Site Audit Report
Remedial Action Plan, Barangaroo Central

Prepared for:

Barangaroo Delivery Authority

Prepared by:
ENVIRON Australia Pty Ltd

Date:
July 2013

Project Number:
AS121473

Audit Number:
GN 439B-5

ENVIRON

31 July 2013 Our Ref: AS121473

Barangaroo Delivery Authority
Attn: Fleur Mellor
Level 21
201 Kent Street
Sydney NSW 2000

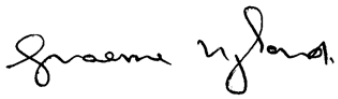
Dear Fleur

Re: Site Audit Report - Remedial Action Plan, Barangaroo Central

I have pleasure in submitting the Site Audit Report for the subject site. Site Audit Statement GN439B-5, produced in accordance with the NSW *Contaminated Land Management Act 1997* follows this letter. The Audit was commissioned by Barangaroo Delivery Authority to assess the suitability of the Remedial Action Plan.

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

NSW Site Auditor Scheme
SITE AUDIT STATEMENT

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 31st October 2012. For more information about completing this form, go to Part IV.

PART I: Site audit identification

Site audit statement no. **GN 439B-5**

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: Hickson Road, Millers Point NSW

Postcode: 2000

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

Part Lots 5 and 6 in DP 876514

Local Government Area: Sydney

Area of site (e.g. hectares): 4.3 ha approximately

Current zoning: Zone B4 Mixed Use and 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: Fleur Mellor Company: Barangaroo Delivery Authority

Address: Level 21, 201 Kent Street, Sydney NSW

Postcode: 2000

Phone: 02 9255 1706 Fax: 9271 5353

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

NA

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])*

Public open space and high density residential use.

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)
- Rosemary Broomham
- AECOM Australia Pty Ltd (AECOM)
- JBS Australia Pty Ltd (JBS)

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
- 'East darling Harbour Geotechnical and Environmental Investigation, Summary of Findings', dated September 2006, by ERM
- '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

Strike out as appropriate

- '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
- 'Overarching Remedial Action Plan for The Barangaroo Project Site, Sydney' dated 1 June 2010, by ERM
- 'Data Gap Investigation, Other Remediation Works North, Hickson Road, Millers Point, NSW', dated 20 October 2010, by AECOM
- 'Supplementary Data Gap Investigation, VMP Area, Hickson Road, Millers Point, NSW', dated 9 March 2012, by AECOM
- 'Sampling, Analysis and Quality Plan, Data Gap Investigation', dated April 2012 (Rev D) and version dated April 2012 (Rev C), by JBS
- 'Ecological Risk Assessment for Proposed Imported Soils', dated May 2012 (Rev B), by JBS
- 'Human Health and Ecological Risk Assessment for Proposed Imported Soils', dated July 2012 (Rev C) and earlier draft versions including dated May 2012 (Rev B), by JBS
- 'Data Gap Investigation', dated August 2012 (Rev C) and earlier version dated July 2012, by JBS
- Letter 'Additional Human Health Risk Assessment Calculations – Basement Exposures, Barangaroo Central Residential Development', dated 25 January 2013, by JBS
- 'The Use of Asbestos-Contaminated Soils on Barangaroo', dated March 2013, by Associate Professor Tim Driscoll, Sydney School of Public Health, Sydney Medical School, University of Sydney
- 'Human Health Risk Assessment', dated May 2013 (Rev C) and earlier version dated July 2012, by JBS
- 'Remedial Action Plan', final draft dated May 2013 (Rev H) and earlier versions dated between September 2012 and March 2013 (Rev B, D, E and G), by JBS

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 'Director General's Assessment Requirements (Section 78(8A) of Environmental Planning and Assessment Act 1979), SSD 5374, Barangaroo Central Waterfront Promenade and Interim Public Domain Works' dated 30 July 2012
- DOP 'Draft Development Consent (Section 89E of the Environmental Planning & Assessment Act 1979), SSD12_5374, Barangaroo Central Waterfront Promenade and Interim Public Domain Works' dated 17 February 2013.

Strike out as appropriate

- 'Site Audit Report, Overarching Remedial Action Plan, Barangaroo', dated June 2010 and Site Audit Statement GN439A by ENVIRON Australia Pty Ltd.
- 'Site Audit Report, Remedial Action Plan, Other Remediation Works (South), Barangaroo', dated 14 July 2011 and Site Audit Statement GN439B-1 by ENVIRON Australia Pty Ltd.
- 'Site Audit Report, Remedial Action Plan, Headland Park, Barangaroo'', dated 14 November 2011 and Site Audit Statement GN439B-2 by ENVIRON Australia Pty Ltd.
- 'Site Audit Report, Remedial Action Plan, Declaration Area and Block 4, Barangaroo', dated 31 July 2013 and Site Audit Statements GN447A and GN439B-3 by ENVIRON Australia Pty Ltd.

Site audit report

Title:... Site Audit Report – Remedial Action Plan, Barangaroo Central

Report no. GN 439B-5 (ENVIRON Ref: AS121473) Date: July 2013


Overlap already assessed (headland park) - excluded from the Central site audit area.
Source: Base image www.nearmap.com (25-10-2011)
© 2013 JBS Environmental Pty Ltd
0 12.5 25 50 m
Scale: 1:1,500
Datum: MGA94 Zone 56 - AHD
A4
Q Original Issue - R06 RF 27-3-2013
Rev Description Drn. Date:
Legend:
Soil Sample Locations (JBS May 2012)
Historic Soil Sample Locations
Approximate Site Boundary
Barangaroo Central Residential Basements (10 m Depth)
Overlap of Area Already Assessed (Headland Park)
Inaccessible for soil and groundwater sampling
Part of Declaration Area - Approximate Extent
JBS ENVIRONMENTAL
Figure 5: JBS (2012a) Soil Sample Locations
Client: Barangaroo Delivery Authority
Project: Barangaroo - Central
Job No: 42021
File Name: 42021_05

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 ... "to remove the risks posed by contamination at the Barangaroo Central Site to future site occupants and the surrounding environment".

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)*

'Remedial Action Plan, Barangaroo Delivery Authority, Stage 1 Public Domain, Barangaroo Central, Hickson Road, Sydney, NSW' Rev H dated May 2013 by JBS Environmental Pty Ltd

subject to compliance with the following condition(s):

1 Preparation of a revised Remedial Work Plan to confirm the sequence of proposed remediation and validation tasks. Clarification also required around the site acceptance criteria and relevant data sets and the proposed remedial extent (including vertically) (refer Site Audit Report (SAR) Section 12.5).

2 Remediation works are undertaken in compliance with an acceptable 'Materials Compliance Management Plan' (refer SAR Section 13).

3 Preparation of a suitable Validation Sampling and Analysis Quality Plan to address ambiguities in the RAP and validation at BH/MW69 and BH530 (refer SAR Section 12.4).

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

4 Implementation of an Asbestos Management Plan during development.

Overall comments

Barangaroo Central comprises the central portion of the site known as "Barangaroo", at Millers Point, NSW. The site is proposed to be developed in the long term for high density residential usage with open space areas. Interim development is proposed for public open space, known as Barangaroo Stage 1 Public Domain. This will require filling across the majority of the site to raise the surface level of the site and create a fall to Darling Harbour. The RAP estimates importation of up to 150,000 m^3 of fill material. The area will be landscaped with grass and some large plantings. The imported fill material will include growing media for the landscaping. The remainder of the site will be used as a temporary construction staging area and will retain the existing site paving.

Risk based remediation and materials acceptance criteria have been developed based on the proposed interim and final site uses. Soil and groundwater investigations have been conducted and the results compared to the criteria to determine the extent of remediation and management required. There are some ambiguities in the proposed remediation and validation, and further clarification is required.

In the Auditor's opinion, the proposed remediation and validation approach described in the Remedial Action Plan (RAP) is appropriate subject to Conditions 1 to 4 above. It is recommended that these Conditions are fulfilled, including review by the Auditor, prior to commencement of the major development works.

The RAP envisages a requirement for long term monitoring / management of the site following completion of the works. The requirements will be determined following review of the validation and materials tracking data and will apply to the interim open space development and future residential use. It is envisaged that a Site Audit Statement will be prepared at completion of the works for both stages of development. This is a condition of the draft Development Consent for the Stage 1 Public Domain.

Barangaroo Central adjoins the northern and western sides of part of Barangaroo that has been declared as significantly contaminated by NSW EPA ("the Declaration Area"). It is noted that the currently proposed southern basement for the future residential development crosses into the Declaration Area. That part of the Declaration Area has not been addressed in a Remedial Action Plan considering the suitability of the site for future residential use. A site audit confirming the site can be made suitable for its intended use should be performed for the Declaration Area portion of the southern basement at the appropriate time.

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... 31/7/2013

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:

EPA (NSW)
Contaminated Sites Section
PO Box A290, SYDNEY SOUTH NSW 1232
nswauditors@epa.nsw.gov.au

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

AECOM	AECOM Australia Pty Ltd
AHD	Australian Height Datum
ALS	Australian Laboratory Services
ASET	Australian Safer Environment and Technology Pty Ltd. (Laboratory)
ANZECC	Australian and New Zealand Environment and Conservation Council
BaP	Benzo(a)pyrene
BDA	Barangaroo Delivery Authority
BTEX	Benzene, Toluene, Ethylbenzene & Xylenes (Monocyclic Aromatic Hydrocarbons)
CEMP	Construction Environmental Management Plan
CCME	Canadian Council of Ministers of the Environment
CN	Cyanide (total or free)
CoPC	Chemicals of potential concern
CPAH	Carcinogenic PAH 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
CT	Certificate of Title
CQAP	Construction Quality Assurance Plan
DEC	Department of Conservation (now EPA)
DECC	Department of Environment & Climate Change (now EPA)
DECCW	Department of Environment, Climate Change and Water (now EPA)
DOP	Department of Planning
DP	Deposited Plan
DQO	Data Quality Objectives
EnRiskS	Environmental Risk Sciences Pty Ltd
EPA	Environment Protection Authority (NSW)
ERA	Ecological Risk Assessment
ERM	Environmental Resources Management Pty Ltd
ESA	Environmental Site Assessment report
ha	Hectare
HHRA	Human Health Risk Assessment
HHERA	Human Health and Ecological Risk Assessment
J&K	Jeffrey and Katauskas Pty Ltd
JBS	JBS Environmental Pty Ltd
km	Kilometres
LOR	Limit of Reporting
LTEMP	Long Term Environmental Management Plan
m	Metres
MAH	Monocyclic Aromatic Hydrocarbons
MCMS	Materials Compliance Management System
Mercury	Inorganic mercury unless noted otherwise
Metals	As: Arsenic, Cd: Cadmium, Cr: Chromium, Cu: Copper, Ni: Nickel, Pb: Lead, Zn: Zinc, Hg: Mercury
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Litre
mbgl	Metres below ground level
MWQG	Marine water quality guidelines
µg/L	Micrograms per Litre
NATA	National Association of Testing Authorities
NC	Not Calculated
ND	Not Detected
NEHF	National Environmental Health Forum
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
n	Number of Samples
OCP	Organochlorine Pesticides

OEH	Office of Environment and Heritage (now EPA)
OH&S	Occupational Health & Safety
OHSMP	Occupational Health & Safety Management Plan
OPP	Organophosphorus Pesticides
ORWN	Other Remediation Works (North)
ORWS	Other Remediation Works (South)
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PID	Photoionisation Detector
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 Works Plan
SAC	Site Acceptance Criteria
SAQP	Sampling and Analysis Quality Plan
SAR	Site Audit Report
SAS	Site Audit Statement
SIL	Soil Investigation Levels
SPGWT	Separate phase gasworks waste and tar
SVOC	Semi Volatile Organic Compounds
TPH	Total Petroleum Hydrocarbons
TVs	Trigger Values
UCL	Upper Confidence Limit
VENM	virgin excavated natural material
VOC	Volatile Organic Compounds
VSAQP	Validation Sampling and Analysis Quality Plan
-	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 central portion of the area known as 'Barangaroo', at Millers Point, NSW, on behalf of Barangaroo Delivery Authority (BDA). Barangaroo is a large area 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 'Barangaroo Central' area ('the site', 'Central'). The site location is shown on Attachment 1, Appendix A. The portion of Barangaroo which previously contained part of a manufactured coal gasworks and which has been declared by the NSW Environment Protection Authority (EPA) as a Remediation Site ('the Declaration Area') adjoins the southeast part of Barangaroo Central.

The Audit was conducted to provide an independent review by an NSW EPA Accredited Auditor of what remediation or management is necessary before the land is suitable for specified uses i.e. a "Site Audit" as defined in Section 4 (1) (b) (iv) of the *NSW Contaminated Land Management Act 1997* (the CLM Act).

1.2 Background

Details of the audit are:

Requested by:	Fleur Mellor of Barangaroo Delivery Authority (BDA)
Request/Commencement Date:	16 April 2012
Auditor:	Graeme Nyland
Accreditation No.:	9808

The Barangaroo project site is a large site being developed in stages for a variety of uses. A number of contamination investigations have been conducted across Barangaroo since 1996. Separate Remedial Action Plans (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 reusing material from one part in another part, an 'Overarching RAP' was prepared (ERM 2010, referenced below) to identify strategies and remedial options for remediation of the whole site.

The Auditor has previously prepared the following document:

- 'Site Audit Report, Overarching Remedial Action Plan, Barangaroo', dated June 2010. This report provided a review of the Overarching RAP (ERM, 2010), and included Site Audit Statement GN439A.

Detailed investigations have subsequently been conducted on Barangaroo Central, followed by preparation of a remediation action plan (RAP). Reports referenced below detail these activities and have been reviewed during preparation of this Site Audit Report (SAR). Reports prepared prior to 2012 that are relevant to Barangaroo Central were prepared for the larger Barangaroo area.

The southern-most portion of Barangaroo, known as Other Remediation Works (South) (ORWS), has been subject to a separate RAP which has been audited, documented in:

- 'Site Audit Report, Remedial Action Plan, Other Remediation Works (South), Barangaroo', dated 14 July 2011 and Site Audit Statement GN439B-1.

This SAR discusses issues such as remediation criteria and building design parameters for basement construction which have been adopted in the Central RAP for part of the proposed Barangaroo Central development.

The northern portion of Barangaroo, known as Headland Park, has been subject to a separate RAP which has been audited, documented in:

- 'Site Audit Report, Remedial Action Plan, Headland Park, Barangaroo', dated 14 November 2011 and Site Audit Statement GN439B-2.

This SAR included a portion of land located within the currently defined Barangaroo Central site, in the northwest.

The Declaration Area has been subject to a separate RAP which has been audited, documented in:

- 'Site Audit Report, Remedial Action Plan, Declaration Area and Block 4, Barangaroo', dated 31 July 2013 and Site Audit Statements GN447A and GN439B-3 (**the Declaration Area Site Audit Report)**

This SAR (specifically SAS 447A) discusses issues such as the extent of remediation required at the Declaration Area, which is relevant to the Central RAP.

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)
  - 'East darling Harbour Geotechnical and Environmental Investigation, Summary of Findings', dated September 2006, by Environmental Resources Management Australia Pty Ltd (ERM)
  - '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
- ‘Overarching Remedial Action Plan for The Barangaroo Project Site, Sydney’ dated 1 June 2010, by ERM (**the Overarching RAP**, ERM 2010)
- ‘Data Gap Investigation, Other Remediation Works North, Hickson Road, Millers Point, NSW’, dated 20 October 2010, by AECOM Australia Pty Ltd (AECOM)
- ‘Supplementary Data Gap Investigation, VMP Area, Hickson Road, Millers Point, NSW’, dated 9 March 2012, by AECOM
- ‘Sampling, Analysis and Quality Plan, Data Gap Investigation’, dated April 2012 (Rev D) and version dated April 2012 (Rev C), by JBS (JBS, 2012a)
- ‘Ecological Risk Assessment for Proposed Imported Soils’, dated May 2012 (Rev B), by JBS (JBS, 2012b)
- ‘Human Health and Ecological Risk Assessment for Proposed Imported Soils’, dated July 2012 (Rev C) and earlier draft versions including dated May 2012 (Rev B), by JBS (**the HHERA**, JBS 2012c)
- ‘Data Gap Investigation’, dated August 2012 (Rev C) and earlier version dated July 2012, by JBS (**the DGI**, JBS 2012d)
- Letter ‘Additional Human Health Risk Assessment Calculations – Basement Exposures, Barangaroo Central Residential Development’, dated 25 January 2013, by JBS (**the Additional Calculations**, JBS 2013a)
- ‘The Use of Asbestos-Contaminated Soils on Barangaroo’, dated March 2013, by Associate Professor Tim Driscoll, Sydney School of Public Health, Sydney Medical School, University of Sydney (**the Driscoll Report**)
- ‘Human Health Risk Assessment’, dated May 2013 (Rev C) and earlier version dated July 2012, by JBS (**the HHRA**, JBS 2013b)
- ‘Remedial Action Plan’, final draft dated May 2013 (Rev H) and earlier versions dated between September 2012 and March 2013 (Rev B, D, E and G), by JBS (**the RAP**, JBS 2013c)

- 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 'Director General's Assessment Requirements (Section 78(8A) of Environmental Planning and Assessment Act 1979), SSD 5374, Barangaroo Central Waterfront Promenade and lnterim Public Domain Works' dated 30 July 2012
  - DOP 'Draft Development Consent (Section 89E of the Environmental Planning & Assessment Act 1979), SSD12_5374, Barangaroo Central Waterfront Promenade and Interim Public Domain Works' dated 17 February 2013.
- Key documents considered in the Declaration Area Site Audit Report and referred to herein are:
  - 'VMP Remediation Extent, VMP Remediation Works Area, (Parts of Barangaroo and Hickson Road), Millers Point NSW', dated 23 July 2013, by AECOM (**the VMP Extent Report**, AECOM 2013a)
  - 'Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW', dated 24 July 2013, by AECOM (**the Declaration Area RAP**, AECOM 2013b)
- A key document considered in the Headland Park Site Audit Report (GN439B-2) and referred to herein is:
  - 'Human Health & Ecological Risk Assessment, Barangaroo Delivery Authority, Barangaroo Headland Park Hickson Road Sydney NSW' dated August 2011 by JBS (Rev 2) (**the Headland Park HHERA**, JBS 2011)
- Key documents considered in the ORWS Site Audit Report (GN439B-1) and referred to herein are:
  - 'Human Health and Ecological Risk Assessment, Declaration Site (Development Works) Remediation Works Area - Barangaroo' dated 9 June 2011, by AECOM (**the Declaration Site HHERA**, AECOM 2011a)
  - 'Human Health and Ecological Risk Assessment Addendum, Other Remediation Works (South) Area, Barangaroo' dated 4 July 2011, by AECOM (**the ORWS HHERA Addendum**, AECOM 2011b)
  - 'Amended Remedial Action Plan, Barangaroo – ORWS Area' dated 7 July 2011, by AECOM (**the ORWS RAP**, AECOM 2011c)
- Site visits by the Auditor commencing 18 March 2010.
- Discussions with BDA, and with JBS who prepared the RAP.

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

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 – overall audit support including analysis of field and laboratory data.
- Emma Struik – review of risk based criteria.
- Tom Onus – data analysis and review of laboratory data quality.

External support was provided by the following persons/organisation:

- Jackie Wright and Therese Manning, Environmental Risk Sciences Pty Ltd (EnRiskS) – review of human health and environmental risk assessments.

2 Site Details

2.1 Location

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

The site details are as follows:

Street address:	Hickson Road, Millers Point NSW 2000
Identifier:	Part Lots 5 and 6 in DP 876514
Local Government:	Sydney
Owner:	Barangaroo Delivery Authority
Site Area:	Approximately 4.3 ha, to current shoreline and including proposed Northern Cove.

The boundaries of the site (Attachment 2, Appendix A) are not well defined on the northern and southern side where they adjoin other parts of the Barangaroo project area. Part of the site in the northwest was previously assessed in the Headland Park SAR (GN439B-2), therefore this portion, shown in red hatching on Attachment 4, Appendix A, is excluded from the current audit area

The site area comprises part of 'Area 2' and 'Area 4' (Attachment 3, Appendix A) as referenced in previous investigations and the Overarching RAP (ERM, 2010).

2.2 Zoning

The current zoning of the site is reported in the RAP as "*Zone B4 Mixed Use and RE1 Public Recreation*".

2.3 Adjacent Uses

The site is located within an area of mixed uses as follows:

- North: open space concrete/hardstand, Headland Park part of Barangaroo project area.
- South: open space concrete/hardstand, part of Barangaroo project area including the Declaration Area to the southeast and the Other Remediation Works (North) (ORWN) Area to the southwest.
- East: Hickson Road followed by commercial and residential properties.
- West: Darling Harbour.

2.4 Site Condition

Based on information presented in the various reports and observations made during a site visit, the current site features are:

- The site is flat, at an elevation 2.5 - 3 metres above Darling Harbour water level.
- The site is covered by hard surfacing including a concrete strip along western boundary and bitumen over the rest of the site. A former large warehouse (Warehouse 5, Attachment 3, Appendix A) has been demolished.
- There is a security gate house (No. 5) on the eastern side of the site on Hickson Road.

- Temporary facilities, consisting of a cruise passenger terminal and a water treatment plant, have been constructed on the northern part and on the southern parts of the site respectively in the areas shown as 'Inaccessible' on Attachment 2, Appendix A.

2.5 Proposed Development

The site is proposed to be initially developed for public open space, known as Barangaroo Stage 1 Public Domain. This is proposed as an interim site use. This will require filling across the northern 70% of the site to raise the surface level of the site and create a fall to Darling Harbour. The RAP estimates importation of up to 150,000 m^3 of fill material. The area will be landscaped with grass and some large plantings. The imported fill material will include growing media for the landscaping.

The southern 30% of the site will be used as a temporary construction staging area and will retain the existing site paving.

The concept plan for Barangaroo Stage 1 Public Domain is included as Attachment 4, Appendix A, and shows the proposed landscaping and area to be retained as pavement. The area of proposed landscaping is referred to as Separable Portions 4 and 5.

Later development is for combined high-density residential and open space purposes. This will include residential apartments at two separate locations on the eastern side of the site shown on Attachment 2, Appendix A. The northern basement is located entirely within the Central however the southern basement extends beyond the site into the Declaration Area. The RAP assumes that basements will extend to a depth of 10m under the buildings and will be used for car parking.

The layout of the future residential development has not been advised but is assumed to include public open space in areas outside the proposed building footprints. The RAP does not indicate what elements, if any, of the Barangaroo Stage 1 Public Domain will be retained for the future development, including how much of the imported fill material will be retained.

