Prepared for

Rail Corporation NSW

Delineation & Characterisation Sampling and Review of Remedial Options

Former Macdonaldtown Gasworks – Burren Street, Erskineville, NSW



Final Report

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CH2MHILL

CH2M HILL Australia Pty Ltd
Level 7
9 Help Street
CHATSWOOD NSW 2067
Phone 02 9950 0200
Fax 02 9950 0600

Executive Summary

Introduction and Objectives

In July 2006 Rail Corporation NSW (RailCorp) engaged CH2M HILL Australia Pty Ltd (CH2M HILL) to undertake a delineation and characterisation soil sampling investigation at the Former Macdonaldtown Gasworks site located at Burren Street, Erskineville (the Site). Refer to **Figure 1** for site location.

The objectives of the project were to fill in data gaps and characterise the Site sufficiently to:

- determine areas, volumes, types of contaminants requiring remediation to meet RailCorp's long term objectives, which include removing the Significant Risk of Harm declaration, removing health risks to future site users and providing beneficial reuse for rail related activities;
- screen available remedial options and recommend appropriate options to allow long term land use objectives to be met; and
- provide indicative remedial cost estimates to implement an appropriate remedial strategy, to be provided in a separate letter to this investigation report.

Site History

The historical use of the Site has primarily been for the manufacturing of gas for use as lighting for train carriages and station lamps. The gasworks operations began in the early 1890's and ceased operations around the 1970's. Subsequent to this time, the Site has remained vacant and unused. Refer to **Figure 2** for current and historical site layout.

Scope of Work

The scope of work entailed a review of existing Site information, preparation of fieldwork safety plans, development of a Sampling, Analysis and Quality Plan (SAQP), conducting a field sampling program, analytical testing of samples and preparing an investigation report. Refer to **Figure 3** for stratified site areas and sampling locations and **Figure 4** for locations of analytical results of impacted areas. The field sampling program included the following sample locations and specific sample types:

Site Area/ Sample Type	August 2006	October 2006	February 2007	Total
Gasholder	5	7	0	12
Retort	7	5	0	12
Gas Purifier	1	2	0	3
Northeast	7	2	0	9
South Central	3	0	0	3
Southwest	4	0	0	4
Retaining Wall	3	0	0	3
Western Lot	2	0	0	2
Surface Water	6	0	0	6
Leachate	8	3	0	11
Tar (dioxin)	0	0	1	1
Total	**46**	**19**	**1**	**66**

Contamination Delineation

The following table details the vertical and lateral extent of impacted fill and soil materials that require remediation. Refer to **Figure 7** for remediation areas and excavation depth estimates.

Area	Contamination Impacts	Vertical Extent	Lateral Extent shown on Figure 7
Tar Wells/ Northern Gasholder/ Free Tar Impacts under Gas Purifier (BHE & BHF)	Tar Sources and Free Tar Impacts	8 – 10m	Pink shaded area
Former Gasworks Areas	Tarry Impacted Soils	up to 4m	Orange shaded area
Northern Gasholder	Demolition/ Asbestos	6m	Shaded blue inside buried annulus
Entire Site Surface	Ash/ Coke Fill	0.5	Yellow and orange shaded areas (excluding the Gasholders and Tar Well structures and the Retaining Wall)
Retaining Wall	Fill and Demolition	Entire thickness (approx. 1.5m)	Shaded blue along northern boundary
Contamination Hotspots	Free Tar or impacted fill	1 – 2m	Shaded green area
Underground Pipework	Residual tar	Varying over Site	Known locations identified on Figure 7

Remediation Volume Estimates

The following table details the remediation volume estimates of impacted fill and soil material. These estimates are based on the findings of vertical and lateral extent of impact provided in the table above.

Remediation Area	Impacted Area	Estimated Volume (m3)	Waste Material	Likely Waste Classification
Tar Wells		1,000	Tar	Hazardous
Northern Gasholder	Base annulus and immediate area	2,100	Tar	Hazardous
Northern Gasholder	Buried wastes inside annulus	1,900	Demolition	Asbestos/Industrial
Tar Impacted Soils	Shallow	9,225	Fill and natural clays	Industrial(a)
	Deeper	2,375	Natural clays and weathered shales	Industrial(a)
	TP16 Hotspot	115	Fill and natural clays	Industrial(a)
Site Surfaces		2,950	Ash and Coke Gravels	Solid(a)
Retaining Wall		1,765	Gravel Sand and Demolition Wastes	Solid
Hotspots	BH14	100	Fill and natural clays	Solid
	MW13s	140	Fill (southwest site area)	Solid
	MW04s	100	Fill and natural clays	Solid
Pipework	Varying across site	unknown	Tar/ scrap metal	Hazardous/ Solid

(a) assumed after treatment and applying the appropriate NSW DEC general approval of immobilisation.

Suitable Remedial Options

The investigation has identified the following available remedial options for site remediation:

- No Action;
- Institutional Controls including a Site Management Plan (SMP) and site access restrictions;

- Insitu Physical/Chemical Treatment including chemical oxidation and soil vapour extraction (SVE);
- Insitu Thermal Treatment;
- Exsitu Biological Treatment including biopiles, composting and landfarming;
- Exsitu Physical/Chemical Treatment including solidification/ stabilisation/ immobilisation and chemical extraction;
- Exsitu Thermal Treatment including incineration/co-burning and thermal desorption;
- Containment including capping and containment;
- Off site Disposal; and
- Reuse and Recycle.

Conclusions and Recommendations

The investigation has identified that remediation of the contamination sources will adequately reduce the risks associated with this Site by:

- Preventing leaching and inturn controlling/minimising ongoing groundwater contamination;
- Controlling the generation of vapours from impacted soils;
- Controlling the generation of vapours from impacted groundwater;
- Preventing exposure of onsite workers to impacted soils and vapours;
- Preventing exposure of employees and residents of adjoining properties to impacted dusts and vapours; and
- Improving the groundwater quality migrating from the Site and inturn controlling exposure of users of extracted groundwater down gradient of the Site, controlling exposure of hypogean ecosystems to toxic groundwater and controlling exposure of receiving waters to poor quality groundwater.

To assess the effectiveness of site remediation in reducing these risks, ongoing groundwater monitoring will be required, utilising the network of monitoring wells already established on and off site, or new wells installed post remediation to monitor site boundary conditions.

Ongoing groundwater monitoring will monitor the status of natural attenuation (monitored natural attenuation – MNA) of the contamination plume on and off site in both the shallow groundwater and deeper bedrock groundwater systems.

CH2M HILL recommends that RailCorp proceed with a Remedial Action Plan (RAP) to enable a full assessment of the remedial requirements of the Site, based on the findings of this investigation.

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1 Introduction

In July 2006, Rail Corporation NSW (RailCorp), engaged CH2M HILL Australia Pty Ltd (CH2M HILL) to conduct delineation and characterisation soil sampling at the Former Macdonaldtown Gasworks site located at Burren Street, Erskineville (the Site). The engagement also included a review of appropriate remedial options for the Site. For ease of reference, the assessment work documented in this report will be referred to as the "Delineation Investigation".

