

Environmental Site Assessment Report, Hendon, SA

22 March 2013

Environment Protection Authority

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22 March 2013

Mr Dale McGill
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Dear Dale

Environmental Site Assessment Report, Hendon, SA

Parsons Brinckerhoff is pleased to provide a final report on the Environmental Site Assessment undertaken within the Hendon area of South Australia.

If you have any queries in relation to this report, please do not hesitate to contact the undersigned on (08) 8405 4300.

Yours sincerely



Shya Jackson
Regional Environmental Service Team Manager
Parsons Brinckerhoff Australia Pty Limited

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Executive summary

Background information

Parsons Brinckerhoff was commissioned by the Environment Protection Authority (EPA) to undertake an Environmental Site Assessment (ESA) of a nominated area of Hendon, South Australia. The investigation area included properties located in the general vicinity of a site (3-5 Philips Crescent) previously identified as having associated metals and volatile organic compound (VOC) groundwater impacts as a result of historical industrial activities.

The main aims of this work were to:

- provide updated groundwater contamination data for areas surrounding the Philips Crescent site
- provide preliminary soil vapour VOC concentrations in selected areas; and
- assess the potential vapour risk to residents and occupants of a nearby childcare centre (*First Steps*) and the Hendon Primary School based on the concentrations of VOCs found in groundwater and soil vapour.

Scope of work

Soil and groundwater investigations undertaken as part of this investigation involved the following:

- drilling of ten soil bores to depths of 4.5 to 5.5 m below ground level (BGL) within sensitive land use areas to the south and west of the Philips Crescent site and analysis of selected soil samples for VOCs
- conversion of the soil bores to groundwater monitoring wells, followed by gauging and sampling of the wells (along with two existing wells) for total cyanide, metals, polychlorinated biphenyls (PCBs) and ultra-trace VOC analysis
- drilling of five soil vapour bores to depths of between 1.1 and 2.2 mBGL adjacent to five of the newly installed monitoring wells, followed by soil vapour and ambient air sampling for selected VOCs; and
- performance of a (conservative) screening vapour risk assessment (VRA) based on the concentrations of designated VOCs (tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (1-1-DCE), *cis*-1,2-dichloroethene (*cis*-DCE), *trans*-1,2-dichloroethene (*trans*-DCE), vinyl chloride and ethene) measured during the groundwater and soil vapour monitoring program.

Discussion and conclusions

The results obtained during the ESA investigations undertaken across the Hendon investigation area have been interpreted to indicate the following:

- The shallow (typically 3 to 4 mBGL) unconfined aquifer that underlies this area is located within interbedded sands and clays (with hydraulic conductivity values of up to 3.4 m/day), and inferred to flow in a westerly direction towards Boating Lake (West Lakes).
- Elevated concentrations of metals (cadmium, cobalt, copper, nickel, zinc), relative to one or more of the adopted groundwater beneficial use (i.e. marine ecosystem, potable, recreational and/or

irrigation) criteria, were detected within the majority of the monitoring wells although no distinct pattern of contaminant distribution could be discerned.

- Elevated concentrations of VOCs (PCE, TCE, 1,1-DCE and vinyl chloride) are present in groundwater at concentrations that exceed one or more of the adopted groundwater beneficial use (i.e. potable and/or recreational) criteria and detectable concentrations of various additional VOCs are also present, including the TCE breakdown products *cis*- and *trans*-DCE (for which no screening criteria are available). Of the 12 wells sampled, the highest groundwater VOC concentrations were detected in a well located within the industrial portion of the investigation area to the immediate south of the Philips Crescent site. Wells located further to the south and west also contained elevated VOC levels but no distinct pattern of contaminant distribution was evident.
- Although the groundwater contaminants are considered likely to have derived, at least partly, from historical industrial activities undertaken at the Philips Crescent site (i.e. based on the results of previous site investigations), this has not been confirmed as the source and historical industrial activities undertaken on surrounding properties may also have contributed.
- Soil vapour bores installed within residential/sensitive land use areas to the south and west of the Philips Crescent site contained detectable levels of VOCs (PCE, TCE, *cis*-DCE and *trans*-DCE) at depths of approximately 1 to 2 m. The highest VOC concentrations were measured in a bore located within the residential area to the south of the Philips Crescent site. The analysis of ambient air adjacent to each of the soil vapour bore locations did not result in the detection of any VOCs.
- None of the soil samples selected from the 10 soil bores/monitoring wells for analysis contained detectable concentrations of VOCs and no odours or visual impacts were noted in the sampled soils.

Based on the available data and the results of a site-specific VRA, it has been concluded that:

- Given the presence of elevated metals and VOC concentrations, groundwater within the shallow aquifer beneath the nominated investigation area is not suitable for a range of beneficial uses, including marine ecosystem protection, potable, recreational and irrigation uses. The extent and source(s) of the groundwater impacts have not yet been determined and the status of the underlying aquifer(s) has not been investigated.
- The VRA identified PCE and TCE in groundwater as the chemicals of concern which triggered soil vapour investigations to assess the potential - vapour risk to the local residents or the occupants of the First Steps childcare centre and Hendon Primary School.
- The results of the VRA indicated that vapour risks associated with the measured soil vapour concentrations within the residential area and at the First Steps childcare centre as well as Hendon primary School, using the site-specific geotechnical data are below the assessment criteria and considered to be tolerable.
- A sensitivity analysis was conducted to account for the uncertainties associated with elevated saturation identified in the geotechnical analysis. The sensitivity analysis indicated soil vapour concentration of TCE has marginally exceeded the assessment criteria when soil with lower water content was adopted in the vapour intrusion model. Hence, further soil vapour investigations may be considered to validate these outcomes.
- Although TCE in well GW9 was interpreted as unacceptable for a residential area, this well is located in an area of commercial/industrial land use, adjacent to the Philips Crescent site, and is therefore not considered representative of conditions associated with more sensitive land uses further to the south and west. An assessment of vapour risks associated with commercial/industrial land use was beyond the scope of this investigation.

1. Introduction

1.1 Background information

Parsons Brinckerhoff was commissioned by the Environment Protection Authority (EPA) in August 2012 to undertake an Environmental Site Assessment (ESA) of a nominated area of Hendon, South Australia, that included properties located in the general vicinity of 3–5 Philips Crescent (the site). A locality map, showing the investigation area, is presented as Figure 1 (Appendix A).

It is understood that significant concentrations of chemical substances have been identified in groundwater in the area surrounding Philips Crescent, Hendon, due to the former industrial activities undertaken on the site and possibly on surrounding properties. It is further understood that the EPA has notified residents in the area not to use groundwater until further notice.

The EPA had recently undertaken sampling of monitoring well GW9, located on Philips Crescent, and the results of this sampling indicated that elevated concentrations of volatile organic compounds (VOCs) and metals were present in groundwater. Previous investigations at the site in 1992 included an ESA (in two stages), to identify and further assess the extent of soil and groundwater contamination, and a short term remediation project. A soil gas assessment was also undertaken. The results of these investigations are discussed further in Section 3 of this report.

This work was undertaken in accordance with our proposal (12-0441-01-201206285), dated 24 July 2012, as approved by EPA on 2 August 2012.

1.2 Objectives

The main objectives of this ESA were to:

- provide updated groundwater data for the vicinity of the Philips Crescent site, including surrounding residential areas
- provide preliminary soil vapour VOC data for selected areas; and
- assess the potential vapour risk to local residents as well as the occupants of a childcare centre (*First Steps*) and Hendon Primary School based on the concentrations of VOCs found in groundwater and soil vapour.

2. Site characterisation

2.1 Regional geology

The Adelaide 1:250,000 geological map sheet (South Australian Department of Mines and Energy, 1969) indicates that the region is underlain by the Quaternary (Pleistocene) Pooraka Formation which is comprised of pale red-brown sandy clay containing carbonate of the Loveday soil.

According to the Australian Soil Resource Information System (ASRIS) website (<http://www.asris.csiro.au/mapping/viewer.htm>), the area of Adelaide that includes the site has an extremely low probability of containing acid sulphate soils (although this is based on limited data).

2.2 Regional hydrogeology

A total of six Quaternary aquifers (Q1 to Q6) have been identified in the Adelaide region and are underlain by a series of deeper Tertiary aged aquifers (T1 to T4), the latter considered to be essentially confined.

The aquifers identified within the Quaternary age sediments of the Adelaide Plains are typically found within the coarser interbedded silt, sand and gravel layers and vary greatly in thickness (typically from 1 to 18 m), lithology and hydraulic conductivity. The confining beds between the Quaternary aquifers consist of clay and silt and range in thickness from 1 to 20 m. These confining beds are absent in some areas, allowing hydraulic connection between the aquifers.

Table 2.1 details the main aquifers located beneath the Adelaide region (South Australian Department of Mines and Energy, 1992).

Table 2.1 Adelaide Plains aquifer geology

Aquifers	Rock Type	Geological Units	Age
Shallow aquifers	Sand and gravel in clay	Pooraka Formation Hindmarsh Clay	Quaternary
Deep aquifer T1	Sand, sandstone and limestone	Dry Creek Sands Hallett Cove Sandstone Port Willunga Formation	Tertiary
Confining bed	Clay with limestone layers	Munno Para Clay	
Deep aquifer T2	Limestone and sand	Port Willunga Formation	
Confining bed	Siltstone and claystone	Port Willunga Formation (Ruarung Member and Aldinga Member)	
Deep aquifer T3	Limestone and sandstone	Port Willunga Formation (Lower Aldinga Member and Chinaman Gully Formation)	
Confining bed	Siltstone	Blanche Point Formation Tortachilla Limestone	
Deep aquifer T4	Sand	South Maslin Sand	
Confining bed	Clay	Clinton Formation	

Aquifers	Rock Type	Geological Units	Age
Shallow aquifers	Sand and gravel in clay	Pooraka Formation Hindmarsh Clay	Quaternary
Fractured bedrock aquifer	Quartzite and siltstone	Adelaidean System	Precambrian

A summary of the Department of Environment, Water and Natural Resources (DEWNR, 2012) bore database for the area (Appendix B) indicates that there are 41 registered bores within a 0.5 km radius of the Tapleys Hill Road – West Lakes Boulevard intersection, 40 of which are groundwater bores. Of the groundwater bores, one was listed as operational and one as unknown. The current status of the remaining 38 bores was not listed. In terms of their primary purpose, 28 bores were listed as being for observation purposes, two bores for domestic purposes and one for the dual purpose of irrigation and observation. The purpose/s of the remaining nine bores were not listed.