Various land use scenarios have been considered for the purposes of this audit. Risk based criteria have been derived for different zones in the proposed development, considering factors such as distance from indoor spaces, potential exposure to humans and plants, and exposure to groundwater or seepage water. These are discussed in Sections 7.3 and 10.

3 Site History

The DGI summarised historical information largely from earlier ERM reports which provided a site history based on aerial photographs, site photographs, title deed searches and previous environmental investigations. JBS also conducted their own historical aerial photograph review.

The DGI notes that a gasworks operated to the southeast of the site but within the Barangaroo project area from approximately 1840 to 1925. Site history specific to Central is summarised in Table 3.1.

Table 3.1: Site History

Date	Activity
1840-1936	Ship berthing and associated activities such as workshops, stores and merchants.
1936-1972	Finger wharves, which were removed over time as reclamation occurred. Land was reclaimed from the harbour with fill from unknown sources, mainly after 1951. Finger wharves were demolished 1961-1968. The site was used for various port related activities.
1972-2007	Commercial and port related activities including warehousing continued.
2007-present	Majority of the site vacated, warehouses demolished and site cleared. A temporary cruise ship terminal was established with associated parking areas. A public walkway was present on part of site.

The summary indicates that the site has been used for wharf/port related activities since the 1800s. In the Auditor's opinion, the site history provides an adequate indication of general past activities, though few details have been provided specific to contamination potential.

The major uncertainty in the site history appears to be the sequence and source of filling activity. Uncontrolled or undocumented fill was used in various stages of site reclamation. It does not appear that any sections of the site were filled during the gasworks operation. The use of gasworks waste in bulk filling therefore seems unlikely, but the exact extent of the gasworks is not known and it could extend onto the south-eastern part of the site. The potential remains for contaminated fill from other sources to have been used.

No details have been provided for other site uses including workshops, which have potential for more localised contamination.

Details regarding the contamination potential of specific site usages are lacking, and the exact extent of the gasworks and potential impact on the site is not known. The gaps in site specific history have been compensated for by the density of sampling and analyses undertaken.

4 Contaminants Of Concern

The primary potential for contamination at the site is associated with uncontrolled fill used in various stages of site filling, possibly including fill from the former gasworks that was located southeast of the site within the Barangaroo project site. The DGI presents a conceptual site model which includes a brief list of contaminants of concern.

Contaminants of concern are tabulated in Table 4.1 below:

Table 4.1: Contaminants of Concern

Area	Activity	Potential Contaminants
All of site	Historic reclamation with fill from unknown sources	Could include metals, TPH, BTEX, PAH, PCB, OCP, VOC, SVOC and asbestos.
Localised but unknown areas	Workshops, fuel storage	Contaminants could include metals, TPH, BTEX, PAH and VOC.
Locations of former buildings	Demolition of buildings or deterioration of building materials	Could include lead, PCB and asbestos.
Southeast near former gasworks	Waste disposal from gasworks or migration of contamination onto the site	Could include metals, TPH, BTEX, PAHs, phenol, sulphate, cyanide and ammonia.

Notes:

Metals: arsenic, copper, chromium, cadmium, mercury, lead, nickel and zinc

TPH: total petroleum hydrocarbons

BTEX: benzene, toluene, ethylbenzene and xylenes

PAH: polycyclic aromatic hydrocarbons

PCB: polychlorinated biphenyls

OCP: organochlorine pesticides

VOC: volatile organic compounds

SVOC: semivolatile organic compounds

Most soil samples in the earlier ERM investigations were analysed for the primary contaminants of concern, being heavy metals and PAH. There were no VOC or SVOC scans, but some analyses of the most likely constituents, which are BTEX (VOC) and PAH, phenols, OCP, OPP and PCB (SVOC). There were relatively few analyses of OCP, OPP, and PCB. A lower sampling density was also completed for asbestos.

AECOM collected soil samples from the site during investigation of other areas of Barangaroo. Most samples were analysed for metals, TPH, BTEX, PAHs and phenols. Selected samples were also analysed for VOC and SVOCs, cyanide, ammonia and asbestos.

On the basis of the ERM investigation results, the majority of soil samples in the DGI were analysed for PAH, with a lesser but substantial number for a suite of 8 heavy metals. A small number of samples were analysed for VOC selected on the basis of field screening. The Auditor considers that the analytical strategy was appropriate. Where potential contaminants of concern have not been analysed, associated substances have been. Soil results are discussed in Section 8, together with the number of samples analysed for each analyte.

JBS note that asbestos has been found on other parts of Barangaroo. Although none was observed in the Central investigations, the investigations were conducted by boreholes which are not conducive to identifying asbestos.

ERM groundwater samples were analysed for the primary contaminants of concern, being heavy metals, TPH/BTEX and PAH. AECOM groundwater samples were analysed for metals, TPH, BTEX, PAHs, phenols and cyanide, with selected samples analysed for the full VOC and SVOC suite. Groundwater samples in the DGI were analysed for PAH, 8 metals, VOC (including BTEX) and ammonia. Groundwater results are discussed in Section 9.

The Auditor considers that the analyte lists used by ERM, AECOM and JBS in the investigations undertaken are appropriate for the site history and condition.

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 JBS air photo review indicates that in 1943 prior to the site's initial development it was inundated. Pre-filling conditions would therefore have consisted of marine sediments overlying Hawkesbury Sandstone. Bores along the eastern side of the site near Hickson Road typically have 6-9 m of fill, with the fill thickness increasing to 16-18 m near Darling Harbour.

The sub-surface profile of the site is summarised in Table 5.1.

Table 5.1: Stratigraphy

Thickness (m)	Material	Location	Description
0.5	Pavement	Over all of site	Hard surfacing, bituminous concrete except for 20 m concrete strip along the shoreline
			Gravel, occasionally concrete slab
6 – 18	Fill	Shallowest on eastern side near Hickson Road, increasing in thickness towards Darling Harbour	Variously described as sand or clay but mainly sandy, gravelly, silty or clayey in places. Possibly broken sandstone. Contains some brick, concrete, tile, but appears minor
0 – 2	Alluvial soil	Overlying bedrock or residual soil, absent in places on eastern side	Alluvial sediments consisting predominantly of dark silty clay
0 – 20	Residual soil	Overlying bedrock, absent in places on eastern side	Sandy clay residual, highly weathered rock
	Bedrock	Whole of site	Sandstone, some shale. Weathering and fracturing decreasing with depth.

None of the reports reviewed were able to identify any distinct differences in fill types within the fill. Most logs indicate layering within the fill, based on colour or texture. Comparison of logs from holes close to each other indicates significant differences in soil descriptions and presence of anthropogenic material or hydrocarbon odours. JBS logs were based on disturbed samples from augers only, and therefore are likely to be less reliable than the J&K, ERM and AECOM logs where more SPT or push tube samples were obtained. The ERM logs seem to record more sand than the JBS logs, and indicates that much of the fill may be crushed sandstone.

The presence of anthropogenic material such as brick or concrete is noted in places, but does not appear to be a major component of the fill. Bores in which anthropogenic material was logged are spread over the whole site and do not appear to indicate any particular area of demolition rubble fill. Hydrocarbon odours are noted in bores across the whole site.

In the Auditor's opinion, the overall stratigraphic conditions are well known. Uncertainties include the distribution of different fill types and whether they will have any significance on contaminant distribution.

5.2 Hydrogeology

Groundwater at the site is shallow, generally about 2 m below ground level (bgl) reflecting sea level and tidal fluctuations. Tidal studies at the southern end of Barangaroo indicate a high degree of connectivity between groundwater at the site and the adjoining waters of Darling Harbour, decreasing towards Hickson Road. The amplitude of tidal fluctuations has not been measured at Central.

Wells at Central have not been subject to hydraulic conductivity testing. Field sampling sheets do not include observations of recovery. A wide range of hydraulic conductivity can be expected depending on the local fill type. As most of the fill is logged as sandy, relatively high permeability is anticipated.

There are a series of east-west subsurface drainage channels across the site. As groundwater is shallow, these may provide more permeable flow paths.

Groundwater quality would be expected to be saline, approaching seawater composition. The overall groundwater flow direction is expected to be to the west towards Darling Harbour, but the flow regime will be impacted by tidal influence and hydraulic conductivity variability in the fill.

In the Auditor's opinion, hydrogeological conditions are reasonably well know allowing for local variations, with overall flow towards Darling Harbour and migration of contaminants influenced by tidal action.

6 Evaluation of Quality Assurance and Quality Control

6.1 Data Sources

The Auditor has assessed the overall quality of the data by review of the information presented in the referenced reports. The data sources are summarised in Table 6.1.

Table 6.1: Summary of Investigations

Investigations	Field Investigations	Analytical Data Obtained
ERM (2007) Investigations over the whole of Barangaroo project area Groundwater sampling conducted in July 2006	33 bores on Central, 4 completed as monitoring wells. Some cored into bedrock, with rock core logs reported in J&K (2006).	Chemical analysis of wide range of potential organic and inorganic contaminants in soil and groundwater. Included TPH, BTEX, 8 metals (As, Cd, Cr, Cu, Pb, Ni, Hg, Zn), major ions, cyanide, ammonia, PAH, PCB and some other SVOC.
ERM Groundwater sampling conducted in August 2007	Sampling of groundwater wells	Results tabulated in ERM (2008).
ERM (2008) Groundwater sampling conducted in May 2008	Additional 11 boreholes, 3 converted to monitoring wells. Included former Warehouse 5 footprint and an upgradient well. Initial groundwater wells resampled.	Chemical analysis of wide range of potential contaminants in soil and groundwater.
AECOM (2010) Investigations mainly in Declaration Area	7 boreholes, 2 converted to monitoring wells. Locations were concentrated downgradient of the Declaration Area. Groundwater sampling of 5 wells.	Chemical analysis of wide range of potential contaminants in soil and groundwater.
AECOM (2012) Investigations mainly in Declaration Area	4 boreholes, 1 converted to monitoring well. Locations were concentrated downgradient of the Declaration Area. Groundwater sampling of 3 wells.	Chemical analysis of wide range of potential contaminants in soil and groundwater.
JBS (2012) Specific to Central. Majority of soil analyses on Central were from this investigation, all from disturbed samples.	52 boreholes spread over accessible areas of the site. 18 locations converted to monitoring wells, including 6 shallow/deep pairs. Six of 7 existing wells resampled.	Soil analysis for 8 metals and PAH, with a few also analysed for VOC. Some column leaching tests with distilled water for PAH and metals. Groundwater analysis for VOC including BTEX, 8 metals, PAH and ammonia.

6.2 Data Quality Review

The Auditor's assessment follows in Tables 6.2 and 6.3. No source documents were provided for the ERM groundwater sampling in August 2007, therefore the data quality cannot be reviewed.

Table 6.2: QA/QC – Sampling and Analysis Methodology Assessment		
Sampling and Analysis Plan and Sampling Methodology	**Auditor's summary**	**Auditor's Comments**
Soil Sampling Pattern and Locations (Attachment 2, Appendix A)	**Soil:** ERM (2007) boreholes were on a grid pattern of approximately 50 m spacing but also with many targeted bores. Initial investigation locations were restricted by the presence of a warehouse, but footprint was investigated in 2008. JBS investigations were on an approximate grid, but the cruise ship terminal and water treatment plant areas were inaccessible. There are ERM bores in those areas. AECOM investigations targeted areas down gradient of the Declaration Area.	The use of a generally grid-based investigation strategy is considered appropriate as there are no known areas of higher contamination potential to target, apart from the former gasworks located to the southeast of the site.
Groundwater Sampling Pattern and Locations (Attachment 5, Appendix A)	There are a total of 28 **Groundwater** monitoring well locations, of which 6 have shallow and deep pairs. Wells were installed as follows: • Along the western side of the site, typically spaced 30-40 m apart. Wells mainly located 20-30 m from the shoreline/site boundary. • Along Hickson Road, spaced 30-50 m apart. • In the south east of the site, downgradient from the Declaration Area. • In the centre of the site, approximately half way between Hickson Road and Darling Harbour.	The wells are considered to be appropriately located given the absence of specific targets on the site. The density of downgradient boundary wells is adequate to investigate the quality of water leaving the site. There are also sufficient upgradient wells, including near the boundary with the former gasworks Declaration Area. Internal wells are at a low density but target the areas of primary soil contamination.
Soil Sampling Density	The total number of investigation locations is approximately 86, which exceeds the minimum recommended in Table A of EPA (1995) *Sampling Design Guidelines* for hot spot detection. Spacing between bores varies from a few metres to in excess of 30 m, but is typically 15-20 m. As the spacing between bores varies, the hot spot size	Nowhere is the spacing between bores considered excessive.

Table 6.2: QA/QC – Sampling and Analysis Methodology Assessment		
Sampling and Analysis Plan and Sampling Methodology	**Auditor's summary**	**Auditor's Comments**
	that could be detected also varies over the site.	
Sample depths	ERM samples were collected from a range of depths within fill, but typically only 2-3 samples per bore were analysed. More samples per bore were analysed in the JBS sampling. Samples were generally selected for analysis based on field indications (visual, olfactory, PID) and not related to fill type. Some samples were obtained from alluvial soils, with one sample at each of 52 locations in the JBS (2012) investigation. JBS bores were terminated near the top of natural soil. Sandstone bedrock was cored in a number of locations (J&K, 2006) after drilling through the weathered rock profile, but few samples were analysed.	As sample recovery generally decreased with depth, the vertical spacing between samples generally increased with depth.
Drilling method	Most ERM bores were advanced to about 1.5 m using hand methods, then continued with solid stem auger. Due to difficult drilling conditions (obstructions, caving), some bores were continued with rotary mud, casing advancer or air hammer methods. ERM (2008) advanced some bores to up to 12 m using a 75 mm geoprobe. Some J&K (2006) holes were cored into rock with a NMLC diamond core barrel. JBS (2012) bores were advanced with solid stem augers. Boreholes for monitoring well installation were redrilled using hollow augers. AECOM (2010 and 2012) bores were advanced by air-knife for the first metre and then drilled with hollow flight augers, with standard penetration tests (SPT) undertaken every metre.	
Soil Sampling Method	ERM samples were obtained from augers, SPT split spoon, drill cuttings and geoprobe. Samples from augers and cuttings were used for logging and	Sampling from solid stem augers can result in cross contamination and loss of volatiles. The SAQP (JBS,

Table 6.2: QA/QC – Sampling and Analysis Methodology Assessment		
Sampling and Analysis Plan and Sampling Methodology	**Auditor's summary**	**Auditor's Comments**
	field screening. Nearly all samples for laboratory analysis were semi-undisturbed samples obtained from SPT, geoprobe or core. AECOM samples were collected from SPT split spoon. JBS samples were disturbed samples taken from solid stem auger flights.	2012a) stated "*undisturbed samples, as collected by pushtube or SPT sampler, are preferred where able to be effectively implemented*". Sampling by SPT was effectively implemented by AECOM and should have been adopted by JBS.
Well construction	Wells were constructed with 50 mm PVC, 0.4 mm machine slotted screens, sand packs and bentonite seals. JBS and AECOM used a 2 mm sand pack. ERM (2007) wells typically screened the upper to middle sections of the fill. Screen lengths typically range from 3.5-7 m. ERM (2008) wells used a variety of screen lengths and screened shallow fill. JBS state that their shallow wells were drilled to 2 m below water level and then completed with a 3 m screen, and therefore screen shallow fill. The logs show that most wells are screened from 3 m to 6 mbgl, and the standing water level is at or just above the well. Tidal conditions are not recorded. JBS state that their deep wells were placed approximately 1 m from their shallow pair, and were intended to be screened at the interface of fill and natural material. The logs indicate mostly 3 m screens, with some wells just above the interface and some higher up in the fill. None actually screen the interface. Wells installed by AECOM (2010 and 2012) were each screened differently. MW69 had a 3 m screen across fill and sandstone; MW74 was screened from 1.5 m to 13.5 m across fill material; and MW401 was screened across natural material from 14.5 m to 20 mbgl, with a 0.5 m sump. ERM, JBS and AECOM wells were	Well construction generally adequate. Screen intervals need to be considered in relation to specific use of the data obtained. The deep downgradient wells may be too shallow to identify deep groundwater contamination identified in upgradient wells.

Table 6.2: QA/QC – Sampling and Analysis Methodology Assessment		
Sampling and Analysis Plan and Sampling Methodology	**Auditor's summary**	**Auditor's Comments**
	developed with submersible pumps.	
Groundwater Sample Collection Method	Purging and sampling in sampling rounds by ERM and JBS was by low flow methods. AECOM used low flow submersible pump for most wells. A footvalve and tube were used on MW69 (the pump could not fit). No report is available for the 2007 sampling, results are tabulated in ERM (2008) with the 2008 results. ERM (2007 and 2008), JBS (2012) and AECOM (2010 and 2012) stated that groundwater samples to be analysed for heavy metals were field filtered using a 0.45 micron filter. Field sheets mainly indicated field filtering.	Collection methods adequate where details provided.
Decontamination Procedures	ERM and AECOM stated that downhole sampling equipment was decontaminated or dedicated, and new nitrile gloves were used in handling samples. Field filtering of water samples was conducted with disposable filters. JBS did not discuss decontamination, but daily 'Field Equipment Calibration and Decontamination' forms state that new nitrile gloves were used for each sample and that augers were decontaminated after each location.	Adequate
Sample handling and containers	Samples were placed into prepared and preserved sampling bottles provided by the laboratory and chilled during storage and subsequent transport to the labs. Laboratory sample receipts noted that samples were received in good condition and cool.	Appropriate
Chain of Custody	Completed chain of custody forms signed by the receiving laboratory were provided in the DGI report. Occasionally instructions were provided by email from JBS to the laboratory. Forms were forwarded from the primary to the secondary laboratory.	Appropriate
Field screening	Field screening for volatiles was	Adequate

Table 6.2: QA/QC – Sampling and Analysis Methodology Assessment		
Sampling and Analysis Plan and Sampling Methodology	**Auditor's summary**	**Auditor's Comments**
	undertaken using a PID. PID readings are presented on borelogs.	
Calibration of field equipment	Calibration records from the supplier and field calibration records for PIDs were provided. JBS did not provide calibration records for groundwater meters and some results appeared incorrect, however these were used only for stability in purging. AECOM provided calibration records for groundwater meters.	Adequate
Sampling Logs	Borehole logs are provided within the reports, indicating sample type and depth, PID readings and lithology. Soil logs generally provide adequate detail, though there were some constraints due to recovery. Rock logs by J& K (2006) provide detail of weathering and fracturing. Logs record indications of contamination such as odours and staining, where noted. Groundwater field sampling records were provided, and generally recorded whether there were odours or sheens and water clarity.	Logs were prepared by different people even within the same investigation stage, and there is some noticeable difference between logs and interpretations. There are noticeable differences when comparing logs by ERM and J&K with logs prepared by JBS at locations shown as close to each other. The JBS logs were prepared from disturbed samples only and are less reliable.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
Field quality control samples	Field quality control samples undertaken by ERM, JBS and AECOM included trip blanks, trip spikes, rinsate blanks, field intra-laboratory and inter-laboratory replicates.
Field quality control results	ERM reports included 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. AECOM reports included data quality assessment. Some RPD exceedances were reported for soil and groundwater field duplicates, mostly for metals in fill material. These were attributed to fill material heterogeneity and/or low concentrations. Rinsate blanks, trip blanks and trip spike results were generally acceptable. JBS included detailed QA/QC results. There were some exceedances of desirable RPDs in duplicates, attributed to results

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
	just above LORs and/or fill heterogeneity.
NATA registered laboratory and NATA endorsed methods	Laboratories used by ERM were: ALS and LabMark. JBS (DGI) used Envirolab and SGS. AECOM used ALS, LabMark, SGS and Australian Soil Testing. Laboratory certificates were NATA stamped. It is noted that the appendix containing laboratory certificates for ERM (2007) was not provided to the Auditor. Detailed quality control reports were provided.
Analytical methods	Analytical method summaries were included in the laboratory test certificates from each laboratory.
Holding times	Review of the COCs and laboratory certificates indicate that the holding times had generally been met. ERM reported several minor exceedances. AECOM reported exceedances for samples scheduled for additional analyses and several other minor exceedances. JBS reported that all holding times were met. Random checks of sampling dates and laboratory certificates supports this, except that check laboratory SGS reported a PAH extraction outside of holding time.
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 matrix interference by other contaminants. For the JBS DGI groundwater sampling, the PQL was 0.1 µg/L for most individual PAHs. Mercury PQL was 0.05 µg/L. The check lab SGS had some different but generally lower PQLs.
Laboratory quality control samples	Laboratory quality control samples including laboratory control samples, matrix spikes, surrogate spikes, method blanks, standards and duplicates were undertaken. ALS reports surrogates with organic results, and provide separate quality reports covering duplicates, laboratory control samples, method blanks and holding times. Envirolab reports surrogates with organic results, and provide a separate quality report with each batch including method blanks, control spikes and duplicates. LabMark reports laboratory control samples, method blanks and surrogates with the results, and also certified reference material results with metals. SGS provided separate statements of QA/QC including surrogates, method blanks, duplicates, laboratory control samples, matrix spikes and matrix spike duplicates.
Laboratory quality control results	Laboratory certificates for ERM (2007) were not provided to the Auditor. ERM provided a detailed quality review and concluded that data were acceptable. The results from nearly all ERM laboratory quality control samples were within appropriate limits. Exceptions were: - RPDs for some duplicate samples for PAH analysis, for which the laboratory accepted the results because the soil was non

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
	homogenous. - Some samples where spike recovery could not be reported because of interference from high concentrations of analytes. In the DGI, Envirolab reported a few RPD exceedances for metal duplicates (Pb, Cu, Ni or Hg). In these cases they analysed a triplicate. They also reported a few PAH exceedances of RPD, which they attributed to non homogeneous samples. A few low spike recoveries were redigested with similar results, attributed to matrix interference. A high spike recovery for zinc was attributed to non homogeneity. Several spike recoveries were not possible due to high analyte concentrations. SGS reported a few failures of QA/QC samples, attributed to "sample heterogeneity".
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. JBS included data quality objectives in their SAQP for the DGI. The DGI included a review of data and concluded that the analytical results were reliable and representative. AECOM reports included data quality objectives, data quality indicators, and a review of data. AECOM concluded that the analytical results were reliable and representative.

