AECOM

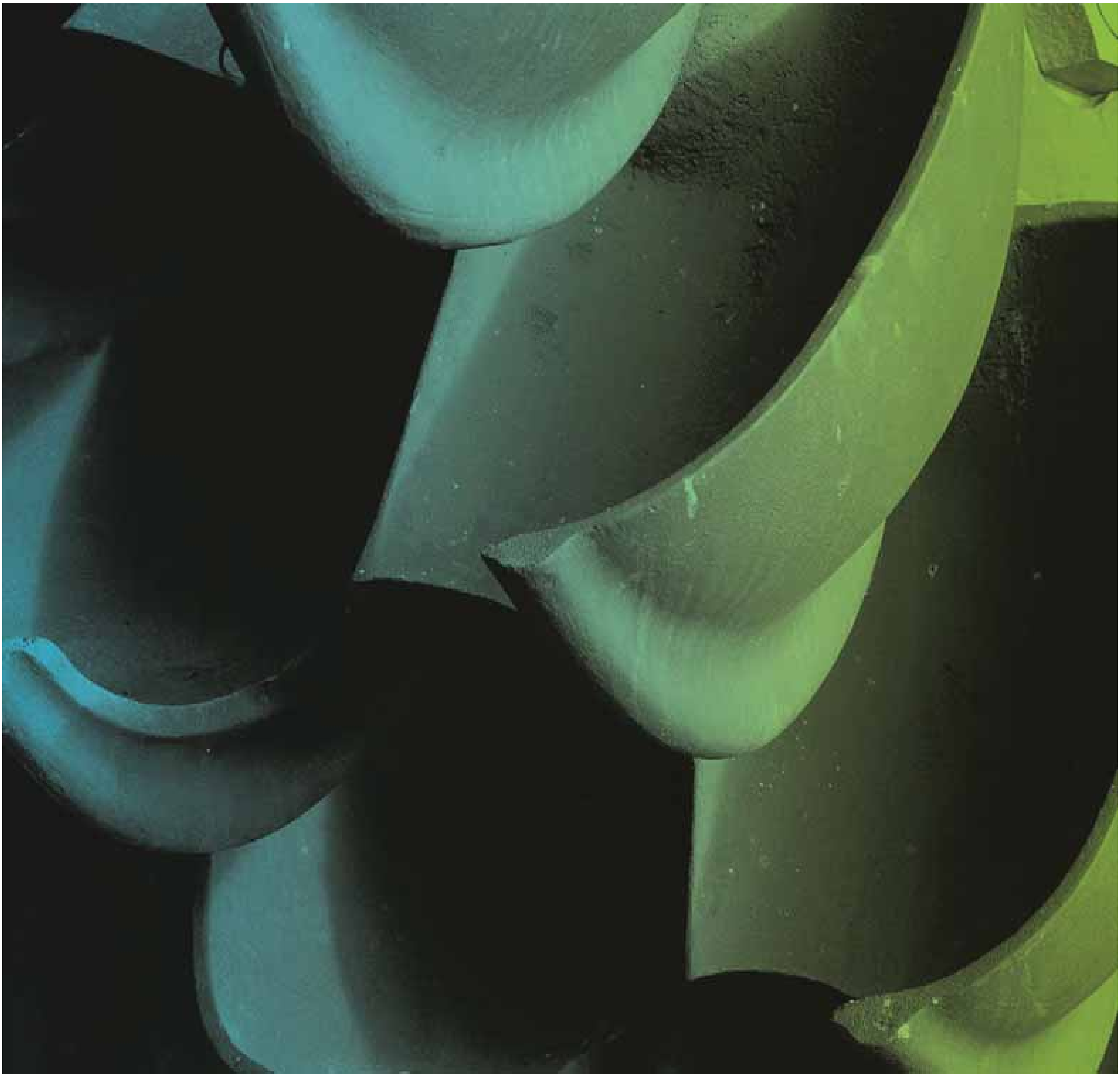
Remediation Development Application, Barangaroo Block 5

Lend Lease (Millers Point) Pty Limited

03-Jul-2014

Air Quality Impact Assessment

Remediation Development Application, Barangaroo Block 5, EPA Declaration Area No 21122, Hickson Rd, Millers Pt, NSW



Air Quality Impact Assessment

Remediation Development Application, Barangaroo Block 5, EPA Declaration Area No 21122, Hickson Rd, Millers Pt, NSW

Client: Lend Lease (Millers Point) Pty Limited

ABN: 15 127 727 502

Prepared by

AECOM Australia Pty Ltd
17 Warabrook Boulevard, Warabrook NSW 2304, PO Box 73, Hunter Region MC NSW 2310, Australia
T +61 2 4911 4900 F +61 2 4911 4999 www.aecom.com
ABN 20 093 846 925

03-Jul-2014

Job No.: 60321826

AECOM in Australia and New Zealand is certified to the latest version of ISO9001, ISO14001, AS/NZS4801 and OHSAS18001.

Quality Information

Document Air Quality Impact Assessment

Ref 60321826

Date 03-Jul-2014

Prepared by Holly Marlin

Reviewed by Adam Plant

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	21-May-2014	Draft for internal review	David Rollings Principal Engineer	
B	22-May-2014	Draft for client review	Amanda Lee Associate Director	
C	03-Jul-2014	Final	Amanda Lee Associate Director	Amanda Lee

Table of Contents

Glossary of Terms				i
1.0	Introduction			1
	1.1	Scope of Works		1
2.0	Site Description			2
	2.1	Barangaroo		2
	2.2	EPA Declaration Area (#21122)		2
	2.3	Summary of Site History and Key Contaminants		2
	2.4	Definition of Site		3
	2.5	Role of Lend Lease		3
	2.6	Surrounding Land Use and Receptors		3
3.0	Proposed Development			6
	3.1	Haul Roads and Required Plant		7
	3.2	Environmental Controls		8
		3.2.1	Sediment Controls	8
		3.2.2	Temporary Odour Control Structures	8
		3.2.3	Filtration Systems	9
		3.2.4	Sealed Trucks during Off-site Transport	9
		3.2.5	Management Controls for Retention Wall Construction	9
		3.2.6	Management of Dust	9
	3.3	Decontamination Area		9
		3.3.1	Personnel	9
		3.3.2	Plant	10
	3.4	Site Access		10
	3.5	Potential Impacts		10
	3.6	Impact Assessment Criteria		11
	3.7	Potential Emission Sources		12
4.0	Existing Environment			13
	4.1	Regional Air Quality		13
	4.2	Climate		13
	4.3	Terrain		14
5.0	Dispersion Modelling Methodology			15
	5.1	Overview		15
	5.2	Dispersion Model		15
		5.2.1	Meteorology	15
		5.2.2	Terrain	16
	5.3	Modelling Scenario		16
		5.3.1	Assumptions	16
	5.4	Source Characteristics		17
		5.4.1	Block 5	17
		5.4.2	Block 4	18
		5.4.3	Water Treatment Plant	18
		5.4.4	Building C3/T1	19
		5.4.5	Trucks	19
	5.5	Emissions Inventory		19
		5.5.1	Block 5	21
		5.5.2	Block 4	22
		5.5.3	Water Treatment Plant	22
		5.5.4	Building C3/T1	23
	5.6	Sensitive Receptors		23
	5.7	Prediction of Cumulative Impacts		24
	5.8	Conversion of NO_X to NO_2		25
	5.9	Metals, PAHs and Cyanide		25
6.0	Results			26
	6.1	Modelling Predictions		26
	6.2	Metals, PAHs and Cyanide		26

6.3 Limitations 27
7.0 Recommended Air Quality Management and Mitigation 28
7.1 Mitigation Measures 28
7.2 Contingency Measures 29
7.3 Air Quality Monitoring Program 30
8.0 Conclusion 34
9.0 References 35

Appendix A
Pollutants of Potential Interest A

Appendix B
Climate Averages B

Appendix C
Soil Sampling Results Summary C

Appendix D
Sensitive Receptor Locations D

List of Tables

Table 1 Sediment Control Options 8
Table 2 EPA Impact Assessment Criteria – Combustion Products, Dust and Soil Contaminants 11
Table 3 EPA Impact Assessment Criteria – Complex Odours 12
Table 4 Ambient Pollutant Concentrations, Rozelle Monitoring Station 13
Table 5 CALPUFF Input Parameters 15
Table 6 Block 5 Excavation Equipment 17
Table 7 Block 5 Excavation OCS Stack Characteristics 18
Table 8 Block 4 Excavation Equipment 18
Table 9 Block 4 Excavation OCS Stack Characteristics 18
Table 10 Water Treatment Plant Stack Characteristics 19
Table 11 Emission Source Characteristics – Buildings 19
Table 12 OCS Filtration Unit Efficiency 20
Table 13 VOC Components 20
Table 14 Treatment Tent Stack Emission Rates 21
Table 15 Block 5 Truck Emissions 21
Table 16 Block 4 Excavation OCS Stack Emission Rates 22
Table 17 Block 4 Truck Emissions 22
Table 18 Water Treatment Plant Emission Rates 22
Table 19 Emission Rates – Building C3/T1 23
Table 20 Site-Specific Soil Concentrations of Miscellaneous Toxic Pollutants 25
Table 21 Dispersion Modelling Results 26
Table 22 Predicted Pollutant Concentrations - Metals 26
Table 23 Reactive Management Procedure – PM_{10} 29
Table 24 Reactive Management Procedure – Total VOCs 30
Table 25 Ambient Monitoring Agenda 31
Table 26 Suggested Monitoring Frequency and Concentration Limits for OCSs 33

List of Figures

Figure 1 Barangaroo Site Location 4
Figure 2 Site Layout and Surrounding Area 5
Figure 3 Sensitive Receptor Locations 24
Figure 4 Approximate Existing Barangaroo South Monitoring Locations 33

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)
BTEX	Benzene, toluene, ethylbenzene and xylenes
DEC	Department of Environment and Conservation
EPA	Environment Protection Authority
EPA Declaration Area	Remediation Site Declaration 21122
EPL	Environment Protection Licence
Ex-situ Remediation Methodology	Excavation of contamination followed by off-site treatment and disposal of excavated material or reuse on-site (where applicable).
Lend Lease	Lend Lease (Millers Point) Pty Ltd
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
OCS	Odour control structure
PAHs	Polycyclic aromatic hydrocarbons. Benzo(α)pyrene is often used as an indicator for PAHs in dispersion modelling assessments.
PM_{10}	Particulate matter with an average diameter less than 10 micrometres
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).
SVOCs	Semi volatile organic compounds
TSP	Total suspended particulates
USEPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by Lend Lease Millers Point Pty Ltd (Lend Lease) to prepare an Air Quality Impact Assessment (AQIA) 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*.

1.1 Scope of Works

The Secretary's Environmental Assessment Requirements were issued for the project on 13 June 2014. The AQIA was to include:

- *the identification of the pollutants of concern, including individual toxic air pollutants, dust and odours;*
- *the identification and assessment of all relevant fugitive and point source emissions, including cumulative impacts of the operation of the plant in relation to other construction activities;*
- *appropriate coverage of all aspects of the remediation, including excavation, storage, transport and treatment of contaminated material;*
- *proposed air quality management and monitoring procedures during remediation, excavation, treatment, off-site transport and construction; and*
- *consideration of the requirements of the Protection of the Environment Operations (Clean Air) Regulation 2010.*

This AQIA includes the following works:

- Identifies the pollutants of potential concern;
- Identifies and assesses relevant fugitive and point source emissions, including those associated with excavation, storage, transport and treatment of contaminated material; and
- Recommends air quality management and monitoring procedures for use during the remediation works.

