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Table of Contents

[Executive Summary 3](#__RefHeading___Toc1527_621954388)

[1Introduction & Background 1](#__RefHeading___Toc1529_621954388)

[1.1Objectivities 1](#__RefHeading___Toc1531_621954388)

[1.2Scope of Work 1](#__RefHeading___Toc1533_621954388)

[2Conceptual Site Model 2](#__RefHeading___Toc3145_1081603945)

[3Data Review 3](#__RefHeading___Toc1535_621954388)

[3.1Groundwater Gauging, Purging and Sampling 3](#__RefHeading___Toc1537_621954388)

[4Pumping Rate Estimates 4](#__RefHeading___Toc579_1212542411)

[5Borefield Positioning 5](#__RefHeading___Toc581_1212542411)

[6Estimate of Time Required to Achieve Target Water Levels 6](#__RefHeading___Toc583_1212542411)

[7Review of Cut-off Trench Impacts 7](#__RefHeading___Toc585_1212542411)

[8Conclusion 8](#__RefHeading___Toc1561_621954388)

[9References 9](#__RefHeading___Toc1563_621954388)

Tables in Text

**Appendices**

**Appendix A** Figures

**Appendix B** Results Summary Tables

**Appendix C** Bore Logs

**Appendix D** Groundwater Field Sampling Records

**Appendix E** Laboratory Reports

# Executive Summary

**Background**

Environmental Strategies Pty Ltd (ES) was commissioned by Kleinfelder Australia Pty Ltd (Kleinfelder) to prepare a Groundwater Monitoring Event (ESA) at onsite and offsite locations at the former Mobil Parkes Service Station (Site ID: NEN4651), hereafter referred to as ‘the Site’, located at 168 Peisley Street, Orange, NSW.

**Objectives**

ES provided data on the environmental conditions associated with contamination from any petroleum hydrocarbons at the Site. The objective of the factual ESA report was to:

* Collect data relating to soil and groundwater quality at onsite and off-site locations; and
* Present the factual results with those reported from previous groundwater assessments.

**Scope of Work**

To achieve the objective of the ESA, ES conducted the following activities.

* Preparation of an Occupational Health and Safety Plan (OH&S), Job Hazard Analysis (JHA) and Operation Integrity Management Systems (OIMS) permitting procedures;
* Gauging of depth to water in the four (4) existing monitoring wells (MW1, MW5, MW6, and MW7) and three (3) new monitoring wells (MW1A, MW2A and MW3A);
* Measurement of field groundwater quality parameters (dissolved oxygen (DO), electrical conductivity (EC), pH, redox potential (Eh) and temperature) of stabilised purged groundwater prior to sampling;
* Collection of seven (7) primary groundwater samples using low flow sampling techniques, one (1) intra-laboratory duplicate groundwater sample, one (1) inter-laboratory triplicate groundwater sample, one (1) trip blank sample, one (1) trip spike sample and one (1) equipment rinsate sample;
* Groundwater samples submitted to the NATA accredited laboratory ALS for analysis of TPH, TRH, BTEXN, polycyclic aromatic hydrocarbons (PAHs), phenols and natural attenuation parameters (including ferrous iron, nitrate, sulphate and methane);
* Collection of soil vapour samples from XX soil vapour sampling points (SV1, SV2, Sv3 and SV4) using laboratory supplied summa canisters;
* Submission of five (5) primary and one (1) QA/QC soil vapour samples to NATA accredited laboratory Envirolab for analysis of the following: benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN) and speciated total recoverable hydrocarbons (TRH) C6-C12;
* Provide data pertaining to soil, groundwater and vapours as appropriate within the scope of work above and within the context that there is always a degree of uncertainty with the subsurface environments due to changes being possible between data points; and
* Preparation of a factual report in general accordance with the NSW OEH (2011) Guidelines for Consultants Reporting on Contaminated Sites, presenting the activities and results of the environmental site assessment. ES note that this a factual report only and does not provide interpretation or opinions.

**Summary of Works and Key Findings**

Groundwater gauging and sampling was completed on 26th February 2013 by ES’ Environmental Scientist Colin Biggs. Soil vapour sampling was completed by xxx on xxx

The key findings of the ESA were as follows:

