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Executive summary

Parsons Brinckerhoff was commissioned by the Environment Protection Authority (EPA) in May 2013 to undertake an additional 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 the additional ESA were to:

- provide additional groundwater and soil vapour data to allow assessment of potential temporal variations and confirm the results of the previous vapour risk assessment
- provide additional soil vapour data in the vicinity of the First Steps childcare centre to confirm that vapour intrusion risks in this area are acceptable
- undertake additional assessment of the lateral extent of groundwater contamination within the surrounding area to assist EPA in the determination of an appropriate groundwater abstraction exclusion zone
- undertake assessment of soil vapour at additional locations to the north, south and east of the previously assessed area to allow assessment of potential vapour risks to residents in these areas
- assess selected service pits within the vicinity of sensitive receptors to assess whether service trenches may be providing preferential migration pathways for VOC vapours; and
- obtain additional information regarding the potential for natural attenuation of chlorinated contaminants.

Scope of work

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

- installation of ten groundwater monitoring wells to depths of between 5.5 and 6.0 mBGL
- installation of two double cased groundwater wells to depths of 9.4 to 11.5 mBGL to further characterise the vertical spread of TCE contamination
- gauging and analysis of all groundwater samples (including 14 existing wells) for ultra-trace VOCs, metals (Cd, Co, Cu, Ni and Zn) and natural attenuation parameters (nitrate, ferrous iron, sulphate, sulphide, methane, chloride, TOC, alkalinity)
- drilling of ten soil vapour bores to depths of between 2.0 and 2.2 mBGL, followed by soil vapour sampling (including five existing soil vapour bores) for selected VOCs
- installation of three Radiello passive samplers within service pits around the First Steps child care centre and three passive samplers along the western side of West Lakes Boulevard (i.e. adjacent to the residential area), followed by analysis for 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 additional ESA investigations undertaken across the Hendon investigation area have been interpreted to indicate the following:

- The shallow (typically 3.5 to 5 mBGL) unconfined aquifer that underlies this area is located within interbedded sands and clays, and inferred to flow in a westerly direction towards Boating Lake (West

Lakes). In comparison to the previous ESA conducted in 2012, the SWL across the investigation area has decreased approximately 0.3-0.5 m.

- A confining bed, intersected during installation of deeper wells MW21 and MW22, consisted of red-brown or grey silty clay of at least 2 m thickness. The permeable deeper layers consisted of fine to medium grained, grey sand and fine to medium grained, brown, grey-brown or mottled orange-brown and grey clayey sand/sandy clay.
- Elevated concentrations of chloride and sulphate, relevant to adopted potable water and/or recreational criteria, were present within the majority of the wells sampled. Nitrate (as N) was present within MW10, MW14, MW17, MW18 and MW22 at concentrations exceeding the adopted potable and recreational guidelines.
- Elevated concentrations of metals (cadmium, cobalt, copper, nickel, zinc), relative to one or more of the adopted groundwater beneficial uses (i.e. marine ecosystem, potable, recreational and/or irrigation) criteria, were detected within 16 of the 24 shallow monitoring wells sampled, with the highest concentrations reported in GW1 (all concentrations of metals exceeded adopted assessment criteria). Deeper wells MW21 and MW22 did not contain concentrations exceeding adopted assessment criteria.
- Elevated concentrations of VOCs (PCE, TCE, 1,1-DCE, chloroform, 1,2-dichloroethane 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). As with the previous groundwater investigation, GW9, located within the industrial portion of the investigation area and immediately south of the Phillips Crescent site, recorded the highest groundwater TCE concentration. Only wells MW09, MW11, MW16 and MW22 did not record any detectable concentrations of VOCs.
- Pre-existing wells GW1 and GW2 (located within the Phillips Crescent site boundary) reported vinyl chloride concentrations of 28.4 and 145 µg/L respectively, which may be indicative of a separate source of vinyl chloride not a breakdown product of TCE.
- A review of the *SA EPA Public Register Directory, site contamination index* has found two sites listed within the vicinity of the investigation area which have the potential to impact upon the monitoring wells sampled. The potentially contaminating activities are listed as motor vehicle repair or maintenance (service station) for the site located at 136-138 Tapleys Hill Road, Royal Park and agricultural activities for the site located at 150-152 Tapleys Hill Road, Royal Park.
- All soil vapour results were below adopted assessment criteria, however all 15 soil vapours bores reported detectable concentrations of at least one of the selected VOCs. The highest TCE concentration was reported within SV04 (located on the footpath outside the First Steps Childcare Centre), while SV01 and SV02 (located on the western side of West Lakes Boulevard, south of the Phillips Crescent site) reported the highest PCE concentration.
- Detectable concentrations of TCE were reported from the three passive samplers placed within service pits along the western side of West lakes Boulevard. This may indicate the movement of vapour through service tranches from the industrial site.

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

- Due to the presence of elevated concentrations of chloride, sulphate, nitrate, metals (cadmium, cobalt, copper, nickel, zinc) and VOCs within shallow groundwater beneath the investigation area, it is not suitable for a range of beneficial uses, including marine ecosystem protection, potable, recreational and irrigation uses.
- The wider groundwater monitoring well network has identified groundwater contamination north of the Phillips Crescent site, as well as detectable concentrations up-hydraulic gradient and it is likely that there is more than one source of the identified groundwater contaminants from historical industrial activities undertaken on surrounding properties.

- Groundwater VOC contamination has been delineated to the east and south-west of the investigation area.
- A vapour risk assessment was conducted to determine if the designated chlorinated hydrocarbons identified in the groundwater pose vapour risks to the residential receptors, including those using the childcare centre and the schools in the nominated area in Hendon. Based on the available data, including the use of site-specific geotechnical data and vapour intrusion modelling, it is concluded that the vapour intrusion risks are considered to be acceptable.
- Whilst actual soil moisture results were used in the calculation of potential risk, it was noted in the sensitivity analysis that lower soil moistures have the potential to result in vapour concentration exceeding the calculated indoor air threshold concentration. Therefore, further soil vapour monitoring should be considered in the period (e.g. November to March) with low rainfall to evaluate the vapour risks in the drier season.

1. Introduction

1.1 Background information

Parsons Brinckerhoff was commissioned by the Environment Protection Authority (EPA) in May 2013 to undertake an additional 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).