Dispersion modelling of the proposed remediation activities was undertaken using the CALPUFF model. The assessment was undertaken in accordance with and/or in reference to the following documents:

- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales 2005, published by the Environment Protection Authority (EPA);
- Assessment and Management of Odour from Stationary Sources in NSW: Technical Framework 2006;
- Assessment and Management of Odour from Stationary Sources in NSW: Technical Notes 2006; and
- Protection of the Environment Operations (Clean Air) Regulation 2010.

The potential impacts of the proposed works were assessed through the analysis of a single operational scenario, which represented the expected highest activity levels of all on-site activities that may be occurring during the Block 5 remediation works. Based on staging information provided by Lend Lease, the following concurrent activities are expected to represent the worst-case emissions during the Block 5 works that have not been addressed in previous assessments, and were assessed through dispersion modelling:

- Block 5 excavation;
- Block 4 remediation activities;
- Construction works associated with the C3 (T1) building; and
- The operation of an on-site water treatment plant.

Meteorological and terrain files, receptor locations and relevant source characteristics used in previous assessments undertaken by AECOM for the Barangaroo development were used in this assessment for consistency.

2.0 Site Description

2.1 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.

2.2 EPA Declaration Area (#21122)

In May 2009, the NSW 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.

2.3 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.

2.4 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).

2.5 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.

2.6 Surrounding Land Use and Receptors

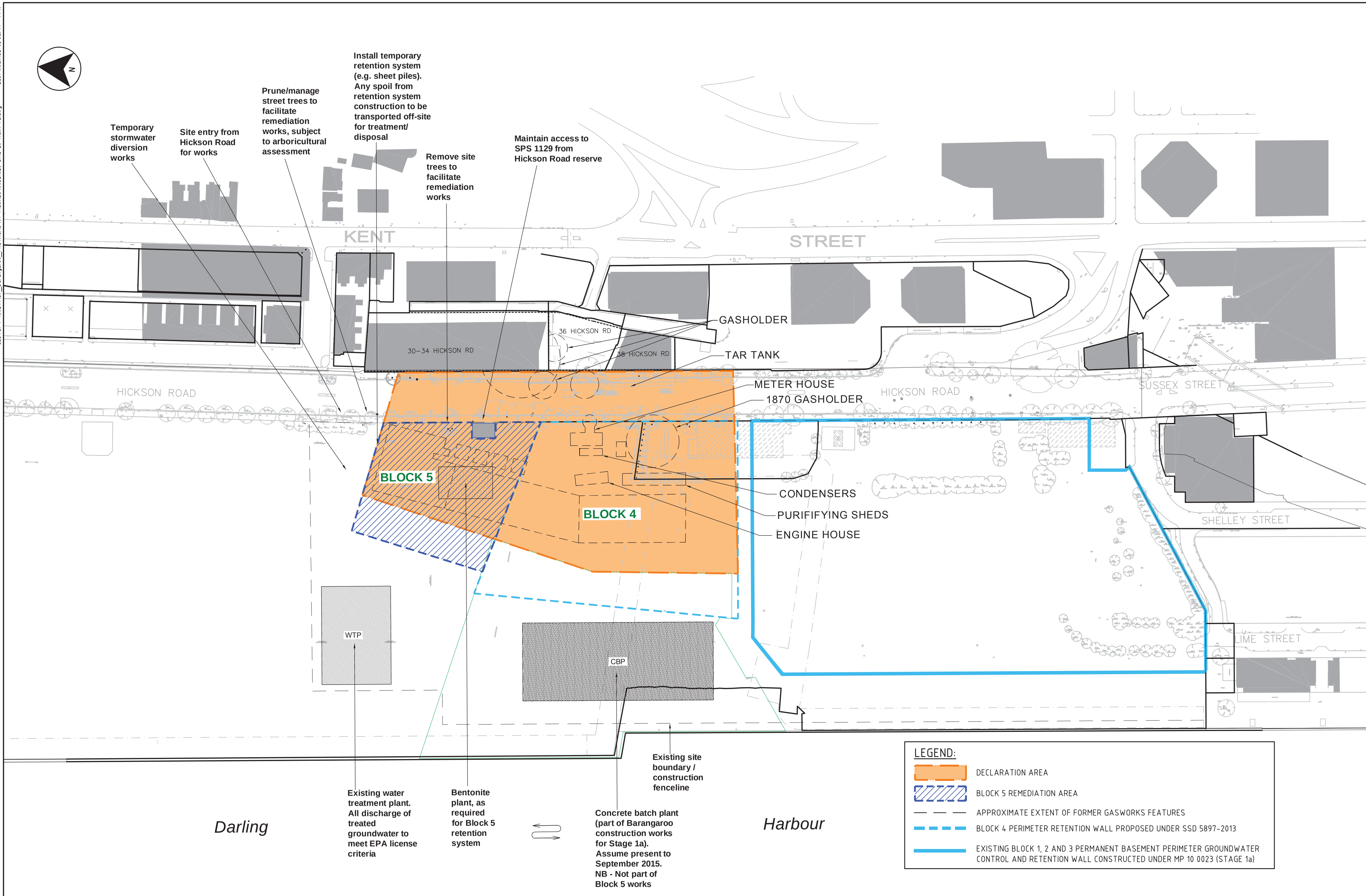
The Site is bordered by Sydney Harbour on the western side and by Hickson Road to the east. The closest receptors are located approximately 25 m to the east of the site boundary, on Hickson Road, and consist of residential and commercial properties. A number of finger wharves containing a mixture of residential and commercial developments are located directly opposite the Site, the closest being approximately 250 m west of the site, while the residential suburb of Balmain East is located approximately 400 m to the west of the northern end of the site. Details of the sensitive receptors incorporated into the dispersion modelling are provided in **Section 6.6**.

G:\Projects\602 Projects\60247139 Barangaroo\FIGURES\Air Quality Impact Assessment\60247139 F1 Barangaroo Site Location 31 10 2012 TO Rev A

AECOM

BARANGAROO SITE LOCATION
Air Quality Impact Assessment
Barangaroo Declaration Area
Millers Point, New South Wales

FIGURE 1



REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
02	PAS	03.07.14	FINAL ISSUE	AKL
01	PAS	16.05.14	DRAFT ISSUE	AR

SCALES: 10 0 10 20 30 40m — 1 : 2000 FULL SIZE A3

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	AKL	DATE	03.07.14

DESIGNER:

AECOM

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

AIR QUALITY IMPACT ASSESSMENT, BLOCK 5, BARANGAROO

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

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

Cad ref: P:\60247139_Barangaroo_Pha\9.CAD\07-FIGURES\60321826-DRG-20-AQIA-F2.dwg
Last modified: 03 Jul 14 - 14:19

3.0 Proposed Development

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 approximately 10 m below ground level or to the depth of bedrock (whichever is shallower) across much of the Remediation Area. 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.
- 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 landfill disposal. All loads would be appropriately sealed to prevent odour and dust emissions during transport (for example through the use of odour suppressant foam), and any off-site treatment would be undertaken at a licenced treatment facility, and, as such, the emissions associated with treatment would be subject to the EPA licence conditions.
- Backfilling of Block 5 excavation with suitable fill (imported and/or won from site) where required.

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 m^3).
- 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 would be transferred to the onsite WTP for treatment and licensed discharge. Where required, highly contaminated liquid waste may 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.

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.

3.1 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.

3.2 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.

3.2.1 Sediment Controls

Sediment can lead to dust generation; as such, management measures for sediment are management measures for air emissions. 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 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

3.2.2 Temporary Odour Control Structures

To the extent practicable, Lend Lease has committed to undertaking all excavation and *ex-situ* treatment works (if undertaken on-site) within temporary odour control structures (OCSs) fitted with emission control systems (filters). The purpose of the odour control structures is to minimise the release of malodorous and potentially harmful emissions during treatment and 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 (and above treatment operations, if undertaken on-site), 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 were developed based on three primary goals, which were to:

- 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.

3.2.3 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 and treatment 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.

3.2.4 Sealed Trucks during Off-site Transport

All excavated material taken off site would be treated to minimise potential emissions of dust or odour. For example, odour suppressant foam or similar materials would be used to seal the loads.

3.2.5 Management Controls for Retention Wall Construction

It is noted that it is not practical to undertake the construction of the perimeter retention wall, which involves limited excavation areas for each wall panel, within an OCS. Alternative odour control measures would be employed during these activities, including (but may not be limited to):

- covering of exposed soil as soon as possible, with appropriate covers or clean material;
- the use of odour suppressants and foam;
- implementing appropriate exclusion zones between public and the workface, based on occupational hygienist recommendation; and
- undertaking odour monitoring during the works.

Final measures to be implemented will be based on selected contractor methodology for retention wall construction. Following contractor selection, and prior to commencing works, final odour control measures would be detailed in the Air Quality and Odour Management Sub-Plan, and provide to the EPA for review and comment.

3.2.6 Management of Dust

Management of Dust during Backfilling works have the potential to generate dust emissions. Mitigation measures would be implemented while these works are undertaken to minimise emissions. Such emissions can be adequately managed through standard construction measures, such as watering of material when visible dust is present, and suspending activities during high wind conditions.

3.3 Decontamination Area

3.3.1 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.

3.3.2 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.

3.4 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.

3.5 Potential Impacts

The proposed works will generate particulate emissions associated with both excavation and materials handling. Heavy metals detected within the soil may be released to the air attached to the dust. The works will primarily use electrical and diesel-powered plant and equipment. The combustion of diesel fuel generates a range of pollutant emissions, primarily oxides of nitrogen (NO_X) and particulate matter (including PM_{10} and TSP), as well as volatile organic compounds (VOCs)(particularly benzene, toluene, ethylbenzene, and xylenes, which are known collectively as BTEX). Other emissions, such as carbon monoxide and sulfur dioxide, are also emitted from combustion engines, but were not assessed as they were considered to be lower risk than particulate and NO_X emissions due to their generally higher trigger values. When exposed to air, the contaminated material is also expected to generate gaseous emissions of the contaminants and associated odours.

For the purposes of this AQIA, pollutants of interest were defined as chemicals that have been detected on the site in concentrations greater than relevant human health screening criteria. The pollutants assessed were:

- Nitrogen dioxide (NO_2);
- Particulate matter;
- Heavy metals (cadmium, chromium VI, copper, lead, mercury, nickel, zinc);
- VOCs (specifically BTEX, naphthalene and phenol);
- PAHs; and
- Odour.

The potential health effects of the pollutants of interest are summarised in **Appendix A**.

The off-site transport and treatment of the excavated material also have the potential to result in air emissions. Emissions associated with transport operations will be minimised through the management practices outlined in **Section 3.2.4**. The material would be treated at a licensed facility; as such, any emissions would be managed in accordance with the operating conditions of the facility specified by the Environment Protection Licence. These potential emission sources were not assessed through dispersion modelling.

3.6 Impact Assessment Criteria

The EPA has specified ground level concentration criteria that are intended to minimise the adverse effects of airborne pollutants on sensitive receptors (DEC, 2005a). The ambient air quality criteria for the pollutants considered in this assessment are shown in **Table 2** (combustion products, dust and soil contaminants) and **Table 3** (odorous compounds).

Table 2 EPA Impact Assessment Criteria – Combustion Products, Dust and Soil Contaminants

Pollutant	Averaging Period	Criteria ($\mu g/m^3$)
Combustion Products and Dust		
Nitrogen dioxide (NO_2)	1 hour	246
	Annual	62
Total suspended particulates (TSP)	Annual	90
Fine particulate matter (PM_{10})	24 hours	50
	Annual	30
Soil Contaminants		
Arsenic	1 hour	0.09
Benzene	1 hour	29
Beryllium	1 hour	0.004
Cadmium	1 hour	0. 018
Chromium VI	1 hour	0.09
Copper (dust and mist)	1 hour	18
Cyanide	1 hour	90
Ethylbenzene	1 hour	8,000
Lead	Annual	0.5
Manganese	1 hour	18
Mercury (organic)	1 hour	0.18
Naphthalene	1 hour	440*
Nickel	1 hour	0.18
Phenol	1 hour	20
Polycyclic aromatic compounds (PAHs) (as benzo[α]pyrene)	1 hour	0.4
Toluene	1 hour	360
Xylenes	1 hour	190
Zinc (as zinc chloride fumes)	1 hour	18

*As adopted for previous Barangaroo assessments undertaken by AECOM (e.g. AECOM, 2010a). Criterion is equivalent to the odour threshold for naphthalene.