* No non-aqueous phase liquids were reported within groundwater monitoring wells during gauging;
* Purged groundwater was observed as slightly turbid with no odour in MW1A while MW2A, MW3A, MW5, MW6 and MW7 were observed as clear. MW1 was noted to have a hydrocarbon odour;
* Depth to water ranged between 1.10m below top of casing (btoc) at MW1 and 8.60m btoc at MW6. Standing groundwater levels ranged between 324.8mAHD (MW6) and 332.3mAHD (MW1);
* Groundwater samples were collected from a total of XX groundwater monitoring wells and submitted for laboratory analysis of TRH and BTEXN. Selected groundwater samples were submitted for laboratory analysis of natural attenuation parameters (including ferrous iron, nitrate, sulphate and methane). Results have been summarised within Table X of this report and copies of the laboratory reports are provided in **Appendix XX**.
* A total of 5 active soil vapour samples (including four primary samples and one intra-laboratory sample)were collected into laboratory supplied Summa Canisters from the NATA Accredited laboratory ALS. Soil vapour samples were analysed for BTEXN and TRH C6-C12. Results have been summarised with Table X of this report and copies of the laboratory reports are provided in **Appendix XX**.

# Introduction & Background

Environmental Strategies Pty Ltd (ES) was commissioned by Origin Energy Eraring Pty Limited (Origin) to investigate waterlogging of soil at the Eraring Power Station at Rocky Point Road, Dora Creek, NSW (refer to Figure 1, **Appendix A**).

An area of the site between the TransGrid 500/300 kV Switchyard (the Switchyard), the Auxilliary Cooling Water (ACW) Plant (located on top of a small hill) and the cooling water canals has recently (since February 2016) been found to be permanently waterlogged. This ground had previously been dry, but is now covered in areas of dampness and where potholes have been excavated they have filled with water to ground level. At one location adjacent to the cooling water canals there is a spring with water emanating at approximately 1L/s. This water is currently discharging to a surface drain. The area affected is shown in Figure 2, **Appendix A**.

Origin Energy is concerned that the water logging may result in structural concerns for power plant infrastructure, with particular concern regarding uplift pressure on the canals during the scheduled maintenance in October 2016. This report aims to provide a review of the readily available data to form an opinion on the likely source of the water and potential methods for resolving the issue.

Within this report, the area affected by the water logging is referred to as “the inundation area”.

A conceptual site model illustrating the mechanism by which the inundation is occurring was developed in an earlier hydrogeological report by Environmental Strategies (16087 R01 Stage 1 Root Cause). The conceptual model is summarised in Section 2 below.

A dewatering solution was proposed involb=ving the installation of a series of dewatering wells in the inundation area to decrease the head to acceptable levels to protect infrastructure at the site. Currently, site specific aquifer details are not known and formal design of a dewatering system can not be conducted until such time as these values, and other hydrogeological behaviour at the site) are determined. A pumping test programme has been proposed but is yet to be executed.

## Objectivities

The objective of this report is to provide a preliminary estimate of the number of wells required, their placement, and the volume of water required to achieve the desired degree of dewatering. This analysis is presented using estimated values for aquifer parameters and initial assumptions regarding aquifer interconnectivity. The design presented here should not be used for costing or construction of a dewatering system, but can be used to conceptualise the system.

## Scope of Work

To achieve the objective above, ES conducted the following activities.

* Review GHD (May 2010) *Awaba Colliery Water Balance Assessment* and other relative literature with respect to likely range of aquifer characteristics;
* Use classical hydrogeological equations to calculate the likely range of pumping rates and lateral effective range of drawdown (pressure reduction) in the aquifer.
* Use the estimates above to allow notional positioning of the dewatering wells sufficient to protect the canals from uplift pressure, as well as the potential volumes of water requiring disposal.
* Use classical hydrogeological equations to estimate the timeframe for dewatering influence to extend beneath the canals.
* Review of site data to allow estimation of the depth required for a cut-off trench, and the potential lateral influence it may have and volume of water extracted from the trench requiring disposal.

# Conceptual Site Model

Based on the available information, Environmental Strategies have formed the following conceptual model relating to the occurrence of inundation at the site.

