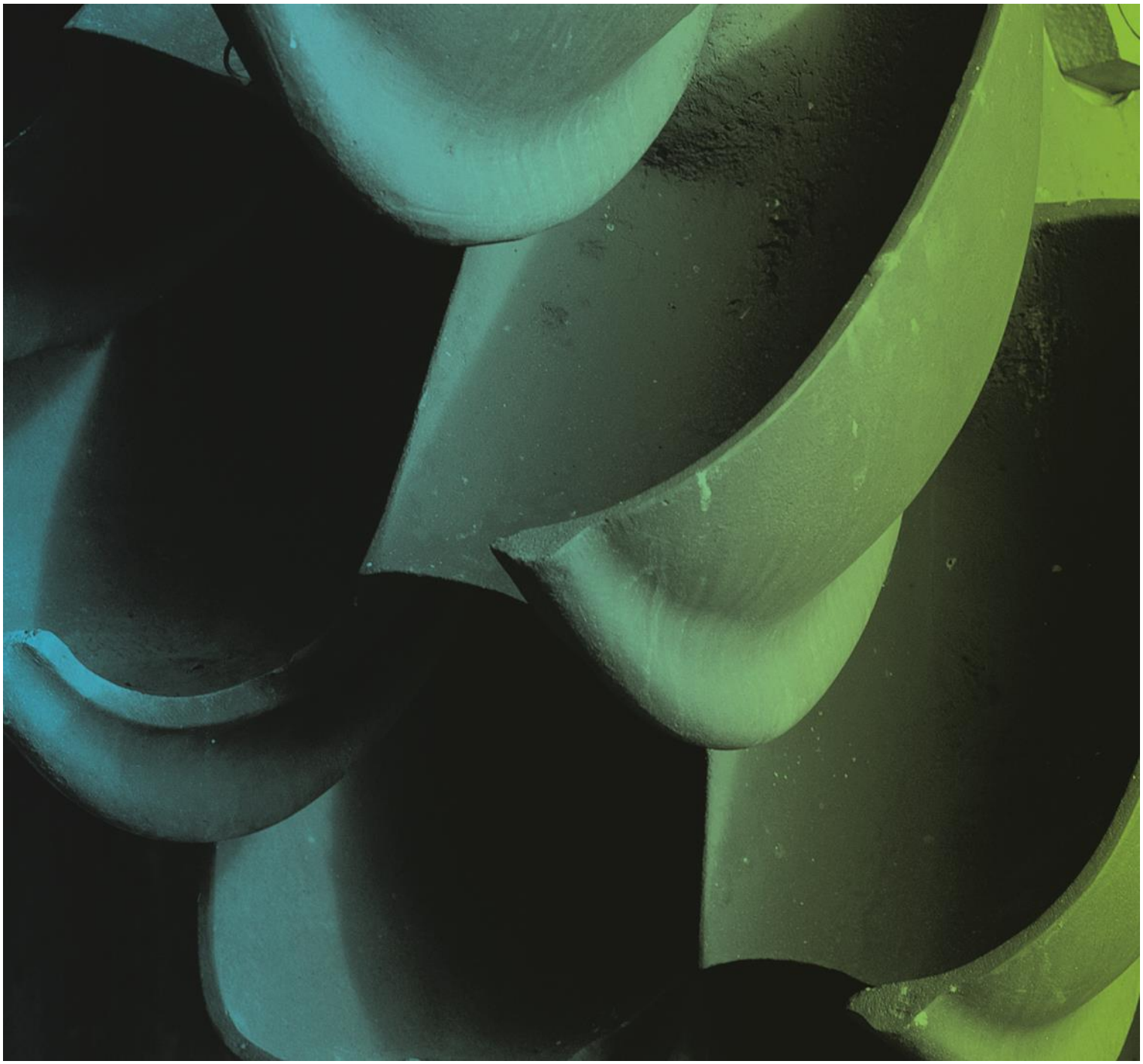
Barangaroo Declaration Area 21122

18-Feb-2014

Air Quality Impact Assessment

Remediation and Landforming Works, DA SSD 5897-2013, Barangaroo Block 4, Hickson Road, Millers Point, NSW



Air Quality Impact Assessment

Remediation and Landforming Works, DA SSD 5897-2013, Barangaroo Block 4, Hickson Road, Millers Point, NSW

Client: Lend Lease (Millers Point) Pty Limited

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Quality Information

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Reviewed by David Rollings & Adam Plant

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	1-Nov-2012	Draft for internal review	David Rollings Principal Engineer	
B	1-Nov-2012	Draft for client review	David Rollings Principal Engineer	
C	14-Nov-2012	Final draft for review	David Rollings Principal Engineer	
D	8-Feb-2013	Final draft for submission	David Rollings Principal Engineer	
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H	12-Sep-2013	Modification to project scope	Adam Plant Senior Environmental Scientist	
I	01-Oct-2013	Modification to project scope	David Rollings Principal Engineer	
J	8-Nov-2013	Response to DPI Comments	David Rollings Principal Engineer	
K	17-Feb-2014	Draft response to EPA Comments	David Rollings Principal Engineer	
L	18-Feb-2014	Final response to EPA Comments	David Rollings Principal Engineer	

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Glossary of Terms

Term	Description
Block 4 Remediation Area	A portion of the Site included under SSD 5897-2013-8 including: - Development Block 4 (both within and outside the EPA Declaration Area); - The area immediately south of Development Block 4 and north of the Stage 1A basement groundwater retention wall system. With reference to **Figure 2**, the Block 4 Remediation Area includes the area labelled as: - Site Remediation Area; and - Excavation for stormwater diversion and remediation to address the EPA Declaration (where required).
BTEX	Benzene, toluene, ethylbenzene and xylenes
EPA	Environment Protection Authority
EPA Declaration Area	Remediation Site Declaration 21122
EPL	Environment Protection Licence
Ex-situ Remediation Methodology	Excavation of contamination followed by above-ground treatment on-site (or off-site), then either off-site disposal of treated 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(a)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
RE	Remediation Enclosure (also referred to as a Soil Treatment Area by **Figure 2**)
S-ESCO	Surfactant Enhanced Ex-situ Chemical Oxidation Soil is mixed with chemicals in a pugmill and then stockpiled for a period of time until the chemical reactions have been completed.
Site	Area required for the purpose of Development Application SSD 5897-2013 identified as: - Block 4 Remediation Area - Any other areas of Barangaroo or Hickson Road required for staging and undertaking the remediation works or proposed stormwater diversion. Refer to **Figure 2**.
Site Remediation Area	The part of Development Block 4 Remediation Area that is within the proposed basement groundwater retention wall system. Refer to **Figure 2.**
SVOCs	Semi volatile organic compounds
TSP	Total suspended particulates
VMP	Voluntary Management Proposal
VOCs	Volatile organic compounds

1.0 Introduction

This report supports a Development Application (SSD 5897 - 2013) submitted to the Minister for Planning pursuant to Part 4 of the *Environmental Planning and Assessment Act, 1979*. The Application seeks approval for remediation and landforming works within a portion of the area of Millers Point declared by the Environment Protection Authority (EPA) as Contaminated Land under the Contaminated Lands Act (Declaration No. 21122, referred to herein as the Declaration Area) and some adjacent land. The area to be remediated under SSD 5897-2013 (the Site) is the Block 4 Remediation Area, located on Barangaroo South. Remediation of the remaining parts of the Declaration Area (Block 5 and Hickson Road) will be the subject of separate Development Applications, and is not considered further in this report.

This Air Quality Impact Assessment (AQIA) addresses the potential air quality impacts associated with the remediation works on behalf of Lend Lease Millers Point (Lend Lease), and is submitted as part of the Environmental Impact Statement (EIS) accompanying the Development Application.

1.1 Scope of Works

Director General's Requirements were issued for the project on 20 May 2013. 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; and*
- *proposed air quality management and monitoring procedures during construction.*

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.

In addition to the Block 4 pollutant emission sources, emissions associated with the following concurrent works were considered in the dispersion modelling:

- construction works for the C3, C4 and C5 buildings;
- construction works associated with the R8 and R9 buildings; and
- the operation of a concrete batching plant and a water treatment plant.

It should be noted that the C4, C5, R8 and R9 buildings are scheduled to be at the finishing and fit-out stage at the time the Block 4 remediation works commence; the construction works were included in the dispersion model to allow for delays in the construction timetable. A second, more likely scenario was, therefore, modelled to ensure a more realistic examination of the operations was undertaken.

