Independent Review of Groundwater Investigations

Lot 36 Abernethy Road, Oakford, Western Australia

Prepared for:
Department of Water and Environmental Regulation
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3 January 2018

Distribution

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Author:

Patrick Clarke
Senior Principal Geological Engineer

Executive Summary

I, Patrick Clarke, have been engaged by the Department of Water and Environmental Regulation (DWER) to complete an independent review of groundwater investigations completed at Lot 36 Abernethy Road, Oakford, Western Australia (the site). A compost manufacturing facility was operated at the site, under DWER License, by Bio-Organics from 2002 until 2014.

The groundwater investigations at and around the site are documented in a series of reports, the most recent being a Detailed Site Investigation report completed by Douglas Partners Pty Ltd (DP) in March 2017. Bio-Organics also engaged John Throssell of GHD Pty Ltd (GHD), a Contaminated Site Auditor, to prepare a Mandatory Auditor's Report (MAR) for the site. The investigations completed and MAR were completed in response to an Investigation Notice issued by DWER in October 2014.

In conducting my review of groundwater investigations and forming an opinion as to their adequacy, I have relied upon the review of the reports and documents provided to me by DWER (refer to **Section 2.0**). I did not have the opportunity to conduct a site inspection.

In summary, I find that groundwater investigations completed to date provide a reasonable basis for assessing groundwater impacts extending east of the site. The extent of groundwater contamination has been delineated east of the site and existing groundwater extraction wells hydraulically down-gradient do not appear to have been impacted. Generally, groundwater in both shallow and deep groundwater systems beneath the site appear to be flowing away from public drinking water resources to the west of the site (i.e. the Jandakot Underground Water Pollution Control Area).

However, I don't believe the existing network of groundwater monitoring wells provide sufficient coverage and data to form an opinion regarding the potential for contaminated groundwater to be moving off-site in a south or southeast direction.

Specific short-comings of groundwater investigations completed to date include the following:

- Limited detail on the locations of specific activities and infrastructure onsite which may have acted as sources of groundwater contamination and a screening process to rule out sources which do not require targeted investigations.
- Insufficient wells installed close to suspected onsite sources of contamination to assess groundwater impacts and define groundwater flow direction.
- Definition of the vertical extent of contamination could have been more effectively defined by installation of shallow and deep wells in close proximity of specific onsite sources.
- The absence of groundwater monitoring bores on the southern boundary of the site does not allow reliable assessment of the likelihood of groundwater impacts to be migrating across the southern boundary of the site.
- Insufficient monitoring wells to the north and south of the existing east-west alignment of deeper wells to assess whether there is, or is not, a component of flow to the northeast or southeast.
- Insufficient assessment of impacts on surface water and the potential for shallow groundwater to discharge off-site as surface seepage.

Consequently, I have recommended additional wells and surface water sampling to address data gaps.

The key potential risks which I don't believe have been adequately assessed to date are:

- Potential environmental impacts associated with discharge of shallow contaminated groundwater in the Bassendean Sands across the southern boundary of the site. Shallow groundwater contamination moving across the site boundary may affect plant ecosystems on surrounding properties or discharge to wetland ecosystems south and southeast of the site.
- Whether there is a more southeast component of groundwater flow in the Guildford Aquifer, which would suggest that the existing deeper groundwater wells do not reflect the highest concentrations of contaminants that may be present along the central axis of a groundwater plume extending off-site. Although deeper groundwater impacts are unlikely to reach existing groundwater extraction wells, the off-site extent of potential impacts on extractive use may not be defined southeast of the site.

It should be noted that completing the recommended additional investigations may not change the conclusions of Detailed Site Investigation report and MAR in relation to off-site extent of groundwater impacts and the key risk identified above. However, I believe the existing information does not allow reliable conclusions to be drawn regarding extent of ecological and human health risk off-site to the south and southeast.

The findings of additional investigations may also inform decommissioning requirements for infrastructure associated with the former composting facility.

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List of Acronyms

Acronym	Definition
AHD	Australian Height Datum
AMG	Australian Map Grid
AS	Australian Standard
ANZECC	Australian and New Zealand Environment and Conservation Council
BH	Borehole
BOD	Biological Oxygen Demand
COC	Chain of custody
CoC	Contaminant of concern
CSM	Conceptual site model
DO	Dissolved oxygen
DWER	The Department of Water and Environmental Regulation
EC	Electrical conductivity
EIL	Ecologically based investigation level
ESL	Ecological screening level
GME	Groundwater monitoring event
HIL	Health-based investigation level
HSL	Health screening level
LOR	Limit of reporting
LTV	Long term trigger values
m	Metre
m^3	Cubic metres
m AHD	Metres Australian Height Datum
m bgl	Metres below ground level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per litre
MW	Monitoring well
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council

Acronym	Definition
SVOC	Semi-volatile organic compound
SWL	Standing water level
TDS	Total dissolved solids
TKN	Total kjeldahl nitrogen
TOC	Total organic carbon
µg/kg	Micrograms per kilogram
µg/L	Micrograms per litre

1.0 Introduction and Objectives

1.1 Introduction and Objectives

I, Patrick Clarke, have been engaged by the Department of Water and Environmental Regulation (DWER) to complete an independent review of groundwater investigations completed at Lot 36 Abernethy Road, Oakford, Western Australia (the site). I am an employee of Senversa Pty Ltd (Senversa), based in our Melbourne offices at Level 6, 15 William Street, Melbourne.

My opinion relates to whether adequate groundwater investigations have been completed to delineate the nature and extent of contamination that may originate from former composting activities undertaken by Bio-Organics Pty Ltd (Bio-Organics) at the site.

1.2 Background

The site is described as Lot 35 on Diagram 66393 and Lot 36 on Diagram 66394, Abernathy Road, Oakford, Western Australia.

A compost manufacturing facility was operated at the site by Bio-Organics from 2002 until 2014. The composting facility operated subject to a licence, Licence No. 8475/2010/2 (the Licence), issued under Part V of the Environmental Protection Act 1986 (EP Act). The Department revoked the Licence on 27 June 2014 following multiple odour complaints and an alleged discharge of composting leachate onto a property to the south.

It is understood that in consultation with the Western Australian Department of Health, the Department classified the site as “possibly contaminated – investigation required” under the Contaminated Sites Act 2003 (CS Act) on 10 December 2013. The classification of the site was based on an assessment of groundwater monitoring results around the facility. Bio-Organics did not voluntarily undertake the required investigations, and an Investigation Notice was subsequently issued under the CS Act (2003) in October 2014.

On 7 July 2016, the Department commenced a prosecution against Bio-Organics in relation to continued non-compliance with a Closure Notice issued under the EP Act, which remains in force. The matter was adjourned to 31 October 2017 for listing.

An inquiry by the Standing Committee on Environment and Public Affairs was undertaken after public concern was raised about the contamination caused by the compost facility. The Committee’s report was released on 15 September 2016, and the State Government presented their response to Parliament on 15 November 2016 supporting the Committee’s findings.

Bio-Organics’ engaged environmental consultant Douglas Partners Pty Ltd (DP), to complete a groundwater investigation in response to the Investigation Notice during 2016. DP documented its investigations in the Detailed Site Investigation report, dated March 2017 (DP, 2017).

Bio-Organics also engaged John Throssell of GHD Pty Ltd (GHD) as the accredited contaminated sites auditor, to prepare a Mandatory Auditor’s Report (MAR) for the site. Mr Throssell completed his MAR in March 2017 (GHD, 2017).

The Serpentine-Jarrahdale Ratepayers Association and a Member of Parliament raised concerns in May and July 2017 about the groundwater investigation and audit and requested a further peer review.

Additionally, DWER engaged a contaminated sites consultant Golder Associates Pty Ltd (Golder) to carry out groundwater investigations at a vineyard to the south-west of the site at Lot 6 King Road, Oakford. Golder issued a report on their investigation of the vineyard in August 2017.

1.3 Scope of Review

DWER provided me with copies of the MAR (GHD, 2017), Report on Detailed Investigations (DP, 2017) and a number of existing reports and communications relating to the site. A comprehensive list of documents provided to me is presented in **Section 2.0**.

In forming my opinion, I attempted to rely primarily on data contained in the various reports and documents provided by DWER. I reviewed many of the opinions contained in the reports provided, in particular those of Mr John Throssell. However, I attempted to identify reliable data in the documents and form my own opinions based on those data.

As part of my engagement, DWER asked that I provide my opinion on the following questions in relation to contamination associated with the site:

1. Are the locations and depths of groundwater monitoring wells at the site adequate to assess the condition of groundwater beneath the site and off-site associated with areas of concern at the former composting site, such as the composting pad and stormwater basin?
2. After considering the geology and hydrogeology at the site, the auditor found that there is limited potential for groundwater impacts to be present beyond the site boundary, or below the vertical extent of the monitoring well network. Does the independent reviewer agree?
3. The auditor found that groundwater conditions at the site, including potential off-site migration, do not pose an unacceptable risk to the environment or human health, subject to the findings of ongoing groundwater monitoring in the vicinity of the stormwater basin. Does the independent reviewer agree?
4. Overall, has an adequate groundwater investigation been undertaken to determine the nature and extent of any potential groundwater contamination originating from the former composting site?
5. If not, what further work does the independent reviewer recommend?

Additionally, DWER requested I form an opinion in relation to the following questions, raised by parties external to DWER:

6. Would it have been useful for the initial groundwater investigation to include a groundwater numerical model to provide information on the best locations and depths for sighting the groundwater monitoring bore locations and depths?
7. Has the consultant's groundwater investigation taken into account the characteristic behaviour of contaminant plumes in a close to the surface, unconfined sand aquifer?
8. Where the groundwater monitoring bore instillations (locations and depths) in line with the instructions given by DWER in 2014.
9. Can the interpretation of the groundwater quality results (after 2 years of monitoring) be considered sufficient in terms of the groundwater contaminant plume that was indicated by DWER in 2014?
10. Is there a possibility that the groundwater contaminant plume is still migrating away from the Bio-Organics site and that water bores downstream of the Bio-Organics site be affected in the future?

My responses in relation to these questions are presented in **Section 5.0** of this report.

In forming my opinion, I considered "contamination" and "site" are to have the meanings given by Sections 3 and 4 of the Contaminated Sites Act, 2003.

1.4 Qualifications

I am a Senior Principal Geological Engineer employed by Senversa. A copy of my curriculum vitae is provided in **Appendix A**.

I completed a Bachelor of Engineering in Geological Engineering at the Royal Melbourne Institute of Technology (RMIT) in 1987. Since 1988 I have worked continuously as a consultant providing advice on contaminated soil and groundwater assessment and remediation and solid waste management projects across Australia, the United States of America (for three years) and Asia. I have particular experience in assessment and clean-up of groundwater contamination associated with a wide range of industrial and solid waste management facilities.

I am an Environmental Auditor (Contaminated Land), appointed pursuant to the Environment Protection Act, 1970 (the EP Act) by the Environment Protection Authority Victoria (EPAV). I was first appointed in April 2002 and have been an active environmental auditor since that time. My statutory environmental auditing activities have included auditing of significant groundwater contamination plumes associated with operating and former industrial facilities. I am an active member of the EPAV's groundwater approvals working group (GWAWG) and Landfill Auditor group providing input to the regulation of groundwater contamination issues in Victoria.

