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Dewatering Plan

Redevelopment of Former Brick Pit, Kirrawee

for Henroth Investments Pty Limited
October 2010

J1418.10R-rev0

CMJA

C. M. Jewell & Associates Pty Ltd

Dewatering Plan - Redevelopment of Former Brick Pit, Kirrawee
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Controlled copy 1	*Mr Daniel Maurici* Henroth Investments Pty Limited Level 8 46-56 Kippax Street SURRY HILLS NSW 2010
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C. M. Jewell & Associates Pty Ltd
ABN: 54 056 283 295
1/13 Kalinda Road, Bullaburra, NSW 2784
PO Box 10, Wentworth Falls, NSW 2782
Phone (02) 4759 3251 Fax (02) 4759 3257
www.cm-jewell.com.au postie@cm-jewell.com.au

CHRIS JEWELL
Principal

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Appendix A Groundwater Flow Model

Measures

µg/L	micrograms per litre
km	kilometre
L	litre
m	metre
m^2	square metre
µS/cm	microsiemens per centimetre
mS/cm	millisiemens per centimetre
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mm	millimetre

General

AHD	Australian Height Datum
AMG	Australian Map Grid
ANZECC	Australian and New Zealand Environment and Conservation Council
AST	above-ground storage tank
CLM Act	Contaminated Land Management Act
CMJA	C. M. Jewell & Associates Pty Ltd
COPC	contaminants of potential concern
DA	development application
DEC	Department of Environment and Conservation
DECC	Department of Environment and Climate Change
DECCW	Department of Environment, Climate Change and Water
DLWC	Department of Land and Water Conservation
DNAPL	dense non-aqueous-phase liquid
DNR	Department of Natural Resources
DP	deposited plan
DQO	data quality objectives
EPA	Environment Protection Authority
ESA	Environmental Site Assessment
GDE	groundwater dependent ecosystems
HDPE	high-density polyethylene
MNA	monitored natural attenuation
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measure
PID	photoionisation detector
PQL	practical quantitation limit
ppmv	parts per million volume
PSH	phase-separated hydrocarbons
QA	quality assurance
QC	quality control
RAP	remediation action plan
RL	relative level
RPD	relative percentage difference
SWL	standing water level
TCLP	Toxicity Characteristics Leaching Procedure
THI	target hazard index
TOC	top of casing
TWA	time weighted average
UCL	upper confidence limit
UST	underground storage tank

Analytes – Organic

BaP	benzo(a)pyrene
BTEX	benzene, toluene, ethylbenzene, xylene
OCP	organochlorine pesticides
OPP	organophosphorus pesticides
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
SVOC	semivolatile organic compounds
TPH	total petroleum hydrocarbons
VHC	volatile halogenated compounds
VOC	volatile organic compounds

Analytes – Inorganic

As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
Fe	Iron
Hg	Mercury
Mn	Manganese
Ni	Nickel
Pb	Lead
Zn	zinc

1.0 INTRODUCTION

1.1 Background

This Dewatering Plan has been prepared in support of an application for Concept Plan approval under Part 3A of the Environmental Planning and Assessment Act at 566-594 Princes Highway, Kirrawee (as shown on Figure 1), otherwise known as the former Kirrawee Brick Pit (Reference MP 10_0076). The application seeks approval for a mixed use development comprising residential, retail and commercial uses and building envelopes of between 5 and 15 storeys. The proposal also involves basement car parking and includes commuter parking, landscaping, services and the provision of a major new public park.

Specifically, this report addresses requirements related to groundwater, pit dewatering, and associated contamination issues, as detailed in the Director General's Requirements (DGR) issued by the Department of Planning on 24 August 2010 and outlined below.

The proposal to redevelop the former Kirrawee Brick Pit will include construction of basement car-parking within the existing pit. As the pit is currently flooded, dewatering will be required, and as the proposed development extends below the local water table, long-term management of groundwater inflow will also be necessary.

The DGR included the following

> Plans and documents to accompany the Application.
>
> The following plans, architectural drawings, diagrams and relevant documentation shall be submitted;
>
> . . .
>
> 10. Site Contamination Assessment / Human Health Risk Assessment / documentation that demonstrates that the land is or can be made suitable for the intended purpose within the project delivery timeframe.
>
> . . .
>
> 12. Groundwater Assessment – identifying groundwater issues and potential degradation to the groundwater source that may be encountered during excavation. The assessment should identify contingency measures to manage any potential impacts.
>
> **10. Drainage and Stormwater Management**
>
> - The EA shall address drainage/groundwater/flooding issues associated with the development/site, including stormwater, drainage infrastructure and incorporation of Water Sensitive Urban Design measures.
> - An urban design integrating ‘best practice’ stormwater management principles to minimise the generation of stormwater from the development and maximise opportunities for reuse on-site.
> - Measures to ensure that water quality in the ornamental lake/compensatory pond is continuously maintained to a standard suitable for wildlife known to drink from the existing water body and to a standard compatible with public safety and amenity.
> - Measures to ensure that stormwater flows from the site including any discharges from the ornamental lake/compensatory pond are controlled and appropriately treated to ensure that there will be no short-term or long-term detrimental impacts to the receiving waters or environment.
> - A methodology to dewater the brick pit in preparation for construction of the development that specifically addresses the following issues:
>   - Measures to protect against possible environmental impacts associated with dewatering the brick pit;
>   - Opportunities to reuse the water for beneficial purposes in preference to disposal;
>   - Analysis of water quality and risk to the receiving environment;

- Impact of dewatering the brick pit on wildlife habitat;
- Affect of withdrawing the water from the brick pit on the groundwater resource; and
- Stability of the empty impoundment and potential for bank failure, particularly the influence on Flora Street.

11. Contamination, Human Health Risk Assessment and Geotechnical Issues.

- Contamination and geotechnical issues associated with the proposal should be identified and addressed in accordance with SEPP55.

In order to address data and information gaps, Mr Daniel Maurici of Henroth Investments Pty Limited commissioned C. M. Jewell & Associates Pty Ltd (CMJA) to carry out an investigation and to prepare plans for dewatering and long-term groundwater management.

This document is the Dewatering Plan. A Hydrogeological Data Report (CMJA ref. J1418.9R-rev0, dated October 2010) setting out the results of the investigation, and a Long-Term Groundwater Management Plan (CMJA ref. J1418.11R-rev0, dated October 2010) have been prepared and submitted under separate covers.

1.2 Project Objectives

The objectives of this document are to describe an approach to dewatering of the flooded former brick pit at Kirrawee, prior to redevelopment of the site for commercial and residential purposes. This report also sets out the detailed procedures required to implement that approach.

It is intended to be a stand-alone document that can be used to guide the dewatering program, and also address the relevant parts of the DGRs.

1.3 Scope and Data Sources

This report addresses hydrogeological issues associated with dewatering of the pit, the dewatering operation itself, and disposal of the water currently contained within the pit. It does not deal with geotechnical issues concerning the stability of the pit sides during and following dewatering; these issues have been addressed by others.

The procedures described in this report are based on data compiled in the Hydrogeological Data Report and on groundwater flow modelling described in Appendix A of this report.

1.4 Report Format

Section 2 of this report provides a brief summary of hydrogeological conditions on the site. For further detail, and a full list of information sources, reference should be made to the Hydrogeological Data Report.

Section 3 outlines the basis for the dewatering design, while dewatering and water disposal options are discussed in Sections 4 and 5 respectively.

Section 6 briefly describes the groundwater modelling that has been carried out, with a more complete presentation provided in Appendix A.

Some regulatory aspects are discussed in Section 7, and conclusions and recommendations, which form the essence of the dewatering plan, are set out in Section 8.

1.5 Limitations and Intellectual Property Matters

This report has been prepared by C. M. Jewell & Associates Pty Limited for the use of the client identified in Section 1.1, for the specific purpose described in that section. The project objectives outlined in Section 1.2 were developed for that purpose, taking into consideration any client requirements and budgetary constraints set out in the proposal referenced in Section 1.1.

The work has been carried out, and this report prepared, utilising the standards of skill and care normally expected of professional scientists practising in the fields of hydrogeology and contaminated land management in Australia. The level of confidence of the conclusions reached is governed, as in all such work, by the scope of the investigation carried out and by the availability and quality of existing data. Where limitations or uncertainties in conclusions are known, they are identified in this report. However, no liability can be accepted for failure to identify conditions or issues which arise in the future and which could not reasonably have been assessed or predicted using the adopted scope of investigation and the data derived from that investigation. An information sheet – 'Important Information about your Environmental Site Assessment' – is provided with this report. The report should be read in conjunction with that information sheet.