This Delineation Investigation focused on reducing uncertainty associated with the characterisation of impacts to Site stratigraphy from historical contamination sources, therefore enabling estimates of the depth, lateral extent and leachability of contaminated material in soil in an attempt to evaluate the suitability and feasibility of appropriate remedial strategies.

1.1 Background and Project Objectives

1.1.1 Background

The Site has been declared by the NSW Environment Protection Authority (EPA)[1] to pose a Significant Risk of Harm (SRoH) to human health and the environment. The declaration was made in consideration of the concentrations of contaminants in the soil and groundwater reported in previous site investigations. RailCorp wish to remediate the Site such that the SRoH declaration can be removed, and to allow beneficial use of the Site for rail related activities.

The following is a chronological list of dates relevant to the SRoH determination made by the NSW EPA:

- StateRail (now RailCorp) notified the NSW EPA of potential SRoH on the Gasworks site on 30 June 2000;
- NSW EPA declared that the Site poses a SRoH on 14 August 2000;
- StateRail provided the NSW EPA with a draft Voluntary Investigation Agreement (VIA) for the Gasworks site on 13 March 2001;
- NSW EPA provided the StateRail with a final VIA (#19009) for the Gasworks site on 22 October 2001;
- StateRail provided NSW EPA with a copy of a site investigation report (CH2M HILL, June 2000) on 14 December 2001;
- NSW EPA confirmed that the VIA #19009 had been adequately completed on 28 May 2002.

It is understood that the Site is likely to be utilised in the future for rail-related activities, and therefore remedial works are required to remove the health risk to site users and to remove the potential for contaminated groundwater to migrate from land owned by RailCorp. The Investigation was undertaken in response to RailCorp's requirement to understand the existing environmental contamination status at the Site in preparation for site remediation planning and implementation.

[1] *The EPA is incorporated into the NSW Department of Environment and Conservation (DEC).*

RailCorp consider this Delineation Investigation to be the definitive step in collecting site data prior to developing remediation options and cost estimates.

1.1.2 Project Objectives

The objectives of the project are to fill in data gaps and characterise the Site sufficiently to:

- determine areas, volumes, types of contaminants requiring remediation to meet RailCorp's long term objectives;
- screen available remedial options and recommend appropriate options to allow long term land use objectives to be met; and
- provide indicative remedial cost estimates to implement an appropriate remedial strategy, to be provided in a separate letter to this investigation report.

The Delineation Investigation incorporates a detailed review of previous investigations, focusing on appraising spatial contamination data uncertainties with respect to historical site operations, and development of a preliminary conceptual site contamination model (PCSM) to interpret information and data gaps. Intrusive ground investigations followed, including the excavation of test pits and trenches, in order to ground truth the PCSM and determine the current environmental condition of the Site.

This investigation consolidates available previous site data with additional new data in order to characterise the site contamination and develop remedial options for the Site. The reliability of data collected during the current investigation has been assessed according to the Sampling, Analysis and Quality Plan (SAQP, CH2M HILL 2006) procedures. The reliability of previous data will also be assessed by collecting additional data in an attempt to lower uncertainties associated with contamination impacts.

1.1.3 RailCorp Long Term Objectives

The objectives and purpose identified above will enable RailCorp to meet their long term objectives for the Site, which include:

- Removing the SRoH declaration;
- Removing health risks to future site users; and
- Beneficial reuse of the Site for rail related activities.

1.2 Site Identification

The Site is located approximately 3km south west of the Sydney Central Business District (CBD) (**Figure 1 – Site Location**) and encompasses an area of 7,732m^2. The Site is roughly triangular in shape, and is bound to the north by rail land, to the south and east by a rail corridor, and to the west by a row of residences on Burren Street (**Figure 2 – Current Site Layout and Historical Layout**).

Site identification information is presented in **Table 1-1** below.

Table 1-1 Site Identification	
Street Address	Burren Street, Erskineville NSW 2043
Lot and DP Number	Part Lot 50 in DP1001467
Site Area	7,732m^2
Geographical Coordinates	624700N; 343200E
Owner	RailCorp
Zoning	Zone No. 5 – Special Uses (Railway)
Current/Proposed Land Use	Vacant/Commercial-Industrial
Local Government Area	City of Sydney
Parish	Petersham
County	Cumberland

1.3 Areas of the Site

For the purpose of this Delineation Investigation, the Site has been separated into eight "stratified" Areas, as shown on **Figure 3 – Stratified Site Areas, Sampling Locations and Cross Sectional Transects**. Stratifying the Site into Areas was primarily based on the Site history and layout of historical operations; and soil/fill contaminant characteristics provided in previous investigations. A stratified site provided an easier method to target investigations of potentially contaminated areas and manage collected data.

A description and summary of the Areas is provided below.

- **Gasholder:** encompasses both existing Gas Holder structures adjoining the western boundary. The southern Gas Holder remains intact with the superstructure standing approximately 12 metres above the ground surface. The northern Gas Holder has been demolished, however the annulus structure remains buried beneath the ground.
- **Retort:** encompasses the footprint of the former Retort House, Tar Wells, Condensers, Coal and Shale Storage areas and other building structures associated with the gasworks operations (office, amenities, etc). These buildings and structures have been demolished and associated structures are no longer visible above the ground surface, however underground structures remain in place; including the two Tar Wells, pipe work, brick foundations and concrete slabs.
- **Gas Purifier:** encompasses the footprint of the former Purifier Beds, Scrubbers and Gas Meters. Similar to the Retort Area, structures only remain buried below the ground surface.
- **Northeast:** includes the majority of the northeast section of the Site.
- **South Central:** includes the expanse along the central southeast boundary.
- **Southwest:** includes the majority of the southern area of the Site.
- **Retaining Wall:** includes the filled area north of the Retort.

- **Western Lot:** includes the section of land that extends west to Burren Street from the northwest corner of the main area of the Site.

A summary of the historical uses of each of these Areas is provided in **Section 2**.

1.4 Previous Site Investigations

The environmental contamination and/or archaeological and heritage investigations carried out on the Site between 1999 and 2006 are listed below.

- Rail Services Australia "Eveleigh Gasworks - Site History" November 1999 (RSA, Nov 1999).
- CH2M HILL Australia "Phase I & II Environmental Site Assessments" June 2000 (CH2M HILL, June 2000).
- CH2M HILL Australia "Vegetable, Soil and Sediment Sampling – Letter Report" November 2000 (CH2M HILL, Nov 2000).
- CH2M HILL Australia "Soil & Groundwater Investigations of the Former Gasworks Area and Offsite" December 2001 (CH2M HILL, Dec 2001).
- Australian Railway Historical Society "A Brief History of NSW Railway Gasworks" June 2003 (ARHS, June 2003).
- Banksia Heritage & Archaeology "Macdonaldtown Station Works - Archaeological Assessment" April 2004 (Banksia Heritage, April 2004).
- GHD "Macdonaldtown Triangle (Former Cleaning Sheds) - Delineation and Classification Sampling" September 2005 (GHD, Sept 2005).
- Sinclair Knight Merz "Macdonaldtown Triangle (Former Gasworks Site) - Human Health and Ecological Risk Assessment" April 2006 (SKM, April 2006).

