northwest corner of the 'triangle' to Burren Street. The Site area is vacant land that has tall trees growing along the western and northern boundaries.

The Southern Gasholder is a prominent relic of the past gasworks operations that stands against the western boundary and reaches approximately 12m from the ground surface. Other structures include:

- brickwork at ground level, associated with the former Northern Gasholder;
- the in-ground Tar Wells located adjacent and to the north east of the Northern Gasholder brick annulus, that appear as two circular concrete lids at the ground surface;
- a small shed known as the Connection Shed located in the Southwest Area;
- retaining walls/embankments along the northern boundary including the small rectangular portion of the Site adjoining Burren Street; and
- a concrete service trench and a shallow surface drain located along the western boundary.

The ground surface appears hard and gravelly in the main central sections of the Site and overgrown with grasses and shrubs in the outer perimeter areas along fence lines. The health of existing vegetation appears to be generally in good condition, given the overgrown state of grasses and shrubs. No dead or dieing vegetation was observed or signs of vegetative stress.

Other features of the Site include small stockpiles of materials such as ballast, decaying vegetation (tree stumps) and spent car tyres.

A photographic record of the Site along with locations of photographs is presented in **Appendix A.**

2.3.1 Topography

The Site is generally flat with a gentle grade that falls toward the south east. Along the western boundary that adjoins residential properties, the ground level falls off sharply to the backyards of the residential homes forming an embankment. This is considerable in the southern corner where there is a surface level difference of approximately four metres.

The ground surface of the adjoining northern property (Stabling Yards) is approximately 2m higher than the gasworks site, and this surface elevation extends into the gasworks site up to five metres in some places, where an old retaining wall was constructed.

2.4 Lithology

The Sydney Geological Series Sheet 9130 (C. Herbert, 1999) indicates that the geological formation underlying the Site is the Wianamatta Group Ashfield Shale comprising black to dark-grey shale and laminite.

The Sydney Soil Landscape Series Sheet 9130 (G. A. Chapman et. Al, 1999) indicates that the Site soils are of the Residual Blacktown Grouping, consisting of:

> *Landscape – gently undulating rises on Wianamatta Group shales and Hawkesbury shale. Local relief to 30m, slopes are usually <5%. Broad rounded crests and ridges with gently inclined slopes. Cleared woodland and tall open-forest.*
>
> *Soils – shallow to moderately deep (<100cm) Red and Brown Podzolic Soils (Dr3.21, Dr3.11, Db2.11) on crests, upper slopes and well-drained areas; deep (150-300cm) Yellow Podzolic soils and Soloths (Dy2.11, Dy3.11) on lower slopes and areas of poor drainage.*
>
> *Limitations – moderately reactive highly plastic subsoil, low soil fertility, poor soil drainage.*

2.4.1 Fill Material

Based on the findings of previous investigations, the fill materials identified at the Site can be grouped as follows:

- Ash and Coke Gravels – observed across the majority of the Site in surface and near surface layers from ground level to approximately 0.5m depth.
- Reworked Clays – observed in subsurface layers in some site areas between 0.5m depth to approximately 1.5m depth. This material was observed in the majority of areas as general filling.
- Sands and Gravels – observed in subsurface layers in some site areas between 0.5m depth to approximately 1.5m depth. This material was observed in the North East, South Central and Gas Purifier areas.
- Gravely Sand and Clay with Minor Ash – observed in surface and subsurface layers in some site areas from ground level to approximately 3.5m depth. This material was predominantly observed in the South West area of the Site as general filling.
- Gravel, Sand and Demolition Wastes – observed in the fill embankment of the Retaining Wall and inside the annulus of the Northern Gasholder. 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 Material (ACM) and other building rubble in a gravely sand matrix.

2.4.2 Natural Soil

Based on the findings of previous investigations, the natural soil materials identified at the Site can be grouped as follows:

- Silty Clay – observed generally from between 1.5m depth to approximately 2.5m depth. This material exists across the majority of Site areas. This horizon was predominantly a saturated zone, which sustained the perched groundwater system.

- Red/Grey Mottled Clay – observed generally from between 2.5m depth to approximately 4.0-6.0m depth. The soil profile is consistent with a Red Podzolic soil, being moderately to highly plastic, stiff to very stiff, moist and mottled red/grey.
- Weathered Shale – observed underlying the natural clay. This material grades from extremely weathered to moderately weathered at depths of up to 10m depth. At depths beyond 6m, fracturing of the material is common.

2.4.3 Tar Impacts

A number of areas of fill/natural soil materials were observed to be impacted by tar. The tar impacts have been categorised as follows:

- Soil/fill impacted by free tar – consisting of soil and fill materials impacted to a high degree with black ooze, highly odorous, liquor type material;
- Tarry soils – consisting of soil and fill materials with minor tar impacts and moderate odours; 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 moderately odorous.