Previous investigations in 2012 in the area surrounding the Phillips Crescent site have identified elevated concentrations of metals (cadmium, cobalt, copper, nickel, zinc) and volatile organic compounds (VOCs) (PCE, TCE, 1,1-DCE and vinyl chloride) in groundwater as a result of former industrial activities undertaken in the area. The EPA has notified residents in the area not to use groundwater until further notice.

The additional ESA was undertaken to assist the EPA in the management of identified groundwater contamination in the area surrounding the Phillips Crescent site, Hendon.

This work was undertaken in accordance with our proposal (13-0119-01-201304685), dated 10 May 2013, as approved by EPA on 16 May 2013.

1.2 Objectives

The main objectives of this additional ESA were to:

- provide additional groundwater and soil vapour data to allow assessment of potential temporal variations and confirm the results of the previous vapour risk assessment
- provide additional soil vapour data in the vicinity of the First Steps childcare centre to confirm that vapour intrusion risks in this area are tolerable
- undertake additional assessment of the lateral extent of groundwater contamination within the surrounding area to assist EPA in the determination of an appropriate groundwater abstraction exclusion zone
- undertake assessment of soil vapour at additional locations to the north, south and east of the previously assessed area to allow assessment of potential vapour risks to residents in these areas
- assess selected service pits within the vicinity of sensitive receptors to assess whether service trenches may be providing preferential migration pathways for VOC vapours; and
- obtain additional information regarding the potential for natural attenuation of chlorinated contaminants.

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	
Fractured bedrock aquifer	Quartzite and siltstone	Adelaidean System	Precambrian

A summary of the Department of Environment, Water and Natural Resources (DEWNR, 2013) bore database for the area (Appendix B) indicates that there are 117 registered bores within a 1 km radius of the Tapleys Hill Road – West Lakes Boulevard intersection, 114 of which are groundwater bores. Of the groundwater bores, ten were listed as backfilled, six were listed as operational, two as unknown and one as abandoned. The current status of the remaining 95 bores was not listed. In terms of their primary purpose, 33 bores were listed as being for observation purposes, 33 bores for investigation purposes, 15 bores for domestic purposes, five bores for monitoring purposes, two bores for irrigation purposes and one for the dual purpose of irrigation and observation. The purpose/s of the remaining 25 bores were not listed.

Based on information contained in the database, the wells were drilled to depths of between 4.5 and 200.0 m between 1934 and 2012. Standing water levels (SWLs), recorded for 70 of the bores, ranged from approximately 0.91 to 20.3 m below ground level (BGL). Groundwater salinity, recorded for 44 bores, ranged from 419 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 419 and 9,873 mg/L TDS.

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, observation wells (drilled to depths of up to 10 m) installed between Cedar Avenue and Tapleys Hill Road (north of Hendon Primary School) and investigation wells (drilled to depths of up to 7.5 m) installed south of Myrtle Street between Cedar Avenue and Tapleys Hill Road.

3. Previous investigations

Previous investigations undertaken at the Philips Crescent site and surrounding area 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) *Delon 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.

3.4 Environmental Site Assessment (Parsons Brinckerhoff, 2012)

The results of an ESA undertaken in the area surrounding the Phillips Crescent site were detailed in the following report:

- Parsons Brinckerhoff (2012) *Environmental Site Assessment Report, Hendon, SA*, report number 12-01-2171471A, dated 22 March 2013.

The investigation area included properties located in the general vicinity of the Philips Crescent site and the main aims of the investigation 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.

The scope of work undertaken in September 2012 included 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.

The results of the ESA undertaken in the Hendon investigation area indicated 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).
- Due to elevated concentrations of metals and VOCs within the shallow aquifer beneath the nominated investigation area, the groundwater 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 the soil vapour concentration of TCE 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.

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:

- National Environment Protection (Assessment of Site Contamination) Measure 1999
- SA EPA Guidelines for the Assessment and Remediation of Groundwater Contamination 2009
- SA EPA Guideline – Regulatory Monitoring and Testing Groundwater Sampling 2007
- ASTM Guide D5314-92 (2001) Standard Guide for Soil Gas Monitoring in the Vadose Zone
- Relevant Australian Standards.

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

4.1 Groundwater investigations

Groundwater investigations, undertaken between 29 May and 26 June 2013, involved groundwater well installation in areas agreed upon through discussions with the EPA.

The groundwater investigation program involved the following:

- installation of ten groundwater monitoring wells (MW11 to MW20) to depths of between 5.5 and 6.0 mBGL
- installation of two double cased groundwater wells (MW21 and MW22) to depths of 9.4 to 11.5 mBGL to further characterise the vertical spread of TCE contamination
- 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
- development of groundwater wells upon completion of installation and at least seven days prior to sampling
- professional surveying of all wells to Australian Height Datum (AHD)
- well gauging, purging and collection of field readings on 10 to 13 June and 10 July 2013, immediately prior to sampling; and
- analysis of all groundwater samples for ultra-trace VOCs, metals (Cd, Co, Cu, Ni and Zn) and natural attenuation parameters (nitrate, ferrous iron, sulphate, sulphide, methane, chloride, TOC, alkalinity)

Soil samples were not selected by the EPA for analysis.

In addition to the twelve newly installed monitoring wells, existing monitoring wells BH22 and GW9 were also sampled as part of this groundwater investigation. Two wells, labelled as GW1 and GW2 (located within the Phillips Crescent site) were cleared of obstruction (i.e. accumulation of silt) with a steel bailer (at least seven days prior to the groundwater monitoring event), surveyed and also sampled as part of this groundwater investigation.

4.2 Soil vapour investigations

Soil vapour investigations, undertaken between 27 May and 13 June 2013, involved the following:

- drilling of ten soil vapour bores (SV06 to SV15), with SV08 to SV13 approximately 1 m from groundwater monitoring wells, to depths of between 2.0 and 2.2 mBGL

- collection of soil samples from each soil bore at nominal depths of 0.35-0.5 m, 0.85-1.0 m and 1.85-2.0 m
- collection of undisturbed soil cores (retained in 63 mm plastic push tube sleeve) from selected locations (SV08, SV09, SV14 and SV15)
- field screening of the completed soil vapour bore using a hand-held PID unit
- professional surveying of all soil vapour bores to AHD
- to assist in classification of waste soil for disposal, analysis of two soil samples for the SA EPA waste screen, including volatile halogenated compounds
- to assess soil moisture content and the potential for soil contaminants to impact on recorded soil vapour results, analysis of eight soil samples for moisture content
- analysis of two soil samples for geotechnical parameters (bulk density, moisture content, dry density, void ratio, porosity (air & water) and specific gravity); and
- soil vapour sampling at each location (conducted by SGS Leeder Consulting), at least 15 days after bore installation, for the analysis of trichloroethene, tetrachloroethene, 1,1-dichloroethene, 1,2-dichloroethene (*cis*- and *trans*-), vinyl chloride and general gases, as requested by the EPA.