Based on information contained in the database, the wells were drilled to depths of between 4.5 and 176.78 m between 1934 and 2007. Standing water levels (SWLs), recorded for 20 of the bores, ranged from approximately 2.50 to 13.11 m below ground level (BGL). Groundwater salinity, recorded for 16 bores, ranged from 686 mg/L to 50,540 mg/L total dissolved solids (TDS). Shallow wells drilled to depths of up to 12 m recorded salinity levels between approximately 1,500 and 7,000 mg/L TDS whereas a larger range in salinity levels was recorded for deeper wells, coinciding with the minimum and maximum values stated previously.

The majority of the bores listed in the DEWNR bore database relate to shallow observation wells (drilled to 6 m depth) installed on and around the Philips Crescent site as well as observation wells (drilled to depths of up to 10 m) installed between Cedar Avenue and Tapleys Hill Road (north of Hendon Primary School).

3. Summary of previous site investigations

Parsons Brinckerhoff was provided with three reports detailing previous investigations at the Philips Crescent site, the major findings of which are summarised below.

3.1 Environmental Site Assessment (Coffey Partners, 1992)

The results of an ESA previously undertaken for the site were detailed in the following report:

- Coffey Partners International Pty Ltd (1992a) *Delen Corporation Site, 3-5 Philips Crescent, Hendon Environmental Site Assessment Summary Report*. Report A2300/1-BD, dated August 1992 (two volumes).

Coffey Partners undertook an ESA at the site with the aim of identifying and characterising surface soil and groundwater contamination and initiating remediation of the site for proposed continued commercial/industrial land use. The program included some short term remediation (removal of liquid wastes and chemical residues), assessment of soil vapour and sampling of soil and groundwater.

The results were interpreted to indicate the following:

- Soils at the site consisted of interbedded clays, sands and silts.
- The depth to groundwater was approximately 3.5 mBGL with an interpreted flow direction towards the west, south-west and north-west at different locations on the site.
- Soil contained elevated concentrations of metals, boron and fluoride. It was concluded that deeper contamination may have also existed around some sumps and remediation of those areas was proposed.
- Groundwater impacts were also identified, with elevated concentrations of metals, boron, fluoride, and VOCs detected. It was noted that arsenic and VOC contamination may have originated from off-site sources.

3.2 Second Stage Environmental Site Assessment and Site Remediation (Coffey Partners, 1992)

The results of the second stage of an ESA previously undertaken for the site were detailed in the following report:

- Coffey Partners International Pty Ltd (1992b) *Delen Corporation Site, Philips Crescent, Hendon, SA. Second Stage Environmental Site Assessment and Site Remediation*. Report A2300/2-AQ, dated October 1992 (two volumes).

In the second stage ESA, Coffey Partners aimed to further assess the extent of soil contamination (particularly around the underground tanks), leachability of soil contaminants, quality of groundwater and the extent of groundwater impacts. To achieve these objectives, they undertook the collection of soil samples, installation of additional groundwater wells (two on-site and seven off-site), assessment of groundwater hydraulic parameters and surveying.

The results were interpreted to indicate the following:

- Groundwater flow direction was inferred to be north-westerly, with shallow gradients noted and low permeability calculated for the shallow aquifer.
- Elevated soil metal concentrations were found in the vicinity of the sumps.
- Copper was found to be leachable from soil and was therefore inferred to have contributed to some of the on-site groundwater impacts, along with underground tank leakage and dispersion of contaminants.
- Elevated levels of metals and VOCs were detected within on-site groundwater and it was concluded that VOC impacts may have been due to both on-site and off-site sources. Although on-site sources may have included the surface dumping of solvents, specific source locations were not identified. It was also noted that high concentrations of VOCs were detected in groundwater from monitoring well GW10, comprising the most southerly located bore on West Lakes Boulevard.
- It was stated that discussions with government agencies had resulted in the South Australian Health Commission (SAHC) not requiring the removal or covering of the shallow soil impacts, provided that the land use remained commercial/industrial.

3.3 Soil Gas Survey (Coffey Partners, 1992)

The results of a soil vapour survey previously undertaken for the site were detailed in the following report:

- Coffey Partners International Pty Ltd (1992c) Delen Corporation Site, 3-5 Philips Crescent, Hendon, SA. Results of Soil Gas Survey and Preliminary Costings of Selected Site Remediation/Options. Report A2300/3-AD, dated December 1992.

This report presented the results of a soil vapour survey aimed at determining the source of identified volatile chlorinated hydrocarbon (VCH) impacts, as well as concepts and cost estimates for selected groundwater remediation options.

The methodology used was to assess soil gas using a photo-ionisation detector (PID) as a screening assessment and then to further assess high readings using a portable gas chromatograph (GC).

The results were interpreted to indicate the following:

- Although no specific VOC leakage or dumping could be confirmed, soil gas concentrations of VOCs were widespread.
- An unacceptable health risk may exist for site users and possible nearby residents. Further soil gas surveys and guidance from the SAHC was recommended
- Preliminary modelling suggested that the use of interception drains may assist in the removal of contaminated groundwater beneath the site.

4. Scope of work

The scope of the intrusive investigation program was undertaken in accordance with standard Parsons Brinckerhoff field procedures, with reference (where applicable) to the following guideline documents:

- ASTM Guide D5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone.
- Australian/New Zealand Standard (1998) Water Quality Sampling, Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples. AS/NZS 5667.1:1998.
- Australian/New Zealand Standard (1998) Water Quality Sampling, Part 11: Guidance on Sampling of Groundwaters. AS/NZS 5667.11:1998.
- National Environment Protection Measure (1999) *National Environment Protection (Assessment of Site Contamination) Measure*. National Environment Protection Council, Australia.
- South Australian Environment Protection Authority (2007) *Regulatory Monitoring and Testing Groundwater Sampling*.
- South Australian Environment Protection Authority (2009) *Site Contamination – Guidelines for the Assessment and Remediation of Groundwater Contamination*.
- Standards Australia (2005) *Guide to the Sampling and Investigation of Potentially Contaminated Soil Part 1: Non-Volatile and Semi-Volatile Compounds*. AS4482.1-2005.
- Standards Australia (1999) *Guide to the Sampling and Investigation of Potentially Contaminated Soil Part 2: Volatile Substances*. AS4482.2-1999.

A plan of the site, showing all soil, soil vapour and groundwater sampling locations, is presented as Figure 2 (Appendix A).

4.1 Soil investigations

Soil investigations, undertaken between 3 and 7 September 2012, involved targeted soil sampling in areas agreed upon through discussions with the EPA.

The soil sampling program involved the following:

- drilling of ten soil bores, that were subsequently converted to groundwater monitoring wells (MW01 to MW10), to depths of between 4.0 and 5.5 m BGL
- collection of soil samples from each soil bore at nominal depths of 0.35-0.5 m, 0.85-1.0 m and every metre thereafter as well as any additional depth intervals that exhibited visual or olfactory evidence of contamination
- field screening of soil samples using a handheld PID unit to evaluate the presence of VOCs; and
- analysis of selected soil samples, as stipulated by the EPA and detailed in Table 4.1.

Soil samples, including the soil vapour cores that were not analysed initially were archived for possible future use (i.e. within specified holding times). For the purposes of the vapour risk assessment (Section 9), it was decided to obtain site-specific geotechnical parameters and three samples (SV01_0.3-0.8, SV01_0.8-1.5 and SV02_1.0-1.5) were submitted for the analysis of moisture content, bulk density, dry density, void ratio, degree of saturation, porosity, water porosity, air porosity and specific gravity.

Table 4.1 Soil bore sampling and analytical program

Sampling Program				Analytical Program	
Sampling Location	Rationale	Depth of Soil Bore	Depth of Fill	Natural Soil	
				Sample depth (m)	Analytes
MW01	Residential area to south-west, and down-hydraulic gradient, from Philips Crescent site	5.5	-	4.3-4.5	halogenated aliphatics
				4.8-5.0	
MW02	West Lakes Boulevard to south of Philips Crescent site	5.5	0.3	4.4-4.6	
MW03	Residential area to south, and down-hydraulic gradient, from Philips Crescent site	5.5	0.35	1.0-1.2	
				4.0-4.2	halogenated aliphatics
MW04	West Lakes Boulevard, south to south-west of Philips Crescent site	5.5	-	3.7-3.9	
MW05		5.0	0.5		
MW06		5.5	0.5	1.0-1.2	volatile halogenated compounds
			1.8-2.0		
				3.5-3.7	
MW07	Adjacent to First Steps childcare centre, located west of Philips Crescent site	4.0	0.6	1.1-1.3	halogenated aliphatics
				3.8-4.0	
MW08	Hendon Primary School grounds	5.0	0.4	4.2-4.4	
MW09		4.5	0.2	1.75-1.9	
				2.4-2.6	
				3.5-3.7	
MW10	5.0	0.45	2.3-2.5		
			3.5-3.7		

Abbreviations: VHCs = volatile halogenated compounds

4.2 Groundwater investigations

The groundwater investigation program, undertaken between 3 and 19 September 2012, comprised the following:

- installation of ten groundwater wells (MW01 to MW10), between 3 and 7 September 2012, as outlined in section 4.1
- development of groundwater wells upon completion of installation
- professional surveying of all wells to Australian Height Datum (AHD)
- well gauging, purging and collection of field readings on 17 to 19 September 2012, immediately prior to sampling; and
- analysis of groundwater samples, as detailed in Table 4.2.

