Site Audit Report
Remedial Action Plan, Other Remediation Works (South), Barangaroo

Prepared for:

Lend Lease (Millers Point) Pty Ltd

Prepared by:
ENVIRON Australia Pty Ltd

Date:
July 2011

Project Number:
AS121111

Audit Number:
GN 439B-1

ENVIRON

14 July 2011 Our Ref: AS121111

Lend Lease (Millers Point) Pty Ltd
Attn: Warwick Bowyer
Level 4, 30 The Bond
Hickson Road
Millers Point NSW 2000

Dear Warwick

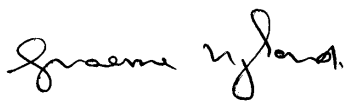
Re: Site Audit Report - Remedial Action Plan, Other Remediation Works (South), Barangaroo

I have pleasure in submitting the Site Audit Report for the subject site. The Site Audit Statement, produced in accordance with the NSW Contaminated Land Management Act 1997, follows this letter. The Audit was commissioned by Lend Lease (Millers Point) Pty Ltd to assess the appropriateness of a plan of remediation.

This Site Audit is a Director General's Requirement under the NSW Planning consent and is therefore statutory.

Thank you for giving me the opportunity to conduct this Audit. Please call me on 9954 8100 if you have any questions.

Yours faithfully,
ENVIRON Australia Pty Ltd



Graeme Nyland
EPA Accredited Site Auditor 9808

/ City of Sydney Council
/ Office of Environment and Heritage

NSW Site Auditor Scheme
SITE AUDIT STATEMENT

NSW GOVERNMENT | Environment, Climate Change & Water

A site audit statement summarises the findings of a site audit. For full details of the site auditor's findings, evaluations and conclusions, refer to the associated site audit report.

This form was approved under the* Contaminated Land Management Act 1997 *on 1st June 2010. For more information about completing this form, go to Part IV.

PART I: Site audit identification

Site audit statement no. **GN 439B-1**

This site audit is a **statutory audit/~~non-statutory audit~~*** within the meaning of the *Contaminated Land Management Act 1997*.

Site auditor details (as accredited under the *Contaminated Land Management Act 1997*)

Name:	Graeme Nyland	Company:	ENVIRON Australia Pty Ltd
Address:	Level 3, 100 Pacific Highway (PO Box 560)		
	North Sydney NSW	Postcode:	2060
Phone:	02 9954 8100	Fax:	02 9954 8150

Site details

Address: Wharf 8, Hickson Road (Sussex Street), Barangaroo, NSW

Postcode: 2000

Property description *(attach a list if several properties are included in the site audit)*

Southern portions of Lot 3, Lot 5 and Lot 6 in DP 876514

(see attachment at end of Part I of this Statement)

Local Government Area: Sydney

Area of site (e.g. hectares): 4.27 ha approximately

Current zoning: Part zone B4 Mixed Use and part zone RE1 Public Recreation

To the best of my knowledge, the site **~~is~~/is not*** the subject of a declaration, order, agreement or notice under the *Contaminated Land Management Act 1997* or the *Environmentally Hazardous Chemicals Act 1985.*

Declaration/Order/Agreement/Proposal/Notice* no(s): NA

Strike out as appropriate

Site audit commissioned by

Name: Warwick Bowyer Company: Lend Lease (Millers Point) Pty Ltd

Address: Level 4, 30 The Bond, 30 Hickson Road, Millers Point NSW

Postcode: 2000

Phone: 9236 6408 Fax: 9383 8259

Name and phone number of contact person (if different from above)

Mark Burns, Ph: 9277 2724

Purpose of site audit

~~☐ A. To determine land use suitability *(please specify intended use[s])*~~

.....

~~**OR**~~

☑ B(i) To determine the nature and extent of contamination, and/~~or~~

☑ B(ii) To determine the appropriateness of an ~~**investigation/**~~**remedial action/**~~**management**~~ **plan***, and/~~or~~

☑ B(iii) To determine if the land can be made suitable for a particular use or uses by implementation of a specified **remedial action plan/**~~**management plan***~~ *(please specify intended use[s])*

Mixed commercial, high density residential and public open space

Information sources for site audit

Consultancy(ies) which conducted the site investigation(s) and/or remediation

- Jeffery and Katauskas Pty Ltd (J&K)
- Environmental Resources Management Australia Pty Ltd (ERM)
- AECOM Australia Pty Ltd (AECOM)

Title(s) of report(s) reviewed:

- 'Report to Sydney Harbour Foreshore Authority on Geotechnical Investigation for Proposed Redevelopment of Wharves 3-8 at Hickson Road, Darling Harbour East, NSW' dated 21 August 2006, by J&K
- 'Land at Millers Point, Ownership and Usage' dated 1 June 2007, by Rosemary Broomham
- 'Environmental Site Assessment, East Darling Harbour, Sydney, NSW' dated 21 June 2007, by ERM
- 'Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW' dated July 2008, by ERM
- 'Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney' dated September 2008, by ERM

Strike out as appropriate

- 'Barangaroo Data Gap Investigation Proposal, Proposed Blocks 1 to 3, Hickson Road, Millers Point, NSW' dated 16 October 2009, by AECOM
- 'Sampling, Analytical and Quality Plan, Data Gap Investigation, Barangaroo, Hickson Road, Millers Point, NSW' draft dated 20 November 2009, by AECOM
- 'Data Gap Investigation, Other Remediation Works (South) Area, Hickson Road, Millers Point, NSW' dated 27 May 2010, by AECOM
- 'Overarching Remedial Action Plan for the Barangaroo Project Site, Sydney', dated 1 June 2010 by ERM
- 'Remedial Action Plan, Barangaroo – Other Remediation Works (South) Area' dated 2 June 2010, by AECOM
- 'Sampling Programme – In Situ Validation Works, ORW(S) Area' letter dated 3 August 2010, by AECOM
- 'Groundwater Discharge Study, Stage 1 Barangaroo Development' dated 3 November 2010, by AECOM
- 'In situ Soil and Fill Validation, Other Remediation Works South Area' dated 13 May 2011, by AECOM
- 'Human Health and Ecological Risk Assessment, Declaration Site (Development Works) Remediation Works Area Barangaroo' dated 9 June 2011, by AECOM
- 'Human Health and Ecological Risk Assessment Addendum, Other Remediation Works (South) Area, Barangaroo' dated 4 July 2011, by AECOM
- 'Amended Remedial Action Plan, Barangaroo – ORWS Area' dated 7 July 2011, by AECOM

Other information reviewed (including previous site audit reports and statements relating to the site)

- EPA 'Declaration of Remediation Site (Section 21 of the Contaminated Land Management Act 1997), Declaration Number 21122; Area Number 3221' dated 6 May 2009
- EPA 'Notice of Approval of Voluntary Management Proposal (Section 17 of the Contaminated Land Management Act 1997), Approval No.: 20101719, Approval Date: 23 July 2010, Area No.: 3221'
- DOP 'Major Project Assessment: Bulk Excavation and Basement Car Park, Barangaroo Stage 1, MP 10_0023' dated October 2010
- DOP 'Project Approval under Section 75J of the Environmental Planning & Assessment Act 1979, Bulk excavation, remediation and construction of a basement carpark', Application No. 10_0023' dated 2 November 2010.
- OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South (Ref DOC11/30893) re human health and environmental risk assessments.
- "Site Audit Report - Overarching Remedial Action Plan, Barangaroo", and Site Audit Statement GN 439A, dated June 2010.

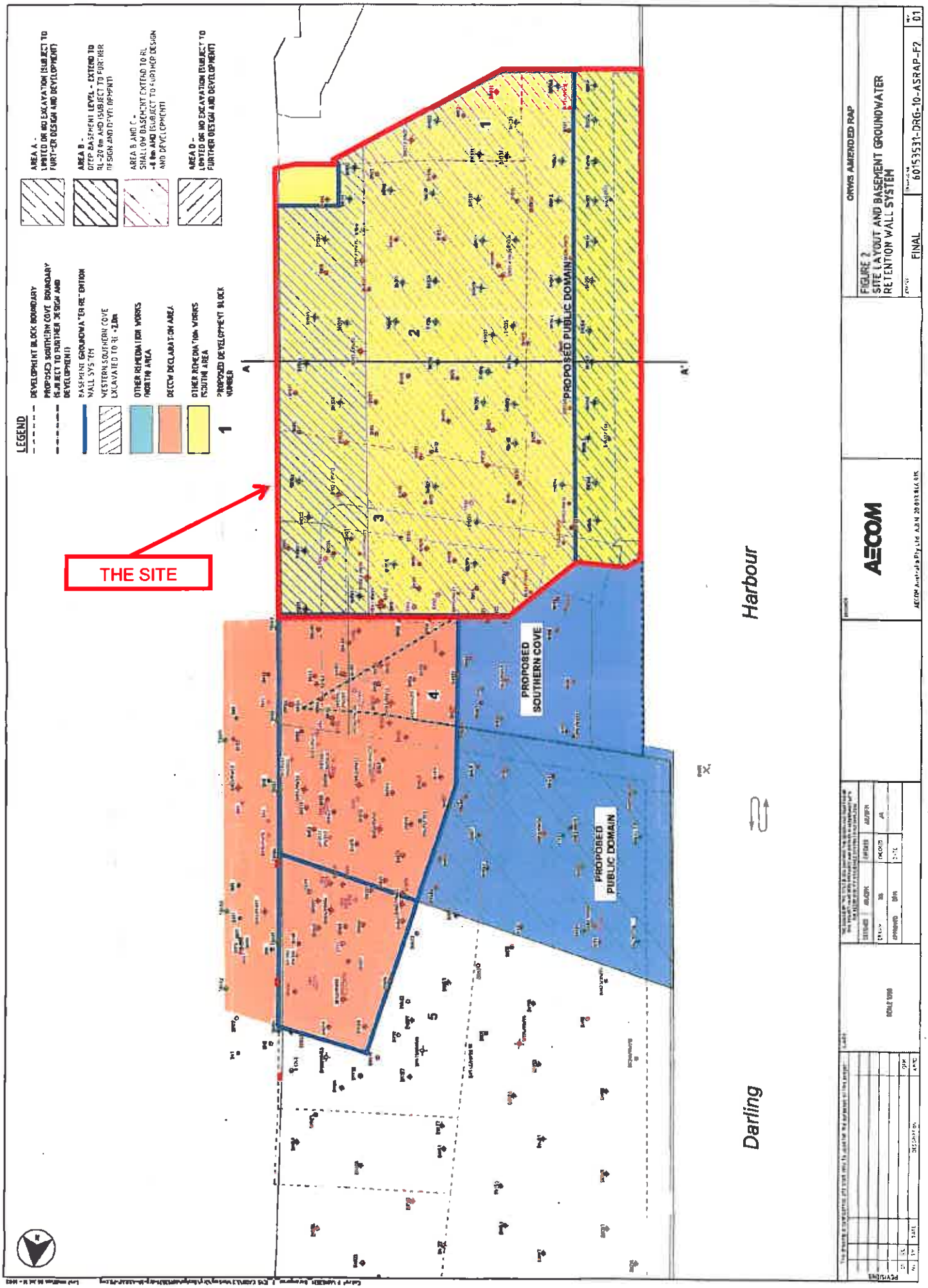
Strike out as appropriate

Site audit report

Title: Site Audit Report – Remedial Action Plan, Other Remediation Works (South), Barangaroo

Report no. GN 439B-1 (ENVIRON Ref: AS121111) Date: July 2011

Strike out as appropriate


LEGEND
DEVELOPMENT BLOCK BOUNDARY
PROPOSED SOUTHERN COVE BOUNDARY SUBJECT TO FURTHER DESIGN AND DEVELOPMENT
BASEMENT GROUNDWATER RETENTION WALL SYSTEM
WESTERN SOUTHERN COVE EXCAVATED TO RL +2.0m
OTHER REMEDIATION WORKS NORTH AREA
DEEPER DECLARATION AREA
OTHER REMEDIATION WORKS SOUTH AREA
PROPOSED DEVELOPMENT BLOCK NUMBER
AREA A - LIMITED OR NO EXCAVATION (SUBJECT TO FURTHER DESIGN AND DEVELOPMENT)
AREA B - DEEP BASEMENT LEVEL - EXTEND TO RL -20.0m AHD (SUBJECT TO FURTHER DESIGN AND DEVELOPMENT)
AREA B AND C - SHALLOW BASEMENT EXTEND TO RL -8.0m AHD (SUBJECT TO FURTHER DESIGN AND DEVELOPMENT)
AREA D - LIMITED OR NO EXCAVATION (SUBJECT TO FURTHER DESIGN AND DEVELOPMENT)
THE SITE
PROPOSED PUBLIC DOMAIN
PROPOSED SOUTHERN COVE
PROPOSED PUBLIC DOMAIN
Harbour
Darling
ORWS AMENDED RAP
FIGURE 2
SITE LAYOUT AND BASEMENT GROUNDWATER RETENTION WALL SYSTEM
FINAL
60153531-DRG-10-ASRAP-F2
01
AECOM

PART II: Auditor's findings

Please complete either Section A or Section B, **not** both. *(Strike out the irrelevant section.)*

Use Section A where site investigation and/or remediation has been completed and a conclusion can be drawn on the suitability of land use(s).

Use Section B where the audit is to determine the nature and extent of contamination and/or the appropriateness of an investigation or remedial action or management plan and/or whether the site can be made suitable for a specified land use or uses subject to the successful implementation of a remedial action or management plan.

~~Section A~~

☐ **I certify that, in my opinion, the site is SUITABLE for the following use(s)** *(tick all appropriate uses and strike out those not applicable)*:

- ☐ Residential, including substantial vegetable garden and poultry
- ☐ Residential, including substantial vegetable garden, excluding poultry
- ☐ Residential with accessible soil, including garden (minimal home-grown produce contributing less than 10% fruit and vegetable intake), excluding poultry
- ☐ Day care centre, preschool, primary school
- ☐ Residential with minimal opportunity for soil access, including units
- ☐ Secondary school
- ☐ Park, recreational open space, playing field
- ☐ Commercial/industrial
- ☐ Other *(please specify)* .....

subject to compliance with the following environmental management plan *(insert title, date and author of plan)* **in light of contamination remaining on the site:**

.....

.....

.....

OR

☐ **I certify that, in my opinion, the site is NOT SUITABLE for any use due to the risk of harm from contamination.**

Overall comments

.....

.....

.....

.....

Section B

Purpose of the plan[1] which is the subject of the audit is to remediate the site to facilitate the future land-uses proposed as part of the Barangaroo Stage 1 Development Works, known as the Other Remediation Works (South) area (ORWS).

I certify that, in my opinion:

☑ **the nature and extent of the contamination HAS/~~HAS NOT*~~ been appropriately determined**

AND/~~OR~~

☑ **the ~~investigation~~/remedial action plan/~~management plan~~* IS/~~IS NOT~~* appropriate for the purpose stated above**

AND/~~OR~~

☑ **the site CAN BE MADE SUITABLE for the following uses** *(tick all appropriate uses and strike out those not applicable)*:

- ☐ ~~Residential, including substantial vegetable garden and poultry~~
- ☐ ~~Residential, including substantial vegetable garden, excluding poultry~~
- ☐ ~~Residential with accessible soil, including garden (minimal home-grown produce contributing less than 10% fruit and vegetable intake), excluding poultry~~
- ☐ ~~Day care centre, preschool, primary school~~
- ☑ Residential with minimal opportunity for soil access, including units
- ☐ ~~Secondary school~~
- ☑ Park, recreational open space, playing field
- ☑ Commercial/industrial
- ☐ ~~Other *(please specify)* .....~~

if the site is remediated/~~managed~~* in accordance with the following remedial action plan/management plan* *(insert title, date and author of plan)*

Amended Remedial Action Plan, Barangaroo – ORWS Area' dated 7 July 2011, by AECOM Australia Pty Ltd

~~subject to compliance with the following condition(s):~~

.....

.....

.....

[1] For simplicity, this statement uses the term 'plan' to refer to both plans and reports.

Strike out as appropriate

Overall comments

Risk based remediation criteria have been developed based on the proposed site uses and development plans. Soil and groundwater investigations have been conducted, and the results compared to the criteria to determine the extent of remediation required.

In the Auditor's opinion, the proposed remediation and validation approach described in the Amended Remedial Action Plan (RAP) is appropriate. The proposed remediation strategies for ORWS are generally consistent with the Overarching RAP for Barangaroo. Those principles are:

- Establishment of appropriate remediation end points applicable to both human health and the environment by a risk assessment that considers future land use and potential long term impacts to Darling Harbour
- Establishment of a lateral and vertical extent of remediation that will address the remediation end points.
- Development of technical details for the remediation methods proposed that support that the selected method(s) are technically feasible with a low chance of failure
- Sustainable remediation, by reuse of material within the Barangaroo project area where possible
- Documentation of a methodical and rigorous process for validation of the results of remediation.

Site Auditor review of a Post-Remediation Groundwater Monitoring Program (GMP) and a Site Management Plan (SMP) for future land owners is required. These documents are to be prepared based on the final design of the basement groundwater retention wall system and as an outcome of the site validation, respectively. This approach is considered appropriate.

If significant changes are made to the development design, or if beneficial reuse of excavated material outside the area of the Stage 1 Development Works is contemplated, the Amended RAP proposes to prepare the following documents for approval by OEH and the Site Auditor:

- revision of the Amended RAP and the ORWS HHERA Addendum if the final development design is changed from the assumptions used in the development of risk based criteria or the remedial design
- preparation of an Addendum to the Amended RAP if beneficial reuse of excavated material at Headland Park or other areas of Barangaroo is an available option.

This is considered an appropriate approach.

PART III: Auditor's declaration

I am accredited as a site auditor by the NSW Environment Protection Authority under the *Contaminated Land Management Act 1997* (Accreditation No. 9808).

I certify that:

- I have completed the site audit free of any conflicts of interest as defined in the *Contaminated Land Management Act 1997*, and
- with due regard to relevant laws and guidelines, I have examined and am familiar with the reports and information referred to in Part I of this site audit, and
- on the basis of inquiries I have made of those individuals immediately responsible for making those reports and obtaining the information referred to in this statement, those reports and that information are, to the best of my knowledge, true, accurate and complete, and
- this statement is, to the best of my knowledge, true, accurate and complete.

I am aware that there are penalties under the *Contaminated Land Management Act 1997* for wilfully making false or misleading statements.

Signed ..... Date 14/7/2011

PART IV: Explanatory notes

To be complete, a site audit statement form must be issued with all four parts.

How to complete this form

Part I identifies the auditor, the site, the purpose of the audit and the information used by the auditor in making the site audit findings.

Part II contains the auditor's opinion of the suitability of the site for specified uses or of the appropriateness of an investigation, or remedial action or management plan which may enable a particular use. It sets out succinct and definitive information to assist decision-making about the use(s) of the site or a plan or proposal to manage or remediate the site.

The auditor is to complete either Section A or Section B of Part II, **not** both.

In **Section A** the auditor may conclude that the land is *suitable* for a specified use(s) OR *not suitable* for any beneficial use due to the risk of harm from contamination.

By certifying that the site is *suitable*, an auditor declares that, at the time of completion of the site audit, no further remediation or investigation of the site was needed to render the site fit for the specified use(s). Any **condition** imposed should be limited to implementation of an environmental management plan to help ensure the site remains safe for the specified use(s). The plan should be legally enforceable: for example a requirement of a notice under the *Contaminated Land Management Act 1997* (CLM Act) or a development consent condition issued by a planning authority. There should also be appropriate public notification of the plan, e.g. on a certificate issued under s.149 of the *Environmental Planning and Assessment Act 1979*.

Auditors may also include **comments** which are key observations in light of the audit which are not directly related to the suitability of the site for the use(s). These observations may cover aspects relating to the broader environmental context to aid decision-making in relation to the site.

In **Section B** the auditor draws conclusions on the nature and extent of contamination, and/or suitability of plans relating to the investigation, remediation or management of the land, and/or whether land can be made suitable for a particular land use or uses upon implementation of a remedial action or management plan.

By certifying that a site *can be made suitable* for a use or uses if remediated or managed in accordance with a specified plan, the auditor declares that, at the time the audit was completed, there was sufficient information satisfying guidelines made or approved under the CLM Act to determine that implementation of the plan was feasible and would enable the specified use(s) of the site in the future.

For a site that *can be made suitable*, any **conditions** specified by the auditor in Section B should be limited to minor modifications or additions to the specified plan. However, if the auditor considers that further audits of the site (e.g. to validate remediation) are required, the auditor must note this as a condition in the site audit statement.

Auditors may also include **comments** which are observations in light of the audit which provide a more complete understanding of the environmental context to aid decision-making in relation to the site.

In **Part III** the auditor certifies his/her standing as an accredited auditor under the CLM Act and makes other relevant declarations.

Where to send completed forms

In addition to furnishing a copy of the audit statement to the person(s) who commissioned the site audit, statutory site audit statements must be sent to:

Department of Environment, Climate Change & Water (NSW)
Contaminated Sites Section
PO Box A290, SYDNEY SOUTH NSW 1232
Fax: (02) 9995 5930

AND

the **local council** for the land which is the subject of the audit.

Contents

List of Tables and Figures

List of Appendices

List of Abbreviations

AASS	Actual Acid Sulphate Soils
AC	asbestos cement
ACM	asbestos containing material
AECOM	AECOM Australia Pty Ltd
AHD	Australian Height Datum
ALS	Australian Laboratory Services
ASET	Australian Safer Environment and Technology Pty Ltd. (Laboratory)
ASAC	Analyte Specific Acceptance Criteria
ASLP	Australian Standard Leaching Procedure
ASS	acid sulphate soils
ANZECC	Australian and New Zealand Environment and Conservation Council
BACM	Bonded asbestos containing material
BaP	Benzo(a)pyrene
BDA	Barangaroo Delivery Authority
BGL	below ground level
BTEX	Benzene, Toluene, Ethylbenzene & Xylenes (Monocyclic Aromatic Hydrocarbons)
CIM	Confirmed impacted material
CLM Act	NSW *Contaminated Land Management Act 1997*
COPC	Contaminants of Potential Concern
CPAH	carcinogenic PAHs and includes: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h) anthracene and indeno(1,2,3-cd)pyrene
CRS	Chromium Reducing Sulfur
DAF	Dilution Attenuation Factor
DEC	NSW Department of Environment and Conservation (now OEH)
DECC	NSW Department of Environment and Climate Change (now OEH)
DGI	data gap investigation report
DOP	Department of Planning (NSW)
DP	Deposited Plan
DQI	Data Quality Indicators
DQO	Data Quality Objectives
ENM	excavated natural material
EPA	Environment Protection Authority (NSW)
EPL	Environment Protection License
ESA	Environmental Site Assessment report
ERM	Environmental Resources Management Australia Pty Ltd
GDS	Groundwater Discharge Study
ha	Hectare
HHERA	Human Health and Ecological Risk Assessment
J&K	Jeffery & Katauskas Pty Ltd
km	Kilometres
LCS	Laboratory Control Sample
LLMP	Lend Lease (Millers Point) Pty Ltd
LOR	Limit of Reporting
m	Metres
MAH	Monocyclic Aromatic Hydrocarbons
Mercury	Inorganic mercury unless noted otherwise
Metals	As: Arsenic, Cd: Cadmium, Cr: Chromium, Cu: Copper, Fe: Iron, Ni: Nickel, Pb: Lead, Zn: Zinc, Hg: Mercury, Se: Selenium
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Litre
mBGL	Metres below ground level
MWQC	marine water quality criteria
µg/L	Micrograms per Litre
NATA	National Association of Testing Authorities

NC	Not Calculated
ND	Not Detected
ng/L	Nanograms per Litre
NEHF	National Environmental Health Forum
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
n	Number of Samples
OEH	Office of Environment and Heritage, NSW Department of Premier and Cabinet
OCPs	Organochlorine Pesticides
OH&S	Occupational Health & Safety
OPPs	Organophosphorus Pesticides
ORWN	Other Remediation Works (North) Area
ORWS	Other Remediation Works (South) Area
PAHs	Polycyclic Aromatic Hydrocarbons
PASS	Potential Acid Sulphate Soils
PCBs	Polychlorinated Biphenyls
PID	Photoionisation Detector
PIM	Potential impacted material
PQL	Practical Quantitation Limit
pH	a measure of acidity, hydrogen ion activity
QA/QC	Quality Assurance/Quality Control
RAP	remedial action plan
RPD	Relative Percent Difference
RWP	Remedial work plan
SAR	Site Audit Report
SILs	Soil Investigation Levels
SMP	site management plan
SSESCs	site specific ecological screening criteria
SSTCs	site specific target criteria
SVOCs	Semi Volatile Organic Compounds
TCLP	Toxicity Characteristics Leaching Procedure
TCM	tar containing material
TPH	Total Petroleum Hydrocarbons
TSC	terrestrial soil criteria
TTM	Total toxicity of mixtures
TV	Trigger value
UCL	Upper Confidence Limit
VENM	virgin excavated natural material
VOCs	Volatile Organic Compounds
WAD	weak acid dissociable (cyanide)
-	On tables is "not calculated", "no criteria" or " not applicable"

1 Introduction

1.1 Site Identification

A site contamination audit has been conducted in relation to the southern portion of the site known as "Barangaroo", at Millers Point, NSW, on behalf of Lend Lease (Millers Point) Pty Ltd (LLMP). Barangaroo is a large site to be developed in stages and for a variety of uses, with different portions subject to separate audits. The portion of Barangaroo that is the subject of this audit has been designated as the "Other Remediation Works (South)" area (ORWS). It is made up of Blocks 1-3 (three development blocks, "the development area") and a proposed area of public domain, comprising around 40% of the site. The site location is shown on Attachment 1, Appendix A; an overview of the proposed development layout is shown on Attachment 2, Appendix A; and the development blocks are shown on Attachment 3, Appendix A. The portion of Barangaroo which previously contained part of a manufactured coal gasworks and which has been declared by the NSW EPA(now part of Office of Environment and Heritage OEH) as a Remediation Site ("the declaration area") adjoins the site to the northeast.

Approximately 80% of the site including about half of the public domain will be subject to excavation to accommodate the proposed development. For the purpose of this audit, the site has been considered in two portions (refer Attachment 4, Appendix A), as follows:

- Development Area (South) – Blocks 1, 2 and 3, including the 'Deep Basement area' (adjacent to Hickson Road, Attachment 3) and the majority of the 'Shallow Basement area'
- Public Domain (South) – including part of the 'Shallow Basement area' and the unexcavated area closest to darling Harbour.

The Audit was conducted to provide an independent review by an NSW Environment Protection Authority (EPA) Accredited Auditor of the suitability and appropriateness of a plan of management, long-term management plan or a voluntary management proposal i.e. a "Site Audit" as defined in Section 4 (1) (b) (v) of the *NSW Contaminated Land Management Act 1997* (the CLM Act).

1.2 Background

Details of the audit are:

Requested by:	Warwick Bowyer on behalf of Lend Lease (Millers Point) Pty Ltd
Request/Commencement Date:	30 October 2009
Auditor:	Graeme Nyland
Accreditation No.:	9808

A number of contamination investigations have been conducted at the larger Barangaroo site since 1996. As part of the audit, I have reviewed investigation results relevant to the ORWS site, and prepared the following letter to provide my preliminary comments on the original Remedial Action Plan (RAP) prepared for ORWS:

- 'Review of Remedial Action Plan, Other Remediation Works (South) Area, Barangaroo' dated 3 June 2010.

Further investigations, development of risk-based remediation criteria and further remediation planning (in the form of an Amended RAP) has been undertaken since completion of the above letter, which have been reviewed in preparation of this Site Audit Report.