Where data collected by others have been used to support the conclusions of this report, those data have been subjected to reasonable scrutiny but have essentially, and necessarily, been used in good faith. Liability cannot be accepted for errors in data collected by others.

This report, the original data contained in the report, and its findings and conclusions remain the intellectual property of C. M. Jewell & Associates Pty Ltd. A licence to use the report for the specific purpose identified in Section 1.1 is granted to the persons identified in that section on the condition of receipt of full payment for the services involved in the preparation of the report.

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2.0 SUMMARY OF SITE CONDITIONS

This section includes a brief summary of hydrogeological conditions on the site. For further detail, and a full list of information sources, reference should be made to the Hydrogeological Data Report (CMJA report no. J1418.9R-rev0, dated October 2010).

2.1 Site Identification

The site is located in Kirrawee, between the Princes Highway, which forms the northern boundary of the site, and Flora Street, as shown on Figure 1. It is bounded to the east by a number of industrial units, and to the west by Oak Road. The site address is 566-594 Princes Highway, Kirrawee, and the land title designation is Lots 1 and 2 in DP589977 and Lot 1 in DP179075.

2.2 Site Description

The site is roughly rectangular and measures approximately 250 metres east-west by 170 metres north-south, and has an area of 4.25 hectares. As shown on Figure 2, the former quarry occupies most of the southern half of the site; the northern side of the site falls towards the Princes Highway in a series of slopes and shallow terraces.

2.3 Current Site Use

The site is currently disused. The former quarry pit is filled with water, and the remainder of the site is heavily overgrown with vegetation, including many species of exotic weeds.

2.4 Surrounding Area

Land use in the area surrounding the site is predominantly low-density residential, with commercial and light industrial use immediately to the east of the site and also to the north of the Princes Highway, and a small commercial area to the south-east. There is commercial (retail) development to the south-west, and light industry to the south. The Sutherland–Cronulla railway lies one block to the south, and there are a number of recreational open space areas nearby.

2.5 Topography and Drainage

The site is located on the northern flanks of the Woronora Plateau, about 30 kilometres south of Sydney. The site lies on the crest of a ridge that divides the lower Woronora River and Hacking River drainage systems.

Most of the surface of the site – excluding the area of the brick pit itself – dips gently to the east in line with the structural inclination of the region. The elevation in the south-western corner of the site – which is also the highest point of the site – is about 105 metres above Australian Height Datum (AHD), and that part of the site lies along the crest of a locally prominent ridgeline; this ridgeline generally follows the direction of the Princes Highway and forms the major surface water divide in the area. From the south-western corner, the site gently slopes to the east and south-east, with the elevation in the south-eastern corner measured at 94 metres AHD.

The height of the pit walls range from over 15 metres along the western face of the quarry, to a little over 3 metres in the south-eastern corner of the site. The quarry walls vary in slope between near vertical to 20 degrees, with the steepest faces along the southern boundary of the former quarry where some remedial works, including rock bolting and shotcrete application, have been carried out to ensure the stability of these walls.

2.6 Geology

The site is situated on one of the 'claystone, siltstone and laminite' (shale) lenses that occur within the Hawkesbury Sandstone on the Woronora Plateau. These lenses are usually mid to dark-grey, lensoidal in shape, and may either grade into the overlying sandstone or have sharp boundaries. They vary in thickness from a few millimetres to more than 10 metres and may be laterally continuous for several hundreds of metres.

Geological conditions on site have been documented by URS Australia Limited (URS). In 2003 URS drilled four geotechnical boreholes to depths of 15 metres, logged the core for geological and geotechnical purposes, and carried out pit wall geotechnical mapping, then defined the geological and geotechnical units encountered and drew a geotechnical cross-section of the northern part of the site. The cross-section and borehole logs are included in CMJA's Hydrogeological Data Report and the geological units are summarised in Table 1.

TABLE 1
Geological Units as Defined by URS

Unit No.	Geological Description	Approximate Thickness (m)	Rock Mass Classification
1	FILL: silty CLAY and sandy CLAY with assorted fragments, orange brown, low plasticity, firm to very stiff, fragments include concrete and bricks.	1.0 to 2.5	-
2	RESIDUAL SOIL: silty CLAY, red-brown and grey, low to medium plasticity, stiff to hard occasional sub-angular to angular shale fragments.	1.0 to 7.0	-
3a	EXTREMELY TO DISTINCTLY WEATHERED SHALE: extremely low to very low strength, light and dark-brown grey, laminated, fractured to fragmented, some residual clay zones, local siltstone towards the base.	3.0 to 7.0	Class V-IV shale
3b	SLIGHTLY WEATHERED SHALE: medium strength, dark grey, thinly laminated, poorly developed bedding, fractured, localised fragmented zones and low strength although stronger where iron staining is present.	3.0 to 4.5	Class III shale
4a	EXTREMELY TO DISTINCTLY WEATHERED SANDSTONE: low to medium strength, orange brown, massive to faintly cross-bedded, fine to medium-grained, fragmented to slightly fractured.	2.0 to 3.0	Class IV sandstone
4b	SLIGHTLY WEATHERED SANDSTONE: medium to high strength, light-grey brown, massive to faintly cross-bedded, fine to medium-grained, fractured to slightly fractured	Greater than 2.0	Class III sandstone

In the northern portion of the site, bedding dips very gently from west to east at about 2 degrees, which is consistent with the regional trend inferred from the Wollongong–Port Hacking geological map sheet; this was confirmed during site reconnaissance works carried out by CMJA.

The depth to and thickness of some of these units, and also their degree of weathering, vary across the site; this is most evident in the declining thickness of the weathered profile from west to east. A thicker soil horizon is also evident along the western batters of the quarry lake compared to those along the eastern batter.

Discontinuities in the bedrock are dominated by jointing planes and bedding plane partings, that, according to URS, are typical of jointing patterns in the Hawkesbury Sandstone. CMJA agrees with that statement. Specifically, URS identified two prominent sub-vertical joint sets – which they referred to as Set 1 and Set 2 – and a weak and ill-defined third set. These sets were mapped along the exposed cuttings along the southern face of the pit and were described as follows.

Set 1 (major set): strikes north-north-west and is sub-vertical in orientation; URS also noted that the strike of this set is roughly perpendicular to the east-west alignment of the southern wall of the former quarry.

Set 2 (secondary set): strikes east-south-east and is subvertical in orientation; the strike of this set is sub-parallel to oblique to the southern wall of the former quarry.

Set 3 (weak set): randomly orientated, and variably dipping; was also encountered along well-exposed sections of the western pit wall, although no other description of its occurrence was provided.

Spacings between joints in each of the above sets were typically between 0.5 and 1.0 metre, however there appeared to be a lot of variability in joint frequency, with URS noting that locally, joint spacing could be ‘much closer or wider’ than that described above.

URS also provided the following geotechnical description of the shale horizons exposed in the walls of the pit.

> Slope stability in exposed rock cuts is controlled by the presence of planes of weakness consisting of a combination of bedding plane partings and jointing which results in various modes of instability. The bedding plane is sub-horizontally orientated and thinly to very thinly spaced (with partings varying between 2 to 20 centimetres) and may be persistent for tens of metres or more.

2.7 Hydrogeology

Groundwater in the vicinity of the site flows predominantly within the numerous discontinuities such as joints, bedding plane partings and miscellaneous fractures, which form a fractured rock aquifer within the shale; minor flows associated with weathered horizons and lithological contrasts may occur within the shale and siltstone layers as well (i.e. primary porosity flows), however these are likely to be restricted to the western half of the site.

Hydraulic conductivity test results (detailed in the Hydrogeological Data Report) indicate that the hydraulic conductivity of the shale and the upper part of the weathered sandstone on the site (Australian Water Technologies screened its monitoring wells across both of these units) varies between 1.3 x 10^{-6} and 6.4 x 10^{-6} metres per second (m/s^{-1}); values of transmissivity vary between about 1.4 x 10^{-5} and 3.7 x 10^{-5} metres squared per day (m^2/day^{-1}).

Whilst these measured values of hydraulic conductivity lie within the regional range (as described in the data report), they are towards the upper end of that range. It is possible that in the vicinity of the former quarry the aperture and connectivity of defects (which together control the secondary hydraulic conductivity) have been enhanced by the combined effects of blasting and ground movement, and that further away from the quarry, the hydraulic conductivity is lower.