The EPA's odour assessment criteria for complex mixtures of odorous air pollutants (DEC, 2005a) are shown in **Table 3**. These criteria take into account individual sensitivity to odour in the community, and use a statistical approach for determining the appropriate criterion for a particular site based on the size of the surrounding population. As population size increases, the likelihood of sensitive individuals being within that population also increases; as such, areas with larger populations require more stringent criteria.

Table 3 EPA Impact Assessment Criteria – Complex Odours

Population	Criteria (OU)*
Urban (≥ ~2000) and/or schools and hospitals	2
~ 500	3
~ 125	4
~ 30	5
~ 10	6
Single residence (≤ ~2)	7
*99th percentile nose response time	

An odour assessment criterion of 2 OU was adopted for this assessment due to the urban nature of the area surrounding the project site. The following pollutants were combined and assessed as a complex mix of odour:

- BTEX (including 1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene and isopropylbenzene);
- Cyanide;
- Naphthalene;
- Phenols (2-methylphenol; 4-chloro-3-methylphenol and phenol);
- Dibenzofuran; and
- Styrene.

Further details are provided in **Section 5.5**.

3.7 Potential Emission Sources

Details of plant and equipment expected to be used during the remediation works considered in this assessment were provided by Lend Lease, and include:

- Excavators;
- Front end loaders;
- Bulldozers;
- Bobcats;
- Screens;
- Crushers; and
- Generators.

All of the plant used to excavate and handle odorous materials would be working inside the OCSs, and their associated emissions would be emitted from the stacks associated with the OCSs following filtration. Trucks would be used to transport materials from the excavation OCSs to off-site treatment destinations; these emissions would occur outside of the OCS and, as such, would be directly vented to atmosphere.

Other equipment expected to be used during the excavation works, such as the water pumps and fans, would be expected to be powered by mains electricity and, as such, would not generate combustion products during their operation.

Further emission source details are provided in **Section 5.4**, including details of sources associated with onsite works being undertaken concurrently with the Block 5 remediation works. Pollutants of interest are discussed in **Section 4.0**. It should be noted that this assessment considered the worst-case emissions associated with the Block 5 remediation works, which were considered to be those occurring during the Block 5 excavation works. Emissions associated with the construction of retaining walls, such as dust and combustion emissions from piling rigs, were not considered in this assessment as they would be undertaken at different stages of the works, and are expected to have lesser emissions than those occurring during the excavation stages. Similarly, backfilling operations, which are expected to be of relatively short duration and manageable through standard management practices, were also not assessed,

4.0 Existing Environment

4.1 Regional Air Quality

The EPA operates a network of air quality monitoring stations around the state. The closest station to the site is located at Rozelle (approximately 3.5 km to the west). Ambient pollutant concentrations recorded at this station in 2008 were adopted for this assessment for consistency with previous assessments undertaken for the Barangaroo site.

Ambient TSP concentrations have not been monitored at Rozelle since 2004. The ratio of PM_{10} to TSP from Rozelle for 2004 (the last recorded year of TSP monitoring at Rozelle) was used with the ambient annual PM_{10} concentration from Rozelle in 2008 to estimate the annual TSP concentration. The ratio of PM_{10} to TSP for 2004 was calculated to be 49 % at Rozelle (i.e. 49 % of TSP in the region monitored by Rozelle was PM_{10}), which, when applied to the 2008 ambient annual PM_{10} concentration of 17.4 $\mu g/m^3$, equates to an annual TSP concentration of 35.5 $\mu g/m^3$.

The background concentrations used in the AQIA are summarised in **Table 4**. It should be noted that contemporaneous assessments of 24 hour PM_{10} and 1 hour NO_2 were conducted as part of the modelling assessment, which added actual measured pollutant concentrations for each averaging period to the corresponding concentrations predicted by the dispersion modelling; as such, the respective background concentrations provided in **Table 4** were not used in the cumulative assessment and should be considered as indicative concentrations only.

Table 4 Ambient Pollutant Concentrations, Rozelle Monitoring Station

Air Emission	Averaging Period	Background Concentration ($\mu g/m^3$)	Assessment Criteria ($\mu g/m^3$)
NO_2 [1]	1 hour maximum	75.2	246
	Annual	20.7	62
PM_{10}	24 hour maximum	43.1	50
	Annual	17.4	30
TSP [2]	Annual	35.5	90
Ozone [3]	1 hour maximum	109.8	214
	4 hour maximum	93.6	171
	Annual	27.1	-

[1] NO_2 contemporaneous background data used to predict background concentrations using the OLM detailed in **Section 5.8**.
[2] Calculated from annual PM_{10} concentration as described in text.
[3] Ozone concentrations used for NO_2 contemporaneous assessment calculations. Ozone was not modelled as a pollutant.

4.2 Climate

The Bureau of Meteorology (BOM) collects meteorological data from various sites in the Sydney Basin. The station at Observatory Hill is less than 200 m from the eastern boundary of the Barangaroo Site, while Fort Denison is approximately 2 km to the east of the site. The meteorological data collected from these two stations is complementary and, together, provides an indication of the climate in the immediate area around Barangaroo. Long term data averages recorded between 1859 and June 2014 are summarised in **Appendix B**.

Average maximum temperatures in summer range from 25.2 °C to 25.9 °C, while minimum temperatures range from 17.5 °C to 18.8 °C. In winter, the average maximum temperature ranges from 16.3 °C to 17.8 °C and the average minimum temperature ranges from 8.0 °C to 9.3 °C.

The annual average humidity reading collected at 9 am from the site is 69 %, and at 3 pm the annual average is 57 %. Rainfall data collected at Observatory Hill shows, on average, that the wettest months are January to June, with average rainfall of greater than 100 mm for each of the intervening months.

4.3 Terrain

The Barangaroo Site is located on Sydney Harbour. The ground surface of the entire Barangaroo Site is at an elevation of approximately 2 - 5 m (AHD). The surrounding landform (outside the bounds of the site) rises rapidly to the east, with a 10 m high sandstone cliff situated east of Hickson Road and Sussex Street. This is the most substantial natural terrain feature in the area; high rise buildings may potentially also affect wind patterns in the project site.

5.0 Dispersion Modelling Methodology

5.1 Overview

Dispersion modelling was undertaken to predict the potential effects of the remediation and excavation works associated with the Declaration Area. The following sections outline details of the dispersion model used and its inputs (specifically meteorology, terrain, building parameters, modelling scenarios, source characteristics and emissions inventory), sensitive receptor locations, and the methodology used in the estimation of pollutant concentrations.

The modelling was conducted in accordance with and/or in consideration of the following statutory documents:

- Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (DEC, 2005a);
- Assessment and Management of Odour from Stationary Sources in NSW: Technical Framework 2006;
- Assessment and Management of Odour from Stationary Sources in NSW: Technical Notes 2006; and
- Protection of the Environment Operations (Clean Air) Regulation 2010.

5.2 Dispersion Model

The CALPUFF air dispersion model was used in the AQIA in accordance with the EPA Approved Methods (DEC, 2005a). CALPUFF is a non steady-state, three-dimensional Gaussian puff model developed for the US Environmental Protection Agency (USEPA) for use in situations where basic Gaussian plume models are not effective, such as areas with complex meteorological or topographical conditions, including coastal areas with re-circulating sea breezes. Input parameters used in the CALPUFF dispersion modelling are summarised in **Table 5**.

Table 5 CALPUFF Input Parameters

Parameter	Input
CALPUFF version	6.42 - March 2011
Modelling domain	2 km x 2 km
Terrain data	Included in CALMET
Building wake data	Not included in model
Dispersion algorithm	PG (Rural, ISC curves) & MP Coeff. (urban)
Hours modelled	8760 hours (365 days)
Meteorological data period	1 January 2008 – 31 December 2008

Inputs to CALPUFF are discussed in the following sections.

5.2.1 Meteorology

The CALMET meteorological model uses meteorological observations to generate three dimensional wind fields on an hourly time step at a grid of points covering the area under investigation. Topographical features and land use factors are then used to further refine the wind fields, which are subsequently used in the CALPUFF dispersion model.

Local meteorological and topographical data were used to develop the CALMET wind fields to ensure the data used in the dispersion modelling were representative of local conditions. Data used in previous air quality assessments for the Barangaroo development, considered representative of local conditions and appropriate for use in dispersion modelling, were used in this assessment for consistency. Further details are provided in AECOM (2010a).

Meteorological data were obtained from two sources in the area immediately surrounding the Barangaroo Site. Hourly averaged meteorological data for 2008 were sourced from the Rozelle monitoring station (operated by the EPA) and the Fort Denison and Observatory Hill meteorological stations operated by the BOM for the following parameters:

- Observatory Hill - rainfall and temperature;
- Fort Denison - wind speed and direction; and
- Rozelle - wind speed, wind direction, sigma theta, temperature, relative humidity, and solar radiation.

These data were used as input to CALMET as surface file data. The CSIRO-developed prognostic model, TAPM (The Air Pollution Model), was used to define the upper air meteorology for the area surrounding Barangaroo. TAPM data were entered into CALMET as an initial guess for the site meteorological conditions, together with the surface meteorological data recorded at Rozelle, Observatory Hill and Fort Denison.

5.2.2 Terrain

The NASA Shuttle Radar Topographic Mission (SRTM) provides digital elevation data (DEM) for over 80 % of the globe. The SRTM data are available as 3 arc second DEMs, which provide a resolution of approximately 90 m. The vertical error of the DEMs is reported to be less than 16 m.

Digital terrain data required by CALMET were obtained for an area of approximately 7.2 km x 7.2 km (corresponding to the innermost grid of the TAPM meteorological data modelling), approximately centred on the site, from the global SRTM database. The 90 m resolution data were included in the CALMET GEO.dat input file and used together with the TAPM, EPA and BOM meteorological data for determination of the three dimensional modelling meteorological data file required by CALPUFF.

5.3 Modelling Scenario

The potential impacts of the proposed works were assessed through the analysis of a single operational scenario, which represented the expected highest activity levels of all on-site activities that may be occurring during the Block 5 remediation works. Based on staging information provided by Lend Lease, the following concurrent activities are expected to represent the worst-case emissions during the Block 5 works, and were assessed through dispersion modelling:

- Block 5 excavation;
- Block 4 remediation activities;
- Construction works associated with the C3 (T1) building; and
- Operation of the on-site water treatment plant.

While works such as those associated with the Public Domain, Stage 1a Basement and Headland Park may overlap some stages of the Block 5 works, the emissions from these activities expected to occur during the highest activity period of the Block 5 excavations were expected to be of a minor nature. As such, these activities were not included in the operational scenario modelled.

All other activities on the Barangaroo site, including works associated with Barangaroo South and the operation of a concrete batching plant, which were addressed in previous assessments, are expected to be completed when the Block 5 excavation works commence. Other works associated with the Block 5 works, such as construction of the retention wall, were also not expected to occur concurrently with the excavation works, and were not, therefore, included in the modelling scenario. Furthermore, the modelling was confined to on-site activities. Off-site material treatment was not modelled as any treatment would be at a licensed treatment facility that must comply to their site specific air emissions license conditions.