Separate RAPs are to be prepared for each development stage at Barangaroo. As it is envisaged that remediation in different portions of Barangaroo will be linked, for example by re use of material from one part in another, an Overarching RAP has also been prepared (ERM 2010) to identify strategies and remedial options for remediation of the whole site. Review of the Overarching RAP was conducted for Barangaroo Delivery Authority (BDA) by the Auditor and a Site Audit Report (SAR) prepared as follows:

- "Site Audit Report - Overarching Remedial Action Plan, Barangaroo", and Site Audit Statement GN 439A, dated 2 June 2010.

1.3 Scope of Work

The scope of the audit included:

- Review of the following reports:
  - 'Report to Sydney Harbour Foreshore Authority on Geotechnical Investigation for Proposed Redevelopment of Wharves 3-8 at Hickson Road, Darling Harbour East, NSW' dated 21 August 2006, by Jeffery and Katauskas Pty Ltd (J&K)
  - Report 'Land at Millers Point, Ownership and Usage' dated 1 June 2007, by Rosemary Broomham
  - Final Report 'Environmental Site Assessment, East Darling Harbour, Sydney, NSW' dated 21 June 2007, by Environmental Resources Management Australia Pty Ltd (ERM)
  - Report 'Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW' dated July 2008, by ERM (2008a)
  - Report 'Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney' dated September 2008, by ERM (2008b)
  - Final 'Barangaroo Data Gap Investigation Proposal, Proposed Blocks 1 to 3, Hickson Road, Millers Point, NSW' dated 16 October 2009, by AECOM Australia Pty Ltd (AECOM)
  - Draft 'Sampling, Analytical and Quality Plan, Data Gap Investigation, Barangaroo, Hickson Road, Millers Point, NSW' dated 20 November 2009, by AECOM
  - Report 'Data Gap Investigation, Other Remediation Works (South) Area, Hickson Road, Millers Point, NSW' dated 27 May 2010 (and drafts dated 7 April and 18 May 2010), by AECOM (2010a) (*the DGI*)

  - Report 'Overarching Remedial Action Plan for the Barangaroo Project Site, Sydney', dated 1 June 2010 by ERM *(the Overarching RAP)*
  - Report 'Remedial Action Plan, Barangaroo – Other Remediation Works (South) Area' dated 2 June 2010 (and drafts dated 19 April, 20 May and 31 May 2010), by AECOM (2010b) (*the Original RAP*)
  - Letter 'Sampling Programme – In Situ Validation Works, ORW(S) Area' dated 3 August 2010, by AECOM (2010c)
  - Report 'Groundwater Discharge Study, Stage 1 Barangaroo Development' dated 3 November 2010 (and drafts dated 16 June, 4 August and 20 October 2010), by AECOM (2010d) (*the Groundwater Discharge Study*)
  - Report 'In situ Soil and Fill Validation, Other Remediation Works South Area' dated 13 May 2011 (and drafts dated 20 January 2011 and 21 April 2011), by AECOM (2011a) (*the In Situ Validation report*)
  - Report 'Human Health and Ecological Risk Assessment, Declaration Site (Development Works) Remediation Works Area - Barangaroo' dated 9 June 2011 (and drafts dated 30 July 2010, 10 January, 31 January, 12 April and 6 May 2011), by AECOM (2011b) (*the Declaration Site HHERA*)
  - Report 'Human Health and Ecological Risk Assessment Addendum, Other Remediation Works (South) Area, Barangaroo' dated 4 July 2011 (and drafts dated 4 August 2010, 3 February , 18 April, 6 May, 10 June and 24 June 2011), by AECOM (2011c) (*the ORWS HHERA Addendum*)
  - Report 'Amended Remedial Action Plan, Barangaroo – ORWS Area' dated 7 July 2011 (and drafts dated 20 January 2011, 21 April , 13 May and 22 June 2011), by AECOM (2011d) (*the Amended RAP*)

- Review of the following OEH, EPA and Department of Planning (DOP) documents:
  - EPA 'Declaration of Remediation Site (Section 21 of the Contaminated Land Management Act 1997), Declaration Number 21122; Area Number 3221' dated 6 May 2009
  - EPA 'Notice of Approval of Voluntary Management Proposal (Section 17 of the Contaminated Land Management Act 1997), Approval No.: 20101719, Approval Date: 23 July 2010, Area No.: 3221'
  - DOP 'Major Project Assessment: Bulk Excavation and Basement Car Park, Barangaroo Stage 1, MP 10_0023' dated October 2010
  - DOP 'Project Approval under Section 75J of the Environmental Planning & Assessment Act 1979, Bulk excavation, remediation and construction of a basement carpark', Application No. 10_0023' dated 2 November 2010.
  - OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South (Ref DOC11/30893) re human health and environmental risk assessments.

- Site visits by the Auditor on 18 March 2010 and subsequently.
- Discussions with LLMP, BDA, and with AECOM, who undertook the recent works.

The ERM investigations were completed prior to the Auditor's engagement and no discussion with ERM was undertaken.

1.4 Audit Team

The Audit was completed by Graeme Nyland with the assistance of a site audit team.

Internal (ENVIRON) support was provided by the following staff:

- Rowena Salmon – analysis of field and laboratory data and review of proposed remediation
- Emma Struik – review of risk based remediation criteria
- Sara Arthur – review of laboratory data quality.

External support was provided by the following person/organisation:

- Jackie Wright, Environmental Risk Services Pty Ltd – review of human health and environmental risk assessments, primary preparer of Section 10 of this SAR. Ms Wright has also prepared a separate detailed report supporting the summary provided in Section 10.

2 Site Details

2.1 Location

The site locality is shown on Attachment 1, Appendix A.

The site details are as follows:

Street address:	Wharf 8, Hickson Road (Sussex Street), Barangaroo, NSW 2000
Identifier:	Southern portions of Lot 3, Lot 5 and Lot 6 in DP 876514
Local Government:	City of Sydney
Owner:	Barangaroo Delivery Authority
Site Area:	approximately 4.27 ha

The boundaries of the site are defined by adjoining roads and the harbour to the east, south and west (refer Attachment 2, Appendix A). The northern boundary of ORWS is not readily identifiable as it is a proposed development boundary, and not based on current site features or usage.

The site area comprises the southern portion of 'Area 2'(Attachment 5, Appendix A) as referenced in previous investigations and the Overarching RAP (ERM 2010).

2.2 Zoning

The current zoning of the site was identified in the Amended RAP (AECOM, 2011d) as "part zone B4 Mixed Use and part zone RE1 Public Recreation".

2.3 Adjacent Uses

The site is located within an area of mixed uses, (Attachment 2, Appendix A):

- North: Barangaroo, currently open space concrete/hardstand.
- South: Shelley Street, commercial buildings and King Street Wharf
- East: Hickson Road, commercial and residential buildings
- West: Darling Harbour.

Attachment 5, Appendix A, shows the location of the former gasworks facilities to the north east of ORWS. The former gasworks facilities have potential to have caused contamination at ORWS.

Darling Harbour is a nearby environmental receptor.

2.4 Site Condition

The site is flat, at an elevation a few metres above Darling Harbour water level. AECOM noted the following site features in their DGI report (AECOM, 2010a):

- Wharf 8 Overseas Passenger Terminal (including cruise ship loading dock, terminal, car park and landscaped areas)

- A disused brick office building and electrical substation in the southeast corner of the site
- Security gate house on the eastern boundary
- Majority of site was covered by a hardstand including concrete and bitumen
- Landscaped garden strips on eastern and southern boundaries and main driveway to Wharf 8 Terminal.

Based on the Auditor's most recent inspections, and as reported by AECOM in the Amended RAP (2011d), the electrical substation is the only permanent building remaining on site, and this is due for demolition in the near future. Temporary/ demountable site sheds are present and hardstand remains at the site, including new bitumen used to resurface the footprints of recently demolished structures and buildings. Landscaped areas also remain.

Some excavation works to near the water level at approximately 2mBGL were undertaken between January and June 2011 for archaeological study purposes. Excavated spoil was reinstated or stockpiled on site. Fragments of asbestos cement (AC) were observed during these works (AECOM, 2011d).

2.5 Proposed Development

Based on current development plans described in the Amended RAP (AECOM, 2011d), the site is to be redeveloped for mixed commercial and high density residential usage with associated public open space area (incorporating community and related land uses), overlying extensive basements.

Key components of the site development are as follows (AECOM, 2011d):

- Basement car parking across approximately 80% of the site typically ranging between depths of Relative Level (RL) 20.0 m (Deep Basement area) and RL -6.0 m (Shallow Basement area)
- The basement car parks will be constructed within a basement groundwater control system that will extend around the perimeter of the Shallow and Deep Basement areas
- High density residential and commercial multi-storey towers, together with associated open space areas, overlying the basement car parking
- Public Domain (South) usage will incorporate open space with community, mixed commercial and retail land use, and landscaping (planter boxes, paved areas and parkland). While shallow basement excavations are proposed along the eastern portion of the Public Domain (South), the existing concrete hardstand surfaces are proposed to be retained (and perforated to facilitate the drainage of water through them) within the Public Domain (South)
- The existing caisson walls associated with the historic wharf structures will be retained along the western (Darling Harbour) side of the Public Domain (South)
- The maximum height of any development within the Public Domain (South) will be limited to two storeys
- Material excavated for basement construction may be beneficially reused to build up the elevation of the Public Domain (South) by approximately 1m

- Slab on grade multi-storey commercial development (i.e. with no basement excavations) in the southeast corner of the site only, at the location of the former proposed Sydney Metro Station site.

The Amended RAP (AECOM, 2011d) describes the potential for the final details and configuration of land uses within the site to be revised from time to time by LLMP as part of the continued development design. The ORWS HHERA Addendum (AECOM 2011c) assumes a number of development concepts and controls in developing risk-based acceptance criteria for different areas of ORWS. These have been made conditions of approval of the risk assessments (AECOM 2011b and 2011c). AECOM (2011d) state that "… the proposed land uses … will remain generally consistent with that described within this Amended RAP". AECOM (2011d) note that "If the final development design is changed from the assumptions in the ORWS HHERA Addendum and this Amended RAP, an Addendum will be issued…" This is discussed further in Section 13.4 of this SAR.

The general land use scenarios applicable to this audit are 'commercial/industrial' and 'residential with minimal access to soil' for the Development Area (South) and the 'parks, recreational, open space' for the Public Domain (South), noting that some buildings may also be constructed in the public domain. The AECOM (2011b and c) risk assessments derive criteria for the following scenarios, as discussed in Section 10 of this SAR:

- Scenario 1 – lower-most basement car park level below water
- Scenario 2 – upper-most basement car park level partially above water
- Scenario 3 – unpaved public domain
- Scenario 4 – paved public domain
- Scenario 5 – commercial slab on ground – two storeys
- Scenario 6 – short term ground-intrusive maintenance
- Scenario 7 – residential above basement construction
- Scenario 8 – commercial slab on ground – multi-storey.

3 Site History

AECOM provided a site history summarised from information in previous reports prepared by ERM (2007 and 2008) and Broomham, (2007). Information relevant to ORWS is summarised in Table 3.1 based on the DGI (AECOM, 2010a) and the Auditor's review of Broomham (2007).

Table 3.1: Site History

Date	Activity
Pre 1839	The original shoreline ran approximately along the western edge of Hickson Road
1839-1920s	Land to north (declared area) occupied by Australian Gaslight Company (AGL). Included gasworks, retort house and gasholder. Demolished in mid 1920s, new finger wharves constructed; area subsequently used for various workshop facilities.
1800s	The western portion of the site was occupied by three finger wharves and the site was used for shipping and manufacturing.
1930s	MSB painted creosote on the wharf piles to protect them against insects.
1961-68	Finger wharves demolished. New sea walls and new longshore wharfs constructed. Filling undertaken behind (east of) sea walls. Site and remainder of Barangaroo filled with the exception of Southern Cove. Southern Cove straddled the site and declared area to north, and was previously located between the Wharf 6 and 7 buildings.
1972	Two large warehouse buildings on the northern boundary (former Wharf 7 building) and western boundary (former Wharf 8 building) and a smaller building in the southeast. Site covered by hard stand, used for various port related activities.
1990-1993	Southern Cove filled in
1995-2006	Longshore wharves leased to Patrick Stevedores. Port related activities.
1999	Overseas passenger terminal constructed at Wharf 8, requiring demolition of two previous buildings.
2007, 2009	Declaration of Investigation Area then Remediation Site for Wharfs 5 and 7 and Hickson Road by NSW EPA (north east of site).
2008-2011	Wharf to north of site vacated, buildings demolished.

The summary indicates that the site has been used for wharf/ port related activities since the 1800s. Original finger wharves were removed and the site was largely filled in 1961-1968 for the construction of longshore berthage, with some additional filling in the north of the site (area of former Southern Cove) in the late 1980s or early 1990s.

In the Auditor's opinion, the site history provides an adequate indication of past activities, with the primary potential for contamination being in uncontrolled fill used in various stages of site reclamation. It does not appear that any part of the site was filled during the gasworks operation.

4 Contaminants Of Concern

The DGI (AECOM, 2010a) provided a list of the contaminants of concern and potentially contaminating activities. These have been tabulated in Table 4.1.

Table 4.1: Contaminants of Concern

Area	Activity	Potential Contaminants
North of site	Former gasworks	Gasworks waste – could include HM, TPH, BTEX, PAHs, phenols, sulphate, cyanide, ammonia
Whole of site	Importation of fill materials to reclaim land	Unknown, could include HM, TPH, BTEX, PAHs, PCBs, OCPs, VOCs, SVOCs, asbestos
Whole of site	Demolition of buildings	Unknown, could include lead, PCBs, asbestos
Whole of site	Land reclamation	Acid sulphate soils (ASS)

HM heavy metals: arsenic, copper, chromium, cadmium, mercury, lead, nickel, zinc
TPH total petroleum hydrocarbons
BTEX benzene, toluene, ethylbenzene and xylenes
PAHs polycyclic aromatic hydrocarbons
PCBs polychlorinated biphenyls
OCPs organochlorine pesticides
VOCs volatile organic compounds
SVOCs semivolatile organic compounds

The Auditor considers that the analyte lists used by ERM and AECOM in the investigations undertaken are generally appropriate for the site history and condition. Details of the soil and groundwater analyses performed are provided in Section 8 and 9, respectively.

The majority of soil samples were analysed for the primary contaminants of concern, being heavy metals, TPH/ BTEX and PAH (over 700 samples analysed). Between 8 and 70 samples were also analysed for the extended suite of potential organic contaminants, including phenols, OCP, OPP, PCBs, other SVOCs and VOCs. This sampling density is considered acceptable since very few detections were made, and when they did occur, they were generally of low concentration and occurred in conjunction with other more significant concentrations of the primary contaminants. A lower sampling density was also completed for asbestos, with 48 samples analysed. Asbestos is discussed in Section 8.3.4.

All groundwater samples, from three rounds of monitoring, were analysed for the primary contaminants of concern, being heavy metals, TPH/BTEX and PAH. Cyanide (either total, free or weak acid dissociable (WAD)) was analysed in each round. Analytes included for two rounds were phenols and PCBs, while monitored natural attenuation parameters were included for one round. These sampling densities are considered adequate.

The individual substances included in each suite of analytes are listed in Appendix D.

5 Stratigraphy and Hydrogeology

Following a review of the referenced reports, a summary of the site stratigraphy and hydrogeology was compiled as follows.

5.1 Stratigraphy

The 1:100,000 Geological Survey of NSW (Sydney) Sheet 9130 indicates the site to be underlain by Hawkesbury Sandstone and man-made fill, where man-made fill may consist of "dredged estuarine sand and mud, demolition rubble, industrial and household waste". The sub-surface profile of the site is summarised in Table 5.1.

Table 5.1: Stratigraphy

Depth (mBGL)	Subsurface Profile
Surface	Hardstand, comprising concrete asphalt or concrete pavement
Occurs below hardstand To between 3 and 19m Thickness increases from east to west.	Fill, highly heterogeneous, comprises gravel, sand, silt and clay, with sandstone, bricks, concrete, timber, steel, slag and ash.
Occurs between fill and bedrock Thickness varies from 0 to 10m	Alluvial sediments, clayey sand, sandy clay, clayey silt and clay, some shell fragments and organic matter
	Residual soils weathered from sandstone bedrock, clayey sand and sand
Occurs below natural soil or directly below fill From between 3 and >27.5m	Sandstone bedrock with shale bands.

Based on review of the site history (refer Section 3) the Auditor considers that there were three main stages representing the filling history:

- original filling of the eastern portion for development, including construction of finger wharves, in 1800s
- demolition of finger wharves and filling of the majority of the western portion of the site in 1961-1968 for the construction of longshore berthage
- filling of southern cove (previously located in the north of the site) between 1990-1993.

The filling of the majority of the site would have occurred during the second stage. AECOM (2011d) reported that based on observations from the various investigations undertaken, distinct differences in fill type relative to the historical filling sequence of the site are difficult to identify.

5.2 Hydrogeology

Groundwater at the site is within 2-3mBGL, varying due to tidal fluctuation. The amplitude of fluctuation in groundwater due to tidal effect decreases with distance from the Darling Harbour (western) boundary, however, fluctuation is still noted as far east (inland) as

Hickson Road (AECOM, 2010a). A caisson (sea) wall is present along the western boundary of the site. This wall has been found to be highly permeable and does not prevent the tidal flow of groundwater (AECOM, 2010d).

Hydraulic conductivity of fill at the site was assessed by ERM (2008a) using tidal lag response equations based on site tidal fluctuation data, and by AECOM (2010a) using rising head permeability tests in three wells. AECOM (2010a) observed the wells tested to recover almost instantaneously, reflecting the sand and gravel nature of fill material. AECOM (2010a) reported that testing conducted elsewhere at Barangaroo indicated a wide range of hydraulic conductivity depending on the local fill type. Further hydraulic testing was performed to the north of the site as part of the Groundwater Discharge Study (AECOM, 2010d), discussed below.

Groundwater quality at the site is saline, approaching seawater composition (AECOM, 2010a).

A Groundwater Discharge Study (AECOM, 2010d) was conducted to investigate the interaction between site groundwater and Darling Harbour. Transects of multilevel piezometers were installed to the north of the site and a range of hydraulic and analytical testing was performed. Key findings from this study were:

- Significant changes in water level in the unconfined fill aquifer (>1m in some cases) suggested significant quantities of water are exchanged across the aquifer – harbour interface.
- Relative to the fill, groundwater discharge volumes and therefore contaminant mass flux from the marine sediments and basal sandstone was considered to be negligible.
- The proportion of groundwater to seawater discharging during the low tide cycle to Darling Harbour was derived from a connate water displacement model. The results suggest that much of the water discharged during ebb tides comprises seawater which infiltrated during the previous flood tide. The mixing analysis indicates that the groundwater component of any discharge is likely to be 10-20% of the total.
- Contaminant mass flux is difficult to estimate on a site wide basis due to the heterogeneity of the fill, but mass flux is likely to be strongly limited by dilution occurring up-gradient of the tidal exchange prism. A five-fold dilution factor was estimated for dissolved phase contamination migrating from an upgradient source zone into Darling Harbour.

The “tidal prism” is the area behind the caisson wall where full inundation of sea water occurs during the incoming and outgoing tide. This area does not refer to the zone of tidal influence, where the groundwater level fluctuates with the tides due to the transmission of head (pressure) through the aquifer. The tidal prism concept has been used in the development of risk based remediation criteria, discussed in Section 10, since “Where leachable source material is present within the tidal exchange prism, any resultant groundwater contamination is expected to discharge largely without further attenuation” (AECOM, 2011d). AECOM determined the dimensions of the tidal prism using two methods:

- the change in storativity estimated from site tidal monitoring data, documented in the Groundwater Discharge Study (AECOM, 2010d); and

- calculated groundwater velocity using hydraulic conductivity data from the site and estimating how far inundated seawater could physically travel into the site in a 6 hour incoming tide, documented in the ORWS HHERA Addendum (AECOM, 2011c).

The tidal prism was estimated by AECOM to be a prism that exists as a rectangular volume extending 10m, on average, landward of the existing caisson wall.

Based on the Auditor's review, the hydrogeological conditions are reasonably well understood.

6 Evaluation of Quality Assurance and Quality Control

The Auditor has assessed the overall quality of the investigation data by review of the information presented in the referenced reports, supplemented by field observations. The initial investigations by ERM included parts of Barangaroo that are not included within the ORWS site. Only the information relevant to ORWS has been reviewed for this audit. The primary information reviewed comprised soil and groundwater well logs, and field and analytical methods and results for the following investigations at the ORWS site:

- ERM (2007): environmental site assessment comprising 30 boreholes, installation of seven groundwater wells and sampling of seven wells
- ERM (2008a): additional investigations comprising five boreholes and sampling of seven wells
- Rock core logs for the above ERM investigations were reported in J&K (2006)
- AECOM (2010a): DGI comprising 35 boreholes, installation of seven groundwater wells and sampling of 14 wells and four soil vapour sampling points. Data from the soil vapour sampling is not relevant to the RAP and is therefore not included in this assessment.
- AECOM (2011a): In Situ Validation comprising 57 boreholes.

The Auditor's assessment follows in Tables 6.1 and 6.2.

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment

Sampling and Analysis Plan and Sampling Methodology	Auditor Comments
Sampling Pattern and Locations	**Soil:** The initial investigations by ERM (2007) comprised low density "strategic" sampling to support a design competition and identify any further work needed to complete the development approval, rather than full characterisation of the site. Investigation locations were restricted by the presence of the large Wharf 8 terminal building and some smaller buildings on the eastern boundary, as well as operational constraints of the stevedoring business on the site. Additional investigations by ERM (2008a) and AECOM (2010a) aimed to fill data gaps from the preceding investigation, to support remediation planning. Key data gaps included: • Characterisation of deep fill • Delineation of previously identified impacts • Assessment of acid sulphate soils (ASS). There were no localised sources of contamination identified onsite that were targeted by the soil investigation locations, however, the declared area to the north was recognised as a primary source of contamination. The resulting combined site coverage therefore comprises a higher density of sampling in the northern portion, adjoining the declared area, with a lower density of sampling across the remaining areas of the site. In situ validation works by AECOM (2011a) supplemented the previous locations to provide coverage across the site on an

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	approximate 20m grid. Along the western site boundary (shore), the first row of investigation locations is placed between 20-25m from the site boundary. Drilling is not possible within around 12m of the western site boundary due to the presence of the below ground caisson wall. The locations near the western boundary are located approximately equidistant between the caisson wall and the proposed basement groundwater retention wall system (refer Attachment 4, Appendix A), and are therefore considered adequately located to characterise the western boundary (Area A) material. In the Auditor's opinion, the investigation locations performed adequately target the main areas of concern and provide reasonable coverage of the remainder of the site to allow for remediation planning. **Groundwater** monitoring wells are concentrated in the northeast and southeast of the site, as well as a series of wells on the downgradient, western side of the site, located 30-40m from the western site boundary. Given the variability of the fill encountered, the full range of groundwater conditions are not likely to have been assessed by the wells installed. However, wells have been placed in proximity to the highest soil contaminant detections, therefore, they should be reasonably representative of the upper range of potential contamination. It is noted that sampling was never undertaken from a well installed in the northeast of the site (EMW23). The soils encountered during installation of this well displayed significant evidence of contamination and associated groundwater would be expected to be significantly impacted. All of the wells (including EMW23) are located within the proposed basement groundwater retention wall system. Groundwater conditions within the proposed Public Domain (South), where existing soils and hardstands are to be retained (Area A) have not been assessed. AECOM (2011d) consider the western boundary wells to be adequately representative of groundwater within Area A. The Auditor considers this to be reasonable given their proximity to Area A and the likely common source of fill material during placement. It is noted that new wells will be required within Area A (and outside the proposed basement groundwater retention wall system) for any groundwater monitoring to be undertaken during or post-remediation. In the Auditor's opinion, the groundwater well locations are adequate to demonstrate the likely range of contamination within groundwater at the site and are considered adequate to allow for remediation planning.
Sampling Density	**Soil:** The combined sampling density of 127 soil investigation locations over approximately 4.27ha exceeds the minimum recommended by EPA (1995) "Sampling Design Guidelines" (51). If the locations were evenly spaced (not the case), this coverage would provide a 95% confidence of detecting a

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	residual hot spot of approximately 22 m diameter. As noted above, there is a higher density of sampling in the northern portion of the site, adjoining the declared area. The density of investigation locations is considered adequate for remediation planning. The density of analysis for specific analytes was discussed in Section 4, and is generally considered appropriate. The low sampling density for asbestos is discussed in Sections 8.3.4. **Groundwater:** A total of 14 groundwater wells were installed at the site. Wells were sampled for all potential contaminants of concern, between one and three times each. The groundwater well location and analytical sampling density are considered adequate to allow for remediation planning.
Sample depths	**Soil:** Soil sampling focussed primarily on fill materials. Investigations have also assessed underlying natural sediments and the upper layers of weathered bedrock which could be penetrated by standard drilling methods. Deeper bedrock conditions (generally 3-4m) were assessed by coring at around 18 locations from across the site (ERM, 2007), however, no samples were collected, therefore only a visual assessment of contamination could be performed. Photographic records of the cores were provided (J&K, 2006) to the Auditor for review. Generally between 2-5 samples were analysed per location from the first three investigation stages (ERM 2007 and 2008a and AECOM 2010a). With the exception of the cored boreholes, these locations were advanced until refusal, generally in weathered sandstone and occasionally in fill. For the in situ validation (AECOM, 2011d), locations were advanced to the proposed basement levels for the deep and shallow basement areas (-20 and -6mAHD, respectively), or at least 1m into natural soils (or to the extent of no obvious contamination in natural soils) for areas where soil is to be retained (below the shallow basement area or in the proposed Public Domain (South)). Samples were analysed from every 1-2m depth interval. In the Auditor's opinion, this sampling strategy was appropriate and adequate to characterise the primary material types present on site, and to allow for remediation planning.
Well construction	All wells were constructed wells from 50mm uPVC casing with 0.4-0.5mm machine slotted screen, graded sand filter pack and bentonite seal. The ERM wells screened the upper to middle sections of the fill. Screen lengths range from 3.5-7m. The maximum well depth was 9mBGL. The AECOM wells were generally constructed over the full depth of fill. The base of each well is at or close to natural clay/ sandstone. The screen lengths are long except for AMW08 (10.5-14mBGL). The remainder range from 7.5-14m in length.