Some services and finishing works in the basement carpark area may occur concurrently with the Block 4 works; these works would be expected to be of a minor nature in terms of air pollutant emissions and were, therefore assessed qualitatively.

Works at Barangaroo Central and Headland Park may also be undertaken at the time of the remediation works. These works were the subject of a separate assessment by JBS (2012). The cumulative impacts associated with

these works were assessed using the concentrations predicted by JBS for the three sensitive receptors common to both assessments.

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 Site Location

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 site location is shown in **Figure 1**.

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

The NSW Government held an international urban design competition for the site in 2005 and the winning entry was used as the basis for the original Barangaroo Concept Plan which was approved in February 2007 and sets out the urban design and policy initiatives to be employed in the redevelopment of the site.

The Concept Plan (as modified) is the statutory planning approval to guide the urban renewal of Barangaroo and currently provides for the development of 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 authority that manages and delivers the development of Barangaroo.

The Barangaroo Site has been divided into three distinct redevelopment areas (from north to south) – the Headland Park, Barangaroo Central and Barangaroo South. Lend Lease has also been contracted by the Barangaroo Delivery Authority to undertake remediation of the Declaration Area.

2.2 EPA Declaration Area (#21122)

In May 2009, the NSW Environment Protection Authority (EPA) determined that a portion of land at Millers Point (part of the Barangaroo Site and an adjacent portion of Hickson Road), was contaminated in such a way as to present a significant risk of harm (SROH) 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)
    - 38 Hickson Road (SP72797) Millers Point

Refer to **Figure 2** for the location of the Declaration Area as gazetted by the NSW EPA.

The Barangaroo Delivery Authority has entered into a Voluntary Management Proposal (VMP) with the EPA associated with 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 (to be finalised following Phase 1) 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.

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 as 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 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.

2.4 Definition of Site

For the purposes of Development Application SSD 5897-2013, the Site (refer to **Figure 2**) includes the area of land to be remediated (the Block 4 Remediation Area) plus any adjacent land used for the staging and undertaking of the proposed remediation works and proposed stormwater diversion. The Block 4 Remediation Area includes: Development Block 4 (both within and outside the EPA Declaration) and the area immediately south of Development Block 4 and north of the Stage 1A basement groundwater retention wall system. With reference to **Figure 2**, the Block 4 Remediation Area includes the areas labelled as: 'Site Remediation Area'; and 'Excavation for stormwater diversion and remediation to address the EPA Declaration (where required)'.

Development Application SSD 5897-2013 seeks approval for:

- Remediation of the Block 4 Remediation Area such that the EPA Declaration can be revoked (here-in referred to as the Block 4 VMP Remediation Works). It should be noted that areas of the EPA Declaration Area that are outside the Block 4 Remediation Area (i.e. Block 5 and Hickson Rd) will be the subject of separate Development Applications;
- Construction of a basement groundwater retention wall system within part of the Block 4 Remediation Area (refer to **Figure 2**);
- Remediation within the perimeter of the basement groundwater retention wall for future development use (here-in referred to as the Block 4 Development Remediation Works);
- Diversion/augmentation of stormwater drainage infrastructure within the proposed basement groundwater retention wall system and to the south of the proposed basement groundwater retention wall and north of the existing Stage 1A basement; and
- Bulk excavation.

2.5 Remedial Action Plan

The proposed remediation of the Site is detailed in the RAP (AECOM, 2013). The RAP (AECOM, 2013) details the remediation works required to enable the NSW EPA's declaration to be revoked from the Block 4 Remediation Area (refer to **Figure 2**) and to enable future development of the area within the proposed basement groundwater retention wall system (the Site Remediation Area, refer to **Figure 2**). To this end, the RAP (AECOM, 2103b) describes the extent of remediation required, and the validation testing and monitoring to be undertaken to confirm completion of remediation works.

The RAP (AECOM, 2013) also addresses remediation of Block 5 and Hickson Road (which will be the subject of separate Development Applications).

The proposed remediation methodology is an ex-situ methodology within the Block 4 Remediation Area.

The proposed works also include the augmentation and diversion of existing stormwater drainage infrastructure within the Site. This will involve decommissioning existing pipes and the construction of a new pipe network and associated water treatment system to connect to the existing Sydney Water Pipeline in the western part of the Site.

2.5.1 Separate Phase Gasworks Waste and Tar

For the purposes of this report, and as referred to in the RAP (AECOM, 2013), gasworks related contaminated materials will be referred to as Separate Phase Gasworks Waste and Tar (SPGWT) which includes the following materials:

- Tar Containing Materials (TCM), as per the following definition:
    - Greater than 10% visible coal tar (where coal tar is a phase separated hydrocarbon by-product from coal gasification); and/or
    - Contaminant concentrations exceeding the following limits:
        - Polycyclic aromatic hydrocarbons (PAHs) - 2,000 mg/kg; or
        - Benzo(a)pyrene (B(a)P) - 150 mg/kg.
        - Dense Non Aqueous Phase Liquids (DNAPLs).

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**.

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AECOM

BARANGAROO SITE LOCATION

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

FIGURE 1

LEGEND:

- DECLARATION AREA
- SITE REMEDIATION AREA
- INDICATIVE EXTENT OF LOGISTICS, STORAGE AND DECONTAMINATION AREA (THIS AREA WILL INCLUDE MINOR EXCAVATION BUT WILL EXCLUDE REMEDIATION WORKS)
- EXCAVATION FOR STORMWATER DIVERSION AND REMEDIATION TO ADDRESS THE EPA DECLARATION (WHERE REQUIRED)
- BLOCK 4 — PROPOSED DEVELOPMENT BLOCK AREA
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- SITE BOUNDARY

30-34 HICKSON RD

36 HICKSON RD

38 HICKSON RD

HICKSON ROAD

HICKSON ROAD

SUSSEX STREET

SITE ACCESS

HICKSON ROAD REMEDIATION SUBJECT TO SEPARATE DA

BLOCK 4 RETENTION WALL TO BE CONSTRUCTED

SOIL TREATMENT AREA (STA)

BLOCK 5 REMEDIATION SUBJECT TO SEPARATE DA

BLOCK 4

BLOCK 5

SHELLEY STREET

WATER TREATMENT PLANT (WTP)

STAGE 1A SUBJECT TO SEPARATE APPROVAL

LIME STREET

CONCRETE BATCHING PLANT (CBP)

WTP

Darling

Harbour

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

REVISIONS					
No.	BY	DATE	DESCRIPTION	APPD
05	PAS	01.10.13	ISSUED FOR FINAL REPORT	DM
04	PAS	30.08.13	ISSUED FOR FINAL REPORT	MAJ
03	PAS	19.07.13	ISSUED FOR FINAL REPORT	DM
02	TR	11.01.13	ISSUED FOR FINAL REPORT	DM
01	TT	15.10.12	DRAFT ISSUED	DM

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	KP	CHECKED	
DRAWN	PAS	CHECKED	
APPROVED	DM	DATE	15.10.12

DESIGNER: AECOM

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

CLIENT:

WASTE MANAGEMENT PLAN, BARANGAROO

FIGURE 2:
EPA DECLARATION AREA AND SITE REMEDIATION AREA

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-WMP-F2

REV: 05

3.0 Proposed Development

3.1 The Project

Details of the proposed remediation options for the Site are provided in the AECOM RAP (AECOM, 2013), while the proposed remediation work methods and staging are provided in the SSD 5897-2013 Staging Plans prepared by ARUP. A summary of information from these documents is provided in following sections.

The proposed works also include the augmentation and diversion of existing stormwater drainage infrastructure within the Site, involving decommissioning existing pipes, and construction of a new pipe network and associated water treatment to connect to the existing Sydney Water Pipeline in the western part of the Site. For the purposes of this report, reference to remediation works includes stormwater diversion works on the Site.

The proposed remediation of Block 4 comprises ex-situ remediation as described in the following sections.

3.1.1 Ex-situ Remediation

Materials excavated from the Site will comprise heterogeneous fill materials, soil, and bedrock. Materials will typically be excavated using dozers and hydraulic excavators and loaded to trucks by front end loaders and hydraulic excavators. Material will generally be classified in-situ to determine whether it requires treatment or is suitable for disposal off-site or beneficial reuse without treatment.