The information obtained from the previous investigations is summarised in **Section 5**.

Furthermore, the following archaeological assessment was completed concurrently with this Delineation Investigation:

- Heritage Concepts "Archaeological Assessment and Remediation Management Strategy" November 2006 – Draft Report (Heritage Concepts, November 2006).

1.5 Limitations

The advice tendered in this report is based on information obtained from the field investigation locations, test points and sample points and is not warranted in respect to the conditions that may be encountered across the Site at other than these locations. It is emphasized that the actual characteristics of the sub-surface and surface materials may vary between adjacent test points and sample intervals and at locations other than where observations, explorations and investigations have been made. Sub-surface conditions and contaminant concentrations can change in a limited space and

time. However, it is our opinion that the test points chosen are representative of conditions on the Site areas of concern.

Changed or unanticipated sub-surface conditions may occur that could affect the outcomes of an investigation, because of the inherent uncertainties in sub-surface evaluations. Any opinions or recommendations presented herein apply to site conditions existing when services were performed. CH2M HILL is unable to report on or accurately predict events that may change the site conditions after the described services are performed, whether occurring naturally or caused by external forces.

An understanding of the Site conditions depends on the integration of many pieces of information; some regional, some site specific, some structure-specific and some experienced-based. This report should not be altered, amended or abbreviated, issued in part or issued incomplete in any way without prior checking and approval by CH2M HILL. CH2M HILL accepts no responsibility for any circumstances that arise from the issue of the report which has been modified in any way as outlined above.

This report has not been prepared for the purposes of assessing the suitability of soil and fill on the Site for building or pavement foundations or the establishment of gardens.

CH2M HILL assumes no responsibility for conditions we were not authorised to investigate or conditions not generally recognised as environmentally unacceptable when the services were performed.

This report has been prepared for the exclusive use of RailCorp ("Client") relating to the property as described in the report. No warranty, expressed or implied, is made. There are no beneficiaries to this report other than the Client, and no other person or entity is entitled to rely upon this report without the written consent of CH2M HILL, and a written agreement limiting CH2M HILL's liability.

2 Site History

The Site history is based on information from previous investigations including RSA (Nov 1999) and CH2M HILL (June 2000). The following is a summary of the information gathered from these previous investigations. The historical Site layout is shown in **Figure 2**.

2.1 Land Title and Previous Land Use

The Site was originally part of the land title granted to Nicholas Devine in 1794. Subsequent title transfers continued through the 1800's until the land was transferred to the Commissioner for Railways (now RailCorp) in 1888. Although it is known that the gasworks operation began in the early 1890's, the land use prior to this time was not identified or documented on previous land title records.

2.2 Site Operations

The Site was acquired in 1888 and has been owned by the railways department to the present day, and none of the original parcel of land has been sold.

The Site operated as a Manufactured Gas Plant (MGP) between 1892 and 1958. Gas was produced from coal and shale raw products and stored in two gas holders. Operations included raw product storage, gas production, waste disposal, filling and storage of liquor wastes. To facilitate these operations, site structures and buildings included a Retort House, an Exhauster, a Boiler, Condensers, Purifier Beds, a Scrubber, two tar wells, above ground tar tanks, a Gas Meter, two Gasholders, service pipework, raw store areas for coal and shale, and other buildings likely to be offices, washrooms and compressors.

The MGP consisted of two separate but parallel works for coal and shale processing. Gas produced from coal was stored in the larger (southern) Gasholder, with a capacity of 100,000 cubic feet (approx. 3,000m^3), while gas produced from shale was stored in the smaller capacity (northern) Gasholder, at 50,000 cubic feet (approx. 1,500m^3).

The following gives the chronology of the Site, pre and post operation:

- 1891:- Design plans approved;
- 1892:- Construction completed. The detailed layout of the various components of the operation are slightly different to the design plans;
- 1942:- The use and location of two tar wells is documented on plans;
- 1950's:- The use of inferior coal during the coal strike of the 1950's causes damage to the plant machinery and as a consequence the MGP ceased operations. The two Gasholders are used to store gas that was manufactured and piped from the Mortlake operations;
- 1958:- The MGP is demolished, with the exception of the southern Gasholder, which remains extant;
- 1970's:- During the mid 1970's the Site closed down and is no longer used for storing and pumping gas product;

- Present:- The Site remains as vacant railway land. The only structure remaining is the southern Gasholder.

The MGP was adjoined by a railway corridor that ran the length of the MGP along its southeast border. The corridor consisted of three rail lines in a siding that divided from the Illawarra Main Line and terminated at the southern corner of the Site. A fourth siding divided from the Illawarra Main Line and ran the length of the northern boundary of the MGP area, terminating at the northwest corner of the Site in the vicinity of the northern Gasholder. The alignment of these rail sidings is only approximate, as the actual locations are unknown.

2.3 Aerial Photographs

Aerial photographs from the years 1951, 1961, 1970, 1978, 1986 and 1999 were included in the review, and the findings are summarised below.

1951:- Major site structures are identified in this photo including the two gas holders at the western boundary, the retort house and coal/shale storage areas at the north boundary and the gas purifier building (orientated northeast-southwest in the centre of the Site). Rail lines are noted running the length and inside the southeast boundary. The land to the north shows the large Cleaning Shed being present, while surrounding lands include the residential properties and Erskineville neighbourhood along the western boundary and rail corridor along the southeast boundary.

1961:- The land and structures appear unchanged from 1951.

1970:- All building structures appear to have been demolished, with the exception of the southern gas holder. Surrounding lands appear to be unchanged.

1978:- The land and structures appear unchanged from 1970.

1986:- The land and structures appear unchanged from 1978. The large Cleaning Shed building at the north of the Site has been demolished, with rail tracks and concrete slabs only remaining.

1999:- The rail lines inside the southeast boundary have been removed, while the remained of the Site and surrounds remain unchanged from 1986.

Currently the Site appears much like it did in 1999. A description of current site conditions is given in Section 3.4.

2.4 Site Heritage

The Southern Gasholder is listed on the State Heritage Register and the Sydney Regional Environment Plan 26 (SREP 26) as part of the Eveleigh Railway Workshops. This structure is the only item from the gasworks site to be listed on the register. Other site structures have been assessed for historic and archaeological significance in the report prepared by Banksia Heritage, April 2004, which is summarised in **Section 5.1.6**. Further archaeological assessment of the Site was conducted and assessed in the report prepared by Heritage Concepts, November 2006.

3 Site Description

This section describes the setting of the Site in its current condition. Refer to **Appendix A – Site Photographs** which provides a photographic record of the Site features.

3.1 Existing Site Condition

The Site is generally a triangle shape that is somewhat irregular and completely secured with a perimeter fence (Photo 1). A narrow rectangular area extends west from the 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.

Access to the Site is from a gate located on the southwest perimeter fence. This gate enters from an access road (used for the construction activities on the adjoining northern property), which follows the rail corridor south to the entry gate on Swanson Street, Erskineville.