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. Although conditions may vary locally within non-homogenous fill, it is considered that the analytical results should be representative of the overall soil and groundwater conditions. As many samples were selected for analysis based on field indications of contamination, results are likely to be biased towards "worst case".
- All samples were obtained from boreholes and the majority of the samples, being all the samples in the DGI, were disturbed samples. This limits the ability to produce detailed logs and for inspection of contaminant distribution and identification of anthropogenic material such as asbestos. It may also result in cross contamination, which appears to be evident in the higher frequency of PAH detections in samples collected by JBS (86%), compared to samples collected by ERM in Central (39%) and on Barangaroo (60%).
- 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. There was very few departures from laboratory QA/AC control limits within a large amount of data.
- Laboratory data was not provided to the Auditor with the ERM (2007) report. The same laboratories were used as for ERM (2008), and a detailed quality assessment was provided. No information was provided in respect to groundwater sampling and analysis in August 2007. While methods are likely to have been equivalent to the 2006

and 2008 ERM investigations, this cannot be confirmed. As noted in Section 9, some data is anomalous. The 2007 results appear unreliable. The DGI greatly increased the amount of data, so that the ERM results represent a small minority of the analytical results for the major contaminants.

- Apart from the 2007 groundwater results, the data is 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 to characterise the contaminant status of the site and to manage contamination.

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 and distribution. The findings are discussed in Sections 8 and 9 of this SAR. Risk-based remediation and materials acceptance criteria have been developed by JBS to determine the extent of remediation required at the site as discussed in Section 10 of this SAR.

7.1 Soil

Table 7.1 presents a summary of the soil screening criteria used for the main contaminants of concern. Equivalent screening criteria have been used for other potential contaminants. Although these criteria would generally be above background, they provide an overall indication of the degree of contaminant impact. They would be protective of most site uses, but not necessarily of leaching of contaminants to groundwater.

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 C_{10}-C_{36}	1000	EPA (1994) *Guidelines for Assessing Service Station Sites*

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

7.2 Asbestos

Criteria for asbestos are provided in the recently amended NEPM 1999. Criteria considered by the Auditor are for open space use and are summarised as follows:

- Less than 0.02% asbestos as asbestos containing material (ACM)
- Less than 0.001% asbestos as Asbestos fines (AF) or fibrous asbestos (FA)
- No visible asbestos on the surface

These criteria apply to the initial site development and are also relevant for future open space areas included in the residential site development (outside building footprints).

JBS has referred to the Driscoll Report (2013) which recommends asbestos criteria to be applied to soils on the Barangaroo site as may be potentially accessible during construction phases of works. The relevant criteria are summarised as:

- No free asbestos or asbestos fibres (i.e., no fibrous asbestos or asbestos fines)
- Less than 0.001% asbestos / less than 0.006% ACM
- No visible ACM.

JBS has adopted these criteria for all imported soils and all potentially accessible soils with the proposed extent of excavation / construction works on the Barangaroo Central site. It is noted that these criteria are more conservative that the NEPM criteria.

7.3 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 PAHs.

7.4 Risk Based Criteria

The RAP summarises risk-based criteria that have been derived by AECOM for the Declaration Area for removal of environmental risk and to make the site suitable for development. AECOM criteria specific to the Barangaroo South Development are also discussed, and JBS derived separate criteria for Central. The RAP discusses the applicability of the various criteria to the proposed Central development, both for the Stage 1 Public Domain and the future residential development with separate southern (near and crossing into the Declaration Area) and northern basements.

Criteria which JBS then proposed as Site Acceptance Criteria cover the following elements:

- For the southern basement: criteria for groundwater and unsaturated soil in contact with the southern basement. These criteria are derived assuming a number of design and construction elements are incorporated into the basement design, and also require that no tar is in contact with the basement wall.
- For the northern basement: criteria for soil within 10 m of the basement wall, to apply to both saturated and unsaturated soil; criteria for unsaturated soil greater than 10 m from the basement wall; criteria for groundwater in contact with the basement
- Soil in open space areas: criteria for human health protection are derived for the upper 0.5 m and for soil below 0.5 m. Separate criteria are derived for soil to be used as growing media.

- Imported soil to be used anywhere on site, with criteria derived to prevent leaching of contaminants to groundwater and adversely impacting Darling Harbour. Criteria are presented for saturated and unsaturated soils and are also relevant for existing soils.

The risk-based criteria are reviewed in Section 10. Many of these criteria apply to the same soils, and the RAP does not provide a single set of criteria for each element. The RAP does not present a summary of investigation data compared to the presented criteria.

8 Evaluation of Soil Analytical Results

Soil conditions have been investigated by over 100 boreholes as outlined in Section 6.1. Soil sampling locations are shown on Attachment 2, Appendix A.

Soil data summary tables are provided in the RAP for the JBS data and historical data (ERM and AECOM). Some data is missing from the historical summary tables in the RAP including ERM heavy metals and inorganics.

The following sections discuss the field and laboratory results.

8.1 Field Observations

Borelogs included observations of odours. Hydrocarbon odours were noted in fill and natural soil in approximately 20% of bores. These appeared to be concentrated in the south-eastern area of the site, near the Declaration Area boundary. Odours were also noted at a number of locations elsewhere on the site and appear to be randomly distributed in fill material.

Field screening using a PID was undertaken at all locations and results recorded on borelogs. Most results were low, <5 ppm, indicating absence of volatile organic compounds in most locations. The highest PID readings (up to 2,314 ppm) were recorded in the base of the fill and natural material at the southeast corner of the site near the Declaration Area. The highest PID reading coincided with observations of tar, staining, sheen and hydrocarbon odour. Samples with a PID reading above 10 ppm or with a hydrocarbon odour were analysed for VOC by JBS.

Tar was observed in natural soil in the southeast of the site (BH70, BH400, BH401, BH402 and BH403) and in shallow fill material in BH70 (2.5-4 mbgl) and BH74 (1-2.5 mbgl) located in the south of the site. JBS did not note any observations of tar. JBS boreholes are located in close proximity to AECOM locations where up to 8 m of tar was observed. The absence of tar observations by JBS is attributed to the drilling method adopted (solid stem auger), which limits the ability to observe the stratigraphy.

ERM noted black staining in fill material at a number of other locations across the site. This is not considered to be indicative of tar from the former gasworks due to the general absence of hydrocarbon odours and elevated PID readings.

Borelogs also recorded the presence of anthropogenic material. Brick, concrete and/or tile were recorded in about 50% of bores which appear randomly distributed over the site. Anthropogenic material content appeared minor, although this is difficult to assess from boreholes.

Bedrock was sampled only in the J&K (2006) investigation. There were no indications of contamination recorded.

8.2 Soil Analytical Results

Soil samples were analysed for a variety of contaminants including metals, cyanide, phenols, PCBs, pesticides, petroleum hydrocarbons, PAHs, VOCs, SVOCs, sulphate and asbestos. The results for samples of fill material have been summarised in Table 8.1. Table 8.1 excludes duplicate analyses.

Table 8.1: Screening of Fill Material Analytical Results – Summary Table (mg/kg)

Analyte	n	Detections	Maximum	n > Screening Criteria	n > SIL Column 1 (DEC 2006)
Arsenic	467	88	**49**	**1**	0
Barium	30	27	200	-	-
Beryllium	30	0	<PQL	0	0
Cadmium	467	7	3	0	0
Total Chromium[1]	467	458	84	0	0
Cobalt	30	15	28	0	0
Copper	467	444	**716**	**23**	0
Lead	467	462	**1,900**	**37**	**37**
Manganese	30	27	**524**	**1**	0
Nickel	467	439	**99**	**31**	0
Vanadium	30	28	108	-	-
Zinc	467	462	**3,780**	**28**	0
Mercury (inorganic)	467	209	**8.3**	**16**	0
Total Cyanide	47	3	8	0	-
Total Phenols	42	1	28	0	-
PCBs	16	0	<PQL	0	-
OCP	2	0	<PQL	0	-
OPP	2	0	<PQL	0	-
TPH (C_6-C_9)	101	2	31	0	-
TPH (C_{10}-C_{36})	101	38	**13,770**	**7**	-
Benzene	103	9	**64**	**3**	-
Toluene	103	6	**69**	**3**	-
Ethylbenzene	103	4	**8**	**3**	-
Xylene	103	5	**87**	**2**	-
Benzo(a)pyrene	636	530	**84**	**263**	**263**
Naphthalene	636	255	1,100	-	-
Total PAHs	636	548	**2,798**	**187**	**187**
VOCs[2]	15	4	31	-	-
SVOCs[3]	6	1	4	-	-

Table 8.1: Screening of Fill Material Analytical Results – Summary Table (mg/kg)

Analyte	n	Detections	Maximum	n > Screening Criteria	n > SIL Column 1 (DEC 2006)
Sulphate	31	30	8,470	-	-
Asbestos	13	**1**	-	-	-

n number of samples
- No criteria available/used
<PQL less than practical reporting limit
1 Cr assumed to be Cr(III); Cr(VI) not indicated by site history or site inspection
2 VOCs included trimethylbenzenes, isopropylbenzene, n-propylbenzene and styrene
3 SVOCs included carbazole and dibenzofuran

The results for samples of natural material have been summarised in Table 8.2.

Table 8.2: Screening of Natural Material Analytical Results – Summary Table (mg/kg)

Analyte	n	Detections	Maximum	n > Screening Criteria	n > SIL Column 1 (DEC 2006)
Arsenic	75	26	**94**	**6**	0
Barium	12	7	20	-	-
Beryllium	12	0	<PQL	0	0
Cadmium	75	2	1	0	0
Total Chromium[1]	75	72	76	0	0
Cobalt	12	0	<PQL	0	0
Copper	75	29	**235**	**2**	0
Lead	75	68	**1,490**	**3**	**3**
Manganese	12	4	30	0	0
Nickel	75	32	16	0	0
Vanadium	12	10	248	-	-
Zinc	75	50	**813**	**3**	0
Mercury (inorganic)	75	20	**6.9**	**4**	0
Total Cyanide	27	4	3	0	-
Total Phenols	22	4	2,618	0	-
PCBs	1	0	<PQL	0	-
OCP	3	0	<PQL	0	-

Table 8.2: Screening of Natural Material Analytical Results – Summary Table (mg/kg)

Analyte	n	Detections	Maximum	n > Screening Criteria	n > SIL Column 1 (DEC 2006)
OPP	2	1	2.6[4]	0	-
TPH (C_6-C_9)	51	15	**2,640**	**9**	-
TPH (C_{10}-C_{36})	51	30	**58,140**	**13**	-
Benzene	52	29	**300**	**13**	-
Toluene	52	17	**346**	**15**	-
Ethylbenzene	52	11	**40.1**	**7**	-
Xylene	52	14	**660**	**11**	-
Benzo(a)pyrene	63	34	**194**	**16**	**16**
Naphthalene	63	19	3,440	-	-
Total PAHs	63	39	**7,677**	**17**	**17**
VOCs[2]	12	3	528	-	-
SVOCs[3]	2	2	277	-	-
Sulphate	13	10	2,480	-	-
Ammonia	6	0	<PQL	-	-

n number of samples
- No criteria available/used
<PQL less than practical reporting limit
1 Cr assumed to be Cr(III); Cr(VI) not indicated by site history or site inspection
2 VOCs included trimethylbenzenes, isopropylbenzene, n-propylbenzene, 2-methylnaphthalene and styrene
3 SVOCs included 1,3,5-trinitrobenzene, 2,6-dinitrobenzene, azobenzene, carbazole and dibenzofuran
4 OPP detected was Ethion (BH70_16-16.2)

In considering the analytical data for fill and natural material relevant to Central, the Auditor notes:

- The most common contaminants are PAHs, which were detected in about 85% of fill samples. PAHs can be naturally occurring at low concentrations, but most of these detections indicate some contaminant impact. These are contaminants associated with gasworks wastes and ash from industrial processes. They appear to have been placed with and to be randomly distributed throughout the fill.
- The highest PAH concentrations in fill and natural material were detected in the southeast of the site, adjacent to the Declaration Area. The PAH concentrations in this area appear to be related to the former gasworks. The highest concentrations coincide with observations of tar, hydrocarbon odour and sheen.

- Elevated PAH concentrations were also detected in natural material in the northern portion of the site (BH179 and BH186). Soil samples were collected from less than 0.2 m into natural material and may therefore represent leaching from the fill material or cross contamination.
- Nearly all of the detections and all of the highest concentrations of TPH recorded were associated with PAHs.
- Volatile concentrations (TPH C_6-C_9, BTEX) were higher and more frequent in natural material than fill material. Where detected, they were found with the highest PAH concentrations along the eastern boundary, immediately down gradient of the Declaration Area (BH70, BH400, BH401, BH402, BH541 and BH542).
- Lead is the main metal contaminant in fill material. Most of the detections are indicative of natural occurrences, with about 8% of results exceeding the screening criteria, which is the human health soil investigation level for sensitive sites such as children's day care centres. There were relatively few high concentrations of lead recorded in fill, with only 8 results (<2%) exceeding the recreational open space and phytotoxicity investigation level of 600 mg/kg.
- While there were a few elevated concentrations of other metals in fill material (mainly copper, nickel, mercury and zinc), there do not appear to be any indications of major metal contamination in soil (although some dissolved metal concentrations in groundwater exceed groundwater trigger values, see Section 9).
- Metals concentrations in natural material were generally less than the screening criteria. The few elevated concentrations in natural material were generally in samples collected from near the interface with fill material.
- Elevated sulphate concentrations were detected in fill and natural material.
- While there was only limited analysis of cyanide, phenols, pesticides and PCBs, detections were generally not elevated. One elevated total phenol concentration was reported in natural material in BH403, where tar content was noted to be greater than 30%.
- Analysis for VOCs was undertaken where PID readings exceeded 10 ppm and/or hydrocarbon odours were observed. This resulted in a low density of analyses, however the results are likely to be biased towards "worst case". Elevated VOC concentrations (typically trimethylbenzenes and styrene) were detected in samples containing elevated PAH concentrations in the southeast of the site.
- Analysis for SVOCs was undertaken at low densities. Elevated concentrations of carbazole (154 mg/kg) and dibenzofuran (277 mg/kg) were detected in a sample of natural material from the south of the site (AECOM BH70) that also contained the highest PAH, TPH and BTEX concentrations on the site. Other SVOCs were detected at low concentrations.
- Borehole logs from ERM (2007 & 2008), JBS (2012) and AECOM (2010 & 2012) did not note the presence of asbestos. The Auditor notes that the investigation methods adopted limit the ability to assess the composition of the fill material. There is therefore the potential for asbestos to be present in the fill material at a higher frequency than

suggested by the site investigations, as has been found to be the case on other parts of the Barangaroo project area.

- Asbestos fibres were identified in one sample of fill material collected from a depth of 9-9.4 mbgl in the southeast of the site (AECOM BH401). The laboratory certificate identified “several small fibre bundles” in a sample comprising fine grained soil with some vegetation and rocks. The borehole log indicated the presence of gravelly sand fill with building rubble inclusions and “no fibre cement material noted”. There were only 13 laboratory analyses for asbestos. One other sample from BH401 was analysed for asbestos, from 3-3.4 mbgl, with none detected. There have been few detections of respirable fibres within the Barangaroo project area and it is understood that no airborne asbestos fibres have been identified in air quality monitoring undertaken to date. Asbestos within the Barangaroo project area appears to be predominantly associated with broken fibro or pipes. There have been no indications of the presence of friable asbestos sources.

JBS compared unsaturated soil data collected by ERM (2007 & 2008) and JBS (2012) with the open space criteria. The data was found to exceed the lead criterion in one location and PAH/ benzo(a)pyrene criteria in several locations. Attachment 6, Appendix A, indicates the extent of unsaturated soils (excluding AECOM data) exceeding the open space human health criteria. It is noted that the basement layout shown on Attachment 6 has been superseded.

In the Auditor’s opinion, soil contamination in fill and natural material at the site has been sufficiently characterised for the purpose of preparing a RAP.

In the Auditor’s opinion, the investigation method used (borehole drilling) does not allow for adequate observation of the bulk filling to identify fragments of asbestos-containing materials. 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 fragments of asbestos-containing materials that may not have been observed during the drilling investigations. However, the potential for friable asbestos or respirable fibres, and therefore the associated level of risk, is considered low.

JBS and AECOM analysed samples of fill and natural material for actual or potential acid sulphate soils. Four samples (two fill and two natural) were considered potential acid sulphate soils. JBS concluded in the DGI that an Acid Sulphate Soils Management Plan will be required for the site where any excavation of saturated soils is proposed.

9 Evaluation of Groundwater Analytical Results

Groundwater samples were collected from 34 wells (28 locations) installed between 2006 and 2012 which have been sampled between one and five times each. The groundwater monitoring well installation and sampling undertaken is summarised as follows:

- Groundwater samples were collected by ERM from 7 existing wells in 2008, including wells that had been installed and sampled in 2006, 2007 and/or 2008. Groundwater was analysed for the contaminants of concern, although not all samples were analysed for all analytes.
- AECOM (2010 and 2012) installed 3 wells on Central as part of investigation of other areas of the Barangaroo project site in 2010 and 2011. New and selected existing wells were sampled.
- JBS (2012) installed wells at 18 locations, including 6 shallow/deep pairs, during the DGI in 2012. The newly installed wells and selected existing wells installed by ERM were sampled.

Well locations are shown on Attachment 5, Appendix A.

Field records indicate that groundwater was generally clear and slightly turbid. Sulphur or organic odours were noted in approximately half of the wells. Hydrocarbon odour was noted in MW08, MW514, MW515, MW539 and MW541S. An organic odour was noted in MW529D, MW541D, MW543 and MW544S. Sheen was observed in MW69, MW501, MW502, MW507 and MW515.

The analytical results are summarised below in Table 9.1. Detections listed for 2006-2011 are for the number of wells in which the analyte was detected at least once, noting that wells were sampled different numbers of times and sometimes with different detection limits (PQLs). The 2012 results from JBS monitoring are also included below.

Table 9.1: Screening of Groundwater Analytical Results – Summary Table (µg/L)

Analyte	TV	ERM and AECOM, 2008-2012			JBS, 2012		
		Detections (n=10)	Maximum	n >ANZECC Marine (2000)	Detections (n=30)	Maximum	n >ANZECC Marine (2000)
Arsenic	2.3	8	**3.7**	**2**	20	**140**	**9**
Cadmium	0.7	5	**10.4**	**3**	26	0.5	0
Total Chromium	4.4	2	0.6	0	3	2	0
Copper	1.3	1	**3**	**1**	7	**12**	**5**
Lead	4.4	3	1.2	0	3	4	0
Nickel	7	9	**86.8**	**5**	16	**41**	**6**
Zinc	15	7	**41**	**8**	30	**120**	**16**
Mercury (inorganic)	0.1	0	<PQL	0	0	<PQL	0

Table 9.1: Screening of Groundwater Analytical Results – Summary Table (µg/L)

Analyte	TV	ERM and AECOM, 2008-2012			JBS, 2012		
		Detections (n=10)	Maximum	n >ANZECC Marine (2000)	Detections (n=30)	Maximum	n >ANZECC Marine (2000)
Ammonia-as Nitrogen	910	6	**90,400**	**2**	27	**42,000**	**12**
Cyanide	4	1	**14**	**1**	NA	NA	-
TPH (C_6-C_9)	-	2	3,400	-	NA	NA	-
TPH (C_{10}-C_{36})	-	4	11,500	-	NA	NA	-
Benzene	500	3	**868**	**1**	6	**4,300**	**1**
Toluene	180	2	**804**	**1**	5	**1,900**	**1**
Ethylbenzene	5	2	**77**	**1**	3	**78**	**1**
Xylenes	75	3	**384**	**1**	4	**760**	**1**
Other VOCs	var	1	194[a]	-	7	83[a]	0
Phenol	400	2	15	0	0	<PQL	0
Naphthalene	50	4	**1,920**	**2**	14	**1,900**	**3**
Benzo(a)pyrene	0.2	3	**6**	**3**	2	**50**	**1**
Anthracene	0.4	3	**28**	**3**	10	**56**	**6**
Phenanthrene	2	5	**126**	**4**	17	**170**	**5**
Fluoranthene	1.4	4	**34**	**3**	17	**120**	**3**
Total PAHs	3	6	**2,450**	**5**	20	**2,818**	**10**
PCBs	1	0	<PQL	-	NA	NA	-
SVOCs	var	1	11[b]	-	NA	NA	-

n number of samples
- No criteria available/used
var Varies for individual compounds
NA not analysed
a detections were MAHs, chloroform and bromodichloromethane
b Detection was carbazole, phthalate, acetophenone, dibenzofuran and carbazole

In review of the results, the Auditor notes:

- The highest PAH concentrations were detected in wells located in the southeast of the site, adjacent to the Declaration Area (MW69 and MW541D). Concentrations decrease to the west, and were either not detected or were marginally above the PQL in wells located near the western (downgradient) boundary of the site.

- Field observations of significant impact were not noted during sampling of MW541D, although JBS noted in the DGI that *"… the low flow sampling method adopted, with an enclosed flow cell for parameter assessment is not conducive to comprehensively assessing the aesthetic characteristics of groundwater samples"*.
- The high PAH concentrations in MW69 recorded during monitoring in March 2010 were an order of magnitude less in subsequent monitoring in February 2011. The well was not sampled a third time.
- Limitations with the groundwater data were identified in Section 6. Wells installed by JBS have been sampled only once. It is also noted that deep wells on the downgradient boundary were not extended to the interface between fill material and natural soil. The wells may therefore be too shallow to identify deep groundwater contamination identified in upgradient wells.
- PAHs were detected at low concentrations in groundwater wells in the remainder of the site. Some exceedances of the criteria were noted (MW179 and MW514), however were generally marginal. The low PAH concentrations are likely to be related to leaching from fill material.
- Hydrocarbon concentrations (TPH and BTEX) were highest in the southeast of the site in wells MW69 and MW541D, which also contained the highest PAH concentrations. JBS samples were not analysed for TPH.
- The elevated TPH C_{10}-C_{36} concentration in MW08 does not coincide with significantly elevated PAHs and phenols. The concentrations in MW08 have been confirmed by multiple sampling events. The source of the elevated TPH concentration is not clear.
- Elevated metals concentrations (arsenic, cadmium, copper, nickel and zinc) were present in wells from across the site. The JBS metals results were consistent with those recorded by ERM and AECOM, with differences being consistent with normal sampling and analysis variations. The exceedances are minor and do not indicate that groundwater remediation is required.
- Free tar that was recorded in many wells in the former gasworks was not found in wells in Central. Tar was however noted in soil during drilling of boreholes in the southeast of the site.
- Ammonia was detected in association with PAHs in the wells down gradient of the former gasworks. Ammonia also exceeded the criteria in wells in the northern portion of the site (MW501, MW502, MW507, MW506D, MW514 and MW515). The source of the elevated ammonia in the northern portion of the site is not clear. Groundwater from most of these wells was observed during sampling to display a sheen, however, significant hydrocarbon impact was not detected by laboratory analysis. The sheen may be associated with the ammonia detections.
- Detections of various VOCs and SVOCs were generally in wells containing elevated PAH, TPH and BTEX concentrations (MW69 and MW541D).
- JBS considered that the elevated contaminant concentrations identified in wells in the southeast of the site were migrating onto the site from the Declaration Area and sourced from localised gasworks waste identified on Central near the upgradient site

boundary. JBS reported that the contamination appears to attenuate within the site. The Auditor notes that apparent attenuation may be a result of tidal flushing.

