

Health Impact Assessment

Remediation Development Application, Barangaroo Block 5, EPA
Declaration Area Number 21122, Hickson Road, Millers Point, NSW



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Contents

Glossary of Terms	i
1.0 Introduction	1
1.1 Barangaroo	1
1.2 EPA Declaration Area (#21122)	1
1.3 Summary of Site History and Key Contaminants	2
1.4 Definition of Site	2
1.5 Role of Lend Lease	2
1.6 Scope of Works	2
2.0 Historical Investigations	4
3.0 Project Description	5
3.1 Summary of Proposed Works	5
3.2 Haul Roads and Required Plant	7
3.3 Environmental Controls	7
3.3.1 Sediment Controls	7
3.3.2 Temporary Odour Control Structures	7
3.3.3 Filtration Systems	8
3.3.4 Other Controls	8
3.4 Decontamination Area	8
3.4.1 Personnel	8
3.4.2 Plant	9
3.5 Site Access	9
4.0 Pollutants	10
4.1 Screening of Pollutants	10
4.2 Pollutants of Potential Concern (POPC)	10
4.3 Potential Health Effects of Identified POPC	12
4.3.1 BTEX	12
4.3.2 Polycyclic Aromatic Hydrocarbons (PAHs)	12
4.3.3 Total Petroleum Hydrocarbons (TPH)	13
4.3.4 Particulate Matter	13
4.3.5 Heavy Metals	13
4.3.6 Odour	15
4.3.7 Asbestos	15
5.0 Expected Pollutant Sources	16
6.0 Potential Sensitive Receptors	17
7.0 Relevant Exposure Pathways	19
7.1 Conceptual Site Model	20
7.2 Measures for Reducing Exposure	20
7.2.1 Source Controls	20
7.2.2 Pathway Controls	21
8.0 Potential Health Impact Assessment	22
8.1 Assessment of Risks to Local Receptors	22
8.2 Assessment of Risks to Offsite Receptors (During Transportation)	24
9.0 Conclusions	25
10.0 Recommendations	26
11.0 References	27
Figures	28
Appendix A	
Qualitative Risk Ranking Framework	A

List of Tables

Table 1	Sediment Control Options	7
Table 2	Pollutants of Potential Concern and Expected Distribution Block 5 Remediation Area	11
Table 3	Significant Exposure Groups	17
Table 4	Exposure Pathway Analysis	19
Table 5	Conclusions Regarding Site-derived Risks to Local Receptors	22

Table 6	Conclusions Regarding Site-derived Risks to Offsite Receptors (During Transportation)	24
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List of Figures

Figure 1	Site Location	A
Figure 2	Declaration Area and Surrounding Land	B
Figure 3	Illustrated Conceptual Site Model for Exposure to Pollutants of Potential Concern	C

Glossary of Terms

Term	Description
Block 4 Remediation Area	Portion of the Declaration Area situated within Barangaroo South.
Block 5 Remediation Area	Portion of the Declaration Area located within Barangaroo Central (including remediation of some land adjacent to the Declaration Area on the west)
CSM	Conceptual Site Model
EPA	Environment Protection Authority
EPA Declaration Area	Remediation Site Declaration 21122
Ex-situ Remediation Methodology	Excavation of contamination and off-site disposal (with on-site pre-treatment, where required)
Hickson Road Remediation Area	Portion of the Declaration Area situated within the Hickson Road reserve
LLMP	Lend Lease (Millers Point)
MSDS	Material Safety Data Sheets
POPC	Pollutants of Potential Concern
PPE	Personal Protective Equipment
RAP	Remedial Action Plan
RWP	Remediation Works Plan
SEG	Significant Exposure Group
Site	Area required for the purpose of the Block 5 Remediation Development Application identified as: - Block 5 Remediation Area - Any other areas of Barangaroo or Hickson Road required for staging and undertaking the remediation and stormwater diversion works
Site Remediation Area	The Block 5 Remediation Area (including remediation of some land adjacent to the Declaration Area on the west).
VMP	Voluntary Management Proposal

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by Lend Lease Millers Point Pty Ltd (Lend Lease) to prepare a Health Impact Assessment (HIA) report to accompany a Development Application for the Remediation of Block 5 at Barangaroo Central to be submitted to the Minister for Planning pursuant to Part 4 of the *Environmental Planning and Assessment Act, 1979*. The HIA was prepared to respond to the Secretary's Environmental Assessment Requirements (SEARs) issued in respect of SSD 6533 Remediation and Land Forming Works dated 13 June 2014, specifically SEAR 6 as described below:

Assess the impacts on health (including extraction of sediments, off-site transport and treatment as well as disposal of sediments), during and following remediation, including details of human exposure scenarios and demonstration that the project will not have unacceptable acute or chronic health effects.

The assessment was conducted in general accordance with national guidelines for human health risk assessments (enHealth, 2012).

This report should be read conjunction with the *Addendum to the Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW - Offsite Treatment/Transport of Contaminated Material* (AECOM, October 2015) – hereafter referred to as the 'Addendum to the VMP/Block 4 RAP'.

1.1 Barangaroo

Barangaroo is located on the north western edge of the Sydney Central Business District, bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The 22 hectare (ha) Barangaroo site is roughly rectangular in shape and has frontage to the harbour foreshore of 1.4 km. Hickson Road delineates the eastern boundary.

The Barangaroo Concept Plan (as modified) is the statutory planning approval to guide the urban renewal of Barangaroo, and currently provides for the development of a mixed use precinct comprising commercial, retail, residential and community development and new public open space / public domain.

The Barangaroo Delivery Authority is the state government managing and delivering the development of Barangaroo.

1.2 EPA Declaration Area (#21122)

In May 2009, the NSW Environment Protection Authority (EPA) determined that a portion of land at Millers Point (part of the Barangaroo Site and an adjacent portion of Hickson Road) was contaminated in such a way as to present a significant risk of harm to human health and the environment. As a consequence, the EPA declared the area to be a remediation site (Declaration Number 21122; Area Number 3221) under the Contaminated Land Management Act 1997.

The Remediation Site Declaration 21122 indicates that the area of the declaration coincides with the known footprint of the former Millers Point gasworks facilities. This area is located on part of Barangaroo and part of Hickson Road adjacent to Barangaroo.

In accordance with Declaration Number 21122, the Declaration Area comprises:

- Part Lot 5 and Part Lot 3 DP 876514, Hickson Road, Millers Point, NSW 2000.
- Part of Hickson Road adjacent to:
 - 30 - 34 Hickson Road (Lot 11, DP1065410);
 - 36 Hickson Road (Lot 5, DP873158); and
 - 38 Hickson Road (SP72797) Millers Point.

The Barangaroo Delivery Authority has entered into a Voluntary Management Proposal (VMP) with the EPA associated with EPA Declaration Area (Approval No. 20101719). Phase 1 of this VMP involves investigative

works and undertaking remedial design to determine and obtain agreement on a proposed remediation methodology. Phase 2 of the VMP will involve the implementation of the agreed remediation works.

An independent, EPA-accredited Site Auditor has been appointed to undertake review of proposed remediation works and prepare statutory audit statements prior to and following completion of remediation.

For the purposes of planning and staging works, the EPA Declaration Area is divided into the following three areas:

- Block 4 Remediation Area - the part of the Declaration Area on Barangaroo South;
- Block 5 Remediation Area - the part of the Declaration Area on Barangaroo Central (including remediation of some land adjacent to the Declaration Area on the west); and
- Hickson Road Remediation Area - the part of the Declaration Area located on Hickson Road.

1.3 Summary of Site History and Key Contaminants

The Millers Point gasworks operated on the Declaration Area between 1840 and 1921. The Site has subsequently been used for various activities, but predominantly a commercial port facility and public road.

When the EPA declared parts of Barangaroo and Hickson Road a "Remediation Site", it described the nature of contamination as gasworks waste with the following particular substances: polycyclic aromatic hydrocarbons (PAHs); benzene, toluene, ethylbenzene and total xylenes (BTEX); total petroleum hydrocarbons (TPH); ammonia and cyanide.

The *VMP/Block 4 Remedial Action Plan (RAP)* (AECOM, 2013) provides more specific details regarding the type, magnitude and location of ground contamination as identified in previous site investigations. Separate phase gasworks waste and tar have been identified in one area of the Block 5 Remediation Area.

1.4 Definition of Site

For the purposes of the Block 5 Remediation Development Application, the Site includes the area of land to be remediated (Site Remediation Area), plus any adjacent land used for the staging and undertaking of the proposed remediation and temporary stormwater diversion works.

The Site Remediation Area comprises the Block 5 part of the Declaration Area (including some land adjacent to the Declaration Area on the west).

1.5 Role of Lend Lease

Lend Lease was appointed by the Barangaroo Delivery Authority as the Proponent to undertake the development for Barangaroo South.

Lend Lease has also been contracted by the Barangaroo Delivery Authority to undertake remediation of the Declaration Area.

1.6 Scope of Works

The aim of this assessment was to identify contaminant exposures associated with remediation works that may potentially affect health in order to describe workplace controls that may be implemented to prevent these potential risks. The HIA included development of a Conceptual Site Model (CSM) for pollutants of potential concern (POPC), identification and assessment of potential exposure pathways, analysis of the potential for health impacts with respect to POPC location and availability, and identification of proposed risk-mitigating workplace controls.

This HIA constitutes a qualitative assessment of potential health impacts associated with the proposed remediation and land forming works of the Site Remediation Area.