I was the founding President of the Victorian Branch of the Australian Contaminated Land Consultants Association (ACLCA), elected into that role in 2001 by my peers in the contaminated land consulting industry. I am a Fellow of the Institute of Engineers Australia (FIEAust), a Chartered Professional Engineer (CPEng) and Engineering Executive (EngExec). I am listed on the National Engineering Register (NER) and the Asia-Pacific Economic Cooperation (APEC) Engineers Register.

2.0 Documents Provided

For the purposes of conducting my review and providing an opinion on the investigations completed at the site, Senversa received the following documents from DWER on 3 October 2017:

- Stass Environmental, 2013, Report on: Ground Water Bore Installation and Water Quality Assessment, Oakford, WA, The Serpentine Jarrahdale Shire, 13 August 2013.
- Bioscience, 2013, Interpretation of analysis data, drainage water overflow, 13 September 2013.
- Galt Geotechnics, 2014a, Factual Report on Geotechnical Study Water Retention Pond, Bio-Organics Composting, 36 Abernethy Road Oakford, 14 February 2014.
- Galt Geotechnics, 2014b, Factual Report on Geotechnical Study, Composting Pad Bio-Organics Composting Yard, 36 Abernethy Road Oakford, 14 February 2014.
- Strategen, 2014a, Groundwater Management Plan and Hydrogeological Study, Bio-Organics Oakford Composting Facility, 14 February 2014
- Strategen, 2014b, Compost facility water balance, Bio-Organics Oakford Composting Facility, 14 February 2014.
- Strategen, 2014c, Groundwater Quality Assessment, Bio Organics Oakford Composting Facility, 14 April 2014.
- Strategen, 2014d, Summary Report – Environmental Investigations Bio-Organics Oakford Composting Facility, 14 April 2014.
- Department of Water and Environment Regulation, 2014a, Memo from Dr Steve Appleyard, Principal Hydrogeologist, Department of Environment Regulation. Groundwater quality issues, Bio-Organics site, Oakford, 5 May 2014.
- Department of Water and Environment Regulation, 2014b, Closure Notice, 24 June 2014.
- Bio-organics, 2014a, Bio-Organics Oakford Compost Facility, Monthly Groundwater Monitoring Report, September 2014, DER Closure Notice Condition 11, September 2014.
- Department of Water and Environment Regulation, 2014c, Investigation Notice, 2 October 2014.
- Bio-organics, 2014b, Bio-Organics Oakford Compost Facility, Monthly Groundwater Monitoring Report, October 2014, DER Closure Notice Condition 11, 4 November 2014.
- Bio-organics, 2014c, Bio-Organics Oakford Compost Facility, Monthly Groundwater Monitoring Report, November 2014, DER Closure Notice Condition 11, 27 November 2014.
- Bioscience, 2014, Groundwater investigation on 945 Abernethy Road, Oakford, 8 December 2014.
- Bio-organics, 2014d, Bio-Organics Oakford Compost Facility, Monthly Groundwater Monitoring Report, December 2014, DER Closure Notice Condition 11, December 2014.
- Bio-organics, 2015, Report for Douglas Partners on Waste Volumes and Waste Categories Received at Bio-Organics Oakford Facility for Period 2006 – 2014, 7 April 2015.
- Douglas Partners, 2015a, Report on Preliminary Site Investigation, Sampling Analysis and Quality Plan, Lot 36 Abernethy Road, Oakford, WA, 27 July 2015.
- Douglas Partners, 2015b, Report on Community Consultation Plan for Groundwater Investigations - Rev 1, Lot 36 Abernethy Rd, Oakford WA, 27 July 2015.
- Douglas Partners, 2015c, Report on Community Consultation Plan for Groundwater Investigations, Lot 36 Abernethy Road, Oakford, WA, 18 September, 2015.
- Douglas Partners, 2015d, Interim Report on Groundwater Investigation and Monitoring Programme, Lot 36 Abernethy Road, Oakford, Rev 0, 24 December 2015.
- Shire of Serpentine Jarrahdale, 2016, Letter to Minister for Environment; Heritage. Bio-Organics Composting Facility at Oakford, 15 March 2016.
- Eurofins, 2016, Certificate of Analysis, Report 490096-W, Stass Environmental, Bore Water Sampling Dempsey, March 2016.

- Douglas Partners, 2016a, Interim Report on Groundwater Investigation and Monitoring Programme, Lot 36 Abernethy Road, Oakford, Rev 1, 5 April 2016.
- Department of Water and Environment Regulation, 2016a, Memo from Dr Steve Appleyard, Principal Hydrogeologist, Department of Environment Regulation. Assessment of the interim report on the groundwater investigation and monitoring program for the Bio-Organics site, Oakford, 17 April 2016.
- Douglas Partners, 2016b, Groundwater monitoring event results table - GME 2, 31 May 2016.
- Douglas Partners, 2016c, Groundwater monitoring event 2, Lot 36 Abernethy Road, Oakford, 7 June 2016.
- Standing Committee on Environment and Public Affairs, 2016, Report 45, Standing Committee on Environment and Public Affairs, Petition Number 59 - Bio-Organics Composting Facility, Oakford. Presented by Hon Simon O'Brien MLC (Chairman), 15 September 2016.
- Douglas Partners, 2016d, Groundwater monitoring event results table - GME 3, 5 October 2016.
- Department of Water and Environment Regulation, 2016b, Amendment to the Investigation Notice, 11 October 2016.
- Albert Jacob MLA Minister for Environment; Heritage, 2016, Government response to the Standing Committee on Environment and Public Affairs report into Petition number 59 – Bio-Organics Composting Facility, Oakford, 15 November 2016.
- Douglas Partners, 2017, Report on Detailed Site Investigation, Groundwater Investigation and Monitoring Programme, Lot 36 Abernethy Road, Oakford, 8 March 2017 (DP, 2017).
- GHD, 2017a, Bio Organics Pty Ltd, Lot 36 Abernethy Road, Oakford, Western Australia, Mandatory Auditor's Report, 9 March 2017.
- GHD, 2017b, Lot 36 Abernethy Road, Oakford, Western Australia, Auditor Response to DER Queries on Mandatory Auditor's Report, 27 March 2017 (GHD, 2017).
- Department of Water and Environment Regulation, 2017a, Bio Organics Pty Ltd compost processing facility, Assessment of the Mandatory Auditors Report and historical groundwater monitoring at the site, 11 April 2017.
- Department of Water and Environment Regulation, 2017b, Basic Summary of Records – Lot 36 (941) Abernethy Road, Oakford, 21 April 2017.
- Department of Water and Environment Regulation, 2017c, Basic Summary of Records – Lot 7 (619) Orton Street, Oakford, 21 April 2017.
- Golder Associates, 2017, 123 King Road, Oakford, Targeted Groundwater Assessment – Factual Report, 31 August 2017.

On 24 October 2017 DWER provided Senversa with the following images and videos:

- Strategen, 2014, Interim report - Compost Pad Geotechnical Assessment Bio Organics Composting Facility, February 2014.
- Department of Water and Environment Regulation, 2014, Photographs and video of site inspection by DWER staff on 21 March 2014, 21 March 2017.
- Malcolm Dempsey, Dempsey Real Estate, Your ref CEO2910/15 # 619 Orton Road Oakford, 18 January 2016.
- Department of Water and Environment Regulation, 2016, Photographs and video of site inspection by DWER staff on 8 March 2016, 8 March 2016.
- Department of Water and Environment Regulation, 2016, Photograph of stormwater retention pond, taken by DWER staff on a site visit in April 2016. Looking south-east towards the Dempsey property, 13 April 2016.
- Department of Water and Environment Regulation, 2017, Aerial photographs from 2014, 2015 and 2016, 24 October 2017.

3.0 Geology and Hydrogeology

3.1 Geology

My interpretation of the geology of the site and surrounds was largely based on the borehole logs provided in Appendices B and C of the Detailed Site Investigation report (DP, 2017). I also found the borehole logs in the Targeted Groundwater Assessment – Factual Report (Golder, 2017) of the Vineyard at 123 King Road, Oakford (the Vineyard Report) to be useful in forming an opinion on geology in the site vicinity. Based on conformity with the Unified Soil Classification System (USCS) of logging soils and sediment, borehole logs prepared by DP and Golder appeared to be the most reliable source of geological data.

My interpretation of the geology of the site is generally consistent with that presented in the Detailed Site Investigation report and Mr Throssell's opinion and is shown in the cross section, running from west to east across the site, presented in **Figure 1**.

The geology of the site and surrounds is summarised as follows:

- The surface formation beneath the composting facility itself consists of Bassendean Sands, extending from the surface to depths of between 2 m to 3 m below ground level (m bgl). The Bassendean Sands appear to be characterised by dark brown to black, cemented sands and "coffee rock" in their lowest sequences.
- Geological mapping for the area indicates that a Peaty Sand forms the surface outcrop beneath the northern part of the property owned by Bio-Organics, i.e. north of the compost facility, and further north of the site. The Peaty Sands appear to have been encountered in boreholes installed in the northern part of the site, e.g. BH04, at depths extending to 2 m bgl.
- The Bassendean Sands reportedly overlie sands of the Guildford Formation. Sands of the Guildford Formation reportedly occur immediately beneath the cemented layers of the Bassendean Sands and appear to be characterised by a brown to light grey sands in the site vicinity.
- From my reading of geological reference materials, the Guildford Formation may generally be characterised as having a higher content of clay and silt than the overlying Bassendean Sands. The formations described as Guildford Formation in the groundwater investigations are not consistent with clayey sands or sandy clays typical of the formation. However, describing the sands underlying the "coffee rock" of the Bassendean Sands as Guildford Formation does not materially affect the understanding of groundwater contamination at the site.
- None of the boreholes drilled as part of the investigations relating to the site extended to depth through the sands of the Guildford Formation. The maximum of boreholes drilled as part of investigations at the site is approximately 10 m bgl and an elevation of approximately 8 m AHD (refer to **Figure 1**).
- The Guildford Formation is described in geological references as predominantly fluvial sediments consisting of lenticular interbeds of sand, silt, clay and in places gravel (Davidson, 1995). Guildford Formation encountered in boreholes as part of investigations in the site vicinity were predominantly described as sands.
- The Bassendean Sands do not appear to be present east of the site, beyond the location of BH102D (refer to **Figure 1**), where ground surface elevations reduce and relatively sandy sequences of the upper Guildford Formation appears to outcrop at the surface.
- The lateral extent of the Bassendean Sands may also be limited beyond the southern boundary of the site. There is no clear evidence of Bassendean Sands being present in the borehole log for VB04, located approximately 100 m south of the site, installed by Golder as part of the Vineyard Investigation. Similarly, there is no evidence of the Bassendean Sands in borelogs for SJS 1 or SJS 2. However, the drilling method used by Stass Environmental was not clear and the level of detail in the borehole logs suggested less accurate logging of the formations encountered in those boreholes.