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 (Photo 2). This is the main structure that is extant on the Site. Other minor structures include:

- brickwork at ground level, associated with the former northern Gasholder (Photo 6);
- the inground Tar Wells located north of the Southern Gasholder that appear as two circular concrete lids at the ground surface (Photo 3);
- a small shed located in the Southwest Area (Photo 4);
- retaining walls/embankments along the northern boundary (Photo 5) including the small rectangular portion of the Site adjoining Burren Street; and
- a concrete service trench 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.

No odorous materials were noted at the ground surface of the Site or as background observations.

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

3.1.1 Surrounding Land Use

A parcel of land that is not part of the Site area and is also owned by RailCorp adjoins the northern boundary (**Figure 2**). This land is currently being developed to accommodate rail carriage stabling and cleaning operations for RailCorp.

The land use of the areas surrounding the Site is as follows:

North:	Land owned by RailCorp, currently in the stages of being redeveloped for railway use.
East and South:	Land owned by RailCorp and used for the suburban railway network (Illawarra Railway Line).
West:	Residential properties of the Erskineville neighbourhood.

3.2 Topography and Drainage

3.2.1 Site Topography

Surface contour gradients are illustrated on the survey diagram presented on **Figure 2**.

The Site is generally flat with a gentle grade that falls toward the south east. The north east corner slopes down toward the southwest then down again to the south east within the general area. Along the western boundary that adjoins residential properties, the ground level falls off sharply to the backyards of the residential homes, particularly in the southern corner where there is a surface level difference of approximately four metres (Photo 4).

The ground surface of the adjoining northern property (Cleaning Sheds) extends into the Site, up to five metres in some places, where an old retaining wall was constructed. The difference between the ground surface levels is approximately two metres (Photo 5).

3.2.2 Surface Water Drainage

Surface water is expected to follow the surface gradients and generally flow southeast. Surface water pooling was observed between sample locations TP11 and TP16 (refer **Figure 3**). A concrete lined open drain runs the length of the western boundary at the rear of the residential properties (Photo 4). The drain has been installed at the level of the residential backyards and receives minor surface water flows from the western side of the embankment.

3.3 Geology

Details of the geological conditions observed at the Site are presented in **Section 8.2**. The following gives a description of the localised geological formations based on current literature.

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.

Shale bedrock was encountered at the Site between approximately 7m to 11mbgs during previous investigations.

Figure 5 and **Figure 6** provide representations of the lithology of the Site.

3.3.1 Soil/Fill Types

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.*

3.4 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.

Previous investigations (CH2M HILL, 2000 and 2001; SKM, 2006) identified two groundwater systems existing at the Site; a shallow groundwater system and a deep bedrock system. The shallow groundwater exists within fill materials above the natural plastic clay (as shallow as 1m below ground surface), and the deeper groundwater exists within the Ashfield Shale bedrock (at approximately 9.5m depth, and under semi-confined conditions).

Elevated concentrations of inorganic and organic contaminants were identified during previous investigations in the majority of groundwater samples collected from the network of monitoring wells. Concentrations of dissolved PAHs, TPH (predominantly C_{10}-C_{36}), metals, phenols and BTEX exceeded the ANZECC (2000) guidelines in both groundwater systems. The concentration of TPH in the C_6-C_9 range also exceeded the solubility in water in MW03D, MW04D and MW07D; however no light-non-aqueous-phase-liquids (LNAPL) have been encountered in any wells. There has also been no identification of dense-non-aqueous-phase-liquid (DNAPL).

Benzene and ethylbenzene exceedences were measured in MW03D, MW04D, MW07D and MW12D, which appears indicative of tarry wastes.

Concentrations in the shallow groundwater are lower compared to the deeper groundwater, indicating that the source of contamination is likely tarry wastes at depth possibly in waste tar pits and the gasholders annuli. The plastic natural clay underlying the fill materials appears to provide an aquitard layer, where interconnectivity between the two groundwater systems is limited.

The plume of dissolved TPH (C_{10}-C_{36}) contamination in the shallow groundwater extends 75m to the south and 50m to the east of the remaining southern gasholder, whilst the deep groundwater plume extends 160m to the south and 50m to the east.

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

The following table is a summary of the groundwater impacts based on previous data.

Table 3.1 – Summary of Groundwater Contamination (all concentrations in µg/L)

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

Note: "nd" is 'Non Detect', or less than the laboratory Limit of Reporting (<LOR).

3.4.1 Groundwater Flow

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).

3.5 Geological and Hydrogeological Overview

In its broadest context, the Ashfield Shale formation comprises fresh unweathered bedrock material (a regional 'aquifer' formation) overlain by a sequence of transitional materials from completely unweathered rock into fully weathered rock, typically clay residuum, over which a soil horizon typically develops (hosting one or

more perched aquifer layers). These materials, and their behaviour as 'aquifers' and media for transport of contaminants, are discussed in more detail below:

(1) Bedrock Shale – the Regional 'Aquifer' - Site investigations undertaken confirm the presence of the regional aquifer described above, namely, the bedrock shales of the Ashfield shale.

The bedrock shales are typically consolidated and have limited primary porosity (the intergranular pore spaces are largely filled with mineral cement) in the Sydney Basin. However, structural deformation has resulted in an overprint of secondary porosities, associated with rock fracturing, faulting, jointing and bedding plane slip. The secondary porosity conduits created by these structural defects in the rock provide the rock mass with its, albeit very limited, transmissive characteristics.

Vertical groundwater flow is facilitated by the sub-vertically orientated fracture network which penetrates through the entire profile.

The bedding plane permeability is the dominant structurally induced hydraulic porosity and is inferred to control the groundwater flow mechanism within the shallow bedrock exposed during the Site works.

Groundwater flow through the bedrock sequence is therefore largely restricted to the secondary porosities provided by the structure overprint (horizontal and vertical planar conduits) and is variable through the profile depending on the bedrock lithology. The typical hydraulic conductivity (K) values for these unweathered bedrock types range from 10^{-8} to 10^{-4} m/day. The storativity of these, generally semi-confined aquifers, is inferred to be low (i.e. fracture density is low) by comparison to the overlying shallow perched aquifer zones (which have a higher intergranular porosity).

(2) Perched Aquifer/s - The Site works have also revealed that the various hydrogeological interfaces (between the soil/fill and the residual clayey soils, the residual clay, weathered shale and the transitional zone into the fresh bedrock mass) are capable of supporting perched groundwater systems. These perched water tables are variable in extent, spatially distributed within the top 2.0m (approximately) of the surface profile across the Site, thin in vertical extent and generally contain fresh quality water (readily recharged by rainfall). They are inferred to be local, with low flow (carry negligible total flow) and poor hydraulic interconnection.

The hydraulic interconnection between the shallow perched and the bedrock aquifer units is limited and patchy, by virtue of their contrasting hydraulic conductivity characteristics. But groundwater recharge to the deeper region aquifer is sustained by the slow infiltration, primarily by the residual structural features (joints, fractures and bedding planes) which persist from the fresh bedrock into the weathered rock and soil zones.