In addition to the ten newly installed monitoring wells, existing monitoring wells BH22 and GW9 were also surveyed and sampled as part of this groundwater investigation.

Table 4.2 Groundwater sampling and analytical program

Groundwater Well Location	Cased Depth	Screened Interval	Analytes
MW01	5.5 m	2.5 to 5.5 m	total cyanide, PCBs, metals, ultra-trace VOC scan
MW02	5.5 m	2.5 to 5.5 m	
MW03	5.5 m	2.5 to 5.5 m	
MW04	5.5 m	2.5 to 5.5 m	
MW05	5.0 m	2.0 to 5.0 m	
MW06	5.5 m	2.0 to 5.0 m	
MW07	4.0 m	1.0 to 4.0 m	
MW08	5.0 m	2.0 to 5.0 m	
MW09	4.5 m	1.0 to 4.5 m	
MW10	5.0 m	2.0 to 5.0 m	
BH22	5.5 m	Unknown	
GW9	5.5 m	2.5 to 5.5 m	

Abbreviations: PCBs = polychlorinated biphenyls, VOC = volatile organic compounds

Notes: Metals included arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, vanadium and zinc.

4.3 Soil vapour and ambient air assessment

Soil vapour investigations, undertaken between 3 and 18 September 2012, involved the following:

- drilling of five soil vapour bores (SV01 to SV05), approximately 1 m from groundwater monitoring wells MW02, MW05 and MW06 (along the edge of the residential area to the south of West Lakes Boulevard), MW07 (adjacent to the First Steps childcare centre) and MW09 (within the Hendon Primary School grounds), to depths of between 1.1 and 2.2 m BGL
- collection of undisturbed soil cores (retained in 63 mm plastic push tube sleeve) from each location

- field screening of the completed soil vapour bore using a hand-held PID unit
- professional surveying of all soil vapour bores to AHD
- analysis of three soil samples for geotechnical parameters (bulk density, moisture content, dry density, void ratio, porosity (air & water) and specific gravity); and
- soil vapour and ambient air sampling at each location (conducted by Leeder Consulting), between 11 and 15 days after bore installation, for the analysis of trichloroethene, tetrachloroethene, 1,1-dichloroethene, 1,2-dichloroethene (*cis*- and *trans*-), vinyl chloride and ethene, as requested by the EPA.

4.4 Quality control program

4.4.1 Soil

Although quality control (QC) sampling was undertaken as part of the soil investigation, field duplicates, equipment rinsate blank and trip blank samples were not selected by the EPA for analysis.

4.4.2 Groundwater

The QC sampling undertaken as part of the groundwater investigation program is detailed in Table 4.3.

Table 4.3 Summary of groundwater QC program

Analyte	Number of Groundwater Samples Analysed			% Duplicate Samples Relative to Primary Samples	Number of Blanks Analysed	
	Primary	Field Duplicates (intra-lab)	Laboratory Splits (inter-lab)		Rinsate	Trip
Total cyanide	12	1	1	16%	2	-
PCBs	12	1	1	16%	2	-
Metals	12	1	1	16%	2	-
Ultra-trace VOC	12	1	1	16%	-	1

4.4.3 Soil vapour and ambient air

The QC sampling undertaken as part of the soil vapour and ambient air assessment is detailed in Table 4.4.

Table 4.4 Summary of soil vapour and ambient air QC program

Analyte	Number of Samples Analysed			% Duplicate Samples Relative to Primary Samples	Number of Trip Blanks Analysed
	Primary	Field Duplicates (intra-lab)	Laboratory Splits (inter-lab)		
Soil Vapour:					
Trichloroethene	5	1	-	20%	1
Tetrachloroethene	5	1	-	20%	1
1,1-dichloroethene	5	1	-	20%	1
1,2-dichloroethene (cis- and trans-)	5	1	-	20%	1
Vinyl chloride	5	1	-	20%	1
General gases	5	1	-	20%	-
Ambient Air:					
Trichloroethene	5	1	-	20%	-
Tetrachloroethene	5	1	-	20%	-
1,1-dichloroethene	5	1	-	20%	-
1,2-dichloroethene (cis- and trans-)	5	1	-	20%	-
Vinyl chloride	5	1	-	20%	-
General gases	5	1	-	20%	-

5. Methodology

Prior to the commencement of the field component of the intrusive investigations, a site specific Health, Environment & Safety Plan (HESP) was prepared. All personnel working at the site were required to read, understand, sign and conform to the HESP.

5.1 Soil sampling

Field methodologies adopted during the soil sampling program were consistent with Parsons Brinckerhoff ESA Field Procedures and have been summarised in Table 5.1.

Table 5.1 Soil investigation methodology

Activity	Details
Service Location	All drilled locations were checked for the presence of buried services by a professional services locator before the commencement of the field investigations. In addition, underground service plans for the area were obtained prior to the commencement of the investigations and were used to assist with locating underground services.
Concrete Cutting	Concrete cutting was conducted at one location (MW07/SV04) to allow intrusive soil investigations beneath concrete pavement.
Soil Collection Method	Soil bores were hand augered and/or drilled, the latter using pushtube and solid flight auger techniques, by a professional drilling company.
Soil Logging	Soil logging was based on field interpretation and was consistent with AS 1726-1993.
Field Screening	Soil samples were screened in the field using PID units that were calibrated to a known concentration of isobutylene gas by the hire company prior to issue. Instrument calibration data are included in Appendix C. The PID unit was fitted with a 10.6 eV globe, considered suitable for the field screening of the majority of common volatile contaminants of concern.
Soil Sampling Method	Soil cores were discharged from the pushtubes into a clean core tray and samples were obtained from the relevant intervals. Soil samples were handled using gloves and samples were stored in glass jars supplied by the primary laboratory. Gloves were changed prior to the collection of each sample.
Sample Preservation	Soil samples were stored on ice in an insulated chest immediately after sampling. Samples were kept chilled prior to and during delivery to the laboratory.
Decontamination	All drilling and sampling equipment was pressure cleaned between each sampling location using mains water and a phosphate free detergent (Decon 90).
Waste Soil Disposal	Waste soil was collected for off-site disposal by a licensed contractor.

5.2 Groundwater well installation and sampling

Field methodologies adopted during the groundwater well installation and sampling program were consistent with Parsons Brinckerhoff ESA Field Procedures and have been summarised in Tables 5.2 and 5.3.

Well permits are included in Appendix D and borehole log reports showing well construction details are included in Appendix E.

Table 5.2 Groundwater well installation methodology

Activity	Details
Well Construction Permits	Individual well permits were obtained from the South Australian Department of Water, Land and Biodiversity Conservation prior to well installation.
Service Location	Groundwater well locations were checked for the presence of buried services by a professional services locator before the commencement of the field investigations. In addition, underground service plans for the area were obtained prior to the commencement of the investigations and were used to assist with locating underground services.
Drilling Method	Drilling and installation of the groundwater wells was undertaken by a professional drilling company in accordance with National Uniform Drillers Licensing Commission (2012) <i>Minimum Construction Requirements for Water Bores</i> . Drilling involved pushtube and solid flight auger techniques.
Well Construction	<p>All wells were constructed with 50 mm, class 18 uPVC screen and casing and completed with gatic covers. A filter pack comprising clean graded sands and/or gravels of suitable size to provide sufficient inflow of groundwater was installed within the annular space between the borehole and the well casing. The filter pack extended from the base of the screened interval to 0.5 m above the termination of the slotted casing.</p> <p>In order to minimise the likelihood of surface water or perched groundwater infiltrating the aquifer, a bentonite plug, comprising pelleted or granulated bentonite, was placed above the filter pack to a minimum thickness of 0.3 m.</p> <p>Grout was used to complete the well from the bentonite plug to the surface.</p>
Well Development	In order to ensure interconnection between the aquifer and the well, and to remove drilling fines from the gravel pack and well, each well was developed by purging a minimum of five well volumes and/or until it purged dry.
Well Surveying	Following construction, the location of each groundwater well was surveyed to Geocentric Datum of Australia (GDA) 1994. The highest point on the top of the internal uPVC casing (TOC) was surveyed relative to Australian Height Datum (m AHD) and marked for future gauging reference.
Waste Disposal	<p>Waste soil was collected for off-site disposal by a licensed contractor.</p> <p>Water removed during well development was collected for off-site disposal by a licensed contractor.</p>

Table 5.3 Groundwater assessment methodology

Activity	Details
Timing of Sampling	<p>Initial gauging and sampling of groundwater wells was undertaken more than seven days after the completion of well installation and development.</p> <p>Prior to sampling, GW9 was cleared of obstruction (i.e. accumulated silt) using a steel bailer.</p>

Activity	Details
Well Gauging	All wells were gauged for standing water level (SWL) and the presence of Light Non-Aqueous Phase Liquid (LNAPL) before sampling using an interface meter.
Sampling Method	<p>With the exception of MW07 (sampled via bailer due to minimal groundwater present in the well which purged dry within the first litre removed), groundwater sampling was undertaken using low flow (micropurge) techniques, in accordance with AS/NZS 5667.11:1998 and SA EPA (2007) <i>Regulatory Monitoring and Testing Groundwater Sampling</i>, ensuring that:</p> <ul style="list-style-type: none"> ▪ the flow rate (0.2-0.3 L/min) was regulated to maintain an acceptable level of drawdown (<100 mm), with minimal fluctuation of the dynamic water level during pumping and sampling ▪ groundwater drawdown was monitored constantly during micropurging and sampling using an interface probe ▪ the stabilisation parameters were recorded after every half to one litre of groundwater purged, using a 90FLMV water quality meter (calibrated prior to use) and a flow cell suspended in a bucket with litre intervals marked. Samples were collected once two to three consecutive stabilisation parameters were recorded. <p>Instrument calibration data are included in Appendix C.</p>
Sample Preservation	All samples were collected in bottles which were supplied by the laboratory and contained the appropriate preservatives (where required). Samples for metals analysis were filtered in the field. All samples were stored on ice in an insulated chest immediately after sampling. Samples were kept chilled prior to and during delivery to the laboratory.
Equipment decontamination	In order to minimise the potential for cross-contamination, the disposable bladder and sample tubing were replaced prior to each sampling event and the pump casing was cleaned with a Decon 90 (phosphate-free) solution between individual groundwater wells.
Wastewater Disposal	Water removed during well purging was collected for off-site disposal by a licensed contractor.