3.2 Hydrogeology

3.2.1 Water Bearing Zones and Vertical Hydraulic Connection

A shallow water table was observed in the Bassendean Sands, where they were present across the area of investigation. A more regionally extensive aquifer was identified in the sands of the upper Guildford Formation, underlying the Bassendean Sands.

Screened intervals for groundwater monitoring wells described as shallow and deep have generally been installed in the Bassendean Sands and Guildford Aquifer respectively beneath the site. Where it is less clear that the Bassendean Sands were present, i.e. east of the site, shallow and deep groundwater wells have been installed at similar depth intervals below ground surface as those installed beneath the site. As such, shallow and deep groundwater wells east of the site appear to be screened in upper and lower depth intervals of the Guildford Aquifer.

In general terms, the shallow and deep water bearing zones appear to be hydraulically connected. I agree with DP that there is not a clear aquitard between the shallow and deep water bearing zones investigated. However, differences in water table elevations between shallow and deep wells at the same locations suggest the coffee rock or increased fines content of the basal layers of the Bassendean Sands may, to some degree, constrain vertical hydraulic connection between the two water bearing zones. I believe there is at least justification to contour groundwater elevations and assess flow in the shallow and deep zones separately.

Standing water levels in both the Bassendean Sands and upper Guildford Sand water tables are within 2 m of ground surface and appear be directly recharged by surface infiltration. The water table in Bassendean Sands, and potentially the upper Guildford Sand, appears likely to be hydraulically connected with deeper surface water features (e.g. dams and the stormwater basin) and are likely to be recharged by shallower surface water features (e.g. surface drainage lines and low-lying surface features).

The degree of hydraulic connection between shallow water table and surface water features will be affected by the elevation of the base of surface features, the elevation of water in surface water features and water table elevations. Standing water levels in surface water features and the shallow water table appear to fluctuate strongly with rainfall and evaporation. Data regarding water table elevations in the documents provide a reasonable indication of seasonal variability. I could not locate accurate information in the documents provided, on invert levels of surface water features or standing surface water levels in those features.

3.2.2 Groundwater Flow

Groundwater contours presented in the Detailed Site Investigation report (Drawings 7 to 14) appeared to use groundwater elevations from some boreholes I believe may not have been reliably used for the shallow or deep contouring based on their screened interval (e.g. use of BH14 and BH106 in deep groundwater contours). Monitoring wells BH103, BH103D, BH104 and BH104D appeared to have been shown on figures in the Detailed Site Investigation report in their proposed locations rather than their actual locations, refer to Groundwater Investigation and Monitoring report (DP, 2015). I have also found that using contouring packages may not provide a thorough understanding of the limitations of available groundwater elevation data.

To confirm interpretations of groundwater flow direction in the Bassendean Sands (shallow) and Guildford Formations (deep) water bearing zones, I have revisited groundwater contouring for the shallow water table elevations for GME 1 and GME 4 and the deep aquifer groundwater elevations for GME 1, presented in **Figures 2**, **3** and **4** respectively. Only monitoring wells from which data were used to contour groundwater elevations have been included in **Figures 2** to **4** to provide a visual indication of coverage provided by the existing well network.

Based on the information provided, my interpretation of groundwater flow is generally consistent with those presented in the Detailed Site Investigation report (DP, 2017). However, I believe a key limitation of the existing monitoring well network is the understanding it provides in relation to the direction of groundwater flow moving away from onsite sources to the south. The following key points arising from groundwater elevation data are worth noting:

Shallow Water Table

- Groundwater flow direction in the shallow water table appears to be generally toward the east, consistent with expected regional flow direction.
- The potential for groundwater in the shallow water table to be moving beneath the southern boundary of the site is difficult to assess due to the limited number of wells onsite and along the southern boundary of the site.
- Groundwater elevations and flows in the shallow water table are likely to be locally affected by recharge and discharge features such as the stormwater infrastructure, dams, ponds and low-lying surface features. Insufficient information currently exists to form a firm opinion on the degree of hydraulic interaction between the shallow water table and specific surface water features or low-lying areas in the surface topography surrounding the site.
- DP estimated groundwater flow velocities in the shallow water table to be approximately 12 m/year, based on a hydraulic conductivity of 3.03 m/day.

Deeper Guildford Aquifer

- Contours of groundwater elevation in the Guildford Aquifer indicate groundwater flow is generally east, consistent with the expected regional flow direction.
- Groundwater monitoring wells in the Guildford Aquifer are effectively aligned in a straight line from west to east through the main composting pad area (refer to **Figure 4**). Due to the absence of deeper monitoring wells north and south of the current well alignment, it is difficult to assess whether there is a component of flow in the Guildford Aquifer to the northeast or southeast.
- DP estimated groundwater flow velocities in the Guildford Aquifer to be approximately 46 m/year, based on a hydraulic conductivity of 10.69 m/day.

4.0 Conceptual Site Model

A conceptual site model (CSM) forms a central part of the process of identifying and understanding potentially complete linkages for exposure of humans or segments of the environment to contaminants in soil and groundwater. The CSM is based on assessment of sources of contamination, pathways for contaminant movement and receptors, both human and segments of the environment.

In forming my opinion in relation to the specific questions asked in my brief, I have considered the CSM for the site as a basis for identifying significant gaps in the information currently available. Limitations of the CSM as presented in the documents provided are discussed in the following sections of the report.

4.1 Sources and Contaminants of Concern

4.1.1 Sources

Potential sources of contamination associated with the former compost facility are documented in a relatively general sense in the Preliminary Site investigation, Sampling Analysis and Quality Plan (PSI report) and Detailed Site Investigation report. Potential areas of environmental concern (AEC) have been aggregated into; 1) …*Composting operations (including stormwater basin)*…, and 2) …*Fertiliser application*… There is limited detail on specific infrastructure and activities onsite, limited assessment of the potential for specific activities and infrastructure to act as sources of groundwater contamination or presentation of a rationale as to need, or otherwise, for specific sources to be targeted for groundwater monitoring wells.

Typically, an assessment of groundwater contamination would involve a more detailed assessment of the potential specific sources at a site. The first stage of intrusive investigations would conventionally involve installation of wells in the immediate vicinity of sources to assess whether the potential sources have caused contamination of groundwater and the direction of groundwater flow moving away from those sources. If contamination is identified in shallow wells around a source, deeper wells can be installed to assess the vertical extent of contamination and the potential direction of groundwater flow at depth.

It appears that the scope of the Detailed Site Investigation was to assess off-site impacts, to address the specific requirements of the Investigation Notice. There appears to have been an assumption that onsite sources had been assessed as part of previous investigations or the establishment of the monitoring well network for the operating compost facility.

Onsite wells are limited to MB03A and MB03D located on the boundary of the site east of the main composting area and BH03A on the boundary of the site east of the Stormwater Basin. The existing onsite wells provide a reasonable basis for assessing groundwater contamination associated with the site moving across the eastern boundary of the site.

Specific potential sources of contamination along the southern boundary of the site have not been targeted for installation of groundwater monitoring wells. As such, the potential for onsite features such as the Stormwater Basin, Above-Ground Phosphorous Reclamation Pond and Machinery Yard and Work Shops to be acting as sources of groundwater contamination and the potential for impacted groundwater to be moving across the southern boundary has not be reliably assessed.

4.1.2 Contaminants of Concern

The potential contaminants of concern (CoC) identified in the Detailed Investigation Report and MAR are consistent with my understanding of the nature of activities associated with the composting facility.

The key CoCs in groundwater associated with the site are nutrients and inorganics such as chloride and sulphate. Chemical parameters for nutrients associated with the site at concentrations above water quality criteria include; total nitrogen, ammonia, nitrate and nitrite. Chemical indicators of

dissolved inorganics potentially associated with the site include total dissolved solids (TDS), chloride, bicarbonate, sulphate and dissolved metals.

Evidence of the key CoCs is provided by analysis of surface water samples from the Stormwater Basin in the southeast corner of the site undertaken by Strategen (Groundwater Quality Assessment, April 2014).

Although the key CoCs are clearly associated with the site, there are strong indications that surrounding agricultural activities may also be sources of nutrients and soluble inorganics in groundwater (wells BH01, MB01, MB02 and BH101) and surface water drains running around the site.

Broad scans for a wide range of other potential contaminants have been conducted on groundwater samples as part of investigations conducted to date. Broad scans for a range of soluble metals, total petroleum hydrocarbons (TPH), volatile organic chemicals (VOCs) and semi-volatile chemicals (SVOCs).

I note that tests were conducted for MBAS surfactants on select samples, have been used to assess for the presence of per- and poly-fluoroalkyl (PFAS) compounds. Since the Detailed Investigation was completed, interim guidance on ecosystem protection screening values have significantly lowered assessment criteria for the presence of PFAS compounds in terms of ecological risk. In response to the lowered assessment criteria, different analytical methods are more commonly used that provide lower detection limits.

The MBAS surfactants appear to have been included as part of secondary broad screen for potential contaminants rather than specific sources of PFAS compounds identified at the site.

If additional wells were installed closer to specific onsite sources, it would be worthwhile to conducting broad scan analyses on samples from those wells to rule out other trace contaminants. It would also be prudent to conduct PFAS analysis with lower detection limits on the groundwater samples from new groundwater wells close to onsite sources and background wells hydraulically up-gradient.

4.1.3 Water Quality Criteria

The Contaminated Sites Ground and Surface Water Chemical Screening Guidelines (DoH 2014) specify a non-potable groundwater use (NPUG) guideline of 500 mg/L nitrate as NO_3, which equates to 113 mg/L nitrate as N. Similarly, the Australian Drinking Water Guidelines (ADWG) specify a guideline of 50 mg/L nitrate as NO_3, which equates to 11 mg/L nitrate as N. The ADWG (aesthetic) and DoH NPUG guidelines both specify a value of 0.5 mg/L for ammonia as NH_3, equating to 0.4 mg/L ammonia as N.

The livestock drinking water quality guideline for nitrate of 400 mg/L is incorrectly referred in Section 11.2.1.1 of the DSI report as nitrate as N, where the ANZECC 2000 guidelines specify the guideline as nitrate as NO_3.

Apart from the error associated with nitrate, which does not affect the conclusions made, the water quality guidelines for key contaminants of concern adopted as part of the Detailed Site Investigation report and used by the Auditor in forming his opinion appear appropriate.

