Phytotoxic Impacts on Future Landscaping

Plants used in landscaping faced a risk to health given heavy metals concentrations in the surface fill materials. An imported growing medium was recommended for use in landscaped areas (between 1-2m thick) as well as the use of native plants with tolerance to heavy metals.

Aesthetics

There was a low risk of aesthetic issues provided the Site continues to be used as commercial/industrial land and subsurface materials were managed appropriately. Given these provisions, a long term management plan was recommended to be prepared to address these issues should they arise.

Remediation

Contamination at the Site presented an unacceptable health risk to short term construction/maintenance workers and long term site users and a program of remedial works was recommended to appropriately manage the contamination.

Recommendations

- Continue to restrict access to the Site;
- Implement a program of remedial works for future use of the Site as commercial/industrial land;
- Remediation should include a program of removal of upper 0.5m of material over the entire Site or install a capping mechanism. Consideration should be given to removal of the ongoing sources of groundwater contamination including the Tar Wells and sludges at the base of Gas Holders;
- A long term management plan should be prepared to not only address and manage contamination during any proposed remedial works but also to address ongoing issues including:
    - a prohibition on groundwater extraction and reuse from the Site;
    - a prohibition on the construction of basement areas of future development s that intersect groundwater;
    - any earthworks are to be conducted under an appropriate occupational health and safety plan;
    - controls on access to the Site;
    - management of any groundwater encountered during future construction/maintenance is to be undertaken on site;
    - landscaped areas should be formed on 1-2m deep layer of clean plant growing medium materials;
    - use of native plants should be preferred in landscaped areas, particularly ones with a tolerance to heavy metals; and
    - aesthetics issues should be appropriately managed during activities associated with sub surface materials.

5.2 Assessment of Previous Data

An assessment of previous data collecting programs was undertaken to assess the quiality and validity of the data. An evaluation of this data is provided in **Appendix B – QA/QC Assessment.**

In summary, it was noted that there are a few minor discrepancies contained within the QA/QC of the past investigations, such as reporting of certain aspects of sampling procedures and occasional field duplicate RPDs not meeting the adopted DQIs, however the data as a whole is considered to be reliable and useable.

6 Development of the Site Investigation Criteria

6.1 Contaminants of Concern in Soils

The following contaminants of concern are based on historic site operations and the contaminants detected in fill and soils during the previous site investigations listed in **Section 1.4**:

- Metals including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni) and zinc (Zn);
- Total Petroleum Hydrocarbons (TPHs);
- Benzene, Ethylbenzene, Toluene and Xylenes (BTEX);
- Polycyclic aromatic hydrocarbons (PAHs);
- Organochlorine Pesticides (OCPs);
- Organophosphorus Pesticides (OPPs);
- Phenolic Compounds (Phenols);
- Cyanides (totals);
- Polychlorinated Biphenyls (PCBs);
- Asbestos.

Although not indicated as contaminants of concern in NSW DEC and other guidance relating to former gasworks sites, recent literature and research has linked PCDD/Fs with oil shale material, which was used a raw material as part of the gas production at the Site, subsequently Polychlorinated Dioxins/Polychlorinated Furans (PCDD/F) were also included as contaminants of potential concern.

Based on the historical operations and previous soil data, the Site has been stratified into delineation areas (refer to **Section 1.3** and **Figure 3**). A summary of the environmental issues and potential sources of soil contamination are described in the table below.

Table 6.1 - Areas of Concern/Contamination Sources

Stratified Delineation Area	Description	Contaminants of Concern in Soil
Gasholders	Former gas storage units.	TPH PAH Phenolics
Retort	Raw gas generation. By products included coke and tar.	TPH/BTEX/PAH/Phenolics PCDD/F[3]
Gas Purifiers	Oxides used to purify gas.	TPH/BTEX/PAH/Metals/ Cyanides/Phenolics
Northeast	Formerly old rail spur from main Illawarra line and coal storage area.	TPH/BTEX/PAH/Metals
South Central	Continuations of former rail spur from main Illawarra line.	TPH/BTEX/PAH/Metals

[3] *Contaminants of potential concern.*

Stratified Delineation Area	Description	Contaminants of Concern in Soil
Southwest	Continuations of former rail spur from main Illawarra line. Deep filling likely from waste disposal.	TPH/BTEX/PAH/Metals
Retaining Wall	Filled area behind retaining wall.	TPH/BTEX/PAH
Western Lot	Unknown historical operations, minor filling.	TPH/BTEX/PAH/Metals/ Cyanides/Phenolics
General fill and surfaces	Coverage over all of Site surfaces/Pesticide application/Building demolition.	TPH/BTEX/PAH/Metals/Cyanides/ Phenolics/OCP/OPP/Asbestos/PCB

Additional information from the NSW Department of Environment and Conservation (DEC) *Information for the assessment of former gasworks sites*, 2005, was also considered.

6.2 Investigation Criteria

Investigation criteria have been adopted from the following guidance documents:

- NSW DEC, *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd Edition)*, 2006 (NSW DEC, 2006)
- NSW EPA, *Contaminated Sites: Guidelines for Assessing Service Station Sites*, 1994 (NSW EPA, 1994); and
- National Environment Protection Council (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) 1999 (NEPC 1999).

6.2.1 Soil Investigation Levels

Soil criteria for this site assessment were obtained from Health Investigation Levels (HILs) listed in the NSW DEC *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme*, (2nd Edition), 2006 (DEC, 2006).

These guidelines provide a range of HILs for soils considered to be appropriate for a range of generic land uses in Australia. These HILs have been endorsed by the NSW Department of Environment and Conservation (DEC) (formerly the NSW EPA). Due to the proposed future rail-related use of the Site, CH2M HILL has compared the laboratory results of the soil samples from across the Site to the following land use scenario and criteria:

> *Commercial or Industrial Health Investigation Levels (HILs) in Column 4 of Appendix II in NSW DEC (2006), referred to as NEHF F, or HIL F.*

In addition, the NSW EPA, *Contaminated Sites: Guidelines for Assessing Service Station Sites*, 1994 (NSW EPA, 1994), guidance document has been used to provide threshold TPH and BTEX concentrations. Although these criteria are for sensitive land use scenarios, they are the only currently endorsed criteria when considering environmental impacts from TPH and BTEX compounds.

The Site is currently being considered by RailCorp for continued commercial/industrial land use, therefore provisional phytotoxicity-based

Investigation Levels (PBILs) will not be used to assess the suitability of the Site soils. This is based on the decision process for assessing urban redevelopment sites outlined in NSW DEC, 2006, which does not require that PBILs be considered for industrial/commercial land uses.

There are no published guidance levels or criterion for PCDD/Fs in NSW. The inclusion of PCDD/Fs in the investigation was not to assess human health or environmental risks for PCDD/Fs, rather to determine remedial options available to manage these types of contaminants if they persist at the Site. For the purposes of comparison, remediation criteria adopted from USEPA Approach for Addressing Dioxin in Soil at CERCLA and RCRA Sites, 1998 are provided here. This document recommends a Preliminary Remediation Goal (PRG) of 5 – 20ng/g (5,000 – 20,000pg/g) for the clean up of surface soils for commercial/industrial sites.

Soil HIL criteria and threshold concentration guidance levels for this site investigation are presented in **Table 6.2**.

Table 6.2 – Soil Criteria (in mg/kg)

Analyte	DEC, 2006 – HIL F	NSW EPA, 1994
Metals		
As	500	-
Cd	100	-
Cr (III)	600,000	
Cr (VI)[1]	500	-
Cu	5,000	-
Hg (inorganic)	75	-
Ni	3,000	-
Pb	1,500	-
Zn	35,000	-
Total Petroleum Hydrocarbons (TPH)		
TPH (C6-C9)	-	65
TPH (C10-C36)	-	1,000
BTEX		
Benzene	-	1
Toluene	-	130
Ethylbenzene	-	50
Xylenes	-	25
Polycyclic Aromatic Hydrocarbons (PAHs)		
PAH – total	100	-
Benz(a)pyrene	5	-
Organochlorine Pesticides		
Aldrin + Dieldrin	50	-
Chlordane	250	-
DDT + DDD + DDE	1,000	-
Heptachlor	50	-

Analyte	DEC, 2006 – HIL F	NSW EPA, 1994
Phenol	42,500	-
Cyanide (total)	2,500	-
PCBs	50	-
PCDD/Fs	5,000 to 20,000 pg/g[2]	-
Asbestos[3]	No detection of fibres in the surface soils. No visible fragments in the surface soils.	-

[1] This value is used as a conservative concentration and used as a preliminary screening value for Chromium.
[2] USEPA Approach for Addressing Dioxin in Soil at CERCLA and RCRA Sites, 1998, Preliminary Remediation Goal (PRG) for the clean up of surface soils for commercial/industrial sites .
[3] Australian Contaminated Land Consultants Association, Asbestos in Soils – Code of Practice, 2002 – Tier 1 HIL Guideline. No detection refers to 95% probability that there are no fibres in surface soils (less than 5 fibres detected).