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	The maximum well depth was 15.5mBGL. AECOM (2010a) noted that "the water quality of the entire saturated column is required for dewatering treatment information". This approach to construction is not ideal for the assessment of groundwater contamination. Long screen length results in dilution of samples, therefore, the sample results from these wells should be considered to potentially underestimate the discrete contaminant concentrations present. Except for AMW08, the top of all of the well screens are located between 1 and 3mBGL, therefore the screened interval is generally above the top of the groundwater table. This allows for identification of any floating separate phase product. Although the screened intervals were generally long and contaminant concentrations in discrete groundwater intervals may be higher than reported, overall, the groundwater well construction is considered adequate to provide average groundwater concentrations. This is considered appropriate for remediation planning based on the following risk-based considerations that are discussed further in Section 10: • The proposed basement groundwater retention wall system will prevent groundwater migration from the majority of the site and will include measures to ensure no ingress of groundwater or vapours into the buildings to be constructed. • Potential risks to Darling Harbour from migration of groundwater have been assessed based on median groundwater concentration.
Sample Collection Method	**Soil**: Samples were obtained from push tube samplers and SPT split spoons used in conjunction with push tube, auger, mud rotary and rotary casing advance techniques. Nearly all samples for laboratory analysis were semi undisturbed samples obtained from SPT or push tube. ERM (2007) included 18 locations coring through bedrock, generally for 3-4m. **Groundwater**: ERM wells were developed by removal of around 100L. AECOM wells were developed using both dedicated Teflon foot valves with LDPE tubing and an electronic high volume submersible pump. Both ERM and AECOM (2010a) reportedly collected groundwater samples by low flow/ micropurge methods. Purge volumes reported were of 5-20L (ERM) and 3-6L (AECOM). Samples collected for metals analysis were field filtered using a 0.45µm filter.
Decontamination Procedures	ERM stated that downhole sampling equipment was decontaminated prior to the commencement of drilling and between drilling locations. AECOM (2010a, 2011a) reported decontamination of augers

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	between each borehole location using a pressurised water cleaner. All reusable sampling equipment (spatula, push tube sampler, split tube sampler) was cleaned with detergent and rinsed with potable water between sampling events to prevent cross contamination and the equipment was then rinsed with deionised water. New gloves were reportedly used for each new sample. AECOM did not report decontamination of groundwater sampling equipment. It is assumed that new sample tubing dedicated to each well was used with the micropurge pump, but it was not stated how cleaning of the pump was performed if that had been necessary. New gloves were reportedly used for each new sample.
Sample handling and containers	All samples were placed into prepared and preserved sampling bottles provided by the laboratory and chilled during storage and subsequent transport to the labs. AECOM (2010) noted that 15 of 40 batches were received by the laboratory at temperatures greater than 4°C but noted that the ambient temperature at the time of sampling was high and that the laboratory received the samples within a few hours of sample collection. This indicates that the samples did not have sufficient time to cool and that sample handling was acceptable. AECOM (2011a) noted all samples were appropriately preserved and chilled during transport. Review of laboratory information indicated no material breaches of sample handling.
Chain of Custody	ERM (2008a) included completed chain of custody forms. AECOM (2010a) and (2011a) included completed chain of custody forms. There was the occasional exception (for instance ES1001619 and ES1003048 within 2010a) which do not affect the quality of the data.
Detailed description of field screening protocols	ERM and AECOM reported that for each sample depth, additional soil was placed in a sealed plastic bag and subsequent PID measurements were taken at ambient temperatures. During the in situ validation works (AECOM, 2011a), all soil samples were field tested using peroxide to evaluate the presence of PASS. Where a positive test was recorded, a sample was placed in a sealed plastic bag and frozen for confirmatory CRS analysis. Both ERM and AECOM reported that groundwater field parameters were measured during well sampling and development.
Calibration of field equipment	ERM stated that meters were calibrated prior to the start of each day. Calibration records for PID and groundwater meters were provided by ERM. AECOM (2010a, 2011a) reported that the PID was calibrated with isobutylene gas at 100 ppm at the commencement of each

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	day of sampling and, if necessary, during the day in accordance with the procedure provided by the supplier. Calibration records were provided in the AECOM reports. AECOM (2010a) included calibration records for the water quality meter for each day of groundwater sampling.
Sampling Logs	Soil logs are provided within the reports, indicating sample depth, PID readings and lithology. Logs recorded information regarding potential for contamination such as odours or staining. A separate sample register was also provided by AECOM (2010a, 2011a). Groundwater field sampling records were provided and included observations regarding potential for contamination such as odours or sheens.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
Field quality control samples	Field quality control samples undertaken by ERM included trip blanks, trip spikes, rinsate blanks, field intra-laboratory and inter-laboratory replicates. AECOM (2010a) for soil and groundwater sampling: field quality control samples including inter-laboratory and intra-laboratory duplicates, trip blanks and rinsate blanks which were undertaken at appropriate frequencies. In addition, for groundwater sampling trip spikes were included at appropriate frequencies. AECOM (2011a): Field quality control samples including inter-laboratory and intra-laboratory duplicates and rinsate blanks were undertaken at appropriate frequencies. The exclusion of trip spikes and trip blanks is considered acceptable since extensive previous investigations did not identify significant volatile contamination in soil.
Field quality control results	ERM reports include detailed data quality assessments. Minor QA/QC non conformances were reported. There were a few samples where holding times were exceeded, or where there was insufficient sample for moisture determination. **Soil:** AECOM (2010a): The results from the field quality control samples were within appropriate limits with some exceptions. Of 587 duplicate pairs of intra-laboratory results, AECOM noted 21 RPD results (<4%) were outside acceptable limits. Of 281 duplicate pairs of inter-laboratory results, AECOM noted 23 RPD results (8%) were outside acceptable limits. It can be concluded that the duplicates results indicate adequate precision and accuracy for the dataset. AECOM reported the highest of duplicates in their results tables.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
	AECOM (2011a): The results of the field quality control samples were within appropriate limits with some exceptions. Of 2275 duplicate pairs of intra-laboratory results, AECOM noted 211 RPD results were outside acceptable limits (9.3%). Of 980 inter-laboratory duplicate pairs, 100 were outside acceptable limits (10%). AECOM attributed the RPD exceedences within the fill to sample heterogeneity or low detected concentrations (<10x LOR) and observed that a much lower number of RPD exceedences were reported in the samples collected from the natural material. The Auditor notes that some intra-laboratory triplicates were analysed and these were not considered in the above Audit assessment. AECOM did not consider the highest of duplicate data in their analysis. The Auditor has reviewed instances where duplicate sample results exceeded the primary sample results and these do not affect the findings of the audit. It is recommended that AECOM consider the highest of duplicate data in preparation of the excavation staging plans to be prepared for the Remedial Works Plan. AECOM (2010a and 2011a) reported minor detections of some metals in three of 17 and six of 22 rinsate blanks, respectively. The potential for cross-contamination is considered low due to the low concentrations measured. **Groundwater:** AECOM (2010a): The results from the field quality control samples were within appropriate limits with some exceptions. Of 129 duplicate pairs of intra-laboratory results, AECOM noted one RPD result was outside acceptable limits. Of 50 duplicate pairs of inter-laboratory results, AECOM noted one RPD result was outside acceptable limits. It can be concluded that the duplicates results indicate adequate precision and accuracy for the dataset. AECOM reported some minor detections of nitrate, total nitrogen and sodium in some rinsate blanks from the micropurge submersible pump. Detections were low, except for the nitrate and total nitrogen which was within the range of that detected within the groundwater. These findings do not affect the outcome of the audit since the detected parameters are not contaminants of concern.
NATA registered laboratory and NATA endorsed methods	Laboratories used by ERM were: ALS and LabMark. It is noted that the appendix containing laboratory certificates for ERM (2007) was not provided to the Auditor. Detailed laboratory quality control reports were provided. Laboratories used by AECOM included: ALS and MGT Labmark for soil and groundwater, SGS for soil vapour and Australian Safer Environment & Technology (ASET) for asbestos. All laboratory certificates inspected were NATA stamped.
Analytical methods	Analytical methods were included in the laboratory test certificates. Summary methods were presented in the AECOM reports.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
	While, references to the USEPA methods for extraction and analysis were given for the certificates for TPH, VOCs and SVOCs the exact methods used have not been detailed.
Holding times	Review of the COCs and laboratory certificates indicate that the holding times had generally been met. ERM reported several minor breaches. AECOM (2010a): Review of the COCs and laboratory certificates indicate that the holding times had generally been met. Exceptions included: Batch numbers ES1003046 for free and complexed cyanide; ES1001619 for moisture; ES1002565 for soil pH. AECOM (2011a): Review of the COCs and laboratory certificates indicate that the holding times had generally been met. Exceptions included: Batch numbers ES1016358 for moisture, ES1016314 for ASLP analysis for six samples where BTEX, metals and PAHs results were reported, and ES1014792 for WAD cyanide. These breaches are considered minor.
Practical Quantitation Limits (PQLs)	PQLs were less than the trigger values (TVs, see Section 7) for the contaminants of concern except for some groundwater analyses. Some PQLs were raised because of salinity or interference by other contaminants, but most PQLs were below the risk based remediation criteria (refer Section 10).
Laboratory quality control samples	ALS reports surrogates with organic results, and provide separate quality reports covering duplicates, laboratory control spike, method blanks, matrix spikes and holding times. MGT LabMark reports laboratory control samples, method blanks, surrogates and spikes with the results, and also certified reference material results with metals. These did not include laboratory duplicates.
Laboratory quality control results	Laboratory certificates for ERM (2007) were not provided, though detailed laboratory quality control reports were. ERM provided a detailed quality review and concluded that data were acceptable. The results from nearly all laboratory quality control samples were within appropriate limits. Exceptions are listed below. • RPDs for some duplicate samples for some metal, TPH fractions and PAH analyses, for which the laboratory accepted the results because the soil was non homogenous. • Some samples where spike recovery could not be reported because of interference from high concentrations of analytes. • Minor detection of zinc in one rinsate blank. ERM (2008a) assessed the laboratory quality control data and concluded that the data were acceptable. Tables detailing the assessment were not included in the report supplied to the Auditor.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
	AECOM (2010a) assessed the laboratory quality control results and listed instances where results were outside acceptance limits as discussed below. AECOM reported poor laboratory duplicate results in 13 instances and the Auditor has estimated that this represents less than 10% of analyses for laboratory duplicates. AECOM consider that the poor duplicate results were due to results close to PQL or to sample heterogeneity. The Auditor does not consider this to affect the useability of the data. AECOM reported that of 93 LCS soil samples, six were outside the laboratory's Analyte Specific Acceptance Criteria (ASAC) or outside AECOM's acceptance criteria of 70 – 130% for different analytes. AECOM noted that most of the relevant compounds have not been historically detected on the site. The Auditor has observed that the only compound with a poor LCS result that has been historically detected at the site, was a PAH indeno(1,2,3,cd)pyrene, and no PAHs were detected in the affected batch. The Auditor concludes that these minor breaches will not affect the useability of the data. All LCS water samples were within acceptance criteria. In considering matrix spike samples, AECOM (2010a) reported that nine of 83 soil samples and three of 78 water samples had results outside acceptance criteria. AECOM noted that the corresponding LCS recoveries were within acceptance criteria except for some instances where poor recoveries were reported for nitrosamines and phenols. The Auditor considers that the poor results for these analytes for the matrix spikes will not affect the useability of the data as historically there have not been detections of the affected compounds at the site. AECOM (2010a) reported some poor recoveries for some acid-extractable and some base/neutral extractable surrogates in two reports, but review of the laboratory data indicates that in both instances there were several other surrogates with results within the acceptable ranges, and the results are not considered to affect the useability of the data. AECOM (2011a) assessed the laboratory quality control results and listed instances where results were outside acceptance limits. These are discussed below. AECOM reported poor laboratory duplicate results in 55 instances, and the Auditor has estimated that this represents less than 5% of analyses for laboratory duplicates. AECOM noted that all of these samples were fill material. The Auditor does not consider that this will affect the useability of the data. AECOM (2011a) noted that of 359 LCS samples, two samples reported LCS results (four analytes) that were either outside the laboratory's Analyte Specific Acceptance Criteria (ASAC) or outside AECOM's acceptance criteria of 70 - 130%. The Auditor has examined the laboratory data and found that the samples reported in the affected batches were not critically close to criteria, so the poor LCS results are not expected to have an

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
	impact on any conclusions that are made from the data set. AECOM (2011a) noted that of 359 matrix spike samples, three samples had analytes outside acceptance criteria. The Auditor has reviewed the results for the relevant analytes, benzene and chromium, in the affected reports and found that for benzene the results were <LOR and for chromium the results were very low. The Auditor therefore does not consider that these non-conformances will affect the useability of the data. AECOM (2011a) reported that 13 of 359 surrogate samples were outside the acceptable DQI range. The Auditor has considered the laboratory data (where supplied) for each breach and found them to be minor – in all cases more than one surrogate was used for the analyte class and there was always one or two surrogates where the results was adequate.
Data Quality Objectives and Data Evaluation (completeness, comparability, representativeness, precision, accuracy)	The ERM reports include data quality objectives. They also include detailed review of data and conclude that the data comply with the ERM quality protocols. AECOM (2010a and 2011a) set data quality objectives for the report and outlined data quality indicators across the five category areas. In both reports, AECOM concluded that the DQI's for the data were achieved and the data "...to be reliable and representative of concentrations of the compounds analysed at the locations sampled."

In considering the data as a whole the Auditor is able to conclude that:

- Investigation locations and sample depths are likely to be representative of the overall site conditions. Though conditions may vary locally within non-homogenous fill, it is considered that the major issues affecting remediation would have been identified by the investigations conducted. Several observations of potential groundwater impact were made during groundwater sampling, discussed in Section 9. Mild/ transient observations of potential contamination impact were noted in a number of wells which was not always reflected in the laboratory analytical results as summarised in Table 9.1. The lack of laboratory detections may be due to dilution of impacts due to the long screen length, inadequacies in field or laboratory methods, or low degree of impact (below detection limit). Given the relatively mild and transient nature of field observations and the detections of more significant groundwater impacts in other locations, this potential deficiency is not considered to affect the conclusions of this report.
- The laboratories provided sufficient information to conclude that data is of sufficient precision, and field and laboratory quality control measures were sufficient to be confident that most of the data is likely to be accurate.
- The data is considered complete and usable. The data set is large enough that the minor departures from data quality objectives noted above would not greatly impact the conclusions from the assessments.

- Although different consultants, different staff and different laboratories were used, data appears to be sufficiently comparable for each sampling and analytical event.

The Auditor therefore concludes that the data is suitable as a basis for preparation of a Remediation Action Plan (RAP).

7 Environmental Quality Criteria

A conservative set of environmental quality screening criteria were developed by the Auditor for use in performing an initial review of the soil and groundwater analytical data for key contaminants, discussed in the following sections. The screening criteria were used to gauge the general degree of contamination impact, for use in identifying trends in contaminant occurrence. The findings are discussed in Sections 8 and 9 of this SAR. Risk-based remediation criteria have been developed by AECOM to determine the extent of remediation required at the site, discussed in Section 10 of this SAR.

7.1 Soil

Table 7.1 presents a summary of the soil screening criteria used.

Table 7.1: Summary of Auditor's Screening Criteria for Key Soil Contaminants

Analyte	Screening Criteria (mg/kg)	Source
Lead	300	Soil Investigation Levels for Urban Redevelopment Sites in NSW in DEC (2006) 'Guidelines for the NSW Site Auditor Scheme, 2nd Edition'. Lower of • SIL Column 1 – 'residential with gardens and accessible soil' • SIL Column 5 – 'provisional phytotoxicity-based investigation levels'
Arsenic	20	
Copper	100	
Zinc	200	
Total PAH	20	SIL Column 1 – 'residential with gardens and accessible soil'
TPH C10-C36	1000	EPA (1994) 'Guidelines for Assessing Service Station Sites'

Further details of the sources adopted are provided in Appendix B.

7.1.1 Asbestos

There are no national or EPA approved guidelines for asbestos in soil relating to human health. DEC (2006) state that Auditors must exercise their professional judgement when assessing whether a site is suitable for a specific use. The DEC states that the position of the Health Department is that there should be no asbestos in surface soil.

AECOM state the following in the In Situ Validation report (2011a) with respect to asbestos criteria "For the purposes of this investigation it is important to determine the presence, nature and extent of asbestos. If asbestos is found to be present, a management approach for the affected soils may be developed".

7.1.2 Acid Sulfate Soils

AECOM (2011a) considered the NSW Acid Sulfate Soil manual (ASSMAC, 1998) for the assessment and management of Acid Sulfate Soils (ASS).

7.2 Groundwater

The Auditor has assessed the groundwater data in reference to ANZECC (2000) 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality' for marine waters. Trigger values (TVs) provided are concentrations that, if exceeded, indicate a potential

environmental problem and 'trigger' further investigation. The 95% level of protection has been adopted for the current review, with reference to Low Reliability criteria where necessary and 99% protection level to account for the potential for bio-accumulation or acute toxicity to particular species. The referenced criteria are listed in Appendix B.

There are no reliable Australian criteria for TPH in groundwater. The current NSW EPA position is that there should be no free phase product in groundwater, and that the aromatic components of dissolved-phase TPH in groundwater should be assessed using the ANZECC (2000) TVs where available. These guidelines include criteria for some BTEX compounds and for some polycyclic aromatic hydrocarbons.

8 Evaluation of Soil Analytical Results Against Screening Criteria

8.1 Introduction

Soil conditions have been investigated by over 125 boreholes advanced by ERM (2007 and 2008a) and AECOM (2010a and 2011a). Soil sampling locations are shown on Attachment 4, Appendix A.

The following sections discuss the field and laboratory results for fill, natural soil and bedrock investigations.

8.2 Field Observations

8.2.1 Soil (Fill and Natural)

Visual and olfactory indications of contamination were observed throughout the fill material during all stages of investigation, including “black staining, ash, slag, slight sheen and odours variably described as hydrogen sulphide, organic, chemical, naphthalene and hydrocarbon” (AECOM, 2011a). Infrequent tar odours were also noted during the DGI (AECOM, 2010a).

Visual and olfactory indicators were less common within natural soils. Primarily odours and occasional staining were noted in natural soil (below fill) in 15 locations from across the site, although concentrated in the north of the site.

Elevated PID readings were associated with the strongest observations, which primarily occurred at depth in the north of the site. Maximums in the order of 500ppm were recorded in natural sandy clay and fill in the central northern portion and northeast corner of the site. These areas correlate with areas where light end petroleum hydrocarbons were detected in soils. These areas have been identified by AECOM (2010a) as Zones 1 and 2, discussed in Section 8.3.2, below.

Field observations with respect to asbestos are discussed in Section 8.3.4, below.

8.2.2 Bedrock

Bedrock conditions were visually assessed by coring in around 18 locations from across the site, and it was reported that "no significant visual or olfactory indications of potential contamination were noted within the bedrock" (ERM, 2007). Based on the Auditor’s review of the cored logs, including photographs (J&K, 2006), no contaminant indicators were present except possibly brown or grey staining.

The AECOM investigations (AECOM, 2010a and 2011a) did not include cored investigations into bedrock, however, some observations were made in the upper weathered layers which were penetrated by standard drilling methods. Visual and olfactory indications of contamination were observed in the top of sandstone in five locations in the central northern portion and northeast corner of the site (Zones 1 and 2), including two locations on the northern site boundary (AECOM BH36 and BH37). Observations included hydrocarbon, chemical or tarry odours, and black staining in a fracture from AECOM BH300 in the

northeast corner (6.6-6.8mBGL). The maximum recorded PID reading was around 220ppm from AECOM BH307 13-13.4mBGL).

8.3 Soil Analytical Results

Soil samples were analysed for a variety of contaminants including petroleum hydrocarbons, PAHs, asbestos and heavy metals. More specialised analyses were also performed to determine Acid Sulfate Soils (ASS) and leaching potential. The following Table 8.1 summarises the analytical program undertaken for the combined stages of work, summarised from the In Situ Validation report (AECOM, 2011a). Table 8.1 excludes duplicate analyses.

Table 8.1: Summary of Soil Analytical Program and Maximum Concentrations Detected

Analyte	Number of Analyses	Number of Detections	Maximum (mg/kg)
Lead	818	747	2450
Arsenic	817	179	168
Barium	127	103	410
Beryllium	127	2	4
Cadmium	817	11	4
Total Chromium [1]	817	820	145
Cobalt	127	57	19
Copper	817	572	509
Manganese	127	98	768
Mercury	816	204	5.9
Nickel	817	580	122
Vanadium	127	121	125
Zinc	817	716	2070
Phenols	68	1	3.9
Total PAHs	711	350	2561
Benzo(a)Pyrene	711	249	155
OCP/ OPP	21	0	<PQL
PCB	10	0	<PQL
Other SVOCs	18	4 [2]	23.6
TPH (C6-C9)	722	15	244
TPH (C10-C36)	722	202	13550
BTEX	725	16	179
Other VOCs	8	3 [3]	45

Table 8.1: Summary of Soil Analytical Program and Maximum Concentrations Detected

Analyte	Number of Analyses	Number of Detections	Maximum (mg/kg)
WAD Cyanide	604	0	<PQL
Free cyanide	7	0	<PQL
Total cyanide	33	3	2.2
SPOCAS	5	0	-
Chromium Reducible Sulfur	37	32	0.454%
Asbestos	48	5	-
Sulphate	34	32	2620

- not applicable

PQL practical quantitation limit

1 Chromium (VI) was analysed for in 5 samples from the site, all results were <PQL. Based on site history and the Chromium (VI) results, Total Chromium detections are expected to comprise Chromium (III).

2 Other SVOCs detected comprised carbazole and dibenzofuran

3 Other VOCs detected comprised trimethylbenzenes, styrene, n-propylbenzene and 1,3-dichlorobenzene

The analytical results have been assessed against screening criteria (Table 7.1) to identify trends in contaminant occurrence. The results have also been assessed against risk based remediation criteria, discussed in Section 11. The following sections present a discussion of the results according to contaminant type.

8.3.1 Heavy End TPH and PAH

The primary contaminants detected at the site were heavy end TPH in the C15-C36 range and a suite of PAH associated with coal tars and other gasworks wastes.

28% of samples analysed contained TPH in the C15-C36 range. 7% of samples exceeded the Auditor's screening criterion of 1000mg/kg. The maximum concentration detected was 9160mg/kg. Concentrations exceeding 1000mg/kg were detected from across the majority of the site area, with multiple exceedances occurring in some deep fill locations. No exceedances were detected:

- towards the eastern boundary where the fill depth is shallow (except associated with light end TPH impact in the northeast corner of the site, discussed below), or
- in the central and western portions of the northern boundary.

PAH detections were associated with all of the heavy end TPH detections. PAH detections were more common than TPH detections (primarily due to the lower PQL for PAH analyses). 22% of samples analysed reported a total PAH concentration exceeding the Auditor's screening criterion of 20mg/kg. Of these, 24% exceeded 100mg/kg (equivalent to 5% of the total samples), and the maximum total PAH concentration detected was 2561mg/kg.

In all locations free from light end TPH/ naphthalene impact, between 40-50% of the total PAH concentration was contributed to by pyrene (Py), fluoranthene (Fl) and phenanthrene (Ph). These occurred in typical suites dominated by (1) Py, Fl and Ph, (2) Py and Fl or (3) Py only. Significant contributions from five more PAH were also made, with individual

concentrations of between 5 and 10% of the total PAH concentration (benz(a)anthracene, benzo(b)fluoranthene, chrysene, benzo(a)pyrene (BaP) and anthracene). These are carcinogens except for anthracene.

The proportion of the total PAH concentration contributed to by BaP, a known carcinogen, was generally between 5 and 10%, with a maximum BaP concentration detected at the site of 155mg/kg.

Suite types 1 and 2 were dominant at the site, and the majority of the highest total PAH concentrations (exceeding 100mg/kg) being of the type (1) suite (Py, Fl and Ph). PAH exceedances occurred in samples from a range of depths, with multiple exceedances occurring in some deep fill locations. At such locations, intervening samples were commonly found to be free of PAH, and more than one of the PAH suite types were commonly detected in different samples from the same location. The results indicate a high degree of both lateral and vertical variability within the fill material. No clear trends were identifiable with respect to the depth, spatial extent or nature of the detected PAH impacts.

The PAH naphthalene was generally a minor contributor except where associated with broader TPH impacts (including light end TPH), discussed in the following section.

8.3.2 Light End TPH, BTEX and Naphthalene

Limited detections of BTEX and light end TPH in the C6–C9 range were made. Where they occurred, detections of C10 through to C28 TPH (and less commonly to C36 TPH) and a more significant contribution by the PAHs naphthalene, acenaphthylene and phenanthrene were also common.

Detections of this nature were made in 10 investigation locations at the site, occurring in between 1 and 3 samples per location. The detections occurred in two primary areas, referred to by AECOM in the Original RAP (2010b) as remediation Zones 1 and 2. The results from these zones are summarised by the Auditor in Table 8.2, below, and were characterised by AECOM as follows (refer Attachment 6, Appendix A):

- Zone 1 (northeast corner), heavy end TPH, PAH, BTEX and lead contamination, impacts derived from gasworks and fill, contamination present in fill materials
- Zone 2 (central northern boundary), light end TPH/BTEX and PAH contamination, impacts derived from gasworks, contamination present in natural soils/ bedrock.

Table 8.2: Summary of Light End Hydrocarbon Impacts

Item / Area	Zone 1 (northeast corner)	Zone 2 (central northern boundary)
Number of affected locations	5	3
Number of affected samples	11	7
Depth range of affected samples (mBGL) and material type	1-15.5, primarily in base of fill, or natural soil over sandstone	15.8-23.8, all within natural soil, under fill/ over sandstone
Maximum concentration (mg/kg)		
BTEX	179	78.6[1]

Table 8.2: Summary of Light End Hydrocarbon Impacts		
Item / Area	**Zone 1 (northeast corner)**	**Zone 2 (central northern boundary)**
TPH C6-C9	244	121[1]
TPH C10-C28	13550	480[1]
Naphthalene	241	948

1 TPH and BTEX were not analysed for in the sample with the maximum naphthalene concentration from this area, therefore actual maximum TPH/ BTEX concentrations are likely to be higher than reported.

BTEX was not detected outside Zones 1 and 2.

Outside Zones 1 and 2, minor concentrations of TPH C6-C9 (maximum 69mg/kg) were detected in two samples in association with broader range TPH (exceeding 1000mg/kg) The locations were in the southeast of the site (BH20 (11-11.2)) and in the northwest of the site (BH339 (1-1.2)).

Outside Zones 1 and 2, naphthalene was only detected in greater proportion than other PAH (discussed in Section 8.3.1 above) in location BH329 (5-5.5) in the approximate central south of the site. The concentration was 15.7mg/kg. No BTEX or light end TPH (C6-C9) were detected in this sample.

8.3.3 Heavy Metals

Soil samples were analysed for a suite of between 8 and 13 heavy metals (refer Table 8.1). The heavy metals which were observed to regularly exceed screening criteria were lead, arsenic, copper and zinc. The Auditor's summary of the occurrence of these key heavy metals is provided in Table 8.3, below. In order to identify trends in occurrence, heavy metal detections exceeding the Auditor's screening criteria were reviewed to determine if they occurred with or without TPH/ PAH impacts, defined as TPH detections (any concentration) and a total PAH concentration exceeding the screening criteria of 20mg/kg.

Table 8.3: Summary of Key Heavy Metal Occurrence							
Analyte	**n**	**Auditor's Screening Criteria (mg/kg)**	**No. Detections Above Auditor's Screening Criteria**	**Occurrence with TPH/ PAH impact**		**Occurrence without TPH/ PAH impact**	
				%	**Maximum (mg/kg)**	**%**	**Maximum (mg/kg)**
Lead	818	300	65	56	**2450**	34	2100
Arsenic	817	20	21	45	48	55	**168**
Copper	817	100	97	25	**509**	56	420
Zinc	817	200	66	63	**1890[1]**	28	1650[1]

Note some occurrence could not be determined since TPH/ PAH not analysed for in samples where heavy metals exceeded screening criteria (therefore total % < 100).

Bold values are the maximum concentration detected at the site

n number of samples

1 The site-wide zinc maximum was 2070mg/kg, however, occurrence with or without TPH/PAH impact could not be determined since TPH/PAH analyses were not performed on this sample.

The following trends in contaminant occurrence are noted:

- Lead – The majority of exceedances (56%) occur with TPH/ PAH impact. Although the highest recorded concentrations occurred with TPH/ PAH impact, several high concentration detections (above 1500mg/kg) were made independent of TPH/ PAH impact.
- Arsenic – Exceedances occurred at an approximately equivalent rate with and without TPH/ PAH impact. Exceedances with TPH/ PAH impact were generally minor in nature, with more significant concentrations occurring without TPH/ PAH impact.
- Copper – The majority of exceedances (56%) were independent of TPH/ PAH impact. The concentrations detected were similar with or without TPH/PAH impact.
- Zinc – The majority of exceedances (63%) occur with TPH/ PAH impact and several high concentration detections (above 1000mg/kg) were associated with TPH/ PAH impact. Although a number of samples exceeded the screening criteria, very high concentrations (far exceeding the screening criteria) were not very common without TPH/ PAH impact.