The objective of this HIA was to perform a qualitative assessment of potential risks to health arising from the remediation and land forming works. Specifically, this HIA is a desktop study conducted through the following procedure:

- Review of available historical investigations conducted at the subject site and land adjacent to that affected by the proposed works;
- Consideration of the results of the quantitative human health risk analysis undertaken for remediation worker and adjacent public exposure during the proposed remediation activities;
- Development of a conceptual site model outlining potential exposure pathways based on proposed remediation options;
- Desktop qualitative assessment of pollutant emissions to a hypothetical on-site worker or public person at the site boundary;
- Preliminary qualitative risk assessment of potential risks to health arising from the proposed remediation works (including cumulative impacts) including:
 - identification of potential hazard sources (both directly related to the works in the Block 5 Remediation DA and other commensurate development);
 - identification of relevant receptors;
 - identification of potentially complete and significant exposure pathways; and
 - consideration and provision of commentary on resultant potential risk consequences.

2.0 Historical Investigations

The Human Health and Ecological Risk Assessment (HHERA) prepared for the remediation activities of the EPA Declaration Area (AECOM, 2012b) provides a comprehensive summary of previous investigations undertaken at the Site. The relevant site investigations are also listed and summarised in Section 5.0 of the *VMP/Block 4 RAP* (AECOM, 2013).

3.0 Project Description

3.1 Summary of Proposed Works

The Development Application for Block 5 Remediation considers the ex-situ remediation methodology detailed in the *VMP/Block 4 RAP* (AECOM, 2013). The Block 5 Remediation Area requires remediation to remove the EPA Declaration. Consequently, the ex-situ remediation works would involve excavation of contaminated materials to the depth specified in the *VMP/Block 4 RAP* (AECOM, 2013) and *VMP Remediation Extent* report (generally depth of bedrock or up to 10 m below ground level). Only small volumes of bedrock would be expected to be excavated during these remediation works. The bedrock is relatively shallow in the eastern portion of the Block 5 Remediation Area and increases in depth significantly to the west. Groundwater control and retention walls would be installed to facilitate excavation of the Block 5 Remediation Area.

The works proposed as part of the Block 5 Remediation DA include the following:

- Temporary diversion of existing stormwater, where required.
- Installing temporary retention structures (e.g. sheet piling in bentonite slurry, secant piles) to facilitate proposed excavation, where required, including:
 - Temporary ground anchors or other restraint system as required into adjoining blocks and road reserve.
 - Support/retain the existing Sewer Pumping Station 1129 and associated infrastructure.
- Installation of temporary odour structure(s) over proposed excavation area.
- Dewatering and water treatment in an on-site water treatment plant.
- Excavation of contaminated soil beneath odour structures, with appropriate air emission controls/monitoring.
- Transfer of contaminated material directly off-site for disposal and/or treatment at a licensed facility. These processes would be subject to the facilities' environmental controls, such as the conditions of their Environment Protection Licences.
- Backfilling of Block 5 excavation with suitable fill (imported and/or won from site).

The construction works associated with the Block 5 remediation are summarised below.

Site Establishment

- Installation of site fencing/exclusion zones and decontamination areas.
- Removal of site trees.
- Local protection/pruning of Hickson Rd trees where required for retention wall construction.
- Installation of general environmental controls for excavation works (e.g. bunding, sediment controls).
- Establishment of plant/equipment.

Services Diversion

- Temporary diversion of existing stormwater service.
- Capping of any remaining site services.

Perimeter Retaining Wall

- Construction of temporary retention wall (e.g. sheet piles in bentonite slurry/secant piles) to facilitate excavation on north, east and west boundaries. Final construction subject to future detailed design.
- Installation of temporary ground anchors or associated support structures.

Dewatering and water treatment

- Use of on-site Water Treatment Plant (WTP) for managing groundwater during excavation.

- Installation of dewatering infrastructure and groundwater extraction; transfer of water to WTP, treatment of water and discharge of water in accordance with Environment Protection Licence requirements.

Construction of Excavation Odour Control Structures

- Installation of temporary odour control structure(s) over proposed excavation areas. This may include installation of temporary ground structures (e.g. piles/capping beam) and/or perimeter weights as required to provide support.
- Odour control may comprise multiple structures side-by-side to achieve coverage of the remediation area, and appropriate individual span of each structure.
- Installation of structures to ensure containment of all odours. Installation and operation of air exhaust system and associated emissions control, air filters/treatment and stack.
- Odour control structures may include retractable doors and an air lock system at the entrance/exit to minimise odour emissions.
- Final structures would be subject to future detailed design.

Excavation

- Excavation of contaminated soil from Block 5 per the AECOM Remedial Action Plan (indicative excavation volume ~ 39,000 m³).
- Excavation of rock is not proposed for remediation purposes, except limited excavation (if required) to remove tar seeps to the extent practical.
- Temporary odour control structure would be operated to manage and treat exhausted air.
- Water from excavation with no visible or olfactory signs of contamination (including surface water sheens or a smell of tar or petroleum) would be transferred to the onsite WTP for treatment and licensed discharge. Where required, highly contaminated liquid waste (i.e. that with a strong odour or high level of visible contamination) would be pumped by licensed liquid waste contractors (vacuum truck) and disposed of off-site.
- Vehicles/plant would be decontaminated in wheel wash/cleaning area prior to moving to other areas of site or off-site. Waste water from the decontamination activities would be transferred to water treatment plant.
- Detailed monitoring (air, noise, water) would be conducted throughout the works.

Soil Treatment / Disposal

- Excavated contaminated material would be transported directly off-site for disposal in accordance with NSW EPA requirements and waste guidelines following in-situ waste classification.
- Non-hazardous waste would be classified and transported off-site in covered trucks for landfill disposal.
- Material classified as hazardous would be transported off-site to a licensed treatment facility for treatment prior to landfill disposal.

Block 5 Area Validation

- The excavation works would be validated in accordance with the inspections and sampling/testing specified in the *VMP/Block 4 RAP* (AECOM, 2013).

Backfilling and Decommissioning

- The excavation temporary odour control structures would be decommissioned following excavation.
- Excavation areas would be backfilled and compacted with suitable fill (either imported to site or won from site, provided the material satisfies the HHERA criteria for the area).
- Temporary sheetpiles and temporary ground anchors would be removed where required.

Safe Work Practices

All workers on site would be required to work under a site-specific Health and Safety Plan, including task-specific Safe Work Method Statements. Personal protective equipment suitable for the task being undertaken would be required to be used by all employees and visitors.

3.2 Haul Roads and Required Plant

The Site is currently covered in hardstand, which would be retained wherever practicable. As such, haul roads between the temporary odour control structures (under which the excavation works would be undertaken) and the site boundary would generally be paved. Regular cleaning/sweeping of the paved haul roads will be required as part of the remediation excavation activities to ensure silt build up does not occur.

Lend Lease proposes to cover haulage trucks prior to exiting the temporary odour control structures and trucks would be decontaminated (where required) prior to moving to other areas of site or off-site trucks transporting potentially odorous material would be covered with odour suppressant foam (or similar) prior to leaving the site, to mitigate odour emissions.

3.3 Environmental Controls

Due to the scale of the works and close proximity to sensitive receptors, the effectiveness of environmental controls and environmental management is critical to the overall success of the project. The EPA recommended that environmental management at Barangaroo should focus on source controls rather than end of pipe controls. Primary management was, therefore, the focus of proposed mitigation strategies; a number of secondary (end of pipe) controls are also recommended where necessary.

3.3.1 Sediment Controls

In accordance with the EPA recommendations, the most effective sediment management measures will be based on source controls. As a contingency for the failure of source controls, a number of secondary controls should be constructed. A list of primary (source) controls and a number of secondary controls recommended in the *City of Sydney Guidelines to Erosion and Sediment Control on Building Sites* are provided in **Table 1**.

Table 1 Sediment Control Options

Category	Control Device	Location
Source controls	Temporary odour control structures	Remediation excavations
	Gutter	Temporary odour control structures /temporary buildings
	Sediment sumps	Inside temporary odour control structures
	Runoff diversion	Perimeter of temporary odour control structures and stockpile areas
	Tarping/mulching/gravel armouring	External stockpiles (non-contaminated material only) and exposed soils, haulage trucks
Secondary controls	Wheel wash	Site exit
	Shaker grids	Exits to temporary odour control structures
	Sediment fence	Stormwater inlets, stockpile perimeters
	Sediment sock	Stormwater inlets, stockpile perimeters
	Straw bales	Stormwater inlets, stockpile perimeters

3.3.2 Temporary Odour Control Structures

The purpose of the odour control structures is to minimise the release of malodorous and potentially harmful emissions during remediation excavation operations. The odour control structures would act as the predominant primary control of all environmental emissions at the Site. Odour control structures would be established above excavation operations, essentially isolating these work areas from the external environment. The odour control structures would be constructed of impervious material, generally creating a seal between the internal and external atmosphere, and would include stormwater interception devices where practicable.

Structure dimensions will be developed based on the following three primary goals:

- Cover and isolate potentially odorous works areas;
- Ensure adequate size to facilitate production rates sufficient to maintain the remediation works program; and

- Encapsulate a volume of air able to be reasonably ventilated and filtered.

