumping test results suggest an average of about 9m/d for the entire aquifer thickness (including the interbedded fine-grained layers). The bounding basement rocks are assumed to have very low permeability (modelled as zero).

4.2 DESCRIPTION OF NUMERICAL MODEL

The model consists of a rectangular grid of 120 rows, 60 columns and one layer covering an area of 12 km east–west by 24 km north–south (Fig. 13). The cells are 200m by 200m in size, in general, but were reduced in size (with additional columns and rows) in simulating the pumping test during model calibration.

The model was run using Processing Modflow Pro version 8.0.2 (Simcore Software, 2010), which utilises Modflow, the finite difference groundwater modelling software designed by the U.S. Geological Survey (McDonald and Harbaugh, 1988).

4.3 MODEL PARAMETERS

Geological data and groundwater levels obtained from the Kakarook North bores drilled by Vimy Resources were used to set up the geometry of the groundwater model. The values of hydraulic conductivity obtained during the pumping tests were applied to the model cells, and varied in calibrating the model.

The specific yield (drainable porosity) was assumed to be 0.1.

A low rate of recharge was adopted in a central part of the model area and assumed to be zero in northern and southern parts of the area.

Constant head cells were set along the northern and southern boundaries of the model to allow groundwater flow into the area modelled from the north and out of the area to the south. The western and eastern boundaries are assumed to be no-flow (barrier) boundaries. Aquifer parameters adopted after model calibration are given in Table 7.

Table 7: Adopted Aquifer Parameters

Parameter	Range of Values	Units
Hydraulic Conductivity	0.2 to 8	m/d
Specific Yield	0.1	v/v
Recharge	0 to 0.000008	m/d

Although some values of hydraulic conductivity were as low as 0.2, these low values were within a small area and the range of values was generally 3 to 8m/d. The relatively low salinities suggest that recharge rates could be higher than assumed, particularly as anecdotal evidence indicates that rainfall readily infiltrates the sandy soils (as was observed during the pumping tests). However, higher recharge rates would require higher and probably unrealistic values of hydraulic conductivity and significant ponded water, as may occur in topographic depressions during large storm events.

4.4 MODEL CALIBRATION

The model was first calibrated in steady-state mode. Values of hydraulic conductivity, and areas and rates of recharge, were varied until there was a close match between calculated and measured groundwater levels (Fig. 14). The Scaled Root Mean Square (SRMS) error was 3.9%, well below the limit of 5% recommended in the groundwater modelling guidelines (Middlemis, 2000), and 5% or 10% (if achievable) given in the more-recent guidelines (Barnett *et al.*, 2012).

The model was then checked by simulating the bore NWB3 pumping test. A good match was achieved between calculated and observed drawdowns in the monitoring bores during the test (Figures 15 and 16), although a semi-confined storativity of 0.0019 was required as was indicated from the pumping test results. As discussed in Section 3.2 above, storativity is somewhat time-dependent, and will increase with extended pumping until it approaches an unconfined value (similar to the adopted value of 0.1).

4.5 SENSITIVITY ANALYSIS

The sensitivity of the model was tested by running it in steady-state mode, and varying the two main parameters (hydraulic conductivity and recharge) by the maximum likely difference from the adopted values (30%) and calculating the change in water levels in bores in the northern, central and southern parts of the aquifer. Storativity doesn't have any impact on steady-state simulations.

The results are given in Table 8.

As would be expected, the model has a similar sensitivity to both parameters and the changes in the parameter values would have a moderately significant impact on the model calibration (by about 0.3m).

Table 8: Results of Sensitivity Analysis

Case	Calculated WLs (m AHD)			Av. Change (m)
	NGW41 (Nth)	NGW45 (Sth)	NGW48 (Centre)	
Calibrated Model	319.36	304.31	310.58	
Hyd. Cond + 30%	318.98	304.16	310.26	0.28
Recharge + 30%	319.78	304.43	310.89	-0.28

4.6 MODEL SIMULATION AND RESULTS

The water supply required from the borefield is estimated to be about 4,900 kL/d (1.8 GL/year) over a period of 16 years. The model was run to simulate pumping from 16 bores, each pumping 305 kL/d and spaced 500 m apart on two lines of eight bores, with the lines 1 km apart.

The results indicate that at the end of 16 years, water levels would have drawn down by up to 14 m (Fig. 17), much less than the available drawdown of about 40 m. There would still be sufficient drawdown available if the hydraulic conductivity (and recharge) were 30% less than the adopted values.

There were no differences to the calculated drawdowns with and without the constant head boundaries at the northern and southern ends of the modelled aquifer, as the impacts of pumping do not extend that far.

4.7 DISCUSSION OF MODELLING RESULTS

The modelling results indicate that the aquifer should provide the quantity of low-salinity water needed for the Project. The planned pumping rate of about 4,900 kL/d may be more than the rate of recharge to the aquifer, and the aquifer through-flow. However, the planned extraction is considered to be sustainable because:

- There are no other potential users of the groundwater (nor are there likely to be), or known groundwater-dependent ecosystems due to the deep water table (~ 20 m bgl);
- The mining and groundwater extraction will be for a finite period – once extraction ceases the aquifer will gradually recharge; and
- There are additional areas of aquifer such as the BP bore area that can be developed to spread the impacts of extraction, if necessary.

As is the usual practice and required by licensing, the impacts of extraction will be regularly monitored, and the monitoring data can be used to re-calibrate the model and update the predictions, if needed.

5 CONCLUSIONS

The collation and assessment of historical groundwater data by Vimy Resources, and the subsequent drilling and bore construction at 52 sites, has identified a substantial low-salinity groundwater resource within a basin containing sediments of Cretaceous and Eocene age. The basin is at least 16 km long (and probably more than 26 km) and 5 to 8 km wide. The sediments consist of interbedded sands and conglomerate, and fine-grained sandy clay and clays of up to 40m total saturated thickness. The total volume of groundwater in the part of the aquifer that has been drilled by Vimy is estimated to be 167GL.

Approximately 1.8 GL/a of low-salinity water will be needed for about 16 years. The results of groundwater modelling indicate that pumping that volume from a borefield of 16 bores could draw-down water levels in the aquifer by up to 14 m after 16 years. If necessary, the impacts of pumping can be spread over a wider area by developing some of the water supply from other areas that have been identified, such as the BP bore area which is closer to the planned mining areas.

Once pumping ceases, groundwater levels will gradually recover, as a result of recharge following occasional high-rainfall events.

The water table in the planned borefield area is about 20 m deep, and there are no known groundwater-dependent ecosystems that could be impacted by groundwater extraction.

Dated: **28 October 2015** **Rockwater Pty Ltd**

M J Taylor
Senior Hydrogeologist

P H Wharton
Principal

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Barnett *et al*. 2012. Australian groundwater modelling guidelines. Waterlines report series No.82, National Water Commission, Canberra.

McDonald, M.G., and A.W. Harbaugh, 1988. A Modular Three Dimensional Finite Difference Ground Water Flow Model. Book 6, Chapter A1, Techniques of Water Resources Investigations. U.S. Geol. Surv., Washington, DC. (A:3980).

Middlemis, H., 2000. Groundwater Flow Modelling Guideline. Report to Murray-Darling Basin Commission.

Simcore Software, 2010. Processing Modflow, An integrated modelling environment for the simulation of groundwater flow, transport and reactive processes.

FIGURES

FIGURE 1

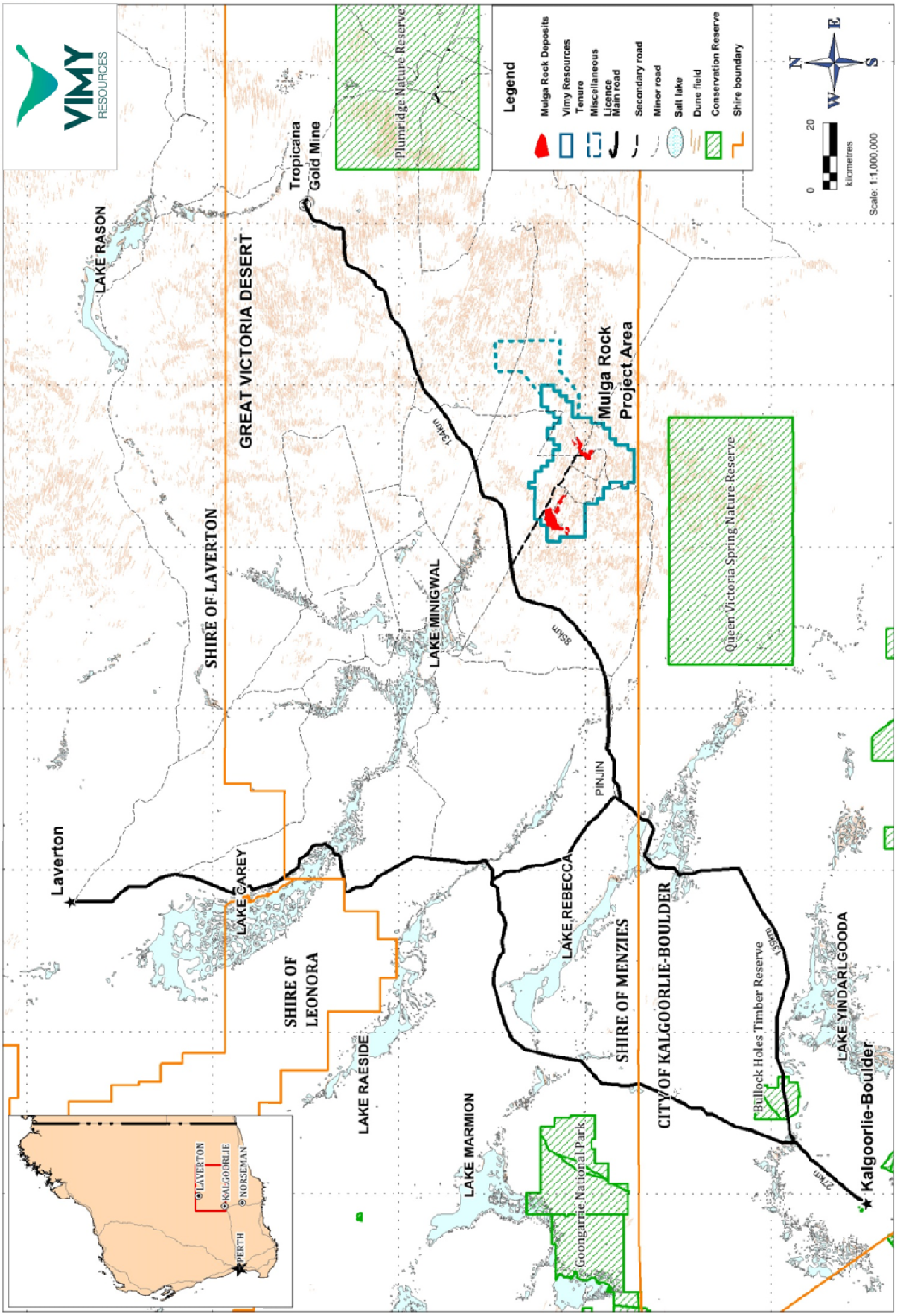


figure 1.srf

CLIENT: Vimy Resources PROJECT: Mulga Rock DATE: June 2015 Dwg No: 345.0/15/1-1	LOCATION OF THE MULGA ROCK URANIUM PROJECT Rockwater Pty Ltd

FIGURE 2

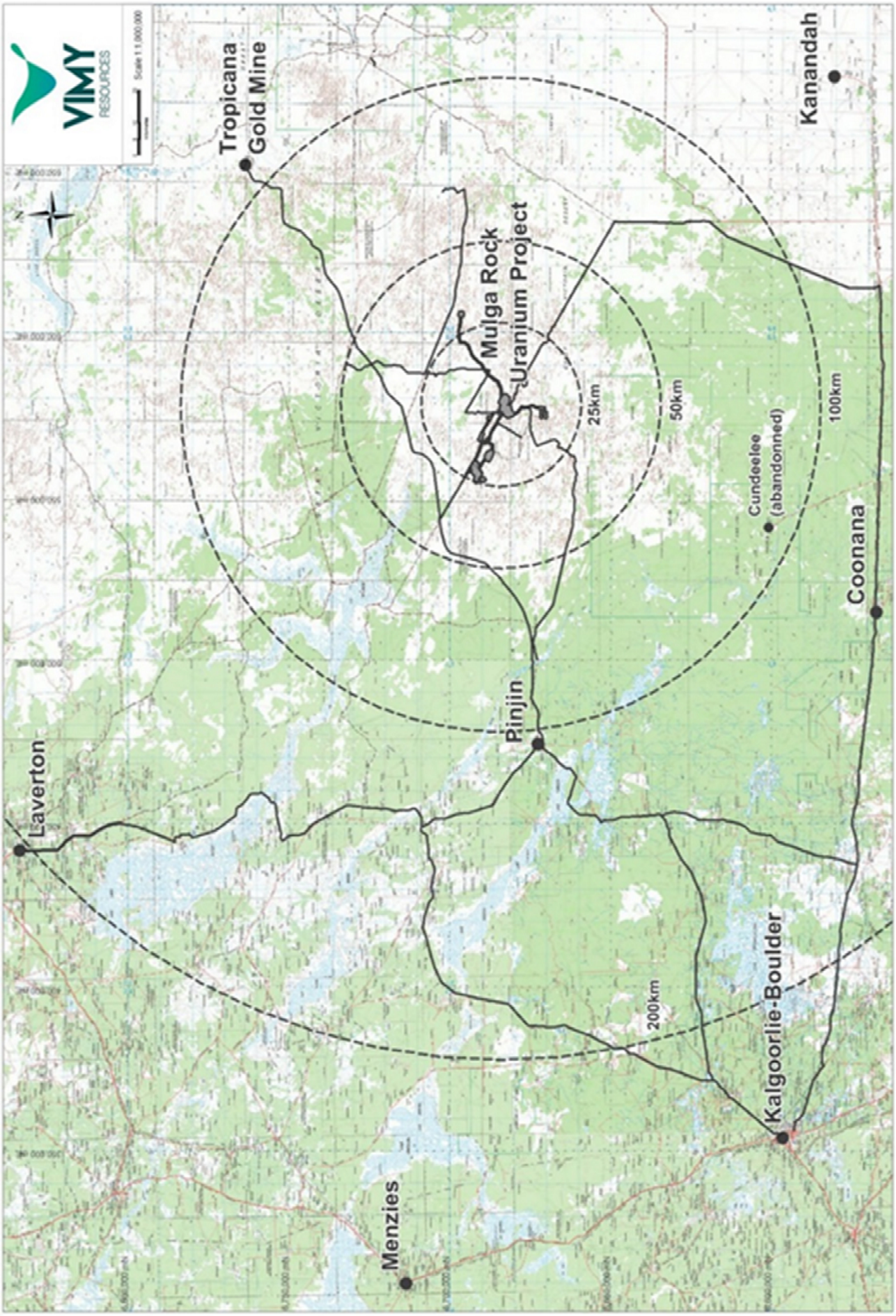


figure 1.srf

CLIENT: Vimy Resources PROJECT: Mulga Rock DATE: June 2015 Dwg No: 345.0/15/1-2	MRUP AND NEARBY COMMUNITIES Rockwater Pty Ltd