Overall, lead and zinc exceedances are more common with TPH/ PAH impact, and high zinc concentrations are primarily associated with TPH/ PAH impact. High concentrations and frequent exceedances for lead also occur independent of TPH/ PAH impact, indicating they are associated with fill. Arsenic and copper exceedances appear associated with fill and unrelated to gasworks impacts (TPH/ PAH).

8.3.4 Asbestos

Limited asbestos analyses were performed during the first three investigations (ERM, 2007 and 2008a and AECOM, 2010a) on the basis that no visual evidence of AC was observed. Six samples of fill containing waste materials were analysed for asbestos, and no detections were made.

A further 42 samples were analysed for in the In Situ Validation (AECOM, 2011a). AECOM reported that no visual evidence of bonded fibre cement or possible asbestos fibres was observed during the intrusive drilling program. Chrysotile asbestos was detected in five samples. The detections occurred in four locations from the southern portion of the western boundary area, between 1.5 and 9.4mBGL. Small fibre bundles were detected in three samples, and one of these three (which contained several fibre bundles) also contained one small piece of asbestos cement sheeting. All samples in which the asbestos detections were made comprised clay/ sand/silt/gravel fill material. The following anthropogenic materials were observed:

- BH354_1.5-1.7: AECOM log indicates brick and bitumen gravels and ash, laboratory sample description indicates “tar-like / sand agglomerates”
- BH356_3-3.5: AECOM log indicates concrete and brick fragments, laboratory sample description indicates concrete pieces
- BH356_9-9.4: laboratory sample description indicates “charcoal and malthoid-like material”. Malthoid is a bitumen impregnated felt material. No anthropogenic material noted in AECOM log.

Two of the five samples in which detections were made contained construction waste (brick/ concrete fragments) which would indicate potential for asbestos to be present. Four of the five samples contained indicators of chemical contamination (odour, tar, ash and malthoid).

The overall sampling comprised 48 samples from 34 locations. In the Auditor's opinion, the investigation method used (borehole drilling) does not allow for adequate observation of the bulk filling to identify AC fragments. The extent of characterisation for asbestos is not considered adequate given the variability of fill materials, the depth of filling and the limited vertical coverage of the asbestos analyses performed. In the Auditor's opinion, there is a high potential for undetected asbestos to be present in the fill, most likely associated with AC fragments that may not have been observed during the drilling investigations.

This likelihood is supported by the observation of AC fragments in six separate areas during the recent archaeological excavations which were to approximately 2m depth (AECOM, 2011d).

8.3.5 Other Analyses

Specialised analyses performed and results were as follows:

- Five samples were analysed for Suspension Peroxide Oxidation Combined Acidity & Sulfur (sPOCAS) and 37 samples were analysed for Chromium Reducible Sulfur. Samples were selected for anlaysis based on field testing to identify potential ASS (PASS). The results indicated around 40% of samples may be PASS, depending on the buffering capacity of the soil. AECOM (2011a) reported "The reported screening results indicate that PASS is variably present within natural silty clay and clay soils. PASS may also be present within gravelly sand and silty sand fill materials across the site, where the source of the fill material comprised dredged sediments".
- 34 samples were analysed for sulphate, with a maximum concentration of 2620mg/kg. Detections at this concentration are not of concern for human health or the environment, but present a potential risk to concrete structures.
- Toxicity Characteristics Leaching Procedure (TCLP) was performed on 14 samples for selected heavy metals and nine samples for BaP, including high concentration samples. The maximum leachable lead was 5.4mg/L and leachable BaP was all <0.5mg/L. The TCLP results can be used for waste classification purposes.
- Australian Standard Leaching Procedure (ASLP) deionised water leachability tests were performed on 78 samples for selected heavy metals, 75 samples for PAH and 67 samples for BTEX, including high concentration samples. Several heavy metals and PAH (excluding BaP) were detected in the leachates. AECOM (2010a) inferred that the soil and fill material at the site had a generally low to moderate leaching potential under deionised water leach conditions.

8.4 Conclusion

The soil analytical results indicate widespread impact to fill materials by heavy end TPH, PAH and some heavy metals. Contaminant impacts appear to be derived from both gasworks wastes and fill materials. Impact by light end TPH and volatile hydrocarbons is restricted to two zones in the north of the site and occurs in both fill and underlying natural materials. Bedrock from the site has not been sampled extensively, however, visual

observations have indicated contaminant impacts to be restricted to the northern portion of the site, within the area of Zones 1 and 2.

Fill from the site has not been well characterised for the potential for asbestos contamination.

The need for remediation of detected soil contamination has been considered by AECOM (2011d) based on risk based remediation criteria, and is discussed in Sections 10 and 11.

9 Evaluation of Groundwater Analytical Results Against Screening Criteria

9.1 Introduction

Seven ERM wells have been sampled in three rounds (July 2006, May 2008 and March 2010). Seven AECOM wells have been sampled once (February 2010). Groundwater sampling was also apparently undertaken in August 2007 as referenced in the ERM Additional Investigation report (ERM, 2008a), however, a source report was not available to allow auditing of that monitoring round.

Groundwater well locations are shown on Attachment 4, Appendix A.

9.2 Overview of Groundwater Monitoring

Table 9.1, below, provides a summary of the wells installed at the site and a summary of the key analytical results from each well. Also included are field indications of contamination noted in soils during installation of the wells (log indicators), observations of the groundwater during sampling (sampling observations) and the coverage of fill materials provided by the well screening (screened fill interval).

Due to the duplication of well numbers, the Auditor has prefaced the well numbers with 'A' or 'E' based on who they were installed by (AECOM or ERM, respectively).

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Screened Fill Interval	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
Development Area (South)							
AMW08	2010	10.5-14	Base	Staining and strong odours (including tar) from 8.5	1	Tar odour, slight sheen	Significant TPH, BTEX and Naphthalene
AMW09	2010	1.4-9.5	Full		1	Tar odour	No organic detections
AMW12	2010	1.5-11.0	Almost full		1	H_2S odour	No organic detections
AMW17	2010	1.5-12.5	Almost full	Gaseous odour	1	PH odour	Minor PAH
AMW19	2010	1.8-11.5	Full	Gaseous odour	1	Mild PH/ H_2S odour	Minor PAH
AMW21	2010	1.5-9.0	Full		1	Mild HC odour	Minor PAH
AMW26	2010	1.5-15.5	Almost full	Staining and tarry odour at depth	1	Tar (?) odour	No organic detections
EMW21	2006	3-9	Upper	Faint HC odour in deep fill (below screen)	3	2008 v slight sheen	TPH/BTEX in 2006 Minor PAH in

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Screened Fill Interval	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
							2006/10
EMW23	2006	1.5-15	Fill and natural clayey sand	Strong HC odour 6-15.5	0	Not sampled	Not sampled
Public Domain (South)							
EMW09	2006	2-9	Middle		3		TPH in 2006
EMW10	2006	1-6	Upper		3	2008 slight sheen	No organic detections
EMW16	2006	3-9	Middle		3		No organic detections
EMW17	2006	3-9	Middle		3	2010 Initial sheen, iron floc	Minor PAH in 2010
EMW18	2006	2-5.5	Middle	Bldg rubble (steel/ conc) in fill, organic odour at top of natural (below screen)	3	2008 H_2S odour	Minor PAH in 2006
EMW20	2006	2-9	Upper	Bldg rubble (steel/ conc) in fill	3	2010 Mild H_2S/ tar odour 2006 HC odour	TPH in 2006 PAH in 2008/10, not analysed in 2006 Cyanide in 2006

n number samples

Observations of impact to soil by hydrocarbons were made during installation of wells in the north of the site (AMW08, EMW21). Groundwater from these wells displayed strong indicators of contamination, including odour and sheen. Mild/ transient observations of potential contamination impact were noted in most other wells, not always evidenced in the laboratory analytical results. The most significant (persistent) field observations of contamination impact to groundwater in other areas of the site were at EMW20, located in the southwest of the site.

9.3 Groundwater Analytical Results

The groundwater analytical results are summarised below in Table 9.2 for the 2010 monitoring round, and for combined data from 2006/2008. Some key results from the 2010 monitoring are shown on Attachment 7, Appendix A. It is noted that the Auditor has used different screening criteria to those used by AECOM (and displayed on Attachment 7) for some contaminants.

Table 9.2: Evaluation of Groundwater Analytical Results – Summary Table (µg/L)

Analyte	Feb/March 2010					July 2006/ May 2008				
	n	Detections	Maximum	n >ANZECC (2000)	Locations	n	Detections	Maximum	n >ANZECC (2000)	Locations
Arsenic	14	12	8.6	3	AMW09, 21, EMW21	14	7[1]	6	1[1]	EMW21
Cadmium	14	8	108	4	EMW09, 10, 16, AMW08	14	4[1]	2.6	3[1]	EMW09, 10, 21
Total Chromium	14	0	<PQL	0	-	14	6[1]	2	0[1]	-
Copper	14	4	79	4	EMW09, 10, 16, 18	14	4	8	4	EMW09, 10, 16, 17
Lead	14	7	12	1	EMW16	14	8	7.2	1	EMW17
Nickel	14	14	87.1	12	(All excl. EMW17, 20)	14	9[1]	102	5[1]	EMW09, 10, 21
Zinc	14	13	188	8	EMW09, 10, 16, 18, 21, AMW09, 17, 21	14	13	128	12	All E wells
Mercury (inorganic)	14	0	<PQL	0	-	14	0	<PQL	0	-
Cyanide (Free)	14	0	<PQL	0	-	0	-	-	-	-
Cyanide (WAD)	10	0	<PQL	-	-	0	-	-	-	-
Cyanide (Total)	4	0	<PQL	-	-	14	3	232	3	EMW09, 20, 21
TPH (C_6-C_9)	14	1	13200	-	AMW08	14	1	60	-	EMW21
TPH (C_{10}-C_{36})	14	1	9380	-	AMW08	14	4	2870	-	EMW20
Benzene	14	1	4410	1	AMW08	14	1	3	0	EMW21
Toluene	14	1	1600	1	AMW08	14	1	8	0	EMW21
Ethylbenzene	14	1	683	1	AMW08	14	1	2	0	EMW21
M & p Xylene	14	1	1160	1	AMW08	14	1	12	0	EMW21
O Xylene	14	1	1130	1	AMW08	14	1	9	0	EMW21
Benzo(a) Pyrene	14	4	7.7	4	EMW20, AMW08, 19, 21	13	2	0.7	1	EMW21
Naphthalene	14	2	4440	1	AMW08	13	1	1.4	0	EMW18

Table 9.2: Evaluation of Groundwater Analytical Results – Summary Table (μg/L)

Analyte	Feb/March 2010					July 2006/ May 2008				
	n	Detections	Maximum	n >ANZECC (2000)	Locations	n	Detections	Maximum	n >ANZECC (2000)	Locations
Total PAH	14	7	4849	-	-	13	3	21.6	-	EMW20, 21
Phenols	7	0	<PQL	0	-	7	0	<PQL	0	-
PCBs	0	-	-	-	-	14	0	<PQL	0	-

n number of samples
- No criteria available/used or not applicable
PQL practical quantitation limit
1 PQLs exceeded the ANZECC (2000) criteria for Arsenic, cadmium, chromium and nickel for July 2006

9.3.1 Contaminant Detections

Results from the three rounds of monitoring indicate the greatest degree of impact was detected in AMW08 (2010), located in the northeast of the site (Zone 1), near the declared area, with significant TPH (22580μg/L), BTEX (11300μg/L) and naphthalene (4440μg/L) concentrations detected. This well has the shortest screened interval of all wells (3.5m) and evidence of contamination was noted in the screened materials. None of these compounds were detected in AMW09, 15m to northwest, although a tar odour was noted during sampling of this well. The closest well, EMW23, 10m to the southeast, was never sampled, however, the log indicated significant petroleum hydrocarbon (including tar) impact at this location.

Minor PAH detections were made in a number of wells from across the site (AMW17, AMW19, AMW21, EMW17, EMW20 and EMW21). PAH were previously detected in EMW20 and 21, and naphthalene was detected at EMW18. In addition to PAH, TPH C10-C36 (2870μg/L) was detected in 2006 in EMW20, located in the southwest of the site.

Other detections from 2006 that were not repeated in 2008 or 2010 were:

- total cyanide detected in EMW20 at 232μg/L and in EMW09 at 5μg/L and EMW21 (7 μg/L) compared to the ANZECC (2000) criterion of 4μg/L
- TPH detected in EMW09 (960μg/L) in the northeast of the site (Zone 1)
- TPH (420μg/L) and BTEX (34μg/L) detected in EMW21 in the central north of the site (Zone 2).

No phenols or PCBs were detected during any sampling rounds.

Elevated heavy metal concentrations were detected in a number of wells, occurring across the site area. Results were reasonably consistent between the 2006/ 2008 and 2010 monitoring, although cadmium and copper concentrations were significantly higher in 2010.

The groundwater analyses indicate that detections of TPH/ BTEX have primarily occurred in the northern portion of the site, associated with petroleum hydrocarbon and coal tar impacts in adjacent soils (Zones 1 and 2). The exception to this was the one-off detection of TPH and cyanide, and repeated detection of PAH in EMW20 in the southwest of the site. Minor PAH detections were reasonably widespread at the site (seven wells). The slightly higher concentrations in EMW20 may be associated with PAH impacts identified in fill in the vicinity (refer Section 8).

Heavy metal impacts do not follow any particular patterns and most likely vary based on contaminant concentrations in adjacent fill soils and the local groundwater conditions (eg, pH) that may affect leaching of metals from soil.

9.3.2 Natural Attenuation

AECOM (2010a) report indicators of biodegradation at well AMW08 in the northeast of the site, the only well where TPH was detected (in 2010).

The Auditor's review of the results from analysis of natural attenuation parameters also indicates evidence of possible biodegradation at AMW17 and AMW21, located in the centre and south of the development area. These wells displayed mild petroleum hydrocarbon odours during sampling but no detections were made by laboratory analysis. It is possible that:

- degradation of naturally occurring organic material, not detectable by the analyses performed, is occurring
- degradation of petroleum hydrocarbons has previously occurred achieving complete destruction
- low level petroleum hydrocarbon impact is present in these wells but was not detected in the samples collected, possibly due to sample dilution across the long screen lengths (9 and 13m).

9.4 Conclusion

The results indicate a significant impact to groundwater by TPH, BTEX and PAH in the north of the site, adjoining the declared area. The most significant impact detected in 2010 is around 130m from the western boundary shoreline (AMW08). Previous detections of TPH indicate this impact may extend further west, but at much lower concentrations. Some contaminant exceedances of a minor nature, primarily PAH, were detected close to the shoreline, in particular in well EMW20. Variable impact by heavy metals was detected, reflecting the variable contaminant levels in fill materials across the site.

The need for remediation of detected groundwater contamination has been considered by AECOM (2011d) based on risk based remediation criteria, and is discussed in Sections 10 and 12. The 2010 groundwater results are considered adequately representative and conservative for consideration in determining groundwater remediation requirements for the site.

10 Development of Risk Based Remediation Criteria

10.1 Criteria developed

Site specific assessment criteria have been developed for ORWS as documented in the Declaration Site HHERA (AECOM, 2011b) and ORWS HHERA Addendum (AECOM 2011c). Criteria were derived for the protection of:

- human health – site specific target criteria (SSTC)
- environment – site specific ecological screening criteria (SSESC)

The SSTC and SSESC are specific to the proposed development and as such the application of the criteria derived and to be implemented within the RAP are tied to some fundamental aspects of the proposed design. If these aspects are not adhered to, then the objectives of the HHERA will not be met as there will be the potential for unacceptable risks to human health or the environment, and the SSTC and SSESCs are no longer valid. The fundamental assumptions and design specifications of the proposed development that have been incorporated in the derived SSTCs and SSESCs are as follows:

- Tar will be removed from the immediate vicinity of outer basement walls to the extent practicable and the basement design and engineering controls (key aspects listed below) will ensure that tar seepage into basements does not occur
- A basement groundwater retention wall system will be constructed around the perimeter of the basement area and will be keyed into the bedrock. It will comprise diaphragm and secant (or equivalent) walls
- Car park basements will include engineering controls (key aspects listed below) to ensure that contaminated groundwater does not accumulate in habitable car park areas
- Car park walls:
  - Above the bedrock
    - At least 600mm wide perimeter retention wall
    - In some locations where required for the development as part of the internal car park basement wall an additional 350mm reinforced concrete wall
    - Sealed plenum (to collect and rain seepage water that may permeate through the perimeter and basement car park walls and vent vapours from the seepage water using a passive pipe riser to the height of the roof level)
    - Minimum of 4 air exchanges per hour within the basement areas;
    - The maximum car park space will span no more than two perimeter walls, the other two will be internal walls that cannot be adjacent to contaminated material
    - Locations where external services intersect the perimeter retention wall these will need to be appropriately sealed to remove any preferential pathway for groundwater or vapour migration.
  - Below/into bedrock
    - 100mm Shotcrete applied to bedrock surface
    - 350mm reinforced concrete wall

  - Sealed plenum
  - Minimum of 4 air exchanges per hour within the basement areas
  - The maximum car park space will span no more than two perimeter walls, the other two will be internal walls that cannot be adjacent to contaminated
  - Locations where external services intersect the perimeter retention wall these will need to be appropriately sealed to remove any preferential pathway for groundwater or vapour migration.

- Paved/unpaved recreation areas to have at least 0.5m suitable fill placed at the surface. “Suitable fill” is defined in the AECOM PDA HHERA as VENM or soil which contains contaminant levels below terrestrial soil criteria (developed for the maintenance of plant health and human health)
- The lower level basement car park level is not used for loading/unloading and does not have a full time car park attendant, or similar, located in is such that there will be no long term workers in this portion of the building
- The sump for the water collected on the inside of the sealed plenum shall not be located inside the car park and shall be separated from the car park atmosphere by a separate ventilation system, or equivalent, to remove the potential for vapour issues from pooled contaminated groundwater inside the car park
- An active venting system on the sealed plenums may be required. A passive venting system is proposed and the effectiveness of this system needs to be demonstrated.

OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South approved the Declaration Site HHERA (AECOM, 2011b) and ORWS HHERA Addendum (AECOM 2011c) subject to Conditions of Approval which incorporate the design, construction and operational parameters listed above.

The Amended RAP has defined four areas within ORWS that are based on land uses and material types. These areas are referenced in some parts of the HHERA and following sections of this SAR and are relevant to the criteria that have been derived. The areas are defined by AECOM as the following:

- Area A – material to remain in situ within the Public Domain (South), outside the retention wall system and potentially in hydraulic connection with Darling Harbour, where limited or no excavation will be required.
- Area B – materials to be removed as part of basement excavations and subject to beneficial reuse including potential beneficial reuse by raising the existing ground elevation in the Public Domain (South).
- Area C – materials to remain in situ below the Shallow Basement area and within the retention wall system which will effectively remove hydraulic connection with Darling Harbour.
- Area D – materials to remain in situ upgradient of the retention wall system with negligible hydraulic connection to Darling Harbour.

10.2 Derivation of Human Health SSTCs

SSTCs have been derived for eight landuse scenarios. The Amended RAP then considers the applicability of the scenarios to the four different areas, A-D, of ORWS. These landuse scenarios are as follows:

Scenario Number	Description	Exposures Assessed	Review Comments
1	**Lower Basement** Lower level basement car park in multi-storey building assuming groundwater seepage occurs and is captured within plenum	Adult and child residents exposed during incidental use of the basement for access to vehicles. Only pathway of exposure assessed is vapour inhalation.	Relevant to incidental use of the basement only. Seepage is contained behind plenum so there is no potential for direct contact. The exposure assumptions (Section 5.3.5 of the Declaration Site HHERA) and calculations are appropriate and have been checked. Note that the scenario does not allow for longer durations of exposures (e.g. workers in a carwash). In addition the scenario relies on only 2 walls being in contact with contamination.
2	**Upper Basement** Upper basement car park in multi-storey building assuming it is adjacent to some saturated soil (groundwater) and the remainder is unsaturated soil.	The most significant exposures occur by adult workers within a car park. Only pathway of exposure assessed is vapour inhalation.	Exposures by a worker in the car park will be more significant than incidental exposure by users of the car park hence it is appropriate that the calculations are based on these exposures. The exposure assumptions (Section 5.3.6 of the Declaration Site HHERA) and calculations are appropriate and have been checked. Note that the scenario is relevant for workers in the basement as ventilated and used as a car park only. No other changes in design/use have been assessed. In addition the scenario relies on only 2 walls being in contact with contamination.
3	**Unpaved recreation** Relevant to the public domain areas.	Recreational exposures by adults and children. Only pathway of exposure assessed is vapour inhalation.	Exposures assumptions (Section 5.3.7 of the Declaration Site HHERA) are appropriate and the calculations have been checked. The scenario is reliant on 0.5m clean fill being placed across the area such that direct contact with underlying soil does not occur.
4	**Paved recreation** Relevant to the public domain areas that are covered with concrete or paving.	Recreational exposures by adults and children. Only pathway of exposure assessed is vapour inhalation.	Exposures assumptions (Section 5.3.8 of the Declaration Site HHERA) are appropriate and the calculations have been checked. The scenario is reliant on the concrete cover remaining in place and intact such that underlying soil is not at the surface of the ground. The AECOM report also recommends 0.5m suitable fill below areas that are paved, however the assessment presented has not considered this in the calculations.
5	**Commercial slab on ground** Slab on ground building used for commercial purposes – no basement.	Adult workers within building. Only pathway of exposure assessed is vapour inhalation.	Exposures assumptions (Section 5.3.9 of the Declaration Site HHERA) are appropriate and the calculations have been checked. The scenario is reliant on the building being small and limited to a maximum of 2 levels in height. No basement levels are assessed for this scenario.
6	**Intrusive maintenance worker** Maintenance of subsurface services	Adult workers who may come in direct contact with soil and groundwater during these works. Exposure pathways	Exposures assumptions (Section 5.3.10 of the Declaration Site HHERA) are appropriate and the calculations have been checked.

Scenario Number	Description	Exposures Assessed	Review Comments
		assessed include: • Incidental ingestion of soil and groundwater • Dermal contact with soil and groundwater • Inhalation of vapours from soil and groundwater • Inhalation of dust	
7	**High Density Residential**	Adults and children living on the ground floor of a multi-story building, overlying basement levels.	The assessment has been conducted on the assumption that vapours from the basement levels migrate into the ground floor living areas. Vapours on the ground floor are assumed to be 10 times lower than modelling in the upper basement (basement used as a car park only). Exposures assumptions (Section 5.3.11 of the Declaration Site HHERA) are appropriate and the calculations have been checked.
8	**Commercial slab on grade multi-storey** Multi-storey slab on grade in SE corner of ORWS site.	Adult workers within building. Only pathway of exposure assessed is vapour inhalation.	This scenario is assessed in the ORWS HHERA Addendum only. Exposures assumptions (Appendix G of ORWS HHERA Addendum) are appropriate and the calculations have been checked. No basement levels are assessed for this scenario.

SSTCs have been derived for chemicals of potential concern (COPC) identified in soil and groundwater. The derived criteria have addressed mixtures of key groups of COPC include BTEX (benzene, toluene, ethylbenzene and xylenes), TPH, CPAHs (carcinogenic PAHs that include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h) anthracene and indeno(1,2,3-cd)pyrene and are assessed based on a toxicity equivalent factor approach), and non-carcinogenic PAHs.

The criteria derived have considered the protection of human health and potential odour issues. While the approach adopted for the assessment of odour issues is considered highly uncertain the outcome of the assessment is generally considered reasonable.

The SSTCs derived on the basis of the approach presented by AECOM (2011b and c) are reasonable provided that the development specific management measures as outlined in the Amended RAP (AECOM 2011d) are implemented.

The HHERA is based on no tar containing materials (TCM) being present, however the HHERA does recognise that while such material may be removed to the extent practical some TCM may remain and will require management in accordance with the Amended RAP to ensure that no TCM seeps into the basement levels.

10.3 Derivation of Environmental SSESCs

SSESCs have been derived for soil and groundwater in areas that remain in hydraulic connection with Darling Harbour, namely Areas A and B. Under the proposed development

Areas C and D will be effectively isolated from Darling Harbour and hence, where there is no hydraulic connection there will be no mechanism for contaminants to migrate to and discharge into Darling Harbour. It is therefore reasonable that no SSESCs are required for these areas.

SSESCs have been derived following a complex process outlined by AECOM (2011b) that can be summarised as:

- Adoption of appropriate marine water quality guidelines (MWQG) as endpoints for the protection of the aquatic environment at the point of discharge into Darling Harbour. The MWQGs adopted are derived from the following:
  - ANZECC (2000) 95% species protection marine water trigger levels
  - ANZECC (2000) 99% species protection marine trigger values for potentially bioaccumulative contaminants
  - Other guidelines that provide a similar level of protection as the ANZECC (2000) trigger values.
- Identification of chemicals of COPC that are present in groundwater or soil leachate (as dissolved phase concentrations following filtration and analysis) that exceeds the MWQG
- Review of the locations of the COPC in Areas A and B, with consideration of the extent of the contamination and co-location of soil and groundwater impacts
- Derivation of groundwater SSESCs based on the MWQGs and application of appropriate dilution attenuation factors (DAFs) that reflect the location of the contamination in relation to Darling Harbour and the potential for a direct hydraulic connection (no dilution) or some dilution with migration to the harbour
- Derivation of soil SSESCs based on the MWQGs and leachate data relevant to the partitioning of contaminants from soil to leachate and subsequent movement and dilution from unsaturated soil to groundwater and/or dilution from saturated soil/groundwater to the harbour. Relevant and appropriate DAFs have been applied depending on the location of the soil and the connection with Darling Harbour.

In addition to the SSESCs, any fill materials considered “suitable” for placement in the top 0.5m of the site, where plants are expected to be grown, are required to meet terrestrial soil criteria (TSC). The TSC (Table T17, Appendix E) are based on the protection of plant/soil health and are adopted from published sources (not derived) and are appropriate for the top 0.5m.

10.4 Application of the SSTCs and SSESCs for the ORWS

The application of the derived criteria presented within the ORWS HHERA Addendum (AECOM 2011c) for Areas A to D) are not defined in the HHERA. The applicability is defined within the Amended RAP (AECOM 2011d, Section 5.3, Table 4) and includes the following:

- Area A (range of proposed uses with the area remaining in hydraulic connection with Darling Harbour):

  - Soil and groundwater SSTCs (termed SSTC-A) for Scenarios 1, 2, 4, 5, 6 and 7
  - SSESCs (termed SSESC-A) for the saturated and unsaturated soil and groundwater within the tidal prism area.
- Area B (for materials to be reused in the Public Domain area and in fill on top of Area A):
  - Soil SSTCs (termed SSTC-B) for Scenarios 3, 4, 5 and 6
  - SSESCs (termed SSESC-B) for the saturated soil to be placed on top of Area A in the unsaturated tidal prism.
- Area C (remaining soil beneath the shallow basement excavation):
  - Soil SSTCs (termed SSTC-C) for Scenario 1.
- Area D (remaining material beneath south east corner of ORWS where a range of uses have been considered):
  - Soil and groundwater SSTCs (termed SSTC-D) for Scenario 1, 2, 3, 4, 5, 6, 7 and 8.

Based on the proposed development and controls, the Auditor considers that the above scenarios are reasonable for the areas defined. In addition the criteria derived and presented within the ORWS HHERA Addendum (AECOM 2011c) for these scenarios and areas are considered reasonable. This is also supported by OEH approval of the risk assessments, subject to Conditions. The criteria are reproduced in Appendix E.

Section 8 of the ORWS HHERA Addendum (AECOM 2011c) includes a large number of conclusions and recommendations that have been incorporated into the Amended RAP (AECOM 2011d). Overall, the conclusions and recommendations presented are supported, with the following additional notes/comments:

1. In relation to recommendation (e): the wording provided by AECOM is

   "*The median groundwater concentrations at the point of discharge to Darling Harbour should, on average, not exceed the MWQC for arsenic, copper, lead, zinc, acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, TPH C_6-C_9 and TPH C_{10} to C_{14}*".