Standing water levels have been measured during a number of monitoring events since May 1999, as described in the Hydrogeological Data Report. During each event, water levels were measured from each of the groundwater monitoring wells installed by Australian Water Technologies (AWT) – namely GW1, GW2 and GW3 – whilst during the November 2001 and December 2008 monitoring events, water levels were also measured in the two wells installed by URS in 2006 (i.e. BH1 and BH4).

The elevation of the water table is greatest in the north-western corner of the site (i.e. in monitoring well GW1), and falls gently with distance to the east. The groundwater flow direction coincides with both the local topographic expression and the regional inclination of the Hawkesbury Sandstone, with groundwater flowing from the north-western corner of the site to the east and south-east.

Discharge from the aquifers is thought to occur primarily through natural flow from springs, both perennial and ephemeral, and baseflow into perennial watercourses.

A review of records held by the Department of Water and Energy (DWE), covering boreholes within 2 kilometres of the centre of the site, identified seven registered boreholes, the closest being GW103885 located about 150 metres east of the site. The bore was drilled for monitoring purposes and screened between the ground surface and 6 metres depth.

Groundwater in the area does not appear to be used beneficially, other than for maintenance of ecosystems by natural discharge.

Groundwater quality is described in the data report and discussed in Section 3.4 of this report.

3.0 DESIGN BASIS

3.1 Levels

CMJA understands from the Woodhead Masterplan Drawing No. 0300 (21/10/10) that the finished floor level of the basement to be constructed within the pit will be 85.00 metres AHD. This implies a construction working level of about 84.40 metres AHD, which will in turn require that the groundwater and lake level be lowered to an average of about 83.90 metres AHD to allow safe and comfortable working conditions to be maintained during construction.

The current water level in the lake is 91.7 metres AHD, so the water level will need to be lowered by 7.8 metres.

3.2 Volume of Water in Pit

Currently, the former quarry pit contains approximately 55 megalitres (ML) of water.

3.3 Groundwater Inflow during Dewatering

The rate of groundwater inflow during dewatering operations and subsequent construction work has been assessed using a three-dimensional groundwater flow model (see Section 6 and Appendix A of this report). It will depend partly upon the rate at which the pit is dewatered. If, as recommended in this report, dewatering takes place over a period of about seven weeks, at an instantaneous pumping rate of about 15 litres per second (L/s) or 1300 m^3/day, then inflow will gradually increase from near zero to a maximum of approximately 2 L/s, then decline to a long-term rate of approximately 90 m^3/d or 1 L/s. Thus groundwater inflow will make up less than 10 per cent of total pumping during initial dewatering.

3.4 Water Quality

The chemistry of water currently within the brick pit is described in detail in the Hydrogeological Data Report, and reference should be made to that document for full information concerning water chemistry.

In summary, most of the water in the pit (down to a depth of approximately 4.5 metres) appears to be well mixed and well oxygenated, with low turbidity and a slightly alkaline pH. This water has a relatively low salinity – an electrical conductivity (EC) of about 1000 microsiemens per cm (μS/cm) – equivalent to a total dissolved solids content of about 650 mg/L, which is at the upper end of the potable-use range, and suitable for irrigation of moderately salt-sensitive plants.

Water in the quarry lake is sodium-bicarbonate dominant. Concentrations of nutrients and heavy metals are low.

Boron concentrations are less than 1 mg/L, which is below the trigger value for irrigation of all but the most sensitive plants, but above the trigger value for 95% species protection in aquatic ecosystems.

Water in the deeper parts of the pond appears to have stratified. The bottom water, while not significantly different in salinity and major ion chemistry, is poorly oxygenated and somewhat reducing in character, with near-neutral pH and elevated concentrations of iron and manganese. This water will need to be handled differently from the bulk of the pit water.

In the long term, the quality of water pumped from the pit will approach that of the local groundwater. Groundwater quality is described in detail in the Hydrogeological Data Report. The groundwater is only slightly more saline than the pit water, with an average EC of 1250 μS/cm, and has insignificant concentrations of anthropogenic contaminants, but it is anoxic and contains high concentrations of iron and manganese.

4.0 DEWATERING OPTIONS

4.1 Major Issues and Constraints

Matters to be considered in developing a dewatering strategy include:

- rate of dewatering
- placement of pumps
- management of anoxic water in the lower section of the pit
- management of sediment.

4.1.1 Rate of Dewatering

The optimal rate of dewatering will be determined by slope stability issues, the capacity of receiving drainage systems and the availability and cost of pumping plant and associated pipe-work.

It has been recognised (URS 2003, 2006) that the sloping faces of the former brick pit, in particular the south wall, are potentially unstable.

If the water level in the lake were to be drawn down at a rate greater than the drainage rate of the slopes, then the development of excess pore pressures and excess water pressure within joints and bedding-plane fractures would exacerbate the risk of slope failure.

The issue of slope stability during dewatering requires specialist geotechnical review, and has indeed been the subject of such review (Jeffery and Katauskas 2010). Jeffery and Katauskas indicate that progressive stabilisation of the southern face will need to be carried out during dewatering.

With regard to the rate of drainage, the following considerations are relevant.

Excluding the extremely weathered material at the top of the slopes, which is substantially above the current water level, the shale that forms the steeper slopes is characterised by a predominant fracture permeability, low intergranular permeability and low effective porosity. These features promote relatively rapid drainage. Assessment of drainage rate carried out with an equivalent porous medium model will tend to underestimate the real drainage rate, and is therefore conservative. This modelling (Section 6 and Appendix A) indicates that if the water level in the lake is lowered at a rate of less than 150 millimetres per day, then excess pressures within 5 metres of the face will be negligible. This implies a dewatering time of about seven weeks.

The modelling provides a guide. Monitoring piezometers installed behind the critical faces would provide reassurance that unacceptable excess pressures do not develop during dewatering. In the event that drainage proved to be slower than predicted, the pumping rate could be reduced.

The need to progressively stabilise the faces during dewatering also indicates that dewatering should be carried out at a rate that permits this work to keep up with the falling water level, and that permits design changes to be made and implemented if necessary. This requirement is consistent with a dewatering time of seven weeks, or a little longer.

As a guide, if the pit were to be dewatered over a period of seven weeks, the average rate of fall would be 157 millimetres per day and the required pumping rate would be about 15 L/s. However, for practical as well as geotechnical reasons, the rate of fall of the water level would be slower during the initial part of dewatering, and would be faster at the end of the process, by which time the critical levels adjacent to Flora Street would be fully drained.

4.1.2 Placement of Pumps

For the modest pumping rate required, a number of options would be viable. However, to minimise sediment entrainment, minimise suction lift and provide maximum flexibility, it would be sensible to place pumps on tethered pontoons located close to the centre of the pond, and linked to bank stations using flexible hose and appropriate waterproof cabling. This would remove the need to relocate pump intakes as the water level in the lake is lowered.

4.1.3 Management of Anoxic Water in the Lower Section of the Pit

The water in the lower part of the lake – below about 4.5 metres depth, or 87.2 metres AHD – is anoxic, and has high dissolved concentrations of iron and manganese. This water will require careful management.

It will be necessary to monitor the pumping system as this layer is approached, to avoid unnecessary mixing.

Once the anoxic layer is reached, several options are available; these may be used singly or in combination.

- Progressively transfer the water to the deepest part of the lake, where it can be treated by aeration (using an air compressor and diffuser) and by the addition of lime. The iron and manganese will form a floc that will settle out, allowing the clear upper layer to be pumped off. This process can then be repeated.
- As the base of the quarry is not all at the same level, and the anoxic layer is thin in some areas, it may prove more economical to use a waste disposal contractor to remove water from residual ponds once the bulk of the dewatering has been completed.
- As some filling of low areas of the quarry floor is envisaged, at least some of the residual water could be used to assist fill compaction in these areas, thus being absorbed into the fill material.
- Some water can be used for dust suppression on site.

4.1.4 Management of Sediment

Use of a pontoon-based pumping system and careful monitoring of water depth and the position of the suction intake will provide the most effective means of eliminating sediment uptake during pumping.

4.2 Recommended Approach

The preferred approach is to dewater the brick pit over a period of approximately seven weeks, at a nominal pumping rate of 15 L/s or 1300 m^3/d, using pumps mounted on one or two pontoons tethered close to the middle of the lake. Water pressure in the banks would be carefully monitored using a series of piezometers installed prior to the start of pumping, and the pumping rate would be adjusted as necessary. Pumping may also need to be slowed to permit the completion of stabilisation works on the south face as the water level is lowered.