4.3 Preferential pathways investigation

To assess if vapour is migrating through services trenches in the vicinity of sensitive receptors, the passive vapour assessment, undertaken concurrently with the soil vapour assessment comprised the following:

- a review of underground service plans within these areas using Dial Before You Dig to nominate appropriate service pits to be monitored
- installation of three Radiello passive samplers (conducted by SGS Leeder Consulting) around the First Steps child care centre and three passive samplers along the western side of West Lakes Boulevard (i.e. adjacent to the residential area) on 13 June 2013
- collection of all passive samplers on 14 June 2013; and
- analysis of all samples for VOCs.

4.4 Quality control program

4.4.1 Groundwater

The QC sampling undertaken as part of the groundwater investigation program is detailed in Table 4.1.

Table 4.1 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
Cadmium, cobalt, copper, nickel & zinc	26	1	2	11%	4	-
Ultra-trace VOCs	26	1	2	11%	-	4
Natural attenuation	25	1	2	12%	-	-

4.4.2 Soil vapour and passive vapour

The QC sampling undertaken as part of the soil vapour and passive vapour investigation program is detailed in Table 4.2.

Table 4.2 Summary of soil vapour & passive vapour 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	15	3	-	20%	2
Tetrachloroethene	15	3	-	20%	2
1,1-dichloroethene	15	3	-	20%	2
1,2-dichloroethene (cis- and trans-)	15	3	-	20%	2
Vinyl chloride	15	3	-	20%	2
General gases	15	3	-	20%	-
Passive vapour					
Trichloroethene	6	1	-	17%	1
Tetrachloroethene	6	1	-	17%	1
1,1-dichloroethene	6	1	-	17%	1
1,2-dichloroethene (cis- and trans-)	6	1	-	17%	1
Vinyl chloride	6	1	-	17%	1

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 (SV15) 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 prior to use. 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	Clean drilling and sampling equipment was used for each sampling location and was washed down off-site at the end of each day 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	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. 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 0.5 m. Grout was used to complete the well from the bentonite plug to the surface.
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	Waste soil was collected for off-site disposal by a licensed contractor. Water removed during well development was collected for off-site disposal by a licensed contractor.

Table 5.3 Groundwater assessment methodology

Activity	Details
Timing of Sampling	Initial gauging and sampling of groundwater wells was undertaken more than seven days after the completion of well installation and development.
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	With the exception of MW07, MW09, MW10 and MW20 (sampled via bailer due to minimal groundwater present in the well), 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: <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 quarter to one litre of groundwater purged, using a 90FLMV or Aquameter 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. Instrument calibration data are included in Appendix C.

Activity	Details
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 0.5 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 SGS Leeder Consulting and guaranteed to be volatile free.

This methodology decreased the zone of impact to the depth of the backfilled sand (0.5 m) to allow for more targeted investigations of sandy lenses within the sand/clay soil matrix.

5.4 Soil vapour and passive vapour sampling

SGS Leeder Consulting were subcontracted to undertake the sampling and analysis of the 10 newly installed wells and five existing wells and passive vapour sampling.

Field methodologies adopted during the soil vapour and passive vapour 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 fifteen locations (SV01 to SV15) 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 (SGS 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 SGS Leeder Consulting laboratory.

Table 5.5 Passive vapour assessment methodology (passive sampling)

Activity	Details
Sampling location	Three Radiello passive samplers were placed around the First Steps child care centre (two within electrical service pits and one within a drain) and three passive samplers were placed along the western side of West Lakes Boulevard (two within electrical service pits and one within a side entry pit)
Sampling Method	The Radiello sampling system is a passive sampler which works on gaseous molecules passing through the diffusive body followed by absorption onto the internal cartridge. Passive sampling was undertaken by a professional company (SGS Leeder Consulting) by suspending the Radiello samplers inside service pits and collected 24 hours after installation.
Sample Preservation	All samples were stored in an insulated chest immediately after sampling. Samples were kept chilled prior to and during delivery to the SGS 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 Eurofins MGT. Both of these laboratories were accredited by the National Association of Testing Authorities (NATA) for the analyses performed.

Soil vapour and passive vapour samples were submitted to the SGS Leeder Consulting Laboratory in Victoria which was NATA accredited for all analyses performed.

Coffey was responsible for undertaking the geotechnical parameter analysis of soil samples from the soil vapour bores. Coffey is NATA accredited for moisture and soil particle density however there is no NATA accreditation for bulk density.

6. 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 Off-site disposal of soil

In order to classify the soil for off-site disposal, the total soil data (from two soil vapour sampling locations) was compared to the SA EPA (2010) *Current Criteria for the Classification of Waste – including Industrial and Commercial waste (Listed) and Waste Soil* waste fill (WF), intermediate waste (IW) and low level contaminated waste (LLCW) disposal criteria.

6.2 Groundwater

6.2.1 Beneficial use assessment

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) was undertaken for the site in 2012 and presented in the previous ESA report (2012). It assessed 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. While the current DEWNR bore search area was expanded, no new beneficial uses were identified, therefore the 2012 BUA will be utilised for the purposes of this report.

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 (2013) bore database for the area has indicated that there are 114 registered groundwater bores within a 1 km radius of the Tapleys Hill Road – West Lakes Boulevard intersection. In terms of their primary purpose, 33 bores were listed as being for observation purposes, 33 bores for investigation purposes, 15 bores for domestic purposes, five bores for monitoring purposes, two bores for irrigation purposes and one for the dual purpose of irrigation and observation. The purpose/s of the remaining 25 bores were not listed. Groundwater salinity recorded for 24 shallow wells (drilled to depths of up to 12 m) ranged between 419 and 9,873 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 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 15 bores were used for domestic purposes. Therefore, although the presence of a reticulated mains water supply, and the moderate to high salinity of the groundwater within the investigation area (i.e. up to 36,647 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 two bores for irrigation purposes plus bores for domestic use (i.e. which could include irrigation), this is considered a likely beneficial use.