Soil/fill impacted by free tar is material predominately associated with former gasworks infrastructure, which include the:

- Tar Wells – shallow subsurface and deep natural soils immediately adjacent to these two structures;
- Northern Gasholder – deep natural soils immediately adjacent to the brick base annulus; and
- Old gasworks pipework – inside pipes and immediately adjacent fill/natural soils.

Tarry soils are present at similar locations, however there is spatial separation between former gasworks infrastructure and tarry soils given tars have not migrated significant distances from gasworks infrastructure. Therefore there is a layer of highly impacted soils (free tar impacts) surrounding these structures followed by less impacted tarry soils. Tarry soils are located in the following areas:

- Tar Wells, Northern Gasholder and Gas Purifier – soil and fill surrounding these source areas in surface/subsurface fill and deeper natural soils;
- Retort – fill and deep soil across the majority of this area;
- Gas Purifier – Sandy fill and deeper soils; and
- Localised impacted fill – observed in one localised pocket in the Northeast Area.

Dark stained impacts were associated with:

- the Southern Gasholder – deep soils below the base annulus.

The dark stained impacts are likely to be secondary sources within the strata in localised areas associated with the Southern Gasholder.

2.5 Hydrogeology

Previous investigations (CH2M HILL, 2000) reviewed the regional hydrogeological conditions and determined that there were 35 registered groundwater bores within a 3km radius of the Site. The nearest bore was located approximately 2km due southeast, where the majority of the bores were situated in the Botany Sands geological formation of Quaternary Sediments.

Considering this information and new information obtained from the NSW Department of Natural Resources (DNR[2]) website, it can be said that there are no registered bores located within the shale bedrock for purposes other than groundwater monitoring within 3km of the Site, and there are unlikely to be any users of extracted groundwater in the vicinity of the Site and down gradient in the extent of the plume that lies beneath RailCorp owned land.

The groundwater system exists as a shallow perched groundwater layer and a deep bedrock layer. The shallow groundwater exists within fill materials and silty clay above the natural clay (as shallow as 1m below ground surface), and the deeper groundwater exists within the Ashfield Shale bedrock under semi-confinement.

The groundwater flow gradient was determined in previous investigations (CH2M HILL, 2000 and 2001; SKM, 2006) to be toward the south/southeast for both shallow and deep groundwater systems, however flows are likely to be influenced by underground structures, including the gasholders annuli and underground waste pits and services associated with gasworks sites. It is possible there may be some interconnectivity given the similar direction of flow gradient.

Flow velocities within the shallow groundwater are estimated to be 6.2 – 13.7m/year, while within the deep groundwater are 12.2 – 36.5m/year (SKM, 2006). However, these values do not correlate with the lateral extent of the plume, given that gasworks operations began over 100 years ago.

2.6 Future Site Use

The exact future use of the Site is unknown. However, considering the current zoning and rail land bordering the north and south of the Site, it is anticipated that the future use of the Site will be rail-related under a commercial/industrial land use scenario.

[2] *The DNR is now part of the Department of Water and Energy (DWE)*

3 Site Contamination Status

The results from analytical testing and characterisation of the Site are discussed in the following sections. This section draws on the results of the previous investigations listed in **Section 1.6**, including the most recent delineation investigation by CH2M HILL (2007).

The contamination status of the Site soils is relative to the existing and proposed commercial/industrial land use setting and corresponding land use criteria.

3.1 Soils

The analytical results for all previous fill and natural soil samples are provided in **Table 1** and **Table 2** in the Tables section at the rear of this RAP. The locations of previous sampling points are presented on **Figure 3**.

Representative samples were collected using a combination of test pits, trenches and bore holes.

3.1.1 Fill

Organic Compounds

The results indicate that the following contaminants report a high number of samples that exceed the relevant commercial/industrial land use land use criteria. The contaminants include:

- benzo(a)pyrene (BaP);
- total polycyclic aromatic hydrocarbons (PAH);
- total petroleum hydrocarbons (TPH) (C_{10}-C_{36});
- benzene; and
- xylenes (total).

PAH and B(a)P impacts are governed by the presence of tar in fill material proximal to source areas including underground tar pipes, the Retort area, Tar Wells and the Gas Purifier. The other major source of PAH and B(a)P impacts is a layer of ash/coke material covering the majority of the Site surface to a depth of approximately 0.5m.

TPH impacts can be attributed to the presence of PAH, considering analytical results indicate that the main constituents of the TPH impacts comprise aromatic compounds (SKM, April 2006). Therefore, it can be said that impacts from TPH are directly linked to the presence of PAHs. This is important for understanding the contaminants of concern (**Section 3.5**) and setting validation criteria (**Section 4**).

Benzene and xylene impacts are related to the presence of tar in fill material proximal to source areas and also to the surface ash/coke fill layer. One benzene impacted area was identified within ashy fill within the Retaining Wall at location TP44.

The remainder of the organic contaminants report relatively low concentrations that meet the relevant land use criteria.