FIGURE 3

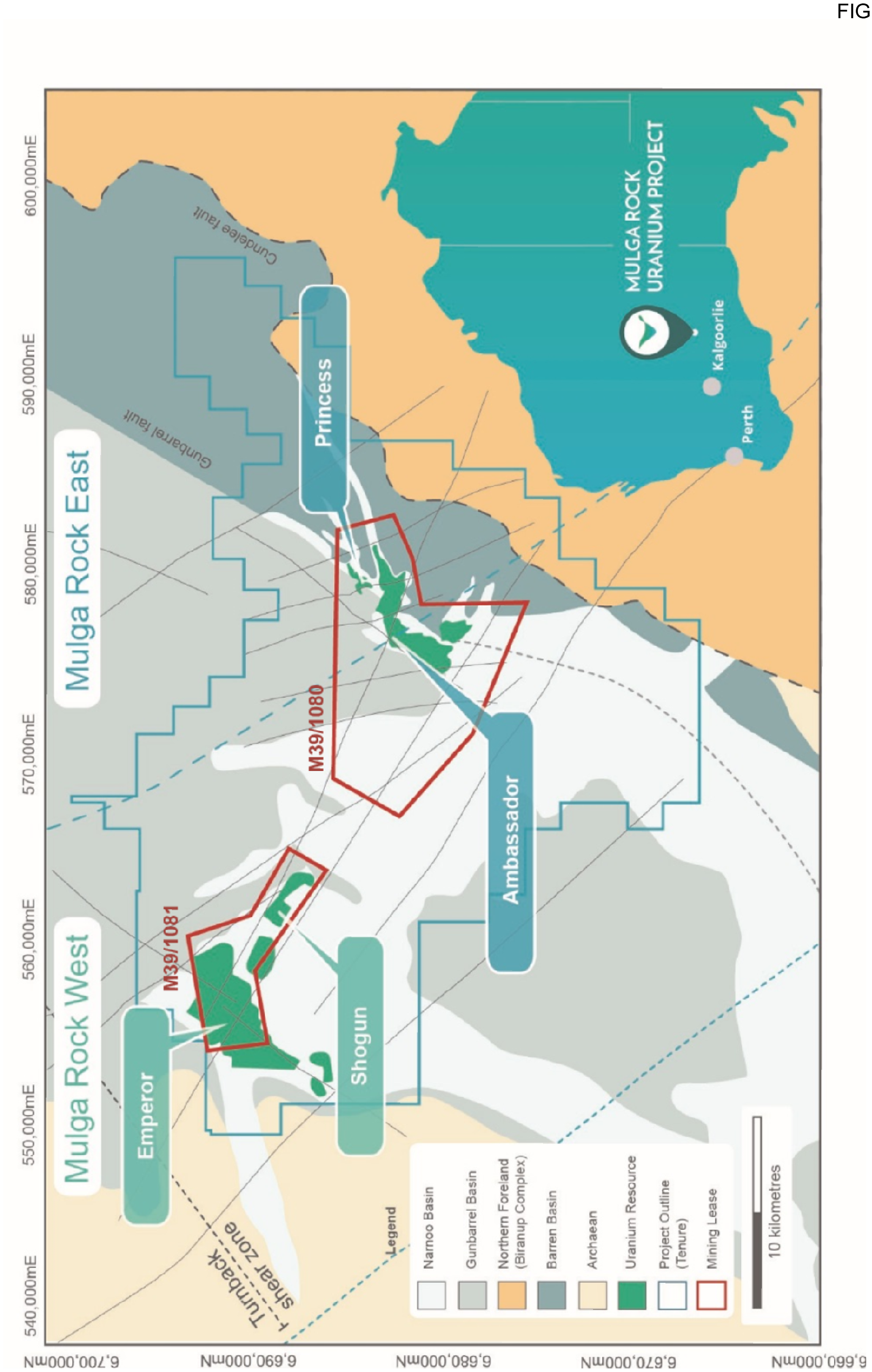
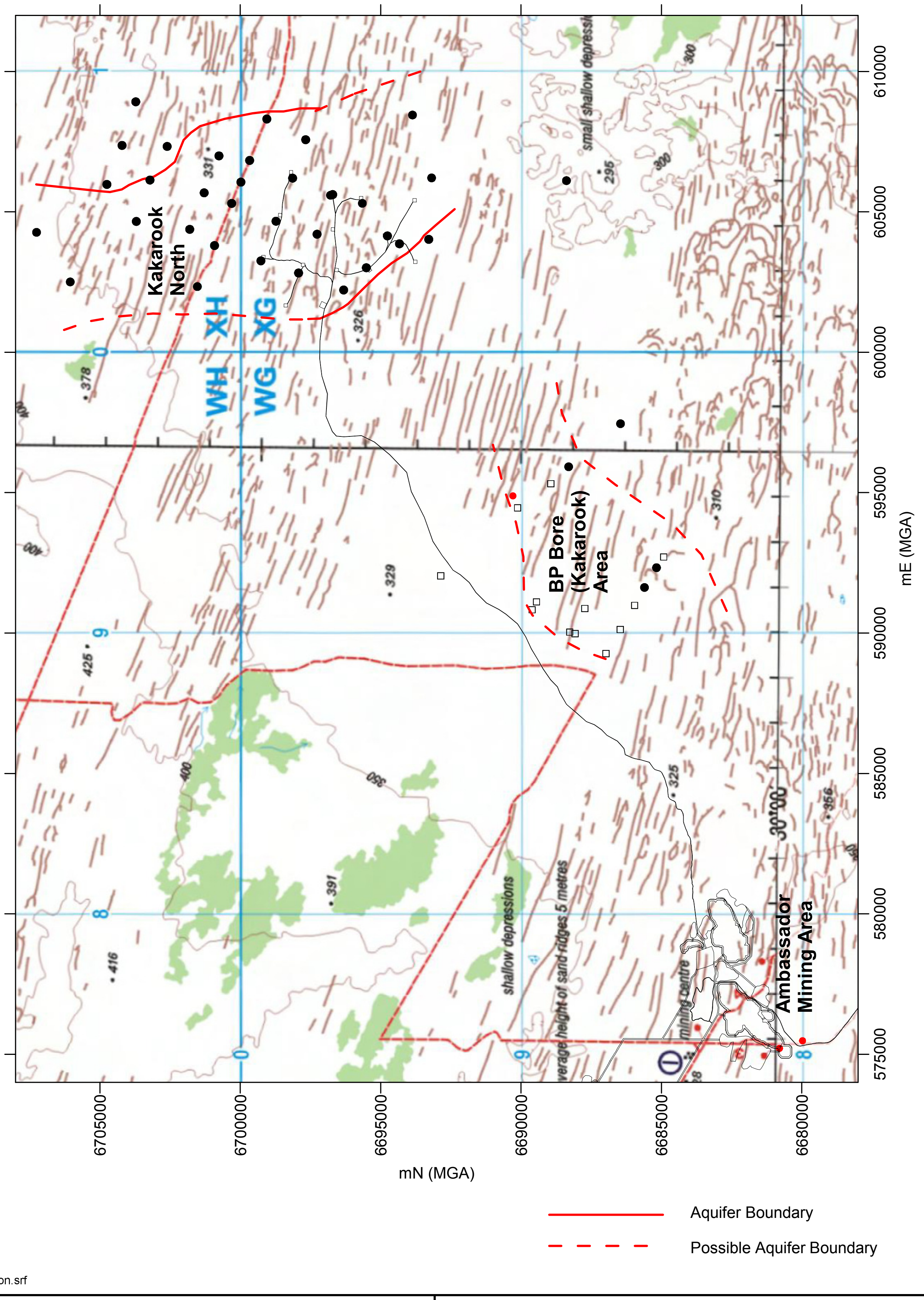


figure 3.srf

CLIENT: Vimy Resources PROJECT: Mulga Rock DATE: June 2015 Dwg No: 345.0/15/1-3	MRUP MINING CENTRES AND ASSOCIATED RESOURCES Rockwater Pty Ltd

FIGURE 4



borefield location.srf

CLIENT: Vimy Resources

PROJECT: Mulga Rock

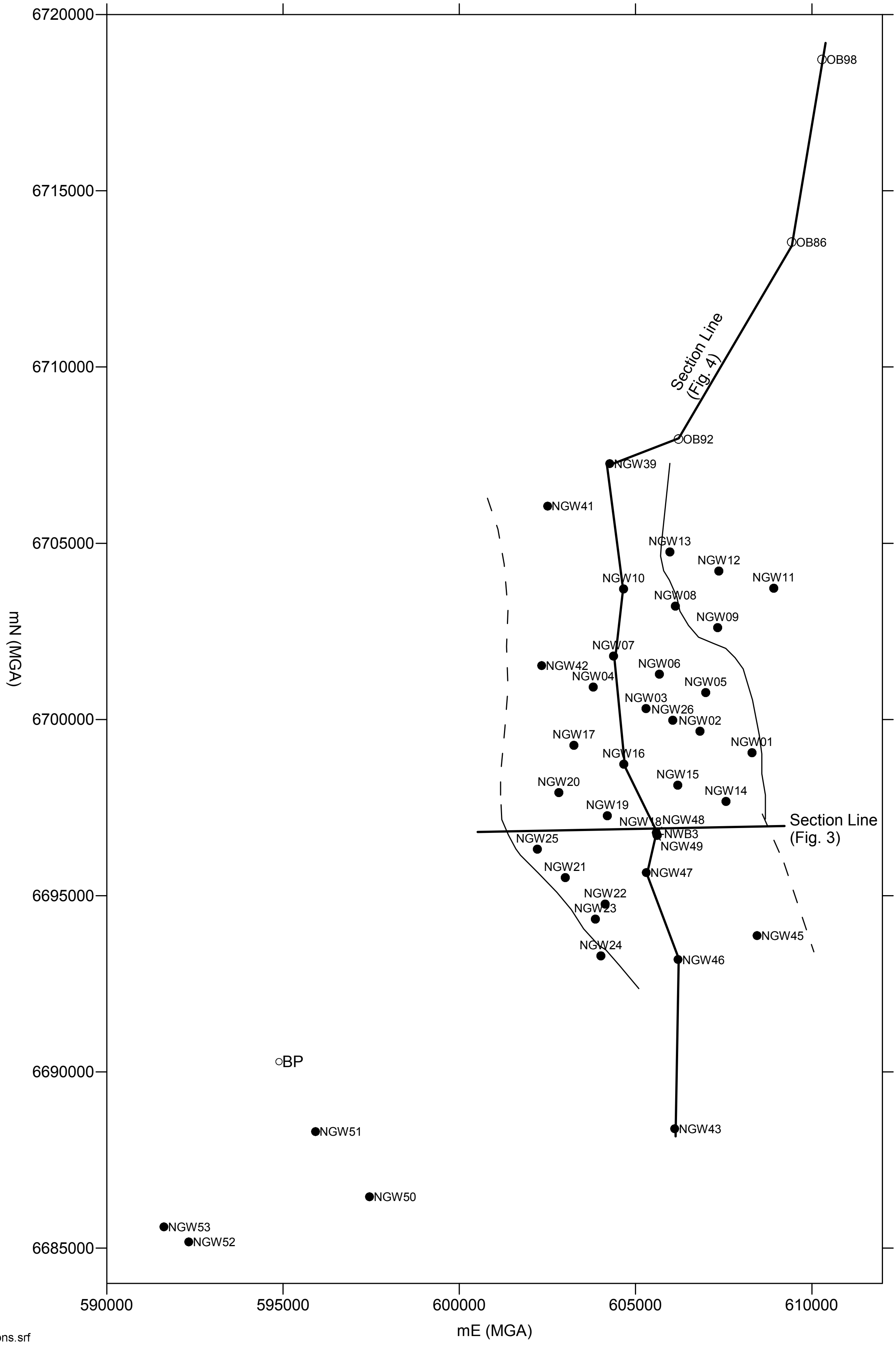
DATE: April 2015

Dwg No: 345.0/15/1-4

BOREFIELD LOCATION

Rockwater Pty Ltd

FIGURE 5



new k bore locations.srf

CLIENT: Vimy Resources

PROJECT: Kakarook Borefield

DATE: April 2015

Dwg No: 345.0/15/1-5

KAKAROOK NORTH BORE LOCATIONS

Rockwater Pty Ltd

CLIENT: Vimy Resources
PROJECT: Kakarook North Borefield
DATE: October 2015
Dwg No: 345-0/15/1-6