3.3.3 Filtration Systems

The temporary odour control structures would be serviced by a number of filtration systems and fresh air fans. The filtration systems would be designed to reduce emissions to concentrations compliant with the relevant environmental standards and/or approved site emission criteria for Barangaroo South and would:

- Maintain fresh air circulation and an appropriate safe working environment inside excavation structures; and
- Reduce the concentration of potentially harmful gas and dust concentrations and malodorous emissions exiting structures.

The system is expected to be designed to achieve two to three complete air exchanges per hour within the structures, which will require the use of many filtration units. The systems would primarily consist of appropriately sized granular activated carbon (GAC) filters with particulate pre-filters. Multiple GAC filters (minimum of two) would be required to prevent fugitive emissions during filter exchanges. Filter saturation and changeover frequency would generally be guided by the environmental consultant based on stack emission monitoring. It is expected that filter changeover will be required approximately every two to three months.

The final design and detailing of Filtration Systems would be subject to further design development.

3.3.4 Other Controls

The environmental control measures mentioned above would be regularly checked to ensure their ongoing integrity and operability. Any spillages would be appropriately managed in accordance with an Emergency Response and Contingency Plan to be prepared by Lend Lease as required by Section 13.1.3 of the VMP/Block 4 Remedial Action Plan (AECOM, 2013).

All excavated odorous material taken off site would be treated to minimise potential emissions of dust or odour. For example, odour suppressant foam (such as Rusmar AC-645 or equivalent) or similar materials would be used to seal the loads. The intent of the foam agent is to form a barrier that provides adequate odour control for the duration of transport. The foam agent will be required to meet the following criteria:

- must be non-hazardous and bio-degradable;
- must be able to be quickly applied to truck loads shortly after the truck is loaded to rapidly mitigate the generation of fugitive emissions and odours;
- must be applied at the recommended thickness;
- must form a seal across the surface of the soil and effectively bind surface dust particles; and
- upon drying, must form a cover which is flexible and capable of resisting degradation during transportation of the materials to the licensed offsite facility.

As confirmed in the *Addendum to the VMP/Block 4 RAP* (AECOM, 2015), the proposed off site transport is consistent with the *VMP/Block 4 RAP* (AECOM, 2013) and compliant with both the NSW EPA (2014) *Waste Classification Guidelines* and the amended *Protection of the Environment Operations (Waste) Regulation* (2014).

3.4 Decontamination Area

3.4.1 Personnel

Decontamination units would be established at the primary entrance/exit to each temporary odour control structure, and should include:

- Potable water supply;
- Running water and industrial hand wash;
- Waste bins;
- Supply of fresh personal protective equipment (PPE);
- Emergency shower (for inclusion based on risk assessment and Material Safety Data Sheets [MSDSs]); and
- Change area.

3.4.2 Plant

Decontamination would be required when earthmoving plant has been working with contaminated material and is due to be removed from site or transferred to a clean validated area. The plant decontamination area would consist of the following:

- A nominated hardstand area with adequate drainage (may be established inside odour and dust control structures);
- A drainage trap and pump system to allow all contaminated washout to be captured and pumped to water treatment system;
- Sediment controls around drains to intercept gross pollutants;
- Adequate water supply and high pressure cleaner;
- Waste bins; and
- Cleaning tools and detergent.

3.5 Site Access

Remediation works would be demarcated with temporary fencing and appropriate construction and traffic warning signage to restrict public access to the Site Remediation Area, as well as unauthorised access of general construction personnel to remediation areas and confined spaces. All confined spaces and other high risk areas of the Site Remediation Area would be identified and signposted/barricaded to restrict access and warn personnel of the risk. Confined spaces would be identified using the definition provided in AS2865-2009 and based on a risk assessment prior to the commencement of remediation works.

4.0 Pollutants

4.1 Screening of Pollutants

The distribution of soil and groundwater contamination in areas relevant to this HIA was assessed within the Data Gap Investigations (DGIs) (AECOM 2010a and 2010b) and the *VMP/Block 4 RAP* (AECOM, 2013) and were not reproduced in this report in detail.

The DGIs identified that the primary potential for contamination at the Site originates from:

- Potentially contaminated fill materials used in historical land reclamation within the Site; and
- Potential migration of contamination from the former gasworks site located on the Site.

Through the DGI study, soil and groundwater sampling results were compared with a multitude of generic regulatory assessment criteria in order to identify criteria contaminants. Concentrations of contaminants including heavy metals, TPH, benzene and xylenes (hereafter referred to within the category of benzene, toluene, ethylbenzene and xylenes [BTEX]), PAHs [including B(a)P] and sulfate were found to exceed the adopted site investigation criteria at various locations and depths.

4.2 Pollutants of Potential Concern (POPC)

For the purposes of this HIA, pollutants of potential concern (POPC) were defined as chemicals that have been detected on the Site in concentrations greater than relevant human health screening criteria. The pollutants considered were restricted to those detected within the Site boundaries as defined previously and were limited to those addressed in the HHERA (AECOM, 2012b).

The principal pollutants considered were:

- BTEX;
- PAHs;
- TPH (C₆-C₉ and C₁₀-C₃₆ fractions); and
- Heavy metals

Asbestos was not identified as a chemical of potential concern within the *Declaration Site HHERA* (AECOM, 2011a) based on the information available at the time of report preparation. Asbestos had been detected in only a limited number of sample locations and was not considered to be widespread. Subsequent investigations and earth works of the Other Remediation Works South (ORWS) Area, located south of and adjacent to the Declaration Site, have identified widespread asbestos contamination. Based on the historical nature of the in-filling at Barangaroo South, it is considered likely that asbestos contamination may be more widespread than initially reported within the historical investigations.

The risk of inhaling asbestos fibres is most appropriately managed through implementation of appropriate management tools in the *VMP/Block 4 RAP* (AECOM, 2013) and through the preparation and implementation of an Asbestos Management Plan. Nevertheless, asbestos is included in the health impact assessment below as a basis for including its consideration throughout the remediation project.

The distributions of the POPC were detailed in the DGI (AECOM, 2010a). The details for the Block 5 Remediation Area are summarised in **Table 2**.

Table 2 Pollutants of Potential Concern and Expected Distribution Block 5 Remediation Area

POPC Category	Distribution
BTEX (particularly benzene and xylenes)	Soil: Maximum concentrations of BTEX were generally in proximity to and down gradient of the former gasworks infrastructure. BTEX compounds exceeded the adopted site investigation criteria. Groundwater: Significant concentrations reported in groundwater underlying the former footprint of the gasworks infrastructure. Air: BTEX may vaporise from exposed soil or water, and also may be carried into the air whilst sorbed to small soil particles. Low concentrations of toluene were detected in some locations, but were below adopted soil vapour guidelines within Block 5 Remediation Area.
PAHs [particularly benzo(α)pyrene or B(α)P]	Soil: B(a)P and total PAH assessment criteria exceedences were detected in shallow fill and at depth in natural soils. Groundwater: Concentrations of naphthalene within the Block 5 Remediation Area exceeded the site investigation criteria. Air: PAHs may vaporise from exposed soil or water, and also may be carried into the air whilst sorbed to small soil particles.
TPH	Soil: Exceedences of soil assessment criteria for C₆-C₉ and C₁₀-C₃₆ were found in a number of areas and a variety of depths. Groundwater: Significant concentrations of TPH were reported in groundwater underlying the former footprint of the gasworks infrastructure. Air: TPH comprises many chemical species, including BTEX and many PAHs, which may be considered representative of the volatile fractions of TPH (ATSDR 1999). Since TPH distribution was found to be consistent with PAH distribution in soil and groundwater, distribution in air is expected to be consistent with PAH distribution in air.
Suspended particulates (dust)	Air: Quantities of suspended particulates concentrations of suspended particulates are expected to be highest during the drilling works within the Block 5 Remediation Area. Suspended particles may carry small quantities of other POPC listed above.
Heavy metals (particularly lead, cadmium, copper, nickel and zinc)	Soil: Lead was the only heavy metal found to exceed soil assessment criteria. Exceedences found at shallow depths. Groundwater: Heavy metals concentrations were reported above the assessment criteria adopted for the DGI in several groundwater samples. Exceedences were recorded for lead, cadmium, chromium (III & VI), copper, nickel and zinc. Air: Heavy metals are not volatile (with the exception of mercury, which may volatilise due to vapour pressure), so the presence of heavy metals in air is generally expected to be associated with suspended particles. Limited soil disturbance should minimise dust generation.
Odour	Air: The Data Gap Investigation (AECOM, 2010a) indicated that odours were commonly encountered in the soil and fill material and groundwater in the Declaration area, including tar-like odours from the former gas-works structures.
Asbestos and asbestos materials	Soil: Based on the observations during recent excavation of fill adjacent to the site asbestos containing materials are considered to be likely within fill materials within the Declaration Area. The asbestos identified in the DGIs comprised either asbestos cement sheeting, friable asbestos fibre bundles or fibre board (AECOM 2013b). ACM and asbestos fibres were rarely detected in soil above the adopted criteria in the Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites of Western Australia (WA Department of Health, 2009). Groundwater: Asbestos is not considered a relevant hazard when wet. Air: Asbestos is not volatile, but may be present in air as asbestos fibres or attached to suspended soil particles.

4.3 Potential Health Effects of Identified POPC

The potential effects of the POPC identified for this project are summarised in the following sections. Details were obtained from the National Pollutant Inventory (NPI, 2010) unless otherwise specified.