The hydraulic conductivity of the surficial soil/fill and weathered bedrock profile is anticipated to have highly variable hydraulic conductivities. Based on the general soil descriptions obtained from the previous reports and current literature, and the location of the groundwater aquifer in the weathered (fractured) shale, the estimated porosity of the natural soils/fill underlying the site would be expected to range between 5 to 20 percent. Groundwater flow (volumetric and velocity) within these perched systems is expected to be highly variable as a consequence.

(4) Contaminant Fate and Transport – Contaminant concentrations, arising for Site activities, located within the surface soils and subsurface materials, would dissolve (to varying degrees based on their physical and chemical properties) and become leached by infiltrating rain water to the perched groundwater and bedrock groundwater systems described above. The dominance of Kh (horizontal conductivity) over Kv (vertical conductivity) means that these contaminants spread laterally in preference to vertically, exploiting the horizontal bedding and structural conduits to migrate away (outward) from their point source areas. The less prominent vertical components of groundwater seepage will take any dissolved (or phase separated) contaminants downward, deeper into the residual and bedrock sequence/s.

As the contaminant load migrates within (or on) the groundwater flows (vertical and horizontal), attenuation processes cause the contaminant concentrations to decline with distance (and time) from the contaminant point source/s. These attenuation processes include (in order of likely effectiveness) dispersion, dilution, adsorption, biodegradation and absorption. Matrix diffusion and adsorption effects enhance the persistence of secondary contaminant sources.

Previous investigations (SKM, 2006) have concluded that the contaminated groundwater plumes migrating from the Site are limited to RailCorp owned land.

4 Data Quality Objectives and Scope of Work

4.1 Data Quality Objectives

In developing the objectives of this Delineation Investigation, CH2M HILL has undertaken the seven step Data Quality Objectives (DQO) process outlined in the US EPA *Data Quality Process for Hazardous Waste Site Investigations* (QA/G-4HW) (2000), as summarised below. The DQO process was established in the Sampling, Analysis and Quality Plan (SAQP) prepared by CH2M HILL for the fieldwork program (SAQP, CH2M HILL July 2006). The SAQP is outlined in **Section 4.2**.

State the Problem

The investigation was designed to address the following issues:

1. Insufficient information was available to estimate the depth and lateral extent of contaminated fill and natural soils;
2. Insufficient information was available on the contamination characteristics and leachability of the different soil/fill types identified on Site; and
3. Insufficient information was available to allow an assessment of potentially suitable and technically feasible remediation strategies that may be appropriate for contaminated materials at the Site, and to enable development of a Remedial Action Plan.

Identify the Decisions

The decisions arising from the Delineation Investigation data are:

1. Is there sufficient information on the distribution and characteristics of soil and fill requiring remediation and/or management to allow remedial planning to progress?
2. Do the findings of the investigation provide a higher level of understanding and certainty on contamination source zones and spatial area?
3. Do the findings of the investigation provide sufficient data that will enable an assessment of remedial screening options for contaminated soils and fills requiring management?
4. Is there sufficient and definitive Site data to enable remedial cost estimates to be developed?

Identify Inputs to the Decisions

The inputs required to make the above decisions are:

- Geological data and information relevant to subsurface structures;
- Existing hydrogeological data;
- Concentrations of chemicals in different fill/soil types;
- Observation data for free product, staining, odours and discolouration of the soil media;
- Distribution of impacts both lateral and vertical;

- Contamination impacts below permanent structures, including the Heritage listed Gasholder.

Define the Study Boundaries

Spatial Boundaries

The investigation boundary is limited to the Site area comprising Part Lot 50 in DP 1001467. The Site area is approximately 7,732m^2.

The Site has been 'stratified' to establish areas of historical importance and significant contamination source zones.

Each stratified area is likely to contain particular fill or waste associated with the historical activity of that area. A spatial boundary may apply to a particular depth of fill and impact by a certain contaminant, i.e. spatial boundaries maybe horizontal layers vertically down the profile.

Temporal Boundaries

All soil data collected from the Site from 2000 to 2006 will enable a robust assessment and delineation of the contaminant distributions at the Site.

Constraints

The following issues presented minor limitations upon the sampling strategy, although these logistical issues did not affect the technical aspects of the project:

1. Live services (underground) traversing the Site. Intrusive locations were repositioned in a nearby location;
2. Items and potential items of archaeological and historic significance presented limitations to delineation of the area near the existing Gasholder and the area identified as the former Retort House.

Develop Decision Rules

The decision rules for this investigation are as follows:

1. **If** a review of the data obtained from this and previous investigations indicate a degree of uncertainty on contamination delineation and distribution, **then** appropriate remedial strategies will be considered to provide management of those uncertainties and limitations;
2. **If** it is determined that additional information is required to further reduce the uncertainties associated with the distribution and characteristics of soil and fill requiring remediation and/or management, **then** appropriate recommendations for further technical assessment or investigation will be provided.

Specify Limits on Decision Errors

A list of Data Quality Indicators (DQIs) for this sampling program is provided in **Appendix B** of this report. These DQIs are based on PARCC parameters (Precision, Accuracy, Representativeness, Comparability and Completeness).

Significant decision errors were minimised by:

- Completing a robust QA/QC program, an assessment of which is detailed in **Appendix B** and a summary of this assessment is provided in **Section 10**;

- Completing a high sampling and analytical density, to enable a high level of certainty of the spatial impact of historical activities.

Optimise the Design for Obtaining Data

The above information was considered during the design of the site investigation program, which is summarised in the scope of work section below and described in more detail in **Section 7**.

4.2 Scope of Work

4.2.1 Existing Data Review and SAQP

An initial phase of review was necessary to appraise relevant background information and develop a preliminary conceptual site contamination model, identifying Site areas where there are gaps in site contamination data and which present a concern to the environmental integrity of the Site. These areas, together with the areas where adequate data appears to have been obtained, combine to provide a stratified data history across the Site. Once the preliminary review was completed, the information obtained was used to develop the SAQP (CH2M HILL, July 2006) using the DQO process.

The scope of work in developing the SAQP included:

- A review of tender documents supplied by RailCorp, including summarised analytical data;
- an initial site visit (pretender meeting) on 22nd May 2006;
- a review of all relevant information from previous site investigations;
- development of a preliminary conceptual site model focusing on identified data gaps; and
- consultation with the NSW EPA Accredited Site Auditor was performed.

Site Groundwater Issues

It was considered that no further investigation of groundwater conditions was necessary under this scope of work, for the following reasons:

- 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 are used for industrial land purposes, therefore there is currently no off site migration;
- adjoining residential properties (along Burren Street) have not been impacted by contaminated groundwater, considering that migration is toward the south west 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 is located immediately down gradient of RailCorp land, which bans the extraction of groundwater for domestic purposes;
- it is considered that 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; and
- it is therefore considered that active groundwater remediation is not be required as part of site remediation, however ongoing management (including monitoring) of groundwater is likely to be a requirement of future site management.