5.3.1 Assumptions

All emission sources associated with the Block 5 (and concurrent Block 4) remediation works assessed by dispersion modelling were assumed to be contained within the OCSs (excavation) with the exception of trucks hauling materials off-site for disposal (modelled as volume sources). Emissions from plant, equipment and activities within the tents were estimated using emission factors, summed, and assumed to be filtered before being released to the atmosphere. Each OCS was assumed to release emissions at a constant rate from a single stack. Emissions associated with the construction of the C3/T1 building were the same as those used in AECOM (2014), while emissions associated with the water treatment plant were assumed to be the same as those used in AECOM (2011) for a water flow rate of 25 L/s.

The methodology used to develop emissions for the Bulk Excavation and Car Parking works (AECOM, 2010a) was used for this assessment for consistency. Emissions from activities such as materials handling were estimated using emission factors and equations in the following National Pollutant Inventory Emission Estimation Technique manuals:

- Australian Government. (2012). National Pollutant Inventory Emission Estimation Technique Manual for Mining, Version 3.1. Commonwealth of Australia: Canberra.
- Australian Government. (2008). National Pollutant Inventory Emission Estimation Technique Manual for Combustion Engines, Version 3.0. Commonwealth of Australia: Canberra.

Emission factors for wheel-generated dust were obtained from US EPA (2011). Additional emission factors for specific construction plant and equipment were sourced from a report on a large construction project (Pacific Institute, 2001), which was accepted by the US EPA and references the South Coast Air Quality Management District (California Environmental Quality Act) Air Quality Handbook. Stack parameters for trucks, which were used in previous assessments (SKM, 2005), were also used for the point sources. A detailed emissions inventory showing calculations can be provided on request.

It should be noted that on-site treatment was not included in this assessment. If on-site treatment is required, such as through the use of a pugmill within an OCS, further assessment would be necessary to determine whether the emissions assessed by this study are representative of the emissions associated with the on-site treatment. If not, further dispersion modelling may be required.

5.4 Source Characteristics

The source characteristics used in the dispersion modelling are described in the following sections. The stacks are proposed to be located on the western side of the odour control structures, i.e. the side furthest from the sensitive receptors on Hickson Road. It should be noted that the generators used to power the filtration units were assumed to be vented through the OCS stacks (located on the western side of the structures); as such, the emissions from these plant were assumed to be filtered before release to atmosphere. Each OCS was assumed to be powered by two generators. All information was based on data provided by Lend Lease.

5.4.1 Block 5

The Block 5 excavations were assumed to be undertaken for 10 hours per day at a rate of 350 tonnes per day. Details of the equipment and stack characteristics are provided in **Table 6** and **Table 7** respectively. The OCS stack was assumed to be located on the western side of the OCS structure.

Table 6 Block 5 Excavation Equipment

Plant/equipment	Number	Notes
Excavator	3	2 x 30 t; 1 x 20 t
Bulldozer	1	
Front end loader	1	
Skid screen bobcat	1	loader
Powerscreen	1	screen
Trucks	50	trips per day (off site)

Table 7 Block 5 Excavation OCS Stack Characteristics

Details	Value	Units
Tent height	14	m
Stack height	4	m
Velocity	25	m/s
Diameter	0.7	m
Volumetric flow rate	11.2	m^3/s
Temperature	25	^oC

5.4.2 Block 4

The Block 4 excavations were assumed to be undertaken for 10 hours per day at a rate of 350 tonnes per day. Details of the equipment and stack characteristics are provided in Table 8 and **Table 9** respectively. The OCS stack was assumed to be located on the western side of the OCS structure.

Table 8 Block 4 Excavation Equipment

Plant/equipment	Number	Notes
Excavator	3	2 x 30 t; 1 x 20 t
Bulldozer	1	
Front end loader	1	
Skid screen bobcat	1	loader
Powerscreen	1	screen
Crusher	1	crusher
Trucks	125	trips per day (to treatment tent)

Table 9 Block 4 Excavation OCS Stack Characteristics

Details	Value	Units
Tent height	14	m
Stack height	4	m
Velocity	25	m/s
Exit area	0.45	m^2
Diameter	0.76	m
Volumetric flow rate	11.2	m^3/s
Temperature	25	^oC

5.4.3 Water Treatment Plant

The Water Treatment Plant (WTP) will have two point sources: the inlet tank displacement valve (ITDV) and the air strippers discharge stack (ASDS). Details of these sources are provided in **Table 9**.

Table 10 **Water Treatment Plant Stack Characteristics**

Source	Eastings (km)	Northings (km)	Base Elevation (m)	Stack Height (m)	Stack Temp (°C)	Diameter (m)	Stack Velocity (m/s)	Source VFR (m^3/s)
ITDV	333.573	6251.675	6	2.77	15.6	0.10	3.2	0.03
ASDS	333.632	6251.779	6	2.77	15.6	0.42	8.2	1.13

5.4.4 Building C3/T1

Source characteristics of the emission sources for Building C3/T1 are outlined in **Table 11**. Forklifts and concrete pumps were modelled as ground level point sources. There were assumed to be four concrete trucks, two forklifts and two concrete pumps associated with the C3/T1 building works.

Table 11 **Emission Source Characteristics – Buildings**

Source	Stack Height (m)	Base Elevation (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)
Cement trucks	4	5	0.1	10	76.1
Forklifts	3	5	0.3	14.6	624.2
Concrete pumps	3	5	0.1	14.6	624.2

5.4.5 Trucks

For this assessment, trucks associated with Block 4 and Block 5 excavations were assumed to move all excavated material from the excavation areas off site. Emissions associated with each area were summed and modelled as volume sources. The haulage routes were assumed to be paved, which is likely as the hardstand will be maintained as much as possible to control odour emissions from the site, and excavated areas will be contained within tents. As such, wheel-generated dust is likely to be negligible. In order to provide a measure of conservativeness, emission rates associated with wheel-generated dust were calculated using the AP-42 emission factors for paved roads for concrete batching plant published by the US EPA (2011).

It should be noted that the assessment only addressed truck emissions within the site boundary. As stated in **Section 3.2.4**, emissions associated with transport would be mitigated through sealing the trucks.

5.5 Emissions Inventory

Emissions from the plant and equipment to be used on site were estimated using factors published by the Australian Government for use in the National Pollutant Inventory, measured vehicle emissions from the M5 Freeway Project (SKM, 2002) and emission factors published for a large construction project (Pacific Institute, 2001).

Expected operational times for the construction works are 7 am – 6 pm Monday to Friday and 7 am – 5 pm Saturdays. No works are expected on Sundays. For modelling purposes, constant emission rates were entered into the model for all activities; that is emissions were assumed to be generated 24 hours per day, seven days per week. Applying these emission times may over-predict the ground level concentrations over the long term but is a conservative modelling approach.

The OCSs were each assumed to be serviced by two filtration units (activated charcoal). The reduction efficiencies applied for particulates, VOCs and odour were developed following liaison with a contractor. The NO_X reduction efficiencies were based on published literature (Nelson and Babyak, 1996). The total reduction efficiencies assumed for each OCS, which are consistent with those used in previous assessments, are provided in **Table 12**.

Table 12 OCS Filtration Unit Efficiency

Pollutant	Reduction %	Notes
NO_X	75	Assumed two filters at 50 % reduction per unit
PM_{10}	98	Assumed total efficiency
TSP	98	Assumed total efficiency
VOCs	99.8	Assumed two filters at 99 % reduction per unit
Odour*	99.8	Assumed two filters at 99 % reduction per unit

VOC Emissions

A number of contaminants present at the site are VOCs. The EPA does not have a criterion for total VOCs or for many of the contaminant pollutants. VOCs/potential VOCs identified on site (BTEX, PAHs, phenol, semi VOCs and VOCs) were summed to provide total VOC emission rates, which were used in the modelling. The emission rates were calculated for the Block 4 and Block 5 excavation areas on the basis of the average concentrations of VOCs detected within the Declaration Area, the volume of excavated material and the duration of the excavations.

VOC emissions associated with the soil contamination were estimated using the percentage of the pollutants in the soil samples as shown in **Table 13** (AECOM, 2010b). It should be noted that the percentages shown in **Table 13** do not add up to100 %, as only those species with EPA criteria are shown; these were the only VOC species assessed. Emissions of these pollutants associated with soil remediation activities were entered directly into the dispersion model.

Table 13 VOC Components

Pollutant	Percentage of Total VOC Emissions (%)
Benzene	0.9
Ethylbenzene	0.7
Toluene	1.3
Xylenes	2.9
Naphthalene	60.7
Phenol	3.4

Odour Emissions

Potentially odorous contaminants were selected based on the results of soil sampling undertaken by AECOM for the site (AECOM 2010b). Of the detected contaminant species, only those with an assessment criterion in the EPA Approved Methods (DEC, 2005a) were included in the calculations.

Odour modelling was undertaken using the same methodology as that used for the assessment of the Bulk Excavation and Carparking works phase of the project (AECOM, 2010a). In brief, odour flux data specified by a previous odour assessment for a large-scale contaminated lands project at Homebush for Lednez (Egis, 2002) were used with contaminant concentration data from the Declaration Area to develop site-specific emission rates. The odorous contaminants identified on site through soil sampling and vapour testing were:

- Benzene;
- Toluene;
- Ethylbenzene;
- Total xylenes;
- Cyanide;
- Naphthalene; and
- Trichlorofluoromethane.

Odour emissions were then calculated as shown in **Appendix C** using the relative concentrations of the pollutants listed above. Cyanide and trichlorofluoromethane were only modelled as odour.\

Odour concentrations affect people over very short time scales, typically less than one second in duration. CALPUFF does not have the capacity to model pollutant concentrations at these times scales with the data available for this assessment; as such, the total hourly concentration was converted to a one second concentration through the application of a peak to mean ratio. The odour emission rates used in the dispersion modelling included a peak to mean ratio of 2.3 (applicable for wake-affected stacks), applied in accordance with the EPA's Approved Methods (DEC, 2005a). Only near-field effects were considered. The site odour flux used in the calculations was 16.4 OU/m^2.s; this was used with the Block 4 and Block 5 OCS areas to calculate the odour emission rates. Following discussion with Lend Lease, half of the OCS areas were assumed to actively emit odour at any time (3,244 m^2 for Block 4 and 1,550 m^2 for Block 5).

5.5.1 Block 5

Details of the emission rates for the Block 5 excavation OCS are provided in **Table 13**.

Table 14 Treatment Tent Stack Emission Rates

Pollutant	Total Emission Rates	
	Before filtration	After filtration
NOx (g/s)	2.74	0.69
PM_{10} (g/s)	0.53	0.011
TSP (g/s)	1.70	0.034
Odour (OU/s)	25,420	51
VOCs combustion emissions (g/s)	0.26898	0.00054
Benzene	0.05	0.0001
Ethylbenzene	0.04	0.00008
Toluene	0.07	0.00014
Total xylenes	0.16	0.0003
Naphthalene	3.28	0.0066
Phenol	0.18	0.0004
* Peak to mean ratio of 2.3 applied to odour emissions		

As described in **Section 5.4.5**, truck emissions were apportioned to four volume sources. The emission rates per volume source associated with the Block 5 are provided in **Table 14**.

Table 15 Block 5 Truck Emissions

Pollutant	ER (g/s/source)
NO_X	0.0003
PM_{10}	0.00002
TSP	0.00002
VOC	0.00003

5.5.2 Block 4

Details of the emission rates for the Block 4 excavation OCS are provided in **Table 16**.

Table 16 Block 4 Excavation OCS Stack Emission Rates

Pollutant	Total Emission Rates	
	Before filtration	After filtration
NO_X (g/s)	2.75	0.69
PM_{10} (g/s)	1.45	0.029
TSP (g/s)	4.80	0.096
Combustion VOC (g/s)	5.6	0.011
Odour (OU/s)*	53,202	106.4
Benzene	0.05	0.00010
Ethylbenzene	0.04	0.00008
Toluene	0.07	0.00014
Total xylenes	0.16	0.0003
Naphthalene	3.28	0.007
Phenol	0.18	0.0004
* Peak to mean ratio of 2.3 applied to odour emissions		

As described in **Section 5.4.5**, truck emissions were apportioned to four volume sources. The emission rates per volume source associated with Block 4 are provided in **Table 17**. The particulate emissions represent combustion emissions only.