The discharge rate will be continuously monitored using an appropriate magnetic flow meter.

Water quality will be regularly monitored.

A range of measures will be implemented to treat the anoxic layer below 87.2 metres AHD.

5.0 DISPOSAL OPTIONS

5.1 Description of Options

The options available for disposal of water produced during pit dewatering are:

- Disposal to the stormwater system, either directly or by using a feeder line.
- Beneficial use of the water off site
- Re-use on site

Disposal to the stormwater system: This is the most practical option. The proposed pumping rate of 15 L/s is low in comparison to the capacity of all but the smallest stormwater drains, and is highly unlikely to cause overload at any point in the drainage system.

If necessary, flow could be split between the system draining north to Oyster Gully (accessible at the corner of Oak Road and the Princes Highway, at the north-west corner of the site), and the system draining south to Dents Creek, accessible on Flora Street east of the site.

Given the steep gradients of both Oyster Gully and Dents Creek, and their large natural flow range, the proposed discharge would not cause flooding in these waterways.

Beneficial use off site: Some of the water can be made available to off-site users by tanker. Suitable uses would be dust suppression; compaction of soil, fill or road-base material; and irrigation of sports ovals, golf courses or similar open spaces. There are approximately eight such facilities, including a large golf course, within 3 kilometres of the site.

As discussed in the Hydrogeological Data Report, the water is suitable for almost all irrigation purposes. Fill time for a 10,000-litre tanker would be approximately 12 minutes. It is hard to estimate what the take-up of an offer of free water would be, and clearly this would depend to some extent on the time of year and prevailing weather conditions.

Re-use on site: Some water could be used on site. Preferentially, this would be the deeper anoxic water, as discussed in Section 4.

5.2 Potential Environmental Impacts

As indicated in the Hydrogeological Data Report, both Oyster Gully and Dents Creek appear to be heavily impacted by urban influences. Weed encroachment and infestation are significant in Dents Creek, and sewage discharge appears to occur in both creeks. In this area the catchments of both creeks are almost entirely urbanised.

As also indicated in the data report, the bulk of the water in the quarry lake (i.e. the upper 4.5 metres of the lake) is of high quality. Salinity is low, oxygenation high, temperature and pH within an ecologically neutral range, and with the sole exception of boron, no nutrients or toxicants are present in significant concentrations.

The boron concentration in the lake water (typically 700 µg/L) is above the ANZECC trigger value for 95% species protection (370 µg/L), but only marginally above that for 90% species protection (680 µg/L) and would fall below this value with minimal in-stream dilution. As indicated in the data report, boron is not assessed to be an anthropogenic contaminant; a natural source, from the shale or decaying vegetation, is considered to be likely.

Examination of the data used for the development of the 95% ANZECC trigger value indicates that this value is driven by the sensitivity of one species of algae (*Chlorella pyrenoidosa*). Most of the freshwater species considered (all fish, crustaceans and macrophytes, and other *Chlorella* species) are much less sensitive to boron. An aquatic ecological assessment would be able to establish whether or not boron-sensitive species are likely to be present in these watercourses.

The background concentration of boron in sea water is 5100 μg/L, and ANZECC recommends the use of this figure as a trigger value for marine waters. Thus, boron concentration will not be an issue below the tidal limit.

Groundwater will contribute less than 10 per cent of the total water volume removed during pit dewatering. Although the groundwater is anoxic and has relatively high concentrations of iron and manganese, the groundwater inflow will mix with oxygenated water in the lake, and most of the iron and manganese will precipitate there. The groundwater does not contain significant concentrations of anthropogenic contaminants.

CMJA considers that natural baseflow in both Oyster Gully and Dents Creek is substantially derived from groundwater in the shale and sandstone of the Hawkesbury Group.

There is thus no reason to expect that any adverse ecological impact due to chemical quality would result from short-term discharge of the quarry lake water to these creek systems.

The proposed discharge of 15 L/s is well within the range of natural flows in the creek systems and is most unlikely to cause scouring, wash-outs or other physical impacts. Additional dry-weather flow may be beneficial to aquatic ecosystems.

5.3 Mitigation Options

It would be possible to cease pumping during heavy rainfall, or on the forecast of thunderstorms, to remove any possibility of overload on the stormwater system. Similarly, in the event of problems such as drain blockages or burst water mains, pumping could cease on demand.

Water quality in Oyster Gully and/or Dents Creek downstream of the stormwater discharge point(s) would be monitored throughout the dewatering period.

On the basis of the water analyses provided in the data report, analysis for conductivity, pH, turbidity, temperature, dissolved oxygen, iron, manganese and boron is considered to be appropriate by CMJA.

5.4 Recommended Approach

It is recommended that the quarry lake water be discharged to the stormwater system using the mitigation measures outlined in Section 5.3.

Water should be made available free of charge to anyone willing to collect it from the site, and an appropriate tanker filling point should be provided for this purpose.

6.0 MODELLING

The groundwater flow system at the site was modelled using the USGS three-dimensional finite-difference flow model MODFLOW 2000. The aquifer system was discretised vertically into three layers, corresponding to the shale, the highly weathered sandstone and the fresh to slightly weathered sandstone units. Laterally, the system was discretised into 132 columns and 100 rows.

An engineering model approach was used, in that measured or judgementally derived boundary conditions and material properties were applied to the system and the validity of these assumptions assessed by sensitivity analysis, rather than adopting the model calibration approach commonly used in resource studies. The engineering approach is commonly used in pre-development studies simply because time-variant calibration data are usually unavailable for such work.

Lateral constant-head boundaries were applied at an elevation of 63 metres AHD, and sensitivity analysis was used to check that these boundaries did not significantly affect model output. Recharge was applied at a constant rate across the urbanised area of the model, with a higher rate applied to the site under pre-development conditions, and to other large open areas.

Material properties were estimated from the on-site measurements provided in the Hydrogeological Data Report. Both steady state and transient models were run.

Chemical changes were assessed using the particle-tracking feature of MODFLOW, supplemented with some geochemical modelling using the Geochemists Workbench.

A full description of the models and the results of groundwater flow and hydrochemical modelling are set out in Appendix A of this report.

6.1 Groundwater Inflow and Aquifer Drawdown

Using a conservative (i.e. high-end) set of assumptions derived from on-site measurements, groundwater flow to the pit for the construction scenario ranged from 109 m^3/day after dewatering to 75 m^3/d three months later, an average of approximately 90 m^3/d or 1.0 L/s; for this scenario, the pit was assumed to have been dewatered to 86.5 metres AHD (the effective pit base, excluding the deepest area), with groundwater recharge occurring across the whole site.

For the post-development scenario, which assumed that the site was substantially paved and incorporated a stormwater harvesting system, the steady-state groundwater inflow to the pit was estimated to be about 44 m^3/d, which is equivalent to about 0.5 L/s.

Although using less conservative assumptions may be justified by hydrogeological reasoning, and generates lower rates of groundwater inflow, the conservative values should be used for design purposes.

Steady-state drawdown around the pit is shown on Figure 3.

The development of transient drawdown around the pit during dewatering is shown in a series of snapshots in Appendix A.

6.2 Salinity Changes

Particle tracking indicates that groundwater flow to the pit is derived predominantly from the west, and that the quality of water pumped from the pit will change to that measured in groundwater monitoring wells GW1 and GW2 within two years. More rapid change is likely, however, because it is probable that groundwater of this quality is already present near the pit.

7.0 REGULATION AND PERMITTING

Discharge to the stormwater system is subject to the approval of Sutherland Shire Council under s138 of the Roads Act 1993.

The discharge would also be subject to the general prohibition of pollution of waters prescribed in s120 of the Protection of the Environment Act 1997.