4.3.1 BTEX

BTEX are a category of volatile organic compounds (VOCs). VOCs are organic compounds with a vapour pressure at 20 °C exceeding 0.13 kPa. These compounds have been implicated as a precursor in the production of photochemical smog, which may cause atmospheric haze, eye irritation and respiratory effects. VOC emissions are typical for oil processing, petrochemical and chemical plants and include emissions from point sources (storage tanks and filling stations vents) and fugitive emissions from pipelines and process equipment leaks.

Benzene

Benzene is an airborne substance that can be washed out of the air by rain, and evaporated into the air. It will decompose in soil or water when oxygen is present. Benzene exposure commonly occurs through inhalation of air containing the substance. It can also enter the body through the skin, although it is poorly absorbed this way. Low levels of benzene exposure may result from tobacco smoke and car exhaust.

Benzene is considered to be a toxic health hazard and a carcinogen. Human exposure to very high levels for even brief periods of time can potentially result in death. Lower level exposure can cause skin and eye irritation, drowsiness, dizziness, headaches and vomiting, and over longer periods damage to the immune system, leukaemia and birth defects.

Toluene

Toluene (methylbenzene) is a highly volatile chemical that quickly evaporates to a gas if released as a liquid. After a few days, the substance breaks down in air into chemicals that are harmful to human health. Bacteria in soil and water also break down toluene. Due to relatively fast degradation, toluene emissions are typically confined to the local area in which it is emitted. Toluene is a component of petrol and paints, and is also found in tobacco smoke. Human exposure typically occurs through breathing contaminated air, but toluene can also be ingested or absorbed through the skin (in liquid form). Toluene usually leaves the body within twelve hours.

Short-term exposure to high levels of toluene can cause dizziness, sleepiness, unconsciousness and sometimes death. Long-term exposure can cause kidney damage and permanent brain damage that can lead to speech, vision and hearing problems, as well as loss of muscle and memory functions.

Ethylbenzene

Ethylbenzene is a highly volatile substance, so is typically present in air. Ethylbenzene rapidly enters the body through the lungs and digestive tract. The substance has both acute and chronic toxic effects on animals and plants, including shortened lifespan, reproductive problems and behaviour changes. Exposure to high concentrations can cause dizziness, paralysis, breathing difficulties and death. Chronic health effects in humans can last for months or years. Ethylbenzene is present in petroleum, pesticides, cleaning products and solvents.

Xylenes

Xylenes are flammable liquids that are moderately soluble in water. They are quickly degraded by sunlight when released to air, and rapidly evaporate when released to soil or water. They are used as solvents and in petrol and chemical manufacturing.

Xylenes can enter the body through inhalation or skin absorption (liquid form), and can cause irritation of the eyes and nose, stomach problems, memory and concentration problems, nausea and dizziness. Excessively high-level exposure can cause death.

4.3.2 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are another category of VOCs. They contain at least two fused benzene rings and are commonly formed by the incomplete combustion of fossil fuels and other organic materials. They travel through the atmosphere as a gas or attached to dust particles. Some PAHs readily evaporate into the air. The compounds can break down over days or weeks by reacting with sunlight and other chemicals in air, but do not dissolve easily in water. PAHs are moderately persistent in the environment and can bioaccumulate.

PAHs can be inhaled or ingested and can also be absorbed through the skin. Exposure can cause irritation of eyes and nose and other mucous membranes, headaches, nausea, damage to blood cells, liver and kidneys, and

(in very high levels) may be life threatening. A number of PAHs are listed as probably or possibly carcinogenic to humans by the International Agency for Research on Cancer. They can have high acute and chronic toxicity effects on animals and aquatic life, with some also affecting agricultural and ornamental crops. Benzo[a]pyrene is one of the most toxic PAHs, and, as it typically found in the atmosphere with other PAHs, is often used as an indicator for the PAH group of pollutants. Naphthalene is another key PAH. Excessive non-life-threatening exposure may cause cataracts in the eyes, while ingestion can cause abdominal cramps, nausea, vomiting, diarrhoea in young infants. It is considered a possible carcinogenic to humans and carcinogenic in animals.

4.3.3 Total Petroleum Hydrocarbons (TPH)

TPH is a group of several hundred chemical compounds that originate from crude oil. Petroleum hydrocarbons are environmental contaminants, though they are not usually classified as hazardous wastes as many petroleum products are commonly used as fuel sources. Due to the variety of crude oil types and derivative products that form TPH, the assessment of health effects associated with these chemicals is problematic. Health effects are often assessed based on the presence of indicator compounds for separate fractions, which consist of petroleum hydrocarbons with similar physical and chemical properties. Common constituents of TPH known to cause severe health effects are PAHs and BTEX. As a worst-case assessment, exposure to TPH may be considered to cause similar health effects in humans as PAH and BTEX compounds (ATSDR 1999).

4.3.4 Particulate Matter

Suspended particulate matter may be emitted from site via combustion activities (i.e. vehicle and plant operations) and site preparation works.

Airborne particles are commonly differentiated according to size based on their equivalent aerodynamic diameter. Particles with a diameter of less than or equal to 50 micrometres (μm) are collectively referred to as total suspended particulates (TSP). TSP primarily causes aesthetic impacts associated with settling on surfaces, which also causes soiling and discolouration. Uncontrolled emissions of these large particles, however, can cause some irritation of mucosal membranes and can increase health risks from ingestion if contaminated. Particles with diameters less than or equal to 10 μm (known as PM_{10} or fine particles) tend to remain suspended in the air for longer periods than larger particles, and can penetrate into human lungs.

Exposure to particulate matter has been linked to a variety of health effects, including respiratory problems (such as coughing, aggravated asthma, chronic bronchitis) and non-fatal heart attacks. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from the inhalation of the dust.

4.3.5 Heavy Metals

A variety of heavy metals were detected at the site. The metals detected at the Site for which soil and groundwater assessment criteria were exceeded are discussed below.

Cadmium

Cadmium is a naturally-occurring element found in the earth's crust. The combustion of coal and other fossil fuels can result in airborne emissions of cadmium compounds, but are typically confined to the local area surrounding the emissions source, with a lifespan of 5 -15 days in particle form. Cadmium can be inhaled or ingested.

Cadmium is considered to be a probable carcinogen, with evidence suggesting it causes cancers of the kidney and prostate in humans, and lung and testicular cancer in animals. It is a known teratogen (i.e. at certain exposures can cause defects or malformations in developing embryos/foetuses) and may cause reproductive damage. Prolonged exposure to low concentrations of cadmium can cause permanent kidney damage, while high exposures can cause rapid respiratory damage resulting in shortness of breath, chest pain and fluid build-up in the lungs, as well as gastrointestinal symptoms such as nausea, vomiting, cramps and diarrhoea. Long-term exposure can result in symptoms such as anaemia, fatigue, and loss of the sense of smell. The general public is typically exposed to cadmium through food, since food material may take up and retain cadmium, and through smoking of tobacco. The toxicity of cadmium is affected by water hardness in freshwater, with greater toxicity associated with softer water.

Chromium VI

When chromium VI is released into the atmosphere as particulate matter from the manufacture/disposal of products or the combustion of fossil fuels, it is entrained in the air for up to ten days before settling in soil and water, adhering strongly to soil particles, where only small amounts dissolve.

While chromium III is an essential element, compounds of chromium VI are usually highly toxic. Inhalation of chromium VI can damage and cause adverse health symptoms of the respiratory and gastrointestinal systems, potentially leading to asthma and other allergic reactions. Long-term exposure to airborne chromium VI can adversely affect the immune system and cause cancer. Dermal contact can lead to skin ulcers, redness and swelling.

Chromium VI can have high to moderate acute toxic effects on plants, birds and land animals, resulting in low growth rates or death. Chromium VI is persistent and is thought to bioaccumulate in aquatic life.

Copper

Copper is a naturally occurring substance that is an essential trace element for both animals and plants. Copper can be inhaled or ingested. Most copper released to air, water, sediment and soil strongly binds to other particles, which greatly reduces its toxicity.

Exposure to high levels of copper can, however, be harmful, and cause irritation to the nasal passages, mouth, eyes and throat, while ingestion of high concentrations can cause nausea, vomiting, liver and kidney damage and, possibly, death. Copper is classified as a hazardous substance by the office of the Australian Safety and Compensation Council.

Lead

Lead is a naturally occurring substance that can enter the body by inhalation or ingestion, and primarily affects the nervous system. Excessive exposure to lead causes symptoms such as paralysis, anaemia, abdominal pain, brain and kidney damage and death. Lead can affect reproduction as well as the mental and physical development of children. Lead may be released as particles into the atmosphere, including through windblown dust and bush fires. Lead usually attaches to particles of organic matter, clay, soil or sand, and can accumulate in tissues.

Mercury

Mercury is a naturally occurring element found in rocks and ores. Mercury chloride acts like a particle, while elemental mercury may be found as a gas in the atmosphere. It is naturally released into the atmosphere by evaporation from soils and water and volcanic eruptions. Significant anthropogenic sources of mercury are the burning of fossil fuels, municipal landfills, sewage, metal refining and chemical manufacturing.

Mercury can enter the body through inhalation, ingestion or dermal contact. The nervous system is very sensitive to all forms of mercury. Exposure can potentially causing permanent damage to the brain, eyes, kidneys and developing fetuses, and can cause fluid build-up in the lungs that can be fatal. Dermal contact can burns to the skin.