4.2 Potential Pathways and Receptors for Groundwater Contamination

Key potential pathways for groundwater contaminated by onsite activities include the following:

Table 1: Summary of Potential Pathways and Receptors of Contaminated Groundwater

Aquifer	Pathway/Receptor	Discussion
Shallow Groundwater Bassendean Sands	Extraction of contaminated groundwater for the following uses: • human consumption; • stock watering; and • irrigation.	Background salinity, as indicated by TDS in BH02A, is within a range that suggest groundwater is of suitable quality for human consumption, stock watering and irrigation. Limited saturated depth and available drawdown in the Bassendean Sands at the site limit the potential of this water table to be developed as a groundwater resource. Therefore, I consider extraction of groundwater from the formation described as the Bassendean Sands in the investigation area unlikely to be a significant pathway of concern at the site. The upper Guildford Sands screened in shallow wells east of the site I considered as part of the deeper water table system.
Shallow Groundwater Bassendean Sands	Discharge of impacted groundwater to stock dams onsite and off-site	Groundwater contours indicate shallow groundwater is, at least during some periods, moving northeast from the Main Compost Pad toward stock dams onsite and off-site. However, concentrations of the key contaminants of concern in bores BH04 and MB04, located between the site and stock dams to the northeast, were below livestock drinking water quality guideline values. I believe potential impacts on the stock dams has been assessed sufficient to form an opinion that there is no unacceptable risk to human health or stock associated with contaminated groundwater from the site.
Shallow Groundwater Bassendean Sands	Discharge to stormwater drains, wetlands and surface water ecosystems	Potentially the most significant pathways for shallow contaminated groundwater associated with the site are; discharge to surface water drainage features, and surface seepage to wetlands. Both pathways may result in impacts to surface water ecosystems and adjacent properties. Assessment of these pathways is difficult due to the relatively high likelihood that other off-site sources of surface water contamination, in particular nutrients, in the surrounding area. Other sources of both direct run-off to surface water and shallow groundwater contamination to surface water appear to be present hydraulically up-gradient of the site. I considered groundwater quality data from well BH02A and BH101 to be indicative of background contamination in shallow groundwater associated with sources hydraulically up-gradient of the site. I could not locate data relating to surface water quality in drainage lines surrounding the site, which made assessment of contributions of contamination from the site or off-site sources to surface water quality difficult. At different times of the year, surface drains may be recharging shallow groundwater and be a separate secondary source of groundwater impacts. Groundwater elevations in well MB04 suggest mounding of the water table in that vicinity, which could be associated with water in the surface water drain running from north to south along the eastern boundary of the site. Additionally, forming an opinion on interactions between the Stormwater Basin, shallow groundwater and surface drainage in the southeast part of the site was difficult due limited coverage by the existing well network. The site is located in an area defined as a “multiple use wetland” and a “conservation wetland” is located approximately 150 m southeast of the site. As such, any low-lying areas in the site vicinity may receive shallow groundwater surface seepage. Understanding the potential for shallow groundwater contamination associated with the Stormwater Basin, and other potential sources in the southern part of the site, to be moving across the southern boundary of the site is a key data gap in the existing information.

Aquifer	Pathway/Receptor	Discussion
Guildford Aquifer	Groundwater extraction and use for: • human consumption; • stock watering; and • irrigation.	The Guildford Aquifer represents a viable groundwater resource based on background salinity and potential yield. In considering potential impacts on extractive uses of groundwater I relied primarily results of monitoring of deep wells. However, I did consider both shallow and deeper wells to be indicative of impacts on groundwater quality in the Guildford Aquifer east of the site, where the Bassendean Sands were not present. The existing groundwater monitoring well network provides a reasonable basis for assessing impacts on groundwater quality east of the main composting area at the site. The absence of deep groundwater monitoring wells north and south of the line of wells (refer to Figure 4) makes it difficult to assess whether there is a component of flow to the northeast or southeast of the well alignment. I considered water quality data from well BH101D to be indicative of groundwater quality hydraulically up-gradient of the site. Ammonia, total nitrogen, nickel were present in deeper groundwater monitoring wells hydraulically down-gradient of the site at concentrations above drinking water or irrigation criteria. However, concentrations these hydraulically down-gradient in the Guildford Aquifer were generally similar to or less than concentrations hydraulically up-gradient of the site, suggesting the site is not contributing significantly to impacts on extractive use of groundwater from the Guildford Aquifer. TDS concentration in monitoring well BH104D were significantly higher than concentrations in other deep wells. Lower TDS concentrations in deep wells closer to the site (BH102D and BH103D) suggests that the TDS concentrations in BH104D may be associated with a source other than the site. In general, contamination associated with the site does not appear to be impacting extractive use of groundwater east of the site.
Guildford Aquifer	Discharge to wetlands and surface water ecosystems	Discharge of groundwater from the deeper Guildford Aquifer to surface water, rather than shallow groundwater, appears more likely to occur a significant distance, at least 500 m, east or southeast of the site. Based on information presented in the reports, the nearest significant drainage feature with the potential to receive groundwater discharge from the deeper Guildford Aquifer beneath the site is the Birrega Drain, approximately 1.5 kilometres east. Nitrate, nitrite, chromium were detected in well BH102D east of the site at concentrations above fresh water ecosystem criteria and background concentrations. However, concentrations of these chemical were less than the ecosystem criteria further east of BH102D (i.e. BH103D and BH104D). There do not appear to be surface water features east of the site likely to receive groundwater discharge from the deeper Guildford Aquifer above ecosystem water quality criteria. The existing monitoring well network does not provide coverage of impacts to the deeper Guildford Aquifer southeast of the site. However, based on the extent of impacts east of the site, it appears unlikely that deeper groundwater would be discharging to surface water features southeast of the site.

The extent of groundwater contamination to the east of the site, in both Bassendean Sands and Guildford Aquifer, appears to be sufficiently well defined by investigations completed to date.

The primary potential pathway for movement of groundwater contamination which may require additional assessment relates to shallow groundwater interactions with surface water drains and potential for surface seepage south and southeast of the site. Additional shallow wells, surface water sampling and surface water and drain invert elevations would assist in forming a firmer opinion.

Additionally, the current monitoring well network does not provide a sound basis to assess groundwater contamination associated with specific sources in the southern part of the site and whether groundwater impacts have the potential to move beneath the southern boundary. Additional

wells in the immediate vicinity of the Stormwater Basin, Above-Ground Phosphorous Reclamation Pond and Machinery Yard would assist in assessing potential impacts and the direction of groundwater flow.

4.3 Temporal Trends

A key element of the CSM at the site involves potential changes in impacts over time. Given that composting activities at the site ceased in 2014, it is reasonable to assume that sources of contamination at the site would reduce.

In general terms, groundwater monitoring from the 2014 through to 2016 suggests that groundwater contamination associated with the site has reduced over time. In particular, secondary sources of nutrients and soluble salts in soil at the site would be expected to slowly decline over time.

Based on information presented in the documents provided, the only remaining primary source of groundwater contamination remaining at the site would appear to be the Stormwater Basin. Depending on the results of further assessment of impacts immediately around it, consideration should be given to filling and capping the Stormwater Basin.

5.0 Responses to Specific Questions

My responses to specific questions, in *italics*, asked by DWER (Questions 1 to 5) and other external parties (Questions 6 to 10) are presented in this section of my report.

5.1 Question 1 – Adequacy of the Monitoring Well Network

> *"Are the locations and depths of groundwater monitoring wells at the site adequate to assess the condition of groundwater beneath the site and off-site associated with areas of concern at the former composting site, such as the composting pad and stormwater basin?"*

The existing groundwater monitoring well network appears to offer a reasonable degree of coverage to assess groundwater contamination to the east of the site.

Background conditions in the Bassendean Sand water table and Guildford Aquifer appear to be reasonably well defined.

The depth intervals targeted by the screened sections of groundwater monitoring wells installed by DP as part of investigations at the site appear appropriate to assess impacts associated with the potential contaminants east of the site.

In my opinion, short-comings in the existing groundwater monitoring well network at the site include the following:

- Insufficient wells were installed close to suspected onsite sources of contamination to accurately assess impacts on groundwater quality and more accurately define groundwater flow direction moving away from those sources. Specifically, an understanding of groundwater impacts would have been enhanced by groundwater monitoring wells installed immediately adjacent to;
  - the Stormwater Basin in the southeast of the site,
  - the Above-Ground Phosphorous Reclamation Pond in the southwest corner of the site,
  - the Machinery Yard and Workshop, and
  - any other specific locations identified by a detailed review of former onsite activities and infrastructure.
- Definition of the vertical extent of contamination could have been more effectively defined by installation of shallow and deep wells in close proximity of specific onsite sources.
- The absence of groundwater monitoring bores on the southern boundary of the site, or on the southern side of specific potential sources of contamination (e.g. the Stormwater Basin), does not allow reliable assessment of the likelihood of groundwater impacts to be migrating across the southern boundary of the site.
- Insufficient deep wells to the north and south of the existing deep well alignment to assess whether there is, or is not, a component of flow to the northeast or southeast. Additional deep wells onsite may be sufficient to assess the appropriateness of deep wells off-site.

Assessment of the potential for discharge and recharge of the shallow water table by surface water features would also have been enhanced by survey data of the invert levels in drains and water levels in onsite ponds.

Assessment of impacts on surface water quality would also have been enhanced by surface water sampling up- and downstream of the site.

It should be noted that installation of additional wells may not change the conclusions of Detailed Site Investigation and MAR in relation to off-site extent of groundwater impacts. However, I believe there are gaps in the existing well network which limit the certainty with which conclusions can be drawn.

In my opinion, the data gap with the greatest potential to have caused off-site impacts is movement of shallow groundwater impacted with nutrients and TDS across the southern site boundary and discharge to stormwater drains or surface seepage on surrounding properties.

5.2 Question 2 – Potential for Impacts Beyond the Site Boundary and at Depth

> *"After considering the geology and hydrogeology at the site, the auditor found that there is limited potential for groundwater impacts to be present beyond the site boundary, or below the vertical extent of the monitoring well network. Does the independent reviewer agree?"*

5.2.1 Off-Site Extent

In general, I agree with the Auditor's conclusions in relation to extent of groundwater contamination off-site to the east. However, I don't believe the well network is adequate to form a firm conclusion in relation to whether contamination associated with the site extends across the southern boundary. In particular, whether contamination from specific sources such as the Stormwater Basin extends across the southern boundary of the site and potential to discharge to surface.

5.2.2 Vertical Extent of the Existing Well Network

In relation to the adequacy of the vertical extent of the monitoring well network, I believe that the existing well network extends to sufficient depth to detect the key contaminants of concern in groundwater east of the site.

The key contaminants of concern generally involve dissolved nutrients and salts. Higher concentrations of dissolved contaminants can result density gradients driving contaminant plumes to depth in an aquifer. A key indicator of density gradients associated with dissolved contaminants at the site would be total dissolved solids (TDS). Typically, I would only expect strong vertical gradients to be evident in plumes with higher TDS concentrations than are evident at the site.

The highest TDS concentrations apparently associated with onsite impacts, measured in shallow groundwater during groundwater monitoring events (GMEs) 1 to 4, were in the range of 660 mg/L to 3,200 mg/L. Background TDS concentrations in shallow groundwater were in the range of 300 mg/L to 500 mg/L. The difference between background and TDS concentrations associated with the site is unlikely to drive strong vertical density gradients.

However, the vertical distribution of contaminants could be more conclusively assessed by shallow and deeper wells installed closer to specific onsite sources. Additional wells in close proximity to specific sources would also assist in confirming the vertical distribution of contaminants, refer to **Sections 5.1** and **5.5** and **Figure 5**.

There was no evidence of contaminants that behave as dense non-aqueous phase liquids (DNAPLs), such as chlorinated ethenes. Notwithstanding that chlorinated solvents were used in the workshop at the site (refer to Section 5), I do not consider the vertical extent of the wells to be problematic in this regard.