6.2.2 Water Investigation Levels

Surface Water results can be compared to a set of trigger values published by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) in *The Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000).

Selection of appropriate trigger values is dependant on the receiving water body of migratory waters. The receiving water body is expected to be the head waters of Alexandra Canal and this system is not under tidal influence, therefore the receiving water body should be a freshwater environment. Criteria for Site water are provided below.

Table 6.3 – Water Criteria (µg/L)

Analyte	Slightly – Moderately Disturbed Systems Trigger Values (µg /l)	Reliability of Trigger Value
Arsenic (AsIII)	24	High
Cadmium	0.2	High
Copper	1.4	High
Lead	3.4	High
Mercury (inorganic)	0.06	High
Nickel	11	High
Zinc	8	High
Cyanide (un-ionised)	7	High
Phenol	320	High
Benzene	950	High
Xylenes (o-xylene)	350	High
Xylenes (p-xylene)	200	High
PAHs (naphthalene)	16	High

Analyte	Slightly – Moderately Disturbed Systems Trigger Values (µg /l)	Reliability of Trigger Value
OCP (chlordane)	0.03	High
OCP (DDT)	0.006	High
OCP (endosulfan)	0.03	High
OCP (endrin)	0.01	High
OCP (heptachlor)	0.01	High
TPH	-[1]	-

1 No recommended value. Analytical testing Limit of Reporting (LOR) will be used as an initial screen to evaluate the protection of environmental values at the site. The LOR for TPH will be 100µg/L.

6.2.3 Comparison of Soil Analytical Results to the Soil Investigation Levels

The usual statistical methodology used for comparison of the soil data to criteria is based on the methods referred to in the NSW EPA *Sampling Design Guidelines* (1995) and NEPM (1999), namely:

- comparison of the 95% upper confidence limit of the arithmetic mean concentration (95% UCL values) of each contaminant to the investigation criteria (HIL F);
- comparison of individual analytical results to 250% of the investigation criteria (HIL F) to identify contamination 'hotspots'; and
- comparison of calculated standard deviations to a value of 50% of the investigation criteria.

7 Fieldwork Methodology

7.1 Overview

7.1.1 Scope of Fieldwork

The scope of the field work undertaken at the Site entailed:

1. An underground service clearance, obtaining necessary work permits;
2. Sampling (soil and water) at nominated areas; and
3. Survey of specific surface infrastructure and sampling locations.

7.1.2 Sampling Program

The sampling program was undertaken in two stages. The reasoning behind the fieldwork being completed in two stages is provided in **Section4.2.3.**

The first stage used heavy machinery to conduct trenching and test pit excavations. This approach enabled the collection of soil/fill samples and provided a better understanding of the subsurface conditions, especially underground structures associated with the MGP. The second stage used a push tube rig to collect undisturbed samples from deep soil layers, and to bore angled holes to target the bases of the Gasholders.

CH2M HILL site personnel followed Standard Operating Procedures (SOPs) for conducting site work. The SOPs follow specific standards in industry guideline documents and are used as a training tool for site personnel. Consistency is maintained as a result of site personnel following the same methodology.

In order to assess the distribution of the chemical compounds analysed, CH2M HILL used a combination of a stratified and judgmental sampling strategy, defined in the NSW EPA *Contaminated Sites, Sampling Design Guidelines* (1995), as follows:

- **Stratified Sampling:** involves the separation of a site into sub-areas and each sub-area sampled as an individual site; and
- **Judgmental Sampling:** is where the location of sampling points is selected based on the investigators knowledge of the Site and previous site activities.

The number of soil sample locations in each area is summarised in **Table 4.1**. The locations of the soil sampling locations are in **Figure 3**.

The methodology employed in determining the location of the soil sampling locations was as follows:

- Nominate the proposed soil sampling locations on a site plan required to meet the data quality objectives outlined in **Section 4.1**;
- Actual sample locations were moved in the field as required due to the presence of underground or above ground structures or services. A professional cable locator was employed to clear areas of uncertainty and service diagrams were obtained from RailCorp and utility companies; and

- All sample locations were recorded by a professional surveyor.

7.2 Soil Investigation

7.2.1 Intrusive Work

Online Contracting Pty Ltd (Online) was subcontracted to carry out trenching and test pit excavations, while Macquarie Drilling was engaged to carry out bore drilling operations.

The bore drilling technique employed consisted of a push tube rig, known as a Geoprobe. This machine uses a percussion technique to drive hollow rods into the ground to collect undisturbed soil core samples in disposable (i.e. single use) plastic tubing.

The depth of sampling was determined based on:

- depth to fill and natural soil;
- depth to groundwater;
- depth to bedrock; and/or
- the origin of potential contaminants (i.e. from surface spills or subsurface release).

7.2.2 Soil Sample Collection

Soil samples were collected in accordance with NEPM (1999), the site-specific Sampling Analysis and Quality Plan (SAQP) (CH2M HILL, July 2006) and CH2M HILL Standard Operating Procedures (SOPs). Soil samples from excavated trenches and test pit holes were collected directly from the machine bucket in the undisturbed bulk of material. Soil samples collected with the Geoprobe were collected from the undisturbed inner core of the push rod.

Soil profiles were logged to the depth of the hole or to refusal. Each sampling location was identified and described on a bore log, which are provided in **Appendix C**.

Collection of field data quality samples was undertaken as appropriate in accordance with NEPM, 1999 and AS 4482.1 – 1997, as per the SAQP.

To support analytical assessment of samples, visual assessment was conducted in the field to positively identify wastes that are specific to gasworks sites. **Table 7.1** below describes the basis for visual assessment of gasworks wastes and other materials undertaken in the field during sampling activities.

Table 7.1 – Visual Assessment of Waste Types

Waste Types	Visual Appearance	Likely Contaminants
Coal Tar & Tar Oils	• Dark Brown to black discolouration • Odorous (aromatic-sweet & hydrocarbon)	PAHs, TPHs, BTEX & Phenolics
Spent Oxides (including cyanides)	• Prussian Blue colouring (oxidised) • Grey/green colouring (reduced) • Iron staining (orange/red)	Metals, Cyanide (complex & free)
Coke, coke breeze, ash, clinker	Light grey to black colour • Black powder (coke breeze) • Granular glassy material (clinker)	PAHs & metals
Drip Oils/Light oils	• Odorous (oily) • Oily sheen	TPHs & BTEX
Asbestos Containing Materials	• Fibrous/powdery texture • Coloured (grey-white, blue, green) • Fragments	Asbestos (Amosite, Chrysotile, Crocidolite)

7.2.3 Field Screening

All soil samples were screened in the field during sample collection for Volatile Organic Compounds (VOCs) with a calibrated Photo-ionization Detector (PID). The PID is a hand held device used in the field to screen the sample headspace for potential volatile contaminants. This type of screening provides on-site assessment of samples likely to contain volatile compounds. However, the PID measurements are indicative only and should not be substituted for sound laboratory testing methods.

The PID used during this assessment was a MiniRae and was calibrated prior to the commencement of each day of field activities using a zero gas calibration and 100 ppm concentration isobutylene gas in accordance with the manufacturer's specifications. The PID was regularly checked throughout the day and recorded.

When screening soil samples, a sub-sample was placed in a sealable plastic bag and labelled with the same identifier as the original sample. The sample was agitated and left to develop in the shade. After sufficient development, the PID hose tip was then placed through the top of the bag and lowered to the top of the sample. The hose tip remained in place until a maximum concentration (ppm) of volatile organic compounds recorded by the PID was noted. Between each reading the PID was allowed to return to a zero reading.

PID field screening along with visual assessment of gasworks wastes provided a good basis with added professional judgement in selecting samples for analysis that would represent site conditions accurately.

The PID results for each sample are provided on the bore logs in **Appendix C**. The initial calibration from the rental supplier calibration and record sheets are presented in **Appendix E.**

7.2.4 Soil Sample Storage and Transport

Each sample was labelled with an alphabetical and numerical identifier consisting of the date, sample location, depth of sample and samplers initials. Soil samples were placed directly into 250mL laboratory prepared and supplied jars.

Samples were not mixed or homogenized during the assessment in order to minimize loss of volatiles. Samples were placed directly into an ice-cooled esky following collection and transported to the laboratory under CH2M HILL chain-of-custody (COC).

7.2.5 Soil Sampling Equipment Decontamination

At each new sample location a new set of disposable nitrile gloves was used to directly collect soil samples and place the samples into the laboratory prepared clean glass sample jars. Between each sample, the machine bucket and Geoprobe rods were washed with a high pressure hose to remove all traces of visible soil material.

At the end of each sampling day, the push tube shoe was decontaminated using a scrubbing brush and a solution of Decon 90 and tap water followed by a rinse in tap water to remove soil material. An equipment rinsate blank was collected at the end of each day from this piece of sampling equipment. No rinsate samples were collected from the machine bucket.

7.3 Surface Water Investigation

7.3.1 Sampling Locations

Samples were collected to understand potential impacts to surface water contained in former gasworks structures from MGP waste materials. The locations are described in **Section 8.6**. In preparation for Site remediation, a better understanding of impacts to the water in structures would enable a better management strategy to be applied.