Pollution of waters is defined in the Act as:

(a) placing in or on, or otherwise introducing into or onto, waters (whether through an act or omission) any matter, whether solid, liquid or gaseous, so that the physical, chemical or biological condition of the waters is changed, or

(b) placing in or on, or otherwise introducing into or onto, the waters (whether through an act or omission) any refuse, litter, debris or other matter, whether solid or liquid or gaseous, so that the change in the condition of the waters or the refuse, litter, debris or other matter, either alone or together with any other refuse, litter, debris or matter present in the waters makes, or is likely to make, the waters unclean, noxious, poisonous or impure, detrimental to the health, safety, welfare or property of persons, undrinkable for farm animals, poisonous or harmful to aquatic life, animals, birds or fish in or around the waters or unsuitable for use in irrigation, or obstructs or interferes with, or is likely to obstruct or interfere with persons in the exercise or enjoyment of any right in relation to the waters, or

(c) placing in or on, or otherwise introducing into or onto, the waters (whether through an act or omission) any matter, whether solid, liquid or gaseous, that is of a prescribed nature, description or class or that does not comply with any standard prescribed in respect of that matter, and, without affecting the generality of the foregoing, includes:

(d) placing any matter (whether solid, liquid or gaseous) in a position where:

    (i) it falls, descends, is washed, is blown or percolates, or

    (ii) it is likely to fall, descend, be washed, be blown or percolate, into any waters, onto the dry bed of any waters, or into any drain, channel or gutter used or designed to receive or pass rainwater, floodwater or any water that is not polluted, or

(e) placing any such matter on the dry bed of any waters, or in any drain, channel or gutter used or designed to receive or pass rainwater, floodwater or any water that is not polluted, if the matter would, had it been placed in any waters, have polluted or have been likely to pollute those waters.

With regard to Part (a) of the definition, as the condition of Dents Creek and Oyster Gully under all flow conditions in all seasons has not been established, it is impossible to be certain that the discharge may not change the condition of the waters in some way. However, with regard to Parts (b) and (c), on the basis of a thorough review of the data presented in the Hydrogeological Data Report, such pollution would not be caused by discharge of water from the quarry lake.

8.0 CONCLUSIONS AND RECOMMENDATIONS

It is concluded that water from the quarry lake can be discharged via the stormwater drainage system without adverse impact on either that system or the natural watercourses to which the stormwater system itself discharges, provided that the lake is dewatered as recommended in Sections 4.0 and 5.4 of this report.

This dewatering plan therefore recommends that:

(a) The brick pit be dewatered over a period of approximately seven weeks.

(b) The dewatering period be extended if piezometric monitoring of the implementation of stability control measures so requires.

(c) A nominal pumping rate of 15 L/s or 1300 m^3/d be used.

(d) Pumps be mounted on one or two pontoons tethered close to the middle of the lake.

(e) Water pressure in the banks be carefully monitored using a series of piezometers installed prior to the start of pumping.

(f) The pumping rate be continuously monitored.

(g) Discharge water quality be continuously monitored.

(h) Measures be implemented to manage the anoxic layer below 87.2 metres AHD. These measures may include water treatment on site prior to discharge, and water re-use on site.

(i) The quarry lake water be discharged to the stormwater system.

(j) If required by the planning authority, pumping cease during periods of heavy rainfall.

(k) Monitoring be carried out in the Dents Creek and Oyster Gully, below the stormwater discharge points.

(l) Water be made available free of charge to anyone willing to collect it from the site, and an appropriate tanker filling point be provided for this purpose.

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Water and Environmental Management

ABN 54 056 283 295

Important Information About Your Environmental Site Assessment

These notes will help you to interpret your hydrogeological and Environmental Site Assessment (ESA) reports.

Why are ESAs conducted?

An ESA is conducted to assess the environmental condition of a site. It is usually, but not always, carried out in one of the following circumstances.

- As a pre-purchase assessment, on behalf of either purchaser or vendor, when a property is to be sold.
- As a pre-development assessment, if a property or area of land is to be redeveloped, or if its use is to change (for example, from a factory to a residential subdivision) – to meet a requirement for development approval.
- As a pre-development assessment of a 'greenfield' (undeveloped) site - to establish baseline conditions and to assess environmental, geological and hydrological constraints to the proposed development.
- As an audit of the environmental effects of an ongoing operation.

Each type of assessment requires its own specific approach. In all cases, however, the aim is to identify and if possible quantify the risks posed by unrecognised contamination. Such risks may be financial (for example, clean-up costs or limitations on site use), or physical (for example, health risks to site users or the public).

What are the limitations of an ESA?

Although the information provided by an ESA can reduce exposure to these risks, no ESA, however diligently carried out, can eliminate risks altogether. Even a rigorous professional assessment may not detect all contamination on a site. The following paragraphs explain why.

ESA 'findings' are professional estimates

The ground surface conceals a complex 3-dimensional subsurface environment. Subsurface materials, whether placed by geological processes or human activities, are always heterogeneous. Large variations in lithology and hydraulic properties can occur over short distances. Surface observation, and data obtained from boreholes and test pits, can never give us a complete picture of the subsurface.

All data from sampling and laboratory testing must be interpreted by a qualified professional – a geologist, engineer or scientist. They then render an opinion - about overall subsurface conditions, the nature and extent of contamination, its likely impact on the proposed development, and appropriate remediation measures.

Interpretation and professional judgement are thus essential to the assessment process.

Accuracy depends on the scope of work

Site assessment identifies actual subsurface conditions only at those specific points where samples are taken and when they are taken. The accuracy of the entire process depends on sampling frequency and sampling methods - yet the extent of sampling and soil analysis must necessarily be limited.

Sampling generally targets those areas where contamination is considered to be most likely, on the basis of visual observation and the site's history. This approach does maximise the probability of identifying contaminants, but it may not identify contamination in unexpected locations or from unexpected sources.

No professional, no matter how qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. For example, there may be contaminants in areas not surveyed or sampled; furthermore, they may migrate to areas that showed no signs of contamination at the time of sampling.

Conditions between sample locations can only be inferred – from estimates of geological and hydrogeological conditions, and from the nature and extent of identified contamination. Soil, rock and aquifer conditions are often variable, and so the distribution of contaminants across a site can be difficult to assess. Actual conditions in areas not sampled may differ from predictions.

The accuracy of an assessment is therefore limited by the scope of work undertaken.

Statistical tools can be helpful, but the validity of conclusions still depends entirely on the degree to which the original data reflect site conditions.

Uncertainty is also inevitable when it comes to assessing chemical fate and transport in groundwater and surface water systems, and calculating human health and environmental exposure risks. It is inevitable, too, when estimating remediation performance and time frames.

Your CMJA report includes a statement of the uncertainty associated with this particular project; you should read it carefully.

We can offer solutions

We cannot prevent the unanticipated, but we can minimise its impact. For this reason we recommend that you retain CMJA's services through the remediation and development stages. We can identify differences from predicted conditions, conduct additional tests as required, and recommend solutions for problems encountered on site.

Don't rely on out-of-date information

Subsurface conditions are changed by natural processes and the activity of people. Your ESA report is based on conditions that existed at the time of subsurface exploration. Don't make decisions on the basis of an ESA report whose adequacy may have been affected by time. Speak with CMJA to learn if additional tests are advisable.

If things change, contact us

Every report is based on a unique set of project-specific factors. If any one of these factors changes after the report is produced, its conclusions and recommendations may no longer be appropriate for the site.

Your environmental report should not be used:

- if the nature of the proposed development is changed - for example, if a residential development is proposed instead of a commercial one;
- if the size or configuration of the proposed development is altered;
- if the location or orientation of the proposed structure is modified;
- if there is a change of ownership; or
- for application to an adjacent site.

To help avoid expensive problems, talk to CMJA. We will help you to determine how any factors that have changed since the date of the report may affect its recommendations.

Your ESA report is prepared specifically for you

Every hydrogeological study and ESA report is prepared to meet the specific needs of specific individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor, or even for another consulting civil engineer. A report should not be used by anyone other than the client, and it should not be used for any purpose other than that originally intended. Any such proposed use must first be discussed with CMJA.

Beware of misinterpretation

Costly problems can occur if plans are based on misinterpretations of an ESA. These problems can be avoided if CMJA is retained to work with appropriate design professionals. We will explain the relevant findings and review the adequacy of plans and specifications.

Logs and laboratory data should not be separated from the report

Final borehole or test pit logs are developed by CMJA's environmental scientists, engineers or geologists, using field logs (assembled by site personnel) and laboratory evaluation of field samples. Our reports usually include only the final logs, which must not under any circumstances be redrawn for inclusion in other documents.

Similarly, our reports often include field and laboratory data, and laboratory reports. These data should not be reproduced separately from the main report, which provides guidance on their interpretation and limitations.