5.3 Question 3 – Impacts to Human Health and the Environment

> *"The auditor found that groundwater conditions at the site, including potential off-site migration, do not pose an unacceptable risk to the environment or human health, subject to the findings of ongoing groundwater monitoring in the vicinity of the stormwater basin. Does the independent reviewer agree?"*

I agree that the information provided to the auditor provides a reasonable basis for assessing risk to human health associated with extractive use of groundwater east of the site, the primary pathway for risks to human health.

Risk to human health associated with extractive use of groundwater appear unlikely to be significant on the basis of results currently available. Based on findings east of the site, the extent of impacts on

drinking water quality and non-potable use of groundwater in the Guildford Aquifer are likely to be limited to within 300 m of the site boundary. As I understand from the Detailed Site Investigation report (Section 112.3.1), the nearest groundwater extraction well potentially hydraulically down-gradient of the site "…*is located 735 m south/southeast of the site*."

Based on information currently available, groundwater impacts in the Guildford Aquifer above water quality criteria for drinking water and non-potable use may extend across the southern boundary of the site. Notwithstanding the information currently available east of the site, assessment of human health risks would benefit from data confirming the potential for contamination in the Guildford Aquifer to extend to the south and southeast of the site.

In Section 2.1 of the MAR (last bullet point), the auditor qualifies his conclusions regarding off-site migration being "…. *subject to ongoing groundwater monitoring in the vicinity of the stormwater basin*."

I agree that monitoring should be continued in the vicinity of the Stormwater Basin. However, as indicated in **Section 5.1**, I believe that additional wells would be required along the southern boundary of the site and adjacent to specific onsite sources, such as the Stormwater Basin, to confirm that opinion.

Potential environmental impacts on surface water quality and wetland ecosystems associated with discharge of shallow contaminated groundwater from the site is the key risk I believe requires further investigation to form a firm opinion. I believe assessment of the environmental risks associated with shallow groundwater impacts would benefit from additional shallow wells, surface water sampling and water elevation data.

5.4 Question 4 – Overall Adequacy of the Groundwater Investigation

> *"Overall, has an adequate groundwater investigation been undertaken to determine the nature and extent of any potential groundwater contamination originating from the former composting site?"*

As discussed in **Section 5.1**, I believe groundwater investigations completed to date have adequately assessed groundwater impacts extending east from the site. However, I believe there are short-comings in the investigations to date.

Further assessment may simply confirm the conclusions drawn to date. Alternatively, shallow and deeper groundwater contamination may be found to extend off-site to the south or the axis of a groundwater plume in the deeper Guildford Aquifer (i.e. the highest concentrations of contaminants) may not coincide with the line of wells extending east of the main compost pad area. If the highest concentrations of contaminants are found to be flowing a different flow path to that currently monitored, our understanding of the extent of groundwater impacts in the Guildford Aquifer may change.

5.5 Question 5 – Recommendations for Further Work

> *"…, what further work does the independent reviewer recommend?"*

5.5.1 Further Investigations

To more thoroughly assess risk to human health and the environment associated with groundwater impacts I would recommend additional investigation works. Recommended additional groundwater well and surface water sampling locations are shown on **Figure 5**.

The additional investigation works be conducted to confirm the conclusions of the Audit report:

- At least five additional shallow wells in close proximity to specific onsite sources (refer to **Figure 5**).

- If further inquiries indicate potential specific sources of contamination existed in the Maintenance Yard and Workshop (e.g. fuel storage tanks or chemical storage and handling), further wells may be required in that area.
- At least two additional deeper wells south and east of the Stormwater Basin, adjacent to shallow wells (refer to **Figure 5**). The deeper wells should be screened in the Guildford Sands, beneath any coffee rock that may be present in those locations (approximately 6 m to 10 m bgl), to assess vertical migration of contaminants immediately adjacent to the Stormwater Basin.
- Invert levels in surface drains on and surrounding the site should be surveyed for comparison to surrounding groundwater elevations.
- Surface water elevation data in onsite ponds, and temporal variations in those levels, should be obtained to assess potential hydraulic gradients with the surrounding water table.
- Samples of any water remaining in onsite ponds should be collected and analysed to assess their potential as on-going sources.
- Samples of stormwater should be collected from the surface drains around the site to attempt to assess contributions from up-stream sources and the site (refer to **Figure 5**).

If the recommended onsite wells indicate significant groundwater contamination and groundwater flow is believed to be moving across the southern boundary of the site, additional off-site wells may be required.

5.5.2 Decommissioning

It is my understanding that the composting facility has ceased operation and composting will not be conducted at the site in future. On that basis, consideration should be given to appropriate decommissioning requirements. The Stormwater Basin still appears to contain water. Decommissioning works may include filling and capping any onsite ponds potentially acting as on-going sources of groundwater contamination.

5.5.3 Future Composting Activities

I would suggest that other sites would be more appropriate for future composting activities. In my opinion, the location of the site in a “multiple use wetland” zone and being underlain by a shallow water table in sand make it less than ideal for a composting facility.

If composting is intended to be conducted at the site, I believe improved engineering controls would be required. Appropriate engineering controls may include:

- Composting conducted on concrete or asphalt paved surfaces with underlain by low permeability liners.
- A first flush system to contain run-off from composting areas.
- Effluent and stormwater ponds constructed above ground, rather than excavated below the water table, lined with low permeability lining systems comprising engineered compacted clay liners, geosynthetic clay liners or geomembranes.

5.6 Question 6 – Groundwater Numerical Model

> *“Would it have been useful for the initial groundwater investigation to include a groundwater numerical model to provide information on the best locations and depths for sighting the groundwater monitoring bore locations and depths?”*

It is my experience that numerical modelling of groundwater plumes is not normally conducted until a sufficiently detailed CSM and hydrogeological parameters have been established to define the detailed model. Rather than being used in the initial phases of an investigation, typically, numerical models have greater applicability in assessing sensitivity of hydrogeological parameters, longer term trends in groundwater plume development, evaluation and design of remedial responses.

I believe that a numerical model would have limited application at the site until the data gaps identified above have been more thoroughly assessed. If sufficient investigation data is collected, a numerical modelling may not be required.

5.7 Question 7 – Characteristic Behaviour of Contaminant Plumes

> *"Has the consultant's groundwater investigation taken into account the characteristic behaviour of contaminant plumes in a close to the surface, unconfined sand aquifer?"*

DP have provided a reasonable understanding of the geology underlying and east of the site. The wells they installed appeared appropriately screened to provide assessment of conditions in the Bassendean Sands and upper sand sequences of the underlying Guildford Formation, where they have installed wells. However, there are key data gaps, primarily associated with an understanding of contamination closer to specific onsite sources, direction of groundwater movement away from those sources and potential for discharge to surface.

The main data gaps I see in the investigation are identified in my responses to earlier questions.

5.8 Question 8 – Compliance with Instruction from DWER

> "*Were the groundwater monitoring bore installations (locations and depths) in line with the instructions given by DWER in 2014.*"

The requirements for groundwater monitoring bore installations in the Investigation Notice issued by DWER on 2nd October 2014 are documented in Requirements 2.3.3. and 2.3.4 and in Schedules 2 and 5 of the Notice.

In most regards, the groundwater monitoring bore installations attempted to address the requirements of the Investigation Notice. The key exceptions to meeting the requirements of the Investigation Notice relate to the following:

- Determining the vertical and horizontal extent of groundwater impact onsite and off-site.
- Establishing sentinel bores along the axis of the groundwater plume.

Requirements of the Investigation Notice included; "…*at least nine bores…to determine the vertical and horizontal extent of groundwater impacts on-site and off-site"* (Requirement 2.3.3).

As discussed in my earlier responses, I believe insufficient monitoring wells were installed onsite, in close proximity to potential sources of groundwater contamination, to assess the vertical distribution of contamination and the direction of groundwater movement away from those sources.

Groundwater monitoring well installations as part of the Detailed Site Investigation did not include additional onsite wells and assumed that groundwater would move directly east from the site.

Requirement 2.3.3.1 of the Investigation Notice required "*Nests of monitoring bores screened at different depths at a minimum of three sites along the axis of the plume located within the potential area of impact*…" In addition, Schedules 2 and 5 included requirements for wells along the axis of the plume.

Establishing the axis of groundwater plumes requires a sufficient data to confirm groundwater flow directions moving away from sources. I believe insufficient wells exist onsite to provide an adequate understanding of the direction of groundwater flow and confirm that the off-site wells are located along the axis of a contaminant plume leaving the site.

In relation to the deeper Guildford Aquifer, deeper wells were constructed in a line from west to east, which does not provide an adequate indication of the potential for groundwater to be moving to the northeast or south east of the site.

5.9 Question 9 – Sufficient Temporal Groundwater Data

> "*Can the interpretation of the groundwater quality results (after 2 years of monitoring) be considered sufficient in terms of the groundwater contaminant plume that was indicated by DWER in 2014?*"

Four groundwater monitoring events, GME1 to GME4, were conducted at approximately 6 month intervals over 2 years. Combined with earlier monitoring data, monitoring data presented in the Detailed Site Investigation report provide a reasonable basis to understand temporal trends at the monitoring well locations.

In general, the adequacy of data provided in the groundwater investigations is limited by spatial coverage rather than temporal variability.

Developing an understanding of temporal variability at the locations where additional wells and sampling is required may require multiple rounds of monitoring similar to sampling events GME1 to GME4.

5.10 Question 10 – Possibility of Further Downstream Impacts

> "*Is there a possibility that the groundwater contaminant plume is still migrating away from the Bio-Organics site and that water bores downstream of the Bio-Organics site be affected in the future?*"