7.3.2 Surface Water Sampling

Samples were collected using a disposable teflon bailer or directly into the sample bottles. A sample of the water at the bottom of the Southern Gasholder was collected using a footvalve mechanism to ensure water from the bottom of the structure was collected.

Non-Aqueous Phase Liquids (NAPLs) were noted at one location in the Tar Well #2 sample.

Collection of field data quality samples was undertaken as appropriate in accordance with NEPM, 1999 and AS 4482.1 – 1997.

7.3.3 Surface Water Sample Storage and Transport

Water samples were transferred directly from the disposable bailer into laboratory prepared and supplied bottles appropriate for the analysis required. Samples were labelled with a unique alphabetical and numerical identifier consisting of the date, sample location and samplers initials.

Duplicate samples were collected by alternatively filling the primary then duplicate bottles. Samples were placed directly into an ice-cooled esky following collection and were transported to the laboratory under CH2M HILL chain-of-custody (COC).

7.3.4 Surface Water Sampling Equipment Decontamination

Decontamination was not required and new nitrile gloves were used at each sample location.

7.4 Analytical Program

The majority of soil and water samples were analysed for the same contaminants of concern. The analyses listed in **Table 7.2** were performed using NATA accredited methods. The majority of the project analytical work was performed by ALS Pty Ltd (Sydney). The Quality Assurance (QA) laboratory was Labmark Pty Ltd (Sydney) used to analyse the inter-laboratory duplicate samples. The laboratory used to analyse for asbestos was ASET Pty Ltd. All three laboratories are accredited by the National Association of Testing Authorities (NATA).

The analytical suite conducted by the laboratories for the investigation is summarised in **Table 7.2**. The analysis of metals in groundwater was based on metals in a dissolved state. Soils were analysed for total metals.

Table 7.2 – Analytical Methods

Analytical Parameters	Detection Limit Soil (mg/kg)/water (µg/L)	Holding Time	Analytical Technique
Metals (As, Cd, Cr, Cu, Ni, Pb, Zn, Hg)	0.1-5 / 0.1-5	6 months / 28 days -Hg	ICP/MS/FIMS
TPH	10-100 / 50-200	14 days (7 days water)	PT-GC/PID/FID/MS
BTEX	0.2-1/ 1-2	14 days	PT-GC/PID/FID/MS
PAHs	0.5-1/ 1-2	14 days (7 days water)	GC/MS
OCPs	0.05/ 0.2	14 days (7 days water)	GC/ Dual ECD
OPPs	0.05/ 0.2	14 days (7 days water)	GC/ Dual ECD
Phenolics	0.5-1/ 1-2	14 days (7 days water)	GC/MS
Total Cyanide	1	14 days	APHA 4500
Asbestos	-	-	PLM in dispersion staining

Analytical Parameters	**Detection Limit** **Soil (mg/kg)/water (µg/L)**	**Holding Time**	**Analytical Technique**
PCBs	0.5/ 5	14 days (7 days water)	GC/ Dual ECD
PCDD/Fs	<0.0409 pg/g	1 year	Isotope Dilution

8 Investigation Results

The following sections present the results of this Delineation Investigation undertaken by CH2M HILL, while **Section 8.4** incorporates the data from all previous soil investigation programs.

Section 12 presents the delineation and characterisation of site contamination, which incorporates all relevant previous data from those investigations listed in **Section 1.4.1**.

8.1 Subsurface Conditions

The trenches, test pits and bore holes completed during the investigation provided a better understanding of the subsurface conditions of the Site than what had previously been reported. This section provides a detailed account of the general Site and subsurface conditions encountered during the investigation. A photographic record of the investigation is provided in **Appendix A.**

8.1.1 Additional Subsurface Findings

Northern Gasholder

A backhoe was used to scrape across the ground surface and uncover the top of the buried brick annulus of the Northern Gasholder (Photo 6). The circumference of the Gasholder annulus was surveyed and determined to be the same as the Southern Gasholder (approximately 20m). The sidewall of the annulus was exposed while trenching at sample location MG05 (Photo 7). Tar/oil was observed to be seeping from the brickwork at approximately 2 metres below ground level (mbgl).

Two test pits were completed inside the annulus of the Northern Gasholder (MG03 and MG04). The material excavated was building demolition and waste materials that included brick, fibro cement sheeting, pipes, wood, scrap metal, tiles and sandstone blocks (Photo 8). The fibro cement sheeting was tested and indicated a presence of asbestos (refer **Section 8.3.11** and **Table 10**).

It was observed that the inside of the Northern Gasholder is acting as a reservoir, similar to a surface water body. The brick annulus acts as a low permeable wall, effectively creating an inground pool (Photo 9). The relatively fast infiltration of surface water coupled with slow permeation through the annulus brickwork results in a positive head of water inside the Gasholder. Compared to groundwater levels outside the annulus (MW06s – approximately 2mbgl), the water level inside the annulus is significantly raised and standing water is at approximately 0.4mbgl. The positive head provides a source of recharge to the shallow groundwater system.

Tar Impacts

Sample locations BHC, BHC1 and BHD were bored at an angle of 17 degrees from the vertical toward the Northern Gasholder. BHC intersected the base of the annulus at 6mbgl. This was an important find, given it was previously expected that the Gasholder was constructed to approximately 3mbgl based on historical data and anecdotal evidence. The sample collected at this depth from the base of the annulus appeared as a tarry oily material and brick (Photo 10). Sample location BHD also showed the presence of similar tarry oily material at approximately 6.0mbgl.

The tarry oily material underneath the northern gasholder exists as a relatively fluid black ooze. The term "free tar" is used to describe this material.

Southern Gasholder

Similar to the Northern Gasholder, the Southern Gasholder was completely full of water and acts as a reservoir. It would also provide a positive head and a source of recharge to the shallow groundwater system.

A groundwater gauging meter was used to measure the depth to the base of the Southern Gasholder through a central hole in the metal lid and at the outside edge. The outside edge was measured at 5m below the top of the brick annulus, while the centre was measured at 3.5m below the metal lid. This gives the impression that the base of the Gasholder is likely to be convex.

Tar Impacts

Sample locations BHA, BHA1 and BHB were bored at an angle of 17 degrees from the vertical to target material below the Southern Gasholder (Photo 11). The bore holes were positioned to clear the base of the Gasholder annulus at 6.5mbgl. This confirmed reports that the Southern Gasholder was no greater than 6.5m deep.

Samples collected and observations made from near the base and underneath the gasholder at BHA, BHA1 and BHB showed the presence of dark stained material within the natural pores and fractures, which was highly odorous (Photo 24). This was observed at approximately 6mbgl to the depth of refusal 10mbgl.

This dark stained material, whether it is tar that has leaked from the Southern Gasholder or migrated from other tar source areas, is different in nature to the free tar below the Northern Gasholder. It is not fluid, but discolours the surface of vertical fractures. The term "dark stained impacts" is used to describe this material. These dark stained materials were only observed underneath the Southern Gasholder.

The terminology of "free tar" and "dark stained impacts" will be used to categorise the tarry materials at the Site.

Retention Pit

A backhoe was used to excavate adjacent to a brick pit located on the southern side of the Southern Gasholder (Photo 15). The pit (referred to as the Retention Pit) was built to approximately 2mbgl and connected to two pipes, which both contained water and an oily/tarry material. The position of the pit adjacent to the Gasholder indicates it was likely constructed to capture tar condensate from the Gasholder. The presence of tar in the interconnected pipes would also indicate this assessment. The pipes were broken during excavation of this pit and the pit was flooded with water. A sample of residual material was collected from one of the pipes for chemical analysis. The results of this sample are presented in **Section 8.3.10**.

Tar Wells

Two Tar Wells are located 5m northeast of the Northern Gasholder. An excavator was used to remove the concrete lids and uncover the contents of the two tar wells. The diameter of each well is approximately 4.0m. Both Tar Wells contained water (Photo 12). A long pole was used to estimate the depth to the base of Tar Well #2, which appeared to be approximately 1.5m deep to the base. However, upon forcing the pole down it appeared to push through a crust and slide to a depth of approximately 3m deep. Once the pole was removed a black free phase product

floated to the surface. It was then considered that the well was likely to contain a free tar material and the excavator was used to collect a sample of this material. The material removed from the base of the well was black, highly odorous and a mixture of free tar and gravels (Photo 13). A sample of this material was collected from the excavator bucket for chemical analysis. The results of this sample are presented in **Section 8.3.10**.

Sample location MG06 was excavated along side Tar Well #2, which showed free tar seepage from the Tar Well into the adjoining soil material (Photo 14), indicating this Tar Well is likely to be a significant contamination source zone. No sampling trench was excavated adjacent to Tar Well #1 as it was considered, given their close proximity and historical use, the conditions would be similar for both wells.

Adjacent to the Tar wells, free tar was observed at sample location BHG in the soil pores and fractured shales up to depths of 7.0mbgl.