- JBS considered that fill material and natural soil was not acting as a source of groundwater contamination outside of the south-eastern portion of the site. The Auditor notes that contaminant concentrations above the PQL were observed in groundwater in these areas, however the concentrations were generally less than the criteria.

Based on the groundwater analytical results, JBS recommended that risks to human health be assessed for future development of the site with deep basements. The risk assessment is reviewed in Section 10.

The RAP does not propose groundwater remediation. JBS has considered the requirement for remediation at the southern and northern basements based on different Site Acceptance Criteria. The RAP does not include data tables that identify the relevant data sets for the two different basements.

10 Assessment of Risk and Development of Site Acceptance Criteria

10.1 Overview

JBS identified the following potential risks based on the investigations performed:

- To vegetation for future development of the open space area, primarily due to heavy metal and PAH contamination.
- To human health of site users under future open space usage, primarily due to lead and PAH contamination.
- To human health of site users under future residential development with basements due to seepage water, particularly in the southern basement which crosses into the Declaration Area.
- To groundwater, with residual tar materials in the southeast acting as a source of groundwater contamination.

Site specific assessment of risk for Central was documented in the HHERA (JBS, 2012c), the HHRA (JBS, 2013b) and the Additional Calculations letter (JBS, 2013a). The HHERA provides human health and ecological criteria for material imported to the site. The HHRA reviewed risks to site users from soil and groundwater contamination identified on the site. The Additional Calculations letter supplemented both documents where basement scenarios were modelled and was based on changes to the proposed building design parameters.

A stand-alone ecological risk assessment considering the current site condition was not performed. JBS considered the risk to the environment due to migration of contaminants in groundwater in the DGI (2012d) and referred to work performed by AECOM with regards to the Declaration Area in consideration of the risk from residual tar at depth.

JBS also referred to criteria developed by AECOM for Barangaroo South for application to Central. SARs prepared by ENVIRON reviewing the AECOM works are therefore relevant to the current review. The interaction in risk issues between Central and the Declaration Area is discussed in Section 10.2.

As discussed in Section 7.3, JBS proposes to address these risks by remediation tasks defined in consideration of a range of Site Acceptance Criteria, the derivation of which is discussed in Sections 10.3 and 10.4, below. The criteria derived are included in Appendix E. The criteria proposed by JBS have been reviewed by the Auditor's specialist support, Environmental Risk Sciences Pty Ltd (EnRiskS). Extracts from the EnRiskS review report are included in Appendix F.

JBS has proposed that only tar contaminated materials above 10 mbgl and located within the proposed extent of the southern basement excavation plus one location outside present a risk and require remediation. The Auditor has considered the risk from saturated soil outside future basement areas and deep tar impact, which is relevant under both future land uses, in Section 10.5, below.

The Auditor's summary of the relevant criteria is presented in Section 10.6.

10.2 Declaration Area

The majority of risk issues at Central are derived from the adjacent Declaration Area. The Declaration Area SAR (GN447A) considered the suitability of the Declaration Area RAP for removal of the EPA declaration, not for development as high density residential and open space usage. Since the southern basement is located substantially within the Declaration Area, JBS notes in the RAP that remediation work on Barangaroo Central is contingent on work completed within the Declaration Area. The Auditor notes that:

- AECOM (2013b) has proposed remediation in two locations within Central, as shown on Attachment 7b, Appendix A, to address the goal of removal of the EPA declaration. Both are located within the proposed southern basement and the maximum depth of remediation proposed is 10 mbgl. The proposed extent of remediation within the Declaration Area (within the southern basement) is also shown on Attachment 7b, Appendix A.
- The remediation standard proposed in the Declaration Area RAP may not be sufficient for future basement construction within the Declaration Area, therefore consideration of any additional remediation will be required for the portions of the southern basement located within the Declaration Area.

10.3 Derivation of Human Health Criteria

10.3.1 JBS HHERA for Imported Soil

Site specific human health criteria have been derived by JBS for a range of soil zones that relate to key areas of the site and are defined as:

- Zone 1 – Soils within 0.5 m of the finished surface of open space areas
- Zone 2 – Soils located below a depth of 0.5 mbgl and located more than 30 m from basements
- Zone 3 – Soils used as fill material within 10 m of the basements to the residential buildings
- Zone 4 – Soils used as fill materials greater than 10 m and less than 30 m from the basements to the residential buildings
- Zone 5 – Soils used as fill material within 10 m of the Cultural Space Building (note that while included in the Central documentation, the Cultural Space applies to Headland Park and not Central)
- Zone 6 – Soils used as fill materials greater than 10 m and less than 30 m from the Cultural Space Building.

Zone 1 and 2 criteria are relevant for open space areas under both future land uses and Zone 3 and 4 criteria are relevant for future residential development where typical basement design is applied. For Central, this is relevant to the northern basement only as alternate criteria/ controls have been adopted for the southern basement (refer Section 10.3.4 below). The RAP (Table 5.1) indicates that Zones 5 and 6 were not relevant to Central since no commercial buildings were proposed. The Auditor understands that a commercial worker (car park attendant) may be present within the residential basement and the risk modelling performed by JBS for Zones 3 and 4 has considered this receptor which is appropriate.

The human health criteria have been derived to address relevant areas of exposure where receptors and exposure pathways have been identified and considered in the HHERA. The scenarios considered include:

- Recreational user – adults and children who breathe vapours and come into direct contact with imported fill
- Gardener – adult who breathes vapours, dust and comes into direct contact with imported fill
- Intrusive Worker – adult who breathes vapours inside excavations, dust and comes into direct contact with imported fill
- Basement car park user – breathes vapours from imported fill next to basement walls and floor; breathes vapours from groundwater seepage and is dermally exposed to groundwater seepage
- Resident – breathes vapours from basement diluted 10 fold and uses car park
- Commercial/retail/cultural space user (including car park attendant within a basement under residential land use) – breathes vapours from imported fill next to basements or from soil adjoining walls of cultural space.

The criteria were derived generally following the same approach as criteria derived for Headland Park, reviewed by the Auditor in SAR GN439B-2 and as amended by the Additional Calculations letter. The Auditor notes:

- The car park user for the temporary surface car park is not considered separately. It is agreed that this is covered by the scenario for the recreational user.
- JBS concluded in the DGI that heavy metal, PAH and monocyclic aromatic hydrocarbons (MAH) impact located at depth in saturated fill and naturally occurring soils were not found to have a complete human exposure pathway, therefore further human health risk assessment was not necessary. Vapour migration from these soils was considered by JBS to be restricted by their saturated condition. This is considered reasonable for open space land use.

The criteria have been derived for chemicals of potential concern (CoPC) that may potentially be present in soil imported to the site from elsewhere on Barangaroo (excluding the Declaration Area). The derived criteria have addressed mixtures of key groups of CoPC including BTEX, TPH, CPAH (carcinogenic PAH 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 following the toxicity equivalent factor approach), and non-carcinogenic PAH.

The criteria derived have considered the protection of human health and potential odour issues.

During their review of the criteria derivation, EnRiskS identified a number of calculation errors as detailed in Appendix F. As a check on the implications of these errors, EnRiskS recalculated the criteria as discussed in Section 10.3.3, below.

10.3.2 JBS HHRA for Current Land Use

This document assessed the risk to human health posed by the site in its current state and considers a range of scenarios relevant to the land uses proposed for the site. The scenarios include the same scenarios as listed for the HHERA for imported soil (Section 10.3.1) with the addition of the following:

- Recreational user – adults and children who breathe vapours from groundwater outdoors
- Gardener – adult who breathes vapours from groundwater outdoors
- Intrusive Worker – adult who breathes vapours inside excavations from groundwater.

The Auditor notes:

- The assessment has removed direct contact with soil from the recreational user and gardener scenario as it was assumed that on site soils would be covered by imported soil (to provide suitable growing medium) so there would be no direct contact with on site soils.
- The intrusive worker scenario is the same as the HHERA as these workers are not expected to work in trenches that extend deeper than 0.5 mbgl at the site which removes direct contact with groundwater as a pathway of exposure. Groundwater is assumed to be at 1.9 mbgl across the site.
- As noted in Section 10.3.1, JBS concluded in the DGI that contamination in saturated fill and naturally occurring soils were not found to have a complete human exposure pathway, therefore further human health risk assessment was not necessary and the risk assessment for future land uses only considered shallow, unsaturated soil. Given that the groundwater well density and construction (screened interval) does not provide a detailed characterisation of groundwater quality in the vicinity of basements, the Auditor has used the presence of significant soil contamination and tar in the subsurface as an indicator for potentially high groundwater contamination which could result in unacceptable seepage. Consideration of saturated soil conditions in proximity of future basements is therefore required where significant contamination is present. A requirement for no tar containing material in proximity to basement is included by AECOM and is therefore relevant for adoption of the AECOM criteria to the southern basement (discussed in Section 10.3.3, below). It is also considered relevant for the northern basement and validation for this aspect is required for both basements.

A shorter list of key chemicals is included in this document as the maximum concentrations present in the Barangaroo Central area have been compared to conservative screening criteria, however, details were not provided on the screening step undertaken. EnRiskS repeated the forward risk assessment and screened out additional chemicals during this process.

JBS concluded the following based on the risk assessment performed:

1 *“The Barangaroo Central site does not pose an unacceptable level of human health risk for a proposed recreational / open space use subject to growing media soils being imported for near surface use in vegetated areas of the site and pavement / surface cover being provided to remaining site areas;*

2 *The site is not considered appropriate from a human health perspective for the proposed residential development with basements where groundwater entering the basements as seepage has a maximum level of benzo(a)pyrene exceeding 0.017 mg/L or an average level of benzene exceeding 0.02 mg/L or an average naphthalene exceeding 0.23 mg/L."*

The Auditor notes that the first finding above relies on maintenance of a clean layer of fill or pavement as a barrier to contact with contaminated soils onsite which will need to be considered in ongoing management. It is also based on growing media criteria being adequately protective of human health (recreational user, gardener and maintenance worker) which is not the case for benzo(a)pyrene and lead (refer Table 10.1, below).

During their review of the risk assessment, EnRiskS identified a number of calculation errors as detailed in Appendix F. EnRiskS performed a repeat calculation of risks based on the maximum contaminant concentrations detected on site in unsaturated soil and groundwater. EnRiskS found there to be risks for the outdoor scenarios only as the pathways that were driving the risk were ingestion and dermal contact rather than inhalation, with the key risk drivers being lead and carcinogenic PAHs. JBS has proposed to account for this risk by the use of imported fill as noted in the first finding above. Consistent with the approach taken by JBS, EnRisks did not consider potential vapour intrusion from saturated soils. As noted above, the Auditor requires consideration of saturated soil conditions with respect to the presence of tar and significant hydrocarbon impact.

10.3.3 EnRiskS Recalculation of JBS Criteria

Since a number of errors and anomalies were identified in criteria derived by JBS, EnRiskS recalculated criteria for imported fill which can also be applied to the existing site soils. The imported fill criteria are just relevant for soil, however, EnRiskS calculations cover exposure to potential contamination both in soil and in groundwater to provide clarification to the criteria developed by JBS. Given the use of the same scenarios as those used in the forward risk assessment, these criteria apply to both the imported fill, the existing soil at the site and the existing groundwater at the site.

The criteria recalculated by EnRiskS are included in Table 4 within Appendix F. The recalculated criteria were found to be higher (less conservative) with the exception of:

- Ammonia – the JBS calculations do not include any ingestion or dermal contact with ammonia in soil for the recreational and other outdoor scenarios. There is no explanation as to why this would be the case. For every other chemical listed ingestion and dermal contact with the chemical in soil in these outdoor scenarios are included.
- Cyanide – the toxicity assessment section of the report lists the oral TDI for cyanide as 0.012 mg/kg/d derived from the Australian Drinking Water Guidelines. The input pages for RISC (the risk calculation software used) show that the TDI entered for cyanide was 0.02 mg/kg/d, an apparent typographical error.
- Dibenzofuran – The US EPA Regional Screening Levels derived RfD is 0.001 mg/kg/d. This is the value quoted in the summary table in the toxicity assessment section in the JBS reports but the value entered into RISC was 0.06 mg/kg/d, an apparent typographical error.
- Lead – a bioavailability factor of 50% was applied by JBS at the end of the calculation of the criteria. This factor should only apply to the ingestion pathway not all the

pathways as it relates to how much lead crosses the gut and so should have been applied earlier in the calculations just to the ingestion pathway. Regardless the approach adopted by JBS to calculate risk from lead was not considered appropriate. A site specific value would require modelling using a blood lead model (the IEUBK model) and there are not considered to be any standout parameters that would be different enough at this site from those used in the health investigation calculation in the NEPM calculations to justify redoing the modelling. EnRiskS has recommended that the HIL C (recreational land use) criterion for lead (600 mg/kg), from the recently revised NEPM, is used.

10.3.4 AECOM Criteria for Barangaroo South

JBS compared their derived seepage water criteria with groundwater data, and groundwater in the vicinity of the southern basement was found to exceed the criteria. Rather than contemplate groundwater remediation at the site, JBS sought an alternate means to address groundwater seepage at the southern basement and adopted criteria developed by AECOM as documented in the ORWS RAP for application to the southern basement (which adjoins the Declaration Area). The referenced groundwater criteria are for Scenario 1 (lower basement) and Scenario 2 (upper basement) and unsaturated soil criteria for Scenario 2 are also listed. The adopted criteria are included in Attachment E.

The criteria were reviewed in the ORWS SAR (GN439B-1) and are considered appropriate for application to the southern basement provided that the assumptions made with regards to basement construction are applied for the Central site. JBS identify the following basement design features as required for the southern basement for consistency with ORWS:

- The air exchange rate within the basement car park is maintained at least at 4 volume changes per hour;
- Tar should be removed from the immediate vicinity of outer basement walls to the extent practicable, and basement designs and engineering controls should ensure that tar seepage into basements does not occur;
- Construction of compartments in the overall basement with each compartment adjacent to basement areas leaving a maximum of 2 exposed walls in contact with contaminated soil / groundwater;
- The basement groundwater retention walls system to comprise a secant pile wall, extending to and keyed into bedrock, with a reinforced concrete basement wall, constructed on the inside. A sealed plenum constructed immediately inside the reinforced concrete basement wall to include (a) passive ventilation to the atmosphere; and (b) dish drains that will drain any seepage;
- Basement design plans to include engineering controls to ensure that contaminated groundwater does not accumulate in compartments which are ventilated to basement airspaces;
- Basement levels should be maintained at lower pressure than occupied areas in accordance with AS1668.2 (Standards Australia 2002); and
- Sump rooms should be placed as far as possible from lift wells.

In the Auditor's opinion, these are generally consistent with the ORWS/ AECOM requirements and are appropriate.

10.4 Derivation of Environmental Criteria

Criteria were derived by JBS for Headland Park for soil and surface water protective of on-site ecological communities and ecological communities in Darling Harbour. These were reviewed in detail in the EnRiskS report included in the Headland Park SAR (GN439B-2). The HHERA for Central presents the same ecological criteria which are based on the following:

- Criteria for fill materials considered suitable for use within the "root zone" of the site, to a minimum depth of 0.5 m in lawn areas and up to 1.5 m in the vicinity of large trees. The criteria adopted are published criteria (not derived) that are based on the protection of plant/ soil health.
- Criteria derived for saturated and unsaturated soil that are protective of surface water quality (within Darling Harbour). These criteria have been derived on the following basis:
  - 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 MWQG 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 appropriate guidelines that provide a similar level of protection as the ANZECC (2000) trigger values. These criteria have been derived from Canadian Council of Ministers of the Environment (CCME).
  - Derivation of soil criteria on the basis of leaching 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. Criteria were also derived on the basis of leaching of contaminants from soil to surface water and runoff to the harbour. Relevant and appropriate dilution factors have been applied depending on the location of the soil and the connection with Darling Harbour.
  - Saturated soils are considered those below 1.9 m Australian height Datum (AHD) based on the predicted 2100 high water mark.
- Criteria for surface water discharges from Central that are based on the protection of surface water within Darling Harbour. These criteria have been adopted from the NSW *Protection of the Environment Operations Act 1997* Environment Protection Licence (EPL) 13336 for Barangaroo, and NSW EPA endorsed guidelines.

While derived for imported fill, these criteria also apply to the existing soil at the site and are relevant under all future land uses.

10.5 Consideration of risk to the environment from saturated soil and deep tar impact

10.5.1 Saturated Soil

Although criteria had been derived for saturated soil to be protective of groundwater and therefore surface water quality (within Darling Harbour), comparison of saturated soil data with these criteria indicated a significant degree of exceedance. As a further line of evidence, JBS considered the risk to the environment from the soil contamination on site in its current state based on review of groundwater conditions. This consideration was documented in the DGI and comprises the primary consideration of risk to the environment from the site in its current condition that has been presented by JBS in the documentation reviewed.

An overall westerly flow direction was assumed, noting tidal fluctuation, with the western boundary (Darling Harbour) being the downgradient direction.

JBS considered the most recent groundwater data (2012) and compared a range of groundwater data sets, including:

1 Shallow groundwater (wells screened to between 6 and 7 mbgl) in the central and northern portions of the site, in upgradient (6 wells), central (3 wells) and downgradient (6 wells) transects. JBS concluded:

- Levels of constituents discharging from the site are generally similar or lower than levels of constituents entering the site.
- No significant evidence that soils are causing shallow groundwater to be impacted.

2 Shallow groundwater (wells screened to between 5 and 6 mbgl) in the southern portion of the site, downgradient of the Declaration Area, in upgradient (5 wells) and downgradient (5 wells) transects. JBS concluded:

- Minor increase noted in copper not indicative of significant copper source material
- Decrease in ammonia, PAH and MAH to generally non-detect levels at the downgradient boundary.
- Contaminants likely to be migrating onto site from Declaration Area and possibly caused by localised source material, but attenuate within the site.

3 Deep groundwater (wells screened to between 8 and 11 mbgl) in the central portion of the site, in one upgradient and one downgradient well. JBS concluded:

- Decrease in ammonia across the site.
- Levels of impact for remaining constituents similar upgradient and downgradient.

4 Deep groundwater (wells screened to between 10 and 14 mbgl) in the southern portion of the site, downgradient of the Declaration Area, in two upgradient and two downgradient wells. JBS concluded:

- Substantial attenuation of ammonia and hydrocarbon impact between upgradient and downgradient locations, although downgradient wells not extended to the fill/natural interface and higher levels of impact than reported may be present.

- Contaminants likely to be migrating onto site from Declaration Area and also caused by localised tar source material, indicated in soil results.
- Hydrocarbon source material onsite likely restricted to the southeast portion.
- Level of impact by heavy metals similar upgradient and downgradient.

JBS did not include data from the three AECOM wells in this assessment, located in the southern portion of the site in upgradient (2) and central (1) positions. No AECOM wells are located along the downgradient boundary of Central. The AECOM groundwater well data is consistent with the above noted trends.

On the basis of the above assessment, JBS concluded that apart from the tar contaminated materials at the south-eastern portion of the site, the fill materials and naturally occurring soils were not considered to be acting as a source of groundwater contamination. The Auditor generally agrees with this conclusion and notes that downgradient groundwater quality in shallow and mid-depth fill does not appear to be significantly impacted by contamination within site soils. The corresponding risk to the receiving water (Darling Harbour) is therefore currently low. However, given that downgradient wells were terminated at a maximum depth of 13 mbgl, above the fill/ natural interface, further consideration of deep tar impact is required, discussed below.

10.5.2 Deep tar impact

Investigations performed within and downgradient of the Declaration Area were considered by the Auditor in audit number GN447A, including data from Central. The most significant impact was found to be present in fill and underlying natural materials in the vicinity of former gasworks infrastructure, however the frequency and concentrations appeared to be higher in fill material. Downgradient of the former gasworks, contamination was more prevalent in natural soils at depth, supporting the migration of contamination from the former gasworks on the natural ground surface, at the base of fill. Tar was generally absent from overlying fill material in these areas, however where identified it was limited in extent. Bedrock was not sampled extensively; however, visual observations have indicated contaminant impacts to be restricted to the upper weathered sandstone bedrock.

When considering the data from Central, the worst case groundwater conditions are not likely to have been assessed in the southeast of the site and downgradient due to the placement of well screen intervals. It is reasonable to assume that the most significant groundwater impact would occur in association with observations in soil of tar and DNAPL associated with the former gasworks. However, the potential for accurate observation of soil conditions was also limited by the use of auger drilling and sampling methods. Overall, the outcome is that the extent of impact to deep natural materials and associated groundwater has not been accurately delineated by the investigations performed.

JBS has proposed in the RAP (Section 6.2.4) that remediation below 10 mbgl is not required at Central, with such works being “both impracticable and unnecessary” based on:

- The absence of tar in fill materials below 10 mbgl where the occurrence of tar is in natural soils/sediments. JBS refers to studies by AECOM that “have reported negligible potential for future migration” from tar impacted material within the natural soil.

- The requirement for consistency in remediation and validation standards between the Barangaroo Central site and the hydrogeologically upgradient Declaration Area, where remediation below 10 mbgl is not proposed.
- There being no evidence that the occurrence of hydrocarbon-impacted materials within the Barangaroo Central site are causing unacceptable ecological impacts to Darling Harbour, although, as noted above, limitations in the assessment performed has not confirmed this.
- The absence of potential unacceptable human health risks where the basement construction methods incorporate the groundwater control walls proposed on Barangaroo South. JBS has relied on risk-based criteria derived by AECOM for the Declaration Area in this argument/ assessment.
- The generation of unnecessary waste materials, inconsistent with the requirements of the *NSW Waste Avoidance and Resource Recovery Act 2001*.
- The potential environmental impact of the deep remediation works causing an environmental impact relative to environmental benefit inconsistent with the principles of ecologically sustainable development.

A qualitative discussion was provided in the RAP for some of the above items. JBS also referred to EPA (2007) *'Guidelines for the Assessment and Management of Groundwater Contamination'* however a detailed consideration of these guidelines or the concept of clean-up to the extent practicable (CUTEP) was not presented in the RAP. It appears that JBS has primarily relied upon AECOM's findings with respect to the Declaration Area in defining the remediation depth as 10 mbgl.