Table 17 Block 4 Truck Emissions

Pollutant	ER (g/s/source)
NO_X	0.00014
PM_{10}	0.000009
TSP	0.000009
VOCs	0.000013

5.5.3 Water Treatment Plant

As described in AECOM (2011), the primary pollutants of interest associated with the operation of the WTP are VOCs (BTEX) (as a surrogate for odour) and naphthalene. Emission rates for the two associated point sources are provided in **Table 18**.

Table 18 Water Treatment Plant Emission Rates

Pollutant	Emission Rate (g/s)	
	ITDV	ASDS
Benzene	0.0010	0.009
Toluene	0.0004	0.004
Ethylbenzene	0.0001	0.001
Xylenes	0.0002	0.001
Naphthalene	0.0071	0.062

The emission rates correspond to a stripping efficiency of 99 % and a water flow rate of 25 L/s.

5.5.4 Building C3/T1

The construction of this building was modelled as per AECOM (2012) with the exception of the cranes, which were formerly assumed to operate using diesel engines. Cranes onsite are and would continue to be run on mains power and, as such, were excluded from the assessment. Forklifts, which are dual fuel (LPG and diesel or unleaded petrol) and predominantly run on LPG, were conservatively assumed to operate solely on diesel fuel.

Source characteristics of the emission sources for the building are outlined in **Table 19**. All plant were assumed to remain at ground level. All emission sources associated with the building were modelled as point sources.

Table 19 Emission Rates – Building C3/T1

Source	Emission Rates (g/s)		
	NO_X	PM_{10}	TSP
Cement trucks	0.11	0.01	0.01
Forklifts	0.19	0.01	0.01
Concrete pumps	0.36	0.001	0.001

5.6 Sensitive Receptors

The EPA considers sensitive receptors to be areas where people are likely to either live or work, or engage in recreational activities (DEC, 2005a). The receptors assessed in this report were selected to be the most representative sensitive receptors in proximity to the proposed works. A total of 139 receptors were assessed, which were primarily located along the eastern side of Hickson Road at various heights, with some located specifically on the site boundary. The receptor locations are shown in **Figure 3** and detailed in **Appendix D**. It should be noted that some of the buildings in Stage 1a of the Barangaroo project may be occupied at the time the Block 5 works commence; these receptors were not modelled in this assessment. The receptors that were included in the modelling, however, are located closer to the proposed works and emission sources than the potential receptors in the Barangaroo buildings. As such, the receptors included in the modelling are expected to represent the most affected receptors.

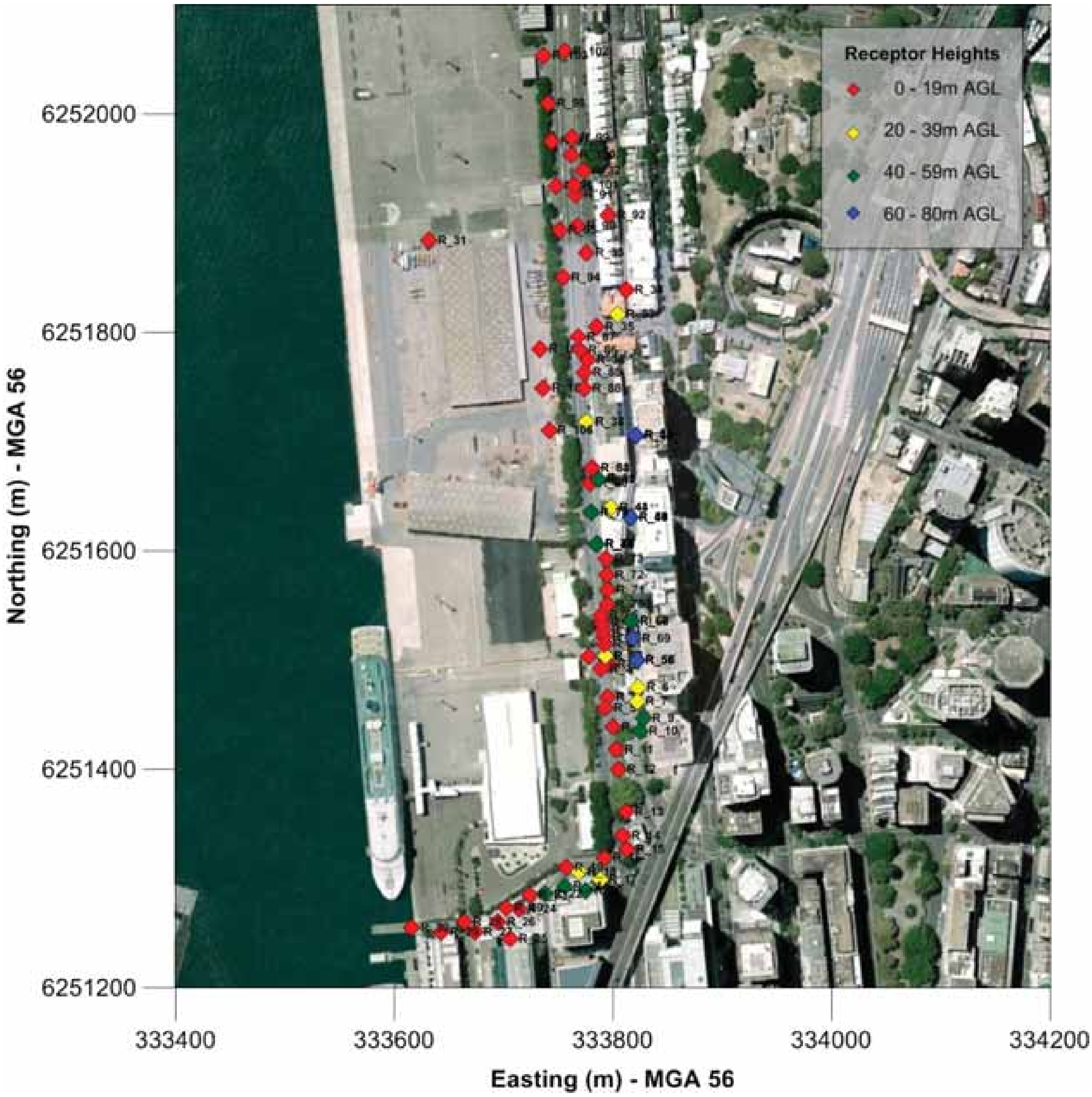


Figure 3 **Sensitive Receptor Locations**

5.7 Prediction of Cumulative Impacts

For NO_2, PM_{10} and TSP, DEC (2005a) specifies that AQIAs are to assess the cumulative impacts of a proposal against their impact assessment criteria. This involves adding existing background pollutant levels and expected pollutant levels from other concurrent developments to maximum pollutant concentrations of these pollutants predicted by dispersion modelling.

The cumulative assessment comprised the addition of the maximum measured data described in **Section 4.1** (assumed ambient pollutant concentrations) for TSP to predicted pollutant concentrations, and comparison of the results to the relevant criteria. For 1 hour PM_{10} and NO_2, contemporaneous assessments were made using data for the modelling period from the EPA's Rozelle monitoring station data summarised in **Section 4.1**.

Pollutant concentrations associated with the concurrent construction works for buildings C3/T1 and the operation of the water treatment plant were included in the dispersion model.

5.8 Conversion of NO_X to NO_2

Nitrogen oxides are produced in most combustion processes and are formed during the oxidation of nitrogen in fuel and nitrogen in the air. During high-temperature processes, a variety of oxides are formed including nitric oxide (NO) and NO_2. NO will generally comprise 95 % of the NO_X by volume at the point of emission. The remaining NO_X will consist of NO_2. Ultimately, however, all nitric oxides emitted into the atmosphere are oxidised to NO_2 and then further to other higher oxides of nitrogen.

The USEPA's Ozone Limiting Method (OLM) was used to predict ground-level concentrations of 1 hour NO_2. The OLM is based on the assumption that approximately 10 % of the initial NO_X emissions are emitted as NO_2. If the ozone (O_3) concentration is greater than 90 % of the predicted NO_X concentrations, all the NO_X is assumed to be converted to NO_2,otherwise NO_2 concentrations are predicted using the equation $NO_2 = 46/48 * O_3 + 0.1 * NO_X$. This method assumes instant conversion of NO to NO_2 in the plume, which overestimates concentrations close to the source since conversion usually occurs over periods of hours. This method is described in detail in DEC (2005a). Background O_3 data from the Rozelle monitoring station (refer to **Section 5.1**) were used to convert the modelled NO_2 concentrations in accordance with the EPA approved OLM (Method 2, Level 2 Assessment; DEC, 2005a). For annual NO_2, all NO_X was conservatively assumed to be NO_2.

5.9 Metals, PAHs and Cyanide

The concentrations of heavy metals, benzo(α)pyrene and cyanide at sensitive receptor locations were estimated using the predicted ground level concentrations of TSP. The proportion of heavy metals and cyanide in the soils (AECOM, 2010b) was applied to the TSP model predictions to derive an estimated concentration for each metal. The concentrations of heavy metals identified on site through the various sampling programs are summarised in **Table 20**; these were converted to a proportion of metals in soil to enable the estimation of heavy metal concentrations from the TSP results.

Table 20 Site-Specific Soil Concentrations of Miscellaneous Toxic Pollutants

Pollutant	Average Concentration (mg/kg)	Proportion of Metals in Soil (%)
Arsenic	4	0.0004
Benzo[α]pyrene	21	0.002
Beryllium	0.51	0.00005
Cadmium	0.56	0.00006
Chromium (III+VI)	17	0.002
Copper	51	0.005
Cyanide	21	0.002
Lead	239	0.02
Manganese	159	0.02
Mercury	0.27	0.00003
Nickel	12	0.001
Zinc	127	0.01

6.0 Results

The results of the dispersion modelling are shown in **Table 21** and **Table 22**. The results show the total cumulative impact of the Block 5 excavation works, the Block 4 excavation works, construction emissions form building C3 (T1) and the operation of the water treatment plant.

6.1 Modelling Predictions

The highest project contributions (pollutant concentrations associated with the project) predicted at any sensitive receptor assessed are provided in **Table 21**. These contributions represent the 100th percentile for NO_2, PM_{10} and TSP and the 99.9th percentile for benzene, ethylbenzene, toluene, xylenes, naphthalene and phenol in accordance with DEC (2005a). While the EPA odour criterion relates to the 99th percentile for odour, a Level 1 Assessment (most conservative) was conducted for odour due to the low predicted concentrations of odour, whereby the 100th percentile odour concentration was compared to the odour criterion. Cumulative pollutant concentrations, which represent the project contribution plus background pollutant concentrations, are provided for NO_2, PM_{10} and TSP as required by the EPA. For TSP, the ambient concentration was estimated from the PM_{10} concentration as described in **Section 4.1**. For 1 hour NO_2 and 24 hour PM_{10}, contemporaneous assessments were undertaken, where the measured background pollutant concentrations for each hour/24 hours of the modelling period were matched to the hourly/24 hour modelling predictions.

The EPA criteria for air toxics apply at and beyond the boundary of the facility. The concentrations reported below represent the highest 99.9th percentile concentrations for any sensitive receptor assessed, which include receptors located on the boundary.

As shown, no exceedences of the EPA criteria were predicted to occur at any sensitive receptor location assessed.