4.2.2 Preparation of Pre Site Work Plans

Prior to any fieldwork being undertaken, site specific OH&S plans were developed to ensure a safe working environment and ensure appropriate safeguards were in place to mitigate impacts to the local environment.

4.2.3 Soil Investigation Program

The investigation entailed two fieldwork programs. One was undertaken in August 2006, which included trenching and test pit excavations, and the other was undertaken in October 2006 and included bore hole drilling.

While the objectives of the August 2006 fieldwork component were chiefly met, a level of uncertainty remained on the vertical and lateral extent of impact in some areas of Site that were further investigated in October 2006 The following limitations gave rise to the October 2006 fieldwork being undertaken:

- Excavation Sidewall Cave-In:- Gravelly fill, tarry soil and silt layers in the fill materials to a depth of two metres below the ground surface (2m bgs) became unstable when excavating trenches and test pits, causing considerable excavation sidewall cave-in. Re-excavation of cave-in material resulted in significant widening of the excavation area and limited the depth to which samples could be collected. The maximum sampling depth possible given these constraints was 5m bgs in natural clay. Deeper samples were unattainable without significant intrusive excavation work (width and length), vertical mixing of fill/soil layers, emission of odours, and in some locations damage to potential heritage structures.
- Shallow Groundwater in Northern Gasholder: - Shallow groundwater flowed into the open pits excavated inside the annulus of the demolished (northern) gas holder. Although the materials used to backfill the demolished gas holder; consisting of brick, concrete rubble and building demolition waste were able to be excavated (and sampled) without difficulty, the rate of water inflow caused substantial sidewall collapse of trenches, similar to that described above. A dewatering pump was employed to arrest this problem and remove the accumulated water, however the inflow became greater than the capacity of the pump and excavations could not be continued past 1.5m bgs.

- Spatial Misalignment of Previous Locations:- Previous sampling locations that required additional depth sampling (for vertical delineation) were estimated in the field using site plans, existing site structures and other site features. It became evident after preparing a survey drawing on completion of the fieldwork in August 2006 that in two areas the additional sampling locations did not accurately represent the previous sampling position. Therefore further sampling to target these locations was undertaken in October 2006.
- Spatial Misalignment of Historical Site Layout:- Sampling locations proposed to investigate areas of historic operations also involve some inaccuracy, similar to the circumstances above. Further sampling to target these locations was undertaken in October 2006.
- Potential Items of Heritage and Archaeological Importance:- Limitations on excavation work and sampling were imposed in areas were potential items of historical or archaeological importance were uncovered. Some areas were therefore not fully investigated (laterally and vertically) because further intrusive work would compromise the condition of the uncovered structure.
- Existing Gas Holder Heritage Item:- A buffer zone of 5m around the existing southern gas holder was established by the Heritage Council, in an attempt to mitigate potential damage to the structure during investigation work with heavy plant machinery. This limitation restricted collection of soil data from within this area, resulting in some uncertainty in the immediate area surrounding the gas holder.

The soil sampling locations are provided on **Figure 3** and a summary of these locations is provided in **Table 4.1**.

Table 4-1 Soil Sampling Locations

Area	August 2006 (trenching and Test pits)	October 2006 (bore holes)	Total
Gasholder	5	7	12
Retort	7	5	12
Gas Purifier	1	2	3
Northeast	7	2	9
South Central	3	0	3
Southwest	4	0[A]	4
Retaining Wall	3	0	3
Western Lot	2	0	2
Total	32	16	48

Notes:

[A] Boreholes BHA, BHA1 and BHA2 target the base of the Southern Gasholder and were not used to assess contamination in the Southwest Area. These bore holes (and corresponding samples) were used to assess underneath the Gasholders, therefore are included as sample locations in the Gasholder Area.

4.2.4 Surface Water Investigation Program

The investigation into surface water contamination involved the collection of 6 samples from areas of the Site. The term 'surface water' in this report is relative to water that had accumulated inside existing structures, in particular the Gasholders, the Tar Wells and the Retention Pit. The term does not include water that has accumulated at the ground surface. The location of the samples is provided in **Section 8.6.**

4.2.5 Leachate Analysis

Analysis was performed on selected samples to understand the leachability of particular contaminants under acidic (landfill) conditions, to understand the potential waste classification of certain materials to aid assessment of remedial options. Other leachate tests were conducted under neutral conditions to understand the potential leaching of contaminants occurring naturally at the Site in the deep weathered shale layers.

4.2.6 Dioxin Analysis

Analysis was performed on one sample of tar material to determine if the tar contained concentrations of polychlorinated dibenzo dioxins and polychlorinated dibenzo furans (PCDD/Fs). This determination would then enable a decision to be made on the appropriate remedial treatment options to manage the tar material.

4.2.7 Reporting

The findings of the investigation program are documented in this report, and focus on the project objectives, providing information required to develop conclusive statements and recommendations. Specifically:

- The reliability of data from previous and current investigations;
- Intergration of previous investigation results;
- Plans and cross-sections presenting relevant data/information; and
- Inclusion of remedial options screening to incorporate heritage issues and long-term site management requirements, as appropriate.

5 Review of Previous Investigations

5.1.1 RSA, Nov 1999

Rail Services Australia (RSA) undertook a site history appraisal in an attempt to identify past and present potentially contaminating activities, and to provide a basis for a more detailed site investigation.

The report provides a chronological list of events that occurred on the Site between 1891 (gasworks design plans approved) to the mid 1970's (site closed down) to the current period (vacant land). The report also includes an "as-built' plan of the gasworks site in 1892 that details the layout of the gasworks plant. This plan is included as **Figure 2** as an overlay of the current Site layout, giving the approximate locations of former gasworks structures. Other plans of physical structures and their position on the Site were also provided.

RSA provide details on potential contaminant sources to include areas of fill around the works (boiler ash), coal and shale raw material stockpile areas, the retort house, the scrubbers, the condensers, the tar wells, the tar tanks, the purifier boxes, buried pipework and the gas-holders.

RSA provided a summary of the gas manufacturing process, as follows:

> *"The gasworks consisted of two separate but parallel works. One works produced gas from coal for lighting nearby stations and signals, and the other works produced a much richer gas from shale for carriage lighting."*

Of note were two articles provided in Appendix D of the RSA, Nov 1999 report that provided detailed information including descriptions of the gasworks operations. The information included:

- The dimensions of the Retort House was 80ft x 60ft (24m x 18m);
- The gas holders were both 60ft (18m) in diameter;
- There were two gas holders located on the Site, one had a capacity of 100,000 cubic feet (approx. 3,000m^3) for storage of gas manufactured from coal, while the other had a capacity of 50,000 cubic feet (approx. 1,500m^3) for storage of gas manufactured from shale;
- The larger gas holder is reported to be 40ft (12m) deep and the smaller gas holder was reported to be 20ft (6m) deep. It is unclear if this refers to depth below the ground surface.

Based on the historical appraisal work, RSA provided the following conclusions:

- a railway gasworks operated on the Site between 1892 and about 1958;
- the gasworks site is likely to have been contaminated by both organic and inorganic residuals;
- residual chemicals and wastes should be addressed in a Stage 2 Detailed Site Investigation; and

- the remaining gas holder is listed as *"gasometer at McDonaldtown end"* as an item within the Eveleigh Railway Workshops Precinct on the SRA Section 170 Heritage and Conservation Register.