5.3 Soil vapour bore installation

Shallow soil bores were drilled using pushtube drilling techniques, as described in Section 5.1. They were converted to vapour wells by backfilling the bore with 0.3 m of clean washed sand with a vapour implant embedded within it at the target depth. The top of the sand interface was plugged with bentonite and the installation completed with grout and a gatic cover. The probes and tubing were provided by Leeder Consulting and guaranteed to be volatile free.

This methodology decreased the zone of impact to the depth of the backfilled sand (0.3 m) to allow for more targeted investigations of sandy lenses within the sand/clay soil matrix.

5.4 Soil vapour and ambient air sampling

Leeder Consulting were subcontracted to undertake the sampling and analysis of the five installed wells.

Field methodologies adopted during the soil vapour and ambient air sampling program were consistent with ASTM Guide D5314-92 (2001) *Standard Guide for Soil Gas Monitoring in the Vadose Zone* and have been summarised in Tables 5.4 and 5.5, respectively.

Table 5.4 Soil vapour assessment methodology (active sampling)

Activity	Details
Sampling locations	Vapour samples were collected at five locations (SV01 to SV05) within the industrial/sensitive land use portion of the investigation area.
Leak testing	To ensure that representative vapour samples were obtained, each vapour point was tested for leaks prior to sampling. A shroud with isopropanol was placed over each vapour probe and vapour samples collected and analysed for the presence of the isopropanol tracer chemical.
Sampling Method	Vapour sampling was undertaken by a professional company (Leeder Consulting) using a vacuum pump. The sampling flow rates were set at the commencement of sampling and checked during, and at the completion of, the sampling run. General gases and VOCs were collected from each vapour sampling point using silonite canisters (equivalent Summa).
Sample Preservation	All samples were stored in an insulated chest immediately after sampling. Samples were kept chilled prior to and during delivery to the Leeder Consulting laboratory.

Table 5.5 Ambient air assessment methodology (passive sampling)

Activity	Details
Sampling location	Ambient air samples were collected at five outdoor locations (AA01 to AA05), within 1 to 2 m of each of the soil vapour bores (SV01 to SV05).
Sampling Method	Ambient air sampling was undertaken by a professional company (Leeder Consulting) using passive vapour samplers that were suspended at a height of approximately 1.0 m above ground level and collected eight hours after installation. VOCs were collected using silonite canisters.
Sample Preservation	All samples were stored in an insulated chest immediately after sampling. Samples were kept chilled prior to and during delivery to the Leeder Consulting laboratory.

5.5 Laboratory analysis

All primary soil and groundwater samples, as well as and blind field (intra-laboratory) duplicate (groundwater) samples were submitted to Australian Laboratory Services (ALS) for analysis. Laboratory split (inter-laboratory) duplicate groundwater samples were submitted to MGTLabMark. Both of these laboratories were accredited by the National Association of Testing Authorities (NATA) for the analyses performed.

Soil vapour and ambient air samples were submitted to the SGS Leeder Consulting Laboratory in Victoria which was NATA accredited for all but MA-1105: MA-5 Additional.

Coffey Information was responsible for undertaking the geotechnical parameter analysis of soil samples from the soil vapour bore. This laboratory was not NATA accredited for the analyses undertaken.

6. Screening criteria and background concentrations

6.1 Screening criteria

In order to assess the relative concentration and significance of any potential contaminants detected through laboratory analysis it is usual to reference established human health and environmental screening criteria. These contaminant screening criteria represent threshold concentrations of specific contaminants which, if exceeded in a particular sample, may pose a health or environmental risk and may therefore warrant further site specific investigation or risk analysis.

All criteria adopted for the assessment of the soil and groundwater results are presented in the analytical results tables (Appendix F) and results exceeding the adopted criteria have been highlighted.

6.1.1 Soil

Since health-based guidelines are unavailable in the NEPM (1999) for VOCs associated with a residential land use setting, alternative international health-based criteria have been adopted from the following document:

- Netherlands MHSPE (2009) *Soil Remediation Circular* – Dutch intervention levels.

6.1.2 Groundwater

6.1.2.1 Beneficial Use Assessment (BUA)

In accordance with NEPM (1999) Schedule B(6) Guideline on Risk Based Assessment of Groundwater Contamination and SA EPA (2009) Guidelines for the Assessment and Remediation of Groundwater Contamination, a Beneficial Use Assessment (BUA) has been undertaken to assess both the current and realistic future uses of groundwater within the uppermost aquifer beneath the site. This is aimed at determining what groundwater uses need to be protected and assessing the risk(s) that groundwater may pose to human health and the environment.

Within South Australia, the assessment of groundwater quality is governed by the SA EPA (2003) *Environment Protection (Water Quality) Policy (Water Quality EPP)*. This policy lists the default protected environmental values for groundwater. The BUA, as described in the SA EPA (2009) groundwater guideline document is linked to the Water Quality EPP and needs to identify all beneficial uses of groundwater and other applicable scenarios. The protected environmental values, as well as the beneficial uses of groundwater that need to be protected, are detailed in Table 6.1.

As stated in Section 2.2, a review of the DEWNR (2012) bore database for the area has indicated that there are 40 registered groundwater bores within a 500 m radius of the investigation area. In terms of their primary purpose, 28 bores were listed as being for observation purposes, two bores for domestic purposes and one for the dual purpose of irrigation and observation. Groundwater salinity, recorded for 16 bores, ranged from

686 mg/L to 50,540 mg/L total dissolved solids (TDS). The salinity of water within shallow wells (drilled to depths of up to 12 m) ranged between 1,552 and 7,144 mg/L TDS.

A summary of the beneficial uses assessed for the site, and considered realistic, is presented in Table 6.1 and the reasoning behind this is discussed below.

Table 6.1 Assessment of groundwater beneficial uses for Hendon

Environmental Values / Beneficial Uses		SA EPA (2003) Protected environmental value	SA EPA (2009) Potential Beneficial Uses	Hendon Beneficial Use Assessment	
				Considered	Realistic
Aquatic Ecosystem	Fresh	✓	✓	✓	No
	Marine	-	✓	✓	Yes
Recreation & Aesthetics	Primary contact	✓	✓	✓	Yes
	Aesthetics	✓	✓	✓	Yes
Potable		✓	✓	✓	Yes
Agriculture	Irrigation	✓	-	✓	Yes
	Livestock	✓	-	✓	No
	Aquaculture	✓	-	✓	No
Industrial		✓	✓	✓	No
Human health in non-use scenarios	Vapour flux	-	✓	✓	Yes
Buildings and structures	Contact	-	✓	✓	No

Maintenance of aquatic ecosystems

The nearest marine water body, located approximately 1 km west of the investigation area, is Boating Lake (also known as West Lakes), which flows into Barker Inlet. Based on a general west to south-westerly groundwater flow direction, it is considered possible that shallow groundwater beneath the investigation area could discharge into the marine ecosystem.

Since the nearest freshwater body is the River Torrens, located some 4.5 km to the south of the investigation area, groundwater discharge to a freshwater ecosystem is considered unlikely.

Recreation and aesthetics

Due to the presence of a reticulated mains water supply in the area it is considered unlikely that groundwater would be used by residents for activities such as the filling swimming pools. However, given the relatively close proximity to a down-gradient water body (i.e. Boating Lake) that is used for recreational (e.g. swimming, boating and fishing) purposes, primary contact recreation and aesthetic (smell, colour, clarity and general appearance) issues should be considered.

Potable

From the DEWNR database search, it was identified that two bores were used for domestic purposes. Therefore, although the presence of a reticulated mains water supply, and the

moderate to very high salinity of the groundwater within the investigation area (i.e. up to 50,540 mg/L TDS), indicates that extraction of groundwater for potable use is unlikely, the SA EPA (2009) groundwater guidelines state that “the EPA considers beneficial use of groundwater is potable unless proven otherwise”.

Agriculture

As the DEWNR database search identified one bore for irrigation purposes plus two bores for domestic use (i.e. which could include irrigation), this is considered a likely beneficial use.

Due to the metropolitan location of the site, and the high salinity of the groundwater, it is considered unlikely that groundwater would be used for stock watering purposes.

As no specific aquaculture activities are undertaken within Boating Lake, this has not been considered a realistic beneficial use and the adoption of the marine ecosystem criteria is considered appropriate to assess possible effects on marine species living in the lake and caught for recreational purposes (i.e. fishing).

Industrial

The DEWNR database search did not identify any bores within 500 m of the investigation area that were listed as being used for industrial purposes and it is therefore not considered to be a likely beneficial use.

Although the SA EPA (2009) groundwater guidelines state that salinity is not an appropriate indicator to use for any beneficial use other than potable, reference has been made to the ANZECC (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters* which indicates that the salinity of the groundwater within a 500 m radius (686 mg/L to 50,540 mg/L TDS – refer to Section 2.2) is unlikely to be suitable for industrial use, as detailed in Table 6.2.