Material requiring treatment will be transferred to the temporary soil treatment work area OCS or transferred directly off-site to a licenced treatment facility. The treatment works will either involve stabilisation/solidification of the fill materials or Surfactant Enhanced Ex-situ Chemical Oxidation (S-ESCO®). Both technologies would be implemented using a pug mill located within the temporary soil treatment work area odour control structure.

3.1.2 Temporary Remediation and Soil Treatment Work Area Odour Control Structures

To the extent practicable, Lend Lease has committed to undertaking all excavation and ex-situ treatment works within temporary odour control structures (OCSs) fitted with emission control systems (filters). The purpose of the OCSs is to minimise the release of malodorous and potentially harmful emissions during treatment and remediation excavation operations. The OCSs will act as the predominant primary control of all environmental emissions at the site. OCSs will be established above excavation and treatment operations, essentially isolating these work areas from the external environment. The odour control structures will be constructed of impervious material, generally creating a seal between the internal and external atmosphere, and will include stormwater interception devices where practicable.

The dimensions of the OCSs were developed on the basis of 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.

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 will be employed during these activities, including covering of exposed soil as soon as possible and the use of odour suppressants and foam.

3.1.3 Filtration Systems

The temporary remediation and soil treatment work area OCSs will be serviced by a number of filtration systems and fresh air fans. The filtration systems will be designed to reduce emissions to concentrations compliant with the relevant environmental standards and/or approved site emission criteria for Barangaroo South, and will:

- 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 the structures.

The system is expected to be designed to achieve two to three complete air exchanges per hour within the structures. The systems will primarily consist of appropriately sized granular activated carbon (GAC) filters with particulate pre-filters. Multiple GAC filters (minimum of two in series) will be required to prevent fugitive emissions

during filter exchanges. Filter saturation and changeover frequency will generally be guided by the environmental consultant based on breakthrough and stack emission monitoring. It is expected that filter changeover will be required approximately every 2 - 3 months.

The final design and detailing of filtration systems will be subject to further design development.

3.1.4 Haul Roads and Required Plant

The site is currently covered in hardstand; which would be retained wherever practicable. Surface slab demolition will be undertaken in a staged manner to maximise utilisation of current hardstand areas to reduce the extent of exposed surfaces. As such, haul roads outside the remediation and excavation areas would generally be paved, while roads within these areas could potentially be unpaved. 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 Remediation Areas, and trucks would be decontaminated (where required) at the end of each shift of haulage operations.

3.1.5 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 has 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 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 NO_X and particulate matter (PM_{10}). Other emissions, such as carbon monoxide, sulfur dioxide and volatile organic compounds, 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.

3.3 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;
- Pug mills;
- Crushers; and
- Generators.

All of the plant used to excavate, handle and treat 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 move materials between the excavation OCSs and the treatment tent (also referred to as the Soil Treatment Area – refer to **Figure 2**) OCS or directly off-site; 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 electrically-powered and, as such, would not generate combustion products during their operation.

Further emission source details are provided in **Section 6.4**, including details of sources associated with onsite works being undertaken concurrently with the Block 4 remediation and landforming works. Pollutants of potential concern are discussed in **Section 4.0**. It should be noted that plant/equipment to be used in the construction of retaining walls, such as piling rigs, would be located outside OCSs; these were not considered in this assessment.

4.0 Pollutants of Interest

For the purposes of this AQIA, pollutants of potential 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;
- VOCs, including BTEX;
- PAHs; and
- Odour.

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

4.1.1 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 oxides of nitrogen (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.

4.1.2 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. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from the inhalation of the dust.

4.1.3 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.

4.1.4 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.

4.1.5 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.

4.1.6 Odour

Odour is a sensory response to the inhalation of one or more chemicals in the air we breathe. A person's perception of an odour can vary significantly depending on the sensitivity of the person, the acuteness of the person's sense of smell and the connotations that the odour bestows on that person. 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.

4.2 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 1** (combustion products, dust and soil contaminants) and **Table 2** (odorous compounds).

Table 1 EPA Impact Assessment Criteria – Combustion Products, Dust and Soil Contaminants

Pollutant	Averaging Period	Criteria (µg/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

Pollutant	Averaging Period	Criteria (µg/m^3)
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 2**. 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 2 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 6.5**.

5.0 Existing Environment

5.1 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 3**. 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 3** were not used in the cumulative assessment and should be considered as indicative concentrations only.

Table 3 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 6.8.1**.

[2] Calculated from annual PM10 concentration as described in text.

[3] Ozone concentrations used for NO_2 contemporaneous assessment calculations. Ozone was not modelled as a pollutant.

5.2 Climate

The 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 May 2010 are summarised in **Appendix A**.

Average maximum temperatures in summer range from 25.9 °C to 25.2 °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.

5.3 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.

6.0 Dispersion Modelling Methodology

6.1 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.

6.2 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 4**.

Table 4 CALPUFF Input Parameters

Parameter	Input
CALPUFF version	6.42 - March 2011
Modelling domain	3 km x 3 km
Modelling grid resolution	20 m
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.

6.2.1 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 Bureau of Meteorology (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.

6.2.2 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.

6.3 Modelling Scenarios

The potential impacts of the proposed and approved works were assessed through the analysis of two operational scenarios. The first scenario represented the expected worst case impacts while the second represented the expected more likely scenario as described below.

Scenario 1: Worst Case Cumulative Emissions

This scenario represented the expected highest activity levels of all on-site activities that may be occurring during the remediation works. It was developed based on information regarding the expected staging of the works provided by Lend Lease. The worst case operational scenario assessed the concurrent occurrence of the following works:

- Block 4 remediation activities;
- Construction works associated with the C3, C4, C5, R8 and R9 buildings;
- Operation of the on-site concrete batching plant; and
- Operation of the on-site water treatment plant.

It should be noted that the construction of retaining walls was not included in the modelling scenarios as previous assessments demonstrated that these works are a minor source of emissions in comparison to the excavation works. As the Stage 1A basement works will be substantially complete by the time the Block 4 works commence, these activities were also excluded from the modelling.

Scenario 2: Likely Case Scenario

In addition to the worst case scenario outlined above, a scenario considered to be a more realistic operational scenario was also considered, which accommodated the changes in activities associated with the staged construction activities and the expected general decrease in the rate of pollution generation as the buildings rise out of the excavations. The C4, C5, R8 and R9 buildings are expected to be at the finishing stages of their construction with minimal pollution generation occurring at the time the Block 4 excavations are undertaken. Based on the descriptions of the expected construction during the Block 4 remediation, the following sources were included in Scenario 2:

- Block 4 remediation activities;
- Construction works associated with the C3 building;
- Operation of the on-site concrete batching plant; and
- Operation of the on-site water treatment plant.

6.3.1 Assumptions

All emission sources associated with the Block 4 remediation works were assumed to be contained within the OCSs (excavation and treatment) with the exception of trucks hauling materials between the structures and off-site for disposal (modelled as volume sources) or piling rigs during retention wall construction. 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, C4, C5, R8 and R9 buildings and the concrete batching plant were the same as those used in AECOM (2012), while emissions associated with the water treatment plant were assumed to be the same as those used in AECOM (2011) for a water flowrate 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 wind erosion and 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 that were used in previous assessments (SKM, 2005) were also used for the point sources. A detailed emissions inventory showing detailed calculations can be provided on request.

6.4 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. Indicative stack locations are shown in **Figure 3**.