Retort Brickwork

An excavator was used to complete trenches across the footprint area of the former Retort House location. The trench work uncovered an incomplete brick-base floor consisting of a layer of bricks (Photo 16). The brickwork was considered an item of potential heritage significance; therefore excavation work was limited to preserve the insitu brickwork. The lateral extent of the brick work was determined as follows:

- Northern extent of brickwork was not determined – the brickwork continues below the Retaining Wall and is evident at sample location TP12.
- Southern extent of the brick work was at the southern end of sample location MG09B.
- Eastern extent of the brick work was likely to be the mid point of sample location MG08 – the brickwork was discontinuous in this area and difficult to delineate.
- Western extent of the brickwork was at the western end of sample location MG09C.

The lateral extent and size of the brickwork is generally in alignment with the former historical layout of the Retort location presented on **Figure 2**.

Sample location TP15 was selected to penetrate through a discontinuous area of brickwork to allow the collection of delineation samples at depth. A brick footing was observed at this sample location. Both the brick footing and the surrounding soil materials were observed to be impacted with free tar. It should be considered that there is a high possibility that similar footings exist across the expanse of the Retort area.

Tar Pipe and Other Gasworks Pipework

A significant number of old gasworks pipework and service lines were uncovered during the sampling program. The majority of these pipes contained residues of black, highly odorous, sticky tar. One pipe was uncovered at sample location MG02, which appeared to have significantly impacted (i.e. observed as free tar) the surrounding soils. Another was uncovered at MG09B, where a sample was collected from the tarry residues (Photo 17). The results of this sample are presented in **Section 8.3.10**.

8.2 Geological Observations

For the following sections, reference is made to **Figure 3** for the location of Site areas and cross sectional transects. **Figures 5** and **Figure 6** present cross sections that indicate fill and natural soil horizons across areas of the Site.

Each sample location was logged on a soil bore log. Bore hole logs are presented in **Appendix C.**

8.2.1 Fill Material

The fill materials identified at the Site can be grouped as follows:

- Ash and Coke Gravels – observed in surface and near surface layers from ground level to approximately 0.5mbgl. A representation of this material is shown in Photo 18. This material was observed at the surface in the majority of Site Areas, particularly as deeper subsurface layers in the North East, South Central, Retort and Western Lot areas of the Site.
- Reworked Clays – observed in subsurface layers from 0.5mbgl to approximately 1.5mbgl. This material was observed in the majority of Site areas as general filling.
- Sands and Gravels – observed in subsurface layers from 0.5mbgl to approximately 1.5mbgl. This material was observed in the North East, South Central and Gas Purifier areas of the Site.
- Gravely Sand and Clay with Minor Ash – observed in surface and subsurface layers from ground level to approximately 3.5mbgl. This material was predominantly observed in the South West area of the Site as general filling. A representation of this material and the stratification of the fill is shown in Photo 19.
- Gravel, Sand and Demolition Wastes – observed in fill embankment areas along the northern boundary (Retaining Wall area) and inside the annulus of the Northern Gasholder (Photo 8). A representation of the fill embankment material is shown in Photo 20 and Photo 21. This material was observed to mainly consist of sandy gravels and some ash gravels. It also consisted of demolition wastes and rubble including bricks, metal pipes, tiles, fibro-cement sheeting and Asbestos Containing Materials (ACMs) and other building rubble in a gravely sand matrix.

Generally the deepest filling was encountered in the South West area to depths of approximately 3.5mbgl. Depth of filling in this area is also indicated by the steep embankment formed above the backyard ground surface of the adjoining residential properties (see photo 4). Fill thickness generally becomes shallower in other areas, forming a wedge of fill in the South West area. The original topography is likely to have been a steeper gradient down in a southerly direction, compared to the current generally level surface.

8.2.2 Natural Soil

The natural soil materials identified at the Site can be grouped as follows:

- Silty Clay – observed generally from 1.5mbgl to approximately 2.5mbgl. This material exists across the majority of Site areas. The material is consistent with

the original surface soils, indicated by the abrupt profile horizon from the overlying fill materials, the gradational horizon into the underlying plastic clays and the high silt and organic matter content (i.e. roots and rootlets). The thickness of this horizon is possibly the result of tilling practices for crop growing in the area during early settlement. However, this information was not confirmed in previous site history reviews. The Silty Clay horizon was predominantly a saturated soil horizon, which sustained the perched groundwater system, overlying the moderately/highly plastic red/grey mottled clays.

- Red/Grey Mottled Clay – observed generally from 2.5mbgl to approximately 4.0-6.0mbgl. The soil profile horizon is gradational from the Silty Clay above and the soil is consistent with a red podzolic, being moderately to highly plastic, stiff to very stiff, moist and mottled red/grey. This material was observed in filled areas of the Site as reworked clay, probably sourced from excavations on site to accommodate inground structures such as the gasholders, tar wells and building footings.
- Weathered Shale – observed underlying the natural clay and the horizon is generally gradational through this profile. This material grades from extremely weathered to moderately weathered at depths of up to 10mbgl. At depths beyond 6mbgl, fracturing of the material is common, giving rise to prominent iron stone gravels and iron staining.

8.2.3 Tar and Tar Impacted Soil

A number of areas of fill/soil materials were observed to be impacted by Tar. The tar material has been categorised as follows:

- Free Tar – consisting of a black, low viscosity, highly odorous material; and
- Dark Stained Impacts – this material was observed as dark brown to black staining in the deep soils and Weathered Shale within the soil pores and shale fractures zones underneath the Southern Gasholder. This material was also highly odorous.

Representations of these materials are shown in Photo 22 and Photo 23 (free tar in deep natural soils) and Photo 24 (dark staining).

Free Tar was predominately associated with former structures including:

- Tar Wells – shallow subsurface and deep natural soils surrounding and underlying these structures;
- Northern Gasholder – deep natural soils surrounding and underlying the brick base annulus;
- Retort – fill and deep soil across the majority of this area;
- Gas Purifier – Sandy fill and deeper soils;
- Old Pipework – generally observed inside the pipes and in immediately surrounding fill/natural soils; and
- Localised impacted fill – observed in one localised pocket in the Northeast Area.

Dark stained impacts were associated with:

- Below the Southern Gasholder.

The primary source of tar at the Site is the free tar sources, whereas the dark stained impacts are likely to be secondary sources within the strata in localised areas associated with the Southern Gasholder.

8.3 Stratified Area Soil Analytical Results

Soil samples were submitted to the laboratory for analysis of inorganic contaminants including metals (As, Cd, Cr(total), Cu, Hg, Ni, Pb, Zn) and cyanide (total)); and organic contaminants including TPH, BTEX, PAH, phenolics, OCPs, OPPs and PCBs. Selected soil samples and building material debris samples were also submitted for asbestos analysis.

Samples were selected for analysis based on either field observations (such as odours, discolorations and visual identification of tar and other wastes) or on historical information of site operative/waste disposal area.

As outlined in **Section 6**, soil analytical results have been compared to the NSW DEC (2006) HIL F investigation levels for commercial/industrial sites. The method for comparison of the soil analytical results to the investigation levels is described in **Section 6.2.3**.

Laboratory Certificates of Analysis and chain of custody forms are provided in **Appendix G.**

A summary of the soil analytical results obtained from each of the Areas (as shown on **Figure 3)** during the Delineation Investigation are presented and discussed below.

8.3.1 PID Field Screening Results

The PID readings at each sample location appear to correlate well to the analytical results for contaminants. Elevated PID readings were identified in samples exhibiting elevated concentrations of contaminants (particularly BTEX and light fraction TPH), while low PID readings correspond to lower concentrations. On this basis, the PID field screening tool worked effectively in identifying the location and depth of samples that were likely to be impacted. This may also be a useful tool during remedial excavation work in determining extent of excavations and limits to chasing-out contaminated areas.

8.3.2 Gasholder Area

A total of 24 samples were analysed from 7 fill and 17 natural soil samples. Of these samples:

- 5 of the 7 (70%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- 8 of the 17 (47%) natural soil samples contained concentrations of one or more contaminants above the investigation criteria.

Summary soil results for the Gasholder Area are presented in **Table 1.** The contaminants that exceed the investigation criteria (and hotspot criteria) in the Gasholder Area are presented below in **Table 8.1.** These sample locations and contamination hotspots are presented on **Figure 4.**

Contamination hotspots were identified in both fill and natural soils. In particular, hotspot locations were identified at:

- MG02 (at 0.2m and 1.8m) for B(a)P, PAHs, TPH (C_6-C_9), TPH (C_{10}-C_{36}), benzene and xylenes;
- MG03 (0.1m) for TPH (C_{10}-C_{36});
- MG05 (at 0.5m and 1.8m) for PAHs, TPH (C_{10}-C_{36}) and xylenes;
- BHC (at 6.0m) for B(a)P, PAHs, TPH (C_6-C_9), TPH (C_{10}-C_{36}), benzene and xylenes; and
- BHD (at 7.0m and 8.4m) for benzene.