Due 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 1 km 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 1 km radius (419 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 (6.24 to 7.79) of shallow groundwater is relatively neutral and is unlikely to present a significant risk to built structures. The depth to groundwater (approximately 3.5 to 4.9 mBGL – refer to Section 7.2.1) in this area, suggests that only deep underground structures would be likely to come into direct contact with groundwater.

6.2.2 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. These criteria have also been used as the basis for determining whether site contamination is present, with respect

to groundwater, whereby the laboratory limit of reporting (LOR) has been adopted for an analyte in the absence of a specified Water Quality EPP criterion.

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.

Health screening levels

To assess the relative concentration and significance of the inferred soil vapour concentrations, it is usual to reference published screening criteria. These contaminant screening criteria represent threshold concentrations of specific contaminants in groundwater which, if exceeded in a particular sample, may pose a vapour risk and may therefore warrant further site specific investigation or risk analysis.

The health screening criteria adopted to assess the significance of the soil vapour concentrations have been sourced from the: NEPC National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1), Schedule B Investigation Levels For Soil and Groundwater Table 1A(4). No soil vapour health screening levels (HSLs) for vapour intrusion are available for the selected VOCs of concern (given soil vapour implants were installed below 1 m depth).

Based on the gauging data, groundwater was intersected between 3.5 and 4.9 mBGL. Monitoring well and soil vapour logs for the site describe soil layers as containing sand, therefore the relevant screening criteria is listed in the table below.

Table 6.4 Groundwater health screening levels for vapour intrusion (mg/L)

Sand	HSL-A&B	HSL-D
Chemical	2m to < 4m	2m to < 4m
Benzene	0.8	5
Toluene	NL	NL
Ethyl benzene	NL	NL
Xylenes	NL	NL
Naphthalene	NL	NL

Note: A&B = Low to high density residential, D = Commercial/industrial

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 0.15 and 0.8 mBGL, at all sampling locations, included:

- dark brown or brown, fine grained **silty sands**
- pale red-brown or brown, fine grained **sand**
- brown or yellow-brown, fine to medium grained **clayey sand**; and/or
- grey, medium to coarse grained **sandy gravel**

The underlying natural soil profile comprised alternating layers of:

- fine grained, low to medium plasticity, **clayey** and **silty sands/sandy clays**,
- fine to medium grained orange-brown, red-brown, yellow-brown, brown and grey **sands**
- red-brown, yellow-brown, orange-brown, brown, mottled red-brown and orange-brown, low to medium plasticity **clayey silt**; and
- brown, orange-brown, grey, red-brown, mottled grey and red-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 1.7 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.

Soil samples were not selected by the EPA for analysis, however to assist in classification of waste soil for disposal, two samples were analysed for the SA EPA Waste screen. All results were reported below the adopted assessment criteria and/or laboratory LOR.

7.2 Groundwater

On 11 June 2013 the depth to the uppermost aquifer within the 24 monitoring wells sampled ranged from 3.521 to 4.912 m below top of casing (BTOC). On 10 July 2013 the depth to groundwater within double-cased wells MW21 and MW22 was 4.058 and 4.672 mBTOC respectively. No odour or sheen was noted during groundwater purging or sampling and no NAPL 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 6.24 to 7.29, thereby indicating neutral groundwater conditions
- electrical conductivity (EC) readings ranged from 1.71 to 60.88 mS/cm (approximating 881 to 36,647 mg/L TDS), thereby indicating fresh to saline groundwater conditions
- dissolved oxygen (DO) levels ranged from 0.33 to 41.6 mg/L, thereby indicating low to high oxygen conditions; and
- redox potential readings ranged from -125 to 265 mV, thereby indicating both reducing and 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, with a depression around monitoring well MW07. The lithology encountered at this location (during the 2012 investigation) consisted of a greater proportion of firm to stiff silty clay and a much reduced groundwater recharge rate in comparison to other monitoring wells. Due to a very small water column depth (50 mm during the groundwater sampling event on 11 June 2013, then 100 mm on 29 June 2013), field parameters could not be obtained from MW07.

Groundwater field sampling sheets are included in Appendix H.

Table 7.1 Groundwater field parameters – September 2012 and June/July 2013

Groundwater Well	Date	SWL (mBTC)	RSWL (mAHD)	pH	EC (mS/cm)	Redox (mV)	DO (mg/L)	Temp (°C)
MW01	Sept 2012	3.597	0.403	7.48	13.38	115	0.50	18.9
	June 2013	3.986	0.014	6.80	11.83	96	1.87	-
MW02	Sept 2012	3.54	0.900	7.30	9.31	126	0.16	18.6
	June 2013	4.051	0.389	6.95	7.99	-125	0.66	18.9
MW03	Sept 2012	3.661	0.729	7.62	6.97	117	3.24	17.9
	June 2013	4.140	0.250	6.62	5.73	138	2.67	23.7
MW04	Sept 2012	3.569	0.601	7.01	22.12	117	0.35	19.5
	June 2013	4.015	0.155	6.76	15.16	-101	0.70	20.5
MW05	Sept 2012	3.554	0.686	7.20	15.03	108	1.05	18.1
	June 2013	4.003	0.237	6.85	11.13	93	1.05	19.9
MW06	Sept 2012	3.787	0.313	7.03	16.71	176	3.25	16.3
	June 2013	4.152	-0.052	7.20	10.76	184	1.82	19.7
MW07	Sept 2012	3.635	-0.005	7.07	8.47	212	2.96	18.5
	June 2013	3.95	-0.320	-	-	-	-	-
MW08	Sept 2012	3.631	0.359	7.62	5.50	137	4.18	16.5
	June 2013	4.156	-0.166	7.57	20.95	-17	-	18.8
MW09	Sept 2012	3.769	0.301	7.54	1.076	121	1.59	16.8
	June 2013	4.187	-0.117	7.64	1.831	112	2.29	20.1
MW10	Sept 2012	3.827	0.423	7.44	30.7	107	3.49	17.3
	June 2013	4.263	-0.013	7.24	60.88	143	8.84	22.2