Table 6.2 Desired salinities for industrial water uses (ANZECC, 1992)

Industrial Water Use	TDS (mg/L)
Once through cooling system and make-up water systems for fresh water	<1,000 and <500, respectively
Textile industry	<100
Food and beverage industry	<850
Iron and steel industry	<1,000
Pulp and paper industry	<500
Petroleum industry	<750

Human health in non-use scenarios

As volatile contaminants have been identified within groundwater in the investigation area, it is considered that there is a potential for these contaminants to migrate beneath occupied areas and thus give rise to vapour generation into indoor/outdoor areas. Therefore, the migration of volatile contaminants from groundwater has been considered and the risks are addressed in more detail in Section 9.

Buildings and structures

As discussed in Section 7.2.1, field measurements taken during the recent monitoring event indicate that the pH (7.01 to 7.62) of shallow groundwater is relatively neutral and is unlikely to present a significant risk to built structures. Although other parameters of potential concern (e.g. sodium, chloride, sulphate) were not measured, the presence of elevated concentrations of certain VOCs could indicate a potential corrosive effect. The depth to groundwater (approximately 3.0 to 3.8 mBGL – refer to Section 7.2.1) in this area, however, suggests that only deep underground structures would be likely to come into direct contact with groundwater.

6.1.2.2 Health and ecological criteria

The health and ecological screening criteria used for the assessment of groundwater have been based on the results of the BUA.

Based on the fact that the Water Quality EPP has detailed water quality criteria for a range of protected environmental values for groundwater within South Australia, an initial comparison of contaminant concentrations has been made to the criteria contained within Schedule 2 (Table 1) of that document.

Where criteria are unavailable for certain analytes, reference has been made to alternative Australian and international criteria to assess likely risks to identified beneficial uses.

A summary of the references used to source the health and ecological groundwater screening criteria is provided in Table 6.3.

Table 6.3 Sources of adopted groundwater screening criteria

Beneficial Use	Reference
Marine Ecosystems	SA EPA (2003) <i>Environment Protection (Water Quality) Policy</i> - protected environmental values for marine aquatic ecosystems
	NEPM (1999) <i>National Environment Protection (Assessment of Site Contamination) Measure Schedule B1</i> - GILs for marine aquatic ecosystems
	ANZECC/ARMCANZ (2000) <i>Australian and New Zealand Guidelines for Fresh and Marine Water Quality</i> - trigger values for marine waters (95% protection)
Recreation and Aesthetics	NHMRC (2008) <i>Guidelines for Managing Risks in Recreational Water</i> – drinking water guidelines (i.e. with an assumed daily consumption rate of 2 L) adjusted by a factor of 10 to account for a more likely (accidental) recreational water consumption of 100 to 200 L/day*
	ANZECC/ARMCANZ (2000) <i>Australian and New Zealand Guidelines for Fresh and Marine Water Quality</i> – recreational guidelines
Potable	SA EPA (2003) <i>Environment Protection (Water Quality) Policy</i> - protected environmental values for potable use
	NHMRC/NRMMC (2011) <i>Australian Drinking Water Guidelines</i>
	WHO (2011) <i>Guidelines for Drinking-Water Quality</i>
	US EPA (2012) <i>Region 9 Screening Levels</i> – tap water
Irrigation	SA EPA (2003) <i>Environment Protection (Water Quality) Policy</i> - protected environmental values for irrigation

*Note that this does not take account of substances that can enter the body through skin adsorption.

6.1.3 Soil vapour

Given that chemicals other than petroleum hydrocarbons have been identified as contaminants within the investigation area, the health screening levels for soil vapour assessment provided within Friebel and Nadebaum (2011) *Health Screening Levels for Petroleum Hydrocarbons in Soil and Groundwater* are not applicable to this investigation and the data have been assessed via a site-specific human health risk assessment (Section 9).

7. Results

7.1 Soil

7.1.1 Soil profile

Soil borehole, groundwater well and soil vapour log reports are included in Appendix E and provide details of soil types encountered at each of the sampling locations.

Surficial fill materials, present to depths of between 0.2 and 0.6 m BGL at eight of the 10 sampling locations, included:

- dark brown, fine grained **silty sands**
- brown, fine to coarse grained **gravelly clayey sands**
- brown/blue/grey, coarse grained **gravels**; and/or
- orange-brown, mottled red and pale brown, low plasticity **silty clays**.

The underlying natural soil profile comprised alternating layers of:

- fine grained, low to medium plasticity, **clayey** and **silty sands/sandy clays**,
- fine to coarse grained orange-brown to yellow-brown **sands**; and
- grey-brown, medium to high plasticity, **silty clays**.

7.1.2 Soil PID readings, odour and staining

No odours or visual impacts (i.e. staining or obvious signs of contamination such as unhealthy vegetation) were noted in the sampled soils.

Headspace PID readings within soils across the site ranged from 0.0 to 168 ppm, with the maximum readings (126, 168 and 78.6 ppm) detected at MW03_0.35-0.5, MW03_1.0-1.2 and MW06_1.8-2.0, respectively, and suggestive of the presence of volatile contaminants. The remainder of the PID readings ranged were less than 4 ppm.

7.1.3 Soil analytical results

Tables of soil analytical results are included in Appendix F and copies of laboratory certificates are included in Appendix G.

All soil sample results were reported below the laboratory limits of reporting (LORs).

7.2 Groundwater

7.2.1 Groundwater field parameters

On 17 September 2012, the depth to the uppermost aquifer within the 12 monitoring wells sampled ranged from 3.064 to 3.827 m below top of casing (m BTOC). No odour or sheen was noted during groundwater purging or sampling and no LNAPL was detected during the gauging of the wells.

Groundwater well gauging data and field parameters measured immediately prior to sampling are presented in Table 7.1 and can be summarised as follows:

- measured pH values ranged from 7.01 to 7.62, thereby indicating neutral groundwater conditions
- electrical conductivity (EC) readings ranged from 1.076 to 30.7 mS/cm (approximating 543 to 17,937 mg/L TDS), thereby indicating fresh to brackish/saline groundwater conditions
- dissolved oxygen (DO) levels ranged from 0.16 to 4.18 mg/L, thereby indicating low to moderate oxygen conditions; and
- redox potential readings ranged from 100 to 212 mV, thereby indicating oxidising conditions.

As indicated in Figure 3 (Appendix A), groundwater within the uppermost aquifer beneath the investigation area was inferred to flow in a general westerly direction, towards Boating Lake and Gulf St Vincent. It should be noted that monitoring well MW07 was excluded during interpretation of the groundwater contour plan as the lithology encountered at this location consisted of a greater proportion of firm to stiff silty clay and a much reduced groundwater recharge rate in comparison to other monitoring wells.

Groundwater field sampling sheets are included in Appendix H.

Table 7.1 Groundwater field parameters – September 2012

Groundwater Well	Easting	Northing	SWL (m BTOC)	RSL (m AHD)	pH	EC (mS/cm)	Redox (mV)	DO (mg/L)	Temperature (°C)
MW01	272586.486	6137351.486	3.597	0.403	7.48	13.38	115	0.50	18.9
MW02	273007.809	6137339.437	3.54	0.900	7.30	9.31	126	0.16	18.6
MW03	272808.771	6137321.933	3.661	0.729	7.62	6.97	117	3.24	17.9
MW04	272858.981	6137455.096	3.569	0.601	7.01	22.12	117	0.35	19.5
MW05	272906.711	6137417.488	3.554	0.686	7.20	15.03	108	1.05	18.1
MW06	272726.033	6137489.299	3.787	0.313	7.03	16.71	176	3.25	16.3
MW07	272649.07	6137524.261	3.635	-0.005	7.07	8.47	212	2.96	18.5
MW08	272567.97	6137746.382	3.631	0.359	7.62	5.50	137	4.18	16.5
MW09	272585.287	6137638.616	3.769	0.301	7.54	1.076	121	1.59	16.8
MW10	272499.548	6137516.444	3.827	0.423	7.44	30.7	107	3.49	17.3
BH22	272564.378	6137862.147	3.37	0.470	7.61	10.71	100	2.53	19.7
GW9	273030.436	6137478.304	3.064	0.836	7.32	12.28	150	2.29	18.9

Note: RSL = reduced standing water level

7.2.2 Groundwater analytical results

The number of groundwater samples analysed, analytes tested for, minimum/maximum constituent concentrations and samples that exceeded the adopted screening criteria are detailed in Table 7.2.

Tables of groundwater analytical results are included in Appendix F and copies of laboratory certificates are included in Appendix G.