* The inundation of groundwater and is not related to surface water or precipitation.
* The water is not migrating laterally from the base of the hill to the north of the Switchyard. If it was migrating laterally in surface soils, the drain would intercept it before it reached the high level intake canal. This is clearly not the case.
* The occurrence of artesian[[1]](#footnote-2) groundwater (as observed in bores installed by Aurecon and the spring adjacent to the high level intake canal) is clear evidence that a pressurised groundwater system is present and that lateral seepage in unconfined surface sediments is not the cause of the water inundation.
* Geological mapping of the area includes faults aligned north-west to south-east running through the affected area. This includes an up-thrust block at the affected area, which is described as heavily fractured. The increased fracturing would give this material a relatively high vertical hydraulic conductivity. These fault lines, including the associated fractures within the up-thrust block, can readily provide a vertical conduit to the surface soils from deeper confined aquifers. See Figure 4, Appendix A.
* There is a set of faults also mapped in the Awaba mine workings immediately north of the site (See Figures 4 and 6, Appendix A). These faults are identified as having low movement, and were not mapped on the Origin Energy site in the original construction geology report. Whilst these faults may contribute to the hydraulic connection to the pressurised groundwater system, and are noted to align with the northern end of the inundation area, there remains the potential for multiple hydraulic connections through other mapped and currently unmapped fractures and faults at the site. In the absence of site specific aquifer testing, Environmental Strategies is of the opinion that these fractures should not be considered to be controlling the inundation as this may result in overlooking other sources of connection between the surface and the pressurised water bearing zones.
* The Awaba mine workings operated by Centennial Coal extend from the north to the northern boundary of the site adjacent to the switchyard. To date, the exact depth of the workings is yet to be confirmed to Environmental Strategies.
* The mine workings were previously dewatered. Dewatering of the significant extent of mine workings will have a radial effect around the mine and will act to depressurise connected aquifer systems. GHD (2011) include indications that the dewatering rate in the southern part of the mine was between 80 and 170 ML/year, although anecdotal evidence indicates a higher rate.
* Dewatering ceased in 2013. This would allow groundwater levels to recover. The mining activities and residual void space may allow and facilitate hydraulic connection between geological zones which were isolated prior to mining.
* Recovery of groundwater levels at the cessation of dewatering would result in increased pressure in groundwater systems adjacent to the mine. Groundwater head above the local ground level will allow saturation and artesian conditions where a hydraulic connection to the surface is available. Such a connection is pre-existing at the inundation area, being the faults and associated features related to the up-thrust bock in and adjacent to the northern end of the switchyard.
* The head in the former mine workings is estimated by the standing water level in the well at the ACW plant. The level in that well is reported as 22.3m below the top of casing (RL 141.29m local datum), which is RL 119m local datum. The ground surface at the switchyard is understood to be at RL 115 m giving a 4m head difference between the confined groundwater system and the ground surface, and
* Groundwater is reaching the surface as seepage along these vertical features.

# Data Review

Several key aquifer properties are required to be understood at the site before a reliable dewatering system design can be prepared. Whilst these values must be determined with pumping tests on site for reliability, preliminary calculations can be made using literature values. This section presents a review of relevant available literature values for these aquifer properties.

Definitions of these properties are presented below and are derived from Fetter, C.W. (1994) *Applied Hydrogeology, Third Edition.*

Hydraulic Conductivity (K)

A quantitative measure of the ability of a rock to transmit water. Note that although hydraulic conductivity is quantified with units of length/time, it should not be mistaken for an actual velocity. Due to restrictions on flow in the rock matrix and differences in driving pressures, the actual rate of water flow is generally much smaller than the hydraulic conductivity of the material in natural situations.

Specific Storage (Ss)

The specific storage is the amount of water per unit volume of a saturated formation that is stored or expelled from storage owing to compressibility of the mineral skeleton and the pore water per unit change in head.

Specific Yield (Sy)

The ratio of the volume of water that drains from a saturated rock (owing to the attraction of gravity) to the total volume of the rock. This is an effect of the pore space and grain size of the material and is only relevant in units which are not fully saturated (i.e. unconfined).

Storativity (S)

In a confined aquifer, the head may decline but the potentiometric surface may remain above the unit. Although water is released from storage, the aquifer remains saturated. The storativity of a confined aquifer is the product of the specific storage and the aquifer thickness (*b*).

In a confined aquifer of thickness *b*, the storativity is found by the formula:

In an unconfined aquifer, the level of saturation rises or falls with changes in the amount of water in storage. As the water level falls, water drains from the pore spaces under the influence of gravity. This storage or release is due to the specific yield of the unit. Water is also stored or expelled based on the specific storage of the unit.

For an unconfined unit with saturated thickness *h*, the storativity is found by the formula:

Effective Porosity (ne)

The porosity of a rock is a measure of the void spaces between solid fragments, usually expressed as a fraction of 1. A porosity of 0.05 means that 5% of the rock space is void.

*Secondary porosity* refers to void space created by features such as bedding planes, faults and joints and is often the dominant form of porosity in rock, while *primary porosity* (void space between grains and particles) dominates in unconsolidated material.

The *effective porosity* is a measure of porosity relating only to the interconnected void spaces capable of transmitting water through the rock. The effective porosity can never be greater than the total porosity.

## GHD (2010) Water Balance Report

GHD prepared a water balance assessment for the Awaba Colliery operated by Centennial Coal immediately north of the site. The assessment included both a numerical water balance model and calibrated numerical hydrogeological model.

With respect to the proposed dewatering, ES has reviewed this report as a potential source of information regarding the aquifer properties, particularly of the Great Northern Seam (coal seam) and overlying conglomerates and sandstones.