   The wording of this recommendation is poor. However it is expected that it means that the median concentrations of the COPC identified in groundwater at the point of discharge into Darling Harbour need to meet the MWQGs. The SSESCs are based on this underlying condition (i.e. meeting the MWQG at the point of discharge). While AECOM has reduced the larger list of contaminants for which MWQGs have been presented to a small list of COPC, it would be appropriate that any validation of these concentrations would consider median concentrations for all the compounds for which MWQGs have been identified in the HHERA.

2. The assessment is based on no TCM being present, however some TCM cannot be ruled out and the basement design must adequately addresses any areas where TCM may remain. This may include the use of a thicker layer of shotcrete on the sandstone walls of these areas.

Implementation of the SSTCs and SSESCs in the Amended RAP (AECOM 2011d) is generally considered appropriate. Tables T1 and T2 of the Amended RAP (included in Appendix E) provide a summary of the criteria adopted for Areas A to D. These have been reviewed in conjunction with the ORWS HHERA Addendum and the following discrepancies need to be noted in relation to the criteria presented in Tables T1 and T2:

- Table T1:
  - SSTC-D, a value (22,000 mg/kg) is missing for vanadium from Scenario 6
  - SSESC-A (unsat), the value for lead is listed as 1800 mg/kg, but is in the ORWS HHERA the value is listed as 1700 mg/kg (same as for SSESC-B). This may be due to rounding of the values but is a minor inconsistency in the values presented.
- Table T2:
  - The criteria presented in the table are correct, however for SSTC-D, Scenarios 1,3,4,5,6,7 and 8 are listed as relevant at the top of the columns however only criteria for Scenario 8 are listed. In this area the criteria considered should essentially be the lower of SSTC-A and SSTC-D.

11 Evaluation of Soil Analytical Results Against Risk Based Remediation Criteria

11.1 Introduction

AECOM (2011d) compared all soil data from the site against the relevant risk based remediation criteria, discussed in Section 10, to determine Confirmed Impacted Material (CIM) at the site. The relevant criteria are included in Appendix E. They then followed the Remediation Decision Making Process Flow Chart (refer Attachment 8, Appendix A) to determine the extent of remediation required for each area of CIM identified.

The Auditor has reviewed the data and analysis presented by AECOM (2011d). The results are summarised in the following sections according to the four different site areas/ material types, Areas A to D (refer Section 10). Additional consideration is given to the presence of asbestos in soil. Samples from above 2mBGL were compared with $SSESC^{unsat}$ criteria while samples from below 2mBGL were compared with $SSESC^{sat}$ criteria.

11.2 Area A

No TCM was identified in Area A.

Exceedances of the SSTC-A and SSESC-A are summarised in Table 11.1.

Table 11.1: Assessment of Area A Soil Results Against Risk Based Criteria

COPC	Exceedances	Statistical Analysis/ Discussion	Consideration of Remedial Extent
arsenic	18/93 samples exceed $SSESC\text{-}A^{sat}$	95% UCL of 6.8mg/kg exceeds $SSESC\text{-}A^{sat}$ of 5mg/kg.. UCL calculation unreliable due to non-detects in 82% of samples, LOR = 5mg/kg.	All arsenic concentrations in groundwater below groundwater SSESC-A. AECOM concluded remediation not required
	5 clay samples exceed $SSESC\text{-}A^{sat}$	Groundwater flux in natural clay is negligible, concentrations detected are probably naturally occurring	AECOM concluded remediation not required
copper	17/93 samples exceed $SSESC\text{-}A^{sat}$	95% UCL of 32.6mg/kg below $SSESC\text{-}A^{sat}$ of 42mg/kg	AECOM concluded remediation not required
	14/27 samples exceed $SSESC\text{-}A^{unsat}$	95% UCL of 290mg/kg exceeds $SSESC\text{-}A^{unsat}$ of 170mg/kg	CIM present in unsaturated fill. Further consideration given to: • Infiltration and therefore leaching will be limited by maintaining hardstand and placement of

Table 11.1: Assessment of Area A Soil Results Against Risk Based Criteria			
COPC	**Exceedances**	**Statistical Analysis/ Discussion**	**Consideration of Remedial Extent**
			additional material (beneficial reuse) • Detected concentrations have not resulted in impact to groundwater significantly exceeding remediation criteria (refer Section 12) • Overall reduction in contaminant mass due to excavation of the majority of fill from the site • Environmental impact from remediation works if performed (ESD). AECOM concluded remediation not required
	3 clay samples exceed SSESC-A^{sat}	Groundwater flux in natural clay is negligible, concentrations detected are probably naturally occurring	AECOM concluded remediation not required
lead	3/93 samples exceed SSESC-A^{sat}	95% UCL of 155mg/kg below SSESC-A^{sat} of 440mg/kg	AECOM concluded remediation not required
zinc	76/93 samples exceed SSESC-A^{sat}	95% UCL of 117mg/kg above SSESC-A^{sat} of 55mg/kg	Further consideration given to: • Median concentration in groundwater less than groundwater SSESC-A (refer Section 12) • Overall reduction in contaminant mass due to excavation of the majority of fill from the site • Environmental impact from remediation works if performed (ESD). AECOM concluded zinc not representative of CIM and remediation not required
TPH C10-C14	1 sample marginally exceeds SSESC-A^{sat}	Vast majority of samples were less than laboratory reporting limit Detection has not resulted in impact to groundwater above remediation criteria (refer Section 12)	AECOM concluded remediation not required
CPAH	3/127 samples exceed SSTC-A	Detections have not resulted in impact to groundwater above remediation criteria (refer Section 12)	AECOM concluded remediation not required

Based on review of the analytical data against the site specific remediation criteria, and in considering the justification presented by AECOM (2011d), the Auditor is satisfied that remediation of soils proposed to be retained in situ in Area A is not required.

11.3 Area B

No TCM was identified in Area B.

Exceedances of the SSTC-B and SSESC-B were detected for heavy metals, PAH and TPH. The most frequent exceedances were for copper and phenanthrene where up to 10% of the samples exceeded the criteria. All of this material is proposed to be excavated as part of the site development. AECOM (2011d) has estimated that between 10 and 20% of the Area B material will not be suitable for beneficial reuse on site within the Public Domain (South) and will require treatment/ validation for beneficial use and/ or offsite disposal. Excavation staging plans to address the destination of these materials will be provided in the Remedial Work Plan technical specification.

11.4 Area C

No TCM was identified in Area C.

As discussed in Section 10, soil SSTC and SSESC are not applicable to the remediation requirements for Area C.

11.5 Area D

Only one existing investigation location falls directly within Area D. AECOM (2011d) made reference to results from nearby investigation locations as also being representative of soil quality at Area D which is considered appropriate. No TCM was identified in Area D and all analytical results were below the SSTC-D. The results to date indicate that remediation at Area D is not likely to be required, however, further investigations (in situ validation) are proposed in this area to ensure adequate characterisation of the fill material and to confirm this finding. The proposed investigations are discussed as a validation item in Section 13.

11.6 Asbestos

Risk based remediation criteria were not developed for asbestos since it does not present a risk to the environment, and is only a risk to human health in the event that soils are disturbed and there is direct exposure. As an alternative, a management approach has been adopted for asbestos. As discussed in Section 8.3.4, only limited characterisation for asbestos was conducted for fill materials at the site. There is a high potential for undetected asbestos to be present in the fill, most likely associated with AC fragments that may not have been observed during the drilling investigations performed. This is an issue that requires management during remediation, and will need to be considered in the event of future site redevelopment in areas where fill potentially impacted by AC is to be retained.

The need for inspection for, and management of, AC materials during the proposed remediation, and consideration of future site redevelopment has been addressed in the Amended RAP (AECOM, 2011d), discussed in Section 13.

11.7 Conclusion

In the Auditor's opinion, the extent of soil remediation and the approach to management of asbestos in soil defined in the Amended RAP (AECOM, 2011d) is considered appropriate. Discussion of the proposed remediation, validation and future management issues is provided in Section 13.

12 Evaluation of Groundwater Analytical Results Against Risk Based Remediation Criteria

12.1 Introduction

AECOM (2011d) compared the 2010 groundwater data from the site against the relevant risk based remediation criteria, discussed in Section 10, to determine Confirmed Impacted Material (CIM) at the site. They then followed the Remediation Decision Making Process Flow Chart (refer Attachment 8, Appendix A) to determine the extent of remediation required for each area of CIM identified.

The Auditor has reviewed the data and analysis presented by AECOM (2011d). The results are discussed in the following sections according to the four different site areas, Areas A to D (refer Section 10).

12.2 Area A

The following groundwater wells were considered to represent the groundwater quality within Area A: EMW10, 16, 17, 18 and 20.

Exceedances of the SSTC-A and SSESC-A are summarised in Table 12.1:

Table 12.1: Assessment of Area A Groundwater Results Against Risk Based Criteria

COPC	Exceedances	Statistical Analysis/ Discussion	Consideration of Remedial Extent
copper	3/5 samples exceed SSESC-A	Median concentration of 7μg/L exceeds SSESC-A of 6.5μg/L Insignificant exceedance, results are considered consistent with the requirement for median groundwater concentrations.	AECOM concluded remediation not required
zinc	2/5 samples exceed SSESC-A	Median concentration of 36μg/L below SSESC-A of 75μg/L Results are considered consistent with the requirement for median groundwater concentrations.	AECOM concluded remediation not required

Based on review of the analytical data against the site specific remediation criteria, and in considering the justification presented by AECOM (2011d), the Auditor is satisfied that active remediation of groundwater in Area A is not required.

12.3 Area B

As discussed in Section 10, groundwater SSTC and SSESC are not applicable to the remediation requirements for Area B

12.4 Area C

The following groundwater wells were considered to represent the groundwater quality within Area C: AMW08, 09, 17, 19, 21, 26 and EMW09, 16, 17, 18, 20, 21. AECOM (2011d) did not

consider results from AMW12 which would also be relevant, however, no significant detections were made in this well therefore inclusion of this data would not affect the findings.

Only one detection exceeded the SSTC-C, being naphthalene at a concentration of 4400μg/L compared to the SSTC-C of 920μg/L in location AMW08 in the northeast of the site. The median concentration was well below the SSTC-C. This well is within the area discussed as Zone 1 (refer Section 8 and 9) and is considered to represent a localised area of soil and groundwater impact, primarily located to the east of the Shallow Basement area (Area C). MW08 and the remainder of Zone 1 will be excavated for the proposed Deep Basement area.

AECOM (2011d) consider that remediation of groundwater in this area is not required since:

- significant source removal works will be included as part of the proposed development plans
- as a result, groundwater quality would be expected to improve
- the impacts are considered to be localised and not indicative of broader impacts in Area C
- the assumptions made in development of the SSTC-C assumed seepage of groundwater into the basement across much larger areas, and therefore the localised elevated concentration is not considered to pose an unacceptable risk.

AECOM (2011d) considered this result to represent a localised area and not representative of CIM. Based on review of the analytical data against the site specific remediation criteria, and in considering the justification presented by AECOM (2011d), the Auditor is satisfied that active remediation of groundwater in Area C is not required.

12.5 Area D

No groundwater monitoring has been undertaken in Area D. Comparison of results from the closest well (AMW21) did not indicate any exceedances of the SSTC-D. The results to date indicate that remediation at Area D is not likely to be required, however, further investigations (in situ validation) are proposed in this area to ensure adequate characterisation of the fill material and to confirm this finding. The proposed investigations are discussed as a validation item in Section 13.

12.6 Conclusion

Active remediation of groundwater is not proposed by AECOM (2011d). Groundwater contamination is proposed to be addressed by source removal/ containment. In the Auditor's opinion, the approach to management of groundwater contamination defined in the Amended RAP (AECOM, 2011d) is considered appropriate. Discussion of the proposed remediation, validation and future management issues is provided in Section 13.

13 Evaluation of Proposed Remediation

13.1 Remediation Strategy and Methodology Overview

The Original RAP identified materials classified as Potential Impacted Material (PIM) by comparison of results with generic screening criteria. Remediation criteria were subsequently developed (refer Section 10), which have been used to determine Confirmed Impacted Material (CIM) that requires remediation due to potential risks to human health or the environment (refer Section 11 and 12).

The Amended RAP includes a Remediation Decision Making Process Flow Chart (refer Attachment 8, Appendix A) which outlines the process for determining the fate and remediation requirements (if any) for PIM. The flow chart indicates how the remediation criteria were applied in determining the required remediation (refer Sections 11 and 12).

Since the site development will require extensive excavation for basements, soil falling within proposed basement areas is required to be excavated from the site regardless of contamination status (Area B). There is proposed to be beneficial reuse of material in the Public Domain (South), where the ground level is to be raised by about 1m. Material will only be reused in ORWS if it meets the acceptance criteria without treatment. Material that cannot be reused will be treated (if required) and disposed offsite. Reused at other areas of Barangaroo including Headland Park will require an addendum to the RAP. Excavation will be supervised and CIM will be segregated based on the results of previous and proposed investigations as well as visual and olfactory evidence of contamination.

No CIM outside the proposed basement excavation areas has been determined to require excavation (refer Section 11 and 12), however, there is some potential that additional remediation (excavation) may be required in Area D based on the results of validation sampling during remediation. Some material within Areas A and C is acceptable to remain on site managed via *in situ* containment that prevents exposure pathways, as follows:

- Between the existing caisson wall and the basement groundwater retention system, and below existing concrete and asphalt hardstand (Area A)
- Within the basement groundwater retention system (Area C).

In summary, the overall remediation approach for the site involves retention of some materials on site, and excavation of soil from basement areas followed by:

- reuse on site within the Public Domain (South) it meets the reuse criteria without treatment
- offsite disposal to a licensed landfill, with treatment if required
- reuse within other areas of Barangaroo if it meets applicable reuse criteria, which will require a RAP addendum.

Ex situ treatment may be required for offsite disposal (with appropriate approvals) or to meet reuse criteria at other areas of Barangaroo. The treatment facility will be located in a central location within Barangaroo, not on the ORWS site.

This review does not consider the reuse of materials at Headland Park or other areas of Barangaroo. An Addendum to the Amended RAP would require approval by OEH if these beneficial reuse options are contemplated.

The Amended RAP proposes groundwater monitoring during and post-remediation for assessment against groundwater MWQC, SSTCs and SSESCs, however, active groundwater remediation is not proposed.

13.2 Excavation and Reuse Process

13.2.1 Overview

The Amended RAP describes the steps to be taken in the excavation and reuse process, including physical separation of recyclable and oversize material, stockpiling, ex situ treatment (if required) and validation. AECOM (2011d) state that "Excavations will be regularly inspected by a suitably experienced environmental engineer or scientist to confirm that the visual and olfactory characteristics of the excavated materials are consistent with expectations... These regular inspections will also serve to identify additional hotspots of CIM that may not otherwise have been identified by the site investigations conducted to date". Depending on the level of contamination in excavated material (relative to the SSTCs and SSESCs), AECOM (2011d) report that excavated CIM will be either:

- "transferred to the ex-situ treatment facility for treatment;
- transferred to stockpile pending ex situ treatment for beneficial reuse
- transferred to stockpile pending beneficial reuse in Public Domain (South)
- transferred directly to landfill in accordance with the appropriate waste tracking requirements".

In the event that material is unsuitable for beneficial reuse it will be designated for off-site recycling (eg, steel, concrete, brick, rock and timber) or disposal. Materials to be disposed will be classified in accordance with the DECC (2008) 'Waste Classification Guidelines'.

13.2.2 Remedial Work Plan

AECOM (2011d) report that a Remedial Work Plan (RWP) will be prepared to detail the options for beneficial reuse of material excavated from ORWS. The RWP will:

- provide a technical and staging specification for LLMP and its Remediation Contractor to assist in delivery of the bulk excavation works
- provide excavation plans for the Shallow and Deep Basement area bulk excavation works
- detail beneficial reuse and staging options for excavated Area B material.

The RWP will not provide further information regarding the contamination status of the site, and therefore it is not required for review in order to complete the current audit.

13.2.3 Materials Tracking

The Amended RAP (AECOM, 2011d) describes a materials tracking process to allow verification of the correct movement and handling of all materials handled during the

remediation works. Standard forms will be prepared as part of a Materials Tracking Procedure to be included in the RWP. The process includes registered survey of stockpiles to reduce the risk of cross contamination and a series of forms including:

- Off-site Transport/Disposal Form
- Imported Fill Form
- Material Excavation Form
- Material Treatment Form
- Material Stockpiling Form
- Material Placement Form.

Of relevance for the future suitability of the ORWS site is the appropriate tracking of materials to be reused within the Public Domain (South).

13.3 Evaluation of Remedial Action Plan

The Auditor previously assessed the Original RAP for the site (AECOM, 2010b), documented in a letter dated 3 June 2010. An Amended RAP has since been prepared (AECOM, 2011d) based on the results of additional investigations. The Auditor has reviewed the Amended RAP by comparison with the checklist included in EPA (1997) 'Guidelines for Consultants Reporting on Contaminated Sites'. The Amended RAP was found to adequately address the required information for all items, as detailed in Table 13.1, below.

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
Remedial Goal RAP s1.1	The key objective of the remediation is "to facilitate the future land-use proposed as part of the Barangaroo Stage 1 Development Works. Additional objectives of the remediation works are: • To ensure the remediated site is protective of human health in the context of the intended future land use; • To protect the environment (specifically groundwater and the adjacent Darling Harbour) by remediation of the Site to a standard that will minimise the risk of ongoing contamination; • Comply with applicable legislative requirements including the appropriate requirements of the NSW Department of Planning (DoP) and DECCW (now NSW OEH]); and • To maximise the beneficial reuse of excavated material from the basement excavations within the Public Domain (South)".	The identified remedial objectives (remedial goal) are considered appropriate.
Discussion of the extent of remediation required	As discussed in Sections 11 and 12 of this SAR, CIM was defined based on screening of soil and groundwater results against the SSTC and SSESC. The remediation extent was then	The defined extent of remediation is considered appropriate as discussed in Sections 11 and 12 of this

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
RAP s6 discussion of CIM RAP s7 discussion of remediation extent	determined based on: • implementation of the Remediation Decision Making Process Flow Chart • consideration of the proposed basement designs and land uses and the location of the associated basement groundwater retention wall system • consideration of the principals of CUTEP and ESD. The remediation extent was defined as follows: **Area A:** No remediation required **Area B:** All material to be excavated for basement. 10-20% of material is likely to be unsuitable for reuse within the Public Domain (South), therefore requiring treatment/ validation and/or offsite disposal. Detailed plans for Area B material are to be documented in the RWP. **Area C:** No remediation required **Area D:** Remediation not likely to be required based on limited investigation. Further characterisation/ validation investigations are proposed to confirm. Auditor approval will be sought for any remediation requirements determined for Area D.	SAR. Any remediation requirements for Area D will be determined after validation.
Remedial Options RAP s8	The Amended RAP includes a remedial technology assessment including consideration of numerous in situ and ex situ remedial technologies. A screening assessment was performed, and more detailed consideration was given to five remedial technologies: 1. Excavation and ex situ thermal desorption (on site) 2. Excavation and ex situ thermal desorption (off site) 3. Excavation and ex situ stabilisation or solidification 4. Excavation and surfactant enhanced ex situ chemical oxidation 5. Physical containment.	The assessment of remedial options is considered adequate.
Selected Preferred Option RAP s9	The Amended RAP defines the preferred management strategy for each area which comprises a combination of: • Excavation for proposed basements, including removal of CIM as part of the proposed excavations (Area B), or excavation of CIM, if found (Area D), then: • beneficial reuse of material, to the extent	The selected preferred management options are considered appropriate.

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
	possible, within the Public Domain (South), or • offsite disposal of surplus material to licensed landfill (including treatment if required) • Retention of material in situ, either: • Between the existing caisson wall and the basement groundwater retention system, and below existing concrete and asphalt hardstand (Area A), or • Within the basement groundwater retention wall system (Area C).	
Rationale RAP s9	The selected preferred management strategy was justified for each area based on feasibility and sustainability considerations.	The rationale presented is considered appropriate.
Proposed Validation Criteria RAP s5	The proposed validation criteria are the remediation criteria (SSTCs and SSESCs) discussed in Section 10 of this SAR. An 'overall' validation criteria for the site remediation works is considered to be that the median groundwater concentrations at the point of discharge to Darling Harbour should, on average, not exceed the relevant MWQC for arsenic, copper, lead, zinc, acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, TPH C_6-C_9 and TPH C_{10} to C_{14} (AECOM, 2011c).	The defined remediation/ validation criteria are considered appropriate as discussed in Section 10 of this SAR.
RAP s16.1	Statistical validation is proposed. For soil, the 95% UCL will be used to assess the mean concentrations of chemicals of potential concern (where appropriate). Data sets will be defined for different areas and different strata. The statistical criteria outlined in NEPM (1999) Schedule B7a are proposed. For groundwater, median concentrations have been compared to the area-specific remediation criteria, and median concentrations will be considered for future monitoring within the tidal zone.	The statistical validation proposed is considered acceptable provided data sets are representative. It is noted that statistical validation should not be applied when considering the Terrestrial Soil Criteria for potential impacts to vegetation plantings, ie, for soil for plantings in top 0.5m in the Public Domain (South).
Proposed Validation Testing RAP s16	The Amended RAP incorporates the following validation approach: • A suitably qualified consultant will undertake the supervision and validation of the remedial works • Excavation faces and excavated material will be assessed for visual and olfactory evidence	General validation approach is considered appropriate.

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
	of potential contamination, and field screening of samples for volatile organic compounds will be undertaken using a PID • Samples will be collected on a grid basis, however, locations will be biased towards material identified to be the most impacted.	
RAP s16.3	Soil validation sampling is proposed at various stages of the remediation works. The proposed soil sampling is summarised in Table 13.2, below.	The approach to validation sampling is considered reasonable. While the various sampling densities (eg, 1 per 400m^3) appear adequate, confirmation of their adequacy will depend on the results obtained and their consistency.
RAP s14.4	Quarterly groundwater monitoring is proposed during remediation works to build a robust data set for groundwater quality at the site and to demonstrate that the continuing remediation works are not having a detrimental impact on the environment. Quarterly post-remediation groundwater monitoring is also proposed for a period of two years. A summary of the proposed monitoring is provided in the Amended RAP, as follows: • Installation of 5 new groundwater monitoring wells within the tidal prism in Area A • all groundwater samples will be analysed for the Area A COPC (Table T2 in Appendix E), including: - Metals (arsenic, copper, lead, zinc) - PAH (anthracene and phenanthrene) - TPH C_6-C_9 and TPH C_{10} to C_{14} • results will be compared with the MWQC. Further details are to be provided in a groundwater monitoring plan (GMP). An outline of the GMP contents is included in the Amended RAP. Auditor approval will be sought for the GMP prior to implementation.	The summary of the proposed monitoring and outline of the GMP is considered acceptable. The proposed analytical suite does not include all of the PAH listed for the groundwater validation criteria. The reduced suite of PAH is based on the COPC determined for Area A (discussed in Section 10). Given the role of the groundwater monitoring for overall site validation, analytical results for the full suite of PAH compounds should be reviewed to verify the assumptions in the ORWS HHERA Addendum (AECOM, 2011c) are correct and that other PAH in groundwater are not increasing in concentration. This should be included in the GMP (to be prepared).
RAP s16.4, 16.6, 16.7	The Amended RAP details the proposed soil and groundwater sampling methods, with groundwater methods to be confirmed in the GMP). A discussion of data quality objectives (DQOs), QA/QC samples and control limits for data quality indicators (DQIs) is also provided.	The proposed sampling methods are considered appropriate. The QA/QC information outlined is considered acceptable.
RAP s16.2	The Amended RAP describes a validation process to confirm that key assumptions regarding the	The proposed approach to validation of key risk

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
	proposed development and on which the ORWS HHERA Addendum was based have been or will be implemented. Review of "issue for construction" or "as constructed" drawings is proposed to achieve this. A review is also proposed to assess the implications of any changes to the design of the depth of basements and/or the final alignment of the basement groundwater retention wall system. Any significant changes to the final development plans will require confirmation that: • The analytical data set and sampling density for the materials of potential concern (specifically Area A, Area B and Area D materials [as appropriate]) are adequate for assessing the suitability of the materials affected by the design changes • Any required additional site investigations are suitable to supplement the current analytical data set. If required, the scope of these works will be endorsed by the NSW OEH Accredited Site Auditor • Confirmation that the assumptions of the ORWS HHERA Addendum are still valid. In order to manage the impact of potential changes to the development design, AECOM (2011d) proposes to revise the Amended RAP and the ORWS HHERA Addendum if the final development design is changed from the assumptions, as discussed in Section 13.4, below.	assessment and remedial design assumptions is considered appropriate.
Interim Site Management Plan (before remediation)	None proposed.	Not required since the site is currently vacant.
Site Management Plan (operation phase) including stormwater, soil, noise, dust, odour and OH&S RAP s12, 13, 14, 17 remediation procedures and EMP	The Amended RAP outlines environmental protection measures proposed to be implemented in relation to materials management, treatment systems, water management and other aspects such as odours, dust, noise and vibration. In particular, a Remediation Enclosure is proposed to be used when excavating particularly odourous materials, and the ex situ treatment facility is also proposed to be enclosed, with both enclosures to be fitted with Emissions Control Systems. For ORWS, odourous material necessitating use of a Remediation Enclosure is expected to be encountered during excavation of the Block 3 area. Minimum standard occupational health and safety (OH&S) measures are also outlined in the	The outline measures are considered appropriate. The level of detail provided is considered appropriate for the Amended RAP.

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
RAP s18 OHS	Amended RAP. A site-specific Environmental Management Plan (EMP) and OH&S Plan are to be developed prior to commencement of the works. Assessment of air quality and noise and vibration impacts is also proposed.	
Contingency Plans to Respond to site Incidents. RAP s20	The Amended RAP identifies a number of potential operational contingency issues and outlines proposed responses.	Contingency measures are considered appropriate.
Contingency Plan if Selected Remedial Strategy Fails RAP s20 RAP s14.4.2	The Amended RAP identifies a number of potential contingency issues relating to the success of the remediation, and outlines the proposed approach to these. Issues identified include: • Increased volumes of contaminated material • Presence of contaminated material at greater depth • Variation of contaminant characteristics • Bonded asbestos containing material (BACM) is encountered • Failure of the preferred treatment approach • Insufficient storage capacity for stockpiling • Change of the basement design and associated basement groundwater retention wall system alignment • Failure of visual validation (with respect to surface water sheen and tar containing materials) • Area A groundwater quality does not meet the MWQC in post remediation monitoring.	The issues identified and proposed responses are considered reasonable. Outline information is provided for the Area A groundwater quality contingency. Details of potential contingency measures are not provided, for example, methods for active groundwater remediation. These should be expanded upon in the GMP (to be prepared). The Auditor is satisfied that groundwater remediation technologies exist that may be applied in this event, and therefore further detail is acceptable to be provided at a later date.
Remediation Schedule and Hours of Operation RAP s10.2	The Amended RAP outlines the task-wise project schedule however the project duration is not specified. The detailed work program is proposed to be prepared prior to site establishment. Hours of operation are not discussed in the Amended RAP.	The identified tasks appear appropriate. The level of detail provided is considered appropriate for the RAP. Operational hours will be required to be in accordance with the development approval.
Licence and Approvals	The Amended RAP outlines the relevant legislation and planning approvals required for the remediation works. The proposed remediation is expected to	The identified approvals and waste classification process appear appropriate.