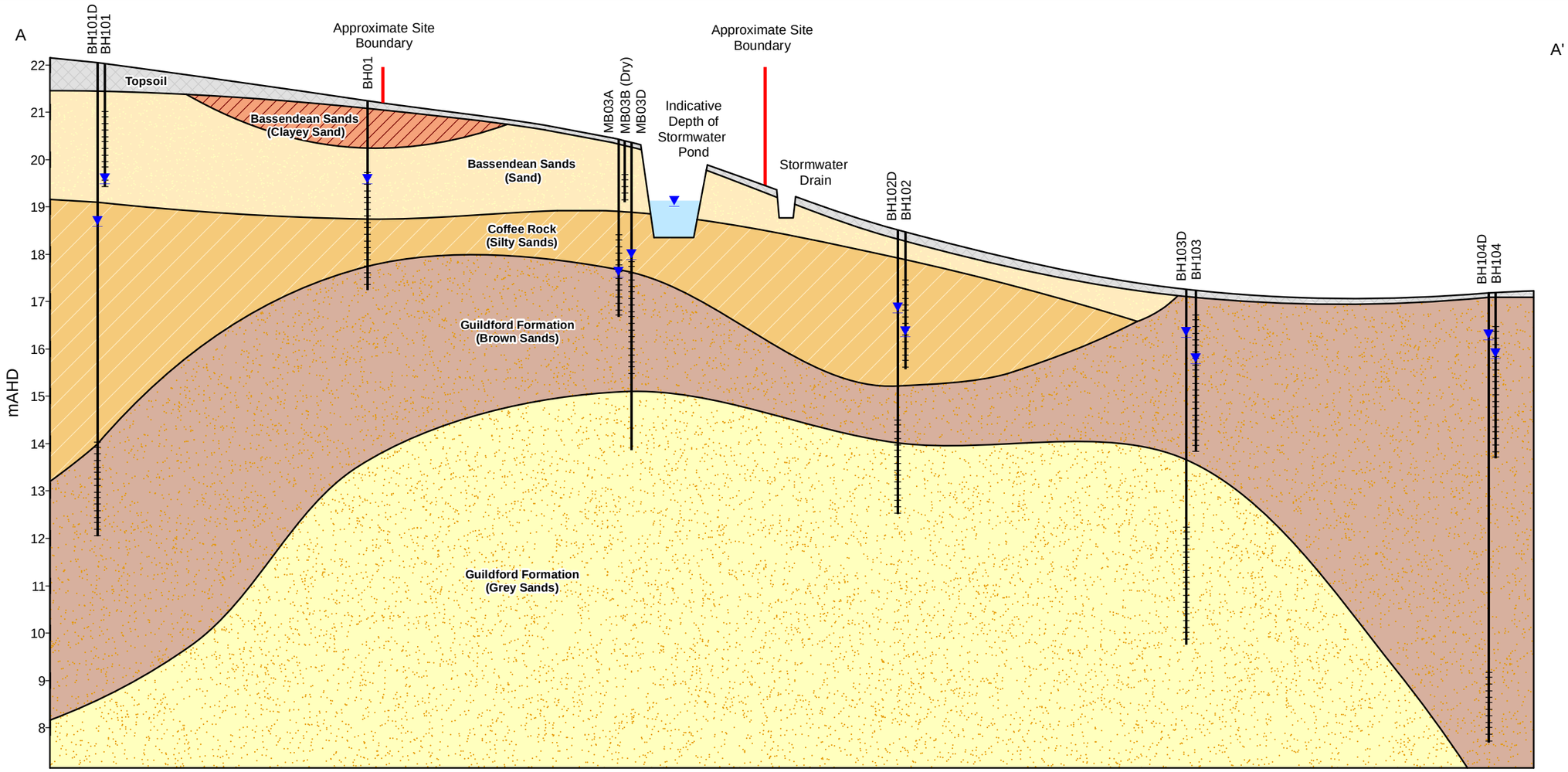
Based on the information available for my review, the likelihood of groundwater contamination reaching existing groundwater bores hydraulically down-gradient of the site would appear to be limited. However, it is not clear that the existing well network provides an indication of the highest concentrations in groundwater along the axis of the plume and it is not clear that groundwater does not have a component of flow toward the southeast. As indicated in my previous responses, I believe additional monitoring wells are required to confirm potential risks to groundwater extraction off-site to the south and southeast.

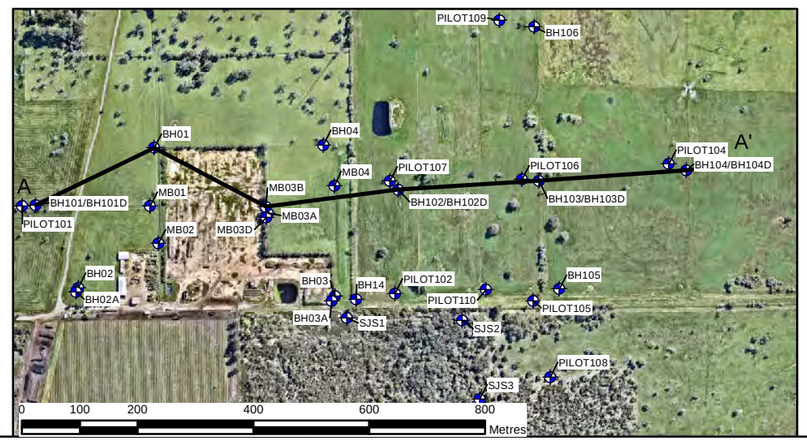
6.0 Principles and Limitations of Opinion

Specific uncertainties and limitations regarding the opinions expressed in this report include the following:

- My opinion presented herein was based on review of the documents and data provided to me by DWER, listed in **Section 2.0**, and my experience investigating groundwater contamination involving the same and similar contaminants. Additional information or data may change my opinions in relation to groundwater contamination.
- I did not have the opportunity to inspect the site and surrounds to familiarise myself with general layout of the site and vicinity. As such, I have relied on aerial photographs, photographs included in reports and correspondence provided to me by DWER to obtain an understanding of the site and surrounds.
- I relied on descriptions of the nature composting activities and infrastructure at the site presented in the reports provided in by DWER. Descriptions of specific activities and infrastructure at the site were relatively limited and I could do no more than high-light the lack of detail as a potential area for further inquiry.
- I have based my interpretation of the geology of the site and surrounds on the information presented in the documents provided and general references on the geology of the Perth region. I have had limited experience working in the Perth region and the variability of its formations. In forming my opinion, I attempted to satisfied myself that the descriptions of the material properties of the formations encountered in borehole were sufficiently accurate to allow interpretation of the hydrogeology of the site and contaminant movement, or otherwise.

Figures





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Legend

- Groundwater RWL (GME 1)
- Casing
- screen
- Topsoil
- Bassendean Sands (Clayey Sand)
- Bassendean Sands (Sand)
- Coffee Rock (Silty Sands)
- Guildford Formation (Brown Sands)
- Guildford Formation (Grey Sands)
- Groundwater Monitoring Well

Notes:
Aerial imagery sourced from Nearmap Pty Ltd

senversa
Address: Level 6, 15 William Street, Melbourne VIC 3000
Phone: (03) 9606 0070
Website: www.senversa.com.au

Designed:	K. Potter	Date:	3/01/2018
Drawn:	M. Byrne	Revision:	0
Checked:	P. Clarke	Scale:	(A3)
File:	P13676_02_F001_Geological Cross Section		

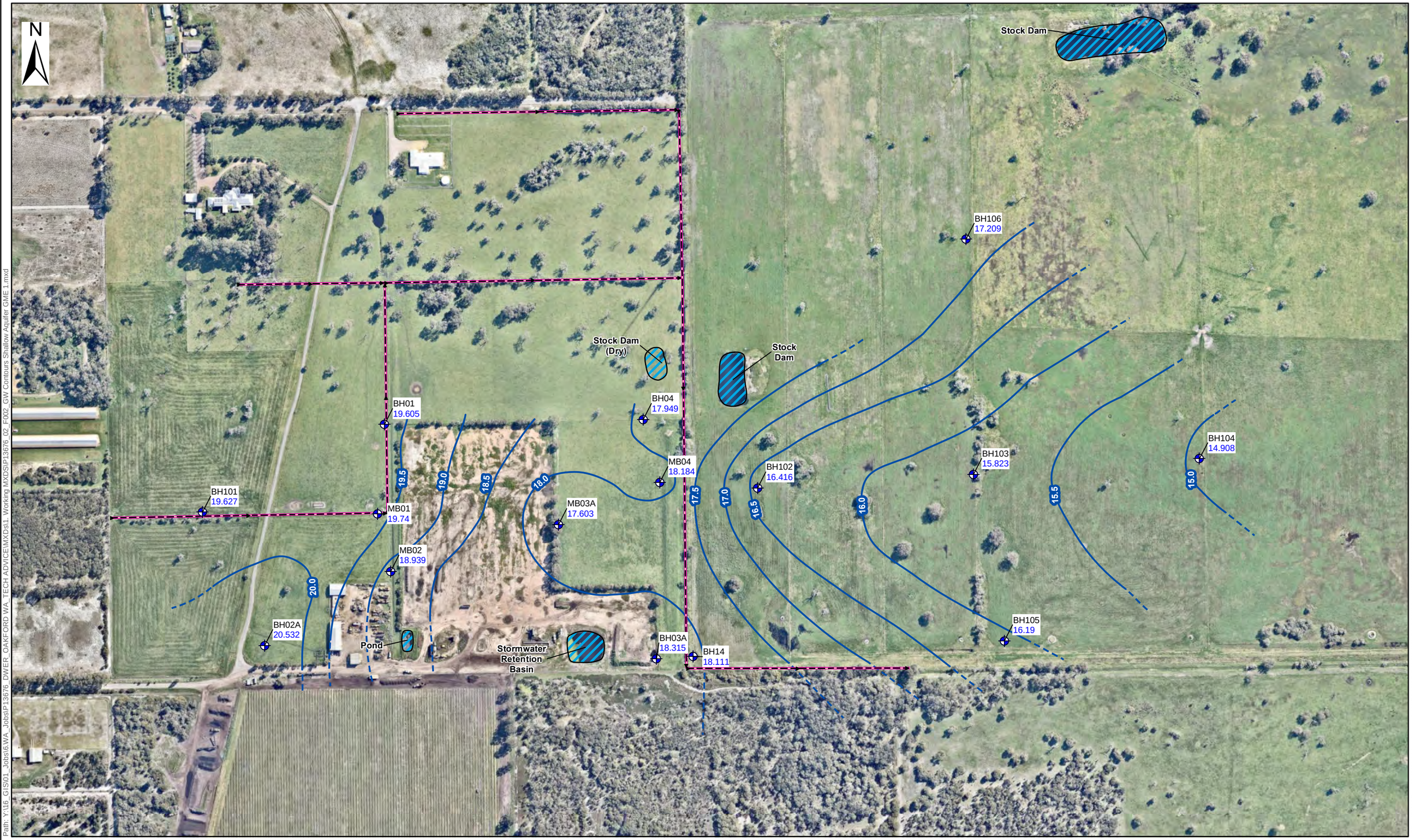
Figure No: 1

Title: Geological Cross Section

Project: Technical review

Location: Lot 36 Abernethy Road, Oakford, WA

Client: Department of Water and Environmental Regulation



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Legend

- Groundwater Monitoring Well
- Open Surface Water Drains
- Waterbody
- Inferred Groundwater Contours
- Estimated Groundwater Contours

Well ID
Reduced Water Level (mAHD)
Notes:
Aerial imagery sourced from Nearmap Pty Ltd

Designed:	K. Potter	Date:	4/12/2017
Drawn:	M. Byrne	Revision:	0
Checked:	.	Scale:	1:4,000 (A3)
File:	P13676_02_F002_GW Contours Shallow Aquifer GME 1		