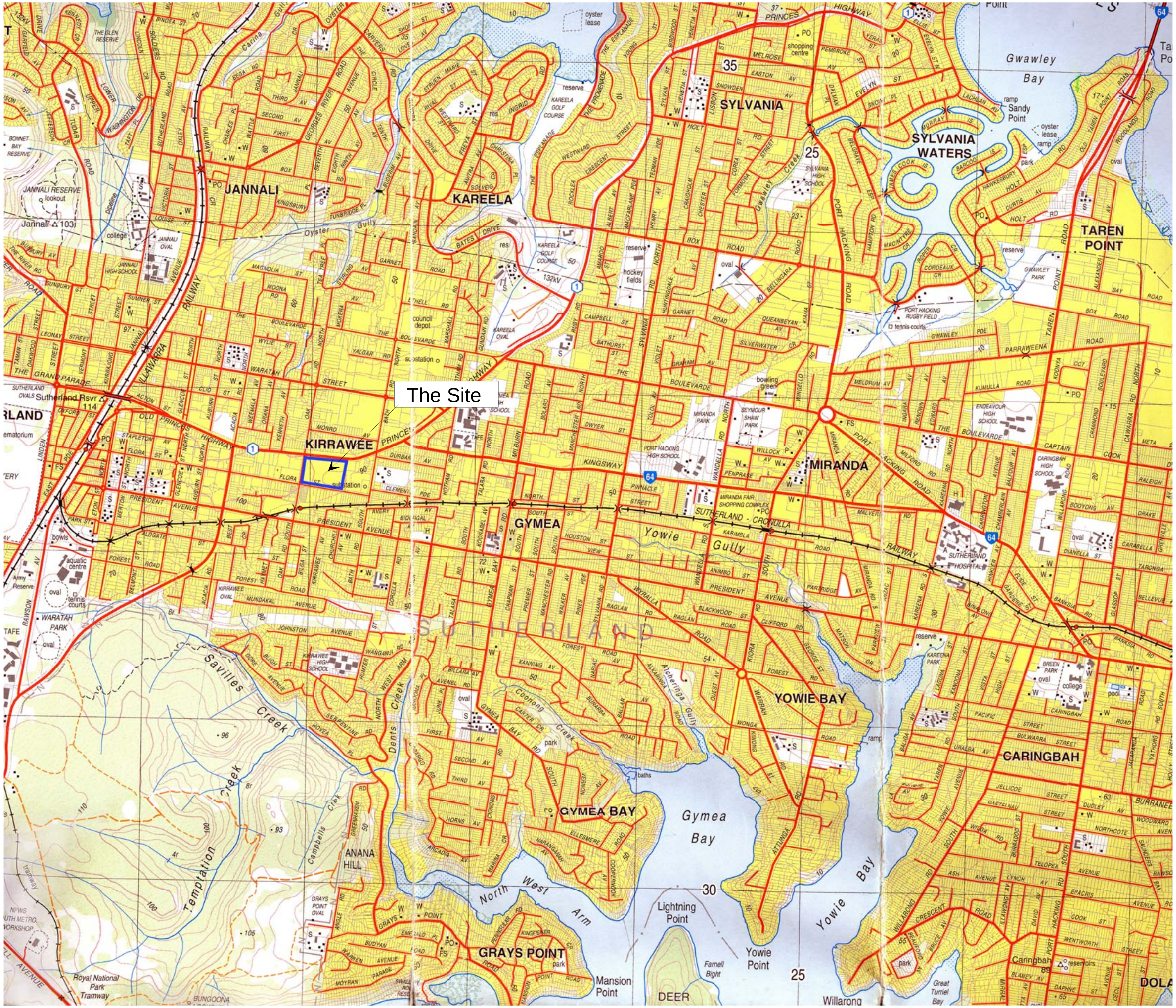
To reduce the likelihood of misinterpretation, only the complete report should be made available for the use of persons or organisations involved in the project, such as contractors. Consult CMJA before distributing reports, and we will assist with any additional interpretation that is required.

Always read responsibility clauses closely

To avoid misunderstandings, our report includes qualifying statements that explain the level of certainty associated with our findings and recommendations, and responsibility clauses that indicate where our responsibilities to clients and other parties begin and end.

These qualifying statements and responsibility clauses are an important part of your report. Please read them carefully. They are not there to transfer our responsibilities to others but to help all parties understand where individual responsibilities lie.

These notes were prepared by C. M. Jewell & Associates Pty Ltd (CMJA) using guidelines prepared by the National Ground Water Association (NGWA) and other sources.



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Author: CBW

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Figure 1
Site Location and Regional Setting

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Author: CBW

The Site

Figure 2

Site Features

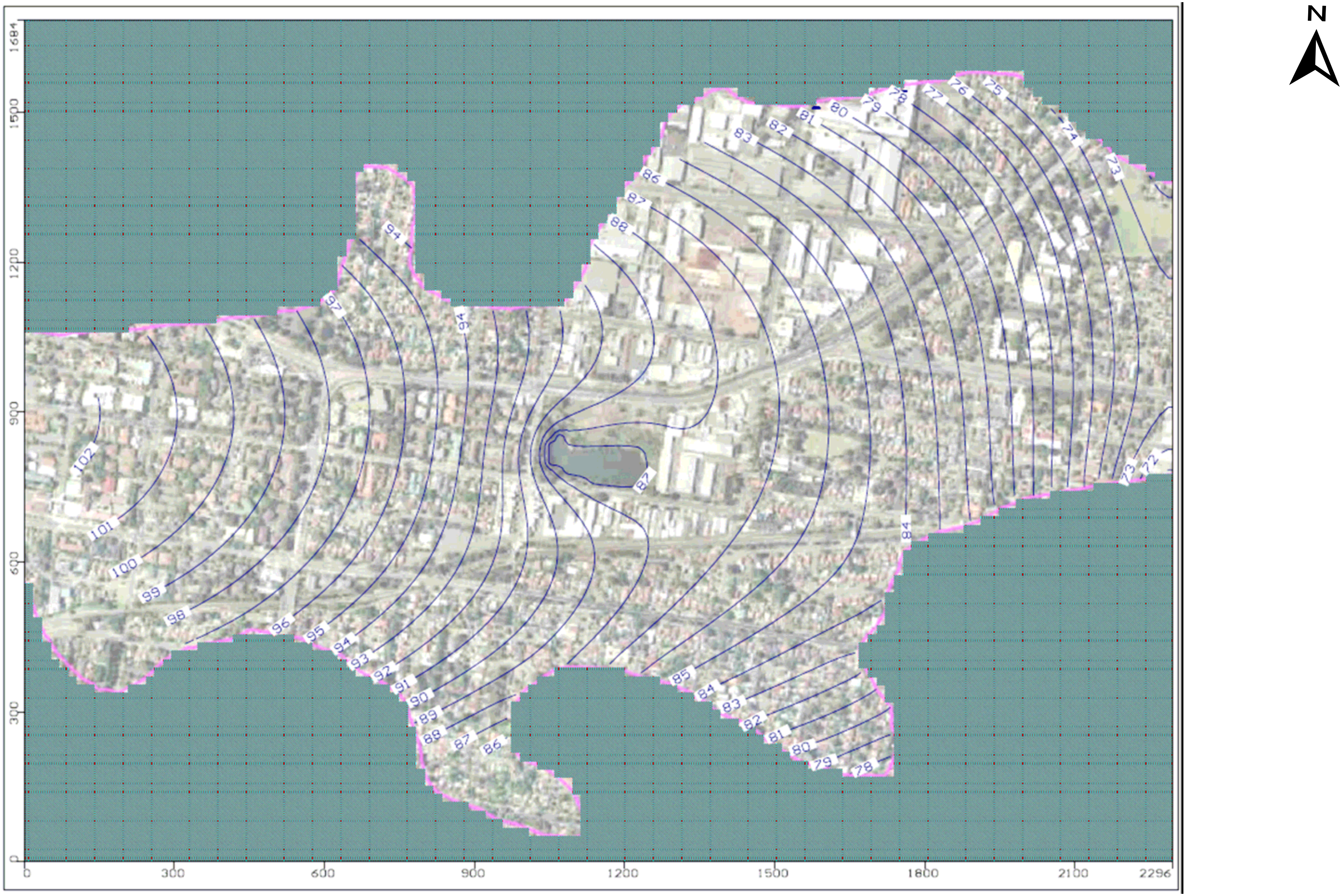

Figure 3

Steady-State Drawdown around the Pit

APPENDIX A
Groundwater Flow Model

Model Grid
Horizontal Discretisation 132 columns x 100 rows

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Current (quasi-steady-state) groundwater levels
Elevation of water table, m AHD