Groundwater Well	Date	SWL (mBTOC)	RSL (mAHD)	pH	EC (mS/cm)	Redox (mV)	DO (mg/L)	Temp (°C)
MW11	June 2013	3.736	0.309	6.61	9.38	81	1.26	24.7
MW12		4.032	0.536	7.04	8.49	201	1.64	20.5
MW13		3.992	-0.110	6.92	13.22	133	0.66	19.7
MW14		4.122	0.112	7.35	5.14	187	1.44	21.6
MW15		4.003	0.807	7.13	13.84	86	41.04	22.0
MW16		3.924	0.576	7.26	15.47	121	41.15	21.6
MW17		3.990	0.450	7.18	14.86	146	41.60	21.1
MW18		4.091	-0.098	7.73	4.24	159	2.84	20.1
MW19		4.132	-0.221	7.79	1.71	130	2.80	21.0
MW20		4.912	-0.410	7.23	57.26	120	6.49	19.8
MW21	July 2013	4.058	0.298	7.48	9.11	121	0.33	19.7
MW22		4.672	-0.088	7.18	13.27	217	1.28	19.3
BH22	Sept 2012	3.37	0.470	7.61	10.71	100	2.53	19.7
	June 2013	4.041	-0.201	7.24	11.35	177	6.27	20.9
GW1	July 2013	3.662	0.180	6.24	6.28	265	1.29	19.1
GW2		3.521	0.289	7.09	10.00	104	0.67	20.4
GW9	Sept 2012	3.064	0.836	7.32	12.28	150	2.29	18.9
	June 2013	3.562	0.338	7.03	10.36	122	1.43	21.5

Note: RWSL = reduced standing water level

7.2.1 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:

- Twenty three out of twenty five groundwater wells recorded chloride concentrations exceeding adopted recreational and/or potable water criteria, ranging from 521 to 11,000 mg/L.
- Nineteen out of twenty five groundwater wells recorded sulphate concentrations exceeding the SA EPA potable water criteria (500 mg/L), ranging from 503 to 2,780 mg/L.
- MW10, MW14, MW17, MW18 and MW22 contained nitrate (as N) exceeding potable water and recreational criteria (10 mg/L), with concentrations ranging from 12 to 20.5 mg/L.
- Cadmium within pre-existing well GW1 exceeded the SA EPA Marine and Potable water criteria (2 µg/L) with a concentration of 4.5 µg/L. All remaining wells were below adopted criteria or the laboratory LOR.
- Eleven out of 24 wells contained cobalt exceeding the NEPM groundwater investigation level (GIL) of 1 µg/L, ranging from 2 to 5 µg/L. GW1 reported a concentration of 94 µg/L also exceeding the SA EPA irrigation criteria of 50 µg/L.

- BH22, MW01 and MW20 reported a copper concentration of 12 µg/L exceeding the marine protection criteria of 10 µg/L. GW1 reported a concentration of 8,380 µg/L also exceeding the irrigation and potable water criteria (200 and 2,000 µg/L respectively).
- Nine of the monitoring wells contained nickel concentrations (up to 115 µg/L) that exceeded the marine and potable water criteria. GW1 contained 2,540 µg/L also exceeding the recreational and irrigation criteria (200 µg/L).
- GW1 and MW20 contained zinc concentrations of 417 and 149 µg/L respectively, exceeding the SA EPA marine protection criteria of 50 µg/L.
- Detectable concentrations of benzene were reported within GW1, GW2, GW9, MW06, MW07, MW08, MW10, and MW14, however these were below adopted criteria.
- MW13 reported detectable concentrations of toluene, ethyl benzene and xylene.
- The naphthalene concentration within MW10 exceeded the US EPA Region 9 screening level of 0.14 µg/L. Naphthalene was also detected within MW12, MW15 and MW20, however concentrations were below the adopted assessment criteria.
- 1,1-dichloroethene within GW9 and MW14 exceeded the potable water criteria of 30 µg/L, with concentrations of 52 and 197 µg/L respectively. Eleven other wells reported detectable concentrations.
- BH22 contained 5.8 µg/L of 1,2-dichloroethane exceeding the potable water criteria of 3 µg/L.
- Chloroform within MW01 (3.03 µg/L) and MW14 (3.47 µg/L) exceeded the adopted NEPM GIL of 3 µg/L.
- The following wells contained concentrations of TCE exceeding the WHO drinking water criterion (20 µg/L) and ANZECC/ARMCANC recreational criterion (30 µg/L): BH22, GW1, GW2, GW9, MW04, MW05, MW07, MW08, MW12, MW13 and MW14.
- Tetrachloroethene (PCE) concentrations (up to 296 µg/L) within GW9, MW05, MW12, MW13, and MW14 exceeded the potable water criteria of 40 µg/L.
- GW9 and MW12 reported a vinyl chloride concentration (0.5 µg/L) exceeding the potable water criterion (0.3 µg/L). GW1 and GW2 contained 28.4 and 145 µg/L respectively, exceeding the recreational criteria of 3 µg/L.
- Only wells MW09, MW11, MW16 and MW22 did not record any detectable VOCs.
- 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.

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
25	1	2	Nitrate as N (mg/L)	<0.01	20.5	<u>SA EPA (2003) Potable Water: 10 mg/L and ANZECC/ARMCANZ (2000) Recreational Guidelines: 10 mg/L</u> MW10: 13.9 mg/L / QC02_130613: 19 mg/L MW14: 12 mg/L MW17: 12.8 mg/L MW18: 16.6 mg/L MW22: 20.5 mg/L
25	1	2	Ferrous iron	<50	820	No criteria available
25	1	2	Sulphate as SO ₄ (mg/L)	17	2,970	<u>SA EPA (2003) Potable Water: 500 mg/L</u> BH22: 845 mg/L GW1: 1,700 mg/L GW2: 786 mg/L GW9: 1,040 mg/L MW01: 652 mg/L MW02: 570 mg/L MW04: 1,330 mg/L / MW04B: 1,320 mg/L MW05: 812 mg/L MW06: 899 mg/L MW08: 749 mg/L MW10: 2,780 mg/L / QC02: 2,970 mg/L MW11: 718 mg/L MW12: 581 mg/L MW13: 503 mg/L MW16: 640 mg/L MW17: 538 mg/L MW20: 2,390 mg/L MW21: 563 mg/L / QC05: 600 mg/L MW22: 722 mg/L
25	1	2	Sulphide**	<100	<100	None
26	1	2	Methane	<10	55	No criteria available