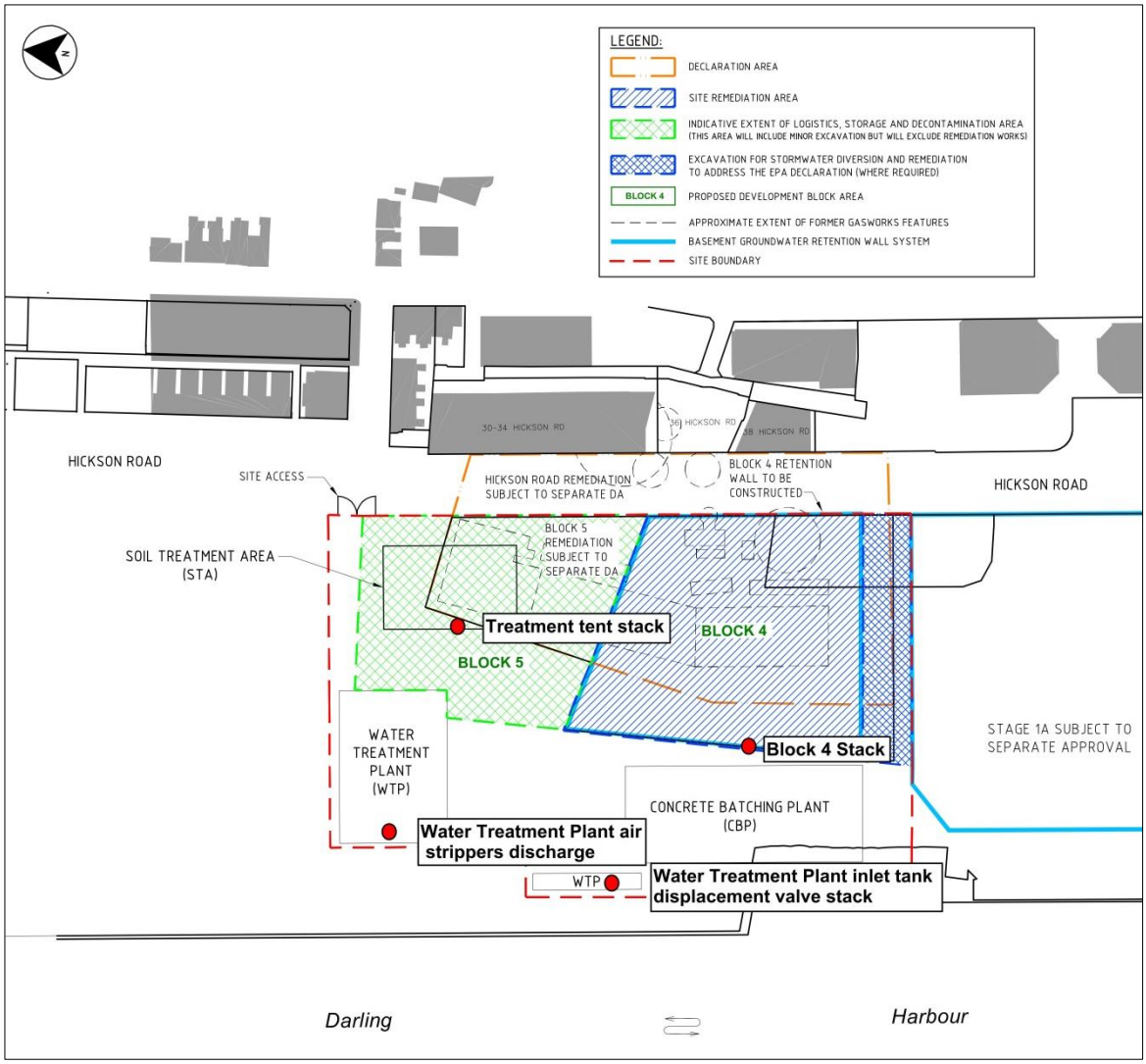

Figure 3 Indicative Stack Locations

6.4.1 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 5** and **Table 6** respectively. The OCS stack was assumed to be located on the western side of the OCS structure.

Table 5 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 6 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

6.4.2 Treatment Tent

Excavated soil may be transported by truck to a treatment tent for remediation if on-site treatment is undertaken. The treatment tent would be maintained under negative pressure to contain all emissions generated within it, such that all emissions will be emitted through a stack following filtration; as such, no fugitive emissions were included in the dispersion modelling for this source. The plant expected to operate within the tent are summarised in **Table 7**. The characteristics of the emission stack are provided in **Table 8**; the stack was assumed to be located on the western side of the treatment tent. The treatment tent was assumed to operate for ten hours per day processing 35 tonnes per hour.

Table 7 Treatment Tent Equipment

Plant/Equipment	Number	Notes
Excavator	1	
Front end loader	1	
Skid steer bobcat	2	loader
Pug mill	2	screen
Trucks	70	trips per day (off-site)

Table 8 Treatment Tent Stack Characteristics

Details	Value	Units
Tent height	15	m
Stack height	4	m
Velocity	25	m/s
Exit area	0.82	m^2
Diameter	1.02	m
Volumetric flow rate	20.4	m^3/s
Temperature	25	^oC

6.4.3 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 9 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

6.4.4 Buildings C3, C4, C5, R8 and R9

Source characteristics of the emission sources for the buildings are outlined in **Table 10**. Forklifts and concrete pumps were modelled as ground level point sources. There were assumed to be eighteen concrete trucks in total for these sources (four concrete trucks for each of buildings C3, C4 and C5 and two concrete trucks for both R8 and R9). Two forklifts per building (ten in total) and two concrete pumps per building (ten in total) were also modelled.

Table 10 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

6.4.5 Trucks

For this assessment, trucks associated with Block 4 were assumed to move all excavated material from the excavation areas to the treatment tent. Trucks associated with the Treatment Tent were assumed to transport all material off-site for reuse/disposal. 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).

6.5 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, emission rates were entered into the model as 7 am – 6 pm, 7 days per week for all activities. 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 (where applied) were based on published literature (Nelson and Babyak, 1996). The total reduction efficiencies assumed for each tent are provided in **Table 11**.

Table 11 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
* This reduction efficiency was examined further by means of a sensitivity analysis outlined in **Section 7.2**		

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 excavation area 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. The emission rate of VOCs applied to the treatment tent was the same as the emission rate from the Block 4 excavation area.

VOC emissions associated with the excavation activities were assessed by species using the relevant proportion of the total VOCs as described in **Section 6.8.3**. As speciation details for fuel exhaust were not identified at the time of preparation of this report, VOC emissions from vehicles and generators were assessed separately.

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 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 B**. 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 OCS and Treatment Tent OCS areas to calculate the odour emission rates. Half of the OCS area was assumed to actively emit odour at any time (3,244 m^2 for Block 4 and 1,207.5 m^2 for the Treatment Tent).

6.5.1 Block 4

Details of the emission rates for the Block 4 excavation OCS are provided in **Table 12**.

Table 12 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 6.4.5**, truck emissions were apportioned to a single volume source. The emission rates per volume source associated with Block 4 are provided in **Table 13**.

Table 13 Block 4 Truck Emissions

Pollutant	ER (g/s/source)
NO_X	0.00054
PM_{10}	0.00224
TSP	0.01149
VOCs	0.00005

6.5.2 Treatment Tent

Details of the emission rates for the on-site soil treatment option OCS are provided in **Table 14**.

Table 14 Treatment Tent Stack Emission Rates

Pollutant	Total Emission Rates	
	Before filtration	After filtration
NO_X (g/s)	1.66	0.41
PM_{10} (g/s)	0.09	0.002
TSP (g/s)	0.18	0.004
VOC (g/s)	5.56	0.011
Odour (OU/s)	19,803	40
Benzene	0.05	0.00010
Ethylbenzene	0.04	0.00008
Toluene	0.07	0.00014

Pollutant	Total Emission Rates	
	Before filtration	After filtration
Total xylenes	0.16	0.00031
Naphthalene	3.28	0.0066
Phenol	0.18	0.00037
* Peak to mean ratio of 2.3 applied to odour emissions		

As described in **Section 6.4.5**, truck emissions were apportioned as a single volume source. The emission rates per volume source associated with the Treatment Tent are provided in **Table 15**.

Table 15 Hickson Road Truck Emissions

Pollutant	ER (g/s/source)
NO_X	0.00008
PM_{10}	0.00618
TSP	0.03209
VOC	0.000001

6.5.3 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 16**.

Table 16 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.

6.5.4 Concrete Batching Plant

The concrete batching plant was assumed to be located on a hardstand area, and the concrete trucks were assumed to drive on paved areas. Source characteristics of the concrete batching plant sources are outlined in **Table 17**. Wind erosion and stockpiling were modelled as area sources; the front end loader and materials processing were modelling as volume sources. In cases where there was no emission factor for TSP, TSP emissions were taken to be equal to PM10. TSP emission factors are not provided by the NPI for wind erosion, stockpiling and materials processing for concrete batching plants; TSP was assumed to comprise only PM_{10} for these sources.