HYDROGEOLOGICAL CROSS SECTION
AT 6697500 mN

Rockwater Pty Ltd

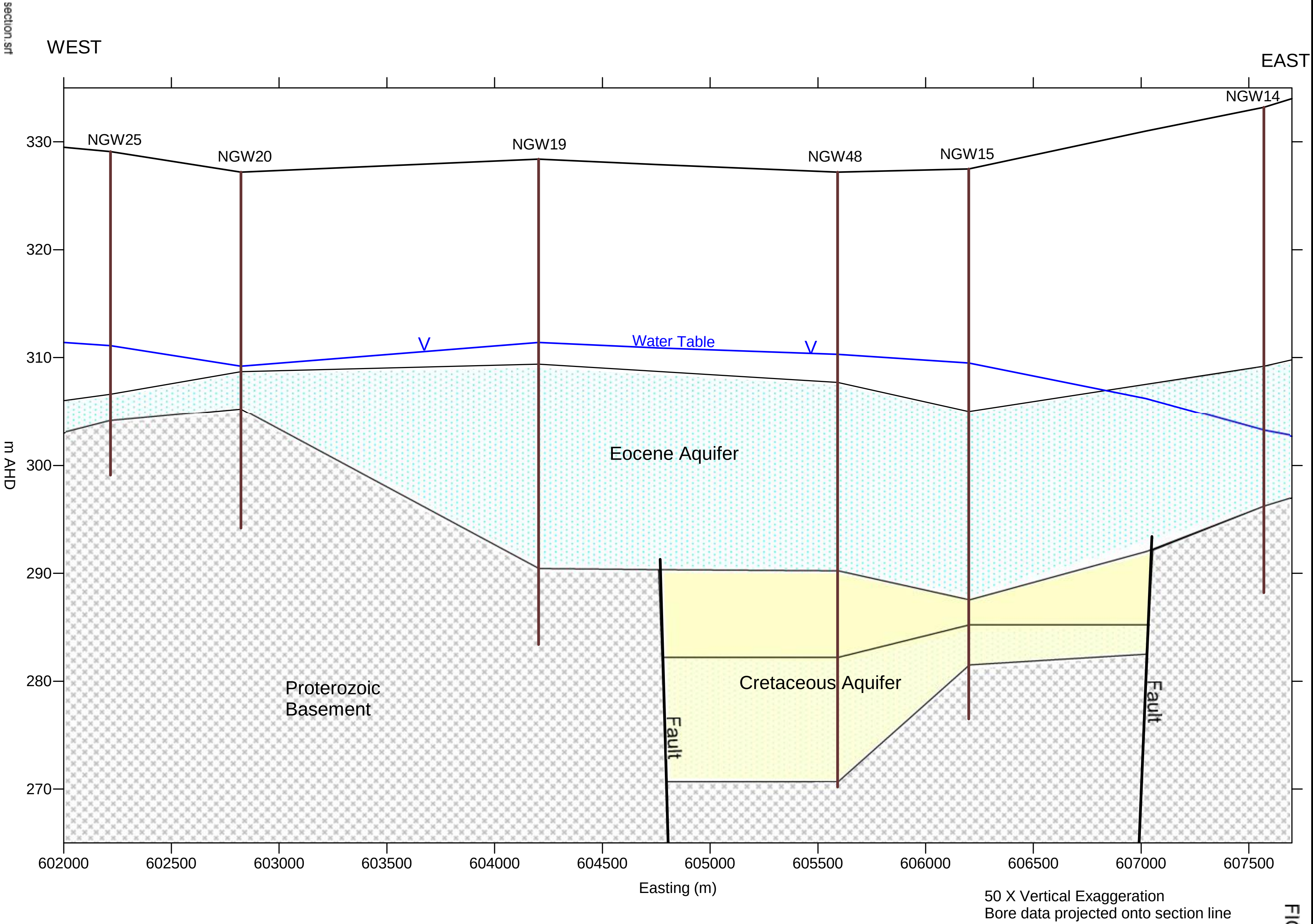
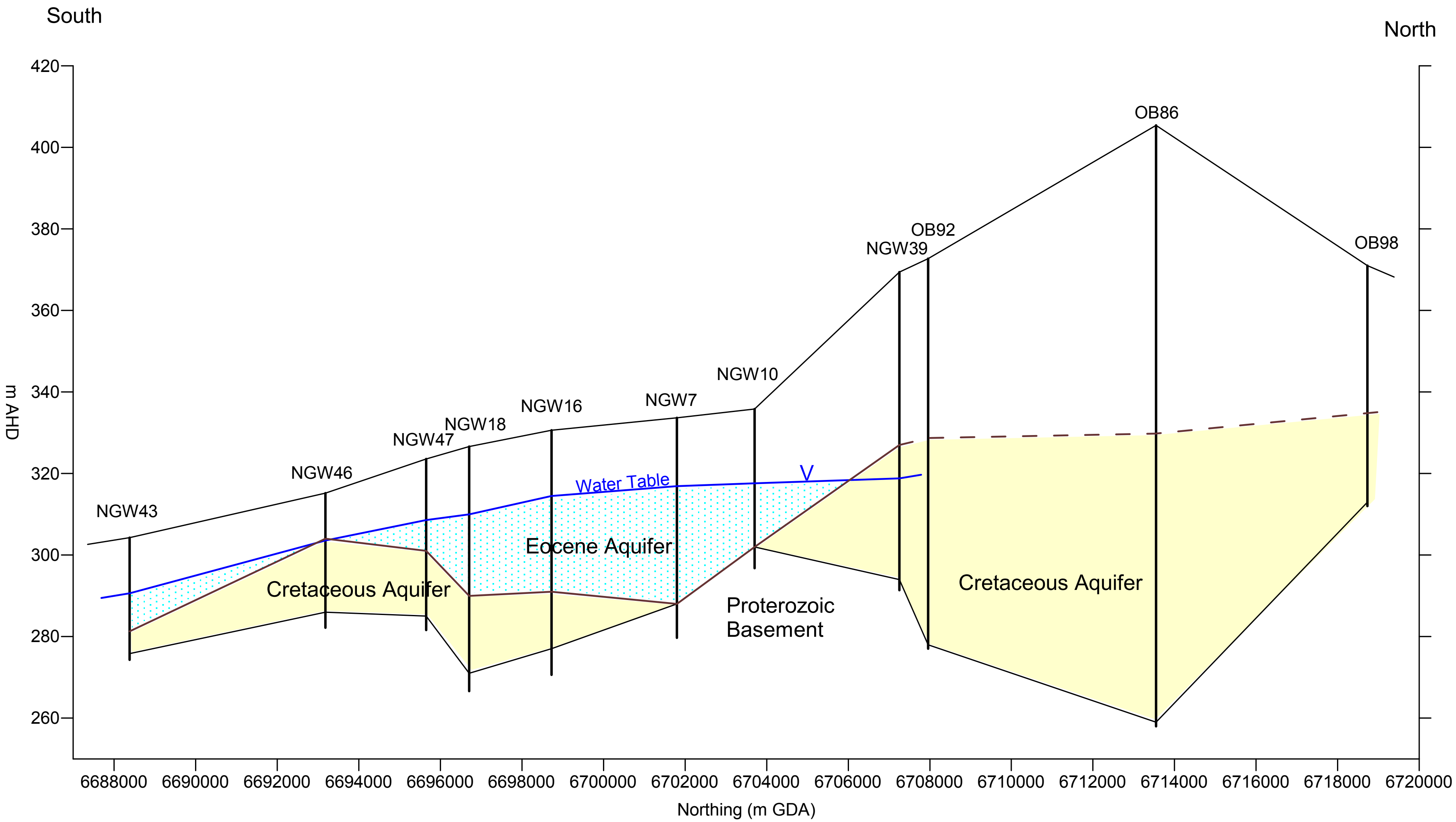


FIGURE 6

CLIENT: Vimy Resources
PROJECT: Kakarook North Borefield
DATE: April 2015
Dwg No: 345-0/15/1-7

n-s section.srf



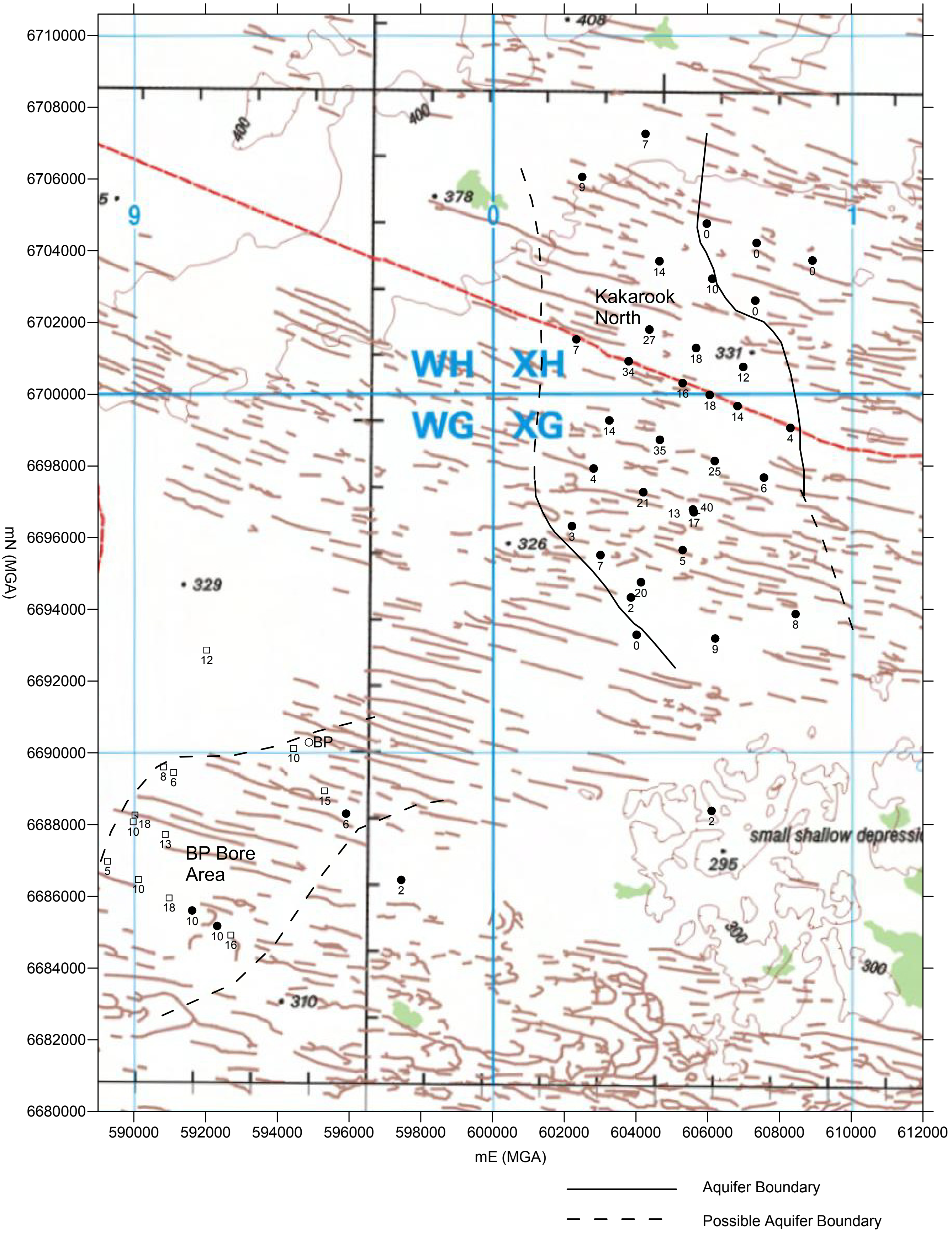
100 X Vertical Exaggeration

HYDROGEOLOGICAL LONG SECTION
KAKAROOK NORTH

Rockwater Pty Ltd

FIGURE 7

FIGURE 8



kakarook_bp aquifer thickness.srf

CLIENT: Vimy Resources

PROJECT: Kakarook Borefield

DATE: April 2015

Dwg No: 345.0/15/1-8

KAKAROOK TOTAL SATURATED

AQUIFER (SEDIMENT) THICKNESS (m)