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
25	1	2	Chloride (mg/L)	22	11,000	<p><u>NHMRC/NRMMC (2011) Australian Drinking Water Guidelines: 250 mg/L</u> GW1: 521 mg/L MW03: 1,170 mg/L MW14: 1,300 mg/L MW15: 2,470 mg/L MW18: 833 mg/L</p> <p><u>NHMRC/NRMMC (2011) Australian Drinking Water Guidelines: 250 mg/L and NHMRC (2008) Recreational: 2,500 mg/L</u> BH22: 3,840 mg/L GW2: 3,960 mg/L GW9: 3,860 mg/L MW01: 3,520 mg/L MW02: 2,770 mg/L MW04: 6,370 mg/L / MW04B: 6,410 mg/L MW05: 4,350 mg/L MW06: 4,100 mg/L MW08: 3,350 mg/L MW10: 10,300 mg/L / QC02: 11,000 mg/L MW11: 2,640 mg/L MW12: 3,160 mg/L MW13: 5,730 mg/L MW16: 2,680 mg/L MW17: 2,690 mg/L MW20: 9,460 mg/L MW21: 2,420 mg/L / QC05: 2,200 mg/L MW22: 3,910 mg/L</p>
26	1	2	Total organic carbon	2,000	24,000	No criteria available
25	1	2	Alkalinity (total as CaCO ₃) (mg/L)	211	1,200	No criteria available
26	1	2	Cadmium	<0.05	4.5	<p><u>SA EPA (2003) Marine Protection and SA EPA (2003) Potable Water: 2 µg/L</u> GW1: 4.5 µg/L</p>

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
26	1	2	Cobalt	<1	94	<p>NEPM (1999) GILs: 1 µg/L BH22: 2 µg/L GW9: 5 µg/L MW02: 3 µg/L MW04: 4 µg/L / MW04B: 3 µg/L MW05: 3 µg/L MW08: 4 µg/L MW10: 4 µg/L / QC02: 4 µg/L MW11: 4 µg/L MW12: 5 µg/L MW13: 2 µg/L MW14: 4 µg/L</p> <p>NEPM (1999) GILs: 1 µg/L and SA EPA (2003) Irrigation: 50 µg/L GW1: 94 µg/L</p>
26	1	2	Copper	<0.05	8,380	<p>SA EPA (2003) Marine Protection: 10 µg/L BH22: 12 µg/L MW01: 12 µg/L MW20: 12 µg/L</p> <p>SA EPA (2003) Marine Protection: 10 µg/L and SA EPA (2003) Potable Water: 2,000 µg/L GW1: 8,380 µg/L</p>
26	1	2	Nickel	<0.1	2,540	<p>SA EPA (2003) Marine Protection: 15 µg/L and SA EPA (2003) Potable Water: 20 µg/L GW2: 43 µg/L GW9: 44 µg/L MW01: 35 µg/L MW02: 88 µg/L MW04: 38 µg/L / MW04B: 41 µg/L MW05: 115 µg/L MW12: 74 µg/L MW13: 41 µg/L MW16: 37 µg/L</p> <p>SA EPA (2003) Marine Protection: 15 µg/L, SA EPA (2003) Potable Water: 20 µg/L and NHMRC (2008) Recreational: 200 µg/L GW1: 2,540 µg/L</p>

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
26	1	2	Zinc	<5	417	<u>SA EPA (2003) Marine Protection: 50 µg/L</u> GW1: 417 µg/L MW20: 149 µg/L
26	1	2	Benzene	<0.05	0.73	None
26	1	2	Toluene	<0.1	0.8	None
26	1	2	Ethylbenzene	<0.05	0.75	None
26	1	2	Xylenes	<0.15	4.24	None
26	1	2	Naphthalene	<0.05	1.55	<u>US EPA (2012) Screening Levels: 0.14 µg/L</u> MW10: 1.55 µg/L
26	1	2	Trichloroethene	<0.05	1,710	<u>WHO (2011) Drinking Water: 20 µg/L and ANZECC/ARMCANZ (2000) Recreational: 30 µg/L</u> BH22: 65.3 µg/L GW1: 37.5 µg/L GW2: 624 µg/L GW9: 1,710 µg/L MW04: 30.9 µg/L / MW04B: 32.5 µg/L MW05: 49.2 µg/L MW07: 164 µg/L MW08: 71.6 µg/L MW12: 31.4 µg/L MW13: 75.5 µg/L MW14: 551 µg/L
26	1	2	Tetrachloroethene	<0.05	296	<u>SA EPA (2003) Potable: 40 µg/L</u> GW9: 296 µg/L MW05: 133 µg/L MW12: 138 µg/L MW13: 42.1 µg/L MW14: 61.8 µg/L
26	1	2	1,1-dichloroethene	<0.1	197	<u>SA EPA (2003) Potable Water: 30 µg/L</u> GW9: 52 µg/L MW14: 197 µg/L
26	1	2	cis-1,2-dichloroethene	<0.1	1,010	No criteria available

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
26	1	2	<i>trans</i> -1,2-dichloroethene	<0.1	9.6	No criteria available
26	1	2	Vinyl chloride	<0.3	145	<u>SA EPA (2003) Potable Water: 0.3 µg/L</u> GW9: 0.5 µg/L MW12: 0.5 µg/L <u>SA EPA (2003) Potable Water: 0.3 µg/L and NHMRC (2008) Recreational: 3 µg/L</u> GW1: 28.4 µg/L GW2: 145 µg/L
26	1	2	VOCs (individual compounds)	<0.05	5.8	<u>SA EPA (2003) Potable Water: 3 µg/L</u> <i>1,2-dichloroethane</i> BH22: 5.8 µg/L <u>NEPM (1999) GILs: 3 µg/L</u> <i>chloroform</i> MW01: 3.03 µg/L MW14: 3.47 µg/L

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 passive vapour results

Tables of soil vapour and passive vapour analytical results are included in Appendix F and copies of laboratory certificates are included in Appendix G. A soil vapour contaminant distribution plan, of volatile organic compounds, is included as Figure 6 in Appendix A.