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
RAP s2	comprise soil treatment of a volume <30,000m^3 within the larger Barangaroo site area (therefore "on site"), therefore AECOM considers that an Environment Protection License (EPL) is not likely to be required under the NSW *Protection of the Environment Operations Act 1997* (POEO Act). If soil treatment works are required, and depending on the quantity of treatment required in association with other parts of Barangaroo, a variation of the existing EPL for the Barangaroo site may be required. The Amended RAP outlines the requirements of SEPP 55 with respect to the definition of Category 1 remediation, which requires development consent. The Amended RAP does not identify if the remediation works are classified as Category 1, however, notes that planning consent is required for the proposed remediation works as a condition of the Director Generals Requirements for the Blocks 1 to 3 Bulk Excavation and Basement Car Parking Development Application. Conditional planning consent was granted by the DOP on 2 November 2010. Discharge to stormwater or sewer, with or without treatment, is proposed as per regulatory guidelines and in accordance with a POEO license and Trade Waste License. Materials to be disposed off site will be assessed in accordance with the DECC NSW (2008) 'Waste Classification Guidelines Part 1: Classifying Waste' or Part 4 of those guidelines in the case of potential ASS (PASS) and ASS. If stabilisation of excavated material is required to facilitate offsite disposal, the required Immobilisation Approvals will be obtained. Further, if treatment of soils is required *Protection of the Environment Operations Act 1997* (POEO Act) licence is required. Imported fill is required to be VENM or ENM as defined in the NSW *Protection of the Environment Operations (Waste) Regulation 2005*. Any BACM encountered will be collected and disposed of by a licensed Asbestos Removal Contractor in accordance with the requirements of the NSW WorkCover the NSW Occupational Health & Safety Regulation Act (2001) and the requirements of the NSW Occupational Health and Safety Commission (NOHSC) Asbestos Code of Practice and Guidance Notes.	It is noted that the need for a POEO license is not confirmed.

Table 13.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
Contacts/ Community Relations RAP s19	The Amended RAP provides a summary of the Initial Community and Stakeholder Engagement Strategy prepared by LLMP (August 2010) that will be implemented for delivery of the remediation works at the site.	The level of detail provided in the Amended RAP is considered appropriate.
Staged Progress Reporting s16.8	The Amended RAP anticipates staged validation reporting according to Blocks 1, 2, 3 and Public Domain. Validation reporting is proposed in accordance with the EPA (1997) 'Guidelines for Consultants Reporting on Contaminated Sites".	Considered acceptable.
Long term site management plan RAP s17.5	The Amended RAP anticipates that "… a Site Management Plan may be required to describe contingency management methods which may need to be applied by future land owners if they wish to re-develop their Barangaroo Stage 1 Development Area beyond the area affected by the Remediation and Development Works undertaken at the Site". The SMP is to be prepared as an outcome of the site validation and in consultation with the Site Auditor.	In the Auditor's opinion, a Site Management Plan for future land owners will be required.
	The Amended RAP states that no other form of Long Term Management Plan is envisaged "on the basis that both the key assumptions and requirements of this Amended RAP and the ORWS HHERA Addendum … are successfully delivered and implemented during the execution of the works, and validated accordingly upon completion".	The Auditor agrees that no active Long Term Management Plan should be required if the Amended RAP is implemented and validated successfully, beyond maintenance of ventilation and seepage control systems. Other elements requiring management may include maintenance of clean surface soil.
	Quarterly post-remediation groundwater monitoring is proposed for a two year period for assessment against groundwater SSTCs. Monitoring is proposed in accordance with a Post-Remediation GMP, proposed to be prepared prior to completion of the remediation works in consultation with the Auditor (Amended RAP Section 14.4). The GMP will make provision for any necessary management measures (contingency measures) that may be required to respond to the monitoring results	Development of the Post-Remediation GMP in consultation with the Auditor is considered appropriate.

Table 13.2: Summary of Proposed Soil Validation

Area	Item	Proposed Validation Method	Analytes	Soil Criteria
A	Limited excavation areas, for service trenches	Visual inspection, free of BACM If visual/ olfactory indicators differ to expected: 1/10 m wall samples 1/10m or 10m grid base samples Sample locations to be selected based on field indicators/ PID	A-COPC and asbestos	SSTC-A and SSESC-A
	Retained fill	None required, adequately characterised/ validated	-	-
B	Untreated soil for reuse in Public Domain (South)	Visual inspection free of BACM If visual/ olfactory indicators differ to expected: 1/400m^3	B-COPC and asbestos	SSTC-B and SSESC-B
	Treated soil for offsite disposal	1/400m^3 Higher frequency if required by Immobilisation Approval Potential for reduced frequency if results consistent	B-COPC and asbestos	DECC (2008) 'Waste Classification Guidelines'
C	Retained fill	None required, adequately characterised/ validated	-	-
	Bedrock exposed in the base of the Deep Basement excavation	Visual inspection free of BACM Visual inspection generally free of tar containing material (TCM)	-	-
	Fill exposed in the base of the Shallow Basement excavation	Visual inspection free of BACM Removal of any tar or TCM	-	-
D	Retained fill	4 boreholes extended 1.5m into natural clay (estimated at 6.5mBGL) or refusal on bedrock Soil samples at 1.5m intervals Assess need for groundwater investigations based on soil results 2 groundwater wells if required	D-COPC and asbestos (soil only)	SSTC-D
Treatment and stockpiling areas (located offsite in	Hardstand	Visual inspection for any contamination relating to treatment operations	-	-
	Soil beneath hardstand if contamination of	20m grid samples 0-0.15m depth	B-COPC	Relevant ORWN criteria (to be

Table 13.2: Summary of Proposed Soil Validation				
Area	**Item**	**Proposed Validation Method**	**Analytes**	**Soil Criteria**
ORWN)	hardstand present			determined)
Entire site	Imported material – VENM/ quarry product	VENM certificate demonstrating physical and chemical quality, including supporting test data Inspection at importation to confirm consistent and no evidence of contamination	-	VENM criteria, SSTC-B and SSESC-B and TSC depending on the depth the material will be placed.
	Imported material – non quarry product (including landscaping products such as mulch)	Inspection of source site Sample at 1/100m^3 or minimum 3 samples per source Inspection at importation to confirm consistent and no evidence of contamination	HM, PAH, phenols, TPH, BTEX, OPP, OCO, PCB, asbestos	ENM criteria, SSTC-B and SSESC-B and TSC depending on the depth the material will be placed.

In the Auditor's opinion, the remediation and validation approach recommended by AECOM are appropriate. The proposed remediation strategies for the ORWS site are generally consistent with the Overarching RAP.

13.4 Additional Remediation Documentation

AECOM (2011d) identify the following supporting documentation that will be prepared prior to commencement of the remediation works:

- Remedial Work Plan (RWP)
- Occupational Health and Safety Plan (OH&S)
- Community Consultation Plan
- Environmental Management Plan
- Project Management Plan
- Quality Management Plan
- Emergency Response and Contingency Plan.

Other remediation documentation or further studies referenced throughout the RAP (AECOM, 2011d) include:

- operation and maintenance management systems for the Remediation Enclosure and Emissions Control System, to be developed on completion of the final design of the system
- an Air Quality Impact Assessment
- a noise and vibration assessment.

Review of these studies and other documentation relating to the site operations is not required by the Site Auditor since these issues are not related to site suitability and are outside the Site Auditor's area of expertise. Specialist peer review or review by the regulator may be warranted.

Monitoring/ management documentation relating to the site suitability that does require review by the Site Auditor is proposed as follows:

- a Post-Remediation Groundwater Monitoring Program (GMP), to be developed prior to completion of the basement groundwater retention wall system and in consultation with the Site Auditor
- A Site Management Plan (SMP) to describe contingency management methods which may need to be applied by future land, to be prepared as an outcome of the site validation.

The Amended RAP (AECOM, 2011d) notes that "If the final development design is changed from the assumptions in the ORWS HHERA Addendum and this Amended RAP, an Addendum will be issued to:

- confirm that any revised design is consistent with the criteria and methodology of the ORWS HHERA Addendum and this Amended RAP; or
- revise the ORWS HHERA Addendum and this Amended RAP, where required, to adequately account for the design changes.

The Addendum will be prepared, as required, and submitted to the NSW OEH/ Site Auditor for approval agreement".

This is considered an appropriate means to manage potential changes to the development design.

13.5 Conclusion

In the Auditor's opinion, the proposed remediation and validation approach described in the Amended RAP (AECOM, 2011d) is appropriate. The proposed remediation strategies for ORWS are consistent with the Overarching RAP.

A Remedial Work Plan (RWP) is proposed to be prepared to detail the options for beneficial reuse of excavated material. The RWP will not provide further information regarding the contamination status of the site, and therefore it is not required for review in order to complete the current audit. Beneficial reuse other than on ORWS will require a RAP Addendum.

Site Auditor review of a Post-Remediation Groundwater Monitoring Program (GMP) and a Site Management Plan (SMP) for future land owners are required. These documents are to be prepared based on the final design of the basement groundwater retention wall system and as an outcome of the site validation, respectively. This approach is considered appropriate and review of these documents is not required to complete the current audit.

If significant changes are made to the development design, or if beneficial reuse of excavated material outside ORWS is possible, AECOM (2011d) proposes to prepare the following documents for approval by OEH and the Site Auditor:

- revision of the Amended RAP and the ORWS HHERA Addendum if the final development design is changed from the assumptions used in the development of risk based criteria or the remedial design
- preparation of an Addendum to the Amended RAP if beneficial reuse of excavated material at Headland Park or other areas of Barangaroo is an available option.

This is considered an appropriate approach to management of significant changes to the development design and the potential for beneficial use of excavated material outside the ORWS site.

14 Contamination Migration Potential

The potential for offsite migration of contamination from the site relates to the leaching potential of contaminants from soils and the movement of groundwater from the site to Darling Harbour. These factors have been addressed in the development of site specific remediation criteria (Section 10) and the Groundwater Discharge Study (AECOM, 2010d, Section 5.2.2).

In the Auditor's opinion, completion of the remediation works as described in Section 13 will minimise the potential for future offsite migration of contamination from the site. Post remediation groundwater monitoring in Area A is proposed.

15 Assessment of Risk

Potential risks to human health and the environment have been addressed through the development of site specific remediation criteria (Section 10) and the design of the remediation works (Section 13).

Following implementation of the Amended RAP, there is potential for odorous soils or AC fragment to be encountered during any future disturbance of fill soils to be retained within Area A and Area D. AECOM (2011d) proposes development of a Site Management Plan (SMP) to describe contingency management methods which may need to be applied by future land owners. The SMP is to be prepared as an outcome of the site validation. An SMP is considered an appropriate means to manage any future risk from contamination.

16 Ongoing Site Management

Following implementation of the Amended RAP, ongoing operational site management is not anticipated to be required beyond maintenance of ventilation and seepage control systems, however, a SMP will be prepared to cover future redevelopment of the site. The SMP is to be prepared as an outcome of the site validation. Implementation of the SMP is likely to be a condition of suitability on a Section A Site Audit Statement certifying suitability for the proposed use. An SMP is considered an appropriate means to manage any future risk provided the document is practical and legally enforceable.

17 Compliance with Regulatory Guidelines And Directions

Guidelines currently approved by the EPA under section 105 of the NSW *Contaminated Land Management Act 1997* are listed in Appendix C. The Auditor has used these guidelines.

The investigations were generally conducted in accordance with SEPP 55 Planning Guidelines and reported in accordance with the EPA (1997) 'Guidelines for Consultants Reporting on Contaminated Sites'. A checklist based on that document was used in reviewing the reports. The EPA's 'Checklist for Site Auditors using the EPA Guidelines for the NSW Site Auditor Scheme' has also been referred to.

NSW Planning Director General's Requirements included that Remedial Action Works Plans be prepared for relevant sections of Barangaroo, and clearly demonstrate that the site will be remediated to a standard commensurate with the site use. Lend Lease Statement of Commitments included that Lend Lease will obtain a Section B Site Audit Statement for the proposed remediation works. This Site Audit Report and attached Site Audit Statement have been prepared to fulfil that commitment.

Regulatory approvals and licenses required for the proposed remediation works are discussed in Table 13.1.

18 Conclusions and Recommendations

AECOM (2011d) concluded in the Amended RAP:

> *"It is concluded that the preferred remediation approach described by this RAP, upon successful implementation, will make the Site suitable for the proposed land uses. Development of the preferred remediation approach has considered the proposed LLMP development plans, including the bulk excavation of the Shallow and Deep Basement areas (as required to accommodate construction of the car park basements) and the construction of the proposed basement groundwater retention wall system."*

Based on the information presented in the reports reviewed, the Auditor concludes that the site can be made suitable for the purposes of:

- 'residential with minimal access to soil' land use for Development Area (South); and
- 'parks, recreational, open space' land use for Public Domain (South)
- commercial/industrial land use

if the site is remediated, developed and managed in accordance with the following remedial action plan:

- 'Amended Remedial Action Plan, Barangaroo – ORWS Area' dated 7 July 2011, by AECOM Australia Pty Ltd.

19 Other Relevant Information

This Audit was conducted on the behalf of Lend Lease (Millers Point) Pty Limited to provide an independent review by an NSW Environment Protection Authority (EPA) Accredited Auditor of the suitability and appropriateness of a plan of management, long-term management plan or a voluntary management proposal i.e. a "Site Audit" as defined in Section 4 (1) (b) (v) of the *NSW Contaminated Land Management Act 1997*.

This summary report may not be suitable for other uses. ERM and AECOM included limitations in their reports. The audit must also be subject to those limitations. The Auditor has prepared this document in good faith, but is unable to provide certification outside of areas over which he had some control or is reasonably able to check.

The Auditor has relied on the documents referenced in Section 1 of the Site Audit Report in preparing his opinion. If the Auditor is unable to rely on any of those documents, the conclusions of the audit could change.

It is not possible in a Site Audit Report to present all data which could be of interest to all readers of this report. Readers are referred to the referenced reports for further data. Users of this document should satisfy themselves concerning its application to, and where necessary seek expert advice in respect to, their situation.

Appendix A: Attachments

Attachment 1	Site Location
Attachment 2	Site Layout and Surrounds
Attachment 3	Proposed Land Use and Development Block Layout
Attachment 4	Site Layout Showing Development Areas, Basement Groundwater Retention Wall System and Investigation Locations
Attachment 5	Former Layout of the Larger Barangaroo Site
Attachment 6	Zone 1 and Zone 2 Contamination Zone Boundaries
Attachment 7	Key Groundwater Analysis Results, 2010
Attachment 8	Remediation Decision Making Process Flow Chart

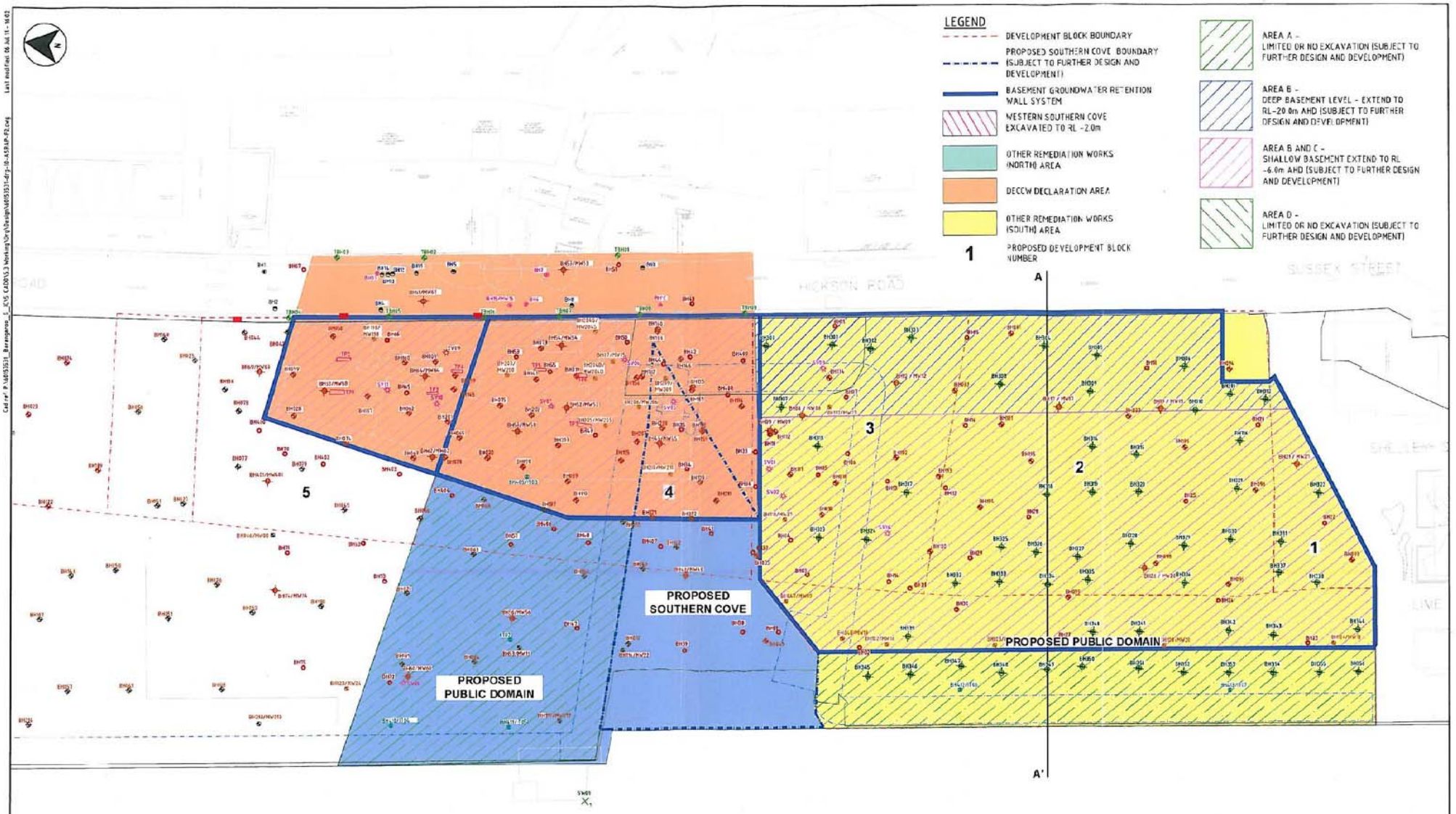
Attachment 1 Site Location

AECOM does not warrant the accuracy or completeness of information displayed in this map and any person using it does so at their own risk. AECOM shall bear no responsibility or liability for any errors, faults, defects, or omissions in the information.

PROJECT ID S4150030 CREATED BY TO LAST MODIFIED TO 15.02.2011	AECOM www.aecom.com	**Site Location**
0 — 600m		**Lend Lease Development** *Amended Remedial Action Plan Barangaroo Other Remediation Works (South) Area* Hickson Road, Millers Point NSW
		Figure 1

Map Document: G:\S4\S41500_S41599\S41500 Barangaroo\S4150030 Remedial Action Plan\S4150030 F1

A4 Size



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

REVISIONS

No	BY	DATE	DESCRIPTION	APPD
01	SS			DFM

SCALE: SCALE 1:750

DESIGNED	AR/DFM	CHECKED	AR/DFM
DRAWN	SS	CHECKED	JA
APPROVED	DFM	DATE	

DESIGNER: AECOM

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

ORWS AMENDED RAP

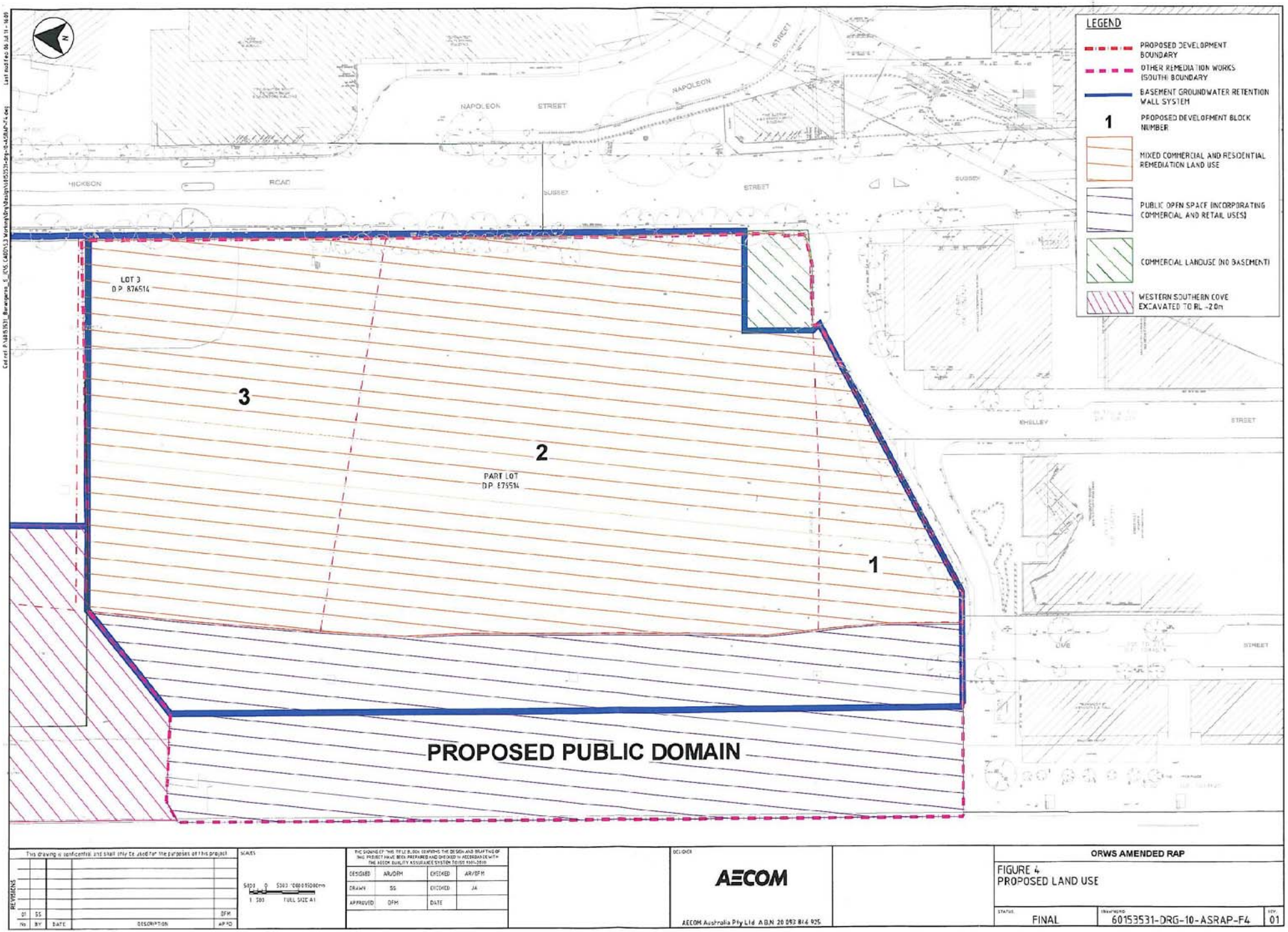
FIGURE 2
SITE LAYOUT AND BASEMENT GROUNDWATER RETENTION WALL SYSTEM

STATUS: FINAL

DRAWING NO: 60153531-DRG-10-ASRAP-F2

REV: 01

Attachment 2 Site Layout and Surrounds



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REVISIONS

NO	BY	DATE	DESCRIPTION	APPD
01	SS			DFM

SCALES

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DESIGNED	AR/DFM	CHECKED	AR/DFM
DRAWN	SS	CHECKED	JA
APPROVED	DFM	DATE	

DESIGNER

AECOM

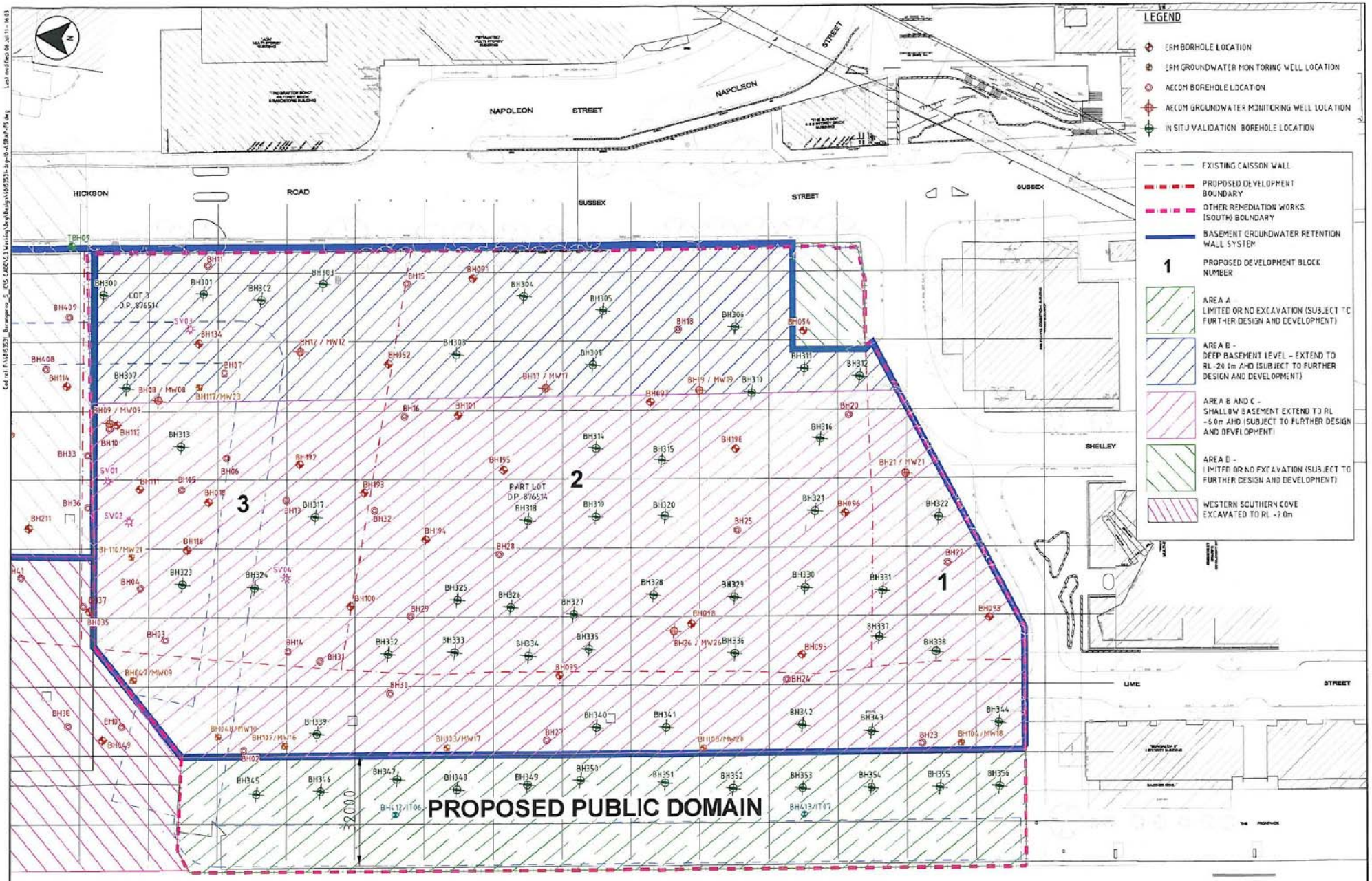
AECOM Australia Pty Ltd A.B.N. 20 093 846 925

ORWS AMENDED RAP

FIGURE 4
PROPOSED LAND USE

STATUS	DRAWING NO	REV
FINAL	60153531-DRG-10-ASRAP-F4	01

Attachment 3 Proposed Land Use and Development Block Layout



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

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
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SCALES