Inorganic Compounds

The majority of metal contaminants report concentrations that meet the land use criteria, with the exception of three samples that exceed the criterion for lead (Pb). These samples include sample number MG04/0.5m, which represents the fill material inside the annulus of the Northern Gasholder, while sample numbers VP01_6 and VP02_2 represent the surface fill material in an area south of the Southern Gasholder.

Reported cyanide contaminant concentrations meet the relevant land use criteria.

Asbestos

All fibrous cement fragment samples collected from the surface and subsurface layers indicate the presence of asbestos. Fill samples collected from inside the Northern Gasholder (MG04) and from the Retaining Wall (TP12) also indicate the presence of asbestos.

The asbestos present in these samples is within a bonded matrix. However, the age and weathered state of these materials may have the potential to generate free fibres.

3.1.2 Natural Soil

Organic Compounds

The results indicate similar high numbers of samples that exceed the relevant land use criteria for some organic compounds as listed for fill materials (**Section 3.1.1**).

In particular, the volatile compounds benzene, xylenes and TPH (C_6-C_9) were reported with a higher ratio of exceeding values compared to fill material. The reasons for this occurrence are likely to be a combination of:

- Higher solubility rates of shorter chained hydrocarbons that become mobile with infiltrating water or migrating groundwater;
- Volatilisation of these compounds from shallower fill materials;
- Higher impacts from leakage of tarry wastes from deep subsurface storage areas, especially from the Tar Wells and the Gasholders; and
- Vertical fracturing of natural clays and weathered shales, which provide a preferential pathway into deeper soils.

The remainder of the organic contaminants report relatively low concentrations that meet the relevant land use criteria.

Inorganic Compounds

Metal and cyanide contaminants report relatively low concentrations that meet the relevant land use criteria.

3.1.3 Tar Material

Tar Impacted Soils

Tar material within the fill/natural soil matrix is prevalent in areas proximal to the former gasworks structures and specific site areas including:

- the Tar Wells (Retort area);
- the network of underground pipes;

- the base annulus of the Northern Gasholder (Gasholder area); and
- the Retort and Gas Purifier areas – where tar exists in soil pores and soil fractures.

These areas are providing a source of gross contamination and appear as hotspot[3] areas for one or more of the contaminants, PAH, TPH and BTEX.

Table 3.1 below presents the results of tar impacted fill and natural soils (refer to **Figure 3** for sample locations).

Table 3.1 – Tar Impacted 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	Ethylbenzene	Total Xylenes
Fill Profile									
MG02	Gasholder	1.8	**178.0**	**5,301.9**	**189.0**	**36,140.0**	**3.0**	30.2	**165.8**
BH07	Retort	1.4-1.5	**26.0**	**1,144.8**	-	-	Nd	8.0	**32.0**
TPA	Retort	1.6	**8.4**	**536.9**	**100.0**	**3,200.0**	**1.6**	7.0	**65.0**
TPC	Retort	1	**8.4**	**750.6**	-	-	Nd	9.0	**48.0**
MG06	Retort	1.0	2.0	**135.0**	18.0	**1,270.0**	0.2	3.0	9.5
MG08	Retort	1.5	**444.0**	**15,237.6**	51.0	**435,100.0**	0.2	3.6	10.6
MG08	Retort	2.1	**6.9**	**321.2**	**97.0**	**2,790.0**	0.3	12.3	6.0
MG09A1	Retort	0.7	**8.2**	**416.6**	39.0	**3,520.0**	**1.7**	2.4	21.0
BH18	Gas Purifier	1.7-1.8	**28.0**	**2,160.8**	-	-	**7.0**	**80.0**	**210.0**
MG11	Gas Purifier	2.0	**48.8**	**728.8**	10.0	**7,750.0**	Nd	Nd	Nd
TP16	Northeast	1.0	**39.4**	**425.1**	**166.0**	**7,640.0**	**3.1**	6.4	**61.2**
Natural Soil Profile									
BHC	Gasholder	6.0	**17.6**	**1,906.4**	**559.0**	**8,760.0**	**6.4**	40.8	**246.7**
BHD	Gasholder	7.0	Nd	Nd	8.0	Nd	**5.4**	0.7	1.6
BH12A	Retort	4.2	**13.9**	**515.6**	**228.0**	**5,350.0**	**20.0**	8.3	**94.9**
MG06	Retort	2.0	0.8	**101.5**	41.0	**1,600.0**	Nd	6.9	22.7
TP15	Retort	2.8	**10.8**	**426.2**	**107.0**	**2,090.0**	**1.8**	17.5	**56.2**
TP15	Retort	4.1	0.5	18.1	**65.0**	Nd	**2.7**	4.9	24.8
TP15A	Retort	6.0	Nd	0.8 (naphthalene)	Nd	Nd	Nd	Nd	Nd
BHG	Retort	6.0	1.0	76.6	24.0	380.0	**2.4**	1.3	8.7
BHF	Gas Purifier	7.0	Nd	0.8 (naphthalene)	7.0	Nd	0.8	Nd	1.0
BHF	Gas Purifier	8.5	1.1	**134.6**	22.0	**1,260.0**	0.8	1.9	9.8

Notes:

Bold – Exceeds investigation criteria.