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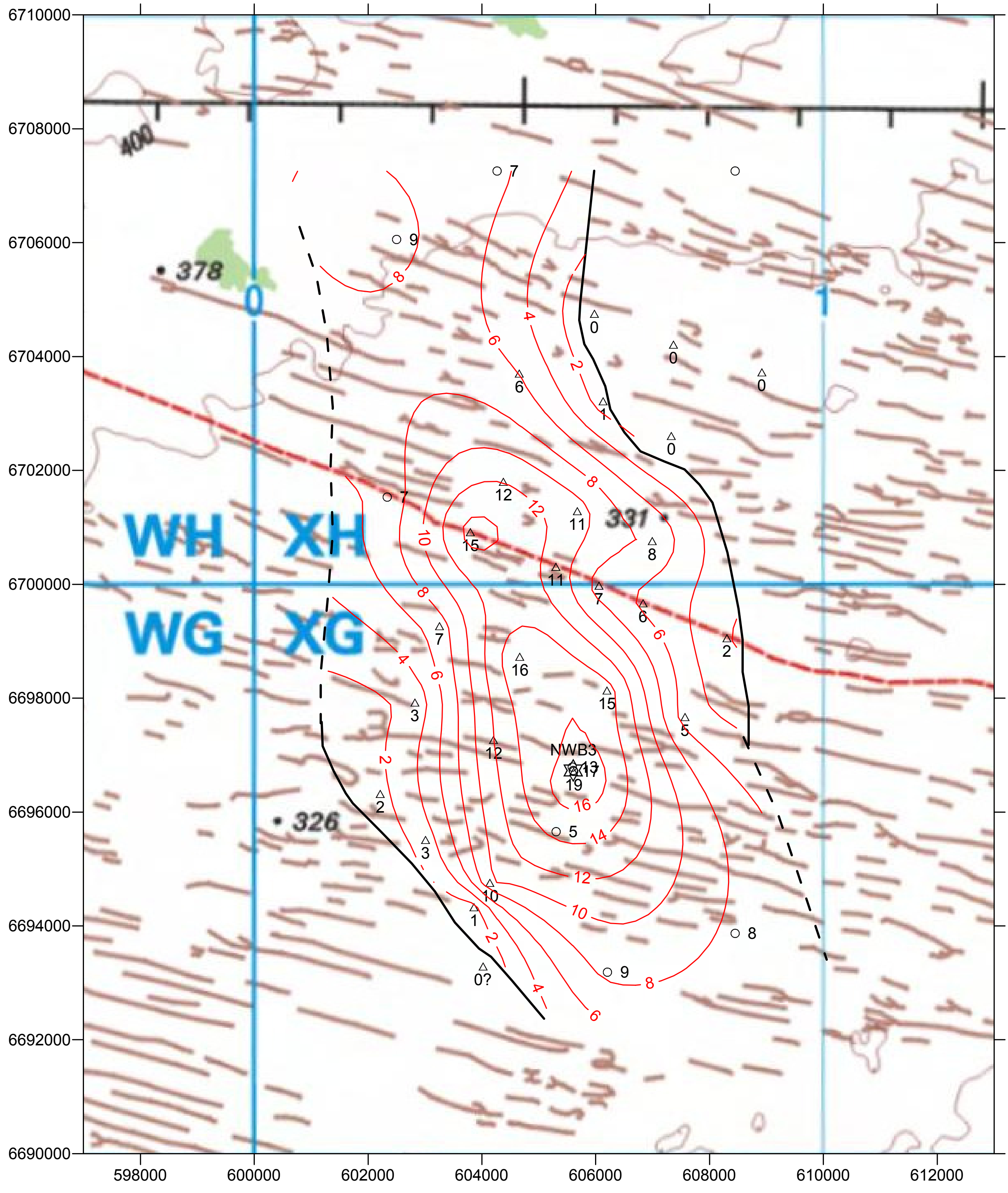
FIGURE 9



Production Bore

New Monitoring Bore with Total Thickness Sand Beds

Old Monitoring Bore with Sand Thickness Est. from Field Sections

kakarook aq thickness.srf

CLIENT: Vimy Resources

PROJECT: Mulga Rock

DATE: April 2015

Dwg No: 345-0/15/1-9

AQUIFER THICKNESS (Sand Beds, m)

KAKAROOK NORTH BOREFIELD

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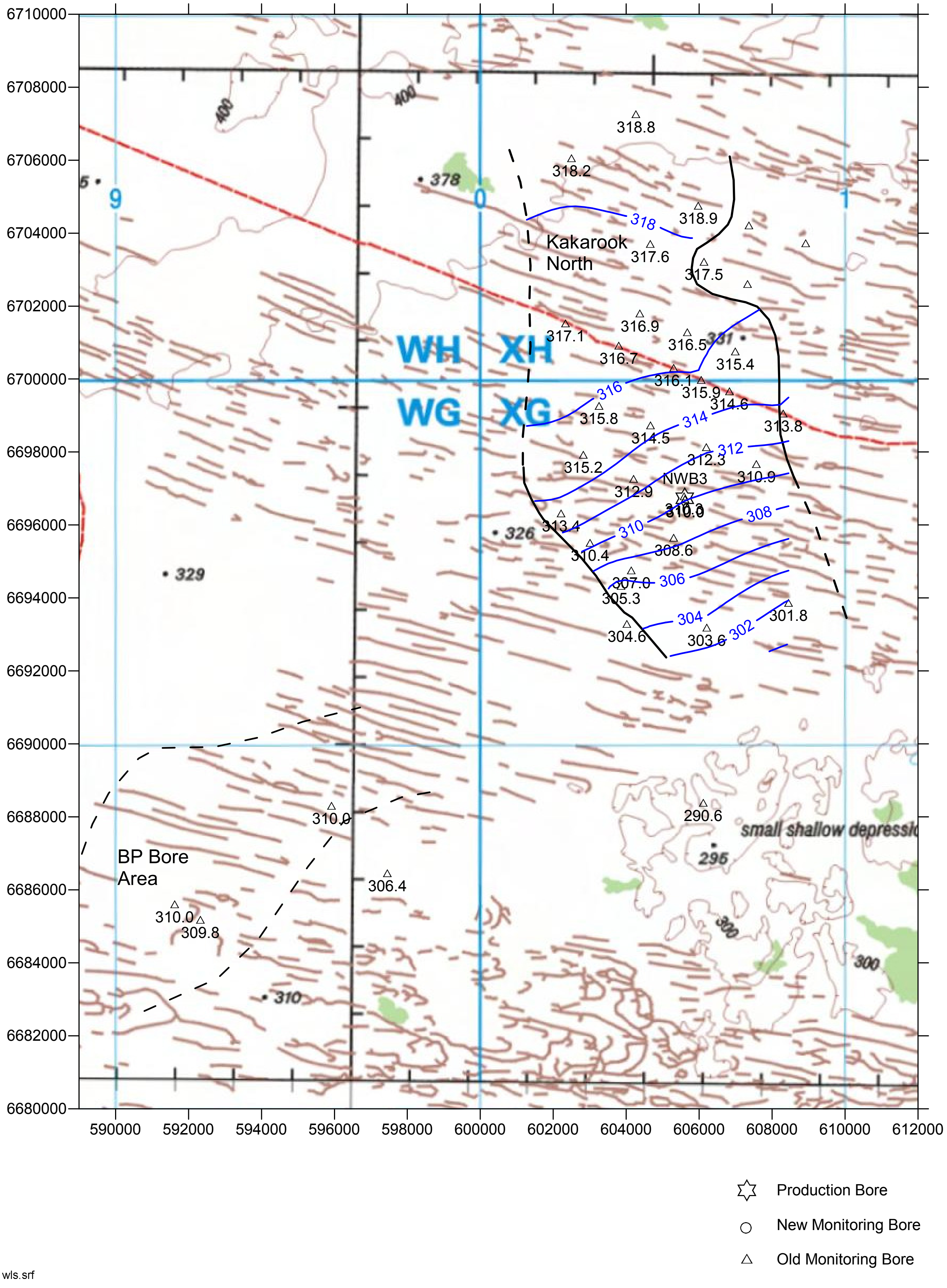
FIGURE 10



CLIENT: Vimy Resources

PROJECT: Mulga Rock

DATE: April 2015

Dwg No: 345-0/15/1-10

GROUNDWATER LEVELS (m AHD)

KAKAROOK NORTH BOREFIELD

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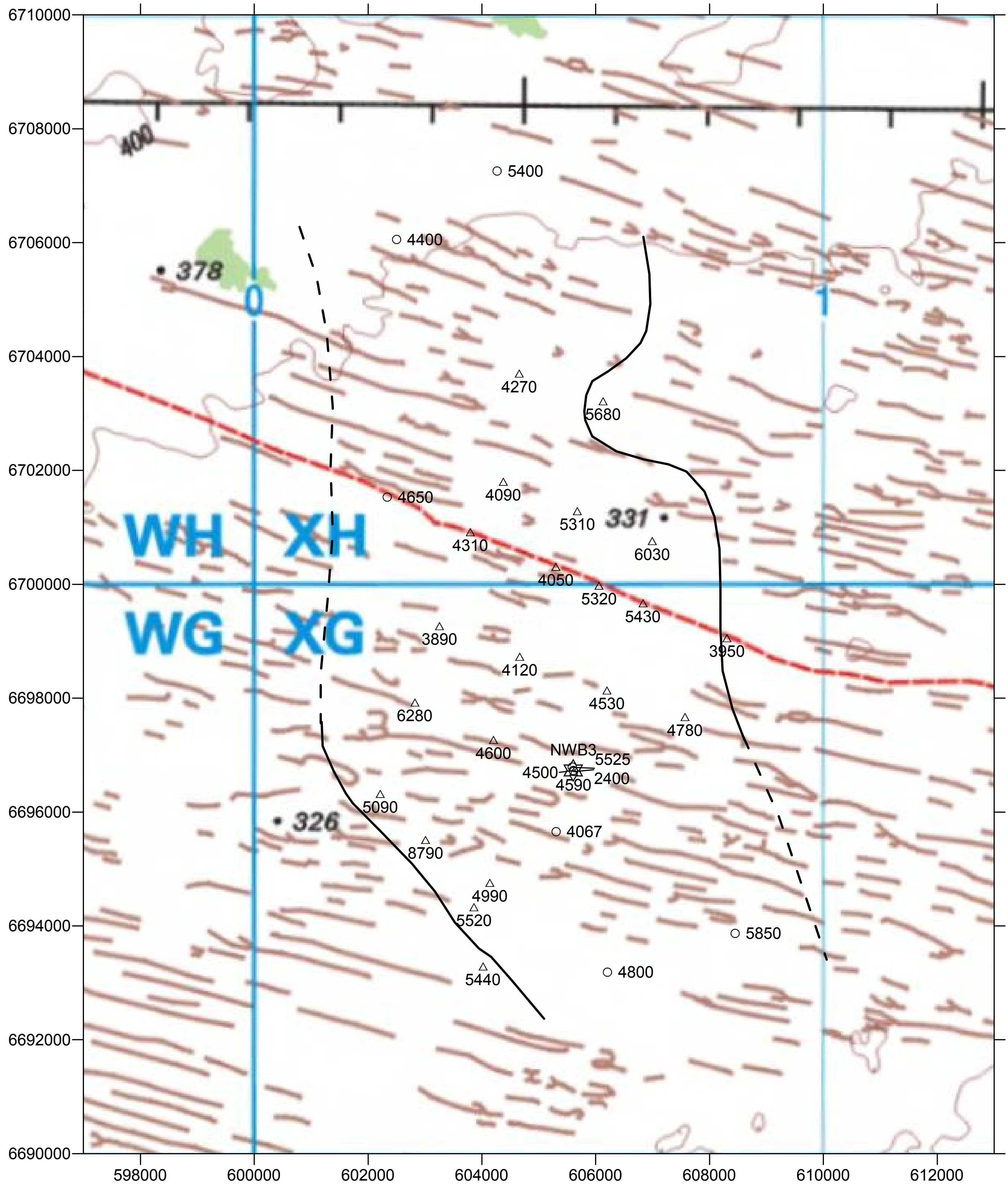
FIGURE 11



kakarook salinity.srf

CLIENT: Vimy Resources

PROJECT: Mulga Rock

DATE: April 2015

Dwg No: 345-0/15/1-11

GROUNDWATER SALINITY (mg/L TDS)

KAKAROOK NORTH BOREFIELD

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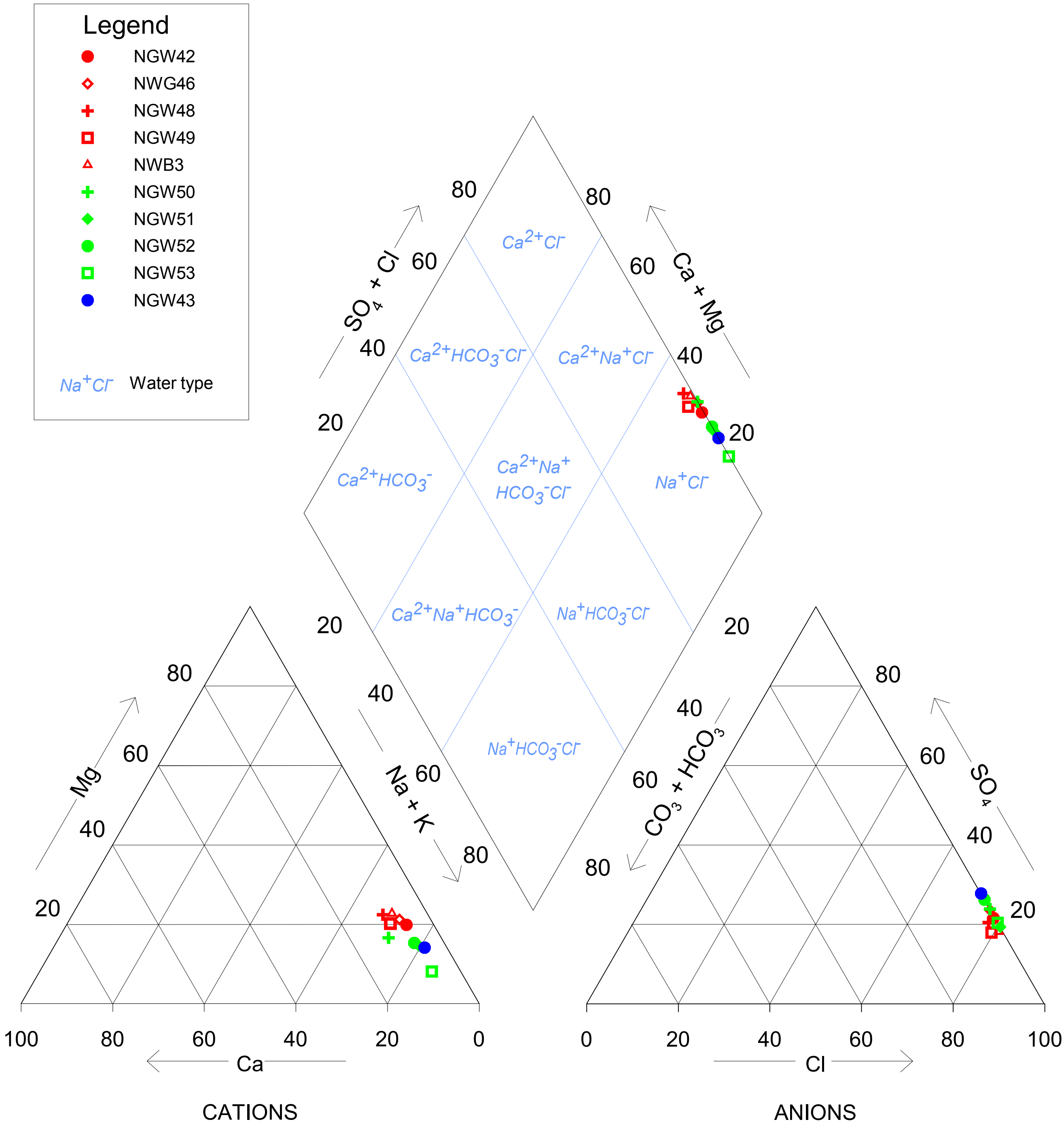
Figure 12