1 : 500 FULL SIZE A1

DESIGNED	AR/DFM	CHECKED	AR/DFM
DRAWN	SS	CHECKED	JA
APPROVED	DFM	DATE	

DESIGNER

AECOM

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

ORWS AMENDED RAP

FIGURE 5
SITE PLAN AND SAMPLING LOCATIONS

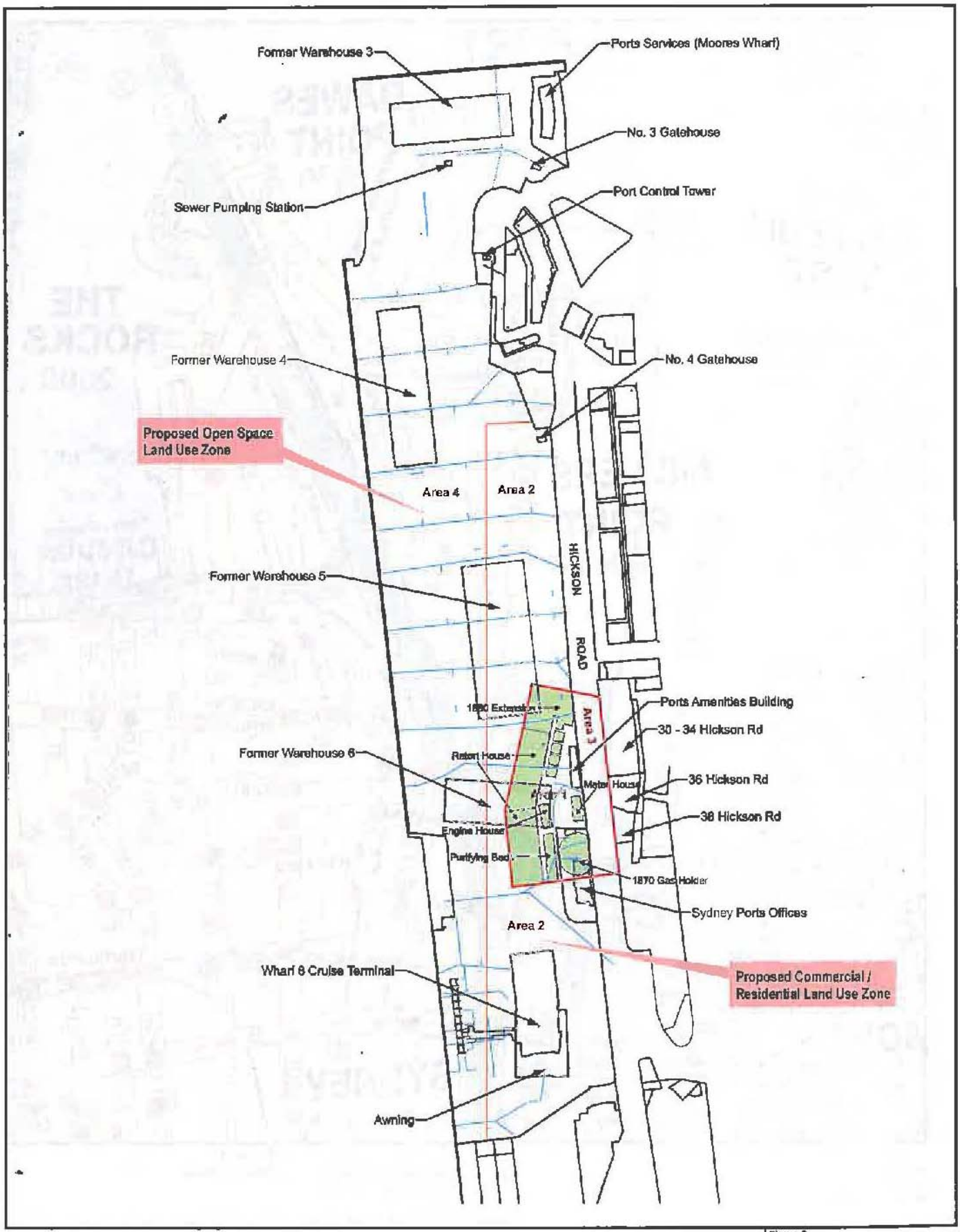
STATUS: FINAL

DRAWING NO: 60153531-DRG-10-ASRAP-F5

REV: 01

Attachment 4 Site Layout Showing Development Areas, Basement Groundwater Retention Wall System and Investigation Locations

Attachment 5 Former Layout of the Larger Barangaroo Site



Legend

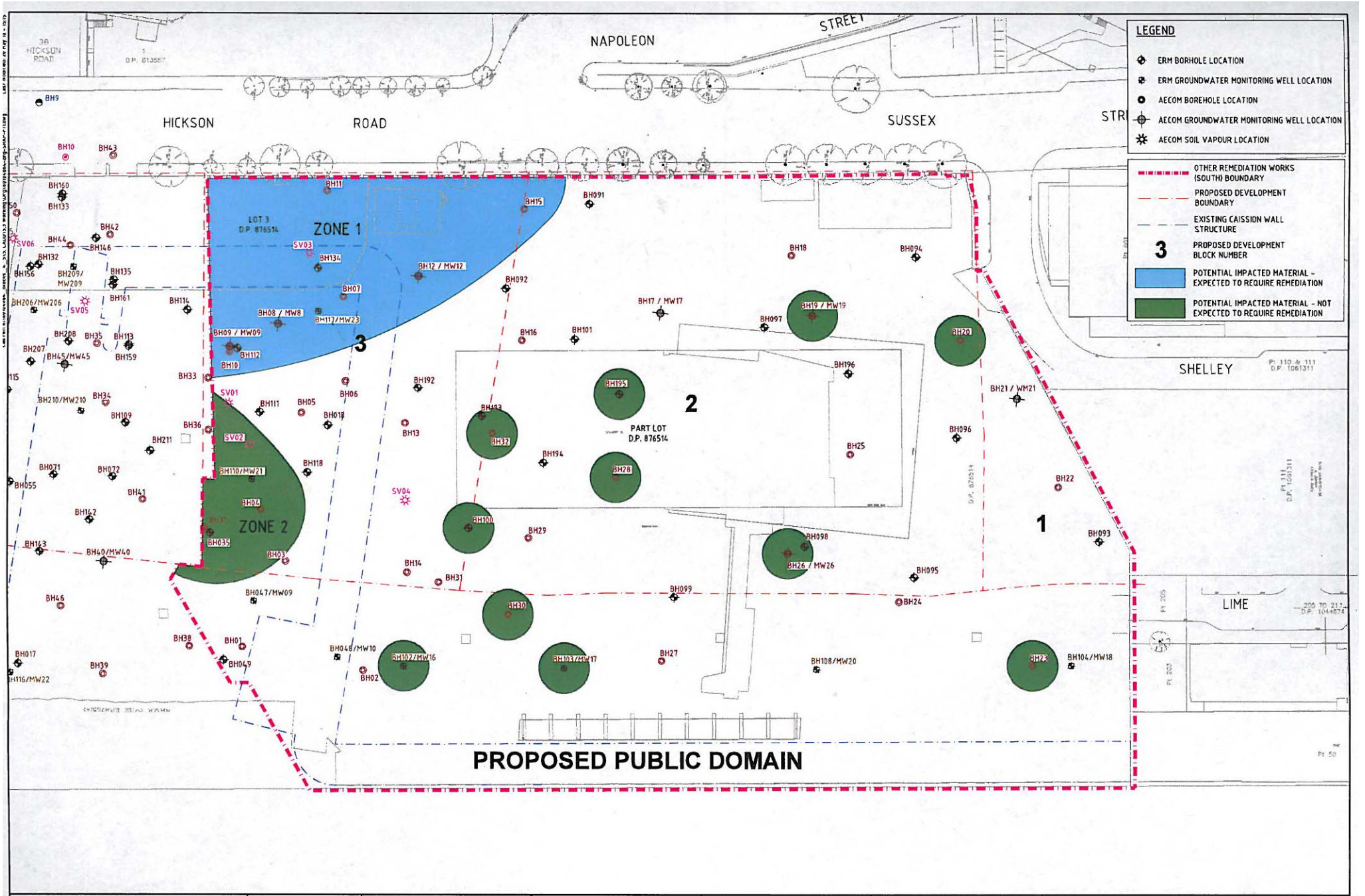
- Remediation Site
- Approximate Location of Former Gasworks Structures
- Lot Boundaries
- Existing or Former Site Features
- Approximate Boundary of Landuse Zones
- Site Drainage

Client:	Barangaroo Delivery Authority
Project:	Barangaroo Overarching RAP
Drawing No:	0114355e_RAP_GIS001_R0.mxd
Date:	31/03/2010
Drawing size:	A3
Drawn by:	JP
Reviewed by:	PL
Projection:	GDA 1994 MGA Zone 56
Scale:	Refer to Scale Bar

Figure 2
Site Layout Plan

Environmental Resources Management Australia Pty Ltd
Building D, 33 Saunders St, Pyrmont, NSW 2009
Telephone +61 2 8584 8888

ERM



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

REVISIONS				
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01	SS	07.04.2010		DFM

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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 9001:2008

DESIGNED	KP/DFM	CHECKED	KP/DFM
DRAWN	SS	CHECKED	JA
APPROVED	DFM	DATE	07.04.2010

DESIGNED: AECOM

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

OTHER REMEDIATION WORKS (SOUTH) AREA RAP

ZONES OF POTENTIAL SOURCE MATERIAL AND HOTSPOTS
FIGURE F11

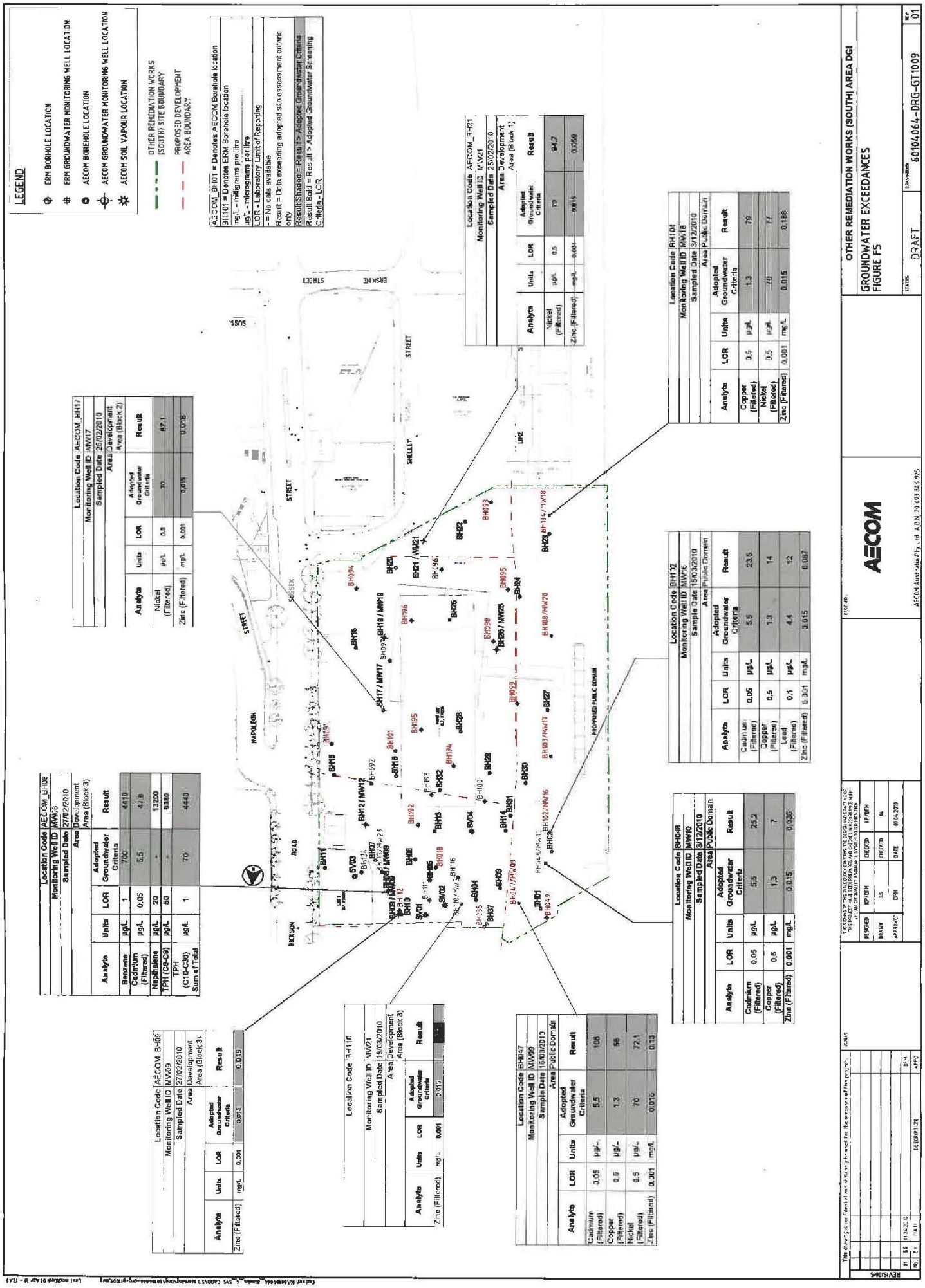
STATUS: DRAFT

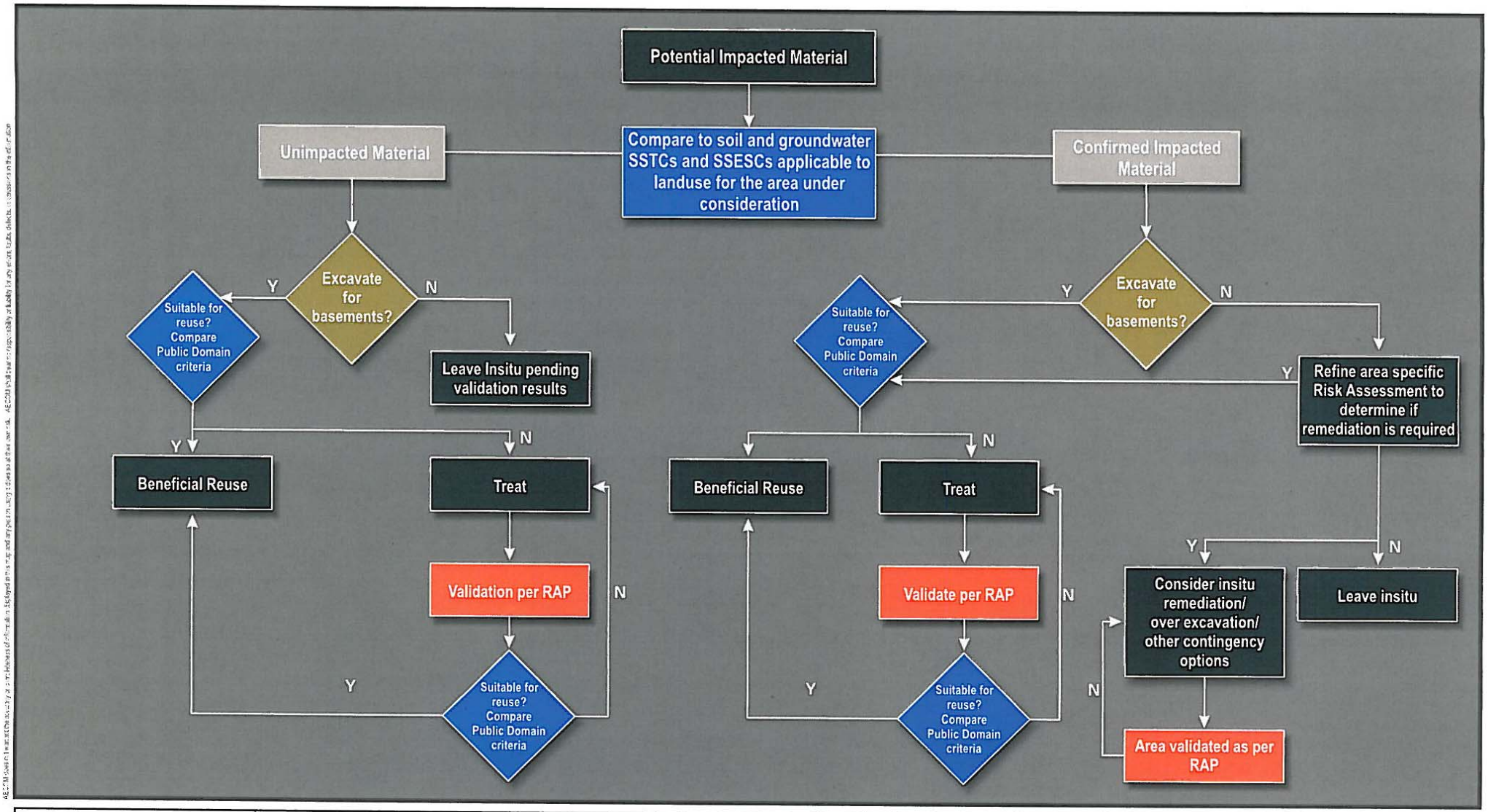
DRAWING NO: 60104064-DRG-SRAP-F11

REV: 01

Attachment 6 Zone 1 and Zone 2 Contamination Zone Boundaries

Attachment 7 Key Groundwater Analysis Results, 2010





PROJECT ID S4150030	AECOM	**Remediation Decision Making Process Flow Chart**
CREATED BY TO		
LAST MODIFIED TO 22.06.2011	www.aecom.com	**Lend Lease Development** *Amended Remedial Action Plan Barangaroo Other Remediation Works (South) Area* Hickson Road, Millers Point NSW — **Figure 11**

Map Document: G:\S4\S41500_S41599\S41500 Barangaroo\S4150030 Remedial Action Plan\S4150030 F11 Rev C

A4 Size

Attachment 8 Remediation Decision Making Process Flow Chart

Appendix B:
Soil and Groundwater Criteria

Soil investigation levels for urban development sites
Department of Environment and Conservation NSW (April 2006)

Substance	Health-based investigation levels[1] (mg/kg)				Provisional phytotoxicity-based investigation levels[2] (mg/kg)
	Residential with gardens and accessible soil (home-grown produce contributing < 10% fruit and vegetable intake; no poultry), including children's day-care centres, preschools, primary schools, townhouses, villas (NEHF A)[3]	Residential with minimal access to soil including high-rise apartments and flats (NEHF D)	Parks, recreational open space, playing fields including secondary schools (NEHF E)	Commercial or industrial (NEHF F)	
	Column 1	Column 2	Column 3	Column 4	Column 5
Metals and metaloids					
Arsenic (total)	100	400	200	500	20
Beryllium	20	80	40	100	–
Cadmium	20	80	40	100	3
Chromium (III)[4]	12%	48%	24%	60%	400
Chromium (VI)	100	400	200	500	1
Cobalt	100	400	200	500	–
Copper	1,000	4,000	2,000	5,000	100
Lead	300	1,200	600	1,500	600
Manganese	1,500	6,000	3,000	7,500	500
Methyl mercury	10	40	20	50	–
Mercury (inorganic)	15	60	30	75	1[5]
Nickel	600	2,400	600	3,000	60
Zinc	7,000	28,000	14,000	35,000	200
Organics					
Aldrin + dieldrin	10	40	20	50	–
Chlordane	50	200	100	250	–
DDT + DDD + DDE	200	800	400	1,000	–
Heptachlor	10	40	20	50	–
PAHs (total)	20	80	40	100	–
Benzo(a)pyrene	1	4	2	5	–
Phenol[6]	8,500	34,000	17,000	42,500	–
PCBs (total)	10	40	20	50	–
Petroleum hydrocarbon components[7]					
> C16–C35 (aromatics)	90	360	180	450	–
> C16–C35	5,600	22,400	11,200	28,000	–
> C35 (aliphatics)	56,000	224,000	112,000	280,000	–
Other					
Boron	3,000	12,000	6,000	15,000	–[8]
Cyanides (complex)	500	2,000	1,000	2,500	–

Soil investigation levels for urban development sites Department of Environment and Conservation NSW (April 2006)					
Substance	**Health-based investigation levels[1] (mg/kg)**				**Provisional phytotoxicity-based investigation levels[2] (mg/kg)**
	Residential with gardens and accessible soil (home-grown produce contributing < 10% fruit and vegetable intake; no poultry), including children's day-care centres, preschools, primary schools, townhouses, villas (NEHF A)[3]	Residential with minimal access to soil including high-rise apartments and flats (NEHF D)	Parks, recreational open space, playing fields including secondary schools (NEHF E)	Commercial or industrial (NEHF F)	
	Column 1	Column 2	Column 3	Column 4	Column 5
Cyanides (free)	250	1,000	500	1,250	–

1 The limitations of health-based soil investigation levels are discussed in Schedule B(1) Guidelines on the Investigation Levels for Soil and Groundwater and Schedule B(7a) Guidelines on Health-based Investigation Levels, *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC 1999)

2 The provisional phytotoxicity-based investigation levels proposed in this document are single number criteria. Their use has significant limitations because phytotoxicity depends on soil and species parameters in ways that are not fully understood. They are intended for use as a screening guide and may be assumed to apply to sandy loam soils or soils of a closely similar texture for pH 6–8.

3 National Environmental Health Forum (NEHF) is now known as enHealth.

4 Soil discolouration may occur at these concentrations.

5 Total mercury

6 Odours may occur at these concentrations.

7 The carbon number is an 'equivalent carbon number' based on a method that standardises according to boiling point. It is a method used by some analytical laboratories to report carbon numbers for chemicals evaluated on a boiling point GC column.

8 Boron is phytotoxic at low concentrations. A provisional phytotoxicity-based investigation level is not yet available.

Notes:

This table is adapted from Table 5-A in Schedule B(1): Guidelines on Investigation Levels for Soil and Groundwater to the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC 1999).

Soil investigation levels (SILs) may not be appropriate for the protection of ground water and surface water. They also do not apply to land being, or proposed to be, used for agricultural purposes. (Consult NSW Agriculture and NSW Health for the appropriate criteria for agricultural land.)

SILs do not take into account all environmental concerns (for example, the potential effects on wildlife). Where relevant, these would require further consideration.

Impacts of contaminants on building structures should also be considered.

For assessment of hydrocarbon contamination for residential land use, refer to the Guidelines for Assessing Service Station Sites (EPA 1994).

Threshold Concentration for Sensitive Land Use – Soils Guidelines for Assessing Service Station Site (NSW EPA 1994)	
Contaminant	**Threshold Concentration (mg/kg)**
TPH (C_6-C_9)	65
TPH (C_{10}-C_{36})	1,000
Benzene	1
Toluene	1.4
Ethylbenzene	3.1
Xylenes (total)	14

Trigger Values (TV) for Screening Marine Water Quality Data (µg/L) for Slightly to Moderately Disturbed Ecosystems (ANZECC 2000)		
Contaminant	**Threshold Concentration (µg/L))**	**Guideline Source**
Metals and Metalloids		
Arsenic – As (III/V)	2.3/4.5	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Cadmium – Cd	0.7	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Mercury – Hg	0.1	
Nickel – Ni	7	ANZECC (2000) 99% protection level due to potential for toxicity to particular species.
Manganese	80	Low reliability trigger values (derived from the mollusc figure) from Volume 2 of ANZECC (2000)
Chromium – Cr (III/VI)	27.4/4.4	ANZECC (2000) 95% protection levels.
Copper – Cu	1.3	
Cobalt	1	
Lead – Pb	4.4	
Zinc – Zn	15	
Aromatic Hydrocarbons		
Benzene	500	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Toluene	180	
Ethylbenzene	5	
o-xylene	350	
m-xylene	75	
p-xylene	200	
Polycyclic Aromatic Hydrocarbons		
Naphthalene	50	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Anthracene	0.01	Low reliability trigger values from Volume 2 of ANZECC (2000) ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Phenanthrene	0.6	
Fluroanthene	1	
Benzo (a) pyrene	0.1	
Chlorinated Alkanes		
Tetrachloroethene - PCE	70	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
1,1,2 Trichlorothene- TCE	330	
1,1,2 Trichlorothene- 1,1,2-TCE	330	
Vinyl chloride (chloroethene)	100	
1,1,1 Trichloroethane – 1,1,1-TCA (111-TCE)	270	
1,1 Dichloroethene	700	
1,1 Dichloroethane	250	
1,2 Dichloroethane	1900	
1,1,2 - Trichloroethane	1900	Moderate reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Chloroform	370	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Non-Metallic Inorganics		
Ammonia Total – NH_3 (at pH of 8)	910	ANZECC (2000) 95% protection levels.

Trigger Values (TV) for Screening Marine Water Quality Data (µg/L) for Slightly to Moderately Disturbed Ecosystems (ANZECC 2000)		
Contaminant	**Threshold Concentration (µg/L))**	**Guideline Source**
Cyanide (Free or unionised HCN)	4	

While the low reliability figures should not be used as default guidelines they will be useful for indicating the quality of groundwater migrating off-site.

Appendix C:
EPA Approved Guidelines

Guidelines made or approved by the EPA under section 105 of the *Contaminated Land Management Act 1997*

(*as of 3 July 2009*)

Guidelines made by the EPA

- *Contaminated Sites: Guidelines for Assessing Service Station Sites*, December 1994 - servicestnsites.pdf, 1.3Mb
- *Contaminated Sites: Guidelines for the vertical mixing of soil on former broad-acre agricultural land*, January 1995 - *vertmix.pdf*, 149kb
- *Contaminated Sites: Sampling Design Guidelines*, September 1995
- *Contaminated Sites: Guidelines for Assessing Banana Plantation Sites*, October 1997 - bananaplantsite.pdf, 586 kb
- *Guidelines for Consultants Reporting on Contaminated Sites* (97104consultantsglines.pdf; 209 KB), September 2000
- *Contaminated Sites: Guidelines for Assessing Former Orchards and Market Gardens,* June 2005 - orchardgdlne05195.pdf, 172 kb
- *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd edition)*, April 2006 - auditorglines06121.pdf, 510kb
- *Guidelines for the Assessment and Management of Groundwater Contamination*, March 2007 - groundwaterguidelines07144.pdf 604 kb
- *Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997*, June 2009 - 09438gldutycontclma.pdf, 1 Mb

Note: All references in the EPA's contaminated sites guidelines to the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, November 1992) are replaced as of 6 September 2001 by references to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, October 2000), subject to the same terms.