Bold and shaded – Exceeds contamination hotspot criteria.

Nd – Not detected.

[3] *Chemical concentrations exceed 250% of the site land use criteria.*

The results show that tar impacts are limited to the former gasworks footprint area (i.e. Gasholders, Retort, Gas Purifier) and are unlikely to persist in areas away from the former gasworks footprint, such as in the Northeast, South Central, Southwest, Retaining Wall or the Western Lot site areas. However, the presence of a localised tar impact in the Northeast Area of the Site at sample location TP16 indicates there is the potential for other areas of localised impact where tarry material may have been dumped or buried on site.

Although the network of gasworks related pipework was delineated to some extent in the previous investigation report (CH2M HILL, March 2007), it should be noted that in areas that were not delineated, pipework, if present have the potential for additional tar impacts that may be encountered during remedial excavation works.

Tar Source Material

Samples of tar were collected from three tar source structures (one Tar Well and the content of two buried pipes). These samples comprised minimal (if any) soil material. The results of these samples are presented in Table 3.2.

Table 3.2 – Tar Source Material

Sample Identication	MG09B/PIPE	RP/PIPE	TAR WELL #2
Analyte			
Benzo(a)pyrene	**595.0**	**491.0**	**164.0**
PAHs total	**26,805.3**	**20,889.8**	**25,557.6**
TPH C6 - C9	**3,770.0**	**70.0**	**6,690.0**
TPH C10 - C36	**1,180,000.0**	**24,660.0**	**98,700.0**
Benzene	**576.0**	**2.0**	**814.0**
Ethylbenzene	**156.0**	1.1	**254.0**
Toluene	**1,210.0**	3.6	**1,680.0**
Xylene Total	**1,516.0**	**47.4**	**3,170.0**

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

These results indicate significantly high concentrations of contaminants, which is discussed further in terms of waste classifications in **Section 3.1.5**.

Dark Stained Impacts

Dark stained 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 appears different in nature to the tars observed at the base of the annulus of the Northern Gasholder. Dark stained materials were only observed underneath the Southern Gasholder.

Minimal contamination impacts were reported beneath the Southern Gasholder, this includes benzene impacts at 10m depth at a concentration of 1.6mg/kg.

The primary source of tar at the Site originates from the former gasworks structures listed in **Section 3.1.3**, whereas the dark stained impacts are likely to be secondary sources within the strata in localised areas associated with the Southern Gasholder.

Dioxins/Furans

A sample of tar was analysed for polychlorinated dibenzo dioxins and polychlorinated dibenzo furans (PCDD/F), which reported a concentration of 1.1pg/g. This concentration is marginally above the laboratory detection limit (0.0409pg/g) and well below the lower comparison criterion (USEPA, 1998) of 5,000 – 20,000pg/g, indicating that PCDD/F at these concentrations would not pose a human health or ecological risk. Additionally, dioxin at these levels would not require remedial action.

3.1.4 Leaching Potential

Neutral water leaching tests were conducted on three deeper natural soil samples collected from between 7.0m and 8.5m depth from areas below the Southern Gasholder, below the Northern Gasholder, and below the Gas Purifier area.

The results indicate that contaminants will leach under neutral conditions from the Northern Gasholder and Retort (deep tar impacted soil) source areas. The results show the contaminants that are likely to leach include benzene, xylene, naphthalene and C_{10}-C_{14} fraction TPH (from aromatic compounds). The propensity for these particular compounds to leach correlates well with higher water soluble compounds being prevalent in deep soil layers (**Section 3.1.2**).

The results also indicate that contaminants are unlikely to leach under neutral conditions from the Southern Gasholder. This supports the scenario that the dark staining is unlikely to be providing a contamination source and there is unlikely to be a source of tar material below this gasholder.

3.1.5 Preliminary Waste Classifications

The previous delineation investigation (CH2M HILL, March 2007) provided preliminary waste classifications on waste materials existing at the Site. This information is summarised below.

In general, soil/fill impacted by free tar (i.e. materials impacted with gross quantities of tar) can be classified as hazardous waste based on the concentrations of B(a)P and PAH. This follows the guidance provided in NSW EPA (1999) Waste Guidelines. However, the waste classification is likely to be dependent on the quantity of free tar within the soil media and the proximal location to source areas.

Tarry soils (i.e. soil and fill that has been impacted with tar to a lesser degree) can be classified as either hazardous or industrial wastes, dependent on the degree of impact. This can be seen in areas away from the source areas, such as the soils underlying the Retort.

The majority of ash/coke surface fill can be classified as hazardous waste primarily based on concentrations of B(a)P.

The material buried within the annulus of the Northern Gasholder is industrial waste given the leachable concentrations of lead and the presence of asbestos containing demolition materials.

Other general fill materials away from the main gasworks area can be classified as either solid waste or inert waste. However, fill materials within the Retaining Wall contain asbestos containing materials such as fibro sheeting fragments and would need to be classified accordingly as asbestos impacted-solid waste material.