Table 17 Emission Source Characteristics and Emission Rates – Concrete Batching Plant

Sources	PM_{10} (g/s)	PM10 ($g/s/m^2$)	TSP (g/s)	TSP ($g/s/m^2$)	Hours of Operation
Wind erosion - storage bins, eastern side	0.001	0.000004	0.001	0.000004	continuous
Wind erosion - storage bins, southern side	0.001	0.000004	0.001	0.000004	continuous
Stockpiling/dumping raw materials	0.027	0.00006	0.074	0.00017	10 am - 4 pm
Front end loader	0.51	-	0.9	-	7 am - 6 pm
Materials processing	0.38	-	0.38	-	7 am - 6 pm

Details of the calculations and assumptions made for this activity are summarised in **Table 18**.

Table 18 Emission Calculations - Materials Handling

Activity	Value	Units	Notes
Sand and aggregate transfer to bin			
Activity rate	372	t/hour	
Overall control efficiency	90	%	Enclosed conveyor (2/3 sides)
Emissions	0.52	kg/hour	
Cement unloading to elevated storage silo			
Activity rate	38	t/hour	pneumatic
Overall control efficiency	99.9	%	enclosed and filtered
Emissions	0.005	kg/hour	
Weigh hopper loading			
Activity rate	410	t/hour	
Overall control efficiency	99.9	%	enclosed and filtered
Emissions	0.004	kg/hour	
Mixer loading			
Activity rate	423	t/hour	
Overall control efficiency	90	%	enclosed (2/3 sides)
Emissions	0.85	kg/hour	
Total emissions	**1.37**	**kg/hour**	
	0.38	**g/s**	

6.5.5 Buildings C3, C4, C5, R8 and R9

The construction of these buildings 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 buildings are outlined in **Table 19**. All plant were assumed to remain at ground level. All emission sources associated with the buildings were modelled as point sources.

Table 19 Emission Rates – Buildings

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

6.6 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 104 receptors were assessed, which were primarily located along the eastern side of Hickson Road at various heights. The receptor locations are shown in **Figure 4** and detailed in **Appendix C**.

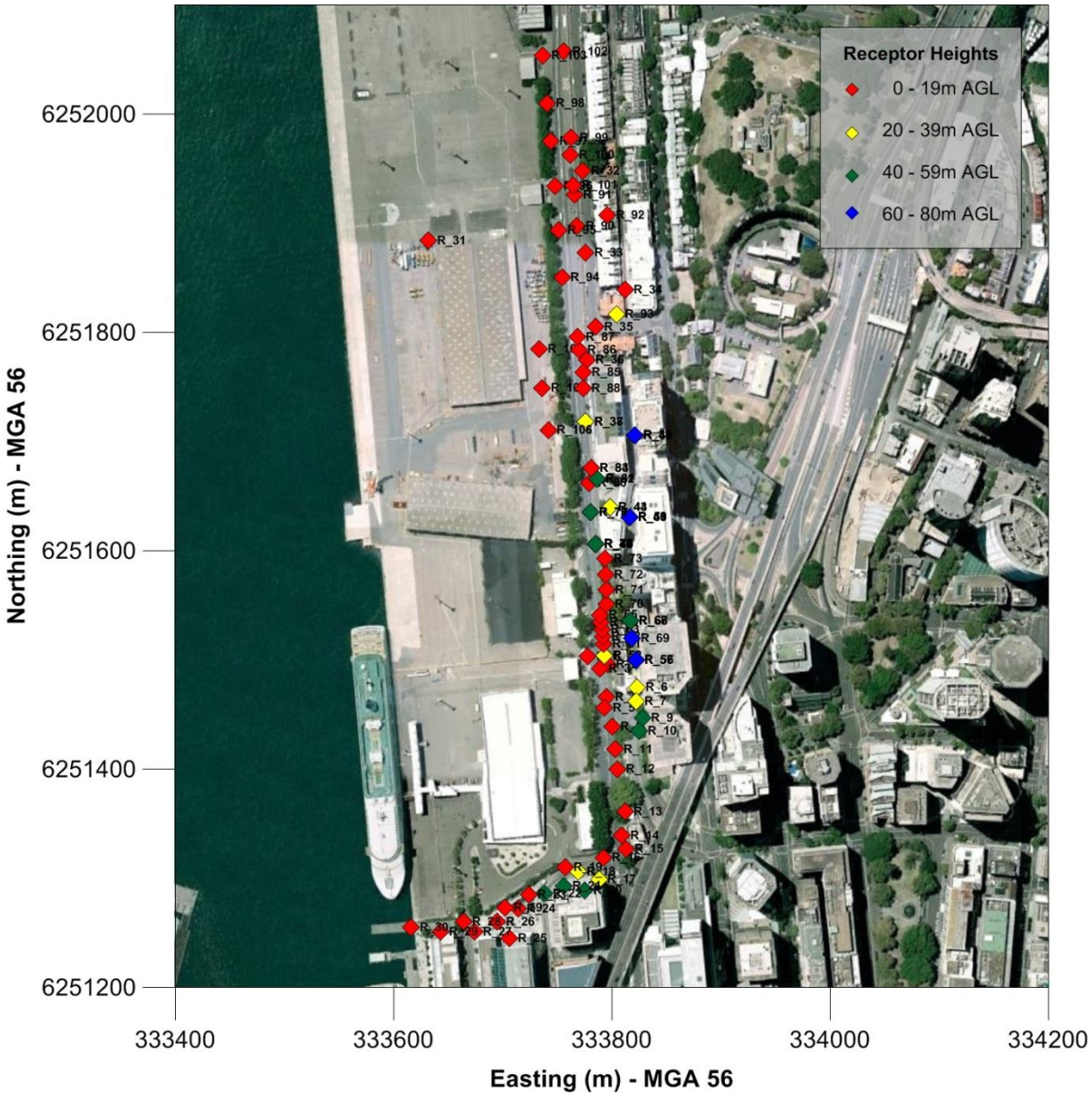

Figure 4 Sensitive Receptor Locations

6.7 Prediction of Cumulative Impacts

DEC (2005a) specifies that AQIAs are to assess the cumulative impact 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 criteria pollutants predicted by dispersion modelling. Criteria pollutants addressed in this assessment were NO_2, PM_{10} and TSP.

The cumulative assessment comprised the addition of data described in **Section 5.1** (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 hourly data for the modelling period from the EPA's Rozelle monitoring station.

Pollutant concentrations associated with the concurrent construction works for buildings C3, C4, C5, R8 and R9 and the operation of the concrete batching plant and water treatment plant were included in the dispersion model as Scenario 1. The emissions from C4, C5, R8 and R9 at the time of the Block 4 excavations were not considered likely to be substantial, so they were not included in the dispersion modelling or cumulative assessment for Scenario 2.

Other works on the Barangaroo Site will occur at the same time as the remediation works. Assessment of these sources is described below.

6.7.1 Basement Works

Works associated with the basement occurring concurrently with the Block 4 remediation and landforming works are expected to involve the installation of services and finishes and, potentially, some structural work. As buildings C3, C4, C5, R8 and R9 will be constructed above the basement area, any residual works associated with the basement would be below ground level and/or of a minor nature in terms of air quality emissions. As such, these sources were not considered in the assessment.

6.7.2 Wynyard Walk

The Wynyard Walk works include demolition, tunnelling, and construction of paved areas and a pedestrian bridge, which can potentially result in the release of dust. Detailed Construction Environmental Management Plans were prepared for Stage 1 and Stage 2 of the works by Thiess (2012, 2013), which include detailed air quality management measures. Provided these measures are implemented, the Wynyard Walk works are not expected to substantially add to the cumulative impacts experienced at sensitive receptors.

6.7.3 Barangaroo Central Waterfront Promenade and Interim Public Domain and Headland Park

The works associated with the Barangaroo Central waterfront promenade and interim public domain area are the works to provide the public domain along the western portion of the Barangaroo Site. The potential air quality impacts associated with these works were assessed in a separate report (JBS, 2012), which also included the contribution from the Headland Park works. The predicted pollutant concentrations associated with those works were added to the concentrations predicted by the dispersion modelling undertaken for the current study where applicable to predict cumulative concentrations.

6.8 Assessment of Contaminants

6.8.1 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 nitrogen dioxide (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 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).

6.8.2 VOCs

The EPA does not have a criterion for total VOC emissions. VOC emissions associated with the soil contamination were estimated using the percentage of the pollutants in the soil samples as shown in **Table 20** (AECOM, 2010b). It should be noted that the percentages shown in **Table 20** 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. VOC emissions associated with combustion engines were modelled as total VOCs as speciation data were not available.