Soil vapour results can be interpreted as follows:

- All vapour results were reported below adopted assessment criteria
- Detectable concentrations of selected VOCs were present as follows:
 - ▶ 1,1-dichloroethene in SV10 and SV13
 - ▶ cis-1,2-dichloroethene in SV02, SV04, SV09, SV10 and SV13
 - ▶ Trichloroethene in all soil vapour bores except SV11 primary sample (detectable concentration recorded in the intra-laboratory duplicate sample)
 - ▶ Tetrachloroethene in SV01 to SV03, SV05 to SV10, intra-laboratory duplicate of SV11, and SV12 to SV14
 - ▶ trans-1,2-dichloroethene in SV09, SV10 and SV13

Passive vapour results can be interpreted as follows:

- Detectable concentrations of benzene and toluene were reported from the three samplers placed within service pits around the *First Steps Childcare Centre*. A detectable concentration of toluene was also reported from the sampler placed in a side entry pit on the western side of West Lakes Boulevard (location R5).
- Detectable concentrations of TCE were reported from the three samplers placed along the western side of West Lakes Boulevard.
- All remaining results were 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 Site Characterisation.
- 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.
- 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, transportation and decontamination procedures	Yes	Refer to Tables 5.1 (soil), 5.2 to 5.3 (groundwater), 5.4 (soil vapour) and 5.5 (passive vapour) for details
Chain of custody documentation completed	Yes	All samples were transported under strict Parsons Brinckerhoff or SGS 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 4.1 (groundwater) and 4.2 (soil vapour and passive vapour) for details. Soil field duplicates were collected at a rate of 1:10, however were not selected for analysis by the EPA.

QA/QC Requirement	Completed	Comments
Acceptable groundwater QC sample RPD results	Mostly	<p>Groundwater RPD results for the intra- and inter-laboratory duplicate sample pairs are included in the analytical results tables in Appendix F.</p> <p>RPD values above 50% were obtained for the following analytes:</p> <ul style="list-style-type: none"> ■ Ferrous iron (84%) within intra-laboratory duplicate sample pair MW04_120613 and MW04_120613B ■ zinc (92%) within inter-laboratory duplicate sample pair MW21 and QC05_100713. <p>This is not considered to significantly impact upon the outcomes of this report as no criteria is available for ferrous iron and the higher zinc concentration has been adopted (which does not exceed adopted criteria) for interpretive purposes.</p>
Acceptable soil vapour and passive vapour QC sample RPD results	Mostly	<p>Soil vapour and passive vapour RPD results for the intra-laboratory duplicate sample pairs are included in the analytical results tables in Appendix F.</p> <p>The RPD results were all below 50% with the exception of naphthalene within SV11 and its intra-laboratory duplicate SV11 Field dup. For the sake of conservatism, the highest concentration has been adopted for interpretive purposes.</p>
Required numbers of trip and rinsate blank samples collected	Yes	Refer to Tables 4.1 (groundwater) and 4.2 (soil vapour and passive vapour) for details.
Acceptable trip and rinsate blank results	Yes	<p>Trip and rinsate blank results are included in the analytical results tables in Appendix F.</p> <p>All results were below the laboratory LORs.</p>
Samples delivered to laboratories within sample holding times and with correct preservative(s)	Mostly	<p>All groundwater samples were delivered to the laboratories within the sample holding times and in laboratory-supplied containers prepared with the appropriate preservative (where required).</p> <p>Soil samples which were analysed only to assist with disposal of soil were delivered to the laboratory outside the recommended holding time for some analytes.</p>

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.

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.

Table 7.4 Laboratory QA/QC procedures

QA/QC Requirement	Completed	Comments
Samples extracted and analysed within relevant holding times	Mostly	Refer to laboratory reports in Appendix G. Soil samples (analysed only to assist with disposal of soil) were analysed and/or extracted outside the recommended holding time for some analytes.
All analyses NATA accredited	Yes	ALS, Eurofins MGT and SGS Leeder are NATA accredited for all the analyses performed. Coffey is NATA accredited for moisture and soil particle density however there is no NATA accreditation for bulk density.
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 382592 and 385703-W laboratory report in Appendix G.
Acceptable laboratory LORs adopted	Mostly	Refer to laboratory reports in Appendix G. Soil: Yes. Groundwater: The LOR for sulphide was above the adopted assessment criteria.
Acceptable laboratory QC results	Mostly	The results of internal laboratory quality control procedures are provided within the laboratory analysis reports (Appendix G). Laboratory replicate RPD values were within the acceptable range with the exception of 1,3,5-trimethylbenzene within QC Lot 2961875. Laboratory recoveries were within the acceptable recovery limits with the exception of some matrix spike recoveries not determined for sulphate, chloride, barium, manganese, copper, zinc and methane. In addition laboratory control spike recoveries were outside the limit for benz(a)anthracene (QC Lot 2945246) and 1,4-dichlorobenzene (QC Lot 2961875). Laboratory control blank results were all below the LORs.

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 7 (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, Albert Park and Royal Park. Monitoring wells GW1, GW2, GW9 and MW15 to MW18 are located within an area zoned *Industry* while the remainder of the wells are zoned *Residential*. 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.

Based on the DEWNR (2013) data it is apparent that groundwater bores in the area are mainly utilised for investigation, observation, domestic, monitoring and irrigation purposes. Shallow wells (drilled to depths of up to 12 m) recorded standing water levels of 2.40 to 6.0 mBGL and salinity levels between 419 and 9,873 mg/L TDS.

8.2 Current and proposed site use and general condition

The current land uses within the investigation area include residential, commercial and industrial. It is understood that the Phillips Crescent site will continue to be used for commercial/industrial purposes.

The soil profile encountered during the additional site assessment indicated that fill materials were present at all sampling locations to depths of between 0.15 and 0.8 mBGL. The underlying natural soil profile consisted of fine grained, low to medium plasticity, clayey and silty sands/sandy clays; fine to medium grained orange-brown, red-brown, yellow-brown, brown and grey sands; red-brown, yellow-brown, orange-brown, brown, mottled red-brown and orange-brown, low to medium plasticity clayey silt; and brown, orange-brown, grey, red-brown, mottled grey and red-brown, medium to high plasticity, silty clays.

The depth to the uppermost aquifer ranged from 3.521 to 4.912 mBTOC.

8.3 Sources of impact and chemicals of concern

As a result of previous industrial activities having been undertaken within parts of the investigation area, elevated concentrations of chemical substances are present within shallow groundwater.