NSW EPA General Approval for Immobilisation

Two general approvals can be applied to the waste materials at the Site. These are:

- Approval # 1999/05 – which can be applied to ash, ash-contaminated natural excavated materials or coal-contaminated natural excavated materials; and
- Approval # 2005/14 - which can be applied to coal tar contaminated soil from former gasworks sites, which has been treated in accordance with the approval specifications.

When applied appropriately, the general approvals give an indicative waste classification for:

- Ash/coke fill as – "solid waste";
- Tar impacted soils after treatment – "solid or industrial waste".

The general approval for coal tar contaminated soil cannot be applied to materials unless they have been treated specifically to immobilise the contaminants. Also, the general approval cannot be applied to materials that contain concentration of contaminants in the untreated waste that exceeds the following limits:

- Polycyclic aromatic hydrocarbons (PAHs) – 13,000 mg/kg
- Benzo(a)pyrene (BaP) – 500 mg/kg
- Non-halogenated phenols – 2,000 mg/kg
- Total cyanide – 4,000 mg/kg

For example, the tar source material in Table 3.2 contain B(a)P and PAH concentrations that exceed the approval specifications.

Copies of the applicable general approvals are provided in **Appendix E**.

3.2 Groundwater

Previous investigations included the installation of groundwater monitoring wells on the Site and off site on RailCorp owned land down gradient of the Site.

Elevated concentrations of inorganic and organic contaminants have been reported in both groundwater systems. Concentrations of PAH, TPH (predominantly C_{10}-C_{36}), metals, phenols and BTEX exceed the ANZECC (2000) guidelines. The concentration of TPH in the C_6-C_9 range also exceeds the solubility limit in water in the deep groundwater system in the vicinity of the Gasholders, although no light-non-aqueous-phase-liquids (LNAPL) have previously been encountered in any groundwater monitoring wells. Also, there has been no identification of dense-non-aqueous-phase-liquid (DNAPL) in any groundwater monitoring wells.

Concentrations of contaminants are lower in the shallow groundwater compared to the deeper groundwater, indicating that the source of groundwater contamination is most likely the tarry waste and sludge accumulated in the Tar Wells and the base annulus of the Northern Gasholder.

The shallow groundwater contamination plume extends 75m to the south and 50m to the east of the Site, while the deep groundwater contamination plume extends 160m to the south and 50m to the east. Off site monitoring of groundwater has determined that the plumes are limited to RailCorp owned land. This land is used for operational railway purposes.

The background water quality at the site is also impacted by some heavy metals, including cadmium, copper, nickel and zinc.

Table 3.3 below provides a summary of the groundwater contamination at the Site.

Table 3.3 – Summary of Groundwater Contamination

	Criteria	Shallow Groundwater			Deep Groundwater		
Analyte	**ANZECC 2000**	**Concentration Range**	**Highest Conc. Location**	**Site Area**	**Concentration Range**	**Highest Conc. Location**	**Site Area**
As	24 (AsIII)	nd - 12	MW42s	Northeast	nd - 20	MW42d	Northeast
Cd	0.2	nd - 2.6	MW13s	Southwest	nd - 1.5	MW06d	Gasholders
Cr(total)	-	nd - 15	MW04s	South Central	nd - 7	MW04d	South Central
Cu	1.4	nd - 220	MW42s		0.001 - 208	MW42d	Northeast
Pb	3.4	nd - 174	MW42s	Northeast	nd - 140	MW03d	South Central
Hg	0.06	nd	-	-	nd - 0.0003	MW03d	South Central
Ni	11	nd - 10	MW04s	South Central	nd - 92	MW36d	Offsite
Zn	8	0.033 - 1,570	MW13s	Southwest	0.015 - 869	MW42d	Northeast
Cyanide (total)	7	0.02 - 0.479	MW20s	Gasholders	nd - 14.9	MW03d	South Central
Benzene	950	nd - 704	MW07s	Gasholders	nd - 14,000	MW03d	South Central
Toluene	-	nd - 117	MW07s	Gasholders	nd - 792	MW03d	South Central
Ethylbenzene	-	nd - 213	MW07s	Gasholders	nd - 317	MW03d	South Central
Total Xylenes	550 (o & p)	nd - 417	MW07s	Gasholders	nd - 5,010	MW03d	South Central
TPH (C6 - C9)	-	nd - 2,170	MW07s	Gasholders	nd - 28,800	MW03d	South Central
TPH (C10 - C36)	-	nd - 9,495	MW07s	Gasholders	nd - 18,220	MW07d	Gasholders
Total PAHs	16 (naphthalene)	nd - 1,677 (naphthalene 1,460)	MW07s	Gasholders	nd - 4,208 (naphthalene 3,840)	MW07d	Gasholders

Note: "nd" is 'Non Detect', or less than the laboratory Limit of Reporting (<LOR).
All concentrations in µg/L.