I:/345-0/Grapher/Piper Kakarook Bores.grf

CLIENT: Vimy Resources Ltd

PROJECT: Mulga Rock

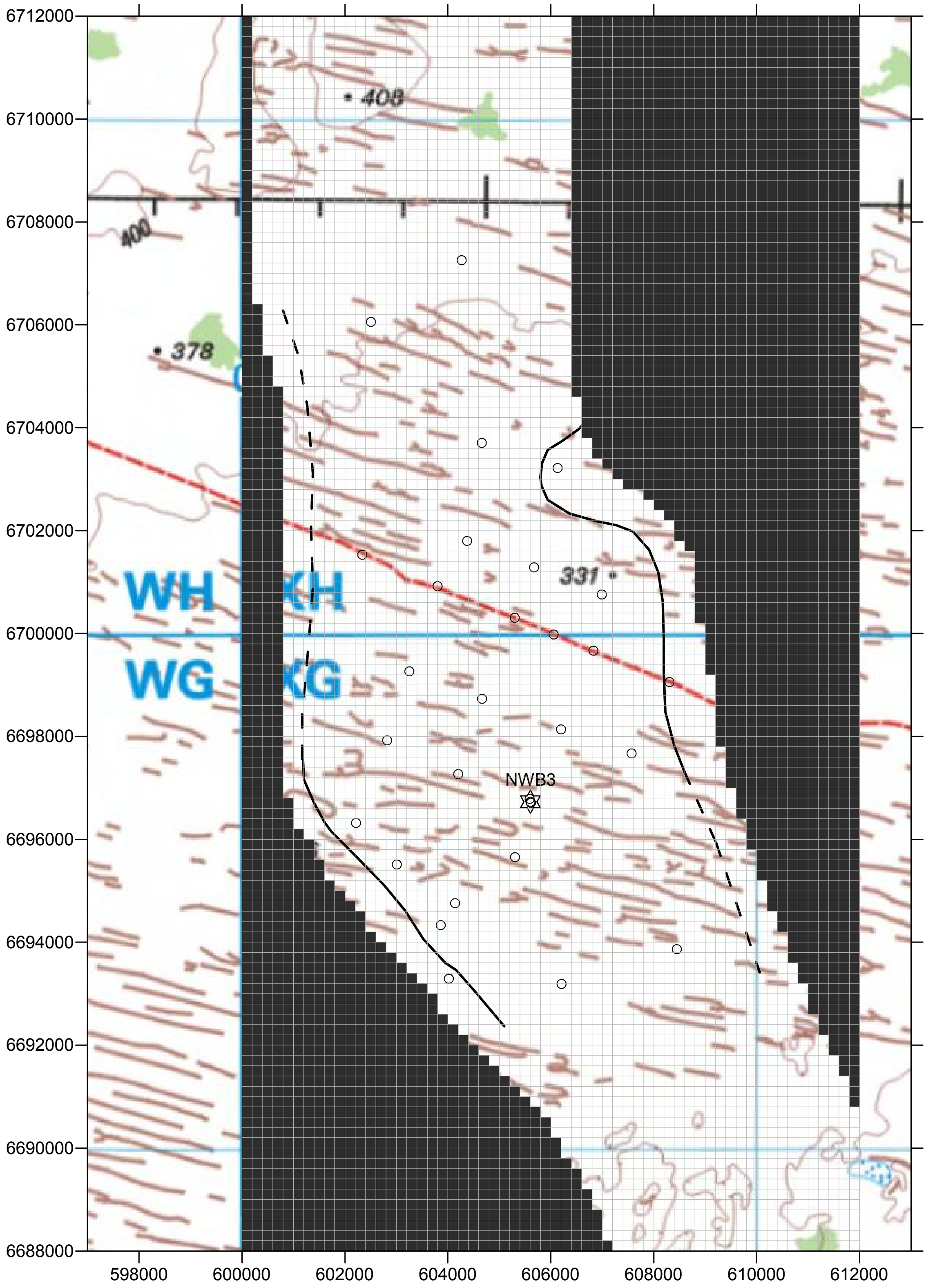
DATE: April 2015

Dwg. No: 345-0/15/01-12

PIPER DIAGRAM
KAKAROOK BOREFIELD

Rockwater PROPRIETARY LIMITED

FIGURE 13



model grid.srf

CLIENT: Vimy Resources

PROJECT: Mulga Rock

DATE: April 2015

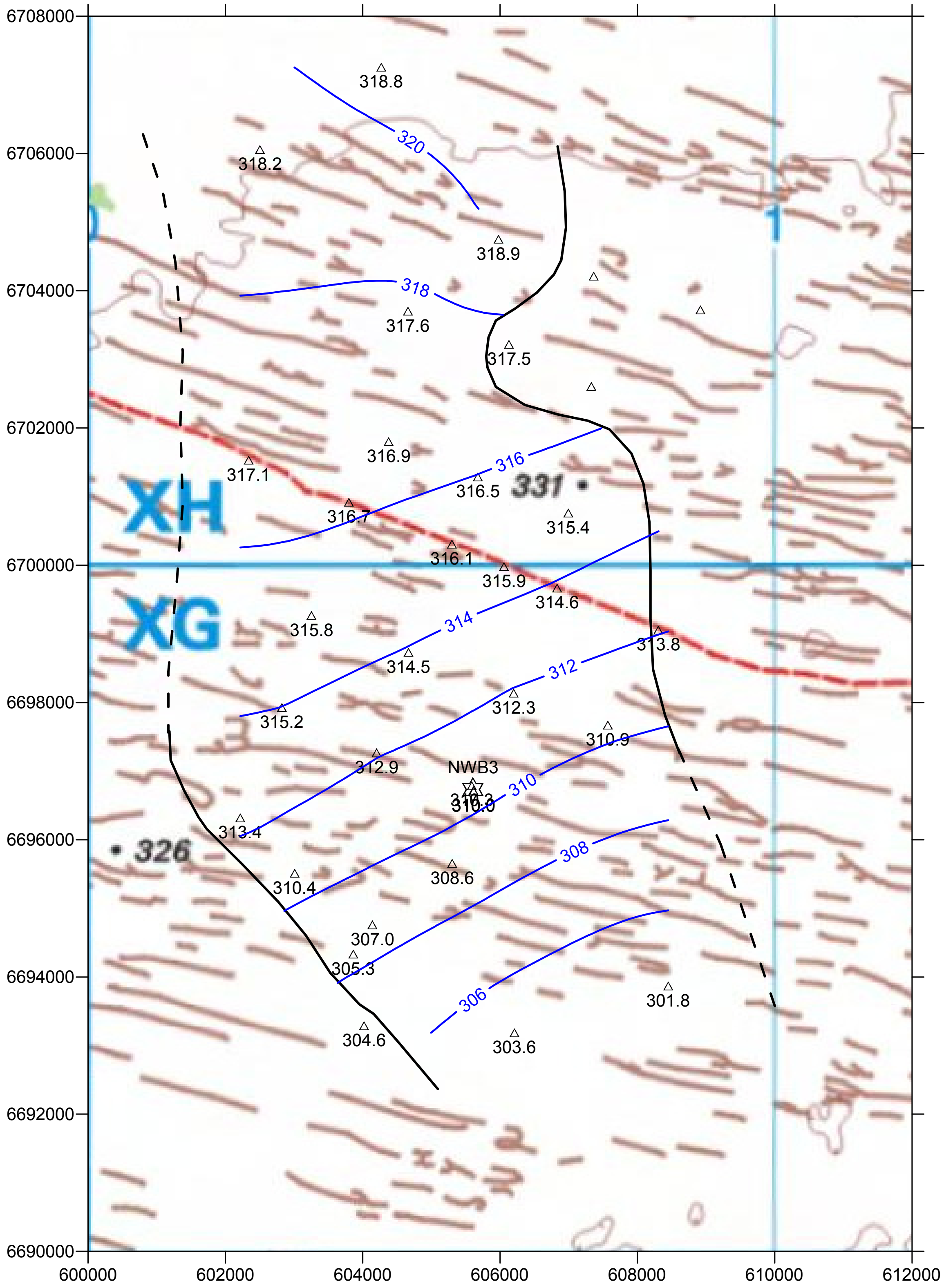
Dwg No: 345-0/15/1-13

MODEL GRID

KAKAROOK NORTH BOREFIELD

Rockwater Pty Ltd

FIGURE 14



meas vs calc wls.srf

CLIENT: Vimy Resources

PROJECT: Mulga Rock

DATE: April 2015

Dwg No: 345-0/15/1-14

MODEL CALIBRATION: MEASURED (POST VALUES) AND CALCULATED (CONTOURS) WATER LEVELS (m AHD)

Rockwater Pty Ltd

Client: Vimy Resources
Project: Mulga Rock
Date: April 2015
Dwg. No: 345-0/15/1-15

KAKAROOK NORTH BORE NWB3
PUMPING TEST AT 600 KL/d, 7/3/15
DRAWDOWNS IN NGW48

Rockwater Pty Ltd

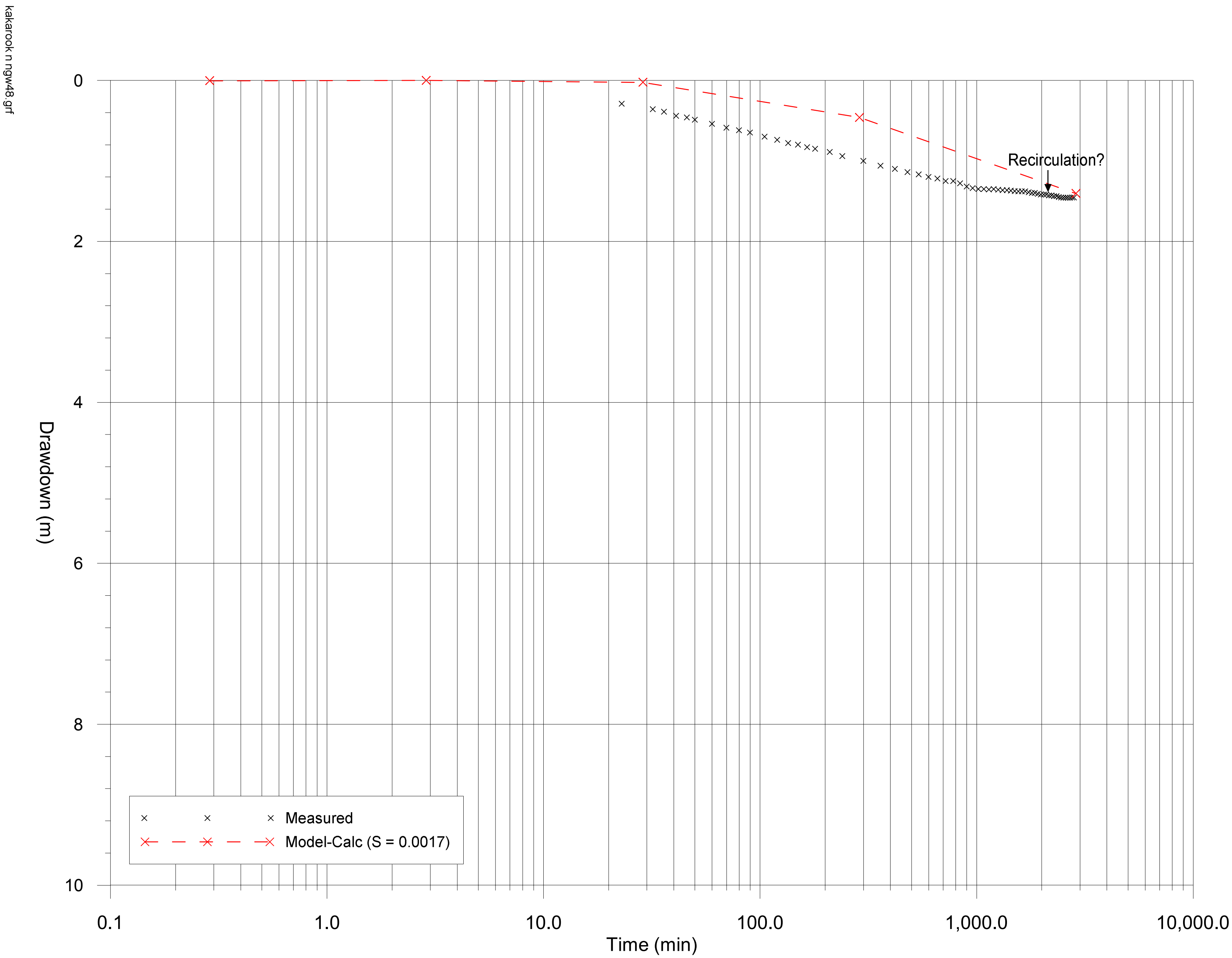


Figure 15

Client: Vimy Resources
Project: Mulga Rock
Date: April 2015
Dwg. No: 345-0/15/1-16