Previous investigations at the Philips Crescent site have identified 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 as possible contaminant sources. 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 Parsons Brinckerhoff 2012 investigation in the surrounding area did not identify VOC contaminants in soil.

Groundwater beneath the (surrounding) investigation area is present at shallow depth (typically 3.5 to 5 mBGL) within an unconfined aquifer of interbedded sands and clays. Based on investigations carried out in the area to date, nitrate, sulphate, chloride, metals (cadmium, cobalt, copper, nickel and zinc), naphthalene and VOCs (PCE, TCE, 1,1-DCE, chloroform, 1,2-dichloroethane and vinyl chloride) are present in groundwater at concentrations that exceed beneficial use criteria. 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.

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) or groundwater bore, primary and secondary contact recreation could also result in human exposure via direct contact and/or accidental ingestion.

Identified possible receptors within the vicinity of the site include the following:

- residential, recreational or 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. 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 and vinyl chloride) measured during the recent groundwater and soil vapour monitoring events, as described in Sections 7.2 and 7.3.

The objective of the VRA is to determine if the VOC concentrations identified in the groundwater and soil vapour within the investigation area pose an un-acceptable health 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 I and concluded the following.

- A vapour risk assessment was conducted to determine if the designated chlorinated hydrocarbons identified in the groundwater pose vapour risks to the residential receptors, including those using the childcare centre and the schools in the nominated area in Hendon.
- For the residential area and the childcare centre, the TCE and/or *cis*-1,2-DCE concentrations in indoor air predicted using the site-specific geotechnical data are below the adopted assessment criteria.
- Based on the available data, including the use of site-specific geotechnical data and vapour intrusion modelling, it is concluded that the vapour intrusion risks are considered to be acceptable.
- Whilst actual soil moisture results were used in the calculation of potential risk, it was noted in the sensitivity analysis that lower soil moistures have the potential to result in vapour concentration exceeding the calculated indoor air threshold concentration. Therefore, further soil vapour monitoring should be considered in the period (e.g. November to March) with low rainfall to evaluate the vapour risks in the drier season.

10. Discussion and conclusions

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

- The shallow (typically 3.5 to 5 mBGL) unconfined aquifer that underlies this area is located within interbedded sands and clays, and inferred to flow in a westerly direction towards Boating Lake (West Lakes). In comparison to the previous ESA conducted in 2012, the SWL across the investigation area has decreased approximately 0.3-0.5 m.
- A confining bed, intersected during installation of deeper wells MW21 and MW22, consisted of red-brown or grey silty clay of at least 2 m thickness. The permeable deeper layers consisted of fine to medium grained, grey sand and fine to medium grained, brown, grey-brown or mottled orange-brown and grey clayey sand/sandy clay.
- Elevated concentrations of chloride and sulphate, relevant to adopted potable water and/or recreational criteria, were present within the majority of the wells sampled. Nitrate (as N) was present within MW10, MW14, MW17, MW18 and MW22 at concentrations exceeding the adopted potable and recreational guidelines.
- Elevated concentrations of metals (cadmium, cobalt, copper, nickel, zinc), relative to one or more of the adopted groundwater beneficial uses (i.e. marine ecosystem, potable, recreational and/or irrigation) criteria, were detected within 16 of the 24 shallow monitoring wells sampled, with the highest concentrations reported in GW1 (all concentrations of metals exceeded adopted assessment criteria). Deeper wells MW21 and MW22 did not contain concentrations exceeding adopted assessment criteria.
- Elevated concentrations of VOCs (PCE, TCE, 1,1-DCE, chloroform, 1,2-dichloroethane 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). As with the previous groundwater investigation, GW9, located within the industrial portion of the investigation area and immediately south of the Phillips Crescent site, recorded the highest groundwater TCE concentration. Only wells MW09, MW11, MW16 and MW22 did not record any detectable concentrations of VOCs.
- Pre-existing wells GW1 and GW2 (located within the Phillips Crescent site boundary) reported vinyl chloride concentrations of 28.4 and 145 µg/L respectively, which may be indicative of a separate source of vinyl chloride not a breakdown product of TCE.
- A review of the SA EPA Public Register Directory, *site contamination index* has found two sites listed within the vicinity of the investigation area which have the potential to impact upon the monitoring wells sampled. The potentially contaminating activities are listed as motor vehicle repair or maintenance (service station) for the site located at 136-138 Tapleys Hill Road, Royal Park and agricultural activities for the site located at 150-152 Tapleys Hill Road, Royal Park.
- All soil vapour results were below adopted assessment criteria, however all 15 soil vapours bores reported detectable concentrations of at least one of the selected VOCs. The highest TCE concentration was reported within SV04 (located on the footpath outside the First Steps Childcare Centre), while SV01 and SV02 (located on the western side of West Lakes Boulevard, south of the Phillips Crescent site) reported the highest PCE concentration.
- Detectable concentrations of TCE were reported from the three passive samplers placed within service pits along the western side of West lakes Boulevard. This may indicate the movement of vapour through service trenches from the industrial site.

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

- Due to the presence of elevated concentrations of chloride, sulphate, nitrate, metals (cadmium, cobalt, copper, nickel, zinc) and VOCs within shallow groundwater beneath the investigation area, it is not suitable for a range of beneficial uses, including marine ecosystem protection, potable, recreational and irrigation uses.
- The wider groundwater monitoring well network has identified groundwater contamination north of the Phillips Crescent site, as well as detectable concentrations up-hydraulic gradient and it is likely that there is more than one source of the identified groundwater contaminants from historical industrial activities undertaken on surrounding properties.
- Groundwater VOC contamination has been delineated to the east and south-west of the investigation area.
- A vapour risk assessment was conducted to determine if the designated chlorinated hydrocarbons identified in the groundwater pose vapour risks to the residential receptors, including those using the childcare centre and the schools in the nominated area in Hendon. Based on the available data, including the use of site-specific geotechnical data and vapour intrusion modelling, it is concluded that the vapour intrusion risks are considered to be acceptable.
- Whilst actual soil moisture results were used in the calculation of potential risk, it was noted in the sensitivity analysis that lower soil moistures have the potential to result in vapour concentration exceeding the calculated indoor air threshold concentration. Therefore, further soil vapour monitoring should be considered in the period (e.g. November to March) with low rainfall to evaluate the vapour risks in the drier season.

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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.