Mercury is highly toxic to aquatic life, with both acute and chronic effects. Mercury accumulates in body tissue; consumption of contaminated fish can poison humans and possibly birds and land animals. It is also highly persistent in water and the environment. It should be noted that mercury has not been frequently detected on site (AECOM, 2010b).

Nickel

Nickel is an abundant, naturally-occurring element found in soil, water and food, typically found in combination with other elements such as arsenic, antimony and sulphur. Nickel is emitted to atmosphere from both natural and anthropogenic sources, such as combustion of fossil fuels, steel production, incineration and sewage treatment. Nickel can be transported as fine particulate matter, which is washed out of the air by rain into soil and water. Nickel is found in soils and sediments, and is kept soluble by organic matter.

Nickel and its compounds can be inhaled or ingested, with food and water being the primary sources of exposure for most people, as well as tobacco smoke. Inhalation of high concentrations of nickel can result in effects on the respiratory system, potentially causing sinus cancer, and nickel dust irritates the eyes, nose and throat.

Zinc

Zinc is a naturally occurring element found in all foods as well as rocks, soil, air, water, plants, animals and humans. Trace amounts are essential for human health. It is found in a variety of compounds, the properties of which vary greatly. The metal has a strong tendency to form complexes with inorganic and organic compounds. Zinc is used in a range of manufacturing, industrial and applications such as fungicides, antiseptics, water-repellants, lubricants and concrete.

Zinc attaches to dust particles in the air and to soil and sediment particles, and can be inhaled or ingested. Excessive zinc ingestion can lead to nausea, vomiting, anaemia, and damage to the pancreas. Zinc dust irritates mucous membranes, while solid zinc compounds can irritate the skin and eyes.

4.3.6 Odour

Odour is a sensory response to the inhalation of one or more chemicals in the air we breathe. A person's perception of an odour can vary significantly depending on the sensitivity of the person, the acuteness of the person's sense of smell and the connotations that the odour bestows on that person. Nuisance caused by odour is dependent on a number of factors including quality, intensity, frequency, timing and duration of the odour. Odour may affect a person's quality of life and can have a large range of effects including stress and other physical symptoms.

It should be noted that the level of odour is not directly related to its health effects; some compounds can adversely affect health when present in concentrations that generate low levels of odour, while other compounds can have very strong odours without producing adverse health effects.

Odorous compounds detected at the site may include BTEX and PAHs, notably ethylbenzene, xylenes and naphthalene.

4.3.7 Asbestos

Asbestos poses a human health risk principally through the inhalation of its fibres from air. If deposited in the lungs, the fibres can initiate diseases that may take many years to produce major health effects. The effects include asbestosis, lung cancer and the normally rare cancer mesothelioma that affects certain chest membrane linings. Impacts tend to be the result of higher levels of exposure, most often occupational, but mesothelioma can also result from low level exposures. The human health risk from asbestos-contaminated soil varies depending on the form of asbestos, its quantity and its exposure situation (WA Department of Health, 2009).

5.0 Expected Pollutant Sources

Expected pollutant emission sources were determined based on conceptual understanding of the excavation and soil movement stages (informed by the Staging Plans prepared by ARUP), and on our previous experience with construction projects of a similar nature.

While there are no expected sources for the release of contaminated water, accidental contact with contaminated water is possible and was considered in this assessment. Formal discharge criteria will be agreed with the EPA. Treated water would be discharged to the harbour in accordance with the agreed discharge licence conditions.

To the extent practicable, remediation excavation activities are proposed to be undertaken within temporary odour control structures, fitted with filtration systems to remove contaminants from the exhaust stream. Typical contaminant removal rates are 85 % for gases and 98 % for dust, and emissions from the filtration units would be compliant with EPA emission standards. Actual emissions would be dependent on air pollutant concentrations within the temporary odour and dust control structures. Retaining wall works and piling would not be under an odour structure.

In addition to pollutant source controls, personnel within the enclosures would potentially be exposed to pollutants through contact with soil, dust, and vapours in the air. Exposure would be mitigated through the use of personal protective equipment (PPE).

The off-site transport and treatment of excavated material are also potential sources of emissions. As indicated in **Section 3.2**, trucks transporting potentially odorous material would be treated with odour suppressant foam prior to leaving the site. The off-site treatment of material would be undertaken at a licensed facility; any emissions associated with the treatment process would be managed in accordance with that site's Environment Protection Licence. These potential emission sources were not considered further in this assessment.

6.0 Potential Sensitive Receptors

A sensitive receptor is identified by the EPA as someone who works or resides or may work or reside near a proposed activity, including people within residential areas, hospitals, hotels, shopping centres, play grounds, recreational centres, and the like. Barangaroo is surrounded by a number of residences, walkways and workplaces. In order to simplify this assessment, human receptors were considered in terms of Significant Exposure Groups (SEGs). SEGs are groups of receptors likely to:

- Experience similar concentrations and duration of exposure to POPC;
- Have similar tolerance to health impacts; and
- Have similar mitigation measures in place to prevent exposure to POPC.

Sensitive receptors relevant to operations at the Block 5 Remediation Areas were classified into the following SEGs:

- Site workers and visitors;
- Residents living to the east, south and north of the Site, including the child care centre located at 37 High Street and including occupants of future residential buildings (R8 and R9) at Barangaroo South Stage 1a;
- Business patrons and staff (Bond Heritage Café, future commercial buildings at Barangaroo South Stage 1a and the King Street Wharf precinct) and office workers to the east and south of the Site, including external and pedestrian receptors associated with King Street Wharf precinct, external dining and bar users, KPMG Tower and Macquarie Bank buildings, future commercial buildings T1, T2 and T3 at Barangaroo South, and employees and customers of open air buildings;
- Pedestrians; and
- Maintenance workers (utilities and adjacent properties).

These SEGs are described in **Table 3**.

Table 3 Significant Exposure Groups

SEG	Description	Notes
Site workers and visitors	Likely to be involved in the works that may potentially generate POPCs. Also likely to be temporarily housed (amenities and ablutions) in areas adjacent to remediation works	Likely to be closest to potential pollutant emissions, but use of engineering controls, personal protective equipment and safe work methods is expected to minimise exposure intensity and duration. Mitigation measures work practices and amenities protection are expected to minimise pollutant concentrating and exposure duration in amenities and ablutions areas.
Residents	Located to the east, south and north of the site.	Exposure possible during and after working hours. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration; these include enclosure of excavations with emissions controls, as well as dust suppression practices and the covering of loads with odour suppressant foam (or similar). Children may be more susceptible to the health effects of certain contamination types. The child care facility at 37 High Street offers long day care services; as such, exposure may potentially occur during

SEG	Description	Notes
		much of the operational hours. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration.
Businesses	Several commercial office blocks across Hickson Road, King Street Wharf, Moores Wharf and adjacent precincts, and future commercial buildings T1, T2 and T3 at Barangaroo South.	Exposure possible during working hours. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration. Existing air conditioning systems that are equipped with particle filters and/or intake areas located away from the proposed works, will provide additional (but not essential) mitigation.
Pedestrians	Footpaths are located adjacent to Block 5 along Hickson Road Remediation Area.	Individual exposure is likely to be of a short duration. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration.

Whilst not considered to be a SEG, offsite receptors located adjacent to the proposed transportation route are also considered in **Section 8.2**. This includes those receptors that may be located in close proximity to the proposed transportation route which will be used for the haulage of contaminated materials to the licensed offsite treatment facility.

7.0 Relevant Exposure Pathways

An exposure pathway describes the course a chemical or physical agent takes from its source to an exposed individual. In order for a human receptor to be exposed to a chemical contaminant from a site, a complete exposure pathway must exist, which generally includes the following elements (USEPA, 1989):

- A source and mechanism of chemical release;
- A retention or transport medium (or paths where chemicals are transferred between media);
- A point of potential human contact with the contaminated medium; and
- An exposure route (inhalation, ingestion or dermal contact) at the point of exposure.

In cases where one or more of the above elements is missing, the exposure pathway is considered to be incomplete. Such circumstances are not considered to pose a risk to receptors.

The potential exposure pathways of POPC to the receptors identified in **Section 6.0** are summarised in **Table 4**. On-site receptors are primarily personnel involved in the remediation trials. Off-site receptors include residents and visitors to the neighbouring areas, including those using Hickson Road.

Table 4 Exposure Pathway Analysis

Exposure Pathway	Complete Pathway		Notes
	On-site	Off-site	
Incidental ingestion of chemicals in soil	✓	(✓)	Airborne soil generation possible during excavation and transport activities. Off-site receptor exposure will be minimised through undertaking excavation activities within enclosures, and where practicable and required, applying odour suppressant foams, covering truck loads and wetting down any external stockpiles. (N.B. all contaminated material will be stored within the OCSs).
Dermal absorption of chemicals from soil	✓	(✓)	
Inhalation of chemicals in soil-derived airborne particulates	✓	(✓)	
Inhalation of soil-derived vapours	✓	(✓)	Filtration systems servicing excavation enclosures will remove the majority of odorous compounds from the exhaust stream. Exhaust from the filtration units will be monitored to maintain emissions at levels generally within acceptable concentrations.
Incidental ingestion of chemicals in groundwater (incidental contact)	✓	x	Due to the shallow nature of and tidal influence on groundwater levels at the Site, groundwater may seep into remediation trenches or other excavations; as a result, there is potential for on-site workers to come in contact with ground water
Dermal absorption of chemicals in groundwater (incidental contact)	✓	x	
Inhalation of groundwater derived vapours	✓	✓	Vapour emissions may potentially travel outside site boundary
x Incomplete exposure pathway (✓) Potentially complete pathway of minor significance ✓ Potentially complete exposure pathway			

7.1 Conceptual Site Model

A conceptual site model (CSM) was developed using the site activities, identified POPC, expected sources of POPC, and identified human receptors and exposure pathways to illustrate the full pathway of the migration of POPC from sources to receptors. **Figure 3** shows the possible exposure pathways; those unlikely to occur or to have minor health effects are denoted by an open circle, while those with the potential to result in noticeable health effects (and, as such, require further analysis) are denoted with a closed circle.