KAKAROOK NORTH BORE NWB3
PUMPING TEST AT 600 KL/d, 7/3/15
DRAWDOWNS IN NGW49

Rockwater Pty Ltd

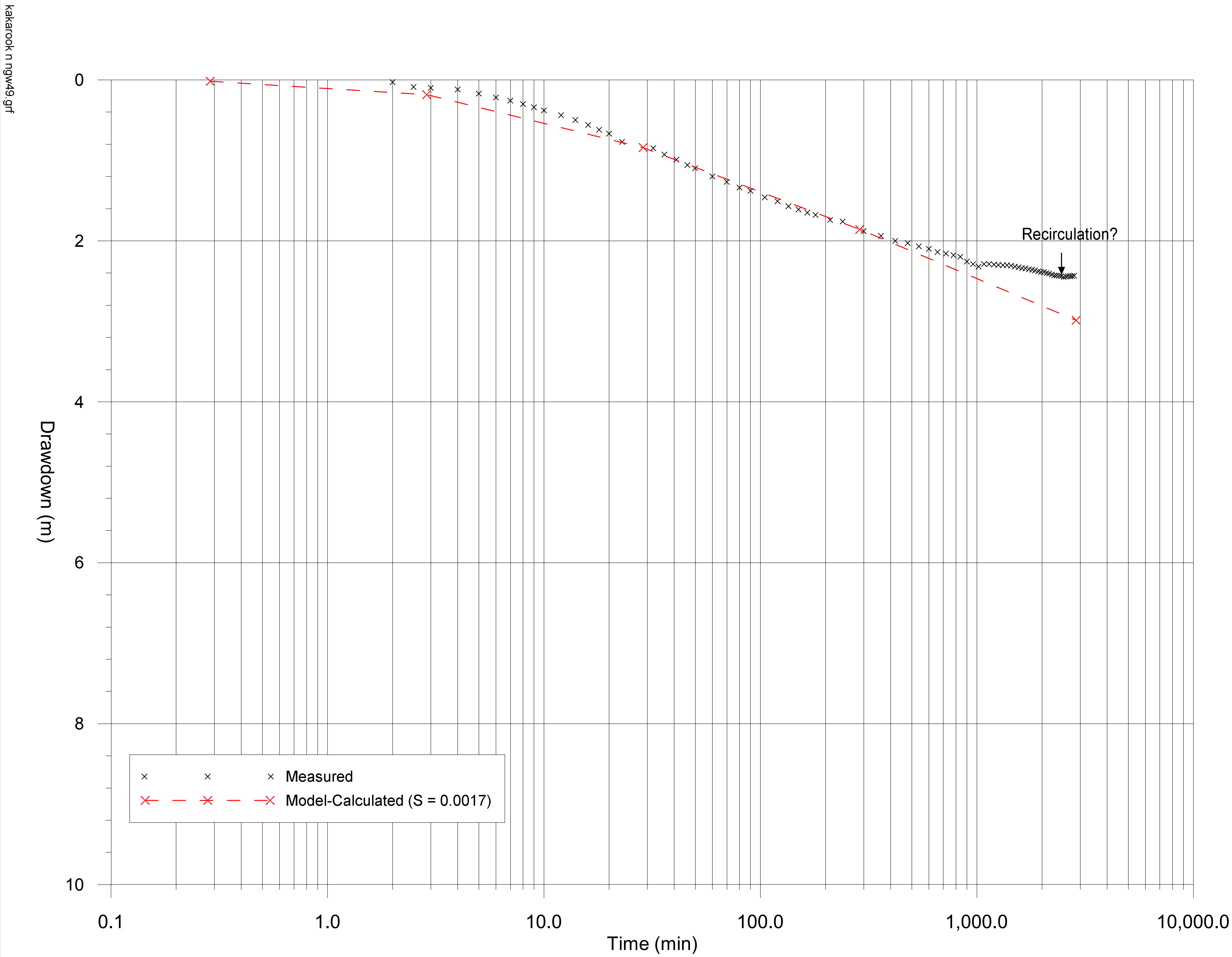
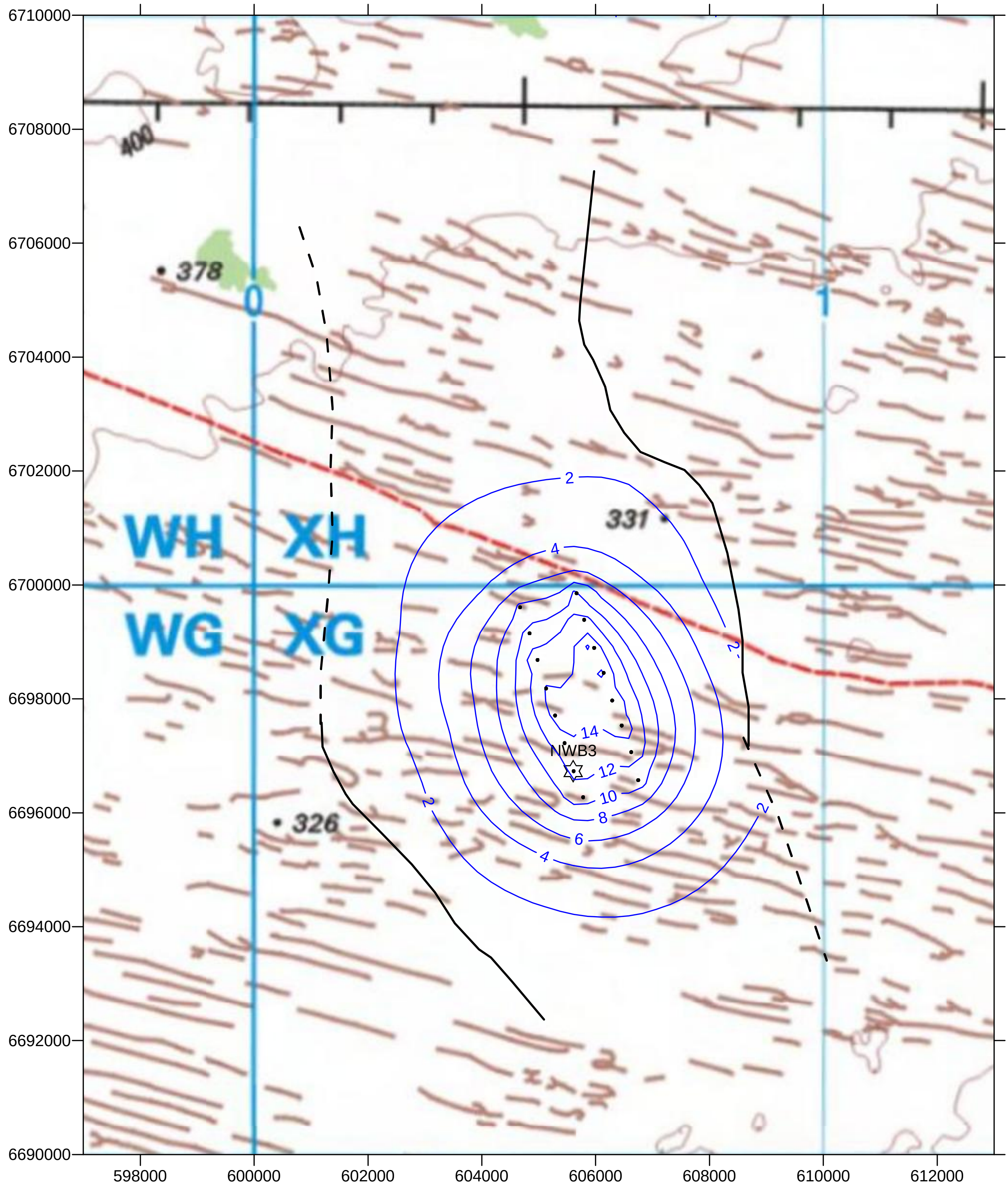


Figure 16

FIGURE 17



Production Bore

Conceptual Production Bore

345-0/Surfer/Oct-15 Update/Fig17.predicted dds.srf

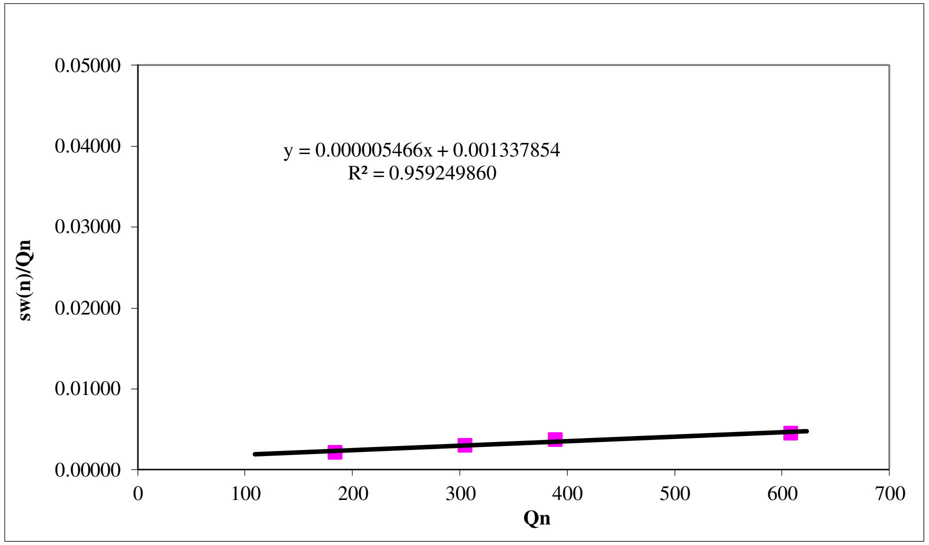
CLIENT: Vimy Resources PROJECT: Mulga Rock DATE: October 2015 Dwg No: 345-0/15/1-17	PREDICTED DRAWDOWNS (m) AFTER 16 YEARS OF PUMPING 1.8 GL/a Rockwater Pty Ltd

APPENDIX A: Pumping Test Results and Plots

Kakarook North (NWB3) Step-Rate Test Analysis

Step	Q_n	$\Delta s_{w(n)}$	$s_{w(n)}$	$s_{w(n)}/Q_n$
1	184	0.4	0.4	0.00217
2	304.99	0.53	0.93	0.00305
3	388.8	0.52	1.45	0.00373
4	608.26	1.3	2.75	0.00452

$s = BQ + CQ^2$
$s/Q = B + CQ$
or $y = b + mx$
Therefore s (total)=0.1105Q-1E-04Q^2
and B= 0.001337
C= 5.46E-06



Q	s fmn	s well	s total	% well loss
25	0.03	0.00	0.04	9.3%
50	0.07	0.01	0.08	17.0%
75	0.10	0.03	0.13	23.4%
100	0.13	0.05	0.19	29.0%
200	0.27	0.22	0.49	45.0%
300	0.40	0.49	0.89	55.1%
400	0.53	0.87	1.41	62.0%
500	0.67	1.37	2.03	67.1%
600	0.80	1.97	2.77	71.0%
700	0.94	2.68	3.61	74.1%
800	1.07	3.49	4.56	76.6%
900	1.20	4.42	5.63	78.6%
1000	1.34	5.46	6.80	80.3%
1200	1.60	7.86	9.47	83.1%
1400	1.87	10.70	12.57	85.1%
1600	2.14	13.98	16.12	86.7%