Table 21 Dispersion Modelling Results

Pollutant	Averaging Period	Units	Maximum Predicted Project Contribution	Total Cumulative Concentration	Criteria
NO_2	Max 1 hour average	$\mu g/m^3$	144	178	246
	Annual average	$\mu g/m^3$	33.2*	53.9	62
PM_{10}	Max 24 hour average	$\mu g/m^3$	8.8	46.1	50
	Annual average	$\mu g/m^3$	1.7	19.1	30
TSP	Annual average	$\mu g/m^3$	3.6	39.1	90
Benzene	99.9^{th} 1 hour	$\mu g/m^3$	2.5	N/A	29
Ethylbenzene	99.9^{th} 1 hour	$\mu g/m^3$	0.3	N/A	8,000
Toluene	99.9^{th} 1 hour	$\mu g/m^3$	1.1	N/A	360
Xylenes	99.9^{th} 1 hour	$\mu g/m^3$	0.3	N/A	190
Naphthalene	99.9^{th} 1 hour	$\mu g/m^3$	17.5	N/A	440
Phenol	99.9^{th} 1 hour	$\mu g/m^3$	0.1	N/A	20
Odour	NRT	OU	0.1	N/A	2

* Annual NO_2 was calculated assuming all NO_X was NO_2
NRT = Nose response time, 100th percentile

6.2 Metals, PAHs and Cyanide

The concentrations of metals, PAHs and cyanide were estimated based on a 100th percentile 1 hour TSP concentration of predictions at all sensitive receptor locations assessed of 109 $\mu g/m^3$; results are shown in **Table 22**. No exceedences were predicted. It should be noted that the EPA criteria for these pollutants relate to the 99.9th percentile concentrations; as such, the concentrations presented here are conservative, as they were calculated from the 100th percentile TSP concentration.

Table 22 Predicted Pollutant Concentrations - Metals

Pollutant	Estimated Maximum Concentrations (100thpercentile) (μg/m^3)	Criteria (99.9th percentile) (μg/m^3)
Arsenic	0.0004	0.1
Benzo[α]pyrene	0.002	0.4
Beryllium	0.00005	0.004
Cadmium	0.00007	0.018
Chromium (III+VI)	0.002	0.09
Copper	0.005	18
Cyanide	0.002	90
Lead	0.022	0.5
Manganese	0.022	18
Mercury	0.00003	0.18
Nickel	0.0011	0.18
Zinc	0.011	18

6.3 Limitations

Best efforts were made to estimate the likely numbers, operational parameters (including operational hours and handling volumes) and emissions of plant and equipment in the AQIA. The numbers used were based on information available from Lend Lease at the time of preparation of this report, and may change to reflect the detailed design of the remediation activities.

If major changes are proposed to pollutant emitting activities during the remediation works, further modelling may be required to assess the effects of those changes on local air quality.

7.0 Recommended Air Quality Management and Mitigation

Mitigation and work practices that should be implemented at the site to minimise pollutant emissions are described below. These measures are intended to reduce risks to human health and nuisance impacts. The proposed monitoring works should be undertaken for the duration of the remediation and land forming works. The management and mitigation strategies, contingency measures and monitoring works will be consistent with the requirements of Environment Protection Licence (EPL) 13336, which will be varied following the granting of project approval for the proposed remediation works.

7.1 Mitigation Measures

Mitigation measures will be implemented based on the reactive management program and the nature of the works being undertaken on site at any time. The proposed mitigation measures are listed below:

- Mains power will be used where available and suitable.
- The dust, VOC and meteorological monitoring program will be continued as per **Section 8.3**.
- Vehicle engines will be turned off while parked on site.
- Vehicular access will be confined to designated access roads. Haul road lengths will be minimised.
- Equipment, plant and machinery will be appropriately tuned, modified or maintained to minimise visible smoke and emissions.
- All excavation, materials handling and ex-situ treatment (excluding retention wall works) will be undertaken within the sealed OCSs, which will be maintained under negative pressure.
- A minimum of two GAC filters will be installed in series for each emission stack in the OCSs as per the modelling assumptions. The GACs chosen will be suitable for the contaminants being treated.
- Prior to commencement of the relevant stage of works where odour control structures will be used, a detailed design plan of the structures, the air discharge point and emission control system, will be submitted to the EPA for review and comment. The detailed design plan will include the following information:
    - Performance specifications, including particle and VOC control efficiency for the proposed technology;
    - Proposed monitoring to confirm the performance of the proposed VOC control technology; and
    - The proposed methodology to detect carbon bed breakthrough.
- The stack heights, pollutant concentrations and minimum velocities assumed in the modelling will be achieved.
- Stacks will be located a minimum of 60 metres (calculation from **Figure 3**) from Hickson Road as assumed in the modelling.
- If off-site treatment is undertaken, all trucks transporting the spoil will be covered, and receivers of the spoil will be appropriately licensed to receive the material.
- Alternate odour control measures will be used during retention wall works, such as covering exposed soil or using odour suppressants and foam.
- The OCSs will be maintained to their design specifications. Regular checking and maintenance of OCS filtration systems will be undertaken.
- Site speed limits will be implemented.
- Generator emissions will be vented through the OCS stacks.
- Exposed areas will be minimised as much as practical.
- Loads will be covered during transport.
- Good housekeeping practices will be implemented to minimise dust on hardstand areas.
- Spills will be immediately cleaned up.
- The complaints management system will be maintained.

- Work practices will be adjusted (as required) based on wind observations and real time monitoring results.
- Water sprays and/or surfactants will be used wherever and whenever necessary.
- Windbreak barriers will be erected at the site boundary.
- Exposed surfaces and roads will be watered as required.

An Air Quality and Odour Management Sub-Plan would be prepared to include mitigation measures from this AQIA, and that it would include an Air Quality Monitoring Plan. The Sub-Plan would contain measures to reflect variations in cumulative emissions from construction activities across Barangaroo.

These measures are intended to reduce risks to human health and nuisance impacts. The proposed monitoring works should be undertaken for the duration of the remediation and land forming works. The management and mitigation strategies, contingency measures and monitoring works will be consistent with the requirements of Environment Protection Licence (EPL) 13336, which will be varied following the granting of project approval for the proposed remediation works.

7.2 Contingency Measures

When monitoring systems continuously measure pollutant concentrations, an early warning system based on trigger levels can be used to minimise adverse impacts on the environment. The trigger levels are generally set below a relevant assessment criterion.

A reactive management plan was developed for the site, based on a three-stage approach:

- Investigate: Identification of the likely reasons for the elevated pollutant concentration and formulation of a contingency response for the action stage;
- Action: Implementation of the measures formulated in the investigative stage and review of their effectiveness; and
- Stop Work: All air polluting works associated with the remediation of Block 5 should stop at this stage until the measured pollutant levels are below the action level to avoid an exceedence of the pollutant criterion.

The reactive management procedure for PM_{10} is provided in **Table 23**.

Table 23 Reactive Management Procedure – PM_{10}

Reactive Management Procedure				
Trigger Stage	Averaging Period	Trigger Value ($\mu g/m^3$)	Primary Responsibility	Action Required
1 Investigate	1 hour	85	Environment Manager	Environmental Manager to undertake review of possible dust sources operating during the average period. Identify possible measures for these activities, action if deemed necessary.
	3 hour	80		
2 Action	1 hour	470		Environment Manager to attend site and ensure implementation of the control actions identified in stage 1. Effectiveness of control actions to be reviewed and escalate where appropriate. Identify long-term solutions to dust issues. Complete Lend Lease Environmental Response Form.
	3 hour	160		
3 Stop Work	1 hour	940		Targeted shut down of dust-generating activities until the measured pollutant levels are below the stated Action period trigger value. Complete Lend Lease Environmental Response Form.
	3 hour	320		

The reactive management procedure for total VOCs is provided in **Table 24**.

Table 24 Reactive Management Procedure – Total VOCs

Reactive Management Procedure – Total VOCs				
Trigger Stage	**Averaging Period**	**Trigger Value ($\mu g/m^3$)**	**Primary Responsibility**	**Action Required**
1 Investigate	1 hour	0.8	Environment Manager	Environmental Manager to undertake review of possible VOC sources operating during the average period. Identify possible measures for these activities, action if deemed necessary.
	3 hour	0.5		
2 Action	1 hour	8.3		Environment manager to attend site and ensure implementation of the control actions identified in stage 1. Effectiveness of control actions to be reviewed and escalate where appropriate. If VOCs deemed to be coming from excavation area, speciation using a Summa canister will be undertaken. Complete Lend Lease Environmental Response Form

7.3 Air Quality Monitoring Program

Ambient air quality monitoring around the Barangaroo site has been undertaken by AECOM since October 2011 in accordance with the Air Quality Management Plan and EPL for the site. The monitoring has the following objectives:

- Allow a real time assessment of the various activities on the site, which can then be related back to operational changes to reduce off-site impacts; and to
- Allow reactive dust mitigation measures to be implemented based on real time monitoring data.

The monitoring is undertaken generally in accordance with the following guidelines and Australian Standards:

- The EPA's Approved Methods for Sampling and Analysis of Air Pollutants in New South Wales (DEC, 2005a);
- AS/NZS 3580.9.3:2003 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - Total suspended particulate matter (TSP) - High volume sampler gravimetric method;
- AS 3580.9.8-2008 Methods for sampling and analysis of ambient air - Determination of suspended particulate matter - PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser;
- AS/NZS 3580.1.1:2007 Methods for sampling and analysis of ambient air - Guide to siting air monitoring equipment; and
- AS 2923-1987 Ambient air - Guide for measurement of horizontal wind for air quality applications.

Details of the relevant monitoring equipment and locations are provided in **Table 25** and **Figure 4**. These monitoring plans vary depending on the types of work undertaken. The works are always carried out in accordance with the site's EPL.

Table 25 Ambient Monitoring Agenda

Parameter	Equipment	Frequency	Locations	EPA Criteria	Sampling Method	Timing
TSP	HVAS	24 hours every 6 days	EPL points 5, 8, 13	90 µg/m^3 as an annual average	AM-15 AS3580.9.3 – 2003	During excavation and backfilling*
PM_{10}	TEOM	Continuous	EPL points 5, 8, 13	50 µg/m^3 as a 24 hour average** 30 µg/m^3 as an annual average	AM-22 AS3580.9.6 - 2003	Throughout construction
Heavy Metals	HVAS	24 hours every 6 days	EPL points 5, 8, 13	***	AM-15 AS3580.9.3 – 2003	During excavation and backfilling*
PAH (speciated)	HVAS	24 hours every 6 days	EPL points 5, 8, 13	N/A	AM-15 AS3580.9.3 – 2003	During excavation and backfilling*
VOC (speciated)	Summa	As needed	As needed	***	USEPA TO-15	During excavation and backfilling
Odour	Field Olfactometer	Morning, followed by afternoon if odour exceeds trigger level	Odour locations 1 to 6	N/A	N/A	During excavation and backfilling*
Met station	-	Continuous	EPL point 5	Site complies with *Approved Methods*	AM-1 to 4 USEPA (2000) EPA 454/R-99-005	Throughout construction

* Or as agreed with the EPA
** 24 hour average of a calendar day defined as midnight to midnight.
*** Too many criteria to list; criteria based on DEC (2005a)