Individual sample results can be interpreted as follows:

- Concentrations of cadmium (up to 11,700 µg/L) within monitoring wells MW01, MW02, MW09 and MW10 exceeded the SA EPA (2003) marine ecosystem protection and potable water criteria (2 µg/L), whereas monitoring wells GW9, MW03, MW06 and MW08 contained cadmium concentrations that also exceeded the SA EPA (2003) irrigation (10 µg/L) and NHMRC (2008) recreational (20 µg/L) guidelines.
- Monitoring wells MW02, MW04, MW05 and MW10 contained cobalt concentrations (2 to 3 µg/L) that exceeded the SA EPA (2003) marine ecosystem protection guideline (1 µg/L), whereas GW9 and its duplicate contained 5 and 6 µg/L cobalt, respectively, thereby also exceeding the US EPA (2012) tap water guideline (4.7 µg/L).
- Four monitoring wells (GW9, MW04, MW06 and MW10) contained copper concentrations (up to 48 µg/L) that exceeded the SA EPA (2003) marine ecosystem protection guideline (10 µg/L).
- Nickel concentrations within MW02 (49 µg/L) and MW05 (47 µg/L) exceeded the SA EPA (2003) marine ecosystem protection (15 µg/L) and potable water (20 µg/L) guidelines.
- Six monitoring wells contained zinc concentrations (up to 93 µg/L) that exceeded the SA EPA (2003) marine ecosystem protection guideline (50 µg/L).
- Wells GW9, MW02 and MW07 recorded concentrations of trichloroethene (TCE) exceeding the WHO (2011) drinking water (20 µg/L) and ANZECC/ARMCANZ (2000) recreational (30 µg/L) guidelines, ranging from 31.8 to 2,000 µg/L. Detectable concentrations (0.61 to 15.9 µg/L) of TCE were also present in BH22, MW03, MW04, MW05, MW06 and MW08.
- The concentrations of tetrachloroethene (PCE) within GW9, including its duplicate, and MW02 (up to 370 µg/L) exceeded the SA EPA (2003) potable water criterion (40 µg/L). Detectable concentrations (1.63 to 33.4 µg/L) of PCE were also present MW03, MW04, MW05 and MW06.
- Well GW9 reported a concentration (41.5 µg/L) of 1,1-dichloroethene (1,1-DCE) that exceeded the potable water criterion (30 µg/L) whereas a detectable concentration (1.1 µg/L) was also present in MW02.
- The vinyl chloride concentrations within GW9 (0.7 µg/L) and MW02 (0.4 µg/L) exceeded the potable water criteria of 0.3 µg/L.
- Detectable concentrations of a range of additional VOCs, some of which (marked with an asterisk) did not have available corresponding screening criteria, were present as follows:
 - ▶ benzene: 0.79 µg/L in GW9
 - ▶ ethylbenzene: 0.53 to 0.72 µg/L in GW9, MW04 and MW05
 - ▶ xylenes: 1.23 to 2.98 µg/L in GW9, MW02, MW04, MW05 and MW10
 - ▶ naphthalene: 0.07 µg/L in MW10
 - ▶ 1,3,4-trimethylbenzene*: 0.12 µg/L in MW10
 - ▶ 1,2-dichloroethane: 0.1 to 1.6 µg/L in GW9 and MW08
 - ▶ chlorobenzene: 0.15 to 0.19 µg/L in MW06 and MW10
 - ▶ chloroform: 0.16 to 0.87 µg/L in GW9, MW01, MW09 and MW10

- ▶ *cis*-1,2-dichloroethene (*cis*-DCE)*: 0.8 to 1,220 µg/L in BH22, GW9, MW02 and MW04 to MW08
 - ▶ trihalomethanes*: 0.1 to 0.87 µg/L in BH22, MW01, MW08 and MW09
 - ▶ *trans*-1,2-dichloroethene (*trans*-DCE)*: 0.7 to 6 µg/L in BH22, GW9, MW02, MW04 and MW05.
- All remaining groundwater analytical results were below the laboratory LORs and/or the adopted screening criteria.
 - Groundwater contaminant distribution plans are included as Figures 4 (metals) and 5 (VOCs) in Appendix A.

7.2.3 Aquifer test results

Aquifer tests were performed on the Quaternary age sediments beneath the site on 26 September 2012. Aquifer tests (rising head slug tests) were performed by a field scientist on five monitoring wells with the data analysed by a qualified hydrogeologist using the Bouwer and Rice analytical method for partially penetrating wells (refer to the assumptions listed below). In each case, the tested material is assumed to be the most permeable saturated unit adjacent to the well screen.

The reported hydraulic conductivity (K) values were calculated as follows:

- GW9 (fine to medium grained sand): 2.9 m/day
- MW01 (gravelly sand): 3.4 m/day
- MW04 (clayey sand): 3.4 m/day
- MW06 (silty clay): 0.08 m/day
- MW09 (sandy clay with gravel): 3.4 m/day.

In calculating the above K values the following assumptions have been made:

- the well is partially penetrating, such that the base of the aquifer does not have an effect on the observed water level response
- the effective length of the tested interval is equal to the saturated thickness of the most permeable unit adjacent to the well screen; and
- the filter pack porosity is assumed to be 0.3.

The calculation sheets and graphical representation of field data is included as Appendix I.

Table 7.2 Summary of groundwater results

Number of Primary Samples	Number of Duplicates (intra-lab)	Number of Duplicates (inter-lab)	Analyte (µg/L unless otherwise marked)	Min. Conc.	Max. Conc.	Sample Results Exceeding Screening Criteria
12	1	1	Total cyanide	<4	<4	None
12	1	1	Arsenic	<1	2	None
12	1	1	Barium	41	247	None
12	1	1	Beryllium	<1	<1	None
12	1	1	Cadmium	0.4	11,700	SA EPA (2003) marine protection and SA EPA (2003) potable: 2 µg/L MW01: 3.3 µg/L MW02: 4.6 µg/L MW03: 1,650 µg/L MW06: 2,690 µg/L / QC01_180912: 11,700 µg/L MW08: 90.4 µg/L MW09: 5.1 µg/L MW10: 9.9 µg/L GW9: 83.2 µg/L / QC02_190912: 61 µg/L SA EPA (2003) irrigation: 10 µg/L and NHMRC (2008) recreational: 20 µg/L GW9: 83.2 µg/L / QC02_190912: 61 µg/L MW03: 1,650 µg/L MW06: 2,690 µg/L / QC01_180912: 11,700 µg/L MW08: 90.4 µg/L
12	1	1	Chromium	<1	1	None
12	1	1	Cobalt	<1	5	ANZECC/ARMCANZ (2000) marine: 1 µg/L MW02: 2 µg/L MW04: 2 µg/L MW05: 2 µg/L MW10: 3 µg/L GW9: 5 µg/L / QC02_190912: 6 µg/L US EPA (2012) tap water: 4.7 µg/L GW9: 5 µg/L / QC02_190912: 6 µg/L

Number of Primary Samples	Number of Duplicates (intra-lab)	Number of Duplicates (inter-lab)	Analyte (µg/L unless otherwise marked)	Min. Conc.	Max. Conc.	Sample Results Exceeding Screening Criteria
12	1	1	Copper	4	48	SA EPA (2003) Marine water protection: 10 µg/L MW04: 13 µg/L MW06: 48 µg/L / QC01_180912: 43 µg/L MW10: 32 µg/L GW9: 15 µg/L
12	1	1	Lead	<1	<1	None
12	1	1	Manganese	1	415	None
12	1	1	Mercury	<0.1	<0.1	None
12	1	1	Nickel	1	49	SA EPA (2003) marine: 15 µg/L and SA EPA (2003) potable: 20 µg/L MW02: 49 µg/L MW05: 47 µg/L
12	1	1	Vanadium	<10	70	None
12	1	1	Zinc	14	93	SA EPA (2003) marine: 50 µg/L MW02: 52 µg/L MW04: 82 µg/L MW05: 54 µg/L MW06: 93 µg/L / QC01: 180912: 91 µg/L MW09: 77 µg/L MW10: 63 µg/L
12	1	1	Benzene	<0.05	0.79	None
12	1	1	Toluene	<0.5	<5	None
12	1	1	Ethylbenzene	<0.1	0.72	None
12	1	1	Xylenes	<0.25	2.98	None
12	1	1	Naphthalene	<0.05	0.07	None**
12	1	1	Total PCBs	<1	<1	None**
12	1	1	Trichloroethene	<0.05	2,000	WHO (2011) drinking water: 20 µg/L and ANZECC/ARMCANZ (2000) recreational: 30 µg/L MW02: 31.8 µg/L MW07: 189 µg/L GW9: 1,290 µg/L / QC02_190912: 2,000 µg/L

Number of Primary Samples	Number of Duplicates (intra-lab)	Number of Duplicates (inter-lab)	Analyte (µg/L unless otherwise marked)	Min. Conc.	Max. Conc.	Sample Results Exceeding Screening Criteria
12	1	1	Tetrachloroethene	<0.05	370	SA EPA (2003) potable: 40 µg/L GW9: 170 µg/L / QC02_190912: 370 µg/L MW02: 91.8 µg/L
12	1	1	1,1-dichloroethene	<0.1	41.5	SA EPA (2003) Potable Water: 30 µg/L GW9: 41.5 µg/L / QC02_190912: 35 µg/L
12	1	1	<i>cis</i> -1,2-dichloroethene	<0.1	1,220	No criteria available
12	1	1	<i>trans</i> -1,2-dichloroethene	<0.1	6	No criteria available
12	1	1	Vinyl chloride	<0.3	0.7	SA EPA (2003) Potable Water: 0.3 µg/L GW9: 0.7 µg/L (QC02_190912: <1 µg/L) MW02: 0.4 µg/L
12	1	1	VOCs (individual compounds)	<0.05	<20	None**

Note: **laboratory detection limits exceeded the adopted assessment criteria for some or all analytes
Numbers in bold exceed adopted assessment criteria

7.3 Soil vapour and ambient air results

Tables of soil vapour and ambient air analytical results are included in Appendix F and copies of laboratory certificates are included in Appendix G.

Soil vapour results can be interpreted as follows:

- Detectable concentrations of *cis*-DCE were recorded for SV01 (210 µg/m³), SV02 (42 µg/m³) and SV04 (12 µg/m³). SV01 and SV02 also reported detectable concentrations of *trans*-DCE (29 and 21 µg/m³, respectively).
- Detectable concentrations of PCE were recorded for SV01 (23,000 µg/m³), SV02 (16,000 µg/m³) and SV03, (15 µg/m³).
- Detectable concentrations of TCE were reported within SV01 to SV04, ranging from 38 µg/m³ (SV03) to 1,700 µg/m³ (SV04).
- Concentrations of 1,1-DCE, vinyl chloride and ethene were below laboratory LORs.

Ambient air results were all below laboratory LORs.