3.3 Surface Water

Previous sample results indicate that water accumulated in the Site structures are impacted to varying degrees with both organic and inorganic contaminants. These structures constitute the main sources of surface water at the Site and include the Tar Wells, the Northern and Southern Gasholders, and shallow fill material. Generally the organic contaminants include the more soluble compounds including naphthalene and BTEX. Also, the waters show moderate to high concentrations of TPH. Metal impacts include cadmium, copper, lead nickel and zinc.

3.4 Vapours

The SKM (March 2006) investigation reported results of soil gas samples and the results of a computer simulation of potential vapour generation, based on actual soil and groundwater concentrations. The soil-gas assessment was targeted at volatile (BTEX) and some semi-volatile contaminants (PAH).

The results of the soil gas analyses indicated:

- Concentrations of benzene, ethylbenzene and xylenes below the LORs;
- Concentrations of toluene ranging from below the LOR to 28mg/m^3;
- Concentrations of PAH below the LORs; and
- Concentrations of naphthalene ranging from below the LOR to 0.00541mg/m^3.

The report concluded that:

> *"All test results measured concentrations of BTEX and PAHs well below the WorkCover Exposure Guidelines."*……and……*"These results suggest there may be a low risk that soil-gas vapours at the former gasworks site are an environmental media of concern."*

The results of the computer simulation indicated a significant difference to the soil-gas analyses, where:

- Concentrations of benzene, ethylbenzene and xylenes were simulated as ranging from below LOR to 103mg/m^3, 39.2mg/m^3 and 64.9mg/m^3, respectively;
- Concentrations of toluene were simulated as below LOR;
- Concentrations of naphthalene were simulated as ranging from below the LOR to 661mg/m^3; and
- Concentrations of the remaining PAH were simulated as ranging from below the LORs to marginally above the LOR.

The report concluded the reasoning behind the significant differences as:

> *"……the results of the computer analyses show that much higher soil-gas levels may occur if the higher volatile concentrations measured in the earlier groundwater monitoring rounds and/or higher soil concentrations measured in some shallow soil samples are more representative of site conditions."*

Based on this conclusion, there is a potential for vapours to be generated by impacted soil and groundwater that may be a potential risk to human health if exposed.

3.5 Contaminants of Concern

The following are considered contaminants of concern for the Site, based on historic site operations and the contaminants detected during the previous site investigations.

The contaminants for soil media include:

- monocyclic aromatic hydrocarbons (MAH), being benzene, toluene, ethylbenzene & xylenes (BTEX));
- polycyclic aromatic hydrocarbons (PAH);
- phenolic compounds (phenol and cresol isomers);
- heavy metals (localised fill materials); and
- asbestos.

The contaminants for water include those contaminants for soil above (excluding asbestos) and also:

- metals including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni) and zinc (Zn); and
- cyanides.

The contaminants for vapours (soil gas) would include those volatile compounds above, which include:

- BTEX and naphthalene (PAH).

TPH were excluded from the list of contaminants of concern considering the main components of TPH are aromatic compounds (SKM, March 2006), which includes the total concentrations of BTEX, PAH and phenolic compounds.

3.6 Areas of Environmental Concern and Contamination Sources

The areas of environmental concern and contamination sources at the Site include:

- Tar in the Tar Wells;
- Tar residues in the network of underground pipework;
- Tar residues in the base annulus of the Northern Gasholder;
- Tar in soil pores and soil fractures in former gasworks areas;
- Potential tar residues in the base annulus of the Southern Gasholder (although not a major source, this area should be identified as a secondary source given the historical use and the marginally elevated concentrations of contaminants;
- Demolition wastes containing asbestos sheeting; and
- Ash and Coke fill materials across the majority of the Site in the surface and shallow subsurface layers

3.7 Exposure Routes and Receptors of Contamination

The human health and ecological risk assessment (SKM, March 2006) concluded that contamination at the Site would present an unacceptable health risk to onsite long term RailCorp employees and onsite short term construction/maintenance workers. The exposure routes determined by SKM for these receptors are:

- Onsite long-term RailCorp employees via dermal contact or ingestion of soils.
- Onsite short-term construction/maintenance workers via dermal contact or ingestion of soils, and dermal contact with groundwater.

The risk assessment concluded that contamination at the Site would present a low health risk to other identified receptors including residents or construction workers at neighbouring residential properties and freshwater aquatic ecosystems at the head waters (stormwater drainage) of the Alexandra Canal.

The vapour risk modelling undertaken during the human health and ecological risk assessment (SKM, March 2006) indicates the potential for the generation of vapours at concentrations that may pose an unacceptable risk to site users listed above (refer to **Section 3.4**). Therefore inhalation of vapours should also be considered as an exposure route to the identified receptors.

3.8 Rationale for Soil Remediation

To meet the long term objectives for the Site, remediation is required to protect the health of the receptors listed above by removing or controlling the identified unacceptable health risks.