5.1.2 CH2M HILL Australia, June 2000

CH2M HILL was commissioned by SRA to conduct a combined preliminary and detailed site investigation (Phase I and II) of an area incorporating the former gasworks site and the adjoining stabling yards (Cleaning Sheds). The investigation was undertaken for purposes of due diligence associated with redevelopment of the stabling yard (Cleaning Sheds) area. The investigation included an assessment of the soil and groundwater conditions.

The objectives were to:

- delineate and define any contamination;
- determine the suitability of the Site for the commercial/industrial land use (i.e. fit for purpose);
- assess whether the Site may pose a significant risk of harm to human health or the environment; and
- obtain information of sufficient standard to enable preparation of a Remedial Action Plan (RAP).

For the soil assessment of the former gasworks area, CH2M HILL concluded there was widespread occurrence of fill material, varying from 0.1m – 3.2m in depth and widespread occurrence of contamination throughout the fill material, but not the underlying soils. Contaminants identified were TPH, PAH and BTEX.

The groundwater assessment was designed to investigate impacts on two groundwater systems. Both a surficial aquifer and an Ashfield Shale bedrock aquifer were identified in the former gasworks area.

CH2M HILL concluded that there was evidence of adverse impacts on the quality of the surficial aquifer, indicated by elevated concentrations of PAH, TPH (C_{10}-C_{36}), heavy metals, phenols and BTEX above ANZECC, 1992[2] guidelines. Shallow groundwater was expected to flow toward the south/southeast, however localised influences around the gas holder structures, foundations, tar wells and pipework were expected to affect flow direction.

CH2M HILL concluded that concentrations of PAH, benzene, heavy metals and phenols were elevated above ANZECC, 1992 guidelines in the Ashfield Shale bedrock aquifer. In the vicinity of the former gasworks site the general bedrock aquifer flow was expected to be toward the south/southeast.

CH2M HILL identified the following receptors of contamination:

- On site workers exposed to impacted fill/soil and the surficial aquifer during excavation activities;

[2] *Australian and New Zealand Environment and Conservation Council, Guidelines for the Protection of Fresh water Ecosystems, 1992.*

- Residents of the residential dwellings adjoining the south western boundary being exposed to dusts, impacted soil and migrating groundwater;
- The local environment may be exposed to migrating groundwater, dusts and surface water/sediment run-off; and
- Users of groundwater down gradient of the Site, particularly unregistered users.

CH2M HILL also concluded that there were no identifiable sensitive receptors within the immediate vicinity of the Site and no groundwater usage had been identified within a 2km radius.

In consideration of the types, concentrations and distribution of soil and groundwater contamination, CH2M HILL concluded that the Site may pose a significant risk of harm to human health and the environment.

The recommendations CH2M HILL provided included:

- Notification to the NSW EPA of the potential for the Site to pose a significant risk of harm;
- Cease all activities on the former gasworks site and secure the Site to prevent access from rail workers and the general public;
- Development of an RAP;
- Additional assessment of soil gas, soils and groundwater to determine potential impacts in the adjoining residential properties along the southwest boundary;
- Additional sampling to assess impacts to the vegetable garden plots established by local residents; and
- Detailed assessment of the groundwater quality of both the surficial and the bedrock aquifers.

5.1.3 CH2M HILL Australia, November 2000

During the Phase I & II investigation undertaken by CH2M HILL in June 2000, vegetable gardens were observed to have been established on the former gasworks site. Two were located at the narrow southern end and one was located on the section of land extending from the northwest corner of the Site to Burren Street. CH2M HILL was commissioned by SRA to conduct further environmental work to assess the health risk associated with the consumption of vegetables grown on the Site and to assess the potential for offsite migration of contamination via a western boundary surface drain.

The objectives of this work were to determine if the inorganic and organic contaminants identified in fill materials of the former gasworks were present in the vegetable gardens and in the foliage of vegetables, and to determine whether the same contaminants were present in the sediments of the open drain located along the western boundary.

CH2M HILL concluded that the vegetable plot soils were impacted with lead, TPH (C_{10}-C_{36}), and PAHs including benzo(a)pyrene (B(a)P), and the soil is likely to be

made up, in part, from fill material of the former gasworks. Assessment of the vegetable foliage indicated that the contaminants had not been taken up by the plants, except for lead which was reported at a level above the adopted Maximum Permissible Concentration (MPC) and the levels in a control sample. Assessment of the sediments in the drain indicated that similar contaminants were impacting drain sediments and likely to be migrating off site through run-off.

5.1.4 CH2M HILL Australia, December 2001

CH2M HILL was commissioned by SRA to conduct a targeted soil and groundwater investigation as part of a Voluntary Investigation Agreement with the NSW EPA. The investigation was undertaken to delineate the groundwater quality and soil contamination in the western portion of the former gasworks site and off site in the adjoining residential properties along the western boundary. The objectives were to:

- Better define the extent of groundwater impacts in both the surficial and bedrock groundwater and refine the flow regime to understand migration characteristics;
- Further assess the potential risks to human health and the environment; and
- Provide land management options and determine the need for further assessment.

The investigation provided sample data from the off site residential properties and the western portion of the former gasworks site.

Off Site Residential Properties

CH2M HILL concluded that there existed fill material up to 1.3m in depth in the residential yards backing onto the former gasworks site. Analytical testing indicated concentrations of some contaminants, including lead, TPH, PAH and B(a)P, that exceeded sensitive land use criteria. Contamination impacts were not reported in the underlying natural clay.

Shallow groundwater existed at approximately 1m below the ground surface in the residential yards. Deeper bedrock groundwater showed a higher potentiometric surface than the shallow wells, indicating semi-confinement characteristics. The flow direction of both groundwater systems was toward the southeast, therefore CH2M HILL concluded that neither shallow nor deep groundwater migrates from the former gasworks site to the residential properties. Analytical results supported this statement, showing no concentrations of contaminants exceeding the assessment criteria in the groundwater beneath the residential properties.

Western Portion of the Former Gasworks Site

CH2M HILL concluded there was the occurrence of fill material, varying from 0.3m to 4.4m in depth that appeared not to be representative of expected gasworks type waste such as ash and coke. Fill materials were underlain by a natural Ashfield Shale lithological profile including (in depth profile) silty clay (red/grey), clay/weathered shale and Shale bedrock at depth. Analytical tests of the fill indicated concentrations of TPH, PAH and B(a)P that exceed the commercial/industrial investigation criteria.

CH2M HILL also found that similar to off site areas, the deeper bedrock groundwater appeared under semi confinement, and both shallow and deep groundwater migrated toward the south east, away from the residential properties. However, the

inground gas holder structure showed a localised influence on the shallow groundwater flow direction. This was also the case for the open drain that runs along the western boundary. This drain was likely to provide a preferential pathway for migrating shallow groundwater and also collect surface water run-off and groundwater seepage from deep fill material that may be impacted. CH2M HILL identified Alexandra Canal as a sensitive receptor of the drainage line. It was concluded that any potential contaminants in the migrating surface water would be unlikely to present a risk to human health or the environment of the Canal considering the distance to the Canal (over 1km) and the effect of dilution on contaminants.