0 37.5 75 150 225 300 Metres

Datum GDA 1994, Projection MGA Zone 50

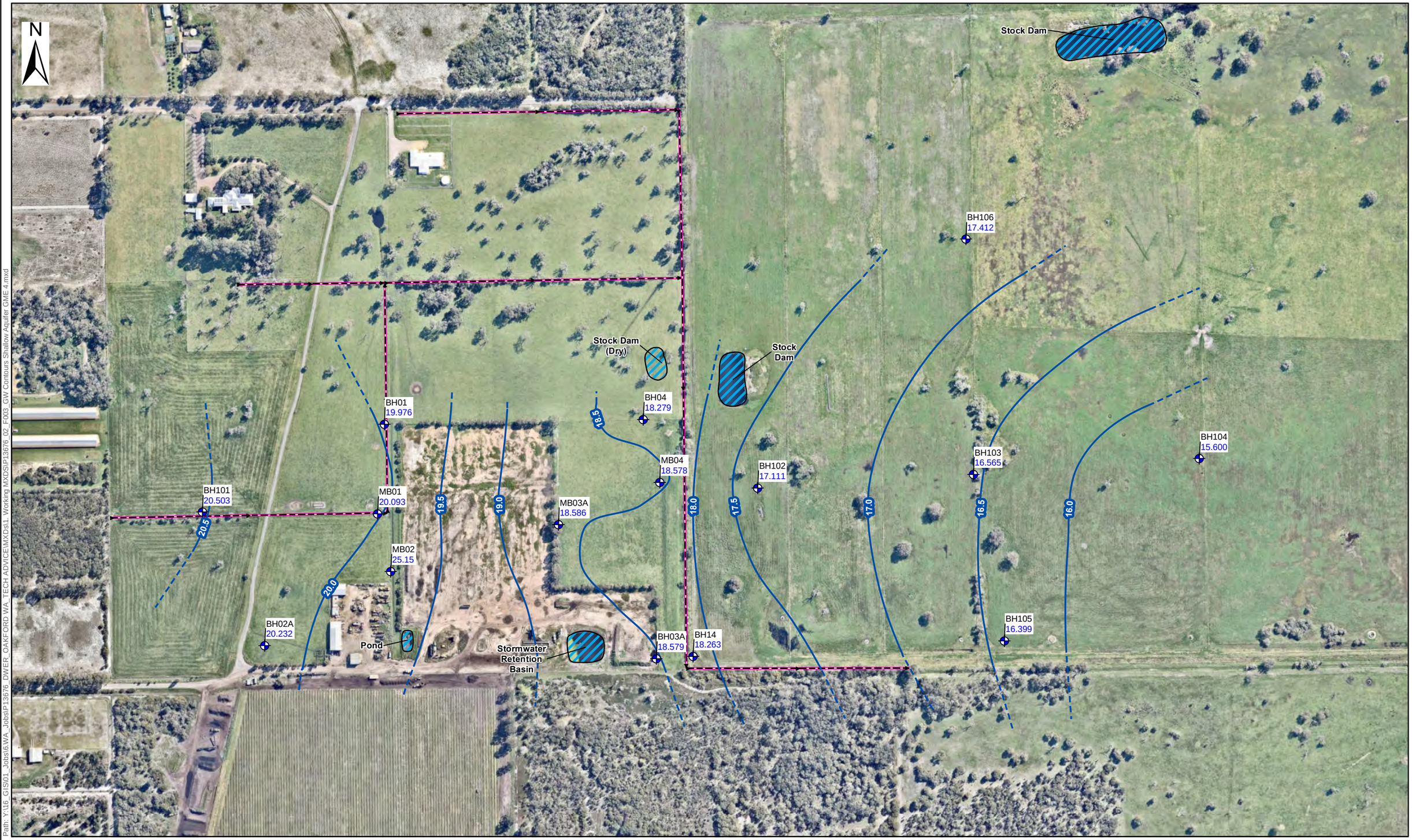
Figure No: 2

Title: Groundwater Contours – Shallow Aquifer – GME 1

Project: Technical review

Location: Lot 36 Abernethy Road, Oakford, WA

Client: Department of Water and Environmental Regulation



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Website: www.senversa.com.au

Legend

- Groundwater Monitoring Well
- Inferred Groundwater Contours
- Estimated Groundwater Contours
- Open Surface Water Drains
- Waterbody

Well ID
Reduced Water Level (mAHD)
Notes:
Aerial imagery sourced from Nearmap Pty Ltd

Designed:	K. Potter	Date:	4/12/2017
Drawn:	M. Byrne	Revision:	0
Checked:	.	Scale:	1:4,000 (A3)
File:	P13676_02_F003_GW Contours Shallow Aquifer GME 4		

0 37.5 75 150 225 300 Metres

Datum GDA 1994, Projection MGA Zone 50

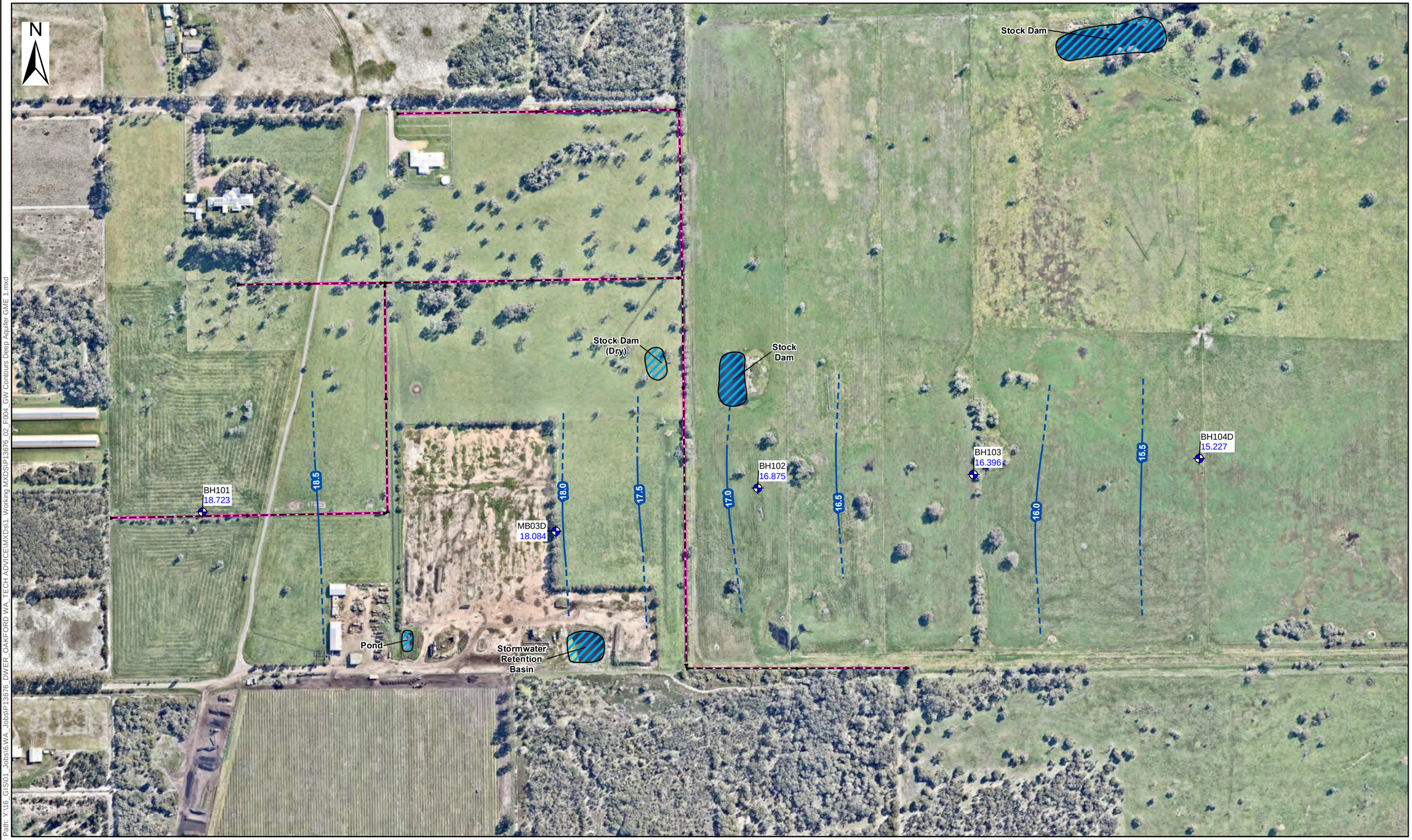
Figure No: 3

Title: Groundwater Contours – Shallow Aquifer – GME 4

Project: Technical review

Location: Lot 36 Abernethy Road, Oakford, WA

Client: Department of Water and Environmental Regulation



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Legend

- Groundwater Monitoring Well
- Inferred Groundwater Contours
- Estimated Groundwater Contours
- Open Surface Water Drains
- Waterbody

Well ID
Reduced Water Level (mAHD)
Notes:
Aerial imagery sourced from Nearmap Pty Ltd

Designed:	K. Potter	Date:	23/11/2017
Drawn:	M. Byrne	Revision:	0
Checked:	.	Scale:	1:4,000 (A3)
File:	P13676_02_F004_GW Contours Deep Aquifer GME 1		

0 37.5 75 150 225 300 Metres

Datum GDA 1994, Projection MGA Zone 50

Figure No: 4

Title: Groundwater Contours – Deep Aquifer – GME 1

Project: Technical review

Location: Lot 36 Abernethy Road, Oakford, WA

Client: Department of Water and Environmental Regulation

N

Stock Dam

PILOT109

BH106

Stock Dam (Dry)

Stock Dam

BH01

BH04

PILOT104

BH104/BH104D

PILOT107

PILOT106

BH102/BH102D

BH103/BH103D

PILOT101

BH101/BH101D

MB03B

MB03A

MB03D

BH02

BH02A

Pond

Stormwater Retention Basin

BH03

BH03A

BH14

PILOT102

PILOT110

BH105

PILOT105

SJS2

SJS1

PILOT108

SJS3

Path: Y:\16_GIS\01_Jobs\16.WA_Jobs\P13676_DWER_OAKFORD WA_TECH ADVICE\MXDs\1. Working MXDs\P13676_02_F005_Additional Wells.mxd

senversa

Address: Level 6, 15 William Street
Melbourne VIC 3000
Phone: (03) 9606 0070
Website: www.senversa.com.au

Legend

- Existing Groundwater Monitoring Well
- Recommended Deep Wells (2)
- Recommended Shallow Wells (5)
- Suggested Surface Water Sampling Location (7)
- Open Surface Water Drains
- Waterbody

Notes:
Aerial imagery sourced from Nearmap Pty Ltd

Designed:	P. Clarke	Date:	4/12/2017
Drawn:	M. Byrne	Revision:	0
Checked:	.	Scale:	1:4,000 (A3)
File:	P13676_02_F005_Additional Wells		

0 37.5 75 150 225 300 Metres

Datum GDA 1994, Projection MGA Zone 50

Figure No: 5

Title: Recommended Additional Wells

Project: Technical review

Location: Lot 36 Abernethy Road, Oakford, WA

Client: Department of Water and Environmental Regulation

Appendix A: Curricula Vitae for Patrick Clarke

Patrick Clarke

Senior Principal

Qualifications & Certifications

Bachelor of. Engineering., Royal Melbourne Institute of Technology (RMIT), 1987

FIEAust, CPEng, EngExec, NER, APEC Engineer

EPA appointed Environmental Auditor (Contaminated Land), since 2002.

Graduate of the Australian Institute of Company Directors Course (GAICD), 2003

Career Profile

Patrick Clarke is a Senior Principal Geological Engineer in the Melbourne office of Senversa. He is Environmental Auditor (Contaminated Land), appointed pursuant to the Environment Protection Act (Vic), 1970. Patrick has provided consulting engineering advice on projects throughout Australia, the United States of America (three years) and the Asia-Pacific region over a period of 29 years. Patrick's main areas of expertise include contaminated soil and groundwater assessment and remediation, contaminant hydrogeology, landfill engineering and environmental auditing.