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Long-term groundwater level around pit
Post construction
Elevation of water table, m AHD

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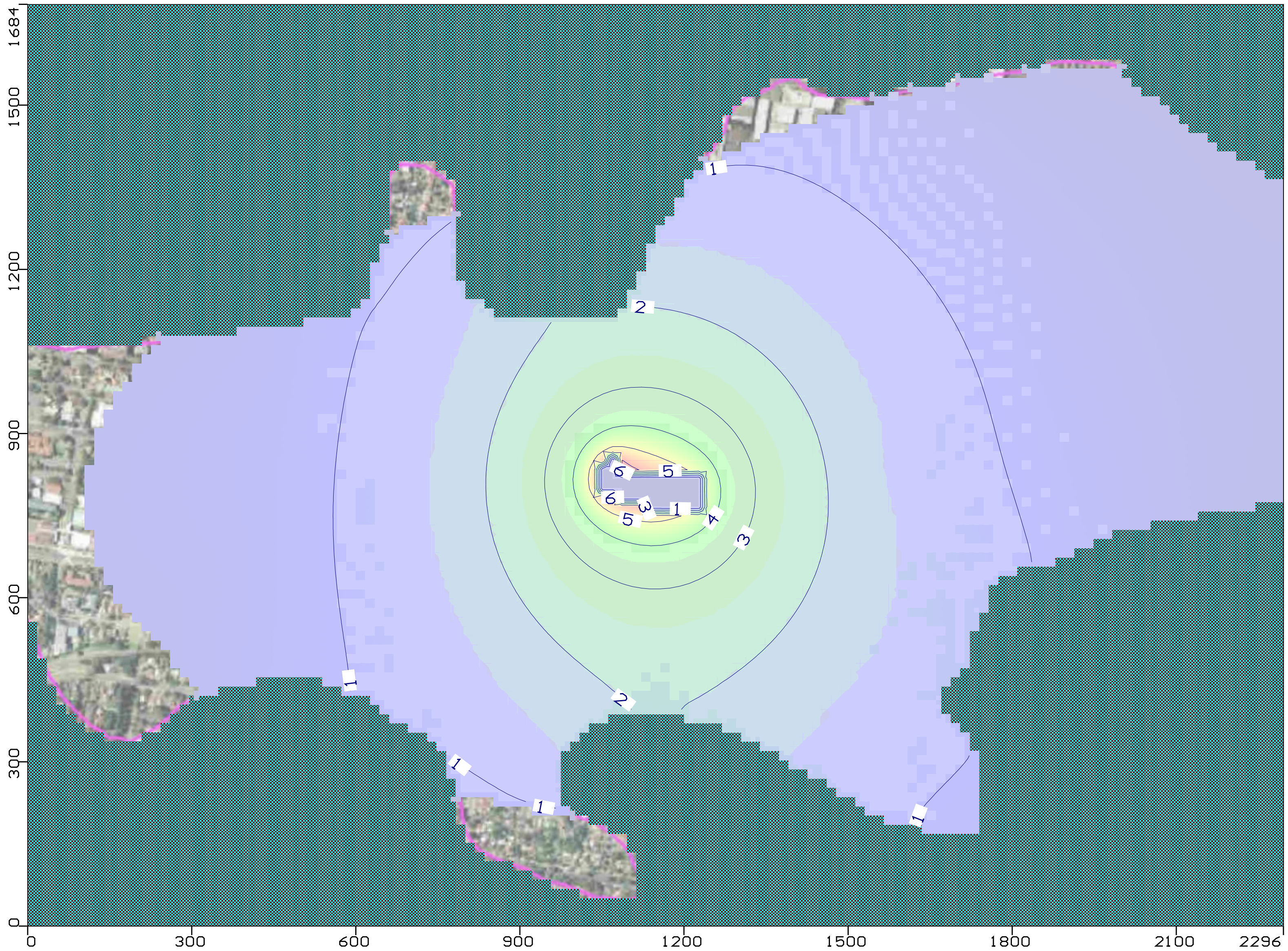
Dewatering and Groundwater Management Assessment



Long-term drawdown around pit
Post construction
Decline in groundwater level, m

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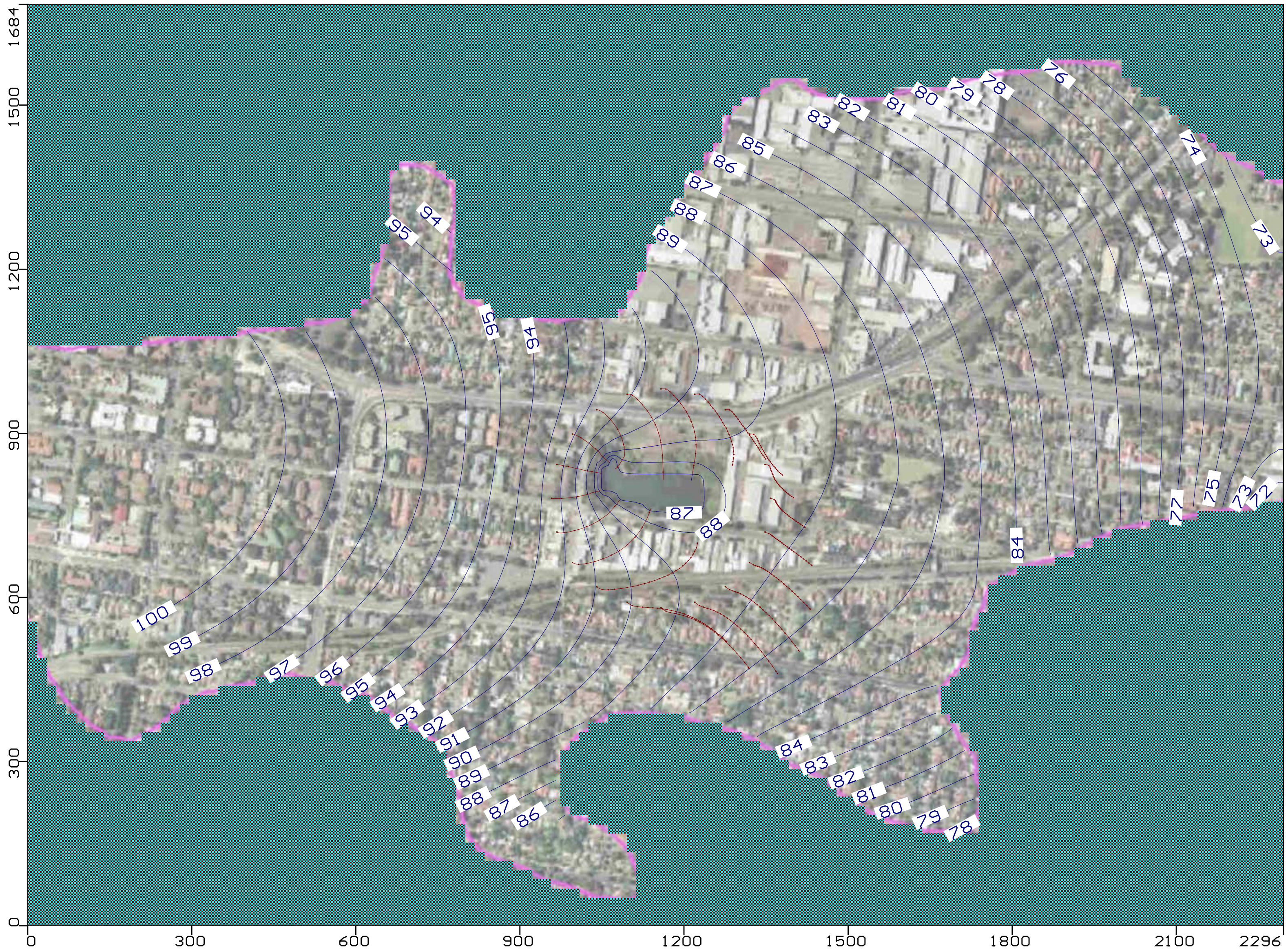
Dewatering and Groundwater Management Assessment



Water levels 12 months following start of dewatering
Contours show the level of the groundwater table in the upper (shale) aquifer in m AHD
Pathlines show groundwater flow directions - each tick represents 30 days travel time