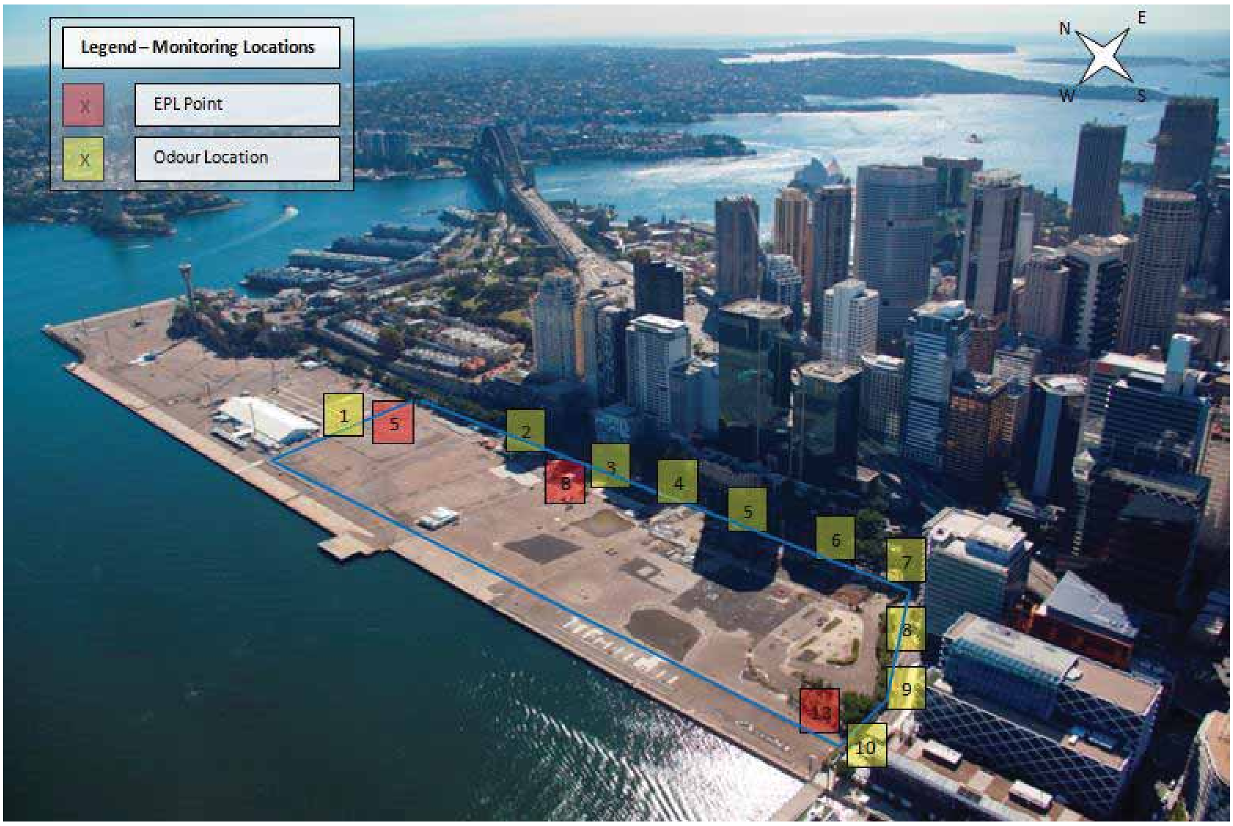

Legend – Monitoring Locations
X
EPL Point
X
Odour Location
N
E
W
S
1
5
2
8
3
4
5
6
7
8
9
13
10

Figure 4 Approximate Existing Barangaroo South Monitoring Locations

The OCS monitoring plan would be expected to address emissions of NO_X, particulates, VOCs and PAHs, which would be tested via stack emission testing undertaken in accordance with the Approved Methods for Sampling and Analysis of Air Pollutants in New South Wales (DEC, 2005b). Suggested concentration limits and sampling frequencies are provided in **Table 26**; the final nature of the sampling program would be determined by the EPA and specified in the EPL.

Table 26 Suggested Monitoring Frequency and Concentration Limits for OCSs

Pollutant	100^{th} Percentile Concentration Limit	Monitoring Frequency
NO_X	N/A	Post-commissioning followed by sampling every alternate month
Total particulates	20 mg/Nm^3	
VOCs as n-propane equivalent	20 mg/Nm^3	
PAHs	N/A	

8.0 Conclusion

AECOM undertook an air quality impact assessment of the proposed remediation of the Block 5 Remediation Area at the Barangaroo site. A cumulative assessment was undertaken to address the potential overlap of the remediation works with the remediation works at Block 4, construction works on building C3/T1, and the operation of a water treatment plant. Dispersion modelling was undertaken using the CALPUFF model to predict pollutant concentrations at sensitive receptor locations located close to the site. The following pollutants were assessed:

- NO_2;
- Particulates (TSP and PM_{10});
- Heavy metals (attached to TSP);
- VOCs (BTEX, naphthalene and phenol);
- PAHs; and
- Odour.

A single operational scenario was considered as part of the assessment, which addressed the excavation of the Block 5 Remediation Area and the concurrent activities described above. No exceedences of the EPA impact assessment criteria were predicted at any sensitive receptor location for any of the pollutants assessed. Emissions associated with the off-site transport of excavated material would be controlled through sealing loads prior to the trucks leaving the site. Emissions associated with the off-site treatment of excavated material would be controlled through the Environment Protection Licence of the facility treating the material.

It should be noted that the predicted pollutant concentrations for this assessment were generally lower than those predicted for previous assessments of the Barangaroo site. This difference is attributable to the cumulative works expected to be undertaken at the time of the Block 5 remediation works. Specifically, the concrete batching plant, which was the attributed cause of high levels of particulates in previous assessments, will not be operational on the site at the time of the Block 5 excavations.

Lend Lease has demonstrated that it can undertake significant materials handling activities with substantial plant and equipment numbers on site without exceeding the relevant air quality criteria. As such, provided the existing monitoring and management plan for the Site is modified to incorporate the proposed Block 5 remediation activities, adverse effects on local air quality are not expected to occur as a result of the proposed remediation works.

9.0 References

AECOM. (2014). Air Quality Impact Assessment – Remediation and Landforming Works, DA SSD 5897-2013, Barangaroo Block 4, Hickson Road, Millers Point, NSW.

AECOM. (2012). Air Quality Impact Assessment – Barangaroo Stage 1A Cumulative Construction Assessment.

AECOM. (2011). Air Quality Impact Assessment – Water Treatment Plant, Barangaroo South.

AECOM. (2010a). Air Quality Impact Assessment – Barangaroo Site Excavation and Preparation Works.

AECOM. (2010b). Data Gap Investigation - EPA Declaration Area (Parts of Barangaroo Site and Hickson Road), Millers Point, NSW.

AECOM. (2013). Remedial Action Plan NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW. July 2013.

Australian Government. (2012). National Pollutant Inventory Emission Estimation Technique Manual for Mining, Version 3.1. Commonwealth of Australia: Canberra.

Australian Government. (2008). National Pollutant Inventory Emission Estimation Technique Manual for Combustion Engines, Version 3.0. Commonwealth of Australia: Canberra.

DEC. (2005a). Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales. Department of Environment and Conservation (NSW).

DEC. (2005b). Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales. Department of Environment and Conservation (NSW).

Duthie, P. (2002). Former Lednez Site and Homebush Bay Remediation Environment Impact Assessment - Air Quality Human Health Risk Assessment. Egis Consulting Australia Pty Ltd, Melbourne.

JBS. (2012). Air Quality and Health Impact Assessment – Barangaroo Central Waterfront Promenade and Barangaroo Central Interim Public Domain.

Nelson, S.G. & Babyak, R.A. (1996). Activated carbon use in treating diesel engine exhausts. Preprints of Papers, American Chemical Society, Division of Fuel Chemistry, 41(1), pp 298 – 301.

Pacific Institute (2001) The Cadiz Valley Groundwater Storage Project; http://www.pacinst.org/reports/cadiz/feir/volumes/vol1/appendix/v1a_c1.pdf

SKM. (2005). Air Quality Assessment – Intermodal Logistics Centre at Enfield. Sinclair Knight Merz.

SKM. (2002). M5 East Freeway Sub-Regional Air Quality Management Plan. Sinclair Knight Merz

Thiess. (2012). Construction Environmental Management Plan – Wynyard Walk, Stage 1.

Thiess. (2013). Construction Environmental Management Plan – Wynyard Walk, Stage 2.

US EPA. (2011). Emission factor Documentation for AP-42, Section 13.2.1 – Paved Roads.

Appendix A

Pollutants of Potential Interest

Appendix A Pollutants of Potential Interest

For the purposes of this AQIA, pollutants of interest were defined as chemicals that have been detected on the site in concentrations greater than relevant human health screening criteria. The pollutants considered were:

- Nitrogen dioxide (NO_2);
- Particulate matter;
- Heavy metals (cadmium, chromium VI, copper, lead, mercury, nickel, zinc);
- BTEX (benzene, toluene, ethylbenzene and xylenes – types of VOCs);
- PAHs (benzo[a]pyrene and naphthalene);
- Phenol; and
- Odour.

The potential health effects of the pollutants of interest are summarised below. Details were obtained from the National Pollutant Inventory (NPI, 2010) unless otherwise specified.

Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a brownish gas with a pungent odour. It exists in the atmosphere in equilibrium with nitric oxide. The mixture of these two gases is commonly referred to as NO_x. NO_x is a product of combustion processes. In urban areas, motor vehicles and industrial combustion processes are the major sources of ambient NO_x. NO_2 can cause damage to the human respiratory tract, increasing a person's susceptibility to respiratory infections and asthma. NO_2 can also cause damage to plants, especially in the present of other pollutants such as ozone and sulfur dioxide. NO_x are also primary ingredients in the reactions that lead to photochemical smog formation.

Particulate Matter

Suspended particulate matter may be emitted from site via combustion activities (i.e. vehicle and plant operations) and site preparation, excavation and remediation 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 and chronic bronchitis) and non-fatal heart attacks.

Heavy Metals

A variety of heavy metals were detected at the site. The metals detected at 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 foetuses, 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.

VOCs

Organic compounds with a vapour pressure at 20 °C exceeding 0.13 kPa are referred to as VOCs. VOCs have been implicated as a major precursor in the production of photochemical smog, which causes atmospheric haze, eye irritation and respiratory problems. 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. A variety of VOCs were detected at the site, which may be released during the proposed activities.

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.

Phenol

Phenol is found as a solid or a thick liquid, and is usually colourless or pink. It has a characteristic odour likened sweet tar. Phenol is a common component of oil refinery wastes, and is also used as a disinfectant, a reagent, and in the manufacture of products such as fertilisers and paints.

Phenol can be inhaled, ingested, or enter through the skin. Exposure can result in irritation or burns, and acute posioning can result in respiratory failure. Phenol is acutely toxic to animals, birds and fish, and can cause a low growth rate or death in plants.

Cyanide

Cyanide is a naturally occurring element that is essential for a healthy diet (as cyanocobalmin, or vitamin B12). Compounds are released into the atmosphere (from natural or human processes) as gaseous or particulate matter, which settles into the soil or water, with most compounds being water soluble. Cyanides break down in a matter of days in water but are persistent in air. Exposure can occur from ingestion of food or water or smoking, or air pollution from silver and gold mining operations, chemical processing facilities, steel and iron industries, high motor vehicle traffic areas and the like. Pesticides and rodenticides can also contain cyanide.

It is very toxic to humans, and exposure by inhalation can cause rapid death. Brief exposures to lower concentrations may result in symptoms such as shortness of breath, convulsions and unconsciousness, while long-term exposure to low concentrations can result in deafness, vision and coordination problems. Exposure to high levels for short periods can result in damage to the respiratory, cardiovascular and central nervous systems and quickly cause death. As cyanide was only detected in very small concentrations at the site (i.e. at concentrations approximately 1,000 times less than relevant assessment criteria[1]), cyanide is not expected to be a significant issue at the site.

Cyanides are also highly toxic to aquatic life, birds and animals over short periods. While cyanides have high chronic toxicity to aquatic life, insufficient data exist to determine chronic toxicity to land organisms. Cyanides are not expected to bioaccumulate.

Cyanide was not identified as pollutant of concern in AECOM (2010)[2], but was included in this assessment for completeness.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs 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.