Patrick has consistently worked as an environmental consultant, since the inception of the waste and contaminated land consulting industries in Australia in the late 1980's. He has assessed soil and groundwater contamination on operating and former industrial sites involving a wide range of potential contaminants and geological environments including the following industries: petroleum, petrochemical, explosives manufacturing, automotive manufacturing, fire fighting, mining equipment manufacturing, electrical and white goods manufacturing, defence industries, dry cleaning, paint manufacturing, textile manufacturing, air, rail and road transport, ports and marine engineering and fire-fighting.

Patrick has provided advice on landfills and solid waste management projects across Australia and internationally since 1988. He has experience in site selection, environmental permitting, landfill engineering, leachate management, landfill gas management and groundwater impacts associated with landfills.

Patrick was first appointed as an environmental auditor (Contaminated Land) by the EPA in April 2002. Since that time he has been an active environmental auditor completing Section 53X audits for change in land use of former industrial sites, Section 53V audits relating to soil and groundwater contamination issues and statutory audits for landfills.

Patrick has been involved in the identification, ranking and management of risk associated with contaminated land issues and waste disposal for a wide range of clients. He developed contaminated land risk management frameworks for organisations including: the Department of Defence, Department of Treasury and Finance and VicTrack.

Expertise

Contaminated Site Assessment

Statutory Environmental Audits

Contaminant Hydrogeology and Groundwater Remediation

Landfill Engineering

Key Industry Sectors

Petroleum and Petrochemical

Manufacturing

Waste Management

Defence

Property Development and Management

Employment History

Nov. 2008 (current): Senversa Pty Ltd

Nov. 1999 to Feb. 2008: HLA & ENSR Australia

Feb. 1988 to Nov 1999: URS Australia Pty Ltd, formerly Woodward-Clyde and Australian Groundwater Consultants

Memberships

Member - Institution of Engineers, Australia (1992)

Founding President of the Australian Contaminated Land Consultants Association (ACLCA), Victorian Branch.

Member of the Australian Land and Groundwater Association.

Member of the EPA Victoria, Landfill Auditors working group.

Member of the EPA Victoria, Groundwater Approvals Working Group (GWAWG).

Regular participant in the EPA's Landfill Auditor reference group

Professional Training & Development

- Developed and Conducted Training Workshops for in Groundwater Assessment and Cleanup to the Extent Practicable (CUTEP) and soil logging on behalf of the ACLCA (Vic. Branch) and the Environment Protection Authority Victoria (EPAV).
- Certificate of Appreciation as Founding President of the Australian Contaminated Land Consultants Association (Victorian Branch).
- University of Waterloo, Short Course, Assessment and Remediation of DNAPL Contaminated Sites.
- Developed and Conducted Training Workshop on Siting and Design of Landfills for EPAV staff.
- Active Participant in the EPA's Landfill Auditors Group.
- 40 hour OSHA Health and Safety Training.
- Graduate of the Australian Institute of Company Directors, Directors Course (2003) and Update (2015).

Project Experience

CONTAMINATED LAND ASSESSMENT

Patrick Clarke has played a key role in a large number of contaminated land assessment and cleanup projects in Australia, the USA and Asia. Sites investigated and/or remediated have involved contamination associated with an extensive range of historical industrial activities including: petroleum refining, storage and handling, petrochemical manufacturing, automotive manufacturing, rail facilities, explosives manufacturing, fire fighting foams, gas works, agricultural chemicals manufacturing, paints and solvents, dock yards, port facilities, tyre manufacturing, timber, airports, aircraft maintenance, construction and waste management. He has extensive experience in characterisation of human health and environmental risks associated with soil and groundwater contamination and development of effective cleanup and management strategies. Relevant projects include:

- Country Fire Authority (Victoria) – advice on assessment and management of PFAS compounds at various sites.
- RAAF East Sale – hydrogeological advice relating to assessment of PFAS impacts on soil and groundwater.
- E-Gate/North Melbourne Railyards - property divestment and redevelopment business case.
- Bradmill Knitting Mills, Yarraville, Victoria redevelopment project.
- Port of Melbourne, Groundwater Contamination Assessments, Holden Dock, Footscray Wharf and Coode Island.
- Orica Southlands (95 hectares) assessment, remediation and sale, Deer Park, Victoria.
- UST Management Plans Victoria and Southern NSW Regions, Department of Defence.
- Former Epsom Racetrack redevelopment ESA and Remediation, Thiess Environmental.
- Due Diligence ESAs, Six Automotive Parts Manufacturing Facilities, Conf. Client.
- ESAs and remediation, Atlas Taiwan Explosives Manufacturing Facility.
- Mulwala Explosives Factory, Groundwater Assessment and Remedial Strategy Development.
- Western Farm, Remediation of a former agricultural chemicals facility in Lompoc, California.
- BP Altona Terminal, ESAs.
- Albion Explosive Factory, Deer Park, Groundwater Assessment.
- Mobil Altona Refinery, Groundwater Contamination Assessment.
- Orica Botany, Groundwater Contamination Assessment.
- Shell Newport Terminal, Groundwater contamination assessment.
- Shell Geelong Refinery, Phase 1 and 2 environmental sites assessments and remediation advice.

REMEDIATION

Within the general field of contaminated site assessment and cleanup, Patrick has particular expertise in groundwater remediation and contaminant hydrogeology. He has extensive experience in assessment of major groundwater contamination plumes and development of remedial strategies. The EPAV has engaged Patrick to provide advice on groundwater/NAPL remediation projects (see below) and provide input to revisions of their Cleanup to the Extent Practicable (CUTEP) processes. Relevant groundwater assessment and remediation projects include:

- Godfrey Hirst, remediation strategy development and probabilistic cost modelling.
- Ford Broadmeadows, groundwater contamination assessment and remediation trial.
- Confidential client, review of remedial strategies for chlorinated solvent impacts on groundwater.
- Confidential client, review of remedial strategies for chemical manufacturing facility.
- Department of Defence, RAAF Williams, Point Cook: groundwater assessment and development of remedial strategies.
- Department of Defence, Mulwala Explosives Factory Groundwater Management Plan
- Advice to EPA on the Newport Foreshore LNAPL Contamination Remediation
- Orica Deer Park Groundwater Assessment and Cleanup
- Shell Geelong Refinery, Phase 1 and 2 ESAs and PSH recovery advice
- San Diego Light Rail Extension, Contaminated Groundwater and PSH extraction and treatment.

ENVIRONMENTAL AUDTING – CONTAMINATED LAND

Patrick has an active environmental auditor since he was appointed in 2002. Contaminated land audits he has completed since that time include the following:

- Spotless Geelong West, former dry cleaning facility, Section 53V audit.
- Ericsson Australia, Former electrical transformer manufacturing site, Section 53X environmental audit.
- Former Mobil Service Station, Sunbury; Section 53X environmental audit including CUTEP determination.
- Former service station, Reservoir; Section 53X environmental audit including CUTEP determination.
- Gibbs Burge Dye Works; Section 53X environmental audit including a CUTEP submission relating to a significant chlorinated solvent plume.
- Former dry cleaning facility, 225 Barkly Street, Brunswick; Section 53V Audit.
- Shell Coburg, Section 53X environmental audit.
- Shell Vermont; Section 53V Audit related to groundwater impacts.
- Maryborough Education Precinct; Section 53X Environmental Audit.

Project Experience

- Derby Road Child Care Centre, Caulfield; Section 53X Environmental Audit.
- Mt Clear Subdivision, Ballarat; Section 53X Environmental Audit.

ENVIRONMENTAL AUDITING - LANDFILLS AND WASTE MANAGEMENT

Patrick has completed statutory environmental audits under the Victorian regulatory system on landfill and solid waste management sites relating to landfill engineering and assessment of risk associated with leachate and landfill gas. Patrick landfill auditing experience includes the following:

- Corangamite Regional Landfill; landfill cell, cap and leachate pond construction audits.
- Carroll Road Landfill; landfill cell and cap construction audits.
- Victory Road Landfill; liner system construction audits.
- Devil Bend Landfill, landfill cell, cap and leachate pond construction audits.
- Fraser Road Landfill, landfill cell construction audits.
- Barro Sunshine Landfill, landfill cell and leachate pond construction audits.
- Quarry Park, former Footscray Landfill, Section 53V environmental audit of risk to the air associated with landfill gas emissions.
- Sir Doug Nichols Reserve, Thornbury, Section 53V environmental audit of risk to the air and groundwater environments associated with landfill gas and leachate emission.
- Bosworth Road Landfill, Bairnsdale, Section 53V environmental audit of risk to the air environment associated with landfill gas emissions.
- Victory Road, Deals Road and Fraser Road Landfills, Melbourne, landfill cell construction audits.
- Maddingley Brown Coal Landfill, Annual Groundwater Audits (2005-2009).
- Highfield Quarry Landfill, landfill cell construction audits.

ASSESSMENT OF ENVIRONMENTAL LIABILITIES

Patrick Clarke has provided advice to a wide range of clients involving assessment of environmental liability. Patrick has been primarily responsible for the development of Senversa's probabilistic methods for quantitative assessment of environmental liability. He has been the principal risk assessor on a number of financial risk assessments involving property divestment/acquisition, company acquisitions and mergers, establishment of financial assurances, development of finance/insurance options for management of environmental risk and assessment of contingent liability. Representative project experience includes:

- Williamstown Dockyards Environmental liabilities assessment.
- Former General Motors Holden, Fishermans Bend Facility and redevelopment options.
- E-Gate precinct redevelopment by Major Projects Victoria.
- South Pacific Tyres; Remedial Options Assessment
- Werribee Landfill; Financial Assurance Support
- State Rail Authority NSW; Risk Management Study
- RAAF Williams, Point Cook Airbase; Redevelopment Options Assessment
- Sterling Pulp Chemicals; financial security deposit
- Abbotsford; Property Development Financial Investment support
- Quenos Environmental Liability Assessment; Petrochemical Company Joint Venture

EXPERT OPINION

Patrick Clarke has provided expert testimony on a number of cases in Australia and the United States of America involving contamination of land and groundwater and landfills. Representative experience in which Patrick provided expert opinion in the following legal matters:

- Independent expert opinion to the Victorian Planning Authority on landfill gas buffers around an operating landfill for a Planning Scheme Amendment.
- Independent opinion for the Western Australian government on requirements for assessment and clean-up of an agricultural chemicals manufacturing facility.
- Expert opinion on assessment and remediation of a former industrial site as part of valuation of a property under a compulsory acquisition by the State Government.
- Expert testimony before the Victorian Supreme Court on the nature and extent of contamination and remediation requirements and clean-up costs for the former Spotless Dry Cleaning facility at Barkly Street, Brunswick.
- Court Appointed Expert for the San Bernardino Superior Court in California, USA. The case involved 20 parties named due to involvement with seven properties on which petroleum hydrocarbons were stored or handled. The properties located less than one kilometer from the municipal water supply wells for the City of Indio in California. In this role, Patrick supervised investigations across all the properties and surrounding areas and development of remedial strategies for soil and groundwater. He provided expert testimony on the case at a series of hearings over a period of 2 years.

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