Guidelines approved by the EPA

ANZECC publications

- *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites,* published by Australian and New Zealand Environment and Conservation Council (ANZECC) and the National Health and Medical Research Council (NHMRC), January 1992
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Paper No 4, October 2000

EnHealth publications (formerly National Environmental Health Forum monographs)

- *Composite Sampling, by Lock, W. H., National Environmental Health Forum Monographs, Soil Series No.3, 1996, SA Health Commission, Adelaide*
- *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards, Department of Health and Ageing and EnHealth Council, Commonwealth of Australia, June 2002*

National Environment Protection Council publications

- National Environment Protection (Assessment of Site Contamination) Measure 1999

The Measure consists of a policy framework for the assessment of site contamination, Schedule A (Recommended General Process for the Assessment of Site Contamination) and Schedule B (Guidelines). Schedule B guidelines include:

B(1) Guideline on Investigation Levels for Soil and Groundwater

B(2) Guideline on Data Collection, Sample Design and Reporting

B(3) Guideline on Laboratory Analysis of Potentially Contaminated Soils

B(4) Guideline on Health Risk Assessment Methodology

B(5) Guideline on Ecological Risk Assessment

B(6) Guideline on Risk Based Assessment of Groundwater Contamination

B(7a) Guideline on Health-Based Investigation Levels

B(7b) Guideline on Exposure Scenarios and Exposure Settings

B(8) Guideline on Community Consultation and Risk Communication

B(9) Guideline on Protection of Health and the Environment During the Assessment of Site Contamination

B(10) Guideline on Competencies & Acceptance of Environmental Auditors and Related Professionals

Other documents

- Guidelines for the Assessment and Clean Up of Cattle Tick Dip Sites for Residential *Purposes*, NSW Agriculture and CMPS&F Environmental, February 1996
- *Australian Drinking Water Guidelines*, NHMRC & Natural Resource Management Ministerial Council of Australia and New Zealand, 2004

Appendix D:
Analytical Lists and Methods

MGT LABMARK ANALYTICAL LISTS AND METHODS

Target Compounds	MGT LabMark Method	Methodology Summary
Heavy Metals		
Arsenic	LM-LTM-MET-3100	0.5 g digested in nitric/hydrochloric acid. Analysis b ICP-MS
Cadmium		
Chromium		
Copper		
Nickel		
Lead		
Zinc		
Mercury	LM-LTM-MET-3100	0.5 g digested in nitric/hydrochloric acid. Analysis by CV-ICP-MS or FIMS.
Polynuclear Aromatic Hydrocarbons (PAHs)		
Naphthalene	E007.2	8-10 g soil extracted with 20 mL DCM /Acetone/ Hexane (10:45:45). Analysis by GC-MS.
Fluorene		
Phenanthrene		
Anthracene		
Acenaphthylene		
Acenaphthene		
Fluoranthene		
Pyrene		
Benz(a)anthracene		
Chrysene		
Benzo(b) & (k)fluoranthene		
Benzo(a)pyrene		
Indeno(1.2.4-cd)pyrene		
Dibenzo(a.h)anthracene		
Benzo(g.h.l)perylene		
BTEX Compounds		
Benzene	E029.2/E016.2	8-10g soil extracted with 20ml methanol. Analysis by P&T/GC/MSD or by P&T/GC/FID/MSD.
Toluene		
Chlorobenzene		
Ethylbenzene		
Meta- & para-Xylene		
Ortho-Xylene		
Total Petroleum Hydrocarbons		
C6-C9 Fraction	E029.2/E016.2	8-10g soil extracted with 20ml methanol. Analysis by P&T/GC/MSD or by P&T/GC/FID/MSD.
C10-C14 Fraction	E006.2	8 – 10 g soil extracted with 20 mL DCM /Acetone /Hexane (10:45:45). Analysis by GC/FID.
C15-C28 Fraction		
C29-C36 Fraction		

Target Compounds	MGT LabMark Method	Methodology Summary
Organochlorine Pesticides		
alpha-BHC	E013.2	8-10g soil extracted with 20 mL heaxane/acetone (1:1). Analysis by GC/dual ECD.
HCB		
beta-BHC & gamma-BHC		
delta-BHC		
Heptachlor		
Aldrin		
Heptachlor epoxide		
Endosulfan 1		
Trans-Chlordane		
Cis-Chlordane		
methoxychlor		
4.4'-DDE		
Dieldrin		
Endrin		
Endosulfan 11		
4.4'-DDD		
Endosulfan sulfate		
4.4'-DDT		
Inorganic Analytes		
Weak Acid Dissociable Cyanide	E040.2/E054.2	Caustic soil extraction, Acetate distillate collected in sodium hydroxide. Analysis by colour.

ALS ANALYTICAL LISTS AND METHODS

Target Compounds	ALS Method	Methodology Summary
Heavy Metals		
Arsenic	EG005T/ EG020A-F	Solid matrix: APHA 21st ed., 3120; USEPA SW 846 - 6010) (ICPAES Appropriate acid digestion of the soil is followed by analysis by ICPAES. Water matrix: (APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): Samples are 0.45 um filtered prior to analysis followed by ICPMS.
Cadmium		
Chromium		
Copper		
Nickel		
Lead		
Zinc		
Mercury	EG035T/ EG035F	Solid matrix: 3550, APHA 21st ed., 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Appropriate acid digestion followed by reduction of ionic mercury to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. Water matrix: 3550, APHA 21st ed. 3112 Hg – B. Samples are .45 um filtered prior to oxidation of any organic mercury with a bromated/bromide reagent. Then reduction of ionic mercury to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve

Target Compounds	ALS Method	Methodology Summary
Polynuclear Aromatic Hydrocarbons (PAHs)		
Naphthalene	EP075(SIM)	Soil Matrix: In-house, Mechanical agitation (tumbler). 10g of sample, Na2SO4 and surrogate are extracted with 20mL 1:1 DCM/Acetone by end over end tumble. The solvent is transferred directly to a GC vial for analysis. Water Matrix: USEPA SW 846 - 3510B) 500 mL to 1L of sample is transferred to a separatory funnel and serially extracted three times using 60mL DCM for each extract. The resultant extracts are combined, dehydrated and concentrated for (USEPA SW 846 - 8270B) Extracts are analysed by Capillary GC/MS in Selective Ion Mode (SIM) andquantification is by comparison against an established 5 point calibration curve.
Fluorene		
Phenanthrene		
Anthracene		
Acenaphthylene		
Acenaphthene		
Fluoranthene		
Pyrene		
Benz(a)anthracene		
Chrysene		
Benzo(b) & (k)fluoranthene		
Benzo(a)pyrene		
Indeno(1.2.4-cd)pyrene		
Dibenzo(a.h)anthracene		
Benzo(g.h.l)perylene		
BTEX Compounds		
Benzene	EP080	Extraction of Solids: (USEPA SW 846 - 5030A) 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS. USEPA SW 846 - 8260B) Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve.
Toluene		
Chlorobenzene		
Ethylbenzene		
Meta- & para-Xylene		
Ortho-Xylene		
Total Petroleum Hydrocarbons		
C6-C9 Fraction	EP080	USEPA SW 846 - 8260B. Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve. Extraction of Solids: (USEPA SW 846 - 5030A) 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS.
C10-C14 Fraction	EP071	USEPA SW 846 - 8015A. Sample extracts are analysed by Capillary GC/FID and quantified against alkane standards over the range C10 - C36. Solid matrix extraction: In-house, Mechanical agitation (tumbler). 10g of sample, Na2SO4 and surrogate are extracted with 20mL 1:1 DCM/Acetone by end over end tumble. The solvent is transferred directly to a GC vial for analysis. Water matrix extraction: USEPA SW 846 - 3510B 500 mL to 1L of sample is transferred to a separatory funnel and serially extracted three times using 60mL DCM for each extract.
C15-C28 Fraction		
C29-C36 Fraction		
Other Analytes		
Cyanide	EK028G	Sample are distilled with a weak organic acid, converting selected CN species to HCN. The distillates are analyzed for CN by Discrete Analyser.
Suspension Peroxide Oxidation-Combined Acidity and Sulphate	EA029	Ahern et al 2004 - a suspension peroxide oxidation method following the 'sulfur trail' by determining the level of 1M KCL extractable sulfur and the sulfur level after oxidation of soil sulphides. The 'acidity trail' is followed by measurement of TAA, TPA and TSA. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5.
Asbestos	EA200	AS 4964 - 2004 Method for the qualitative identification of asbestos in bulk samples

Appendix E:
Risk Based Remediation Criteria (SSTCs and SSESCs)

TABLE T1
SUMMARY OF SSTCS & SSESCS
AMENDED RAP
BARANGAROO ORW3 AREA
LEND LEASE

	SOIL SSTCS AND SSESCS											
CoPC	SSTC-A	Land Use Scenario	SSESC-A	Daf	SSTC-B	Land Use Scenario	SSESC-B	Daf	SSTC-C	Land Use Scenario	SSTC-D	Land Use Scenario
Site Area	Area A				Area B				Area C		Area D	
Arsenic, Inorganic	-	-	5	DAF x 4	-	-	20	DAF x 4	-	NA	-	-
Acenapthene	-	-	-	-	-	-	8	DAF x 4	-	NA	-	-
Acenapthylene	-	-	-	-	-	-	5	DAF x 4	-	NA	-	-
Anthracene	-	-	-	-	-	-	5	DAF x 4	-	NA	-	-
Benz(a)anthracene	**	Scenario 6	-	-	**	Scenario 6	-	-	-	NA	-	-
Benzene	15	Scenario 2	-	-	81	Scenario 5	-	-	-	NA	0.25	Scenario 8
Benzo(a)pyrene	**	Scenario 6	-	-	**	Scenario 6	-	-	-	NA	-	-
Benzo(b)fluoranthene	**	Scenario 6	-	-	**	Scenario 6	-	-	-	NA	-	-
Benzo(k)fluoranthene	**	Scenario 6	-	-	**	Scenario 6	-	-	-	NA	-	-
Benzo(g,h,i)perylene	**	Scenario 6	-	-	**	Scenario 6	-	-	-	NA	-	-
Beryllium	-	-	-	-	-	-	-	-	-	NA	-	-
Cadmium	-	-	-	-	-	-	-	-	-	NA	-	-
Chromium(III), Insoluble Salts	180,000	Scenario 6	-	-	180,000	Scenario 6	-	-	-	NA	-	-
Chromium(VI)	950	Scenario 6	-	-	950	Scenario 6	-	-	-	NA	-	-
Chrysene	**	Scenario 6	-	-	**	Scenario 6	-	-	-	NA	-	-
Cobalt	-	-	-	-	-	-	-	-	-	NA	-	-
Copper	-	-	42	DAF x 20			170	DAF x 20	-	NA	-	-
Dibenz(a,h)anthracene	**	Scenario 6	-	-	**	Scenario 6	-	-	-	NA	-	-
Ethylbenzene	600	Scenario 2	-	-	-	-	-	-	-	NA	64	Scenario 8
Fluoranthene	-	-	-	-	-	-	8	DAF x 4	-	NA	-	-
Fluorene	-	-	-	-	-	-	5	DAF x 4	-	NA	-	-
Indeno(1,2,3-cd)pyrene	**	Scenario 6	-	-	**	Scenario 6			-	NA	-	-
Lead			440	DAF x 40	-	-	1700	DAF x 40	-	NA	-	-
Manganese	-	-	-	-	-	-	-	-	-	NA	-	-
Mercury	-	-	-	-	-	-	-	-	-	NA	-	-
Methylnaphthalene, 2-	1,100	Scenario 2	-	-	-	-	-	-	-	NA	18	Scenario 8
Methylphenol, 3&4	5,400	Scenario 8	-	-	5,400	Scenario 8			-	NA	140	Scenario 8
Naphthalene	-	-	-	-	-	-	21	DAF x 4	-	NA	0.87	Scenario 8
Nickel	-	-	-	-	-	-	-	-	-	NA	-	-
Phenanthrene	-	-	-	-	-	-	4	DAF x 4	-	NA	-	-
Toluene	-	-	-	-	-	-	-	-	-	NA	160	Scenario 8
TPH C06-C09 aliphatic			10	DAF x 1	-	-	39	DAF x 4	-	NA	55	Scenario 8
TPH C10-C14 aliphatic	-	-	50	DAF x 1	90,000	Scenario 6	50	DAF x 4	-	NA	210	Scenario 8
TPH C10-C14 aromatic												
TPH C15-C28 aliphatic	-	-	-	-	-	-	-	-	-	NA	-	-
TPH C15-C28 aromatic												
TPH C29-C36 aliphatic	-	-	-	-	-	-	-	-	-	NA	-	-
TPH C29-C36 aromatic												
TPH C10-C36 (Sum of Total)	-	-	-	-	-	-	-	-	-	NA	-	-
Total PAHs	-	-	-	-	-	-	-	-	-	NA	-	-
Trimethylbenzene, 1,2,4-	14	Scenario 2	-	-	110	Scenario 5	-	-	-	NA	0.23	Scenario 8
Vanadium	22,000	Scenario 6	-	-	22,000	Scenario 6	-	-	-	NA	-	-
Xylenes (total)	-	-	-	-	-	-	-	-	-	NA	14	Scenario 8
Zinc			55	DAF x 20	-	-	220	DAF x 20	-	NA	-	-
CPAH**	67	Scenario 6	-	-	67	Scenario 6	-	-	-	NA	-	-

Notes:
SRG = Soil Remediation Goal (i.e. SRG-A - soil criteria to be adopted in Area A)
** CPAH = carcinogenic PAHs in top 2m of soil profile and includes: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h) anthracene and indeno (1,2,3-cd)pyrene.
NSW EPA (1994) Guidelines for Assessing Service Station Sites
NEPM (HILs "F") for Commercial and Industrial Landuse Scenarios
NA = Not Applicable

Land Use Scenarios:
Scenario 1: Lower-most basement car park level (below water table);
Scenario 2: Upper-most basement car park level (above water table);
Scenario 3: Unpaved Recreation, Public Domain (South) with no concrete/hardstand paving.
Scenario 4: Paved Recreation, Public Domain (South) with concrete/hardstand paving;
Scenario 5: Typical commercial slab on ground construction;
Scenario 6: Short term ground-intrusive maintenance;
Scenario 7: High density residential (above a car park basement); and
Scenario 8: Commercial slab on ground (with advection).

TABLE T2
SUMMARY OF GROUNDWATER SSTCS AND SSESCS
AMENDED RAP
BARANGAROO ORWS AREA
LEND LEASE

	GROUNDWATER SSTCS AND SSESCS									
CoPC	SSTC-A	Land Use Scenario	SSESC-A	Land Use Scenario	NA	Land Use Scenario	SSTC-C	Land Use Scenario	SSTC-D	Land Use Scenario
Site Area	Area A				Area B		Area C		Area D	
	ug/L		ug/L		ug/L		ug/L		ug/L	
Acenaphthene	-	-			-	NA	-	-	-	-
Acenaphthylene	-	-			-	NA	-	-	-	-
Ammonia	-	-			-	NA	2,400,000	Scenario 1	1500000	Scenario 8
Aniline	960,000	Scenario 6			-	NA	-	-	-	-
Anthracene	-	-	1	Tidal Prism	-	NA	-	-	-	-
Arsenic, Inorganic	-	-	2.3	Tidal Prism	-	NA	-	-	-	-
Barium	570,000	Scenario 6			-	NA	-	-	-	-
Benz(a)anthracene	-	-			-	NA	-	-	-	-
Benzene	-	-			-	NA	21,000	Scenario 1	410	Scenario 8
Benzo(a)pyrene	-	-			-	NA	-	-	-	-
Benzo(b)fluoranthene	-	-			-	NA	-	-	-	-
Benzo(g,h,i)perylene	-	-			-	NA	-	-	-	-
Benzo(k)fluoranthene	-	-			-	NA	-	-	-	-
Cadmium	-	-			-	NA	-	-	-	-
Chromium(III)	3,400,000	Scenario 6			-	NA	-	-	-	-
Chromium(VI)	-	-			-	NA	-	-	-	-
Chrysene	-	-			-	NA	-	-	-	-
Cobalt	-	-			-	NA	-	-	-	-
Copper	-	-	8.5	Tidal Prism	-	NA	-	-	-	-
Cyanide (WAD)	-	-			-	NA	-	-	-	-
Dibenz(a,h)anthracene	-	-			-	NA	-	-	-	-
Dibenzofuran	-	-			-	NA	-	-	-	-
Dimethylphenol, 2,4-	-	-			-	NA	-	-	-	-
Ethylbenzene	-	-			-	NA	-	-	49000	Scenario 8
Fluoranthene	-	-			-	NA	-	-	-	-
Fluorene	-	-			-	NA	-	-	-	-
Indeno(1,2,3-cd)pyrene	-	-			-	NA	-	-	-	-
Lead	-	-	44	Tidal Prism	-	NA	-	-	-	-
Manganese	2,400,000	Scenario 6			-	NA	-	-	-	-
Mercury	-	-			-	NA	-	-	-	-
Methylnaphthalene, 2-	-	-			-	NA	38,000	Scenario 1	32000	Scenario 8
Methylphenol, 2	-	-			-	NA	-	-		
Methylphenol, 3&4	-	-			-	NA	1,000,000	Scenario 1	660000	Scenario 8
Naphthalene	-	-			-	NA	920	Scenario 1	1700	Scenario 8
Nickel	-	-			-	NA	-	-		
Phenanthrene	-	-	1	Tidal Prism	-	NA	-	-		
Phenol	23,000,000	Scenario 6			-	NA	310,000,000	Scenario 1	190000000	Scenario 8
Styrene	-	-			-	NA	-	-	110000	Scenario 8
Toluene	-	-			-	NA	-	-	200000	Scenario 8
TPH C06-C09 aliphatic	-	-	110	Tidal Prism	-	NA	28,000,000	Scenario 1	1600	Scenario 8
TPH C10-C14 aliphatic	-	-	40	Tidal Prism	-	NA	7,700	Scenario 1	6300	Scenario 8
TPH C10-C14 aromatic					-	NA				
TPH C15-C28 aliphatic	220,000	Scenario 6			-	NA	-	-		
TPH C15-C28 aromatic		Scenario 6			-	NA	-	-		
Trimethylbenzene, 1,2,4-	87,000	Scenario 1			-	NA	87,000	Scenario 1	1500	Scenario 8
Vanadium	-	-			-	NA	-	-	-	-
Xylenes (total)	-	-			-	NA	-	-	10000	Scenario 8
Zinc	-	-	75	Tidal Prism	-	NA	-	-	-	-
CPAH	-	-			-	NA	-	-	-	-

Notes:
MWQC = Marine Water Quality Criteria
** CPAH = Carcinogenic PAHs as BaP TEF (benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno (1,2,3-cd)pyrene (see main body report for details).
DAF = Dilution Attenuation Factors based on the MWQC values.
NA = Not Applicable
WAD - Weak Acid Dissociable

Table T17
Terrestrial Soil Criteria,
Amended Remedial Action Plan,
ORWS Area, Barangaroo

Key Chemical	Criteria for Protection of Plants and Soil (mg/kg)	Grouped Criteria (mg/kg)	Data Sources/Notes
Metals and inorganics			
Arsenic[1]	20		NEPM (1999) - Interim Urban
Cadmium	3		NEPM (1999) - Interim Urban
Chromium	190		NEPM (draft, 2010) EILs - Public open space - aged
Copper[1]	60		NEPM (draft, 2010) EILs - Public open space - aged
Lead[1]	1100		NEPM (draft, 2010) EILs - Public open space - aged
Mercury	1		NEPM (1999) - Interim Urban
Nickel	30		NEPM (draft, 2010) EILs - Public open space - aged
Zinca	200		NEPM (1999) - Interim Urban
Cyanide (if free)	8		CCME (1999a) coarse soil
Ammonia			Calculate based on irrigation guideline of 5 mg/L as N (based on protection of plants)
Petroleum Hydrocarbons			
TPH C6 - C9a	210		CCME (2008b) coarse soil
TPH C10 - C14a	150		CCME (2008b) coarse soil
TPH C15 - C28	-	300	CCME (2008b) coarse soil
TPH C29 - C36	-		
Benzene	1		NSW EPA (1994)
Toluene	1.4		NSW EPA (1994)
Ethylbenzene	3.1		NSW EPA (1994)
Xylenes	14		NSW EPA (1994)
Low MWT PAHs			
Acenaphthene[1]		sum - 50b	a: CCME (1999b)
Acenaphthylene[1]			b: Total PAHs (excluding carcinogenic PAHs), from USEPA Eco SSLs of 48mg/kg rounded to 50mg/kg
Anthracene			
Fluorene[1]			
Phenanthrene			
Naphthalene[1]	22a		
High MWT PAHs			
Benzo[a]anthracene	40 c		c: Criteria derived from 4 for benzo(a)pyrene and applied using the following TEFs from
Benzo[a]pyrene	4 c		- benzo[a]anthracene, 0.1
Benzo[b]fluoranthene	40 c		- benzo[a]pyrene, 1
Benzo[k]fluoranthene	40 c		- benzo[b]fluoranthene, 0.1
Benzo[ghi]perylene	400 c		- benzo[k]fluoranthene, 0.1
Chrysene	400 c		- benzo[ghi]perylene, 0.01
Dibenz[ah]anthracene	4 c		- chrysene, 0.01
Fluoranthenea	- c		- dibenz[ah]anthracene, 1
Indeno[123cd]pyrene	40 c		- indeno[123cd]pyrene, 0.1
Pyrene	- c		TEFs for fluoranthene and pyrene not used by CCME (2008b)
Phenols			
Phenol	3.8		CCME (1999c) coarse soil
2,4dimethylphenol	3.8		CCME (1999c) coarse soil
2-methylphenol	3.8		CCME (1999c) coarse soil
3&4-methylphenol	3.8		CCME (1999c) coarse soil

Note:
[1] Where the TSC are greater than the derived leachability based soil SSESC (refer to Section 5.7.3.3, ORWS HHERA Addendum) the relevant soil SSESC will be adopted.

Data Entry: AS
Data Review: AR

Summary Table of Groundwater SSESCs
Area A

	Units	MWQC	MWQC x4	MWQC x5	MWQC x10	MWQC x 20	MWQC x 40	Tidal Prism		Upgradient of Tidal Prism	
								Unsaturated Zone to Harbour	Saturated Zone to Harbour	UnSaturated Zone to Harbour	Saturated Zone to Harbour
Arsenic	µg/L	2.3	9.2	11.5	23	46	92	9.2	2.3	9.2	2.3
Copper	µg/L	1.3	5.2	6.5	13	26	52	26	6.5	26	6.5
Lead	µg/L	4.4	17.6	22	44	88	176	176	44	176	44
Zinc	mg/L	0.015	0.06	0.075	0.15	0.3	0.6	0.3	0.075	0.3	0.075
Anthracene	µg/L	1*	4*	5*	10*	20*	40*	4*	1*	20*	5*
Phenanthrene	µg/L	1*	4*	5*	10*	20*	40*	4*	1*	20*	5*
TPH C10 - C14	µg/L	40	160	200	400	800	1600	160	40	800	200
TPH C6 - C9	µg/L	110	440	550	1100	2200	4400	440	110	2200	550
								4 x (1, 5, 10 x Daf)	1, 5, 10 x Daf	4 x (1, 5, 10 x Daf)	1, 5, 10 x DAF

Notes:

MWQC Marine Water Quality Criteria

ANZECC (2000) 95% Marine Water Trigger Value

ANZECC (2000) 95% Marine Water Trigger Value - low reliability

ANZECC (2000) 99% Marine Water Trigger Value

CCME (1999) Freshwater Guideline

CCME (2008) benchmark

Adopted criteria from Acenapthene as surrogate

* = SSESC adopted is the standard LOR where the MWQC is less than the standard LOR

[1]= SSESC was developed based on Analyte Specific Dafs which are based on Site data both inside and outside the tidal prism. Therefore where a analyte speciifc Daf is available, the derived SSESC is the same within the outside the tidal prism.

Summary Table of Groundwater SSESCs
Area B

	Units	MWQC	MWQC x4	MWQC x5	MWQC x10	MWQC x20	MWQC x 40	Tidal Prism		Upgradient of Tidal Prism	
								Unsaturated Zone to Harbour	Saturated Zone to Harbour	Unsaturated Zone to Harbour	Saturated Zone to Harbour
Arsenic	µg/L	2.3	9.2	11.5	23	46	92	9.2	2.3	9.2	2.3
Copper	µg/L	1.3	5.2	6.5	13	26	52	26	6.5	26	6.5
Lead	µg/L	4.4	17.6	22	44	88	176	176	44	176	44
Zinc	mg/L	0.015	0.06	0.075	0.15	0.3	0.6	0.3	0.075	0.3	0.075
Acenaphthene	µg/L	5.8	23.2	29	58	116	232	23.2	5.8	116	29
Acenaphthylene	µg/L	5.8	23.2	29	58	116	232	23.2	5.8	116	29
Anthracene	µg/L	1*	4*	5*	10*	20*	40*	4*	1*	20*	5*
Fluoranthene	µg/L	1	4	5	10	20	40	4	1	20	5
Fluorene	µg/L	3	12	15	30	60	120	12	3	60	15
Naphthalene	µg/L	70	280	350	700	1400	2800	280	70	1400	350
Phenanthrene	µg/L	1*	4*	5*	10*	20*	40*	4*	1*	20*	5*
TPH C10 - C14	µg/L	40	160	200	400	800	1600	160	40	800	200
TPH C6 - C9	µg/L	110	440	550	1100	2200	4400	440	110	2200	550
								4 x (1, 5, 10 x Daf)	1, 5, 10 x Daf	4 x (1, 5, 10 x Daf)	1, 5, 10 x DAF

Notes:

MWQC Marine Water Quality Criteria

ANZECC (2000) 95% Marine Water Trigger Value

ANZECC (2000) 95% Fresh Water Trigger Value

ANZECC (2000) 99% Marine Water Trigger Value

CCME (1999) Freshwater Guideline

CCME (2008) benchmark

* = SSESC adopted is the standard LOR where the MWQC is less than the standard LOR

AECOM

Summary Table of Soil SSESCs
Area A

	alculated EIL (refer to Appendix D for source of 1 x Da						Tidal Prism		Upgradient of Tidal Prism	
	1 x Daf	4 x Daf	5 x Daf	10 Daf	20 Daf	40 Daf	Unsaturated Zone to the Harbour	Saturated Zone to the Harbour	Unsaturated Zone to the Harbour	Saturated Zone to the Harbour
Metals and Inorganics										
Arsenic	5.06	20.24	25.30	50.60	101.20	202.40	20	5.1	20	5.1
Copper	8.45	33.80	42.25	84.50	169.00	338.00	169	42.3	169	42
Lead	43.60	174.40	217.99	435.99	871.98	1743.96	1744	436	1744	436
Zinc	11.05	44.21	55.27	110.53	221.06	442.12	221	55	221	55
Anthracene*	1.19	4.76	5.95	11.90	23.80	47.60	5	1	24	6
Phenanthrene*	0.97	3.88	4.85	9.70	19.40	38.80	4	1	19	5
C6-C9	9.63	38.53	48.16	96.32	192.64	385.27	39	10	193	48
C10-C14	3.19	12.77	15.97	31.93	63.86	127.72	13	3	64	16
							4 x (1, 5, 10 x Daf)	1, 5, 10 x Daf	4 x (1, 5, 10) Daf	1, 5, 10 x Daf

Notes:
All criteria are mg/kg unless otherwise indicated
* SSESC calculated based on the standard LOR where the MWQC is less than the standard LOR

Shaded cells are analyte specific Dafs that are applicable to the Saturated Zone of the fill upgradient of the Tidal Prism

AECOM

Summary Table of Soil SSESCs
Area B

	Calculated EIL (refer to Appendix D for source of 1 x Daf)						Tidal Prism	Upgradient of Tidal
	1 x Daf	4 x Daf	5 x Daf	10 Daf	20 Daf	40 Daf	Unsaturated Zone to the Harbour	Unsaturated Zone to Harbour
Metals and Inorganics								
Arsenic	5.06	20.24	25.30	50.60	101.20	202.40	20	20
Copper	8.45	33.80	42.25	84.50	169.00	338.00	169	169
Lead	43.60	174.40	217.99	435.99	871.98	1743.96	1744	1744
Zinc	11.05	44.21	55.27	110.53	221.06	442.12	221	221
Acenapthene	2.08	8.32	10.41	20.81	41.62	83.24	8	42
Acenapthylene	1.29	5.16	6.45	12.90	25.79	51.59	5	26
Anthracene*	1.19	4.76	5.95	11.90	23.80	47.60	5	24
Fluoranthene	1.88	7.53	9.41	18.82	37.65	75.29	8	38
Fluorene	1.22	4.87	6.09	12.18	24.36	48.72	5	24
Naphthalene	5.34	21.34	26.68	53.36	106.72	213.44	21	107
Phenanthrene*	0.97	3.88	4.85	9.70	19.40	38.80	4	19
C6-C9	9.63	38.53	48.16	96.32	192.64	385.27	39	193
C10-C14	3.19	12.77	15.97	31.93	63.86	127.72	13	64
							4 x (1, 5, 10 x Daf)	4 x (1, 5, 10 x Daf)

Notes:
All criteria are mg/kg unless otherwise indicated
* SSESC calculated based on the standard LOR where the MWQC is less than the standard LOR

Yellow shaded cells are analyte specific Dafs that are applicable to the Saturated Zone upgradient of the Tidal Prism