Table 8.1 – Gasholder Area - Exceeding Concentrations

				MG02/0.2	MG02/1.8	MG03/0.1	MG04/0.5	MG05/0.5	MG05/1.8	MG05/5.0	BHA1/10.2	BHA1/7.0	BHB/6.0	BHC/6.0	BHD/7.0	BHD/8.4
				Fill and Silty Clay Samples					Natural Soil Samples							
Analyte	**NSW EPA, 1994**	**NSW DEC HIL F**	**Hotspot**													
Benzo(a)pyrene	-	5	12.5	<0.5	**178**	**10.4**	**6**	-	2.2	<0.5	<0.5	<0.5	<0.5	**17.6**	<0.5	<0.5
PAHs total	-	100	250	**149.5**	**5,301.9**	**115.3**	62.8	-	**289**	68.1	8	8	13.4	**1,906.4**	8	8
Lead	-	1,500	3,750	-	93	648	**2,140**	325	24	-	-	-	-	-	-	-
TPH C6 - C9	65	-	162.5	**72**	**189**	<2	<2	<2	**118**	**92**	<2	<2	4	**559**	8	9
TPH C10 - C36	1,000	-	2,500	490	**36,140**	**2,750**	**1,860**	**13,340**	**3,140**	**1,420**	<250	<250	<250	**8,760**	<250	<250
Benzene	1	-	2.5	**4.2**	**3**	<0.2	<0.2	<0.2	<1	<0.2	**1.4**	**1.6**	**2**	**6.4**	**5.4**	**7.5**
Xylene Total	25	-	62.5	**29.6**	**165.8**	<0.4	<0.4	<0.4	**80.4**	**35.0**	<0.4	<0.4	0.9	**246.7**	1.6	0.8

Notes:

Bold – Exceeds investigation criteria.

Bold – Exceeds contamination hotspot criteria.

All values in mg/kg.

8.3.3 Retort Area

A total of 31 samples were analysed from 11 fill and 20 natural soil samples. Of these samples:

- 7 of the 11 (63%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- 6 of the 20 (30%) natural soil samples contained concentrations of one or more contaminants above the investigation criteria.

Summary soil results for the Retort Area are presented in **Table 2.** The contaminants that exceed the investigation criteria (and hotspot criteria) in the Retort Area are presented below in **Table 8.2.** These sample locations and contamination hotspots are presented on **Figure 4.**

Contamination hotspots were identified in both fill and natural soils. In particular, hotspot locations were identified at:

- MG08 (at 1.5m and 2.1m) for B(a)P, PAHs and TPH (C_{10}-C_{36});
- MG09A1 (at 0.7m) for PAHs and TPH (C_{10}-C_{36});
- MG09B (at 0.3m) for TPH (C_{10}-C_{36});
- MG10A (at 0.7m and 2.8m) for B(a)P, PAHs and TPH (C_{10}-C_{36});
- BH12A (at 4.2m) for B(a)P, PAHs, TPH (C_6-C_9), TPH (C_{10}-C_{36}), benzene and xylenes; and
- TP15 (at 2.8m and 4.1m) for PAHs and benzene.

Table 8.2 – Retort Area – Exceeding Concentrations

				MG06/ 1.0	MG08/1.5	MG08/2.1	MG09A1/0.7	MG09B/0.3	MG09C/0.3	MG10A/0.7	BH12A/ 4.2	BHG/6.0	MG06/ 2.0	MG10A/ 2.8	TP15/2.8	TP15/ 4.1
				Fill and Silty Clay Samples							Natural Soil Samples					
Analyte	**NSW EPA, 1994**	**NSW DEC HIL F**	**Hotspot**													
Benzo(a)pyrene		5	12.5	2	**444**	**6.9**	**8.2**	-	**5**	**339**	**13.9**	1	0.8	**6.3**	**10.8**	0.5
PAHs total		100	250	**135.5**	**15,237.6**	**321.2**	**416.6**	-	51	**4,758.2**	**515.6**	76.6	**103.5**	**206.9**	**426.2**	21.6
TPH C6 - C9	65		162.5	18	51	**97**	39	12	<2	<2	**228**	24	41	56	**107**	**65**
TPH C10 - C36	1,000		2,500	**1,370**	**435,100**	**2,790**	**3,520**	**20,700**	**1,200**	**234,950**	**5,350**	480	**1,700**	**4,070**	**2,090**	<250
Benzene	1		2.5	0.2	0.2	0.3	**1.7**	0.5	<0.2	<0.2	**20**	**2.4**	<0.2	**1.1**	**1.8**	**2.7**
Xylene Total	25		62.5	9.50	10.60	6.00	21.00	4.00	<0.4	<0.4	**94.90**	8.70	22.70	18.90	**56.20**	24.80

Notes:

Bold – Exceeds investigation criteria.

Bold – Exceeds contamination hotspot criteria.

All values in mg/kg.

8.3.4 Gas Purifier Area

A total of 10 samples were analysed from 4 fill and 6 natural soil samples. Of these samples:

- 4 of the 4 (100%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- 2 of the 6 (33%) natural soil samples contained concentrations of one or more contaminants above the investigation criteria.

Summary soil results for the Gas Purifier Area are presented in **Table 3.** The contaminants that exceed the investigation criteria in the Gas Purifier Area are presented below in **Table 8.3.** These sample locations and contamination hotspots are presented on **Figure 4.**

Contamination hotspots were identified only in fill material. In particular, the hotspot location was identified at:

- MG11 (at 0.2m and 2.0m) for B(a)P, PAHs and TPH (C_{10}-C_{36}).

There were no contamination hotspots identified in natural soils.

Table 8.3 – Gas Purifier Area – Exceeding Concentrations

				MG11/0.2	MG11/2.0	BHE/2.2	BHF/1.0	BHE/8.4	BHF/8.5
				Fill Samples				Natural Soil Samples	
Analyte	**NSW EPA, 1994**	**NSW DEC HIL F**	**Hotspot**						
Benzo(a)pyrene		5	12.5	**42**	**48.8**	<0.5	**6.4**	<0.5	1.1
PAHs total		100	250	**696.6**	**728.8**	32.1	89.5	9.4	**134.6**
TPH C6 - C9	65		162.5	<2	10	**155**	<2	2	22
TPH C10 - C36	1,000		2,500	**6,210**	**7,750**	460	**1,150**	<250	**1,260**
Benzene	1		2.5	<0.2	<0.2	0.4	<0.2	**1.6**	0.8

Notes:
Bold – Exceeds investigation criteria.
Bold – Exceeds contamination hotspot criteria.
All values in mg/kg.

8.3.5 Northeast Area

A total of 26 samples were analysed from 18 fill and 8 natural soil samples. Of these samples:

- 7 of the 18 (39%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- none of the 8 (0%) natural soil samples contained concentrations of contaminants above the investigation criteria.

Summary soil results for the Northeast Area are presented in **Table 4.** The contaminants that exceed the investigation criteria in the Northeast Area are presented below in **Table 8.4.** These sample locations and contamination hotspots are presented on **Figure 4.**

Contamination hotspots were identified only in fill materials. In particular, hotspot locations were identified at:

- TP05 (at 0.25m) for B(a)P and PAHs;
- TP06 (at 0.25m) for B(a)P and PAHs; and
- TP16 (at 1.0m) for B(a)P, PAHs, TPH (C_6-C_9), TPH (C_{10}-C_{36}), benzene and xylenes.

There were no contamination hotspots identified in natural soils.

Table 8.4 – Northeast Area – Exceeding Concentrations

				MG10/0.2	TP05/0.25	TP06/0.25	TP08/0.25	TP09/0.5	TP16/0.3	TP16/1.0
Analyte	**NSW EPA, 1994**	**NSW DEC HIL F**	**Hotspot**	Fill Samples						
Benzo(a)pyrene		5	12.5	1.8	**158**	**55**	**8.2**	**5.4**	**6.9**	**39.4**
PAHs total		100	250	26.2	**4,300.9**	**690.2**	79.4	68.5	56.2	**425.1**
TPH C6 - C9	65		162.5	<2	-	-	-	<2	13	**166**
TPH C10 - C36	1,000		2,500	**1,940**	-	-	-	520	**1,280**	**7,640**
Benzene	1		2.5	<0.2	-	-	-	<0.2	**1.2**	**3.1**
Xylene Total	25		62.5	<0.4	-	-	-	<0.4	5.60	**61.20**

Notes:
Bold – Exceeds investigation criteria.
Bold – Exceeds contamination hotspot criteria.
All values in mg/kg.

8.3.6 South Central Area

A total of 10 samples were analysed from 6 fill and 4 natural soil samples. Of these samples:

- 1 of the 6 (17%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- none of the 4 (0%) natural soil samples contained concentrations of contaminants above the investigation criteria.

Summary soil results for the South Central Area are presented in **Table 5.** The contaminants that exceed the investigation criteria in the South Central Area are presented below in **Table 8.5.** These sample locations and contamination hotspots are presented on **Figure 4.**

There were no identified contamination hotspots in either fill or natural samples.