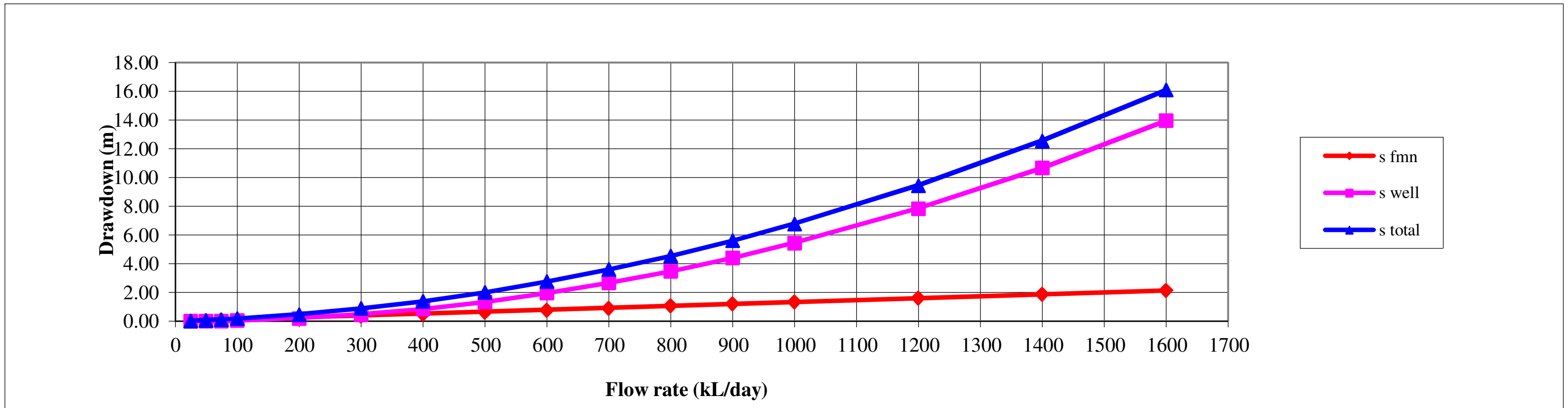
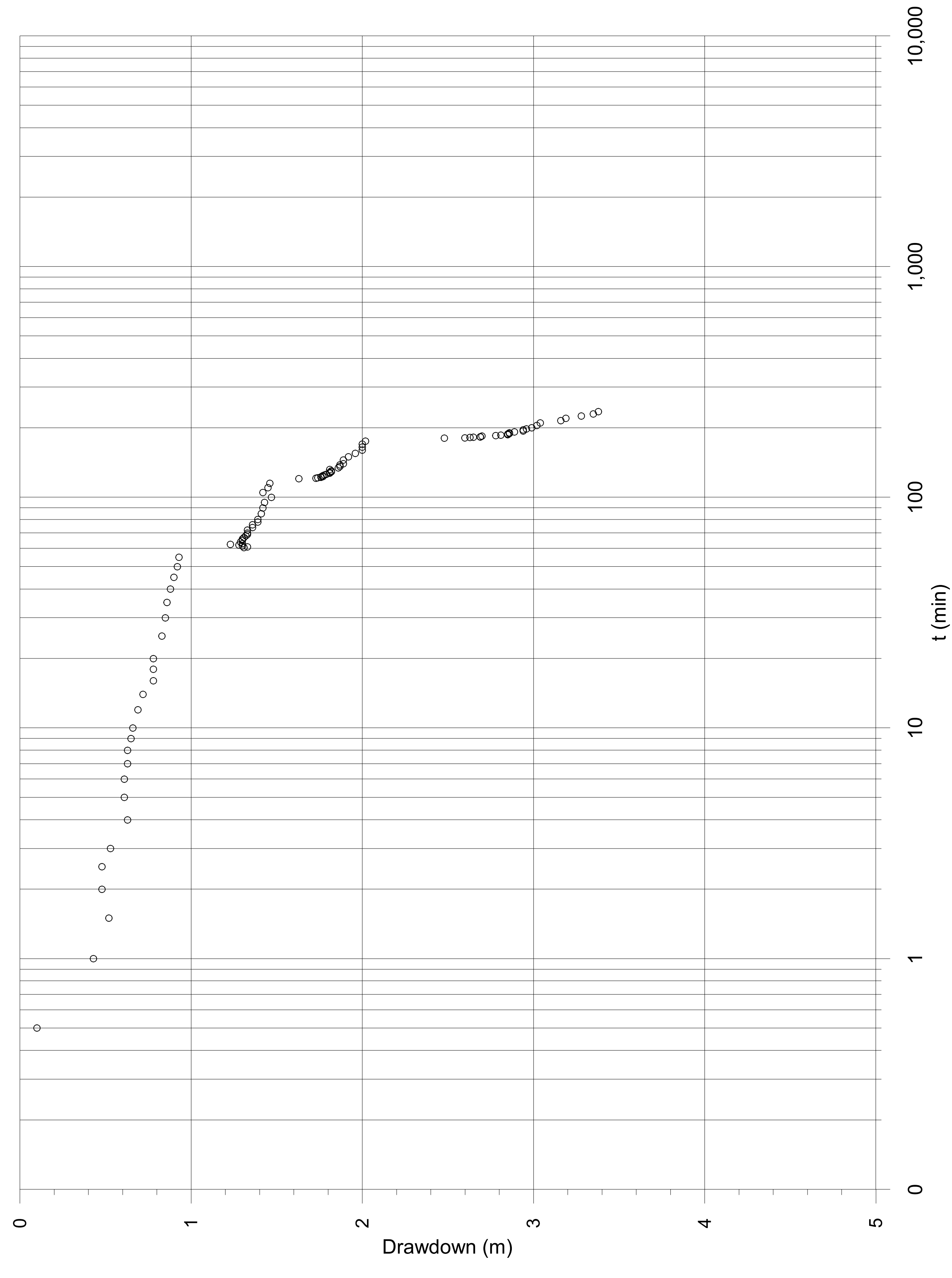


Figure AI-1



kakarook north step test.grf

Client: Vimy Resources

Project: Mulga Rock

Date: April 2015

Dwg. No: 345-0/15/1-AI-1

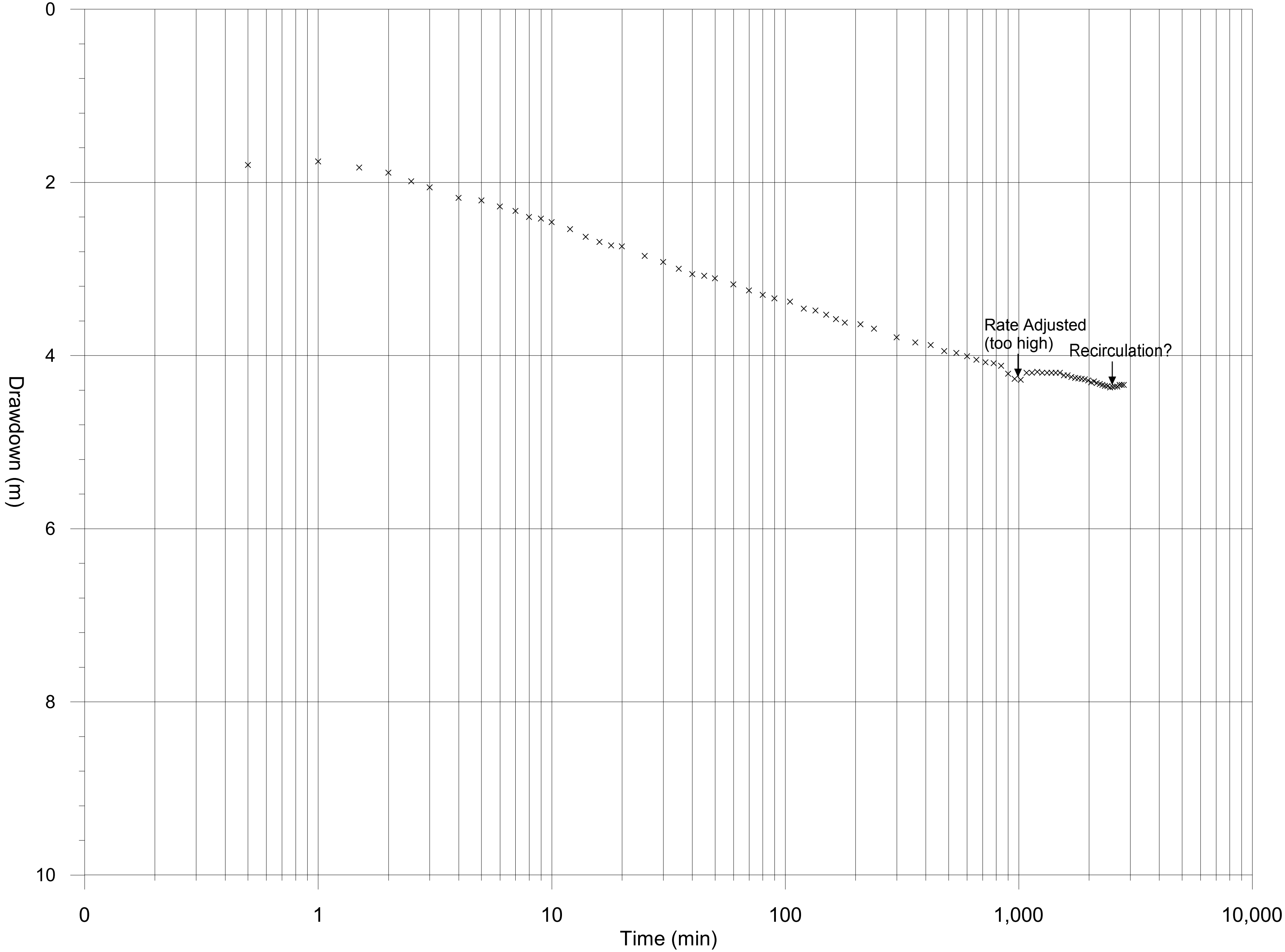
KAKAROOK NORTH PROD. BORE NWB3

STEP-RATE PUMPING TEST
at 184 KL/d, 305 kL/d, 389 kL/d, 608 kL/d

Rockwater Pty Ltd

Client: Vimy Resources
Project: Mulga Rock
Date: April 2015
Dwg. No: 345-0/15/1-AI-2

kakarook n prod.grf



KAKAROOK NORTH BORE NWB3
PUMPING RATE 600 KL/d, 7/3/15

Rockwater Pty Ltd

Figure AI-2

Client: Vimy Resources
Project: Mulga Rock
Date: April 2015
Dwg. No: 345-0/15/1-AI-3

KAKAROOK NORTH BORE NWB3
PUMPING RATE 600 KL/d, 7/3/15
RECOVERY TEST

Rockwater Pty Ltd

kakarook n prod recovery.grf

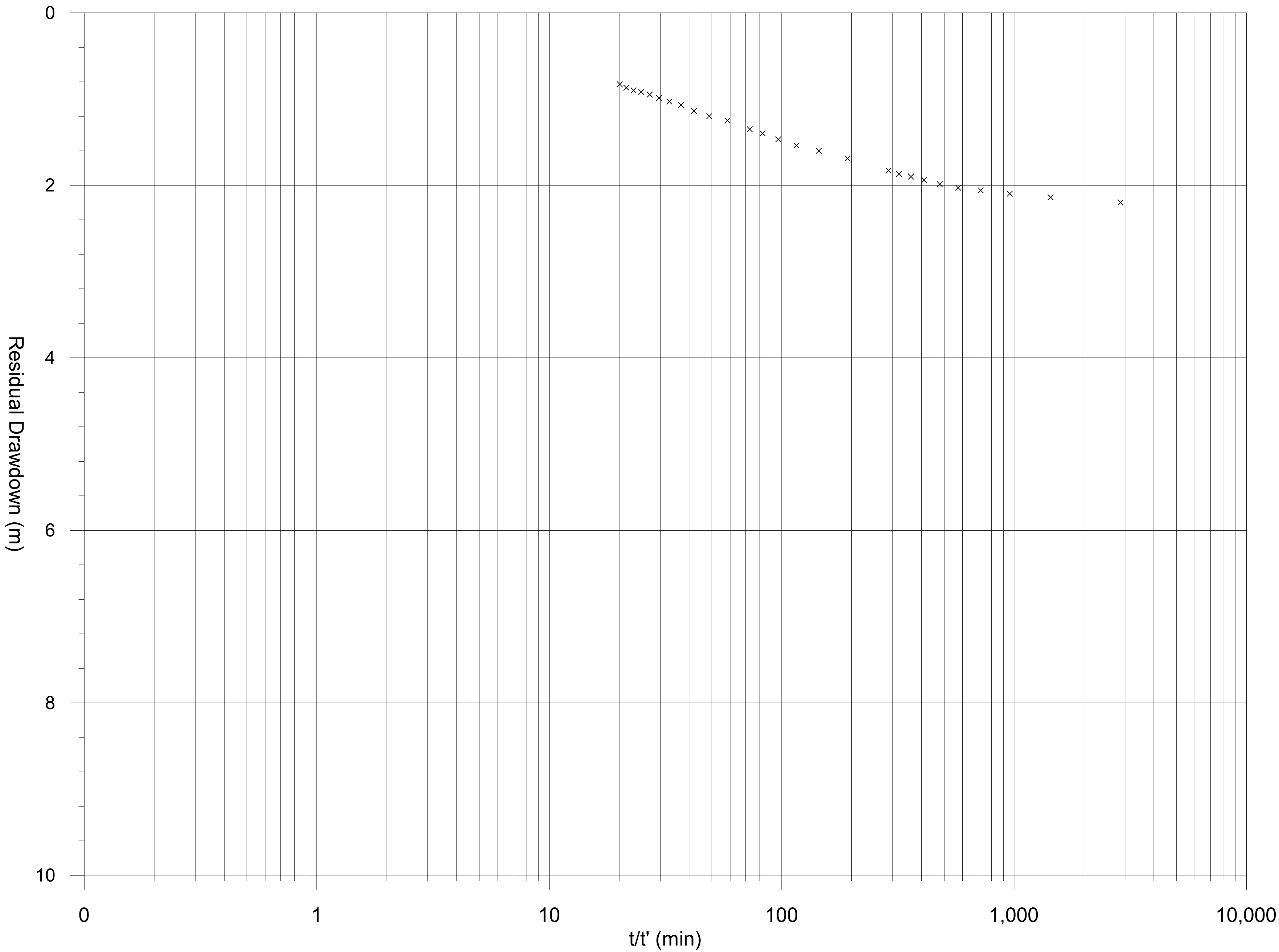


Figure AI-3

Client: Vimy Resources
Project: Mulga Rock
Date: April 2015
Dwg. No: 345-0/15/1-AI-4