The requirement for remediation below 10 mbgl within and downgradient of the Declaration Area has been considered by the Auditor in detail in the Declaration Area Site Audit Report (GN447A). AECOM presented detailed justification and a range of studies in the VMP Extent Report and Declaration Area RAP to support the proposed remediation extent, both lateral and vertical. Attachments 7a and 7b, Appendix A, illustrate the proposed remedial extent for unsaturated and saturated soils, respectively. The maximum remediation depth proposed is 10 mbgl, locally extended by up to 2 m based on observations at the base of excavations. The goal of this remediation is for removal of the EPA declaration. It is noted that remediation within Central is proposed in two locations to address this goal.

Based on the findings of audit GN447A, the Auditor is satisfied that remediation of gasworks impacts in natural soil/sediment below 10mbgl is not required at Central except in proximity to basements as discussed above.

10.6 Summary and Conclusion

JBS has referred to and derived a range of risk-based criteria for different land uses and media, for protection of both the environment and human health. The relevant criteria are provided in Appendix E. Review by EnRiskS identified a number of errors and anomalies in the calculations, however, for the most part the criteria referenced were found to be adequately conservative. Many of the criteria apply to the same soils, and the RAP does not provide a single set of criteria for each element. The following Tables 10.1 and 10.2 present the Auditor's interpretation of the criteria adopted by JBS for key contaminants at the site for soil and groundwater, respectively. Human health criteria derived by EnRiskS are noted in

brackets and are noted to be lower than the proposed criteria for key contaminants for ammonia and lead only.

In the Auditor's opinion, application of these criteria should define an appropriate extent of remediation for protection of human health and the environment, noting the additional consideration of risk with respect to saturated soil and tar discussed in Section 10.5. Application of the SAC to the site data in determining the extent of remediation is discussed in Section 11, following.

Table 10.1 Summary of Soil Site Acceptance Criteria for Key Contaminants (mg/kg)								
Depth/ Location:	**0-0.5 m**	**0-0.5 m (maximum 1.5 m)**	**>0.5 m**	**Unsaturated soil**	**Saturated soil**	**0-10 m of northern basement, all soil**	**10-30 m of northern basement, unsaturated soil**	**Southern basement, unsaturated soil**
Criteria Protective Of:	Open space human health	Protective of phytotoxicity effects (growing media)	Open space human health	Protective of surface water via leaching	Protective of surface water via leaching	Residential use human health	Residential use human health	Residential use human health
Source:	HHERA Zone 1	HHERA EIL	HHERA Zone 2	HHERA EIL	HHERA EIL	HHERA Zone 3 (Amended)	HHERA Zone 4 (Amended)	AECOM Scenario 2
Auditor comments:			Not used by JBS – assumed no contact	Derived for imported soil but also relevant to existing soil	Derived for imported soil but also relevant to existing soil	Not clear why apply to both unsaturated and saturated soils		-
Arsenic	190 (190)	20	-	18	4.6	-	-	-
Benzo(a)pyrene (TEFs)	2 (6)	18 (sum high mol wt PAH)	-	0.7	0.2	62	-	-
Ammonia	5,200 (450)	20	16,000	<LOR	<LOR	<LOR (250,000)	5,300	-
Benzene	0.9 (32)	0.2	4.8	0.3	0.1	<LOR (19)	0.8	15
Lead	480 (600)	1100	-	190	46	-	-	-
Naphthalene	33 (250)	29 (sum of low mol wt PAH)	170	6.4	1.6	0.6 (910)	31	41

Table 10.1 Summary of Soil Site Acceptance Criteria for Key Contaminants (mg/kg)								
Depth/ Location:	**0-0.5 m**	**0-0.5 m (maximum 1.5 m)**	**>0.5 m**	**Unsaturated soil**	**Saturated soil**	**0-10 m of northern basement, all soil**	**10-30 m of northern basement, unsaturated soil**	**Southern basement, unsaturated soil**
Criteria Protective Of:	Open space human health	Protective of phytotoxicity effects (growing media)	Open space human health	Protective of surface water via leaching	Protective of surface water via leaching	Residential use human health	Residential use human health	Residential use human health
1,2,4-trimethylbenzene	6.3 (1,000)	-	215	-	-	<LOR (1,700)	70	14
Zinc	-	200	-	79	20	-	-	-

Table 10.2 Summary of Groundwater Site Acceptance Criteria for Key Contaminants (mg/L)			
Depth/ Location:	**Southern basement, upper**	**Southern basement, lower**	**Northern basement, groundwater/ seepage**
Criteria Protective Of:	Residential use human health	Residential use human health	Residential use human health
Source:	AECOM Scenario 1	AECOM Scenario 2	HHRA
Benzo(a)pyrene (TEFs)	-	-	0.035 (70)
Ammonia	2,400	6,800	5.26 (2300)
Benzene	21	95	0.0044 (17)
Naphthalene	0.92	2.9	0.027 (4)
1,2,4-trimethylbenzene	87	280	0.226 (270)

11 Evaluation of Soil and Groundwater Results Against Site Acceptance Criteria and Determination of Remedial Extent

11.1 Overview

The Auditor has considered the required remedial extent by consideration of the presence of tar and by comparison of soil and groundwater results with the relevant SAC. The presence of tar is considered initially in Section 11.2 due to the potential impact on both human health (via basement seepage) and the environment. The required remedial extent with respect to human health and environmental criteria is then considered in Sections 11.3 and 11.4.

In general, it is difficult to determine how JBS has defined the remedial extent required as there is no tabulation of data against the relevant criteria provided in the RAP. The most detailed consideration of data with respect to the various criteria occurred in the DGI (JBS, 2012d). This was based on ERM and JBS data but did not include the AECOM soil and groundwater data. The RAP (Section 6.2) defines the extent of remediation/ management required.

11.2 Tar

11.2.1 Occurrence

Tar-containing materials were identified in a number of locations in the southeast of the site adjacent to the Declaration Area. Tar observations were restricted to AECOM and ERM boreholes, most likely due to the limitations of the drilling method adopted by JBS. JBS used elevated concentrations of PAH detected in samples as an indicator of tar impact to soils, although the reference concentration for identification of tar was not defined. JBS also appears to have used other field indicators of contamination such as odour to indicate the presence of tar, however, the basis for this is not described in the RAP and cannot be verified by the Auditor as valid.

The Auditor considered the presence of separate phase gasworks waste and tar within Central downgradient of the Declaration Area in the Declaration Area Site Audit Report (GN447A). Tar was identified in Central primarily at depth in natural soil (marine sediment) within around 20 m of the boundary of the Declaration Area. This was primarily present below 10 mbgl, although was present from 9 mbgl in AECOM BH403. JBS inferred the presence of tar in natural material from 7 mbgl in ERM BH074, located on the boundary of the Declaration Area, due to an elevated concentration of PAH in a sample from 9.5-10 mbgl (around 1,200 mg/kg) and the presence of strong hydrocarbon odours above (from 5 mbgl).

Tar was identified in fill within Central, as follows:

- AECOM BH70, around 20 m from Declaration Area boundary in shallow fill at 2.5 mbgl (also at >16 mbgl in marine sediment in this location)
- AECOM BH74, further to the west, around 70 m from Declaration Area boundary in shallow fill at 1-2.5 mbgl. JBS identify the extent of tar to continue to 6 mbgl but the basis for this cannot be determined by review of the log.

Based on elevated concentrations of PAH, tar was also indicated by detections in fill at:

- JBS BH/MW541D, within 20 m of the Declaration Area boundary, in deep fill at 9.9-10 mbgl (total PAH of around 2,800 mg/kg) and overlying samples from 6.9-7.0, 7.9-8.0 and 8.9-9.0 mbgl (total PAH of between 500 and 1,000 mg/kg). The total fill depth in this location is 10.8 mbgl.

Elevated contaminant detections in groundwater from BH/MW541D, screened from 7.4-10.4 mbgl, confirm that tar material present within the screened interval has impacted groundwater.

The Auditor notes that a sheen was detected in groundwater from well AECOM BH/MW69, screened in fill and sandstone from 9-12 mbgl. The log indicates potential tar impact, most likely within sandstone below 10 mbgl. This well is located adjacent to the southeast site boundary, north of the Declaration Area (refer Attachment 5, Appendix A).

All of the above locations except AECOM BH74 are located within the footprint of the proposed southern basement and therefore would require excavation to 10 mbgl for the future residential development.

As noted in Section 10.2, AECOM (2013b) has proposed remediation in two locations within Central to address the goal of removal of the EPA declaration. These are at AECOM BH70 and JBS BH/MW541D, as shown on Attachment 7b, Appendix A.

In the DGI JBS identified potential ‘hotspots’ of hydrocarbon impact located outside the proposed southern basement, as follows:

- BH547 at the southern boundary (over 50 m from Darling Harbour), between 1.5 and 3 mbgl, maximum total PAH and benzo(a)pyrene of 830 and 62 mg/kg, respectively. JBS stated levels of semi-volatile PAHs and MAHs are generally found to be near detection limits, indicating a limited leachability potential. Groundwater data in proximity at monitoring well MW544S (30 m to the west) also indicates a lack of hydrocarbon impact which JBS considered to confirm the lack of leachability.
- BH530 in the northeast, in the northern basement footprint (around 150 m from Darling Harbour), depth of 2 mbgl, total PAH and benzo(a)pyrene of 680 and 56 mg/kg, respectively. JBS stated semi-volatile PAHs are observed to be at significantly reduced levels. Monitoring well MW516 located in close proximity (30 m to southwest) has not reported significant levels of hydrocarbon impact.

The Auditor notes that the proximity of the referenced groundwater wells (at a distance of 30 m) is not sufficient to confirm there is no leaching or localised impact to groundwater. However, the Auditor considers that the impacts identified are likely to be localised in extent as has been found within shallow fill materials across the Barangaroo project site. The location of BH547 at a distance of over 50 m from Darling Harbour is not considered to represent a significant risk. BH530 will be removed for the northern basement excavation. The Auditor notes that similar localised ‘hotspots’ of tar or lesser hydrocarbon impact are likely to be present within the fill material although not identified by the investigations performed.

11.2.2 Proposed Remedial Extent

JBS has defined the occurrence of tar and remediation requirements as summarised in Table 11.1. The maximum depth of remediation proposed is 10 mbgl, correlating with the

proposed basement depth. The proposed remedial extent is shown on Attachment 9, Appendix A. JBS notes in the RAP that "The actual extent of remediation required will be determined through validation inspection, sampling and analyses".

Table 11.1 Proposed Tar Impact Remediation Areas

Location	Tar occurrence	Proposed Remedial Extent	Auditor Comments
BH70 (AECOM)	at 2.5 mbgl in fill materials	10 m x 20 m 2-3 mbgl	Remediation of a circular hotspot over the same depth interval is proposed in the Declaration Area RAP
BH74 (AECOM)	as estimated between the depths of 1 and 6 mbgl in fill materials	10 m x 20 m 1-6 mbgl	Auditor review of log indicates tar impact to 2.5 mbgl only
BH074 (ERM)	as estimated between the depths of 5 – 10 mbgl in fill materials	15 m x 20 m 5-10 mbgl	Located on boundary with Declaration Area BH074 log identified fill from 5-7 and natural silty clay from 7-10 mbgl Auditor review of log does not confirm the presence of tar, although elevated PAH concentration in natural soil at 9.5-10 mbgl is noted (1,200 mg/kg)
BH403	at 9.0-9.4 mbgl in natural clayey sand and silty/sandy clays	15 m x 20 m 9-10 mbgl	Tar impact in natural soil continues to 17 mbgl in this location
BH541	at 6.9-10.0 mbgl in fill materials	15 m x 20 m 6.5-10 mbgl	Upper depth of remediation of 6.5 mbgl considered reasonable based on review of logs No samples below 9 mbgl. Tar impact likely extends below 10 mbgl. Total depth of fill is 10.8 mbgl, underlain by sandstone Remediation of a circular hotspot up to 10 mbgl is proposed in the Declaration Area RAP

JBS notes that "It is likely that tar-/gasworks-based contaminants will extend below the proposed basement depth of 10 mbgl in the western extent of the proposed basement". The RAP proposes further excavation based on visual/ olfactory observations in 0.2 m increments, however, does not specify a maximum proposed depth of 'over-excavation' in the event that tar is found at the excavation base/ walls.

Remediation is not proposed to address the two identified 'hotspots' at BH547 and BH530. This is considered acceptable for BH547. BH530 is located within the proposed northern basement excavation and will therefore require management during excavation works. The

potential for additional 'hotspots' to be identified during basement excavations should also be noted.

It is noted that the Declaration Area RAP (AECOM, 2013b) states that remedial requirements with respect to sheen at BH/MW69 are proposed to be assessed by the Barangaroo Central RAP. JBS did not address the potential need for remediation at BH/MW69 in the RAP. Since it is located within the proposed southern basement, it is likely that impact will be identified approaching the base of the excavation in this area and will require management during excavation works.

11.3 Consideration of Human Health Criteria

11.3.1 Near surface soils

Unsaturated soil data collected by ERM and JBS were considered by JBS in the DGI (2012d) with respect to the NEPM 1999 open space human health criteria (scenario E). The extent of impact, primarily by PAH/ Benzo(a)pyrene, is plotted on Attachment 6, Appendix A. It is noted that the basement layout shown on Attachment 6 has been superseded. JBS has not included in the RAP a comparison of onsite data against the derived human health criteria for imported fill for 0-0.5 and >0.5 mbgl (which would also apply to existing site soils). In conducting the onsite risk assessment, JBS did not consider direct contact with onsite soils by the recreational user, gardener or intrusive maintenance worker since importation of growing media was proposed and intrusive workers were not expected to go below 0.5 mbgl.

JBS state in the RAP that "Surface soils on essentially all of the Barangaroo Central Site have been identified as being unsuitable to be used as growing media. Appropriate soils will need to be brought onto the Barangaroo Central Site for use as growing media in landscaped areas".

The Auditor notes the following with respect to the proposed remediation/ management of surface soils:

- Imported fill should meet both the phytotoxicity-based and human health criteria.
- Ongoing management measures should ensure that 0.5 m of suitable material is maintained to ensure the protection of gardeners and maintenance workers (0.5 m access depth assumed).
- Ongoing management measures should ensure that the pavement is retained in the southern 30% of the site, located outside the proposed landscaped area of the Stage 1 Public Domain.
- Ongoing management measures will be required for protection of maintenance workers required to penetrate the pavement within the southern 30% of the site.

11.3.2 Asbestos

A single detection of asbestos fibres was made in soil at the site. This location is within the proposed southern basement excavation. JBS has proposed remediation of an area 20x20 m over depth 9-10 mbgl to address this detection (refer Attachment 9, Appendix A). According to the RAP this remedial extent was proposed "giving consideration to the nearest sampling locations where similar impact was not observed".

JBS also note that based on findings elsewhere at the Barangaroo project site "ACM is anticipated throughout the site" and that "appropriate protocols also will need to be implemented during the remediation and construction works to ensure that the potential risks posed by further finds of ACM are adequately controlled".

The Auditor notes that:

- The detection was made in AECOM BH401 9-9.4 mbgl
- There was no asbestos-containing materials observed in the sample
- The detection occurred in a fill unit that extended to 14 mbgl
- There were no samples analysed from below this sample and the closest sample analysed above this location was from 3-3.4 mbgl
- Asbestos within the Barangaroo project area appears to be predominantly associated with broken fibro or pipes with minimal detection of fibres in soil.

In the Auditor's opinion, adequate justification is not provided for the proposed extent of remediation. In addition, the remediation works proposed are not considered likely to improve the condition of the site with respect to asbestos contamination. It is considered more appropriate to implement management controls during excavation works with appropriate supervision and waste classification undertaken on the basis of visual evidence of asbestos-containing materials. This is consistent with the guidance regarding asbestos included in the amended NEPM.

11.3.3 Groundwater Seepage

The DGI identified 15 wells that would be representative of groundwater that may seep into future basements. A potential risk to human health was identified due to some constituents exceeding the drinking water criteria. As discussed in Section 10.3.2, site specific risk assessment was considered necessary and seepage water criteria were derived in the HHRA and subsequently modified in the Additional Calculations letter. The Additional Calculations letter identified two sets of wells that would be representative of groundwater that may seep into the future northern (9 wells) and southern (14 wells) basements. The wells considered included offsite wells from within the Declaration Area (Block 4 and Hickson Road). Two AECOM wells within the southern basement footprint, BH/MW401 and BH/MW69 were not considered.

JBS compared average concentrations for the northern and southern basement wells with the derived seepage water criteria and found that the existing groundwater quality in proximity of the northern-most basement will not pose an unacceptable risk to future users of that basement. However several constituents exceeded the criteria for the southern basement. The data for the southern basement was then compared to the AECOM criteria (refer Section 10.3.4) and were found by JBS to meet the criteria therefore groundwater remediation was not considered necessary. However, when considering the additional AECOM well BH/MW69, the Auditor has noted an exceedance for naphthalene at 1.92 mg/L compared to criterion of 0.92 mg/L. This location is within the footprint of the southern basement and will require remediation.

11.4 Consideration of Environmental Criteria

11.4.1 Soil as a growing media

Unsaturated soil data collected by ERM and JBS were considered by JBS in the DGI (2012d) with respect to the ecological investigation levels protective of phytotoxicity effects. Several exceedances for copper, nickel and heavier PAHs were reported, with limited exceedances also noted for arsenic, lead, mercury and light PAHs. Considering the identified exceedances and the heterogeneity of the fill it was considered that the whole of the unsaturated soils potentially have levels of copper, nickel and/or PAHs that will exceed the ecological criteria. JBS state in the RAP that "Surface soils on essentially all of the Barangaroo Central Site have been identified as being unsuitable to be used as growing media. Appropriate soils will need to be brought onto the Barangaroo Central Site for use as growing media in landscaped areas" as discussed in Section 10.3.1, above.

11.4.2 Protective of surface water quality

Unsaturated soil data collected by ERM and JBS were considered by JBS in the DGI (2012d) with respect to the derived criteria that is protective of surface water quality (within Darling Harbour). As discussed in Section 10.4, the criteria were derived based on leaching 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 Darling Harbour. Criteria were also derived on the basis of leaching of contaminants from soil to surface water and runoff to Darling Harbour.

Average concentrations of the following were found to exceed the criteria:

- copper – marginal exceedance of relatively low criterion
- benzo(a)pyrene (assessed as TEF) and phenanthrene
- pyrene – noting the criterion is low - equal to the detection limit.

Copper, BaP and phenanthrene exceedances are shown on Attachment 8, Appendix A. JBS notes that the majority of the impacted soils are located in the eastern (hydrogeologically upgradient) portion of the site.

The potential impact of onsite (saturated) soils on Darling Harbour was assessed by JBS in the DGI by review of groundwater monitoring results, as discussed in Section 10.5.1. Direct comparison with the saturated soil criteria derived as protective of surface water quality was not performed to assess the risk from saturated soils. However, average concentrations were considered in assessing the significance of the above identified unsaturated soil exceedances. The following Table 11.2 presents statistics provided in the DGI comparing the unsaturated and saturated fill data.

Table 11.2 Summary of Unsaturated and Saturated Soil Data with Respect to Protection of Surface Water Criteria

Constituent	Unsat EIL	Unsaturated Soil			Sat EIL	Saturated Soil (All)			Saturated Soil (excluding near Declaration Area) [1]		
		No	Max	Ave		No	Max	Ave	No	Max	Ave
Benzo(a)pyrene	**0.7**	153	40	2.5	**0.2**	454	120	3.6	413	87	2.5

Table 11.2 Summary of Unsaturated and Saturated Soil Data with Respect to Protection of Surface Water Criteria

Constituent	Unsat EIL	Unsaturated Soil			Sat EIL	Saturated Soil (All)			Saturated Soil (excluding near Declaration Area) [1]		
		No	Max	Ave		No	Max	Ave	No	Max	Ave
(TEF)											
Copper	**27**	153	440	38	**6.8**	269	460	26	257	460	24
Phenanthrene	**0.5**	153	33	1.9	**0.1**	454	380	4.7	413	140	2.6
Pyrene	**0.1**	153	61	3.0	**<LOR**	454	210	5.3	413	140	3.7

Note: 1. Excludes Data from Sample Locations BH539, BH540, BH541 and BH542 in proximity of 'Declaration Area'.

JBS presented a discussion in the DGI using this data and concluded that the identified exceedances for copper and PAH in unsaturated soils, excluding tar contaminated areas in proximity to the Declaration Area, are unlikely to pose a future risk to groundwater, and therefore to Darling Harbour, based on:

- Relatively similar fill materials were present at near surface depths as observed at depth on the site.
- Levels of PAH (BaP, phenanthrene and pyrene) in unsaturated and saturated fill materials were found to be comparable.
- Levels of copper in unsaturated soil were found to be slightly higher than the levels in the saturated soil data sets however leaching potential is higher from saturated soil and groundwater results indicate that significant levels of copper are not being leached from the site.
- The derivation of the criteria included a dilution factor of 4 to account for leachate transport from the unsaturated zone to the saturated zone, therefore saturated fill materials are four times as likely to cause groundwater impacts than unsaturated materials.

The Auditor agrees that fill types and contaminant levels are generally comparable between unsaturated and saturated fill materials. However, the Auditor notes that the lack of impact to groundwater due to saturated soils is likely due to the significant leaching and flushing that would have occurred over the 40+ years since placement of the fill. The unsaturated soil has not been subject to this flushing and has been protected from significant infiltration due to the presence of paving. JBS noted that the proposed recreational use involves removal of surface pavements which will result in substantially higher levels of surface water infiltration and potential increased risk to groundwater. An initially high degree of leaching would therefore be expected once the unsaturated soils are exposed, although the exposure (infiltration of rainfall) would be intermittent and would not be the same as full submersion as the saturated soils have experienced. JBS has not quantified this risk. The criteria were derived to be protective of surface waters (Darling Harbour) in consideration of the ANZECC 2000 guidelines and potential leaching. The criteria have been significantly exceeded,

however, the criteria are potentially overly conservative. Overall, in consideration of the analysis of fill data presented and the previous assessment of groundwater results, the Auditor is satisfied that remediation of saturated and unsaturated onsite fill soils is not required except where tar or significant petroleum hydrocarbon impact is present within shallow fill soils (<10 mbgl).

11.5 Conclusion

JBS has defined a lateral and vertical extent of remediation for protection of the environment and human health under the future land uses. The proposed remedial extent is shown on Attachment 9, Appendix A. In addition, all soil to be used as a growing medium (or in contact with outdoor users) is required to be imported material that meets the relevant criteria (environmental and human health).

Based on the Auditor's interpretation of the RAP, the relevant data and the criteria presented by JBS (and reviewed by EnRiskS), the Auditor is satisfied that the proposed remedial extent is sufficient, when combined with future excavations for the northern and southern basement and appropriate management measures for controlling access to soils by future site users. In order to confirm the Auditor's interpretation is correct, it is recommended that an analysis of each complete data set against the relevant criteria, which has not been provided in the documentation provided to date, be conducted. This would be appropriate to include in the Remedial Work Plan (RWP) which is required for the site.