Table 8.5 – South Central Area – Exceeding Concentrations

			TP11/0.2
Analyte	**NSW EPA, 1994**	**NSW DEC HIL F**	Fill Sample
Benzo(a)pyrene		5	**6.2**
TPH C10 - C36	1,000		**1,410**

Notes:
Bold – Exceeds investigation criteria.
All values in mg/kg.

8.3.7 Southwest Area

A total of 13 samples were analysed from 9 fill and 4 natural soil samples. Of these samples:

- 1 of the 9 (11%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- none of the 4 (0%) natural soil samples contained concentrations of contaminants above the investigation criteria.

Summary soil results for the South West area are presented in **Table 6.** The contaminants that exceed the investigation criteria in the South West area are presented below in **Table 8.6.** These sample locations and contamination hotspots are presented on **Figure 4.**

A contamination hotspot at sample location RP/2.0 was identified for B(a)P in fill materials. There were no contamination hotspots identified in natural soils.

Table 8.6 – Southwest Area – Exceeding Concentrations

				RP/2.0
Analyte	**NSW EPA, 1994**	**NSW DEC HIL F**	**Hotspot**	Fill Sample
Benzo(a)pyrene		5	12.5	**12.8**
PAHs total		100	250	**118.2**
TPH C10 - C36	1,000		2,500	**1,730**

Notes:
Bold – Exceeds investigation criteria.
Bold – Exceeds contamination hotspot criteria.
All values in mg/kg.

8.3.8 Retaining Wall Area

A total of 8 samples were analysed from 5 fill and 3 natural soil samples. Of these samples:

- 1 of the 5 (20%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- none of the 3 (0%) natural soil samples contained concentrations of contaminants above the investigation criteria.

Summary soil results for the Retaining Wall Area are presented in **Table 7.** The contaminants that exceed the investigation criteria in the Retaining Wall Area are presented below in **Table 8.7.** These sample locations and contamination hotspots are presented on **Figure 4.**

There were no identified contamination hotspots in either fill or natural samples.

Table 8.7 – Retaining Wall Area – Exceeding Concentrations

			TP12/0.25
Analyte	**NSW EPA, 1994**	**NSW DEC HIL F**	Fill Sample
Benzo(a) pyrene		5	**9.6**
PAHs (Sum of total)		100	**117.4**
TPH_C10 - C36 (Sum of total)	1,000		**2,320**

Notes:
Bold – Exceeds investigation criteria.
All values in mg/kg.

8.3.9 Western Lot Area

A total of 7 samples were analysed from 3 fill and 4 natural soil samples. Of these samples:

- 2 of the 3 (67%) fill samples contained concentrations of one or more contaminants above the investigation criteria; and
- none of the 4 (0%) natural soil samples contained concentrations of contaminants above the investigation criteria.

Summary soil results for the Western Lot Area are presented in **Table 8.** The contaminants that exceed the investigation criteria in the Western Lot Area are presented below in **Table 8.8.** These sample locations and contamination hotspots are presented on **Figure 4.**

Contamination hotspots were identified only in fill materials. In particular, hotspot locations were identified at:

- TP13 (at 0.25m) for B(a)P, PAHs and TPH (C_{10}-C_{36}); and
- TP14 (at 0.25m) for TPH (C_{10}-C_{36}).

There were no contamination hotspots identified in natural soils.

Table 8.8 – Western Lot Area – Exceeding Concentrations

				TP13/0.25	TP14/0.25
Analyte	**NSW EPA, 1994**	**NEPM HIL F**	**Hotspot**	Fill Samples	
Benzo(a)pyrene		5	12.5	**45.5**	**7.4**
PAHs total		100	250	**512**	95.2
TPH C10 - C36	1,000		2,500	**8,870**	**3,500**

Notes:
Bold – Exceeds investigation criteria.
Bold – Exceeds contamination hotspot criteria.
All values in mg/kg.

8.3.10 Tar Samples

A total of 3 tar samples were collected from the contents of one of the Tar Wells and two buried pipes at different locations across the Site area.

Summary soil results for the tar samples are presented in **Table 9.** The contaminants that exceed the investigation criteria in the tar samples are presented below in **Table 8.9.** The majority of concentrations exceed the contamination hotspot criteria.

The sample collected from the Retention Pit (RP) Pipe indicates that volatile compounds have a lower concentration in this sample compared to the MG09B and Tar Well samples. The concentration of TPH (C_{10} – C_{36}) in the MG09B sample is greater than 100% of the sample mass (i.e. greater than 1 million mg/kg). This result is considered an anomaly, and the sample may be considered as pure tar (i.e. 100% tar).

A brief assessment of these samples indicates that the likely percentage mass of other compounds in the tar material would be:

- B(a)P – between 0.02% and 0.06%;
- PAHs – between 2.1% and 2.7%;
- TPH (C_6 – C_9) – between 0% and 0.7%;

- TPH (C_{10} – C_{36}) – between 2.5% and 118% (taken as 100%);
- Benzene – between 0% and 0.08%;
- Ethylbenzene – between 0% and 0.03%;
- Toluene – between 0% and 0.17%; and
- Xylenes – between 0% and 0.3%.

Table 8.9 – Tar Samples – Exceeding Concentrations

			MG09B/PIPE	RP/PIPE	TAR WELL #2
Analyte	**NSW EPA, 1994**	**NEPM HIL F**			
Benzo(a)pyrene		5	**595**	**491**	**164**
PAHs total		100	**26,805.3**	**20,889.8**	**25,557.6**
TPH C6 - C9	65		**3,770**	**70**	**6,690**
TPH C10 - C36	1,000		**1,180,000**	**24,660**	**98,700**
Benzene	1		**576**	**2**	**814**
Ethylbenzene	50		**156**	1.1	**254**
Toluene	130		**1,210**	3.6	**1,680**
Xylene Total	25		**1,516**	**47.40**	**3,170**

Notes:
Bold – Exceeds investigation criteria.
Bold – Exceeds contamination hotspot criteria.
All values in mg/kg.

Dioxins/Furans

The tar sample from the Site that was analysed for PCDD/F reported a concentration of 1.1pg/g. This concentration is marginally above the laboratory detection limit (0.0409pg/g). This value is also well below the lower comparison criterion (USEPA, 1998) of 5,000 – 20,000pg/g.

8.3.11 Asbestos

A total of 20 soil samples and 3 fibro-cement sheeting fragments were collected at different locations across the Site area.

Summary results of the asbestos analysis are presented in **Table 10.** Samples that indicated a positive identification of asbestos are presented below in **Table 8.10.**

All fibro cement fragment samples collected indicated the presence of asbestos, as either amosite, chrysotile or crocidolite. Fill samples collected from the Gasholder Area (MG04 – inside annulus of the northern gasholder) and the Retaining Wall (TP12) indicated the presence of chrysotile and crocidolite asbestos and chrysotile and asbestos, respectively, in the fill materials at these locations.

Analytical results report these samples to include soil, stones, plant matter, fragments of plaster, fragments of fibre cement and brick. Considering the sample descriptions, the asbestos present in these samples is likely to relate to a bonded matrix. However, the age and condition of these materials may generate asbestos fibre material (i.e. friable) at these locations. The definition given by WorkCover (2003) states that friable asbestos includes inappropriately buried asbestos containing material (ACM), in this instance the buried asbestos cement (AC) fragments. Also, any ACM that is weathered or damaged by actions, including mechanical, is classified as friable.

Table 8.10 – Asbestos Analysis Samples – Positive Identification

	MG01/0.2	MG04/1.5	MG04/1.5	MG09B	TP12/0.25
Asbestos Type	Chrysotile & amosite	Chrysotile & amosite	Chrysotile & Crocidolite	Chrysotile	Chrysotile
Sample Matrix	Fibro fragment	Fibro fragment	Fill material	Fibro fragment	Fill material

8.4 Results and Assessment of All Soil Data

This section summarises the soil results of previous investigations and the new environmental data collected during this Delineation Investigation.

A summary of all data that exceeds the Site criteria for the proposed land use is presented on **Figure 4.**

Fill and natural soil sample results for all data have been summarised in **Table 11** and **Table 12**, respectively.

For ease of assessing the data set for soil results, Silty Clay material was grouped with Fill materials for the following reasons:

- The material appeared as a discontinuous layer over the Site;
- it was likely to be impacted by leaching contaminants from the overlying fill;
- it is the more permeable soil horizon that is likely to be providing a preferential pathway that sustains the perched groundwater; and
- based on field observations of discolouration and strong odour, the Silty Clay layer appeared impacted by contaminants migrating with the shallow groundwater.

The summary data was grouped according to the stratified areas established in **Section 1.3**. The summary tables (**Table 11** and **Table 12**) present soil data for Fill and Silty Clay material and Natural Soil material.

8.4.1 Summary of Soil Data

Table 8.11 and **Table 8.12** below summarise all soil data from across the Site.