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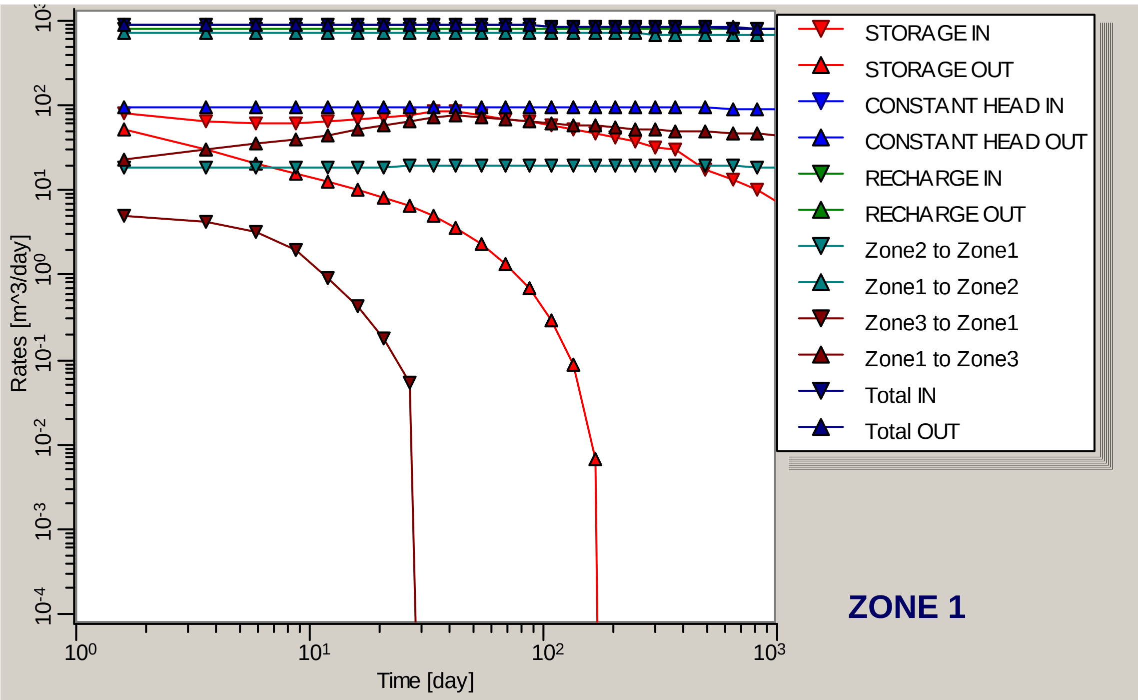
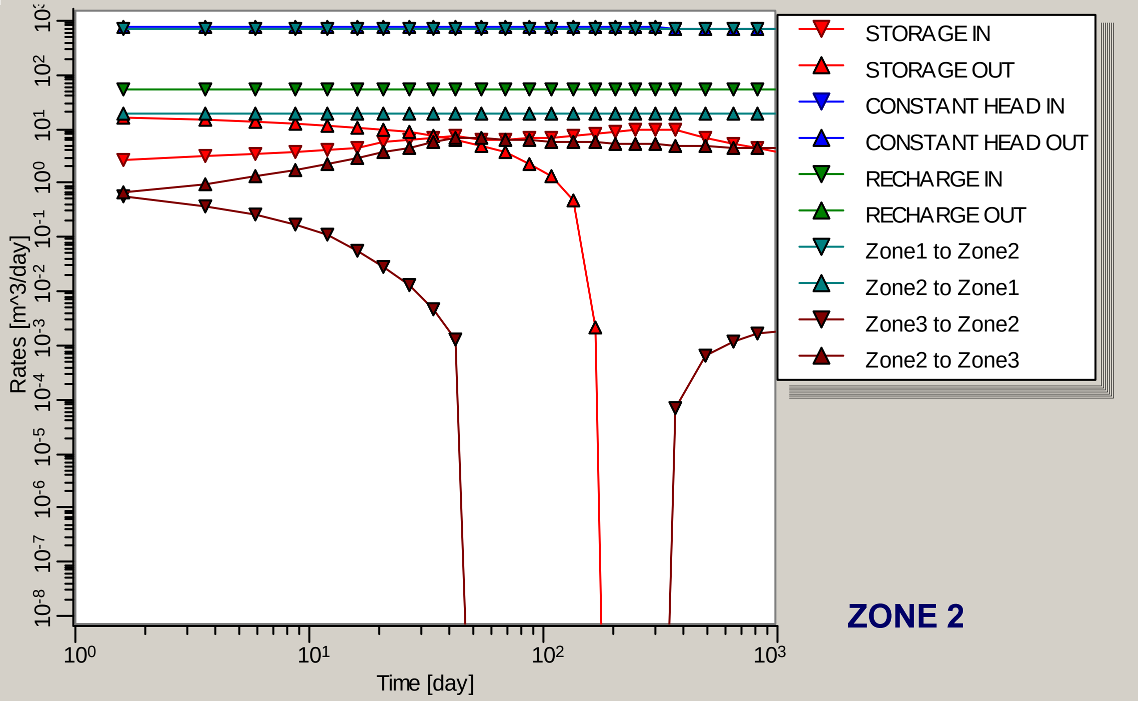
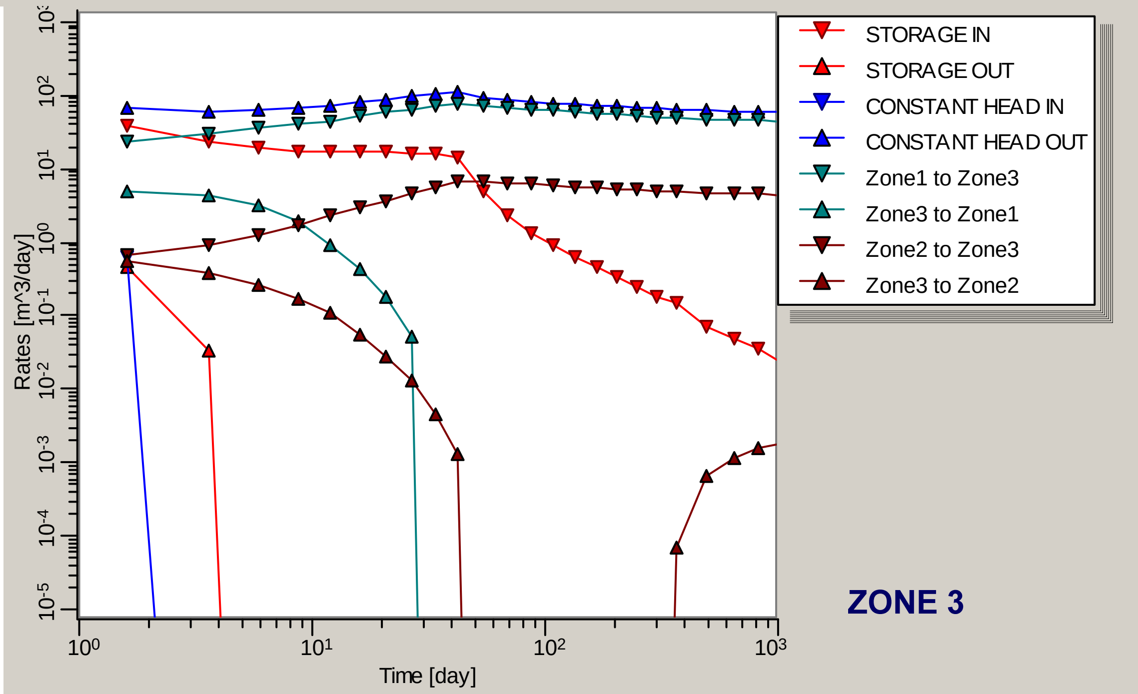
Dewatering and Groundwater Management Assessment



STORAGE IN
STORAGE OUT
CONSTANT HEAD IN
CONSTANT HEAD OUT
RECHARGE IN
RECHARGE OUT
Zone2 to Zone1
Zone1 to Zone2
Zone3 to Zone1
Zone1 to Zone3
Total IN
Total OUT
ZONE 1
Rates [m^3/day]
Time [day]



STORAGE IN
STORAGE OUT
CONSTANT HEAD IN
CONSTANT HEAD OUT
RECHARGE IN
RECHARGE OUT
Zone1 to Zone2
Zone2 to Zone1
Zone3 to Zone2
Zone2 to Zone3
ZONE 2
Rates [m^3/day]
Time [day]



STORAGE IN
STORAGE OUT
CONSTANT HEAD IN
CONSTANT HEAD OUT
Zone1 to Zone3
Zone3 to Zone1
Zone2 to Zone3
Zone3 to Zone2
ZONE 3
Rates [m^3/day]
Time [day]