12 Evaluation of Remediation Action Plan

12.1 Remediation Process Overview

The remediation process has been developed in consideration of the initial use of the site for open space and construction staging, and the final use for high density residential. An overview of the process is:

1 Material unsuitable to remain on the site (e.g. tar) to be excavated and disposed off-site.

2 Importation of material to create landform, with material placed into locations consistent with risk-based site acceptance criteria.

3 Future development for residential usage, including excavation of two basements and construction of the southern basement in accordance with specific design controls to be protective of potentially contaminated groundwater seepage.

The risk-based criteria are discussed in Section 10 and summarised in Appendix E.

With respect to item 1, onsite materials have been identified as unsuitable with respect to human health and the environment and are primarily located within proposed basement footprints. Removal of material to 10 mbgl is proposed. The RAP is not clear if these excavations will be undertaken in advance of the basement excavation which will not occur until the long term residential development.

Material to be imported to the site (item 2) will be assessed to determine where the soil can be used. The two groupings as discussed in Section 10 are:

- growing media within 0.5 m of the ground surface and up to 1.5 m in the vicinity of large trees
- general fill to be placed below growing media.

For this process to be successful, there needs to be adequate characterisation, tracking and validation to ensure that the materials within the final landform are suitable for their location.

Future residential development (item 3) will involve excavation of basements over two areas, with the southern basement extending into the adjoining Declaration Area. Given the differing remedial goals for Central (site suitability) and the Declaration Area (removal of the EPA declaration), additional remediation may be required for portions of the Declaration Area within the southern basement. JBS has addressed this in the RAP as contingency remediation.

The Auditor's interpretation of the elements of the remediation as discussed in the RAP is summarised in Table 12.1.

Table 12.1: Elements of Remediation

Land use/ aspect	Issue	Remediation Strategy	Auditor Comment
Environment	Leaching of contaminants from fill material	Excavation and off-site disposal of identified tar-containing material in shallow fill material (to	Two tar remediation areas overlap with remediation areas proposed for removal of EPA declaration (Attachment 7b, Appendix A).

Table 12.1: Elements of Remediation

Land use/ aspect	Issue	Remediation Strategy	Auditor Comment
		maximum 10 mbgl). Five tar impact remediation areas identified (Attachment 6, Appendix A), four located within southern basement. "Ongoing monitoring and management" proposed for deep residual tar impact, to be incorporated into a long term environmental management plan (LTEMP).	Tar containing material identified at depth is not proposed to be excavated and remediation is not proposed for contaminant exceedances of criteria derived to protect surface water. Tar in fill and natural material at depth has the potential to impact Darling Harbour. Discussed in SAR Section 10.5. There is potential for additional 'hotspots' of tar/ hydrocarbon impacted material to remain on site outside proposed remediation and basement areas.
Open space use – landscaped area (70% site)	Construction of landform with material that is protective of future site users, vegetation and receiving waters	Risk based criteria derived for soil to be used in different zones of the proposed final landform. Placement of soil to be controlled under a Materials Compliance Management System (MCMS).	Derivation of the risk based criteria is discussed in SAR Section 10. The MCMS is discussed in SAR Section 13.
	Construction of landforms from material obtained from elsewhere on Barangaroo or off-site	Up to 150,000 m^3 of material is to be imported. Some may come from the Barangaroo project site subject to availability and if it meets the risk based acceptance criteria. Material will not be sourced from the Declaration Area. Additional fill required will be sourced from other off-site sources.	Requires a robust MCMS as discussed in SAR Section 13.
Open space use – paved area to be retained (30% site)	Maintain pavement	Pavement is required as a barrier for contact with open space users	LTEMP will need to ensure pavement is retained and worker protection measures are implemented for intrusive workers

Table 12.1: Elements of Remediation

Land use/ aspect	Issue	Remediation Strategy	Auditor Comment
Future residential use - Northern Basement	Potential seepage of contaminated water or vapour intrusion into basements, potential risk to human health	No remediation required based on comparison with JBS-derived criteria	Limitations of SAC noted in SAR Section 10.3, however, their use does not change the outcome of the audit. Auditor is satisfied that remediation is not required in vicinity of proposed northern basement. Management of hydrocarbon impacted material at BH530 is required during excavation. Potential for additional 'hotspots' of tar/ hydrocarbon impacted material to be encountered during excavation.
Future residential use - Southern Basement	Potential seepage of contaminated water or vapour intrusion into basements, potential risk to human health	Removal of tar above 10 mbgl from 4 locations within basement footprint. The RAP proposes extending remedial areas based on visual/ olfactory observations in 0.2 m increments Basement design required to be consistent with Stage 1 Development (Barangaroo South). Some design requirements outlined in the RAP as discussed in SAR Section 10.3.4. Detailed design of the basement construction is to be provided in a Construction Quality Assurance Plan (CQAP)	Tar impact is likely to extend below the proposed depth of remediation in some areas. The RAP does not define the maximum proposed depth of 'over-excavation' in the event that tar is found at the excavation base/ walls. Tar impact may be encountered and over-excavation may be required in the vicinity of BH/MW69 (not considered by JBS). There is potential for additional 'hotspots' of tar/ hydrocarbon impacted material to be encountered during excavation. Detailed design was not provided in the RAP. Sign-off of the site would not be possible until construction of the basements is complete and performance verified. It is assumed the basement construction will proceed after remediation of the Declaration Area (to maximum 10 mbgl over extent shown on Attachment 7b, Appendix A) Construction of basement within declaration area will need to consider presence of tar material at base the excavation that may not have been addressed by Declaration Area remediation.
Future residential use - Southern Basement	Asbestos fibre identified in fill	Excavation and offsite disposal of fill from one location where asbestos fibres detected. Implementation of	Discussed in SAR Section 11. Poor basis for proposed remedial extent. Proposed remediation works will not materially affect the contamination status

Table 12.1: Elements of Remediation			
Land use/ aspect	**Issue**	**Remediation Strategy**	**Auditor Comment**
		appropriate protocols during the remediation and construction works. RAP currently proposed management of asbestos under unexpected finds protocol (UFP).	and risks associated with the site. Given the likelihood that asbestos will be found during excavation of basements, development of an Asbestos Management Plan is recommended for the future residential development. Management via an UFP is not considered appropriate. Asbestos criteria for recreational land use will apply to open space areas included in the residential site development (criteria are currently undefined).
Future residential use – open space areas	Details of design not known	Not known – unknown if imported fill is to remain	The RAP does not address the form of the future residential use open space areas. It is assumed appropriate imported material will be retained or additional material will be imported however confirmation is required.

A Remedial Works Plan (RWP) is provided in the RAP that outlines excavation/ validation of identified remediation areas followed by filling of the site and development of the Stage 1 Public Domain and commencement of the LTEMP. Construction of basements in accordance with design requirements is not contemplated in the RWP. Given the proposed remedial excavations are primarily within the proposed basement excavations it would seem more likely that the remediation and construction works would be undertaken concurrently. The proposed excavation areas are outside the area of the Stage 1 Public Domain development, located within the area to be retained as pavement. Revision of the RWP is required to more accurately represent the proposed works at the site and clarify the sequence of the proposed remediation and validation tasks.

12.2 Overarching Principles

The principles incorporated into the Overarching RAP (ERM, 2010) which are to be incorporated into each individual RAP, such as the Headland Park RAP, were listed in SAS GN439A and include:

- 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.

The Overarching RAP identified the following preferred remediation option for 'Area 2' and 'Area 4' (Attachment 3, Appendix A) which include the site area:

- Area 2: excavation and ex-situ on-site treatment and reuse in other areas of project site. May be supplemented by off-site disposal or other methods where excavation is not required for development purposes.
- Area 4: on-site management. May be supplemented by excavation in areas as determined by risk assessment.
- (Likely) ongoing monitoring of groundwater.

The Auditor considers that the remediation proposed is generally consistent with the Overarching RAP, including derivation of risk-based criteria, although a lack of clarity around remediation end points and the required remediation extent is noted. Validation is discussed in Section 12.4.

12.3 Evaluation of Remedial Action Plan

The Auditor has assessed the RAP (JBS, 2013c) by comparison with the checklist included in "Guidelines for Consultants Reporting on Contaminated Sites", as detailed in Table 12.2 below.

Table 12.2: Evaluation of Remedial Action Plan

Element	Details	Auditor Comments
Remedial Objectives RAP s1.2, s6.1	The main objective of the remediation is to remove risks posed by contamination to future site occupants and ecological receptors.	This remedial objective (goal) is considered appropriate.
Discussion of the extent of remediation required. RAP s6.2	Discussed in SAR Section 11. RAP proposes remediation of tar impact at five locations and asbestos impact at one location Surface soil on the site is unsuitable for use as growing media due to metal (copper, lead and nickel) and PAH concentrations therefore imported soil is to be used as a growing medium. Seepage water and vapour intrusion into future basements requires management.	Areas known to require remediation or management are shown on Attachment 9, Appendix A. Soil results in relation to SAC are discussed in SAR Section 11. It is possible that other areas of tar exist and if encountered will need to be managed during the site remediation and development. Asbestos impact is likely to be more common than indicated by site investigations due to the investigation methods adopted. Further comments in Table 12.1, above.
Discussion of the extent of	Groundwater remediation is not	Groundwater characterisation is

Table 12.2: Evaluation of Remedial Action Plan

Element	Details	Auditor Comments
groundwater remediation required. RAP s6.2.6	proposed in the RAP. Removal of tar above 10 mbgl is proposed to remove the groundwater contaminant source.	discussed in SAR Section 9. Risk from migration of deep impact discussed in SAR Section 10.5.2. Auditor is satisfied remedial action with respect to groundwater beyond source removal is not required.
Data Gaps RAP s4.3	JBS identified a potential data gap as the sampling density for material to be imported to site from Barangaroo. Additional sampling may be required prior to importation of the material.	The extent of tar identified in fill and natural material is a data gap. The extent of asbestos impact on the site is also considered to be a data gap. Further investigation may not be necessary as fill material is to be managed in situ.
Remedial Options RAP Table 6.3	Remediation Options Assessment Matrix included. Options discussed include on- and off-site treatment, off-site disposal, and isolation.	General options adequately identified.
Selected Preferred Option RAP s5.3	As discussed in SAR Section 12.1 and Table 12.1.	Consistent with Overarching RAP, see Table 12.1
Rationale RAP Table 6.3	Options justified in Overarching RAP in terms of financial, environmental and social costs. Also discussed in the Remediation Options Assessment Matrix.	Rationale considered reasonable.
Proposed Validation RAP s7	RAP states that a Validation Sampling Analysis and Quality Plan (VSAQP) will be prepared. A CQAP is to be prepared detailing the design of water and vapour tight basements.	Detailed validation plans required. Elements discussed in SAR Section 12.4.
Interim Site Management Plan (before remediation)	Not discussed.	Not required for contamination under current site condition.
Occupational Health and Safety RAP s10	Notes that an Occupational Health and Safety Management Plan (OHSMP) is required to be developed by the Remediation Contractor. RAP includes outline of hazards that need to be considered.	Identified hazards are considered reasonable.
Contingency Plan if Selected Remedial Strategy Fails	Outlines actions to be taken in the event that unsuitable material is received at the site.	Two potential scenarios were not identified in the RAP. These include the final data set for imported material exceeding the average and/or 95% UCL SAC, and a failure

Table 12.2: Evaluation of Remedial Action Plan

Element	Details	Auditor Comments
RAP s8		of the sealed basement.
Contingency Plan if Declaration Area Remediation is Incomplete RAP s8.2.6	RAP proposes installation of a retention structure 10 m outwards from the extent of the southern basement and excavation of contaminated materials down to 10 mbgl, providing 10 m of clean material outside the basement wall.	Remediation standards on the Declaration Area may not be sufficient for construction of the proposed basement since the remedial goal was for removal of the EPA declaration, not to meet high density residential land use. The proposed contingency action is unclear with respect to the placement of the buffer area, suggesting it may extend 10 m beyond the basement footprint, which would be into Hickson Road It is recommended that a full consideration of remediation requirements for the portion of the Declaration Area within the southern basement be undertaken after remediation is performed for removal of the EPA declaration.
Contingency Plans to Respond to Site Incidents. RAP s8	Outlines some scenarios that could feasibly occur during the site development. These include unexpected finds such as additional tar or asbestos, material storage breach and emissions complaints. Contingency plans for managing these occurrences are outlined.	Appears to cover the most likely occurrences and provides adequate responses. Development of an Asbestos Management Plan is considered more appropriate than managing asbestos via an UFP.
Site Management Plan for the Operation Phase including stormwater, soil, noise, dust, odour RAP s9	Lists required elements for a construction environmental management plan (CEMP), but leaves responsibility for preparation with Remediation Contractor. Remedial Works Plan (RWP) included as an Appendix to RAP.	The RAP notes that NSW EPA endorsement of the CEMP is required as part of the project approvals. RAP implies Site Auditor endorsement is required however this appears to be an error (not included in RWP). Revision of RWP is required to clarify sequence of remediation and validation tasks. Level of detail considered appropriate for RAP.
Remediation Schedule	Not included.	Will be subject to approvals. Note revision of RWP required to clarify remediation sequence.
Licence and Approvals RAP s11	The RAP outlines the relevant legislation and planning approvals required for the remediation works.	Existing and future regulatory approvals will apply.

Table 12.2: Evaluation of Remedial Action Plan		
Element	**Details**	**Auditor Comments**
	Work is to be conducted in accordance with approvals obtained under Part 3A of the *Environmental Planning and Assessment Act 1979*. Project Application SSD_5374 refers. Discharge of any waters from the site will be undertaken in accordance with the Environment Protection License (EPL) 13336. Materials to be disposed offsite will be assessed, classified and managed in accordance with the DECC NSW (2009) 'Waste Classification Guidelines Part 1: Classifying Waste'. Imported fill is required to be VENM or ENM as defined in the NSW *Protection of the Environment Operations (Waste) Regulation 2005*. Relevant legislation and guidelines are identified for the event that asbestos impacted fill materials are encountered.	
Community Relations	Overarching RAP notes need for Community Consultation Plan to notify all stakeholders. A community relations plan is to be included in the CEMP prepared by the Remediation Contractor.	BDA is also conducting community consultation, for example via website.
Staged Progress Reporting RAP s7.8.1	RAP does not identify any staged reporting requirement, specifies validation report at completion of Stage 1 Public Domain development.	Staged reporting of hotspot removal and progress reporting of the implementation of the MCMS is recommended. Validation report at completion of future residential development works will also be required.
Long term environmental management plan (LTEMP)	RAP envisages that a LTEMP will be required to control risks from residual contamination and define ongoing monitoring requirements. The RAP outlines the elements of the LTEMP. The management and monitoring required will be determined following remediation/management and	Revision of LTEMP will be required following completion of the future residential development. Discussed in SAR Section 16.

Table 12.2: Evaluation of Remedial Action Plan		
Element	**Details**	**Auditor Comments**
	validation. LTEMP identified as commencing at completion of Stage 1 Public Domain development.	

The RAP was found to address the required information with no critical departures, although it appears that the RWP does not accurately reflect the proposed sequence of tasks.

12.4 Validation

Validation of the as-built status of the soil with respect to contamination will be detailed in the VSAQP. The RAP details elements of the validation required, which included a combination of:

- Validation of excavations following removal of tar containing material, asbestos fibre impact and unexpected finds. Validation sampling will commence only if no evidence of contamination is identified by visual or olfactory means.
- Prevalidation of material which will be imported from other areas of Barangaroo (excluding the Declaration Area) to ascertain suitability for placement within a particular zone or zones within the final landform. Prevalidation will mostly consist of in situ preclassification, with some sampling of stockpiles after importation but before final placement.
- Analysis of material imported from off-site. This would generally be conducted prior to importation or by sampling of stockpiles after importation but before final placement.
- Materials management and tracking. For all material prevalidated or sampled prior to placement in its final location, a MCMS will need to be followed to verify that materials have been appropriately placed.
- Analysis of placed material or final surface. The amount of testing required will depend on the degree of variability or certainty in results, and the clarity of the implementation of the MCMS.
- Validation data are to be compared against the various SAC as follows:
  - Human health based criteria – the 95% UCL average
  - EIL Protective of Potential Phytotoxicity Effects – the maximum concentration
  - EILs Protective of Surface Water – the average concentration.

In addition to soil validation, there is also a requirement for verification of other elements of the construction. The main components of the validation are discussed in Table 12.3.

Table 12.3: Evaluation of Proposed Validation

Element	Proposed	Auditor Comments
Shallow tar-impacted material	Visual inspection for tar. Sampling of excavation base (1/25 m^2) and walls (1/5 m). Excavation will be extended in 0.2 m increments.	The presence of tar at the base of some of proposed remediation areas is likely.
Asbestos fibre hotspot	Sampling of excavation base (1/400 m^2) and walls (1/20 m).	Remediation not warranted for protection of human health or the environment Visual evidence unlikely since no asbestos-containing material observed in sampled material Validation of asbestos finds during construction should be addressed in the Asbestos Management Plan.
Footprint of water treatment plant	Visual inspection for tar. Sampling of excavation base (1/400 m^2) and walls (1/20 m).	This aspect not discussed elsewhere in RAP. Adequacy depends on associated excavation size.
Soil to be imported from other parts of Barangaroo	Validated prior to importation at 1/400 m^3. Sample density increased to 1/25 m^3 and includes leaching analyses if aesthetically impacted. Implementation of MCMS required.	Adequacy will depend on consistency of results.
Material to be imported from outside Barangaroo, e.g. topsoil, mulch	Source inspection and minimum of 10 samples per source site, and implementation of MCMS. Inspected onsite at time of importation.	Adequate.
Placement of material into zone and location suitable for the material	Implementation of MCMS to verify correct soil placement areas. Location plan with coordinates, levels and volumes to be provided for all soil placement areas.	MCMS to be provided for review, SAR Section 13.
Unexpected finds	Sampling of excavation base (1/25 m^2) and walls (1/5 m).	RAP reports two sample frequencies: 1/25 m^2 and a validation grid size of 25 m. The former is assumed to be correct. Adequacy will depend on the nature/ extent of the find.
Basement construction	Testing in accordance with the CQAP required for southern basement As Built or Issued for Construction drawings will be provided.	CQAP to be provided for review. Details are required of validation proposed to address construction requirements as outlined in SAR Section 10.3.4, noting possible need for short or long term monitoring of indoor basement space to verify that the design assumptions are met.

Table 12.3: Evaluation of Proposed Validation		
Element	**Proposed**	**Auditor Comments**
Tar against basement walls and base	Visual inspection of excavation walls and bases and photographic documentation as free of tar containing material. In excavations within bedrock, residual tar containing material is not mobile and is contained within rock defects, and the area of the impacted defects is less than less than 5% tar. Surface waters to be free of a sheen associated with contamination.	Since construction method is unlikely to allow inspection of basement walls, in situ validation (possibly through consideration of existing data) for the position of the basement walls is required and should be included in the RWP.

The RAP proposed preparation of a VSAQP. This will need to clarify some of the issues outlined in Table 12.3, above, as well as address validation of the additional remediation areas identified through the Auditor's review, including at BH/MW69 (southern basement) and BH530 (northern basement). If adequately clarified and competently implemented, the Auditor considers that the validation system is considered sufficient to verify the suitability of the site for the intended uses.

12.5 Additional Remediation Documentation

The RAP identifies the following supporting documentation that will be prepared prior to commencement of the remediation works (not related to site suitability):

- Occupational Health and Safety Plan
- Construction Environmental Management Plan
- Acid Sulphate Soils Management Plan where any excavation of saturated soils is proposed.

Monitoring/ management documentation to be prepared that relates to the site suitability and therefore requires review by the Site Auditor is proposed as below. Additional items recommended by the Auditor are noted and detail is provided where not provided elsewhere and required:

- VSAQP (refer SAR Section 12.4)
- CQAP
- MCMS (refer SAR Section 13)
- Revised RWP (recommended by Auditor):
  - clarifying SAC and relevant data sets
  - confirming the proposed remedial extent based on the above
  - clarify the proposed depth of over-excavation (beyond 10 mbgl) if tar found at the base of remedial excavations

- confirming sequence of proposed remediation and validation tasks
- proposed design for open space areas in future residential development (e.g., extent of filling to be retained) if known
- in situ validation for tar occurrence along proposed basement alignment

- LTEMP (refer SAR Section 16):
  - for Stage 1 Public Domain (proposed in RAP)
  - LTEMP for future residential development (recommended by Auditor)
- Asbestos Management Plan for excavation of basements for future residential development (recommended by Auditor as alternative to management of asbestos via UFP).

12.6 Conclusion

The Auditor has interpreted the remediation works proposed by JBS as summarised in Table 12.1 above. The RAP is not clear about the proposed timing of the tar excavations as it seems unlikely that the excavation works required for these would be undertaken in advance of basement construction which is not proposed for the interim Phase 1 Public Domain development.

Notwithstanding the requirement to clarify the proposed remediation extent and sequence, the proposed remediation and validation approach described in the RAP are considered to be generally appropriate. The proposed remediation strategies are consistent with the Overarching RAP

A number of planning and management documents are to be prepared prior to remediation, including development of a Materials Compliance Management System (refer Section 13). Where they relate to the site suitability, these documents require approval by the Site Auditor. A long term environmental management plan (LTEMP) is proposed for the Phase 1 Public Domain usage and will also be required for future residential usage (refer Section 16).

13 Materials Compliance Management System

The RAP requires that a Materials Compliance Management System (MCMS) be prepared for the reuse of materials on the site. The MCMS documents a system for managing and tracking the testing, verification, transport and placement of material within Barangaroo Central. It must include the following elements:

- Clarification of site acceptance criteria to address risks to both human health and the environment.
- Responsibilities.
- Material classification, including analytical data and visual observations.
- Procedures for managing and tracking material origin and destination (lateral and vertical location using survey data).
- Procedures for recording the quantity of materials.
- Forms and documentation.
- Unexpected finds protocol.
- QA/QC.

The MCMS should also include procedures for stockpile management in the event storage of material is required prior to placement or disposal. Procedures to limit the potential for cross contamination should also be included.

14 Contamination Migration Potential

The potential for offsite down-gradient 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 Acceptance Criteria (Section 10).

In the Auditor's opinion, completion of the remediation works as described in Section 12 will minimise the potential for future offsite down-gradient migration of contamination from the site. As discussed in Section 10.5.2, there is a considered to be a negligibly low potential for migration of contamination from residual impacts to be retained below 10 mbgl, primarily in marine sediments. The RAP notes that groundwater monitoring can be included within the LTEMP. The Auditor will review the need for post-remediation monitoring down-gradient of the site in review of the LTEMP.