7.2 Measures for Reducing Exposure

A number of aspects of the proposed work at the Site Remediation Area will contribute to control of human health risk. These operations can be categorised as source and pathway controls and are discussed in the following sections.

7.2.1 Source Controls

It is widely accepted in the Risk Control Hierarchy (WorkCover, 2010) that if a hazard cannot be substituted for a lesser hazard, then isolating the hazard from people and using engineering means to reduce the hazard are the most effective means of risk control. In regards to isolation and engineering controls for the hazard of POPC within soil and groundwater on the site, the control measures for the Block 5 Remediation Area are detailed below.

Particulate matter source control measures would include a combination of the following techniques:

- Dust suppression using hand held spraying, water sprays, chemical wetting agents, and/or hydromulch or a combination of techniques;
- Excavation of materials within temporary odour control structures;
- Managing groundwater removal and drawdown, where practicable, such that material excavated is retained in a moist state;
- Implementation and enforcement of site speed limits;
- Installation of solid perimeter hoardings adjacent to sensitive receptors;
- Minimising haul road lengths;
- Minimising exposed/excavation areas where practicable;
- Covering surfaces where appropriate;
- Covering loads during transport;
- Watering and sweeping of exposed surfaces including haul roads;
- Undertaking remediation works in a staged and sequential manner;
- Surface stabilisation to minimise dust generation; and
- Regular clean up of soil load spillages.

Source control of the emission of gaseous POPC from exposed contaminated soil and water include a combination of the following techniques:

- Enclosure (where practicable) of remediation excavation and other remediation activities and filtration of exhaust streams to manage POPC that may be produced/released during the soil excavation and remediation processes;
- Prompt removal, covering and managing of heavily contaminated materials that have been exposed and are identified to have caused the emissions;
- Use of additional emissions control features on plant and machinery;
- Location of offending plant or equipment on less sensitive on-site areas;
- Regular tuning, modification and maintenance of equipment, plant and machinery;

- Covering potentially odorous loads with odour suppressant foam (or similar) to mitigate odour emissions; and
- Regular clean up of soil load spillages.

Source control of contaminated water would include a combination of the following techniques:

- Installation of ground water control and retention walls as practicable around the excavation area to minimise the infiltration of groundwater from the Declaration Area into the less contaminated excavation area;
- Treatment of contaminated water to enable safe discharge in accordance with site regulatory requirements;
- Use of surface bunds and drainage diversions to divert clean water away from contaminated areas; and
- Silt fences to prevent potentially contaminated soil from being carried into undisturbed areas, and to prevent undisturbed soil entering disturbed areas.

7.2.2 Pathway Controls

Although controlling the release mechanism of POPC is the most effective strategy for minimising the potential for human exposure, additional post-release controls will also be used to further reduce the potential for health impacts. Key controls measures designed to interrupt the exposure pathways of POPC would include:

- Mandatory issue and use of appropriate PPE for all workers on and around the site to limit the potential for exposure to POPC in air, soil and water. This PPE would include hard hats, high visibility clothing, eye protection, safety gloves and safety boots for all staff, with respirators and overalls used where required;
- Use of fine mist sprays around the site to absorb soluble POPC vapours and to suppress wind-blown dust from exposed site areas (note that the misting sprays are not expected to result in an additional exposure pathway from the site. The misting sprays will reduce the existing potential off-site dust exposure pathway. The only risk associated with misting sprays relates to the accumulation of moisture or liquids from the sprays. This liquid would be monitored and controlled as part of the site surface water management plan);
- The existing fencing and security arrangements around the Block 5 Remediation Area are considered adequate to prevent members of the public from entering the work area;
- It is considered that asbestos may be encountered as occasional ACM fragments, and possibly fill containing asbestos material, and that the potential for asbestos fibres exposure is best managed through the implementation of the management tools in the *VMP/Block 4 RAP* (AECOM, 2013) and through implementation of an Asbestos Management Plan for the works.

8.0 Potential Health Impact Assessment

Risk issues were assessed based on the application of site control measures using a simple risk ranking matrix, based on Australian Standard (AS4360-2004; Standards Australia, 2004), and consistent with risk management approaches recommended in updates to AS4360 (Standards Australia, 2009).

8.1 Assessment of Risks to Local Receptors

The risk classifications (conclusions) for the exposure routes provided in **Table 5** were based on the likelihood and consequence risk analysis matrix used to assess the level of risk for each identified issue, which is provided in **Appendix A**.

Table 5 Conclusions Regarding Site-derived Risks to Local Receptors

Sources of Pollutants of Potential Concern (POPC)	Exposure Route	Receptor Significant Exposure Groups	Conclusions
POPC within contaminated soil: BTEX, PAHs, heavy metals and particulate matter Asbestos and asbestos materials.	Inhalation of suspended particles (dust) and vapours	Workers on and adjacent to the site	Risk considered to be high (possible with moderate consequences) but manageable by: - Adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein; - Asbestos Management Plan; and - Use of appropriate PPE.
		Residences	Risk considered to be moderate (possible with minor consequences) due to utilisation of temporary odour and dust control structures during remediation activities. Further protection will be achieved by source control including: - Adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein; - Asbestos Management Plan; and - On-site water-spraying of exposed soil areas for dust control and /or covering of spoil and surfaces.
		Businesses	Risk considered to be moderate (possible with minor consequences) due to utilisation of temporary odour and dust control structures during remediation activities. Further protection will be achieved by source control including: - Adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein; - Asbestos Management Plan; and - On-site water-spraying of exposed soil areas for dust control and /or covering of spoil and surfaces.
		Pedestrians adjacent to the site	Risk considered to be moderate (possible with minor consequences) due to utilisation of temporary odour and dust control structures during remediation activities. Further protection will be achieved by source control including: - Adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein; - Asbestos Management Plan; and - On-site water-spraying of exposed soil areas for dust control and /or covering of spoil and surfaces.

Sources of Pollutants of Potential Concern (POPC)	Exposure Route	Receptor Significant Exposure Groups	Conclusions
	Ingestion	Workers on and adjacent to the site	Health risks considered moderate (unlikely with minor consequences) but manageable through: - Adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein; - Safe work practices; - Use of appropriate PPE (mandated by works undertaken); and - Effective hygiene procedures.
		Other SEGs	Risks from wind dispersion of dust particles expected to be low (rare with minor consequences) as: - Dust migration off-site site will be controlled; - Further dilution occurs prior to reaching receptors; and - Only a small fraction of dust and, therefore, contaminants, potentially ingested.
	Dermal contact	Workers on and adjacent to the site	Health risks considered high (possible with moderate consequences) but manageable through: - On-site dust control measures; - Use of appropriate PPE (mandated by works undertaken); and - Effective hygiene procedures such as hand washing.
		Other SEGs	Risks from wind dispersion of dust particles is expected to be low (rare with minor consequences) as: - Dust migration off-site site will be controlled; - Further dilution occurs prior to reaching receptors; and - Only a small fraction of dust and, therefore, contaminants, potentially in dermal contact.
	Inhalation of vapours	Workers on and adjacent to the site	Potential health risks are considered high (possible with moderate consequences) but manageable, minimised by: - Following appropriate safe work practices; and - Use of appropriate PPE (where mandated by works undertaken).
		Other SEGs	Off-site receptors are unlikely to be exposed to contaminated water. Health risks are considered low (rare with minor consequences).
POPC within groundwater: BTEX, TPH and heavy metals.	Unintentional ingestion of contaminated water	Workers on and adjacent to the site	While workers may potentially be exposed to contaminated groundwater, it is very unlikely that the water will come into contact with food and subsequently be ingested. Potential health risks are considered moderate (rare with moderate consequences) but manageable, minimised by: - Following appropriate safe work practices; and - Use of appropriate PPE (where mandated by works undertaken).
		Other SEGs	Off-site receptors are unlikely to be exposed to contaminated water. Health risks are considered low (rare with minor consequences).
	Dermal contact with contaminated water	Workers on and adjacent to the site	Workers involved the extraction works may be exposed to water containing POPC. Potential health effects are considered to be low (unlikely with minor consequences) but manageable by: - Following safe work methods; and - Use of appropriate PPE.
		Other SEGs	Off-site receptors are unlikely to be exposed to contaminated water. Health risks are considered low (rare with minor consequences).

8.2 Assessment of Risks to Offsite Receptors (During Transportation)

The risk classifications (conclusions) for the exposure routes provided in **Table 6** were based on the likelihood and consequence risk analysis matrix used to assess the level of risk for each identified issue related to the offsite transportation of materials (as provided in **Appendix A**).