The contaminants that drive the health risks are the known carcinogens, benzene and B(a)P. These contaminants have a direct relationship to the tar source material and the ash/coke surface fill. Therefore remediation of the tar sources and the ash/coke fill will mitigate the health risks these contaminants pose on the receptors. This will manage the risks by restricting direct exposure.

Remediation of the tar sources accumulated in the Northern Gasholder annulus and the Tar Wells, and remediation of tarry impacted soils from the Retort and Gas Purifier areas will also protect the environmental values of the site groundwater by focusing on source removal and a reduction in mass contamination. This will manage the risks by minimising or preventing future leaching of contaminants to groundwater.

3.9 Extent of Remediation

CH2M HILL, March 2007 provided the following summary of the extent of required remediation. This is summarised in Table 3.4

Table 3.4 – Summary of Remedial Extent

Remediation Area	Impacted Area	Estimated Volume (m^3)	Waste Material
Tar Wells	Base annulus and immediate area	1,000	Soil/fill impacted by free tar
	Tar Well contents	100	Tar sludge
Northern Gasholder	Base annulus and immediate area	2,100	Soil/fill impacted by free tar
	Gasholder contents	640	Impacted water
		320	Tar sludge
	Buried wastes inside annulus	1,900	Demolition
Former Gasworks Area	Shallow Fill/Soils	9,225	Tarry soils - fill and natural clays
	Deeper Soils	2,375	Tarry soils - natural clays and weathered shales

	TP16 Hotspot	115	Tarry soils - fill and natural clays
Site Surfaces		2,950	Ash and Coke Gravels
Retaining Wall		1,765	Gravel Sand and Demolition Wastes
Hotspots	BH14	100	Fill and natural clays
	MW13s	140	Fill
	MW04s	100	Fill and natural clays
Pipework	Varying across site	unknown	Tar/ scrap metal

The required remediation and the selection of the preferred remedial approach is discussed further in **Section 5**.

3.10 Evaluating Risk Posed by Contaminated Groundwater

The management of groundwater contamination will be a long term objective of the soil remediation project. Previous investigations (CH2M HILL, March 2007) had concluded that groundwater remediation was not considered necessary given:

- groundwater conditions have been adequately assessed under previous site investigations;
- existing groundwater data concludes that the contaminated groundwater plumes are limited to land owned by RailCorp, which is used for rail and rail-related industrial purposes;
- adjoining residential properties (along Burren Street) have not been impacted by contaminated groundwater, considering that migration is toward the south east away from these properties;
- no sensitive receptors of groundwater are present in the area down gradient of the Site (i.e. on RailCorp industrial land);
- the Groundwater Embargo area (Zone 2) established by the Department of Natural Resources (DNR) is located immediately down gradient of RailCorp land, which bans the extraction of groundwater for domestic purposes; and
- groundwater quality will be improved subsequent to removal of contamination sources and contaminated fill and soil materials. The removal of these source materials will mitigate ongoing groundwater contamination.

It is therefore considered that active groundwater remediation is not required as part of site remediation, however ongoing management (including monitoring) of groundwater is likely to be a requirement of future site management.

The points above are further supported by the following appraisal of the environmental values of the Site groundwater in its regional context and resource value.

Relevance of Beneficial Use of Site Groundwater:- Both shallow and deep groundwater systems are not sustainable groundwater resources given the aquifer

yields (both regional and local) would be insufficient to sustain a use for the groundwater. The shallow system is perched, discontinuous and limited in storage capacity; moreover the deeper system is within shale rock of the Ashfield Shale formation of low storage value. There are no registered bores located within 3km of the Site that utilise deeper groundwater within the shale bedrock for purposes other than groundwater monitoring. Therefore there are unlikely to be any users of extracted groundwater in the vicinity of the Site and down gradient in the extent of the plume. Based on this, the groundwater resource is considered to be of low value.

Protecting Aquatic Ecosystems:- Assimilative capacity and self-purification can be dependent on microscopic organisms in the groundwater. The localised groundwater system is likely to sustain a Groundwater Dependant Ecosystem (GDE) as a hypogean system (refer to NSW State Groundwater Dependency Policy, Department of Land and Water Conservation, April 2002). These organisms have water quality benefits – where microfauna in the groundwater help 'clean-up' contaminants. The urban setting of the Site suggests direct protection of the GDE may not be possible due to the existing degraded groundwater system(s). Therefore maintaining the groundwater from degrading further by specifically removing sources from the gasworks site would be the objective of protecting the GDE.

Potable Water:- The groundwater is not identified as a drinking water supply by the NSW DNR. There are no registered groundwater users in the site vicinity or within the plume, while a groundwater Embargo Area for domestic use exists down gradient of RailCorp land including the Site. Low yields and salinity levels would preclude the groundwater as a potable water resource.

Relevance of other Environmental Values:- Given low yields and sustainability, the groundwater is an unlikely resource for irrigation or agricultural activities. The release to surface water environments is unlikely given impacts have been continuing for over 100 years and the contamination plume has only migrated 160m from the Site. The nearest surface water receptor is the Alexandra Canal, located approximately 1.5km to the southeast of the Site, therefore contaminated groundwater is unlikely to discharge into the Canal. Consequently no recreational, aesthetics or aquaculture environmental values need protecting.