15 Residual Risk Following Remediation

Potential risks to human health and the environment have been addressed through the development of SAC criteria (Section 10) and the design of the remediation works (Section 12).

Following implementation of the RAP, there is potential for odorous soils or asbestos-containing fragments to be encountered during any future disturbance of fill soils to be retained within the site. There is also potential for more significant contamination in the form of tar or hydrocarbon contamination to be encountered, particularly below 10 mbgl. JBS proposes development of a LTEMP to describe contingency management methods which may need to be applied by future land owners, discussed in Section 16, following. A LTEMP is considered an appropriate means to manage any future risk from contamination.

The RWP does not clearly address the sequence of proposed remediation and validation tasks, and there is a potential issue relating to timing of the proposed tar excavations. Remediation of tar impacts seems most likely to occur concurrently with construction of the residential development since the proposed remediation areas occur primarily within the proposed basement excavations. If the interim open space development goes ahead without remediation of tar impacted fill, there is potential that this remediation may be delayed for some time or may not occur if the long term residential development does not proceed. The proposed remediation for the Declaration Area includes remediation of two areas within Central and in proximity to the Declaration Area. These areas represent the worst of the tar contamination on Central, and their remediation for the purposes of removing the EPA declaration should be sufficient to ensure protection of the environment in the long term. Remediation of tar is not required for protection of human health for open space usage.

16 Ongoing Site Management

The RAP (Section 7.8.2) envisages a requirement for long term monitoring/management of the site following completion of the works through a long term environmental management plan (LTEMP). The RAP states that the precise nature and extent of management requirements will be determined following remediation and review of the validation data. The LTEMP will document the site condition under the future land uses.

The RAP outlines the contents of the LTEMP, but does not provide any indication of management measures that may be required or who will be responsible for them. The RWP indicates the LTEMP will be prepared at completion of the Stage 1 Public Domain development.

The Auditor considers that:

- The management plan must be able to effectively prevent excavation beyond the clean shallow soil and to prevent exposure to soils by site workers in portions of the site not subject to landscaping (southern 30%).
- Revision of LTEMP will be required following completion of the future residential development.
- There may be a need for short or long term monitoring of indoor basement space to verify that the design assumptions are met.

The appropriate conditions for the implementation of an Environmental Management Plan stated under Section 3.4.6 of DEC (2006) *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd Ed.)* will have to be met, namely:

- The remnant contamination to be managed must not pose an unacceptable risk to onsite or off-site environments.
- The EMP must be reviewed by the Auditor.
- The provisions of the EMP can be made to be legally enforceable.
- There will be appropriate public notification of restrictions applying to the site through a notification on the Section 149 Certificate for the site.

Implementation of the LTEMP is likely to be a condition of suitability on a Section A Site Audit Statement certifying suitability for the proposed use. A LTEMP is considered an appropriate means to manage any future risk provided the document is practical and legally enforceable. Review of this document is not required to complete the current audit.

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*. The EPA's *Checklist for Site Auditors using the EPA Guidelines for the NSW Site Auditor Scheme 1998 (December 1999)* has been completed and is kept on file.

The relevant legislation and planning approvals required for the remediation works as identified in the RAP are discussed in SAR Table 12.2.

The RAP (Section 11) states *"In accordance with the DGRs relating to the Project Application SSD_5374, this RAP and the RWP, must be the subject of a Site Audit Statement completed by an accredited NSW EPA Site Auditor, confirming the Barangaroo Central Site will have achieved 'remediation to a standard commensurate with the final intended land use' if this RAP is implemented."* This requirement is not included in the DOP documents reviewed by the Auditor, as follows:

The Director General's Assessment Requirements under Section 78(8A) of Environmental Planning and Assessment Act 1979 relating to SSD 5374, Barangaroo Central Waterfront Promenade and lnterim Public Domain Works and dated 30 July 2012 includes as Condition 9. Remediation and Contamination *"The EIS must include a Remedial Action Plan (RAP). The RAP must be prepared in accordance with the contaminated land planning guidelines under section 145C of the Environmental Planning and Assessment Act 1979 and relevant guidelines produced or approved under section 105 of the Contaminated Land Management Act 1997"*. This requires a RAP to be prepared (as reviewed in this SAR) however does not require a site audit.

Draft Development Consent under Section 89E of the Environmental Planning & Assessment Act 1979 relating to SSD12_5374, Barangaroo Central Waterfront Promenade and Interim Public Domain Works, and dated 17 February 2013 includes as condition A5(3) *"Within 6 months of the completion of the remediation works on site, and prior to the commencement of the use of the site as temporary and permanent public domain, the applicant shall submit a detailed Site Audit Summary report and Section A Site Audit Statement and Validation Report to the EPA (OEH), the Director-General, the Certifying Authority, and the Council. The site audit must be prepared in accordance with the Contaminated Land Management Act 1997 and completed by a site auditor accredited by the EPA to issue site audit statements. The site audit must verify that the land is suitable for the proposed uses"*. This requires a Section A site audit at the completion of remedial works.

18 Conclusions and Recommendations

Based on the information presented in the reports referenced in Section 1.3 of this Site Audit Report and observations made on site, and following the Decision Process for Assessing Urban Redevelopment Sites in DEC (2006) *Guidelines for the NSW Site Auditor Scheme (2nd edition)*, the Auditor concludes that the site can be made suitable for the proposed uses including recreational open space and high density residential uses if the site is remediated in accordance with the following remedial action plan/management plan:

- 'Remedial Action Plan, Barangaroo Delivery Authority, Stage 1 Public Domain, Barangaroo Central, Hickson Road, Sydney, NSW' Rev H dated May 2013 by JBS Environmental Pty Ltd

subject to compliance with the following conditions:

1 Preparation of a revised RWP to confirm the sequence of proposed remediation and validation tasks. Clarification also required around the site acceptance criteria and relevant data sets and the proposed remedial extent (including vertically) (refer SAR Section 12.5).

2 Remediation works are undertaken in compliance with an acceptable 'Materials Compliance Management Plan' (refer SAR Section 13).

3 Preparation of a suitable Validation Sampling and Analysis Quality Plan to address ambiguities in the RAP and validation at BH/MW69 and BH530 (refer SAR Section 12.4).

4 Implementation of an Asbestos Management Plan during development.

It is recommended that these Conditions are fulfilled, including review by the Auditor, prior to commencement of the major development works.

The RAP envisages a requirement for long term monitoring / management of the site following completion of the works. The requirements will be determined following review of the validation and materials tracking data and will apply to the interim open space development and future residential use. It is envisaged that a Site Audit Statement will be prepared at completion of the works for both stages of development. This is a condition of the draft Development Consent for the Stage 1 Public Domain.

It is noted that the southern basement proposed for the future residential development crosses into the Declaration Area. The Declaration Area has not been addressed in a Remedial Action Plan considering the suitability of the site for future residential use. A site audit confirming the site can be made suitable for its intended use should be performed for the Declaration Area portion of the southern basement.

19 Other Relevant Information

The Audit was conducted on the behalf of Barangaroo Delivery Authority to provide an independent review by an NSW EPA Accredited Auditor of what remediation or management is necessary before the land is suitable for specified uses i.e. a “Site Audit” as defined in Section 4 (1) (b) (iv) of the *NSW Contaminated Land Management Act 1997* (the CLM Act).

This summary report may not be suitable for other uses. JBS and the consultants conducting the investigations 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 Boundary, Layout and Soil Investigation Locations

Attachment 3: Former Layout of the Barangaroo Project Area

Attachment 4: Barangaroo Central Stage 1 Public Domain Concept Plan

Attachment 5: Groundwater Monitoring Well Locations

Attachment 6: Extent of Soils in Unsaturated Zone Exceeding Open Space Human Health Criteria (ERM and JBS data only)

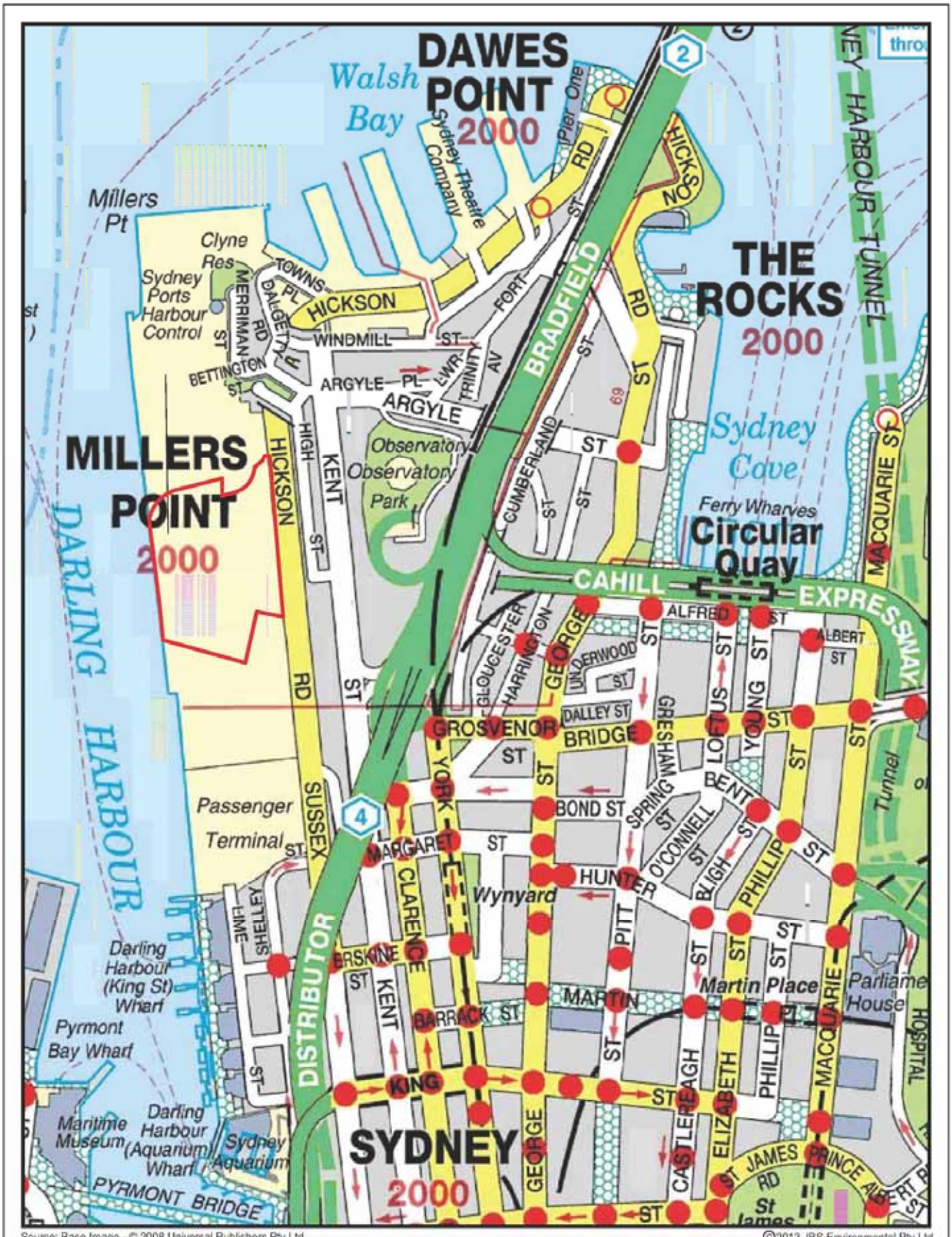
Attachment 7a: Declaration Area Proposed Extent of Remediation – Unsaturated Soils

Attachment 7b: Declaration Area Proposed Extent of Remediation – Saturated Soils

Attachment 8: Extent of Soils in Unsaturated Zone Exceeding Protection of Surface Water Ecological Investigation Criteria (ERM and JBS data only)

Attachment 9: Proposed Remediation Extent

Attachment 1: Site Location



Source: Base Image - © 2008 Universal Publishers Pty Ltd

0 75 125 250 m

Scale: Approximate

Datum: MGA94 Zone 56 - AHD

Rev	Description	Drn.	Date
A4			
G	Issue - R06	RF	27-3-2013

Legend:

Approximate Boundary - Barangaroo Central

JBS ENVIRONMENTAL

Figure 1: Location of Barangaroo Central Site

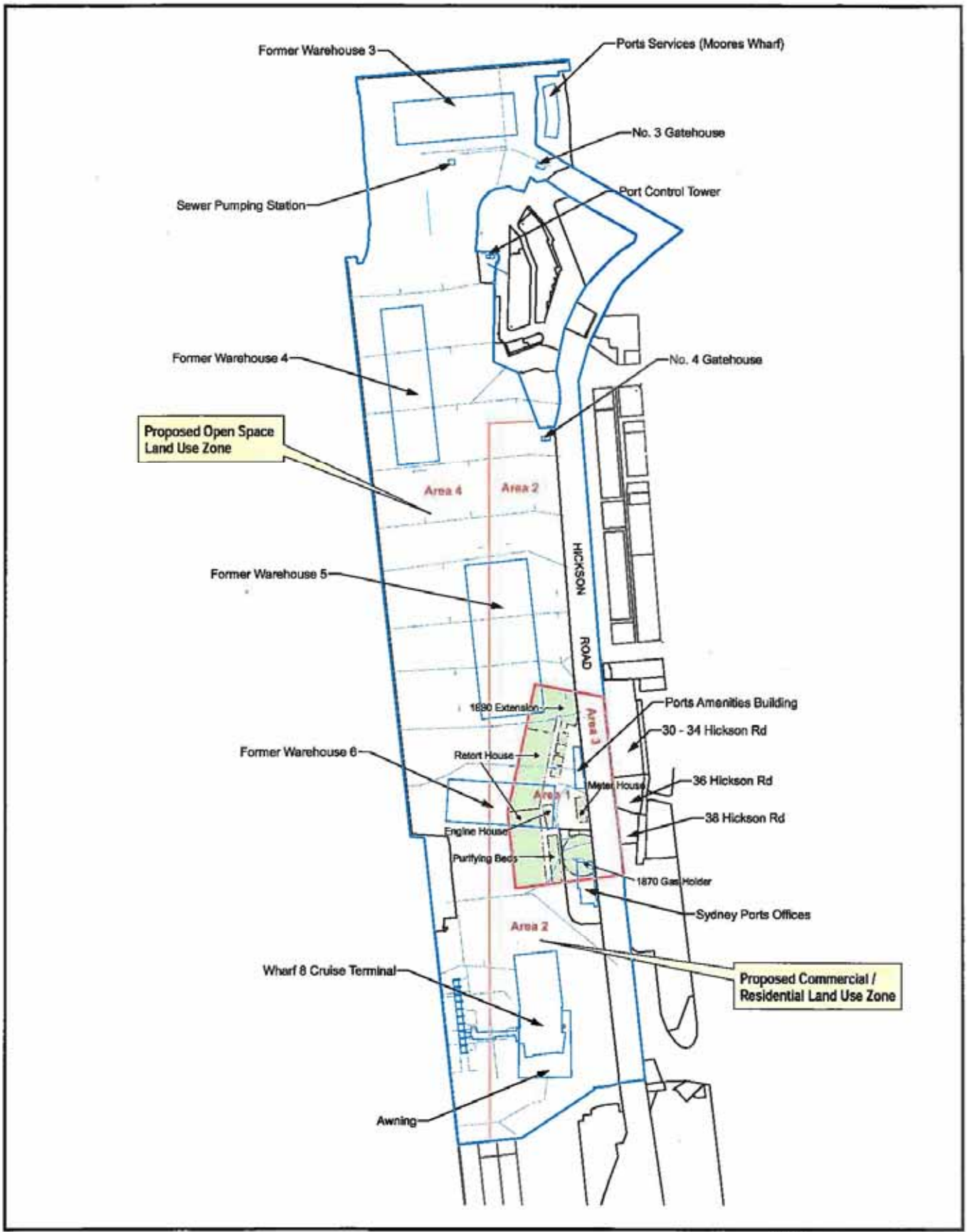
Client: Barangaroo Delivery Authority

Project: Barangaroo Central

Job No: 42021 File Name: 42021_01

Attachment 2: Site Boundary, Layout and Soil Investigation Locations

Attachment 3: Former Layout of the Barangaroo Project Area



Legend

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

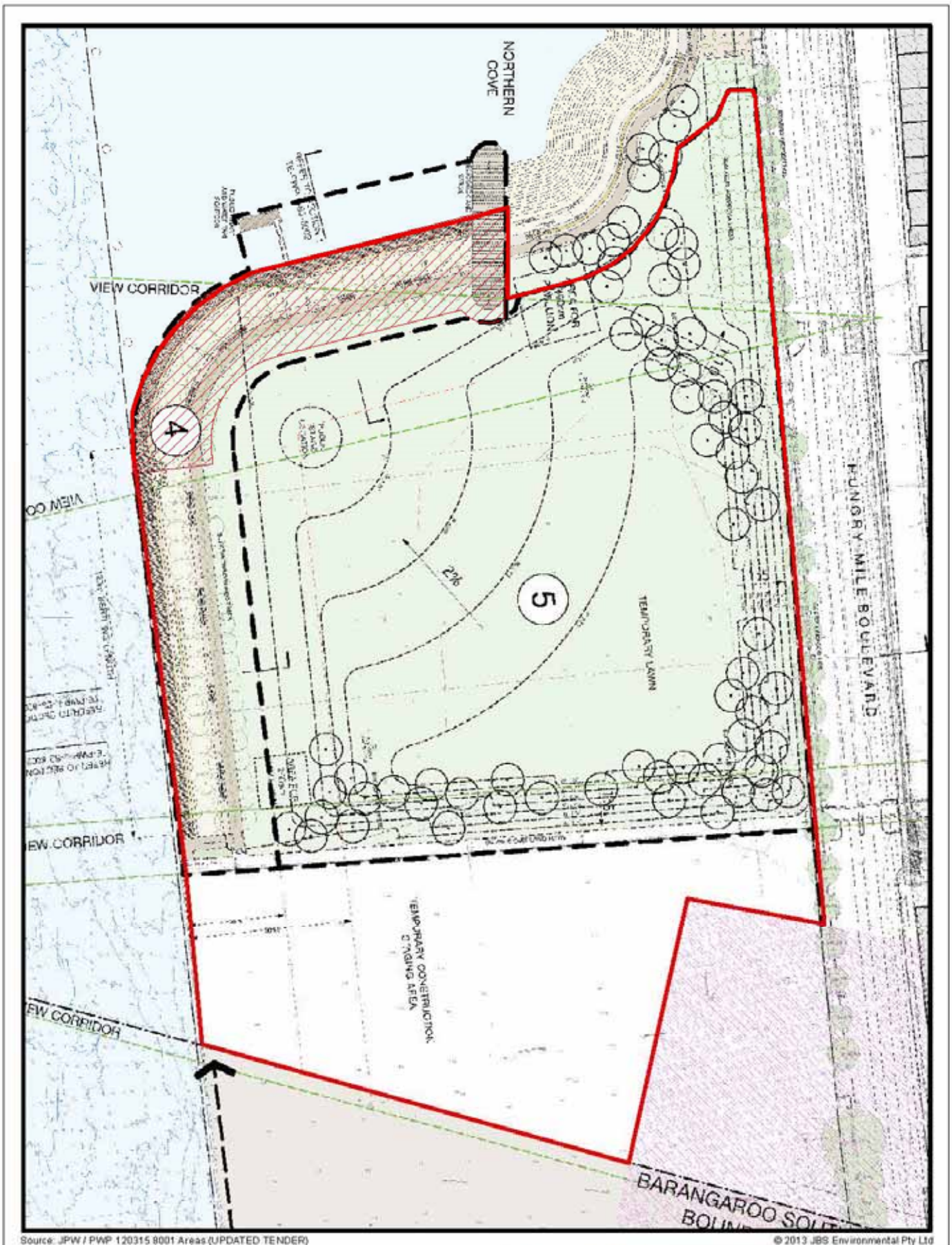
Client: Barangaroo Delivery Authority
Project: Barangaroo Overarching RAP
Drawing No: 0114385s_RAP_GIS001_R0.mxd
Date: 31/03/2010 Drawing size: A3
Drawn by: JF Reviewed by: PL
Projection: GDA 1994 MGA Zone 56
Scale: Refer to Scale Bar

Figure 2
Site Layout Plan

Environmental Resources Management Australia Pty Ltd
Building C, 33 Saunders St, Pyrmont, NSW 2009
Telephone +61 2 8584 [illegible]

ERM

Attachment 4: Barangaroo Central Stage 1 Public Domain Concept Plan



Source: JPW / PWP 120315 8001 Areas (UPDATED TENDER)

0 15 30 60 m

Scale: 1:1,500

Datum: MGA94 Zone 56 - AHD

Legend:
- Approximate Site Boundary - Barangaroo Central
- Overlap of Area Already Assessed (Headland Park)

Rev	Description	Drn.	Date:
A4			
0	Original Issue - R06	RF	27-3-2013

JBS ENVIRONMENTAL

Figure 3A: Barangaroo Central Concept Plan - Barangaroo Central Stage 1 Public Domain

Client: Barangaroo Delivery Authority

Project: Barangaroo - Central

Job No: 42021 File Name: 42021_03A

Attachment 5: Groundwater Monitoring Well Locations

Attachment 6: Extent of Soils in Unsaturated Zone Exceeding Open Space Human Health Criteria (ERM and JBS data only)

Last modified: 23 Jul 13 - 14:19

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30-34 HICKSON ROAD
LOT 2 DP 873158

36 HICKSON ROAD
LOT 3 DP 873158

38 HICKSON ROAD
LOT 3 DP 873158

SEWERAGE PUMPING STATION SP1129 (TO BE RETAINED)

HICKSON ROAD

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- DECLARATION AREA BOUNDARY
- THE SITE BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 AND 5 BOUNDARIES
- EXISTING CAISSON WALL
- BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA
- ESTIMATED REMEDIATION DEPTH (0-2m bgl)

NOTE:
LOCATION OF COFFEY GROUNDWATER WELLS ARE APPROXIMATE ONLY.