Groundwater flux rates were estimated by CH2M HILL to be in the order of 1,000m^3 for shallow groundwater and 200m^3 for semi-confined bedrock groundwater.

The analytical results of groundwater monitoring of wells installed during this investigation reported similar impacts above groundwater assessment criteria from contaminants identified in CH2M HILL, 2000 (i.e. PAH, TPH (C_{10}-C_{36}), heavy metals, phenols and BTEX), albeit at lower concentrations. A similar scenario was reported for the deeper bedrock monitoring wells.

The recommendations CH2M HILL provided included:

- Preparation of an RAP and Environmental and Health & Safety Plans for future development work on the former gasworks site;
- Additional site investigation work to lower uncertainties associated with identified environmental issues, which were:
    - Further characterisation of the fill materials of the residential properties along the western boundary;
    - An evaluation of the open drain along the western boundary for water quality, flow regime and receptors of off site migration;
    - An evaluation of groundwater quality down gradient and off site and assess potential receptors/exposure pathways of groundwater to define risk in off site locations; and
    - Ongoing groundwater monitoring.

5.1.5 ARHS, June 2003

The Australian Railway Historical Society (ARHS) presented an overview of the NSW railway gasworks operations in their Bulletin of June 2003. The overview builds on and confirms much of the information presented in RSA, November 1999, including location and plant layout; and dates of design approval (1891), commencement of operations (1892), cessation of manufacturing (early 1950's), demolition (1958) and eventual site redundancy (mid 1970's). In particular, this overview provides a summary of the information provided in Appendix D of RSA, November 1999.

The overview provides a summary of the '*coal carbonisation*' process for the manufacturing of gas, which will not be presented in this report. It was stated that by 1898 the plant was producing 22,000,000 cubic feet (approx. 6,000,000m^3) of gas per annum.

5.1.6 Banksia Heritage, April 2004

Banksia Heritage & Archaeology were engaged by SRA to prepare an archaeological assessment of the former gasworks site. The purpose was to assess the occurrence and significance of any archaeological remains, and to determine what statutory provisions apply prior to any contamination assessment work to be carried out.

Banksia Heritage recommended that the remaining gas holder should be avoided during contamination assessment work and that further recording take place of selected items of significant value. It was confirmed that the vast majority of the Site is no longer of significant archaeological heritage as a result of earlier demolition of structures.

It was concluded that the gas holder present on the Site was the only single surviving example of its type in NSW. The gas holder is already recognised as being of State heritage significance.

Banksia Heritage made the following notable recommendations:

- Avoid undertaking any work inside a 5m fenced buffer area around the existing gasholder;
- No further archaeological assessment was required for any others structures remaining on the Site;
- If work uncovers in situ intact structural remains, work is to cease until an assessment can be made on the items archaeological importance.

5.1.7 GHD, September 2005

GHD was commissioned by RailCorp to undertake additional investigations within the former Cleaning Sheds site that adjoins the north boundary of the former gasworks site. The purpose was to delineate lateral and vertical extent and classify (for off site disposal) contaminated soil previously identified in CH2M HILL, June 2000. This was to be conducted to enable a sufficient remedial response to the contaminated area, prior to the redevelopment proposed for the Cleaning Sheds site. The additional investigations were to target a BTEX/PAH contamination hotspot previously identified at sample location TP44. This location is presented on **Figure 3** in the area identified as the Retaining Wall.

GHD indicated that part of the contaminated area to be delineated was in fact on the former gasworks site, separated from the Cleaning Sheds site by a chain wire fence. Therefore part of their assessment area would encroach on the gasworks site. Only information relevant to the gasworks site will be summarised here from the GHD report.

Fill materials on the gasworks site consisted of ash, slag, coal and coke and indicated elevated concentrations of BTEX, PAH and TPH that exceed the adopted commercial/industrial assessment criteria. The material was classified as Hazardous Waste, however a classification of Industrial Waste was given based on ash being the source of PAH contamination, enabling application of the NSW EPA *General Approval of the Immobilisation of Contaminants in Waste* (1999/05). Particular volumes and area of the impacted material was not given, other than the lateral and vertical extent could not be confirmed.

5.1.8 SKM, April 2006

SKM were engaged by RailCorp to undertake a human health and ecological risk assessment of the former gasworks site. The purpose of the risk assessment was to identify potential issues that should be addressed in respect to contamination.

SKM made the following conclusions:

Contamination

Soil in the fill material was mainly contaminated with high levels of PAHs and TPH (C_{10}-C_{36}) distributed over much of the Site. Hotspots were identified in the fill that was contaminated by benzene and xylenes, as well as PAHs and TPH (C_{10}-C_{36}). Higher impacts were identified to be near to the historical operations of the tar tanks, gas holders, retort house and scrubber. Natural soil was contaminated with similar contaminants as the fill material, but generally at lower concentrations and in similar historical areas.

Concentrations of volatile contaminants in the soil-gas were expected to be highly variable and generated from the unsaturated soil zone and the shallow groundwater. The soil-gas model indicated much higher concentrations were likely to be present than those measured in the field, and therefore there was potential for elevated levels of vapours to be emitted from the soil and ground surface of the Site. The source of BTEX in soil-gas was likely to be the shallow groundwater, while the source of six targeted PAHs in the soil-gas was likely to be the unsaturated shallow soils.

Groundwater in the location of the gasworks, gas holders and tar tanks on the former gasworks site was contaminated by TPH (C_6-C_9), BTEX and lighter fraction PAHs (naphthalene, acenaphthalene, fluorene, pyrene). There also existed widespread concentrations of heavy metals that exceeded the adopted freshwater trigger values.

Health Risks

There was potential for on-site construction maintenance workers to be exposed to a high risk to health based on available contamination data for PAH and TPH in shallow soils and groundwater. A hazard quotient of 6.6 was calculated, compared to the acceptance criteria of 1. It was recommended to mitigate the risks by employing specific work procedures that minimise dermal contact with soils and groundwater, dust generation and avoid work that requires high levels of hygiene and decontamination. Monitoring the environment was recommended during construction/maintenance work, or consideration should be given for a remedial strategy (i.e. capping the contaminated soils).

There was potential for long term site workers to be exposed to an unacceptable risk to health based on available contamination data for PAH and TPH (C_{10}-C_{36}) in fill materials near the tar tanks/gas holder area. A hazard quotient of 2.95 was calculated, compared to the acceptance criteria of 1. Similar recommendations were given for long term site workers to mitigate exposure and/or implement a capping strategy for the contaminated site areas.

Nearby residents faced a low health risk posed by contamination on the former gasworks site provided public access was restricted and groundwater extraction did not occur in the area. Similarly, off site construction workers also faced a low risk to health if working in deep excavations on the nearby residential sites. No restrictions on managing these works were considered necessary.