Table 8.11 – Summary of Fill and Silty Clay Material

	Contaminants of Concern															
	BaP	**Total PAH**	**TPH (C6-C9)**	**Total C10-C36**	**Benzene**	**Toluene**	**Ethylbenzene**	**Total Xylenes**	**Metals**	**Cyanide (Total)**	**VOCs**	**Total Phenols**	**OCPs**	**OPPs**	**Asbestos**	**PCBs**
Total Samples Analysed	137	137	107	112	133	128	128	128	113	40	9	76	26	22	23	24
Minimum (mg/kg)	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	-	nd
Maximum (mg/kg)	595	26,805	6,690	1,180,000	814	1,680	254	3,170	24	67	4	9,872	6	5	-	7
Detects above criteria	56	40	8	42	12	0	1	9	3	0	0	0	0	0	5	0
% Exceedances	41	29	7	38	9	0	1	7	3	0	0	0	0	0	22	0

Notes:
Nd refers to not detected.

Table 8.12 – Summary of Natural Soil Material

	Contaminants of Concern														
	BaP	**Total PAH**	**TPH (C6-C9)**	**Total C10-C36**	**Benzene**	**Toluene**	**Ethylbenzene**	**Total Xylenes**	**Metals**	**Cyanide (Total)**	**VOCs**	**Total Phenols**	**OCPs**	**OPPs**	**PCBs**
Total Samples Analysed	71	71	67	67	70	70	70	70	24	19	0	41	7	7	4
Minimum (mg/kg)	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Maximum (mg/kg)	21	1,906	559	8,760	35	53	41	247	7	9	0	34	4	4	2
Detects above criteria	5	8	6	8	13	0	0	5	0	0	0	0	0	0	0
% Exceedances	7	11	9	12	19	0	0	7	0	0	0	0	0	0	0

Notes:
Nd refers to not detected.

Fill/Silty Clay

The results indicate a significant number of Fill/Silty Clay samples that report exceedances of the Site criteria. In particular, the following contaminants reported high numbers of exceedances including:

- Benzo(a)Pyrene;
- Total PAHs;
- TPH (C_{10}-C_{36});
- Benzene; and
- Xylenes

The remainder of the contaminants analysed for Fill/Silty Clay samples reported relatively low concentrations that met the Site criteria.

Natural Soil

Natural Soil samples indicated similar exceedances of contaminants listed above in the fill materials, although at a lower ratio, with the exception of volatile compounds including benzene, xylenes and TPH (C_6-C_9) which showed equal or higher ratios of exceedances.

The possible reasons behind volatile compounds showing a higher ratio of exceedances include a combination of:

- Leakage of tarry wastes from deep subsurface storage areas, especially tar wells and the gasholders;
- Vertical fracturing of clays and weathered shales, which provide a preferential pathway into deeper soils;
- Higher solubility rates of benzene, xylene and shorter chained hydrocarbons like TPH (C_6-C_9); and
- Volatilisation of these compounds from shallower fill materials.

Free Tar – Fill/Silty Clays

The following table (**Table 8.13**) provides a summary of the contaminant concentrations reported for free tar materials identified in Fill/Silty Clay materials that exceed the Site criteria or report elevated concentrations.

Table 8.13 – Free Tar Impacts – Fill/Silty Clays

Sample Location	Site Area	Sample Depth (m)	Contaminants of Concern - Concentrations in mg/kg						
			BaP	Total PAH	TPH (C6-C9)	Total C10-C36	Benzene	Ethylbenzene	Total Xylenes
MG02	Gasholder	1.8	**178**	**5,301.9**	**189**	**36,140**	**3**	30.2	**165.8**
BH07	Retort	1.4-1.5	**26**	**1,144.8**	-	-	nd	8	**32**
TPA	Retort	1.6	**8.4**	**536.9**	**100**	**3,200**	**1.6**	7	**65**
TPC	Retort	1	**8.4**	**750.6**	-	-	nd	9	**48**
MG06	Retort	1.0	2	**135.00**	18	**1270**	0.2	3	9.5
MG08	Retort	1.5	**444**	**15,237.60**	51	**435,100**	0.2	3.6	10.6
MG08	Retort	2.1	**6.9**	**321.20**	**97**	**2,790**	0.3	12.3	6
MG09A1	Retort	0.7	**8.2**	**416.6**	39	**3,520**	**1.7**	2.4	21

Sample Location	Site Area	Sample Depth (m)	Contaminants of Concern - Concentrations in mg/kg						
			BaP	Total PAH	TPH (C6-C9)	Total C10-C36	Benzene	Ethylbenzene	Total Xylenes
BH18	Gas Purifier	1.7-1.8	**28**	**2,160.8**	-	-	**7**	**80**	**210**
MG11	Gas Purifier	2.0	**48.8**	**728.80**	10	**7,750**	nd	nd	nd
TP16	Northeast	1.0	**39.4**	**425.10**	**166**	**7,640**	**3.1**	6.4	**61.2**

Notes:
Bold – Exceeds investigation criteria.
Bold – Exceeds contamination hotspot criteria.

The Site areas were these samples were collected indicate the structures and areas identified in **Section 8.2.3** are providing a source of gross contamination in fill materials at those sample locations shown in the table above. These locations appear to be hotspot areas for one or more contaminants, with the exception of MG06. Sample location TP16 is a localised impact in the Northeast Area of the Site.

Free Tar – Natural Soils

The following table (**Table 8.14**) provides a summary of the contaminant concentrations reported for free tar identified in Natural Soil materials that exceed the Site criteria or report elevated concentrations.

Table 8.14 – Free Tar Impacts – Natural Soils

Sample Location	Site Area	Sample Depth (m)	Contaminants of Concern - Concentrations in mg/kg					
			BaP	Total PAH	TPH (C6-C9)	Total C10-C36	Benzene	Total Xylenes
BHC	Gasholder	6.0	**17.6**	**1,906.4**	**559**	**8,760**	**6.4**	**246.7**
BHD	Gasholder	7.0	nd	nd	8	nd	**5.4**	1.6
BH12A	Retort	4.2	**13.9**	**515.6**	**228**	**5,350**	**20**	**94.9**
MG06	Retort	2.0	0.8	**101.50**	41	**1,600**	nd	22.7
TP15	Retort	2.8	**10.8**	**426.20**	**107**	**2,090**	**1.8**	**56.2**
TP15	Retort	4.1	0.5	18.10	**65**	nd	**2.7**	24.8
TP15A	Retort	6.0	nd	0.8 (naphthalene)	nd	nd	nd	nd
BHG	Retort	6.0	1	76.6	24	380	**2.4**	8.7
BHF	Gas Purifier	7.0	nd	0.8 (naphthalene)	7	nd	0.8	1
BHF	Gas Purifier	8.5	1.1	**134.6**	22	**1260**	0.8	9.8

Notes:
Bold – Exceeds investigation criteria.
Bold – Exceeds contamination hotspot criteria.

The Site areas were these samples were collected are similar to those identified in the impacted fill areas, and considered to be providing a source of gross contamination in Natural Soils at those sample locations in the table above. These locations appear to be all contamination hotspot areas for one or more contaminants, with the exception of TP15A and BHF (at 7.0mbgl only).

Dark Stained Impacts – Natural Soils

The following table (**Table 8.15**) provides a summary of the contaminant concentrations reported for dark stained impacts identified in Natural Soil materials (Weathered Shale Fractured zone) below the Southern Gasholder that exceed the Site criteria or report elevated concentrations.

Table 8.15 – Dark Staining – Natural Soils

Sample Location	Sample Depth (m)	Contaminants of Concern - Concentrations in mg/kg
		Benzene
BHA	7.0	0.4
BHA	10.2	0.3
BHA1	7.0	**1.6**
BHA1	10.2	**1.4**
BHA2	10.2	0.9
BHB	6.0	**2**

Notes:
Bold – Exceeds investigation criteria.

The Site area where these samples were collected is specific to the Southern Gasholder. Benzene is the only contaminant that indicates elevated or concentrations marginally exceeding the Site criteria at the depths indicated. BHA, BHA1 and BHB were angled bore holes that targeted below the Gasholder.

The impacts observed underneath the Southern Gasholder appear minor in comparison to those identified underneath the Northern Gasholder.

8.5 Leachate Analytical Results

8.5.1 TCLP Fill and Natural Soil Results

Toxicity Characteristic Leaching Procedure (TCLP) analysis was conducted on the samples indicated in **Table 8.16**. In all, 11 samples were selected to provide indicative results and concentrations of leachate as a preliminary step in the waste classification process for incorporation into remedial options screening.

Table 8.16 – Samples Selected for TCLP Analysis

Fill/Silty Clay Materials		
Sample	Depth (mbgl)	Material Description/Site Area
MG01	1.8	Fill/Southwest
MG02	1.8	Silty Clay (with free tar)/Gasholders
TP10	2.0	Fill/Retaining Wall
TP06	0.25	Fill (ash and coke)/Northeast
MG04	0.5	Fill/Inside Nth Gasholder
MG10A	0.7	Fill (ash and coke)/Retort
MG11	2.0	Fill (free tar)/Gas Purifier
Red/Grey Mottled Clays		
MG06	2.0	Natural Soil (with free tar)/Retort (adjacent to Tar Wells)

Weathered Shales		
BHA	7.0	Natural Soil – Weathered Shale (dark staining)/Gasholders (southern)
BHD	8.4	Natural Soil – Weathered Shale (dark staining)/Gasholders (northern)
BHF	8.5	Natural Soil – Weathered Shale (free tar)/Gas Purifier

The results presented in **Table 13** report non detectable leachable concentrations of inorganic contaminants in the Fill/Silty Clay samples and the Natural Clay sample (MG06), with the exception of MG04, which reported moderately high leachate concentrations for Lead. These samples also reported non-detectable concentrations for B(a)P, while other organic contaminants were not analysed.