Table 6 Conclusions Regarding Site-derived Risks to Offsite Receptors (During Transportation)

POPC	Exposure Route	Receptor Significant Exposure Groups	Conclusions
POPC within contaminated soil: BTEX, PAHs, heavy metals and particulate matter Asbestos and asbestos materials.	Inhalation of suspended particles (dust) and vapours	Pedestrians adjacent to the transport route	Health risks are considered low (unlikely with insignificant consequences) and can be managed by adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein.
		Drivers adjacent to the transport route	Health risks are considered low (unlikely with insignificant consequences) and can be managed by adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein.
		Residences adjacent to the transport route	Health risks are considered low (rare with insignificant consequences) and can be managed by adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein.
		Businesses adjacent to the transport route	Health risks are considered low (rare with insignificant consequences) and can be managed by adopting the control measures detailed in the <i>Addendum to the VMP/Block 4 RAP</i> (AECOM, 2015) and implementing the Inspection and Test Plan required therein.
		Workers involved with an emergency response/clean-up action	Health risks are considered low (rare with insignificant consequences) but manageable through: - Safe work practices (preparation of a Safe Work Method Statement [SWMS]); - Use of appropriate PPE (mandated by works undertaken); and - Effective hygiene procedures.
	Ingestion	Workers involved with an emergency response/clean-up action	Health risks are considered low (rare with insignificant consequences) but manageable through: - Safe work practices (preparation of a SWMS); - Use of appropriate PPE (mandated by works undertaken); and - Effective hygiene procedures.
	Dermal contact	Workers involved with an emergency response/clean-up action	Health risks are considered low (rare with insignificant consequences) but manageable through: - Safe work practices (preparation of a SWMS); - Use of appropriate PPE (mandated by works undertaken); and - Effective hygiene procedures.

It is noted that the assessment of potential risks to offsite receptors related to the licensed off-site treatment facility (for treatment of hazardous materials prior to landfill disposal) will be as per any specific requirements of license/approvals of the treatment facility, so is not required to be considered further by this HIA.

9.0 Conclusions

Through detailed consideration of the scope of works contemplated for the proposed remediation operations, risks to workers were considered to be high (possible with moderate consequences) but manageable. Risks to off-site receptors were considered to be low as the excavation activities would be undertaken utilising temporary odour control structures, where practicable, with emissions to air subjected to filtration. Risks to off-site receptors associated with the offsite transportation of materials was also assessed to be low due to the environmental control measures which will be adopted for the duration of the remediation works (refer to the *Addendum to the VMP/Block 4 RAP* [AECOM, 2015]).

The main risk to human health is considered to be the inhalation of vapours originating from contaminated materials. Dermal contact and oral ingestion/inhalation of deposited dust are not considered likely to significantly affect health. The SEGs most likely to potentially encounter site-derived dust or vapours are workers on site and directly next to the site and local residents. Risks from exposure to asbestos and asbestos materials, should they be encountered, are considered directly manageable by minimising dust generation and by implementing specific source control and exposure measures described in an Asbestos Management Plan for the works.

To ensure that potential human health impacts on nearby sensitive receptors and off-site receptors are minimised, the pollutant management measures listed in **Section 8.1** and **8.2** are considered necessary and appropriate. With diligent implementation of effective control measures (as detailed in the *Addendum to the VMP/Block 4 RAP* [AECOM, 2015]), it is expected that the risk of exposure to harmful concentrations of POPC would be low and acceptable, consistent with the Director-General's Requirement that the project does not have unacceptable (acute or chronic) health effects.

It is noted that gasworks waste is inherently odorous material. While comparison of site data to theoretical odour-based soil concentrations near the gasworks source area indicated minimal exceedences during small scale intrusive works, large scale excavations or intrusive works may potentially result in odour issues (AECOM, 2011b). For odorous chemicals, the thresholds of odour detection are routinely well below toxicity thresholds. Odour is not, therefore, an indicator of health risk. Nevertheless, for work sites where POPC exposure concentrations do not exceed acute tolerance and guideline concentrations, exposure to low concentrations of some POPCs may lead to physical irritation and discomfort for some people.

To confirm that concentrations of POPC are acceptable, it is considered advisable to develop a monitoring program to assess the routine concentrations of POPC at locations representative of each SEG. The results of the monitoring program should be used to manage the intensity, location and duration of works being undertaken. This monitoring should be incorporated into the Air Quality Monitoring Plan included in the AQIA.

It is noted that the assessment of potential risks to offsite receptors related to the licensed off-site treatment facility (for treatment of hazardous materials prior to landfill disposal) will be as per any specific requirements of license/approvals of the treatment facility, so is not required to be considered further by this HIA.

10.0 Recommendations

In order to mitigate potential health impacts to local receptors and offsite receptors (including during the offsite transportation of material), it is recommended that:

- the environmental control measures detailed in the *Addendum to the VMP/Block 4 RAP* (AECOM, 2015) including the required Inspection and Test Plan should be adopted for the duration of the works to mitigate potential health impacts to local receptors and offsite receptors during transportation of material;
- a vapour and dust monitoring program be developed and implemented within the site and at selected sensitive receptors beyond the site boundary during the remediation and land forming work to confirm that actual concentrations of POPC are minimal, and that ongoing risks are low.
- Locations should be selected as a conservative representation of SEGs;
- Results from the monitoring program should be linked to corrective work actions in case of any exceedences of adopted assessment criteria, notably in areas identified as contaminated, including the modification of work patterns and procedures and the implementation of additional control measures; and
- the Project Construction Environmental Management Plan (CEMP) (Lend Lease, 2012, or as amended) should demonstrate and facilitate the implementation of all proposed control measures. The CEMP should, as a minimum, detail the statutory requirements of the project, key site roles, community consultation, complaints management, pollution control measures, monitoring requirements, corrective actions and a procedure for reviewing the effectiveness of the plan.

Overall, reductions of site-derived dust and odour, with confirmation through air concentration monitoring that relevant odorous and non-odorous POPCs are not elevated above health exposure guidelines, are recommended as important goals of proactive site management, as are responses to meteorological and emission conditions such as still (particularly autumn) days where natural ambient air dispersal may be at a minimum.

11.0 References

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Figures

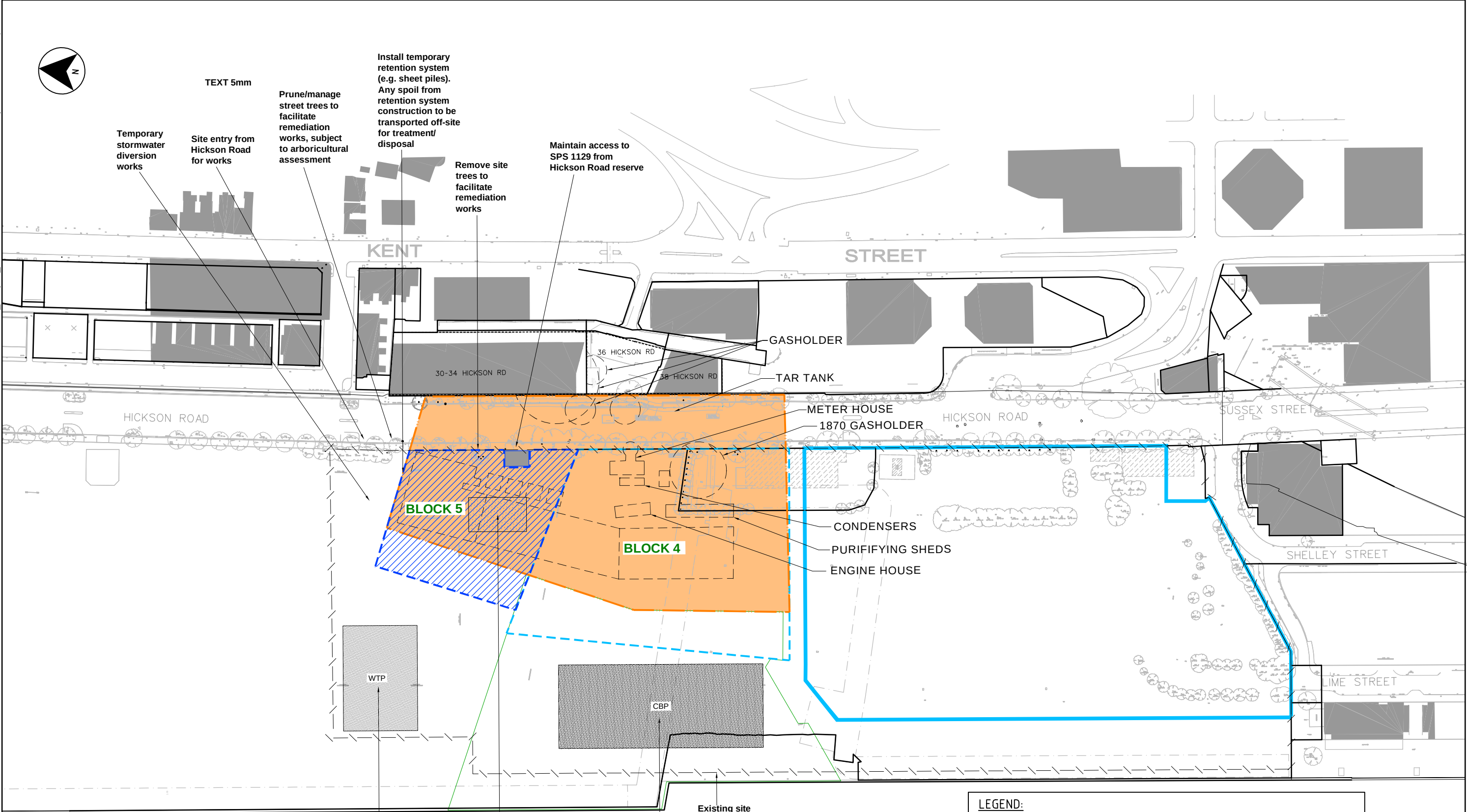


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AECOM

BARANGAROO SITE LOCATION
 Block 5 Health Impact Assessment
 Barangaroo Declaration Area
 Millers Point, New South Wales