Table 20 VOC Components

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

6.8.3 Toxic Pollutants

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 21**; these were converted to a proportion of metals in soil to enable the estimation of heavy metal concentrations from the TSP results.

Table 21 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

7.0 Results

The results of the dispersion modelling are shown in **Table 22** and **Table 24**. The results show the total cumulative impact of the remediation works on the Site coupled with a selection of construction emissions from buildings C3, C4, C5, R8 and R9 and the operation of the concrete batching plant and the water treatment plant.

7.1 Modelling Predictions

The maximum results predicted at any sensitive receptor assessed are provided in **Table 22** for each scenario. These represent the 100th percentile for NO_2, PM_{10} and TSP; the 99.9th percentile for benzene, ethylbenzene, toluene, xylenes, naphthalene and phenol; and the 99th percentile for odour in accordance with DEC (2005a). The concentrations presented for NO_2, PM_{10} and TSP represent cumulative concentrations as required by the EPA for these criteria pollutants, i.e. these numbers represent the contribution from the proposed operations added to the ambient concentrations. For TSP, the ambient concentration was estimated from the PM_{10} concentration as described in **Section 5.1**. For 1 hour NO_2 and 24 hour PM_{10}, contemporaneous assessments were undertaken, where the measured pollutant concentrations for each hour of the modelling period were matched to the hourly modelling predictions.

The EPA does not have a criterion for total VOCs. In order to assess this group of pollutants, the 99.9th percentile VOC concentration from all sensitive receptors assessed (6.3 $\mu g/m^3$) was added to the predicted 99.9th percentile benzene concentration (2.5 $\mu g/m^3$) and compared to the benzene criterion for a very conservative assessment. This resulted in a maximum predicted concentration of 8.8 $\mu g/m^3$, which is lower than the benzene criterion (29 $\mu g/m^3$).

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, including those located on the boundary and those beyond it.

Table 22 Dispersion Modelling Results

Pollutant	Averaging Period	Units	Maximum Predicted Pollutant Concentrations		Criteria
			Scenario 1	Scenario 2	
NO_2	1 hour	$\mu g/m^3$	**377***	**250.6***	246
	Annual	$\mu g/m^3$	62* (20.7)	53.2 (20.7)	62
PM_{10}	24 hour	$\mu g/m^3$	**142***	**141***	50
	Annual	$\mu g/m^3$	29.9* (17.4)	28.5* (17.4)	30
TSP	Annual	$\mu g/m^3$	55* (35.5)	54.5* (35.5)	90
VOCs	1 hour	$\mu g/m^3$	8.8#	8.8#	29^
Benzene	1 hour	$\mu g/m^3$	2.5	2.5	29
Ethylbenzene	1 hour	$\mu g/m^3$	0.27	0.27	8,000
Toluene	1 hour	$\mu g/m^3$	1.55	1.55	360
Xylenes	1 hour	$\mu g/m^3$	0.58	0.58	190
Naphthalene	1 hour	$\mu g/m^3$	17.2	17.2	440
Phenol	1 hour	$\mu g/m^3$	0.22	0.22	20
Odour	1 hour	OU	0.02	0.02	2

* Barangaroo South cumulative concentration
# Represents total VOCs plus benzene (99.9th percentile) but excluding naphthalene
^ The EPA does not have a criterion for total VOCS; as such, the benzene criterion was used as described in the text.
Concentrations in parentheses represent the ambient pollutant concentrations from **Table 3**. These are not provided for 1 hour NO_2 and 24 hour PM_{10} due to the nature of the contemporaneous assessment.
NRT = Nose response time
Exceedences denoted in **bold type**

The model predictions for all pollutants except NO_2 were very similar or the same for both scenarios. As shown, the modelling predicted exceedences of the EPA criteria for 1 hour NO_2 and 24 hour PM_{10} would occur for the project occurring simultaneously with the other activities at Barangaroo for both scenarios assessed. The predicted maximum annual NO_2 concentration was on the criterion level. The numbers of exceedences at each sensitive receptor for Scenario 1 are shown in **Appendix D**.

7.1.1 Particulates

Based on the results of various modelling investigations, the primary source of the PM_{10} exceedences from the Barangaroo South works for both modelled scenarios is considered to be the operation of the concrete batching plant. Emissions from this activity are expected to be manageable through operational practices and reactive management strategies such as real time particulate monitoring (which is currently successfully being used on the site to minimise particulate impacts).

As indicated in **Section 6.7**, concurrent works occurring at Barangaroo Central and Headland Park at the time of the Block 4 land forming and remediation works have the potential to result in particulate emissions. The receptors assessed in JBS (2012) were matched to the receptors in the current assessment; the contributions from the different works for the three matched receptors are shown in **Table 23**. The maximum predicted concentrations from each of the work areas (Barangaroo South (Scenario 1), Barangaroo Central and Headland Park) are presented, representing the worst case potential concentrations.

Table 23 Cumulative Particulate Concentrations (µg/m^3) – Barangaroo South, Barangaroo Central and Headland Park

Source	24 Hour PM_{10}			Annual PM_{10}			Annual TSP		
	R6	R19	R29	R6	R19	R29	R6	R19	R29
Barangaroo South Works	31.1	**63.5**	14.9	5.0	8.3	2.4	6.8	9.2	2.7
Barangaroo Central and Headland Park	3.6	49.0	**61.2**	0.5	13.1	16.0	1.0	26.2	33.2
Ambient Concentration	43.1			17.4			35.5		
Total Pollutant Level	**78**	**156**	**119**	23	**39**	**36**	43	71	71
Criteria	***50***			***30***			***90***		

All concentrations presented in µg/m^3
The JBS receptors were matched to AECOM receptors as closely as possible. The closest matches were as follows: AECOM R6 matched JBS receptor 3; R19 matched JBS receptors 1 and 2 – the maximum values (receptor 2) were used here to be conservative; R29 matched JBS receptor7.

As shown, the concurrent works across the Barangaroo site have the potential to result in a number of exceedences of the PM_{10} criteria, with potentially very high hourly concentrations experienced on occasion (no exceedences of annual TSP are expected). It should be noted, however, that the predictions from the Barangaroo Central and Headland Park works are based on a different assessment methodology and a different dispersion model than the Barangaroo South works; as such, the simple addition of the contributions does not provide a realistic estimate of the total cumulative concentrations at the receptors assessed, particularly due to the high ambient 24 hour PM_{10} concentration. Furthermore, the concentrations presented are maxima, and present a worst-case prediction; in reality, the highest pollutant emissions from the various works are not expected to occur simultaneously. Regardless, the results clearly demonstrate that appropriate management and mitigation of emissions is required for all works associated with the Barangaroo site.

Lend Lease has implemented an extensive reactive air quality management plan for the current Blocks 1 - 3 excavation works being undertaken on site, which is described in **Section 8.0**. The objective of this plan is to enable the ongoing monitoring of emissions and potential impacts and, where exceedences occur, enable the relevant emission sources to be proactively managed. Due to the generally conservative nature of dispersion modelling, extension of the existing monitoring and reactive management plan to incorporate additional monitoring sites located close to the proposed remediation works is expected to be a viable method for addressing the predicted exceedences of PM_{10}.

7.1.2 Nitrogen Dioxide

Exceedences of the 1 hour NO_2 criterion were predicted to occur at 21 of the 104 sensitive receptor locations assessed for Scenario 1, whereas exceedences were only predicted to occur at two of the modelled receptors for Scenario 2. This change in predicted exceedences is directly related to the variability in the expected cumulative construction activities. As many of the pollutant emitting activities associated with the construction of C4, C5, R8 and R9, particularly vehicle movements, are expected to be completed by the time Block 4 remediation commences, the NO_2 concentrations are expected to be more realistically predicted by Scenario 2 rather than Scenario 1, which broadly lumps all worst case emissions into one scenario.

The highest number of exceedences were predicted to occur for Scenario 1 at the southern end of the site[1] at R_19, which is a commercial building (26 exceedences), and at R_23, which is situated on a public walkway (25 exceedences) – due to the nature of these receptors, individuals are not expected to be affected on multiple occasions. A chart showing the times of the exceedences and the number of affected receptor locations is shown in **Figure 5**. Exceedences were predicted to occur during 65 hours throughout the year (0.7 % of the modelled hours).