7.4 Quality Assurance/Quality Control (QA/QC)

Data quality is typically discussed in terms of accuracy, precision and representativeness. In order to assess the quality of the data collected during the investigation program, specific QA/QC procedures were implemented during both the field sampling and laboratory analysis programs, in accordance with the requirements of the following documents:

- Australian Standard AS4482.1-2005 Guide to the Sampling and Investigation of Potentially Contaminated Soil Part 1: Non-Volatile and Semi-Volatile Compounds.
- Australian/New Zealand Standard AS/NZS 5667.1:1998 Water Quality Sampling, Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples.
- NEPM (1999) Schedule B(2) Guideline on Data Collection, Sample Design and Reporting.
- South Australian Environment Protection Authority (2007) *Regulatory Monitoring and Testing Groundwater Sampling*.

7.4.1 Field QA/QC

Field QA procedures generally include the collection of the following QC samples, aimed at assessing possible errors associated with cross contamination as well as inconsistencies in sampling and/or laboratory analytical techniques:

- intra-laboratory duplicate (blind replicate) samples: submitted to the same (primary laboratory) to assess variation in analyte concentrations between samples collected from the same sampling point and/or the repeatability (precision) of the analytical procedures
- inter-laboratory duplicate (split) samples: submitted to a second laboratory to check on the analytical proficiency (accuracy) of the results produced by the primary laboratory

- equipment rinsate blank: used to assess whether decontamination procedures have been sufficient and/or whether cross-contamination may have occurred between samples; and
- trip blank: used to assess whether cross-contamination may have occurred between samples during *transport*.

Whereas analyte concentrations within both the rinsate and trip blanks should be below the laboratory LORs, the duplicate sample results are assessed via the calculation of a relative percentage difference (RPD), as follows:

$$RPD = \frac{(Concentration\ 1 - Concentration\ 2) \times 100}{(Concentration\ 1 + Concentration\ 2) / 2}$$

A maximum RPD within the range of 30% to 50% is generally considered acceptable, with higher RPD values often recorded for organic compounds and where low concentrations of an analyte are recorded.

Table 7.3 indicates conformance to field QA/QC procedures.

Table 7.3 Field QA/QC procedures

QA/QC Requirement	Completed	Comments
Field instruments calibrated	Yes	Refer to Tables 5.1 and 5.3 as well as Appendix C.
Appropriate and well documented sample collection, handling, logging, <i>transportation</i> and decontamination procedures	Yes	Refer to Tables 5.1 (soil), 5.2 to 5.3 (groundwater), 5.4 (soil vapour) and 5.5 (ambient air) for details
Chain of custody documentation completed	Yes	All samples were <i>transported</i> under strict Parsons Brinckerhoff or Leeder Consulting chain of custody procedures and signed chain of custody documents are included in Appendix G.
Required number (1:10) of blind field duplicates collected	Yes	Refer to Tables 4.3 (groundwater) and 4.4 (soil vapour) for details. Soil field duplicates were collected at a rate of 1:10, however were not selected for analysis by the EPA.
Acceptable groundwater QC sample RPD results	Mostly	Groundwater RPD results for the intra- and inter-laboratory duplicate sample pairs are included in the analytical results tables in Appendix F. RPD values above 50% were obtained for the following analytes: <ul style="list-style-type: none"> ▪ cadmium (125%) in intra-laboratory duplicate sample pair MW06 and QC01_180912 ▪ copper (116%), zinc (98%), TCE (43%) and PCE (74%) within inter-laboratory duplicate sample pair GW9 and QC02_190912. The reason for the high RPD values (particularly with respect to cadmium and the VOCs) has not been determined but, for the sake of conservatism, the highest concentrations have been adopted for interpretive purposes.

QA/QC Requirement	Completed	Comments
Acceptable soil vapour QC sample RPD results	Yes	Soil vapour RPD results for the intra -laboratory duplicate sample pairs are included in the analytical results tables in Appendix F. The RPD results were all below 50%.
Required numbers of trip and rinsate blank samples collected	Yes	Refer to Tables 4.3 (groundwater) and 4.4 (soil vapour) for details.
Acceptable trip and rinsate blank results	Yes	Trip and rinsate blank results are included in the analytical results tables in Appendix F. All results were below the laboratory LORs
Samples delivered to laboratories within sample holding times and with correct preservative(s)	Yes	Samples were delivered to the laboratories within the sample holding times and in laboratory-supplied containers prepared with the appropriate preservative (where required).

7.4.2 Laboratory QA/QC

Laboratory QA procedures generally include the performance of a number of internal checks of data precision and accuracy that are aimed at assessing possible errors associated with sample preparation and analytical techniques. Specific types of QC samples analysed by laboratories, and the relevant acceptance criteria are as follows:

- internal laboratory replicate samples: maximum RPD values of 20% to 50%
- spike (matrix¹ and surrogate²) recoveries: recoveries of between 75% and 125%; and
- laboratory control blanks: results below the laboratory LORs.

Table 7.4 indicates conformance to laboratory QA/QC procedures.

Table 7.4 Laboratory QA/QC procedures

QA/QC Requirement	Completed	Comments
Samples extracted and analysed within relevant holding times	Yes	Refer to laboratory reports in Appendix G.
All analyses NATA accredited	Mostly	ALS and MGT LabMark are NATA accredited for all the analyses performed. SGS Leeder Consulting are not NATA accredited for Method MA-1105; MA-5 Additional which includes general gases analysis and additional VOCs from carbon tube analysis. Coffey Information is not NATA accredited for the geotechnical parameter analyses undertaken.

¹ A matrix spike is prepared by splitting a field sample and spiking each portion with a known quantity of a target compound to ascertain the effects of the specific sample matrix on the recovery of the analyte.

² A surrogate spike comprises a sample spiked with a pure substance that has similar chemical properties to the target analyte, but is unlikely to be found in the environment, such that the spike compound is expected to behave, during analysis, in the same way as the target compound.

QA/QC Requirement	Completed	Comments
Appropriate analytical methodologies used, in accordance with Schedule B(3) of the NEPM	Yes	Refer to ALS Interpretive Quality Control reports for methods used and relevance to Schedule B(3) of the NEPM and MGT 352908-W laboratory report in Appendix G.
Acceptable laboratory LORs adopted	Mostly	<p>Refer to laboratory reports in Appendix G.</p> <p>Soil: exceptions existed for 1,1-dichloroethene and vinyl chloride.</p> <p>Groundwater: exceptions existed for PCBs and the following analytes in samples GW9, MW02, MW04, MW05 and MW07: naphthalene, 1,2,4-trichlorobenzene and hexachlorobutadiene. No explanation was provided by the laboratories for the raised LORs within these samples.</p>
Acceptable laboratory QC results	Mostly	<p>The results of internal laboratory quality control procedures are provided within the laboratory analysis reports (Appendix G).</p> <p>Laboratory replicate RPD values were within the range of 0.0 to 66.7%.</p> <p>Laboratory recoveries were within the range of 50.2 to 124%. Matrix spike recovery was not determined for TCE within QC Lot 2513674.</p> <p>Laboratory control blank results were all below the LORs.</p>

In summary, it was considered that the QA/QC procedures and results were generally adequate and that the analytical results obtained were of acceptable quality for the purposes of this report.

8. Conceptual site model

In order to enable an assessment to be made of the potential sources of impact, chemicals of concern, *transport* mechanisms and receptors, a Conceptual Site Model (CSM) has been developed from the information obtained to date.

A diagrammatic representation of the CSM, illustrating known contaminant sources, *transport* mechanisms/pathways and environmental receptors associated with the contamination of groundwater in the investigation area, is included as Figure 6 (Appendix A).

8.1 Local and regional setting

The investigation area is located within the local council area of Charles Sturt and incorporates the suburbs of Hendon, Seaton and Royal Park. Eleven of the monitoring wells are located within an area zoned *Residential*, while the location of GW9 is zoned *Industry*. Land uses in the vicinity of the Philips Crescent site include the following:

- commercial/industrial to the east of Tapleys Hill Road and north of West Lakes Boulevard
- residential to the south of West Lakes Boulevard; and
- Hendon Primary School, First Steps Childcare Centre and residential and commercial properties to the west of Tapleys Hill Road.

The region is underlain by the Quaternary (Pleistocene) Pooraka Formation which comprises pale red-brown sandy clay containing carbonate of the Loveday soil. The shallow unconfined water table is located within interbedded sands and clays and, based on the field investigations and proximity to Boating Lake (West Lakes), groundwater within the uppermost aquifer is inferred to flow towards the west.

8.2 Current and proposed site use and general condition

The investigation area comprises residential, commercial and industrial land uses and it is understood that the Philips Street site will continue to be used for commercial/industrial purposes.

The soil profile encountered during this investigation generally consisted of variable fill material (of 0.2 to 0.6 m thickness) underlain by alternating layers of fine grained, low to medium plasticity clayey sand/sandy clay. Layers of fine to coarse grained sand, of varying thickness, were encountered at depths of between 1.5 and 3.5 mBGL and medium to high plasticity silty clay from approximately 3.5 mBGL. The depth to the uppermost aquifer ranged from 3.064 to 3.827 mBTOC.

8.3 Sources of impact and chemicals of concern

Due to former industrial activities having been undertaken within the general area, and presumably including the site at 3–5 Philips Crescent, elevated concentrations of chemical substances are present within shallow groundwater.

Possible contaminant sources identified in previous investigations at the Philips Crescent site include chemicals used in the manufacture of copper-based printed circuit boards, several underground and above ground tanks (some containing chemicals/chemical waste), drums, a pit and sumps. Identified chemicals of concern within both soil and groundwater at the Philips Crescent site include metals (copper, tin, lead, nickel), boron, fluoride and VOCs. The results of the current investigation in the surrounding area did not identify VOC contaminants in soil.