Key points identified in this report are:

* Whilst the Great Northern Seam is regarded as a water bearing zone, flow from the seam is sufficiently low that the mine is considered a dry mine. This indicates a low hydraulic conductivity in the unit.
* Predicted maximum subsidence in the mine in 200mm. ES notes that subsidence of this degree is consistent with the conceptual site model presented above (Section ) and would be sufficient to enhance water bearing capacity in the rock above the mine but may not be apparent at the surface.
* The model assumed two hydrogeological geological units:
  + Narrabeen Sandstone (modelled as unconfined – hydraulic connection with atmosphere assumed)
  + Great Northern Seam (modelled as confined – assumed to be hydraulically isolated from atmosphere by the Narrabeen Sandstone)
* The Awaba Tuff underlying the Great Northern Seam was considered to be relatively impermeable and to form the floor of model.

The following aquifer parameters () were adoped by GHD (2010) based on the *Statement of Environmental Effects – Groundwater* for Newstan Colliery (Australasian Groundwater & Environmental Consultants Pty Ltd, 2007), prepared as sup[port for modifications to development consent at Newstan Colliery, located some 10km north northeast of the inundation area.

Table 1: Aquifer Parameters from GHD (2010)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Unit** | **Hydraulic Conductivity**  **(K, m/day)** | **Specific Storage**  **(Ss, 1/m))** | **Specific Yield**  **(Sy, unitless)** | **Effective Porosity**  **(ne, unitless)** |
| Conglomerate and Sandstone of the Narrabeen Group | 0.05 | 0.00001 | 0.1 | 0.05 |
| Coal of the Great Northern Seam | 0.5 | 0.00001 | 0.15 | 0.15 |
| Mine Workings | 50 | 0.00001 | 0.5 | 0.5 |

Environmental Strategies note the following regarding these values:

* The same specific storage value is identified for mine working and rock units. This value can not be considered to be accurate.
* The mine workings are shown as being 50% void space, entirely free draining.

## Fetter (1994) Applied Hydrogeology, Third Edition

This text provides discussion of aquifer parameters for common earth materials, with a focus on unconsolidated sediments but notes that in clastic rocks (which includes conglomerate and sandstone) total porosity is highly variable and commonly ranges between 3% and 30%.

Hydraulic conductivity values for several American coal formations are listed as 2.3x10-4 cm/s to 1.2x10-3 cm/s. These are approximately equivalent to 0.2 – 1.0 m/day.

## Domenico & Schwartz (1998) Physical and Chemical Hydrogeology, Second Edition

Selected aquifer properties for various materials are included in this document. Of relevance are:

* Specific yield of sandstone: 21 – 27% (0.21 - .027)

## Freeze & Cherry (1979) Groundwater

Freeze & Cherry give indicative hydraulic conductivity values of 10-6 – 10-4 m/s (approximately 0.1 – 8.0 m/day) for coal measures in the United States, with bulk porosity on the order of 1% (0.01).

The degree of induration (cementing) and fracturing of sandstone controls the hydraulic properties. For heavily indurated and sandstone with little fracturing or faulting, very low values are possible (<1% porosity, hydraulic conductivity less than 10-10 m/s or approximately 1x10-5 m/day). Localised variation in depositional environments can result in variation by factors of 10 – 100 in material which is visually homogeneous. Poorly cemented and/or highly fractured sandstones can have aquifer properties similar to unconsolidated sediments (porosity of 30 – 50%, hydraulic conductivity over 10 m/day).

## Summary of Likely Range of Aquifer Parameters

# Pumping Rate Estimates

# Borefield Positioning

# Estimate of Time Required to Achieve Target Water Levels

# Review of Cut-off Trench Impacts

# Conclusion

ES provided data on the environmental conditions associated with contamination from any petroleum hydrocarbons at the Site. The objective of the factual ESA report was to:

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# References

IT Environmental (June 2003), Phase I Environmental Site Assessment; *Excel Fuels Service Station (Site ID: NN5819) 168 Peisley Street, Orange, NSW.*

IT Environmental (June 2004), Phase 2 Environmental Site Assessment; *Excel Fuels Service Station (Site ID: NN5819) 168 Peisley Street, Orange, NSW.*

Coffey Environments (August 2007), Annual Groundwater Monitoring Report – *Former Mobil Parkes Service Station NN5651, 319-329 Clarinda Street, Parkes, NSW*.

ES (October 2013) *Well Installation Report, Former Mobil Parkes Service Station, 319-329 Clarinda Street Parkes, NSW*

1. Flowing above ground level without artificial pumping. [↑](#footnote-ref-2)