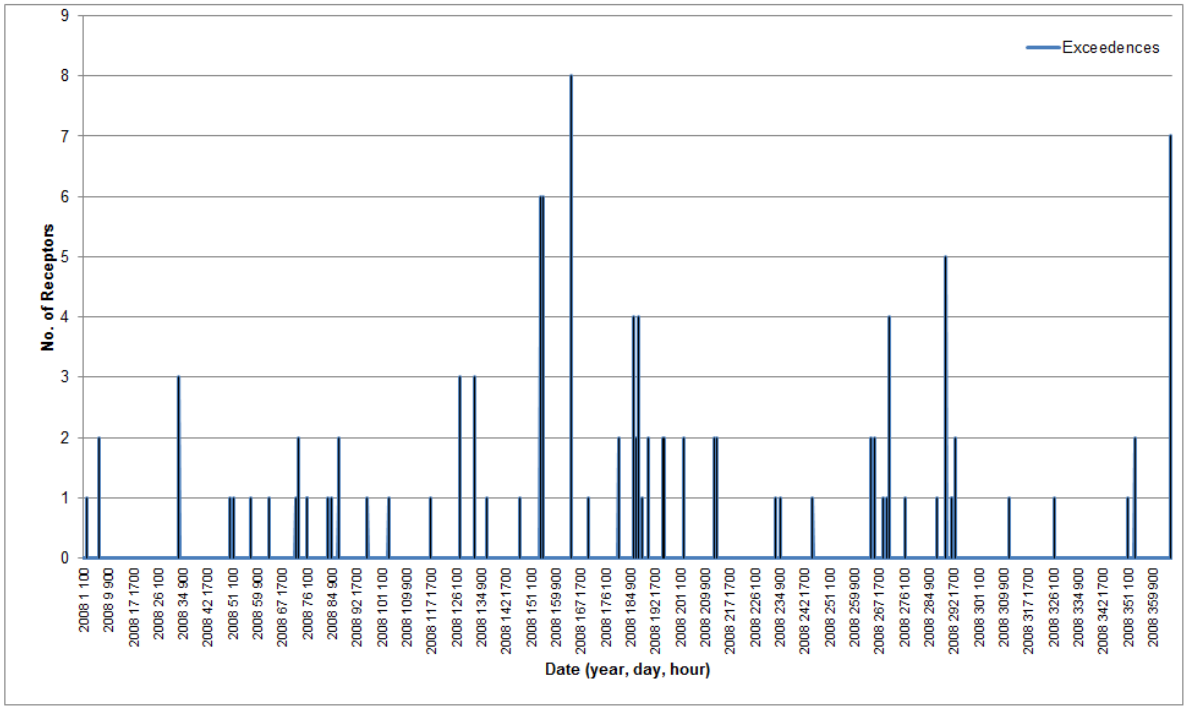

Figure 5 Predicted Numbers of Exceedences of the 1 Hour NO_2 Criterion

A sensitivity analysis was undertaken to further investigate the predicted exceedences in NO_2 concentrations. The analysis suggested that the exceedences of 1 hour NO_2 are likely to be caused by a combination of conservative emission factors and the assumption that the plant were operating on buildings C3, C4 and C5 concurrently when the operations of Block 4 were underway. Conservatism built into the modelling methodology included:

- Placing major contributing sources of NO_x on the site boundary including mobile plant equipment such as concrete trucks which relative position to nearby sensitive receivers would be transient in nature;
- Assuming all mobile construction equipment will operate continuously within the construction hours of 7am to 6 pm; and
- Assuming forklifts will be diesel powered, when they will likely be dual powered and are expected to primarily operate on LPG.

[1] Refer to **Appendix C** for the location and description of sensitive receivers and **Appendix D** for the number of predicted exceedences at each receptor.

These assumptions are considered to have built a substantial layer of conservatism into the modelling, which is likely to result in over prediction of NO_2 concentrations (as demonstrated by the results of Scenario 2). On this basis, monitoring of the NO_2 is not considered necessary.

7.1.3 Metals

Results for the metals are shown in **Table 24**. The EPA criteria for metals relate to the 99.9th percentile for assessments using site specific data, such as this one. As such, the concentrations of metals were estimated based on a 99.9th percentile 1 hour TSP concentration of predictions at all sensitive receptor locations assessed of 369 $\mu g/m^3$, based on Scenario 1. No exceedences were predicted.

Table 24 Predicted Pollutant Concentrations - Metals

Pollutant	Estimated Concentrations (99.9th percentile) ($\mu g/m^3$)	Criteria (99.9th percentile) ($\mu g/m^3$)
Arsenic	0.001	0.1
Benzo[α]pyrene	0.007	0.4
Beryllium	0.0002	0.004
Cadmium	0.0002	0.018
Chromium (III+VI)	0.0074	0.09
Copper	0.018	18
Cyanide	0.007	90
Lead	0.074	0.5
Manganese	0.074	18
Mercury	0.0001	0.18
Nickel	0.004	0.18
Zinc	0.037	18

7.2 Odour Mitigation Capture Efficiency Sensitivity Analysis

As the odour emissions from the OCSs are directly affected by the reduction efficiency of the mitigation equipment, a sensitivity analysis was undertaken to determine the effect of modifications to the odour reduction efficiency of the filters on the OCS stacks. The original modelling (reported above) was conducted assuming a 99.8 % reduction efficiency; additional runs were undertaken for reduction efficiencies of 99 %, 95 % and 90 %. The results are reported in **Table 25**.

Table 25 Sensitivity Analysis - Effect of Filter Reduction Efficiency on Predicted Odour Concentrations

Odour Reduction Efficiency (%)	Total Odour Emission Rate (OU/s)		Predicted 99th Percentile Odour Concentrations (OU)
	Excavation Tent	Soil Treatment Tent	
99.8	106	40	0.02
99.0	532	198	0.09
95.0	2,660	990	0.59
90.0	5,320	1,980	1.17

As shown, all reduction efficiencies considered resulted in odour concentrations below the 2 OU criterion at all assessed sensitive receptor locations. As reduction efficiencies between 98 and 99% are considered the norm for GAC scrubbers, the ability of the facility to operate within the criteria at an efficiency of 90 % provides a good margin of safety for the project.

7.3 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 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.

8.0 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.

8.1 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 granular activated carbon (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 sealed, 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.

8.2 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 4 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 26**.

Table 26 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 27**.

Table 27 Reactive Management Procedure – Total VOCs

Reactive Management Procedure – Total VOCs				
Trigger Stage	**Averaging Period**	**Trigger Value (µg/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

8.3 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 28** and **Figure 6**.

Table 28 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 basement bulk excavation*
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 basement bulk excavation*
PAH (speciated)	HVAS	24 hours every 6 days	EPL points 5, 8, 13		AM-15 AS3580.9.3 – 2003	During basement bulk excavation*
VOC (speciated)	Summa	As needed	As needed	***	USEPA TO-15	During basement bulk excavation
VOC (total)	RaeGuard, or alternate equipment	Continuous	EPL points 5, 8, 13	NA	NA	Throughout construction
Odour	Field Olfactometer	Morning, followed by afternoon if odour exceeds trigger level	Odour locations 1 to 6	NA	NA	During basement bulk excavation*
NO_2	Chemilumine-scent NO_X monitor.	Continuous, if required	Near a receptor where NO_2 levels exceed criteria	246 µg/m^3 one hour average	AM 3580.5.1-1993	If works reflect cumulative impacts as per Scenario 1
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)