Groundwater beneath the (surrounding) investigation area is present at shallow depth (typically 3 to 4 mBGL) within an unconfined aquifer of interbedded sands and clays. A number of metals (cadmium, cobalt, copper, nickel and zinc) and VOCs (PCE, TCE, 1,1-DCE and vinyl chloride) are present in groundwater at concentrations that exceed beneficial use criteria and detectable concentrations of various additional VOCs are also present, including the TCE breakdown products *cis*- and *trans*-DCE (for which no screening criteria are available). These contaminants are considered likely to be present in groundwater as a result of historical industrial activities at the Philips Crescent site (located up-hydraulic gradient) and/or surrounding properties.

It is understood that residents within the investigation area have been advised by the EPA not to use groundwater until further notice.

8.4 Fate and *transport*

8.4.1 Possible *transport* mechanisms

The anticipated primary *transport* mechanisms for the migration of the identified contaminants of concern in groundwater are as follows:

- lateral migration within the shallow aquifer, potentially impacting off-site down-hydraulic gradient receptors (e.g. groundwater bores and local water bodies)
- vertical migration (i.e. of the VOCs, many of which are denser than water) from the shallow aquifer to deeper aquifer(s); and
- diffusion of vapours generated from the VOCs through the soil profile into surface indoor and/or outdoor air as well as into service pits/trenches.

8.4.2 Exposure pathways and potential receptors

Anticipated human exposure pathways for the chemicals of concern identified within groundwater in the investigation area include the following:

- direct contact with contaminated water – this could occur through the use of groundwater to fill swimming pools, during subsurface excavation/maintenance work that intersects the water table and/or during the extraction of groundwater for use as drinking water or for irrigation purposes
- ingestion of contaminated groundwater – this could occur through the deliberate or accidental consumption of bore water if it is used for potable, irrigation or recreational purposes
- inhalation of vapours generated from the VOCs contaminants – this could occur via the breathing in of impacted surface indoor or outdoor air, via contact with accumulated vapours in utility pits/trenches or during excavation works.

Should impacted groundwater discharge to a down-gradient surface water body (e.g. Boating Lake), primary and secondary contact recreation could also result in human exposure via direct contact and/or accidental ingestion.

Identified possible receptors within the investigation area include the following:

- residential, recreational and commercial land users
- construction/maintenance workers undertaking subsurface excavation works and/or accessing utility pits/trenches
- down-gradient groundwater users
- the marine ecosystem of Boating Lake, located approximately 1 km to the west, which drains into Barker Inlet; and
- recreational users of Boating Lake.

9. Screening vapour risk assessment

A screening vapour risk assessment (VRA) was undertaken by Dr Sim Ooi of Parsons Brinckerhoff for the Hendon investigation area, based on the concentrations of designated VOCs (PCE, TCE, 1,1-DCE, *cis*- and *trans*-DCE, vinyl chloride and ethene) measured during the recent groundwater and soil vapour monitoring events, as described in Sections 7.2 and 7.3.

The aim of the VRA was assess the potential vapour risks to local residents to the south and south-west of Philips Crescent as well as the occupants of the First Steps childcare centre and Hendon Primary School, located to the west and north-west of the Philips Crescent site (and the Tapleys Hill Road – West Lakes Boulevard intersection). The VRA is included in Appendix J.

The VRA adopted a conservative stepwise approach based on the following criteria/assumptions:

- Since ethene was not detected at concentrations above laboratory LORs, it was not considered as a chemical of concern.
- The use of chemical specific toxicity criteria (i.e. that assumed maximum exposure at tolerable concentrations of the designated VOCs in air) as screening levels for indoor air, rather than exposed concentrations.
- Estimation of vapour concentrations at the source using groundwater VOC concentrations and the Henry's Law constant, whereby the vapour concentration at the source is considered to be the highest concentration emitted in groundwater.
- Derivation of screening levels for vapour beneath the slab based on the screening levels for indoor air, the adoption of a sub-slab to indoor air attenuation factor of 0.005 (derived from Friebel and Nadebaum, 2011) and the conservative assumption that the source vapour concentration is present directly beneath the slab (i.e. which removed the influence of soil properties during volatilisation through the soil column).
- Derivation of additional screening levels for sub-surface soil vapour using vapour attenuation factors (derived from the USEPA Johnson and Ettinger (JE) vapour intrusion model for generic sand/sandy clay and silt/silty clay soil profiles, as used by Friebel and Nadebaum, 2011), the screening levels for indoor air and an average depth to groundwater of 3.6 mBGL.
- The results of the screening risk assessment for groundwater and soil vapour, using the above approach, triggered a site-specific assessment of vapour risk assessment (VRA), for which the geotechnical soil parameters described in Section 4.1 were required. The screening assessment identified PCE and TCE as the main chemicals of concern, and trigger an investigation to measured soil vapour concentrations of the VOC at various residential locations and the childcare centre
- The results of the VRA indicated that vapour risks associated with the measured soil vapour concentrations within the residential area and at the First Steps childcare centre as well as Hendon primary School, using the site-specific geotechnical data are below the assessment criteria and considered to be tolerable.

- A sensitivity analysis was conducted to account for the uncertainties associated with elevated saturation identified in the geotechnical analysis. Sensitivity analysis indicated soil vapour concentration of TCE has marginally exceeded the assessment criteria when soil with lower water content was adopted in the vapour intrusion model. Hence, further soil vapour investigations may be considered to validate these outcomes.

- It is noted that elevated groundwater concentrations of the VOC were reported in the-located within an area of commercial/industrial land use adjacent to the Philips Crescent site. This area is not considered representative of conditions associated with more sensitive land uses further to the south and west. An assessment of vapour risks associated with commercial/industrial land use was beyond the scope of this investigation.

10. Discussion and conclusions

The results obtained during the ESA investigations undertaken across the Hendon investigation area have been interpreted to indicate the following:

- The shallow (typically 3 to 4 mBGL) unconfined aquifer that underlies this area is located within interbedded sands and clays (with hydraulic conductivity values of up to 3.4 m/day), and inferred to flow in a westerly direction towards Boating Lake (West Lakes).
- Elevated concentrations of metals (cadmium, cobalt, copper, nickel, zinc), relative to one or more of the adopted groundwater beneficial use (i.e. marine ecosystem, potable, recreational and/or irrigation) criteria, were detected within the majority of the monitoring wells (with the exception of BH22 and MW07) with the highest concentrations of cadmium (up to 11,700 µg/L) in wells GW9, MW03, MW06 and MW08. As these wells are scattered across the investigation area, no distinct pattern of contaminant distribution has been discerned.
- Elevated concentrations of VOCs (PCE, TCE, 1,1-DCE and vinyl chloride) are present in groundwater at concentrations that exceed one or more of the adopted beneficial use (i.e. potable and/or recreational) criteria and detectable concentrations of various additional VOCs are also present, including the TCE breakdown products *cis*- and *trans*-DCE (for which no screening criteria are available). Of the 12 wells sampled, the highest groundwater VOC concentrations were detected in GW9, located within the industrial portion of the investigation area and immediately south of the Philips Crescent site. Wells MW02 and MW07, located further to the south and west, also contained elevated VOC levels but no distinct pattern of contaminant distribution is evident.
- Although the groundwater contaminants are considered likely to have derived, at least partly, from historical industrial activities undertaken at the Philips Crescent site (i.e. based on the results of previous site investigations), this has not been confirmed as the source and historical industrial activities undertaken on surrounding properties may also have contributed.
- Soil vapour bores installed within residential/sensitive land use areas to the south and west of the Philips Crescent site contained detectable levels of VOCs (PCE, TCE, *cis*-DCE and *trans*-DCE) at depths of approximately 1 to 2 m. The highest VOC concentrations were measured in SV01, located adjacent to MW02 within the residential area to the south of the Philips Crescent site. The analysis of ambient air adjacent to each of the soil vapour bore locations did not result in the detection of any VOCs.
- None of the soil samples selected from the 10 soil bores/monitoring wells for analysis contained detectable concentrations of VOCs and no odours or visual impacts (i.e. staining or obvious signs of contamination such as unhealthy vegetation) were noted in the sampled soils.

Based on the available data and the results of a site-specific VRA, it has been concluded that:

- Given the presence of elevated metals and VOC concentrations, groundwater within the shallow aquifer beneath the nominated investigation area is not suitable for a range of beneficial uses, including marine ecosystem protection, potable, recreational and

irrigation uses. The extent and source(s) of the groundwater impacts have not yet been determined and the status of the underlying aquifer(s) has not been investigated.

- The results of the VRA indicated that vapour risks associated with the measured soil vapour concentrations within the residential area and at the First Steps childcare centre as well as Hendon primary School, using the site-specific geotechnical data are below the assessment criteria and considered to be tolerable.
- A sensitivity analysis was conducted to account for the uncertainties associated with elevated saturation identified in the geotechnical analysis. The sensitivity analysis indicated soil vapour concentration of TCE has marginally exceeded the assessment criteria when soil with lower water content was adopted in the vapour intrusion model. Hence, further soil vapour investigations may be considered to validate these outcomes.
- Although TCE in well GW9 was interpreted as unacceptable for a residential area, this well is located in an area of commercial/industrial land use, adjacent to the Philips Crescent site, and is therefore not considered representative of conditions associated with more sensitive land uses further to the south and west. An assessment of vapour risks associated with commercial/industrial land use was beyond the scope of this investigation.

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12. Statement of limitations

Scope of services

This environmental site assessment report (“the report”) has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Parsons Brinckerhoff (“scope of services”). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

Reliance on data

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

Environmental conclusions

In accordance with the scope of services, Parsons Brinckerhoff has relied upon the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants or emissions.

Also, it should be recognised that site conditions, including the extent and concentration of contaminants, can change with time.

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

Report for benefit of client

The report has been prepared for the benefit of the Client and no other party. Parsons Brinckerhoff assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising

from any negligent act or omission of Parsons Brinckerhoff or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Other limitations

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

The scope of services did not include any assessment of the title to or ownership of the properties, buildings and structures referred to in the report nor the application or interpretation of laws in the jurisdiction in which those properties, buildings and structures are located.