KAKAROOK NORTH BORE NWB3
PUMPING TEST AT 600 KL/d, 7/3/15
DRAWDOWNS IN NGW48

Rockwater Pty Ltd

kakarook n ngw48.grf

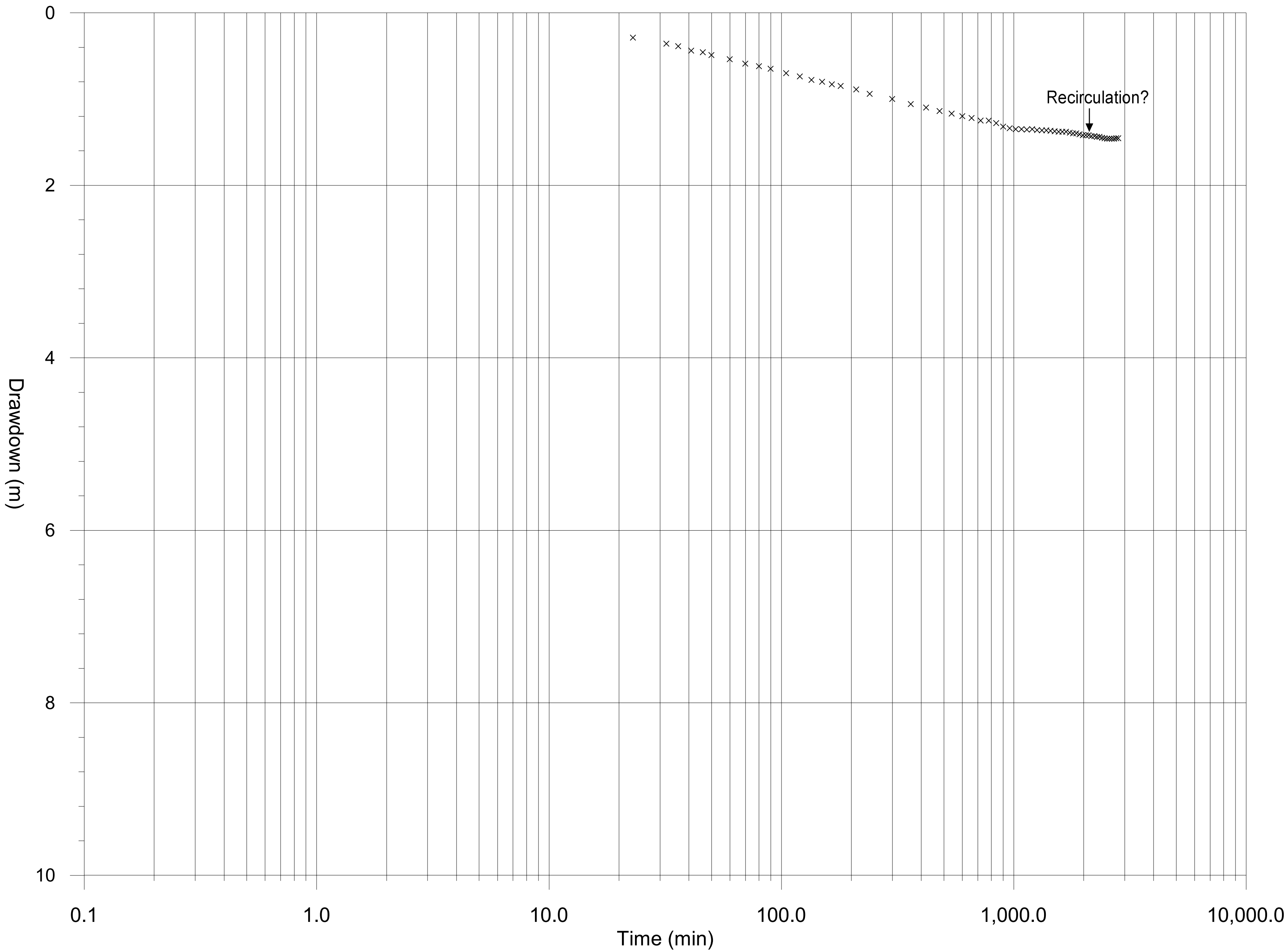
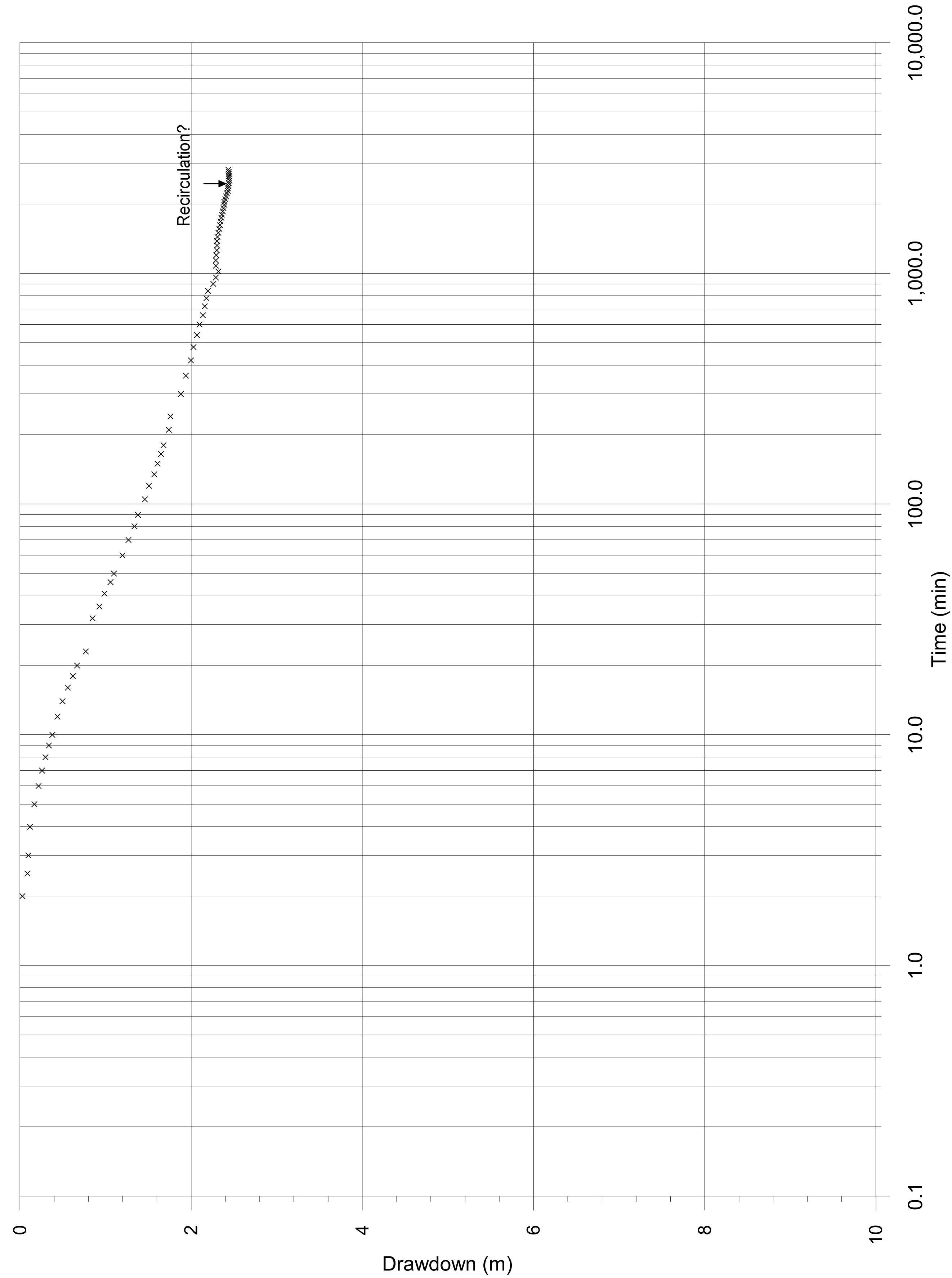


Figure AI-4

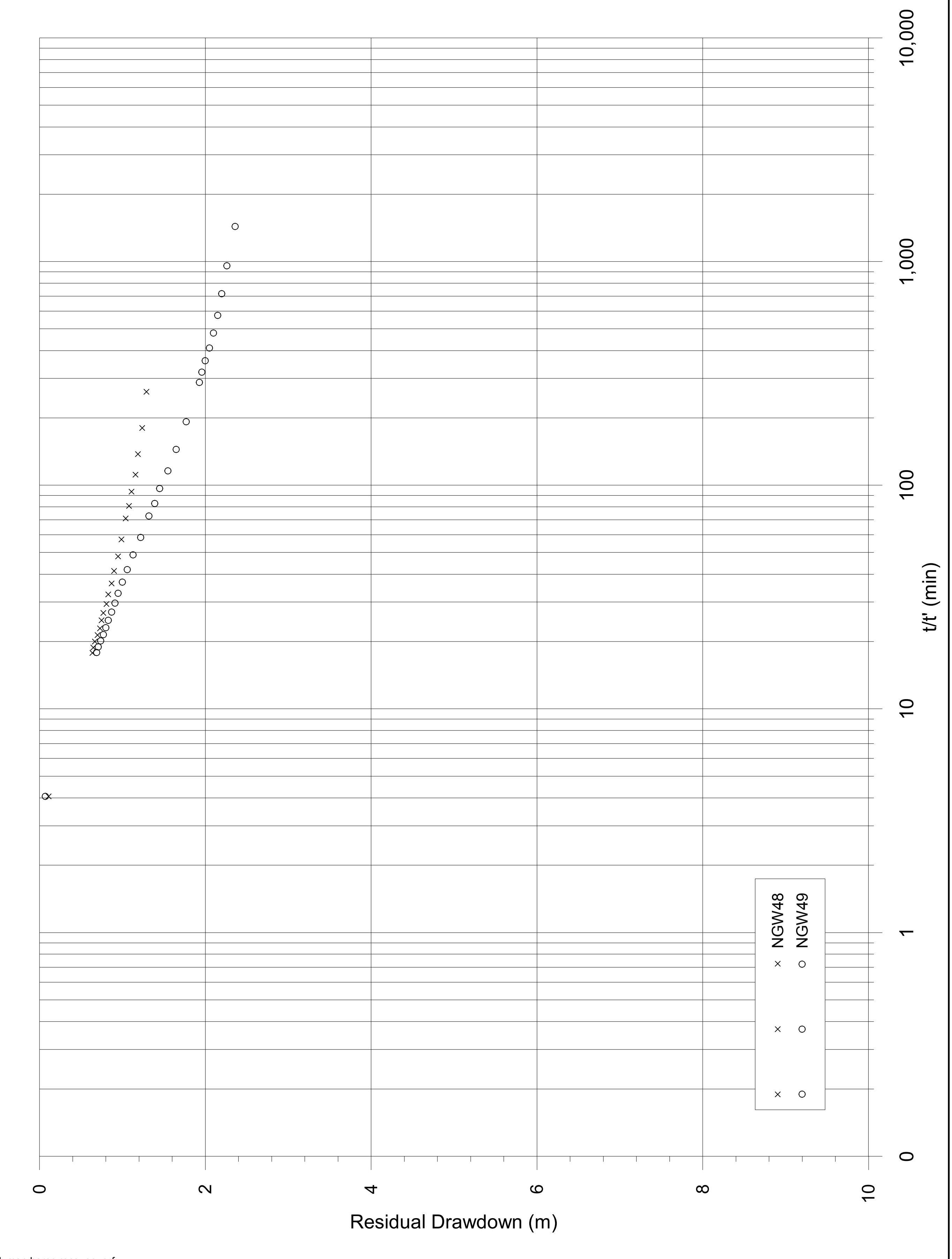
Figure AI-5



kakarook n ngw49.grf

Client: Vimy Resources Project: Mulga Rock Date: April 2015 Dwg. No: 345-0/15/1-AI-5	KAKAROOK NORTH BORE NWB3 PUMPING TEST AT 600 KL/d, 7/3/15 DRAWDOWNS IN NGW49 Rockwater Pty Ltd

Figure AI-6



kakarook mon bores recovery.grf

Client: Vimy Resources Project: Mulga Rock Date: April 2015 Dwg. No: 345-0/15/1-AI-6	KAKAROOK NORTH BORE NWB3 PUMPING TEST 600 KL/d, 7/3/15 RECOVERY IN MON. BORES NGW48 & 49 Rockwater Pty Ltd

APPENDIX B: Results of Chemical Analysis (SGS Australia)

		Description	NWB 03 - START	NWB 03 - END
		Sample Date	7/3/2015 14:45	9/3/2015 14:30
		Matrix	Water	Water
Analyte	Unit	Reporting Limit	Result	Result
pH	pH Unit	0	6.8	6.9
Conductivity @ 25 C	µS/cm	2	11000	9500
Total Dissolved Solids Dried at 175-185°C	mg/L	10	6900	6400
Total Alkalinity as CaCO3	mg/L	5	37	35
Carbonate Alkalinity as CO3	mg/L	1	<1	<1
Bicarbonate Alkalinity as HCO3	mg/L	5	45	42
Fluoride by ISE	mg/L	0.1	0.6	0.6
Chloride, Cl	mg/L	1	3300	2900
Sulphate, SO4	mg/L	1	960	880
Nitrate, NO_3 as NO_3	mg/L	0.2	<0.2	<0.2
Calcium, Ca	mg/L	0.2	160	150
Iron, Fe	mg/L	0.02	<0.02	0.58
Potassium, K	mg/L	0.1	120	110
Magnesium, Mg	mg/L	0.1	290	270
Manganese, Mn	mg/L	0.005	0.12	0.10
Sodium, Na	mg/L	0.5	1700	1500
Reactive Silica, SiO_2	mg/L	0.1	53	51
Total Mercury	mg/L	0.0001	<0.0001	<0.0001
Total Arsenic	mg/L	0.001	<0.005	<0.005
Total Boron	mg/L	0.005	3.3	3.0
Total Barium	mg/L	0.001	0.023	0.019
Total Beryllium	mg/L	0.001	<0.005	<0.005
Total Cadmium	mg/L	0.0001	<0.0005	<0.0005
Total Chromium	mg/L	0.001	<0.005	<0.005
Total Copper	mg/L	0.001	0.98	0.022
Total Cobalt	mg/L	0.001	0.020	0.015
Total Lead	mg/L	0.001	0.005	<0.005
Total Molybdenum	mg/L	0.001	<0.005	<0.005
Total Manganese	mg/L	0.001	0.12	0.094
Total Nickel	mg/L	0.001	0.046	0.025
Total Antimony	mg/L	0.001	<0.005	<0.005
Total Tin	mg/L	0.001	<0.005	<0.005
Total Selenium	mg/L	0.002	<0.01	<0.01
Total Zinc	mg/L	0.005	0.38	0.20
Total Uranium	mg/L	0.001	<0.005	<0.005
Total Thorium	mg/L	0.001	<0.005	<0.005