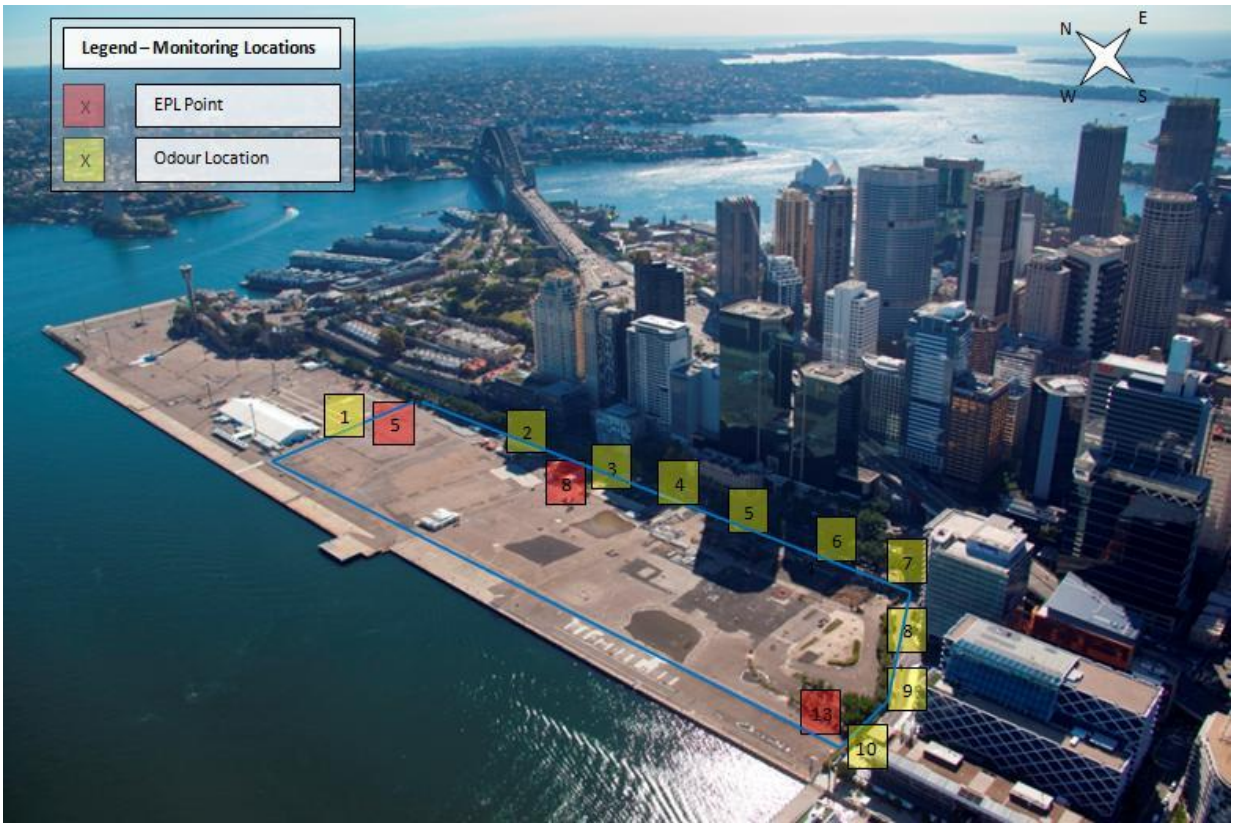

Figure 6 **Approximate Existing Barangaroo South Monitoring Locations**

The 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 29**; the final nature of the sampling program would be determined by the EPA and specified in the EPL.

Table 29 **Suggested Monitoring Frequency and Concentration Limits for OCSs**

Pollutant	100th 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	

9.0 Conclusion

AECOM undertook an air quality impact assessment of the proposed remediation of the Block 4 Remediation Area at the Barangaroo site. A cumulative assessment was undertaken to address the potential overlap of the remediation works with the construction works on Blocks 1 – 3 (buildings C3, C4, C5, R8 and R9) together with the operation of a concrete batching plant and 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, including BTEX;
- PAHs; and
- Odour.

Two operational scenarios were considered as part of the assessment, which addressed the ex-situ remediation of the Block 4 Remediation Area and the concurrent activities described above. No exceedences of the EPA impact assessment criteria for TSP, metals, VOCs, PAHs or odour were predicted at any sensitive receptor location. Exceedences of 1 hour NO_2 and 24 hour PM_{10} were predicted for a number of sensitive receptors for Scenario 1 with a greatly reduced number of exceedences predicted for NO_2 from Scenario 2.

The PM_{10} exceedences were attributed to the operation of the concrete batching plant, and the cumulative contribution of works across the Barangaroo site (including Headland Park and Barangaroo Central) may result in elevated concentrations and additional exceedences if the works are not appropriately managed.

The NO_2 exceedences are considered to be the result of overconservative assumptions made regarding the plant and equipment to be used within the building construction works. When a more realistic, less overly conservative scenario was considered, NO_2 concentrations fell to levels considered more acceptable for a construction site such as Barangaroo.

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 4 remediation activities, that the concrete batching plant continues to operate without particulate impacts, and that the works occurring at Barangaroo Central and Headland Park are adequately managed, adverse effects on local air quality are not expected to occur as a result of the proposed remediation works.

10.0 References

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Appendix A

Climate Averages

Appendix A Climate Averages

Average Climate Data – Observatory Hill and Fort Denison, 1859 – 2010 (May)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average temperature													
Maximum (^{0}C)	25.9	25.8	24.7	22.4	19.4	16.9	16.3	17.8	20	22.1	23.6	25.2	21.7
Minimum (^{0}C)	18.7	18.8	17.5	14.7	11.5	9.3	8	8.9	11.1	13.5	15.6	17.5	13.8
Average wind speed													
9 am (km/h)	8.6	8.2	7.9	8.8	10.5	11.9	13.1	13.3	12.4	12.2	11	9.8	10.6
3 pm (km/h)	17.9	16.8	15.2	13.8	12.7	13.6	15.3	17.6	18.3	19.1	19.4	19.5	16.6
Average relative humidity													
9 am (%)	71	74	74	72	73	74	71	66	62	61	66	67	69
3 pm (%)	62	64	62	59	57	57	51	49	51	56	58	59	57
Rainfall													
Mean rainfall (mm)	101.5	118.7	128.9	125.8	120.7	130.6	97.3	81.2	69.1	77.6	83.1	77.8	1212

Appendix B

Soil Sampling Results Summary

Appendix B Soil Sampling Results Summary

The data used in the development of the VOC and odour emission rates are provided below. As described in **Section 6.4.5**, 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 C

Sensitive Receptor Details

Appendix C Sensitive Receptor Details

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

Appendix D

Exceedence Data - 1 hour NO_2 and 24 Hour PM_{10} – Scenario 1

Appendix D Exceedence Data - 1 Hour NO_2 and 24 Hour PM_{10}

Receptor ID	Number of Exceedences (Scenario 1)	
	1 Hour NO_2	24 Hour PM_{10}
R_1	3	38
R_2	0	4
R_3	2	29
R_4	7	17
R_5	10	18
R_6	0	1
R_7	0	1
R_8	8	19
R_9	0	0
R_10	0	0
R_11	9	17
R_12	6	13
R_13	6	22
R_14	2	1
R_15	0	0
R_16	12	3
R_17	0	0
R_18	0	0
R_19	26	10
R_20	0	0
R_21	0	0
R_22	0	0
R_23	25	9
R_24	1	0
R_25	0	0
R_26	1	0
R_27	0	0
R_28	2	0
R_29	0	0
R_30	2	0
R_31	0	0
R_32	0	0
R_33	0	0
R_34	0	2
R_35	0	3
R_36	0	5
R_37	0	5
R_38	0	0
R_39	0	5
R_40	0	0

Receptor ID	Number of Exceedences (Scenario 1)	
	1 Hour NO_2	24 Hour PM_{10}
R_41	0	0
R_42	0	0
R_43	0	12
R_44	0	1
R_45	0	20
R_46	0	3
R_47	0	2
R_48	0	10
R_49	0	1
R_50	0	0
R_51	0	0
R_52	0	31
R_53	0	4
R_104	0	0
R_55	0	3
R_56	0	0
R_57	0	0
R_58	0	0
R_59	4	0
R_105	0	1
R_61	0	33
R_62	0	34
R_63	0	36
R_64	0	33
R_65	0	37
R_66	1	22
R_67	0	4
R_68	0	0
R_69	0	0
R_70	1	36
R_71	1	29
R_72	1	22
R_73	0	20
R_74	0	7
R_75	0	2
R_76	0	0
R_77	0	13
R_78	0	1
R_79	0	0
R_80	0	10
R_81	0	1
R_82	0	0

Receptor ID	Number of Exceedences (Scenario 1)	
	1 Hour NO_2	24 Hour PM_{10}
R_83	0	0
R_84	0	3
R_85	0	6
R_86	0	5
R_87	0	4
R_89	0	2
R_88	0	6
R_90	0	0
R_91	0	0
R_92	0	0
R_93	0	0
R_94	0	0
R_95	0	0
R_96	0	0
R_97	0	0
R_98	0	0
R_99	0	0
R_100	0	0
R_101	0	0
R_102	0	0
R_103	0	0
R_106	0	2