It is important to note that the fill material inside the Northern Gasholder at sample location MG04 included large quantities of demolition wastes, which were not observed to the same degree in other areas of the Site.

The results for Weathered Shale materials indicate relatively moderate leachable concentrations for organic contaminants, including:

- BHD - Benzene (0.012mg/L) and Xylenes (0.009mg/L) at 8.4mbgl;
- BHF – Benzene (0.001mg/L), Toluene (0.002mg/L), Ethylbenzene (0.106mg/L) and Xylenes (0.648mg/L) at 8.5mbgl;
- BHF – TPH (C_6-C_9) (0.6mg/L), TPH (C_{10}-C_{14}) (4.1mg/L) and TPH (C_{15}-C_{28}) (0.5mg/L) at 8.5mbgl;
- BHF – a range of PAHs, with Naphthalene (0.1018mg/L) reporting the highest concentration at 8.5mbgl.

Weathered Shale samples did not report B(a)P above the laboratory limit of reporting (LOR).

8.5.2 Preliminary Waste Classifications

The TCLP results summary tables in **Table 13** provide a preliminary waste classification of the materials listed in **Table 8.16** above. Based on the total concentrations and the TCLP concentrations, the materials are preliminarily classified as follows in **Table 8.17**. Indicative waste classifications are also provided in the table below that takes into account guidance in general EPA immobilisation approvals, as discussed below.

Table 8.17 – Waste Classifications

Sample		**Preliminary Waste Classification**	**Indicative Waste Classification[A]**
MG01	Fill – ash and shale mixture with coke gravels.	Solid	NA
MG02	Silty Clay (with free tar)	Hazardous	Industrial
TP10	Fill – sandy gravel, shale	Inert	NA
TP06	Fill (with ash and coke)	Hazardous	Solid
MG04	Fill – gravely sand	Industrial	NA

Sample		Preliminary Waste Classification	Indicative Waste Classification[A]
MG10A	Fill (with ash and coke)	Hazardous	Solid
MG11	Fill (with free tar)	Hazardous	Solid
MG06	Fill (with free tar)	Inert	NA
BHA1	Natural Soil - Weathered Shale (with dark staining)	Inert	NA
BHD	Natural Soil – Weathered Shale (with dark staining)	Inert	NA
BHF	Natural Soil – Weathered Shale (with free tar)	Solid	NA

Notes:
[A] – This classification can only be applied after following specific guidance in the general approval for immobilisation for each particular waste stream.

NSW DEC General Approvals of Immobilisation

The NSW DEC provide general approvals of immobilisation for specific contaminants of concern. Two general approvals can be applied to the waste materials at the Site. These are:

- Ash, ash-contaminated natural excavated materials or coal-contaminated natural excavated materials (Approval # 1999/05); and
- Coal tar contaminated soil from former gasworks sites, which has been treated (Approval # 2005/14).

When applied appropriately, the general approval mechanism has a significant impact on the preliminary waste classification, only for those materials impacted by ash/coke or tar. An indicative waste classification is given in **Table 8.17** using the general approvals mechanism. The indicative waste classifications provided for the materials with free tar would only be appropriate following treatment of the materials.

The general approval for ashy materials can be applied directly. However, an assumption must be made for tar impacted material, that the material will undergo treatment prior to applying the general approval mechanism. The approval for coal tar specifically calls for treatment by stabilisation with calcium or magnesium based cement. Other specifics of the coal tar general approval preclude materials impacted with:

- PAHs exceeding 13,000mg/kg;
- B(a)P exceeding 500mg/kg;
- Non-halogenated phenol exceeding 2,000mg/kg; and
- Total Cyanide exceeding 4,000mg/kg.

A comparison of the above approval limits to the concentrations in tar samples from the tar wells and the pipework (as reported in **Table 8.9**) shows exceedances of the limits for B(a)P and PAHs. Therefore the general approval may not be applied appropriately to these materials. However, the concentrations of these contaminants in the fill/soils impacted by free tar (as reported in **Table 8.13** and **Table 8.14)**

indicate that the general approval is likely to be applicable. This may indicate that the tar within the tar wells and pipework contains a more pure type of tar.

It is noted that the concentration of PAH in sample MG08 at 1.5mbgl also indicates concentrations that exceed the general approval limits, suggesting a more pure type of tar at this location also.

It should be noted that the presence of asbestos materials will have an impact on the classification of these materials. The asbestos impacts appear localised and linked to site areas where demolition wastes have been buried. In particular, the materials inside the Northern Gasholder, given the presence of large quantities of asbestos fibro sheeting, would be automatically classified as Industrial waste, following the NSW DEC waste classification guidelines (1999).

8.5.3 Neutral Leach Natural Soil Results

Neutral leach analysis was conducted on the natural soil samples indicated in **Table 8.18**. In all, 3 samples were selected and analysed to provide indicative results and concentrations of contaminants that are potentially leaching (via 'neutral' water infiltration) through fractures in the deep weathered shale zones. This procedure was undertaken to emulate the leaching process under the existing site contamination status and natural conditions, to give a representation of the potential ongoing impacts to groundwater from source zones (such as the Gasholders and Tar Wells). Site groundwater was not considered appropriate for this test given the existing high impacts in the groundwater.

Table 8.18 – Neutral Leach Analysis

Weathered Shales		
Sample	Depth (mbgl)	Material Description/Site Area
BHA1	7.0	Natural Soil – Weathered Shale (dark staining) underneath the Southern Gasholder
BHD	8.4	Natural Soil – Weathered Shale underneath the Northern Gasholder
BHF	8.5	Natural Soil – Weathered Shale (free tar) underneath the former Gas Purifier area

The results presented in **Table 14** for Weathered Shale materials indicate relatively moderate leachable concentrations for organic contaminants for materials underneath the Northern Gasholder and the fractures shale at sample location BHF. The results were compared against ANZECC 2000 trigger values at 95% protection levels. Also, the neutral leach results were compared against the TCLP results for the same samples. Although no results exceed the ANZECC 2000 criteria, neutral leach results showed a similar leaching capacity to the TCLP analysis. However, the neutral leach results showed a higher propensity to leach TPHs and PAHs than the TCLP analysis. This can be said for:

- BHF – TPH (C_{10}-C_{14}) (6.99mg/L) and Naphthalene (3.13mg/L) at 8.5mbgl.

These findings indicate that the infiltration of rainwater and migrating groundwater into these fill/soil types have the potential to leach organic compounds at concentrations that may result in impacts to groundwater.

The results for the material underneath the Southern Gasholder (represented by sample BHA1/7.0m) indicate that this material is unlikely to leach or have a low

propensity to leach as a worst case scenario. If this is the case, then the dark staining identified underneath the Southern Gasholder is unlikely to be providing a contamination source that adds to the contamination load of the deeper groundwater system. The impacts are more likely to originate from the source areas underneath the Northern Gasholder and areas were free tar was observed, including deep weather shale areas (i.e. at sample location BHF).

8.6 Surface Water Analytical Results

A total of 6 surface water samples were collected to assess contamination impacts of water contained in buried structures that may be subject to remediation for future Site redevelopment. The water would need to be removed from these structures prior to remediation, therefore it was important to understand the degree of impact and understand appropriate management options to deal with the water. The samples were collected from the following locations:

- Sample W01 – water that had accumulated in sampling trench MG04 located inside the brick annulus of the Northern Gasholder. The annulus of this Gasholder is providing a low permeable barrier and therefore any rain falling on the unsealed ground inside the annulus is retained. This has the effect of a much shallower groundwater (0.5mbgl) compared to levels outside the annulus (approximately 2.0 – 2.5mbgl at MW06). Effectively the annulus acts like an inground pool
- Sample W02 – water that had accumulated in Tar Well #1 (western tar well).
- Sample W03 – water that had accumulated in Tar Well #2 (eastern tar well). This sample was collected after disturbing the tarry materials that were contained in the base of the well, which produced a free phase product that floated on top of the water in this Tar Well.
- Sample W04 – water that had accumulated in the Retention Pit at the southern side of the Southern Gasholder.
- Sample W05 – water that had accumulated in the brick annulus of the Southern Gasholder.
- Sample W06 – water collected from the base of the Southern Gasholder.

Surface water sample results were assessed for quality against the ANZECC 2000 Freshwater trigger value criteria for 95% protection of species.

Table 15 presents a summary of the surface water samples. A summary of results that exceed the ANZECC (2000) trigger values adopted for this investigation is presented in **Table 8.19** below.