FIGURE 1

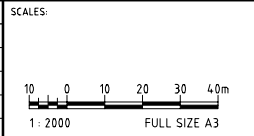


LEGEND:

- DECLARATION AREA
- BLOCK 5 REMEDIATION AREA
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- BLOCK 4 PERIMETER RETENTION WALL PROPOSED UNDER SSD 5897-2013
- EXISTING BLOCK 1, 2 AND 3 PERMANENT BASEMENT PERIMETER GROUNDWATER CONTROL AND RETENTION WALL CONSTRUCTED UNDER MP 10 0023 (STAGE 1a)

This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS	No.	BY	DATE	DESCRIPTION	APPD
01	PAS	16.05.14	DRAFT ISSUE		AR



THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000			
DESIGNED	AD	CHECKED	AR
DRAWN	PAS	CHECKED	
APPROVED		DATE	

DESIGNER:

AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

HEALTH IMPACT ASSESSMENT, BLOCK 5, BARANGAROO

FIGURE 2:
SITE LAYOUT AND SURROUNDING AREA
REMEDATION DEVELOPMENT APPLICATION, BARANGAROO BLOCK 5

STATUS:	DRAFT	DRAWING NO:	60321826-DRG-20-AQIA-F2	REV:	02
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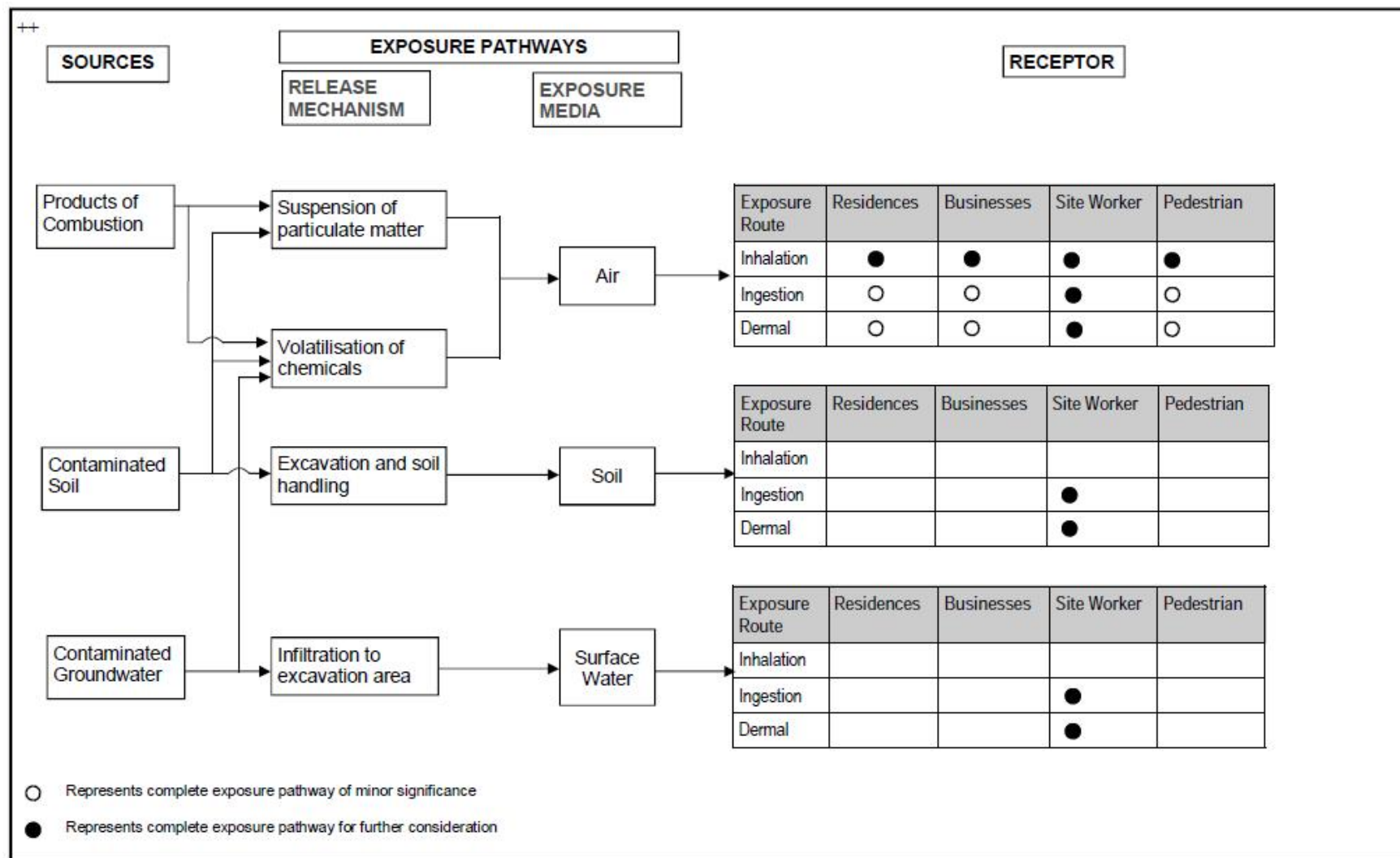


Figure 3 Illustrated Conceptual Site Model for Exposure to Pollutants of Potential Concern

Appendix A

Qualitative Risk Ranking Framework

Appendix A Qualitative Risk Ranking Framework

Risk issues were assessed assuming implementation of the proposed control measures using a simple risk ranking matrix, which was based on Australian Standard (AS4360-2004; Standards Australia, 2004), and consistent with risk management approaches recommended in updates to AS4360 (Standards Australia, 2009). The likelihood and consequence classifications used in the table, and the risk analysis matrix used to assess the overall level of risk due to each identified risk issue, are provided in **Tables A1 to A5**.

Table A1: Qualitative Measures of Likelihood (after AS4360)

Level	Descriptor	Description
A	Almost certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

Table A2: Qualitative Measures of Consequence of Impact (after AS4360)

Level	Descriptor	Description
1	Insignificant	No injuries, low financial loss
2	Minor	First aid treatment, on-site release immediately contained, medium financial loss
3	Moderate	Medical treatment required, on-site release contained with outside assistance, high financial loss
4	Major	Extensive injuries, loss of production capability, off-site release with no detrimental effects, major financial loss
5	Catastrophic	Death, toxic release off-site with detrimental effect, huge financial loss

Table A3: Qualitative Risk Analysis Matrix (after AS4360)

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	H	H	E	E	E
Likely	M	H	H	E	E
Possible	L	M	H	E	E
Unlikely	L	L	M	H	E
Rare	L	L	M	H	H

NOTES:

E: Extreme risk; immediate action required

H: High risk; senior management attention needed

M: Moderate risk; management responsibility must be specified

L: Low risk; manage by routine procedures

Table A4: Risk Matrix – Local Receptors

Sources of Pollutants of Potential Concern (POPC)	Exposure Route	Receptor/ Significant Exposure Groups	Likelihood	Consequence	Risk
POPC within contaminated soil: BTEX, PAHs, heavy metals and particulate matter Asbestos and asbestos materials.	Inhalation of suspended particles (dust) and vapours	Workers on and adjacent to the site	Possible	Moderate	High
		Residences	Possible	Minor	Moderate
		Businesses	Possible	Minor	Moderate
		Pedestrians adjacent to the site	Possible	Minor	Moderate
	Ingestion	Workers on and adjacent to the site	Unlikely	Minor	Moderate
		Other SEGs	Rare	Minor	Low
	Dermal contact	Workers on and adjacent to the site	Possible	Moderate	High
		Other SEGs	Rare	Minor	Low
POPC within groundwater: BTEX, TPH and heavy metals.	Inhalation of vapours	Workers on and adjacent to the site	Possible	Moderate	High
		Other SEGs	Rare	Minor	Low
	Unintentional ingestion of contaminated water	Workers on and adjacent to the site	Rare	Moderate	Moderate
		Other SEGs	Rare	Minor	Low
	Dermal contact with contaminated water	Workers on and adjacent to the site	Unlikely	Minor	Low
		Other SEGs	Rare	Minor	Low

Table A5: Risk Matrix – Offsite Receptors (During Transportation)

Sources of Pollutants of Potential Concern (POPC)	Exposure Route	Receptor/ Significant Exposure Groups	Likelihood	Consequence	Risk
POPC within contaminated soil: BTEX, PAHs, heavy metals and particulate matter Asbestos and asbestos materials.	Inhalation of suspended particles (dust) and vapours	Pedestrians adjacent to the transport route	Unlikely	Minor	Low
		Drivers adjacent to the transport route	Unlikely	Minor	Low
		Residences adjacent to the transport route	Rare	Minor	Low
		Businesses adjacent to the transport route	Rare	Minor	Low
		Workers involved with an emergency response/clean-up action	Rare	Minor	Low
	Ingestion	Workers involved with an emergency response/clean-up action	Rare	Minor	Low
	Dermal contact	Workers involved with an emergency response/clean-up action	Rare	Minor	Low