The above appraisal indicates that the value of the groundwater resource is relatively low at the Site and down gradient of the Site.

4 Remediation Goals and Validation Criteria

This section presents the determination and rationale behind setting the remediation goals and validation criteria.

4.1 Soil Validation Criteria

The primary component of soil remediation is to address unacceptable human health risks and to protect groundwater from ongoing impacts. Tar sources are the main component of contamination risk in that regard and are likely to drive the extent of soil remediation. A set of criteria needs to be established that define an appropriate end point to the extent of remediation that consider the protection of sensitive receptors.

Future site users will be short-term construction/maintenance workers and long-term RailCorp employees. To address the human health risks, these receptors would need protection from dermal contact, ingestion of impacted soils and potential inhalation of vapours, as indicated in **Section 3.7**. The significance of these exposure routes would be directly related to a certain depth, beyond which these health risks would be low or negligible, given that the exposure pathway would be incomplete or not existent. Below this certain depth the importance of protecting the site groundwater would become the main objective rather than protecting human health. For this reason, generic criteria can be used to a certain depth, beyond which risk-based criteria can be used.

The health risk assessment (SKM, April 2006) indicated that dermal contact and ingestion of soils would be exposure scenarios that exist for human receptors in the surface and near surface soils. The health risk assessment indicated that the soil material from the ground surface to a depth of 1.5m would present the greatest exposure risk, using a likely scenario of a construction/maintenance worker working in an excavated trench. Therefore the depth at which potential exposure of human receptors to impacted soil would be limited to 1.5m below the ground surface. Beyond that depth, dermal or ingestion exposure routes would be considered a low risk to humans. However, the potential exposure of humans to inhalation of vapours could still exist with respect to contamination below a depth of 1.5m.

Generic conservative criteria that are protective of human receptors to dermal and ingestion exposure risks associated with impacted soils from the ground surface (0.0m) to a depth of 1.5m have been adopted for validation of soils, as discussed in **Section 4.1.1**.

Site-specific risk-based depth criteria that are protective of human receptors to potential inhalation exposure risks associated with impacted soils will be adopted for validation of soils below 1.5m depth to a depth of 8.0m, as discussed in **Section 4.1.2**.

The approach to protect groundwater from ongoing impacts is discussed in **Section 4.1.3**.

4.1.1 Generic Criteria for Shallow Soils

The generic criteria that will be used for soil validation to a depth of 1.5m have been adopted from the Health Investigation Levels (HILs) listed in the NSW DEC

Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd Edition), 2006 (DEC, 2006).

In consideration of the proposed future land use of the Site, HILs in Column 4 of Appendix II in NSW DEC (2006) relating to commercial and industrial land use scenarios, referred to as NEHF F[4] or HIL F, will apply.

In addition, the NSW EPA, *Contaminated Sites: Guidelines for Assessing Service Station Sites*, 1994 (NSW EPA, 1994), guidance document has been used to provide generic threshold concentrations for BTEX in soil to 1.5m depth.

There are currently no national or DECC-endorsed guidelines relating to human health or environmental investigation of material containing asbestos (DEC, 2006)[5]. The Department of Health issued a letter in September 2000 to the NSW EPA advising that there be no free asbestos fibres at the ground surface, for the purpose of protecting human health.

For the purposes of the remediation the validation criteria for asbestos follows that outlined in the Australian Contaminated Land Consultants Association (ACLCA), *Asbestos in Soils – Code of Practice, 2002*. The criteria adopted will be:

- No detection of fibres in surface soil; and
- No visible fragments in the surface soil.

The adopted generic (and specific risk-based as discussed below) criteria for contaminants of concern are summarised in Table 4.1.

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.

4.1.2 Risk-Based Criteria for Soils at Depth

The health risk assessment (SKM, April 2006) did not identify the inhalation of vapours generated by impacted fill and groundwater as an unacceptable health risk to human receptors. However, the health risk assessment presented results of a computer simulation of soil vapour generation potential, which indicated that vapour generation could be a risk based on previously reported contaminant concentrations in soil and groundwater. Therefore, to protect future site users from potential vapour inhalation (accumulated within buildings) it is considered appropriate to develop risk-based depth criteria to validate soil in remediated areas deeper than 1.5m (with regards to human health risks).

The potential for vapours to generate may still exist beneath this depth if source removal is limited to an extent that is practicable, however it is considered appropriate that residual source material may remain at depth if concentrations in the

[4] NEHF refers to the former National Environmental Health Forum monographs, and is now known as enHealth.

[5] It is noted that enHealth produced Guidelines for the Management of Asbestos in the Non-Occupational Environment, and while these are not currently endorsed by DECC they do provide useful reference for management of asbestos in soil. Further, there are particular regulatory requirements relating to asbestos including those in the Protection of the Environment Operations (Waste) Regulation 1996.