---

[1] NEPC. (1999). National Environment Protection (Assessment of Site Contamination) Measure (NEPM). National Environment Protection Council.
[2] AECOM. (2010). Remediation Action Plan – Barangaroo- Other Remediation Works (South) Area. AECOM, May, 2010

Naphthalene

Naphthalene is the primary PAH of potential concern at the Barangaroo site due to its volatile nature and strong, offensive odour. It is produced from coal tar and petroleum, and is used for the production of chemicals, dyes and as a moth-repellent. It can be absorbed through inhalation, ingestion and dermal contact. Short-term exposure can cause lesions of blood cells (haemolysis), while long-term exposure can result in chronic haemolytic anaemia. Inhalation can generate symptoms such as headache, confusion, nausea, vomiting and sweating. Skin irritation and dermatitis can result from dermal contact. Naphthalene exposure can cause cataracts in the eyes, while ingestion can cause abdominal cramps, nausea, vomiting, diarrhoea and death in young infants. It is considered possible carcinogenic to humans and carcinogenic in animals. The substance is very toxic to aquatic organisms. Naphthalene may cause long-term effects in the aquatic environment[3].

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. Odour may affect a person's quality of life and can have a large range of effects including stress and other physical symptoms. Odorous compounds detected at the site may include BTEX and PAHs, notably ethylbenzene, xylenes and naphthalene.

[3] International Programme on Chemical Safety Poisons Information Monograph 363; http://www.inchem.org/documents/pims/chemical/pim363.htm; accessed 19 May 2010

Appendix B

Climate Averages

Appendix B Climate Averages

Average Climate Data – Observatory Hill, 1859 – 2014 (June)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average temperature													
Maximum (°C)	25.9	26	24.7	22.4	19.4	16.9	16	18	20	22	24	25	21.7
Minimum (°C)	18.7	19	17.6	14.7	11.5	9.3	8	9	11	14	16	18	13.8
Rainfall													
Mean rainfall (mm)	101	118	130	127	120	132	98	80	68	77	84	77	1213
Average 9 am conditions													
Temperature (°C)	22.5	22	21.1	18.2	14.6	11.9	11	13	16	19	20	22	17.5
Relative humidity (%)	71	74	74	72	74	74	71	66	62	61	66	67	69
Wind speed (km/h)	8.6	8.2	7.9	8.8	10.5	11.9	13	13	12	12	11	9.8	10.6
3 pm conditions													
Temperature (°C)	24.8	25	24	22	19.4	16.9	16	18	19	21	22	24	21
Relative humidity (%)	62	64	62	59	57	57	51	49	51	56	58	59	57
Wind speed (km/h)	17.9	17	15.2	13.8	12.7	13.6	15	18	18	19	19	20	16.6

Appendix C

Soil Sampling Results Summary

Appendix C Soil Sampling Results Summary

The data used in the development of the VOC and odour emission rates are provided below. As described in **Section 5.4.5**, the VOC emission rates varied for each excavation location based on the volume of material excavated and the duration of the works. Only the pollutants for which odour thresholds were found were used to estimate odour emission rates. Data were sourced from AECOM (2010b).

Soil Contaminant Sampling Results - VOCs

Category	Pollutant	Number of Results	Number of Detects	Average Concentration (mg/kg)	VOCs/Odour
BTEX	Benzene	164	43	5.2	VOCs/odour
	Ethylbenzene	164	38	3.7	VOCs/odour
	Toluene	164	43	7.1	VOCs/odour
	Total xylenes	164	48	16	VOCs/odour
Inorganics	Total cyanide	105	38	21	Odour
PAH/ Phenols	2,4-dimethylphenol	102	28	11	VOCs
	2-methylphenol (o-cresol)	102	20	14	VOCs/odour
	2-nitrophenol	102	0	0.36	VOCs
	3-&4-methylphenol	102	22	27	VOCs
	4-chloro-3-methylphenol	102	1	0.37	VOCs/odour
	Naphthalene	166	96	338	VOCs/odour
	Phenol	102	17	19	VOCs/odour
SVOCs	1-naphthylamine	14	1	0.48	VOCs
	Diallate	13	1	0.49	VOCs
	2-Picoline (2-methylpyridine)	14	1	0.47	VOCs
	3,3-Dichlorobenzidine	14	1	0.5	VOCs
	4-(dimethylamino) azobenzene	14	1	0.48	VOCs
	4-aminobiphenyl	14	1	0.47	VOCs
	Azobenzene	14	1	0.54	VOCs
	Carbazole	14	9	30	VOCs
	Dibenzofuran	14	10	52	VOCs/odour
VOCs	1,2,4-trimethylbenzene	16	10	18	VOCs/odour
	1,3,5-trimethylbenzene	16	9	7	VOCs/odour
	Isopropylbenzene (cumene)	16	3	0.75	VOCs/odour
	n-propylbenzene	16	4	0.71	VOCs
	Styrene	16	7	3.1	VOCs/odour

The calculations for the odour emissions are shown in the table below.

Excavation Odour Flux Estimate

Chemical	Vapour Pressure (mm Hg)#	Odour Threshold#	Reference Soil Concentration (mg/kg)^	Reference Odour Flux ($OU/m^2.s$)^	Reference Odour Flux to Soil Concentration Ratio (calculated)	Site Average Soil Concentration (mg/kg)	Site Odour Flux ($OU/m^2.s$) (calculated)
Benzene	95.2	4.79	-	0.64	0.01154	5.2	0.060
Toluene	28.4	10.93	-	0.33	0.00151	7.1	0.011
Ethylbenzene	9.53	10	56.3	0.03	0.000554	3.7	0.002
Total xylenes	6.72	4.78	33.0	0.0001	0.000004	16	0.000
Cyanide	264.3	0.64	-	13.79	0.24	21	5.027
Naphthalene	0.087	0.44	1150	0.0014	0.000001	338	0.000
2-methylphenol (o-cresol)	0.299	0.0012	-	-	0.14021	14	1.963
4-chloro-3-methylphenol	0.08	0.10	-	-	0.0005	0.37	0.000
Phenol	0.3513	0.15	-	-	0.001	19	0.025
Dibenzofuran	0.0175	1.00	-	-	0.00001	52	0.001
1,2,4-trimethylbenzene	2.03	1.97	-	-	0.001	18	0.011
1,3,5-trimethylbenzene	2.3	2.70	-	-	0.000	7	0.003
Isopropylbenzene (cumene)	4.5	0.43	-	-	0.006	0.75	0.005
Styrene	5	1.36	-	-	0.002	3.1	0.007
Sum of components							**7.1**
Total odour emission rate (including peak-to-mean ratio of 2.3)							**16.4**

Various sources; primarily US EPA (www.epa.gov)
^ Duthie (2002)
***** Used to calculate the ratio for all other pollutants except total xylenes and naphthalene, for which ratios were available.

Appendix D

Sensitive Receptor Locations

Appendix D Sensitive Receptor Locations

The coordinates and heights of the sensitive receptors included in the dispersion modelling are provided below.

Sensitive Receptors

Receptor ID	Coordinates		Base Elevation (m)	Flagpole Height (m)	Description
	X (m)	Y (m)			
R_1	333778	6251503	6	0	
R_2	333796	6251496	8	18	
R_3	333789	6251492	6	0	
R_4	333795	6251466	6	0	
R_5	333793	6251456	6	0	
R_6	333823	6251475	10	25	
R_7	333822	6251462	7	25	
R_8	333800	6251439	7	0	
R_9	333828	6251447	8	48	
R_10	333825	6251435	8	50	
R_11	333803	6251418	8	0	
R_12	333805	6251400	9	0	
R_13	333812	6251361	6	8	
R_14	333809	6251339	6	12	
R_15	333813	6251327	7	15	
R_16	333792	6251319	6	0	
R_17	333788	6251299	6	35	
R_18	333769	6251306	6	35	
R_19	333757	6251310	6	0	
R_20	333775	6251289	6	40	
R_21	333756	6251293	6	48	
R_22	333738	6251286	6	40	
R_23	333724	6251285	6	0	
R_24	333714	6251272	6	10	
R_25	333706	6251245	6	15	
R_26	333695	6251260	6	10	
R_27	333674	6251251	6	12	
R_28	333664	6251260	6	0	
R_29	333643	6251251	5	15	
R_30	333616	6251255	6	0	
R_31	333632	6251884	5	0	
R_32	333773	6251948	14	0	Preschool
R_33	333776	6251873	16	0	

Receptor ID	Coordinates		Base Elevation (m)	Flagpole Height (m)	Description
	X (m)	Y (m)			
R_34	333812	6251839	26	0	
R_35	333785	6251805	23	0	
R_36	333777	6251775	23	0	
R_37	333776	6251718	7	0	
R_38	333776	6251718	7	30	
R_39	333821	6251706	22	0	
R_40	333821	6251706	22	20	
R_41	333821	6251706	22	40	
R_42	333821	6251706	22	60	
R_43	333798	6251640	10	0	
R_44	333798	6251640	10	20	
R_45	333785	6251606	8	0	
R_46	333785	6251606	8	20	
R_47	333785	6251606	8	30	
R_48	333816	6251631	21	0	
R_49	333816	6251631	21	20	
R_50	333816	6251631	21	40	
R_51	333816	6251631	21	60	
R_52	333793	6251504	7	0	
R_53	333793	6251504	7	20	
R_104	333733.32	6251784.85	0	0	Boundary receptor
R_55	333822	6251500	13	20	
R_56	333822	6251500	13	40	
R_57	333822	6251500	13	60	
R_58	333822	6251500	13	80	
R_59	333702	6251273	6	0	
R_105	333736.22	6251749.05	0	0	Boundary receptor
R_61	333792.4	6251514.59	6	0	
R_62	333791.69	6251521.36	7	0	
R_63	333790.93	6251528.11	6	0	
R_64	333789.85	6251534.56	6	0	
R_65	333789.09	6251541.3	7	0	
R_66	333816.87	6251535.93	16	0	Stamford on Kent
R_67	333816.74	6251535.93	16	20	Stamford on Kent
R_68	333816.74	6251535.93	16	40	Stamford on Kent
R_69	333818.5	6251519.83	13	60	Stamford on Kent

Receptor ID	Coordinates		Base Elevation (m)	Flagpole Height (m)	Description
	X (m)	Y (m)			
R_70	333794.74	6251551.06	12	0	
R_71	333795.15	6251564.05	13	0	
R_72	333794.14	6251578.06	14	0	
R_73	333793.73	6251592.87	7	0	
R_74	333785	6251606.07	7	10	38 Hickson Rd
R_75	333785	6251606.48	7	30	38 Hickson Rd
R_76	333785.2	6251606.07	7	50	38 Hickson Rd
R_77	333780.33	6251635.3	6	0	38 Hickson Rd
R_78	333780.13	6251635.3	6	20	38 Hickson Rd
R_79	333780.13	6251635.3	6	40	38 Hickson Rd
R_80	333779.32	6251662.1	6	0	
R_81	333786.36	6251665.79	6	20	30 The Bond
R_82	333786.36	6251665.79	6	40	30 The Bond
R_83	333780.84	6251675.8	6	30	30 The Bond
R_84	333780.84	6251675.8	6	10	30 The Bond
R_85	333773.59	6251763.63	22	0	
R_86	333769.62	6251783.99	22	0	
R_87	333768.24	6251795.73	22	0	
R_89	333774.56	6251839.7	19	0	
R_88	333773.42	6251748.79	12	0	
R_90	333768.02	6251897.49	14	0	
R_91	333765.67	6251925.99	13	0	
R_92	333795.74	6251907.43	23	10	Observatory Hotel
R_93	333804.11	6251816.69	24	20	Observatory Hotel
R_94	333754.16	6251850.42	8	0	
R_95	333751.28	6251893.57	6	0	
R_96	333747.88	6251934.1	6	0	
R_97	333743.96	6251975.16	6	0	
R_98	333740.82	6252009.94	6	0	
R_99	333762.53	6251978.29	15	0	
R_100	333762	6251962.6	14	10	Preschool
R_101	333764.62	6251934.89	15	0	Preschool
R_102	333755.73	6252057.27	19	0	Boundary receptor
R_103	333736.64	6252053.61	6	0	Boundary receptor
R_106	333741.56	6251710.54	0	0	Boundary receptor