Attachment 7a: Declaration Area Proposed Extent of Remediation – Unsaturated Soils

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

REVISIONS					
04	PAS	23.07.13	FINAL ISSUE		AR
03	PAS	20.06.13	DRAFT ISSUE		AR
02	PAS	18.03.13	DRAFT ISSUE		AR
01	TT	12.09.12	DRAFT ISSUED		DM
No.	BY	DATE	DESCRIPTION		APPD

SCALES: 1:1000 A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

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

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F10:
VMP EXTENT OF REMEDIATION (UNSATURATED)

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F10

REV: 04

Last modified: 23 Jul 13 - 14:20

Cad ref: P:\60153531_Barangaroo_S_JCIS_CAD\S3_Working\Drg\Figures\60247139-drg-28-RAPC-F11.dwg

AA A B C D E F G H I J K L M N

1 2 3 4 5 6 7 8 9 10 11 12

SEWERAGE PUMPING STATION SP1129 (TO BE RETAINED)

REMEDIATION TO APPROXIMATE 5.5m BGL

REMEDIATION TO GREATER DEPTH WITHIN FORMER TAR TANK AND ANNULUS STRUCTURES

HICKSON ROAD

JENKINS STREET

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

REFER TO NOTE 1

Attachment 7b: Declaration Area Proposed Extent of Remediation – Saturated Soils

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- AECOM SUPPLEMENTARY VMP DGI BOREHOLE LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- THE SITE BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING CAISSON WALL
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 AND 5 BOUNDARIES

BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA

ESTIMATED REMEDIATION DEPTH:

- 2.0-3.0m BGL
- 3.0-5.0m BGL
- 5.0-10.0m BGL
- MARINE SEDIMENT CONTOURS mAHD
- BEDROCK CONTOURS mAHD

NOTES:

1. REMEDIATION UNDERTAKEN AS PART OF THE ORWS DEVELOPMENT WORKS.
2. THE ESTIMATED REMEDIATION DEPTHS ARE INDICATIVE. REMEDIATION WILL BE UNDERTAKEN TO THE DEPTH OF THE UNDERLYING BEDROCK TO A MAXIMUM DEPTH OF 10m BGL, SUBJECT TO THE REQUIREMENTS OF THE RAP.

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
05	PAS	23.07.13	FINAL ISSUE	AR
04	PAS	20.06.13	DRAFT ISSUE	AR
03	PAS	12.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM

SCALES: 5 0 5 10 15m — 1:1000 A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

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

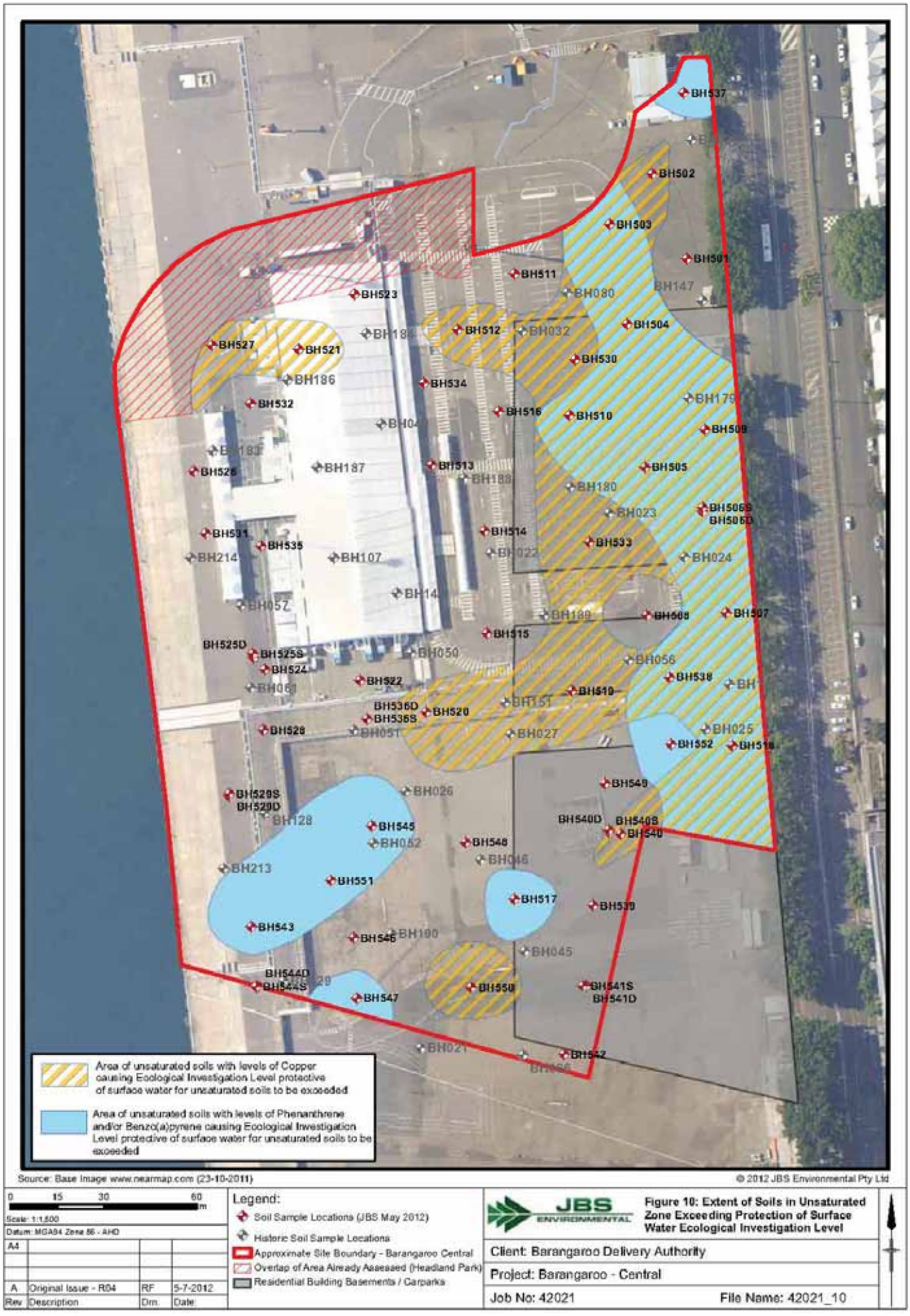
CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F11:
VMP EXTENT OF REMEDIATION (SATURATED)

STATUS:	DRAWING NO:	REV:
FINAL	60247139-DRG-20-RAPC-F11	05

Attachment 8: Extent of Soils in Unsaturated Zone Exceeding Protection of Surface Water Ecological Investigation Criteria (ERM and JBS data only)



Attachment 9: Proposed Remediation Extent

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	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
(complex)					
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)
Phenanthrene	0.6	
Fluroanthene	1	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
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.
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 21 June 2013*)

Section 105 of the Contaminated Land Management Act 1997 (CLM Act) allows the Environment Protection Authority (EPA) to make or approve guidelines for purposes connected with the objects of the Act. These guidelines must be taken into consideration by the EPA whenever they are relevant and by accredited site auditors when conducting a site audit. They are also used by contaminated land consultants in undertaking investigation, remediation, validation and reporting on contaminated sites.

Guidelines made by the EPA

- Guidelines for Assessing Service Station Sites (servicestnsites.pdf, 1.2MB, December 1994)
- Guidelines for the Vertical Mixing of Soil on Former Broad-acre Agricultural Land (vertmix.pdf 148KB, January 1995)
- Sampling Design Guidelines (9559sampgdlne.pdf, 2MB) (September 1995)
- Guidelines for Assessing Banana Plantation Sites (bananaplantsite.pdf; 586 KB) (October 1997)
- Guidelines for Consultants Reporting on Contaminated Sites (20110650consultantsglines.pdf; 428 KB) (reprinted August 2011)
- Guidelines for Assessing Former Orchards and Market Gardens (orchardgdlne.pdf; 172 KB) (June 2005)
- Guidelines for the NSW Site Auditor Scheme, 2nd edition (auditorglines06121.pdf; 510 KB) (April 2006)
- Guidelines for the Assessment and Management of Groundwater Contamination (groundwaterguidelines07144.pdf; 604 KB) (March 2007)
- Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997 (09438gldutycontclma.pdf; 1 MB) (June 2009)

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, published by ANZECC 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, 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 (April 2013)

The NEPM 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:

- Guideline on Investigation Levels for Soil and Groundwater
  Guideline on Site Characterisation
  Guideline on Laboratory Analysis of Potentially Contaminated Soils
  Guideline on Site-specific Health Risk Assessment Methodology
  Guideline on Ecological Risk Assessment
  Guideline on Methodology to Derive Ecological Investigation Levels in Contaminated Soils
  Guideline on Ecological Investigation Levels for Arsenic, Chromium(III), Copper, DDT, Lead, Naphthalene, Nickel and Zinc
  Guideline on the Framework for Risk-based Assessment of Groundwater Contamination
  Guideline on Derivation of Health-based Investigation Levels
  Guideline on Community Engagement and Risk Communication
  Guideline on Competencies and 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 and Natural Resource Management Ministerial Council of Australia and New Zealand (2011)

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		

Target Compounds	MGT LabMark Method	Methodology Summary
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 Cadmium Chromium Copper Nickel Lead Zinc	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.
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
Polynuclear Aromatic Hydrocarbons (PAHs)		
Naphthalene 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	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.
BTEX Compounds		
Benzene Toluene Chlorobenzene Ethylbenzene Meta- & para-Xylene Ortho-Xylene	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.
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 C15-C28 Fraction C29-C36 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.

Target Compounds	ALS Method	Methodology Summary
		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.
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

ENVIROLAB ANALYTICAL LISTS AND METHODS

Target Compounds	ENVIROLAB Method	Methodology Summary
Heavy Metals		
Arsenic	Metals.20 ICP-AES	Determination of various metals by ICP-AES.
Cadmium		
Chromium		
Copper		
Nickel		
Lead		
Zinc		
Mercury	Metals.21 CV-AAS	Determination of Mercury by Cold Vapour AAS.
Polynuclear Aromatic Hydrocarbons (PAHs)		
Naphthalene	GC.12 subset	Soil samples are extracted with Dichloromethane/ Acetone and waters with Dichloromethane and analysed 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	GC.16	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS.
Toluene		
Chlorobenzene		
Ethylbenzene		
Meta- & para-Xylene		
Ortho-Xylene		
VOC Compounds		
See attached list	GC.13	Water samples are analysed directly by purge and trap GC-MS.
Total Petroleum Hydrocarbons		
C6-C9 Fraction	GC.16	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS.
C10-C14 Fraction	GC.3	Soil samples are extracted with Dichloromethane/ acetone and waters with Dichloromethane and analysed by GC-FID.
C15-C28 Fraction		
C29-C36 Fraction		
Other Analytes		
Ammonia as N	LAB.57	Determined colourimetrically based on EPA350.1, soils are analysed following a

Target Compounds	ENVIROLAB Method	Methodology Summary
		water extraction.
Asbestos	ASB.1	Qualitative identification of asbestos type fibres in bulk samples using Polarised Light Microscopyand Dispersion Staining Techniques.

Client Reference: 71723.08, Barangaroo

VOCs in water Our Reference: Your Reference Date Sampled Type of sample	UNITS ---------- ----------	49312-1 MW01 3/12/2010 Water	49312-2 MW02 3/12/2010 Water	49312-3 MW04 3/12/2010 Water
1,2,3-trichloropropane	µg/L	<1.0	<1.0	<1.0
Isopropylbenzene	µg/L	<1.0	<1.0	<1.0
Bromobenzene	µg/L	<1.0	<1.0	<1.0
n-propyl benzene	µg/L	<1.0	<1.0	<1.0
2-chlorotoluene	µg/L	<1.0	<1.0	<1.0
4-chlorotoluene	µg/L	<1.0	<1.0	<1.0
1,3,5-trimethyl benzene	µg/L	<1.0	<1.0	<1.0
Tert-butyl benzene	µg/L	<1.0	<1.0	<1.0
1,2,4-trimethyl benzene	µg/L	<1.0	<1.0	<1.0
1,3-dichlorobenzene	µg/L	<1.0	<1.0	<1.0
Sec-butyl benzene	µg/L	<1.0	<1.0	<1.0
1,4-dichlorobenzene	µg/L	<1.0	<1.0	<1.0
4-isopropyl toluene	µg/L	<1.0	<1.0	<1.0
1,2-dichlorobenzene	µg/L	<1.0	<1.0	<1.0
n-butyl benzene	µg/L	<1.0	<1.0	<1.0
1,2-dibromo-3-chloropropane	µg/L	<1.0	<1.0	<1.0
1,2,4-trichlorobenzene	µg/L	<1.0	<1.0	<1.0
Hexachlorobutadiene	µg/L	<1.0	<1.0	<1.0
1,2,3-trichlorobenzene	µg/L	<1.0	<1.0	<1.0
Surrogate Dibromofluoromethane	%	108	109	109
Surrogate toluene-d8	%	102	102	102
Surrogate 4-BFB	%	104	104	104

Appendix E:
Risk Based Remediation Criteria

5.2 AECOM (2011a and 2011b) Human Health Risk Based Criteria for Proposed Southern Basement

The AECOM (2011a and 2011b) criteria for the protection of human health as proposed to be used with AECOM (2011a, 2011b and 2011c) basement design are summarised in **Tables 5.2** and **5.3** following for groundwater and soil based contaminants respectively.

Table 5.2: AECOM (2011a and 2011b) Risk Based Criteria for Groundwater – to be applied to Southern Basement (mg/L)

Constituent	Scenario 1 – Lower Basement	Scenario 2 – Upper Basement
Ammonia	2400	6800
Benzene	21	95
Methynaphthalene, 2-	38	120
Methylphenol, 3-&4-	1000	2700
Naphthalene	0.92	2.9
Phenol	310 000	NC
TPH C_6-C_9 (aliphatic)	28 000	90 000
TPH C_{10}-C_{14} (aliphatic / aromatic)	7.7	15
Trimethylbenzene, 1,2,4-	87	280

Table 5.3: AECOM (2011a and 2011b) Risk Based Criteria for Soils – to be applied to Southern Basement (mg/kg)

Constituent	Scenario 2 – Upper Basement
Benzene	15
Ethylbenzene	600
Methynaphthalene, 2-	1100
Methylphenol, 3-&4-	8800
Naphthalene	41
TPH C_6-C_9 (aliphatic)	3400
TPH C_{10}-C_{14} (aliphatic / aromatic)	13 000
Trimethylbenzene, 1,2,4-	14

The key assumptions to the derivation of the criteria in **Tables 5.2** and **5.3** include:

- The soils criteria apply to unsaturated soils only. No criteria have been considered for soil constituents in saturated horizons.
- Tar is removed from the immediate vicinity of outer basement walls to the extent practicable and basement design and engineering controls should ensure that tar seepage into basements does not occur.
- In the lower and upper basements a wind speed of 0.03 m/s occurs within the basements.
- The air exchange rate within the basement car park has been assumed to be 4 volume changes per hour.
- No more than two walls will be in contact with contaminated soil / groundwater (with Scenario 1 also considering exposures to the floor). This is based on building plans provided to inform this risk assessment that assumed that basement areas would be compartmentalised with each compartment adjacent to basement areas leaving a maximum of 2 exposed walls.
- The basement groundwater retention walls system will comprise a secant pile wall, extending to and keyed into bedrock, with a reinforced concrete basement wall, constructed on the inside. A sealed plenum constructed immediately inside the reinforced concrete basement wall will include (a) passive ventilation to the atmosphere; and (b) dish drains that will drain any seepage.

In regards to the criteria in **Tables 5.2** and **5.3**, the following recommendations are also provided:

- Basement design plans must include engineering controls to ensure that contaminated groundwater does accumulate in compartments which are ventilated to basement airspaces since potentially adverse risk and odours have been estimated to arise from low concentrations of volatile groundwater contaminants it water enters basements. The following is also recommended:
    - Basement levels should be maintained at lower pressure than occupied areas in accordance with AS1668.2 (Standards Australia 2002);
    - Sump rooms should be placed as far as possible from lift wells;
    - Air exchange rates within basement areas should be maintained at a minimum of the Australian Standard of 4 volume changes per hour;
- Tar should be removed from the immediate vicinity of outer basement walls to the extent practicable, and basement designs and engineering controls should ensure that tar seepage into basements does not occur;
- Validation of soil and groundwater following remediation should be undertaken using appropriate statistical methodologies to ensure the arithmetic average concentration of contaminants are below relevant screening criteria, in accordance with NSW EPA (1995) guidelines. The validation process is recommended to include:
    - Use of systematic sampling patterns;
    - Collection of an appropriate number of samples for estimation of the arithmetic average concentration of contaminant(s) within relevant environmental media and land-use areas (land use areas should be determined based on specific development plans with consideration to areas of soil and groundwater from which vapours may enter a given basement structure); and
    - Estimation of the 95% upper confidence limit (UCL) of the arithmetic average concentration within relevant environmental media and exposure areas.

Additional guidance for applying these criteria is provided in AECOM (2011c) which is the only remedial document available that describes the implementation of the risk based basement criteria. In addition to the requirements listed above, the following are noted:

- The 95% upper confidence limit (UCL) of the mean concentration is less than the adopted human health based criteria;
- Each individual sample concentration does not exceed the adopted human health based criteria by more than 2.5 times;
- The standard deviation of the sample set is not more than 50% of the human health criteria; and
- The criteria are intended to apply to the extent of the basements only, referred to in AECOM (2011c) as ‘Area C’.

The validation of the AECOM (2011a) criteria, as adopted in AECOM (2011b), is described in AECOM (2011c) as comprising two components, relating to the basement construction and the soil and groundwater conditions adjoining the basement.

The validation the basement design is intended to confirm that the key assumptions regarding the proposed basement construction method was implemented. AECOM

(2011c) proposes that validation include review of appropriate documentation nominated as:

- 'Issue for construction' drawings that verify the key elements of the proposed basement design relied upon in the derivation of the risk based criteria (as summarised above) will be constructed; and
- 'As constructed' drawings that document the key elements of the proposed basement design relied upon in the derivation of the risk based criteria (as summarised above).

The validation of the ground conditions is reported by AECOM (2011c) to require the following:

- Inspection of all basement excavation walls and bases by a qualified environmental engineer / scientist to confirm that the excavated material is free of asbestos containing materials (ACM). AECOM (2011c) requires that where ACM is encountered during these works, soil removal and validation works require to be undertaken;
- Removal of tar containing material from the immediate vicinity of the outer basement walls to the extent practicable;
- Visual observation of the deep basement area excavation, as it is proposed to be constructed in rock with observations to confirm that:
    - The final surface is generally free of tar containing material (TCM), specifically;
        - Any TCM present is contained within rock defects;
        - Any TCM present is not mobile (that it does not migrate out of the defects under normal weather conditions); and
        - The area of the TCM impacted defects is less than 5% of the exposed rock face; and/or
    - Surface waters will be free of a sheen associated with contamination.

AECOM (2011c) required that the observations were confirmed via photographic documentation.

Additional clarification of the application of the risk based screening criteria is provided to Environ (2011). The following is noted here:

- Soil based human health criteria only require application to soils underlying the basement excavation; and
- Soil and groundwater based criteria require application to soils adjoining the area of the proposed basement.

5.3 JBS (2012b) Criteria for Open Space Areas

JBS (2012b) provides criteria for the protection of human health in open space areas. These criteria are summarised in **Table 5.4**.

Table 5.4: JBS (2012b) Human Health Based Criteria for Open Spaces

Constituent	Risk Based Soil Criteria, 0-0.5m Soil Horizon (mg/kg)	Risk Based Soil Criteria, Soils >0.5m below Site Surface (mg/kg)
Acenaphthene	900	49 000
Acenaphthylene	900	170 000
Ammonia	5 200	16 000
Anthracene	4500	NC
Arsenic	190	NC
Benzo(a)pyrene	2.0	NC
Benzene	0.9	4.8
Chromium	630	NC
Copper	6 400	NC
Cyanide	310	14 000
Dibenzofuran	4 400	150 000
2,4-dimethylphenol	1 800	NC
Ethylbenzene	130	130
Fluoranthene	610	NC
Fluorene	600	250 000
Lead	480	NC
2-methylnaphthalene	60	9 600
Cresols	4 300	NC
Naphthalene	33	170
Phenanthrene	4 500	NC
Phenol	25 000	25 000
Pyrene	460	NC
Toluene	92	92
TPH C_6-C_8 (aliphatic)	890	4 400
TPH C_{10}-C_{14}	830	4 500
TPH $C_{>15}$	5 100	NC
1,2,4-trimethylbenzene	6.3	215
Xylenes	33	33

The 0-0.5m criteria were based on potential recreational worker exposure and the >0.5m criteria were based on potential sub-surface maintenance / excavation worker exposure. The criteria were intended to be assessed by comparison of a 95% UCL_{avg} concentration of constituents.

5.4 JBS (2012b and 2013a) Criteria for Soils Adjoining Northern Basement

JBS (2012b and 2013a) provides criteria for the protection of human health for potential basement users (**Table 5.5**). These criteria were based on a standard basement design and contained no provisions for specialist designs to prevent infiltration of seepage water / tar etc. It is considered that these criteria will apply only to the proposed northern basement with the residential development of the site.

Table 5.5: Human Health Based Criteria for Soils Adjoining Northern Basement

Constituent	Risk Based Soil Criteria, Soil Within 10m of Basement Car Park (mg/kg)	Risk Based Soil Criteria, Unsaturated Soil Within 30m and Greater than 10m from Basement Car Park (mg/kg)
Acenaphthene	470	17 000
Acenaphthylene	1400	31 000
Ammonia	<LOR	5300
Anthracene	49 000	No criteria
Benzo(a)pyrene	62	No criteria
Benzene	<LOR	0.8
Chromium	59 000	No criteria
Cyanide	75	5300
Dibenzofuran	3.2	24 000
2,4-dimethylphenol	3300	No criteria
Ethylbenzene	<LOR	120
Fluoranthene	180 000	No criteria
Fluorene	750	45 000
2-methylnaphthalene	2.5	1900

Constituent	Risk Based Soil Criteria, Soil Within 10m of Basement Car Park (mg/kg)	Risk Based Soil Criteria, Unsaturated Soil Within 30m and Greater than 10m from Basement Car Park (mg/kg)
Cresols	7200	No criteria
Naphthalene	0.6	31
Phenanthrene	41 000	No criteria
Phenol	88	25 000
Pyrene	99 000	No criteria
Toluene	<LOR	90
TPH C_6-C_8 (ali)	210	910
TPH C_8-C_{16} (ali)	160	690
TPH C_8-C_{16} (aro)	290	1200
Trimethylbenzene	<LOR	70
Xylenes	<LOR	33

Note: <LOR, less than laboratory detection limit

All criteria were derived by potential exposure of residential receptors and commercial workers within the basements, and by reference to residential receptors, also within the overlying residential apartments. The criteria are only applicable to imported materials that are placed on the Barangaroo Central Site. The criteria for soils within 10m of the basement apply to soils within the saturated and unsaturated zones. Criteria for soils greater than 10m and less than 30m only applies to soils within the unsaturated zone.

The criteria were intended to be assessed by comparison of a 95% UCL_{avg} concentration of constituents.

JBS (2013a) also undertook an assessment of soil and groundwater quality to identify any potential risks. Groundwater criteria were generated by this assessment as summarised following in **Table 5.6** following. These criteria are applicable only to seepage water / groundwater adjoining the northern basement. The southern basement design has not been considered in these criteria.

Table 5.6: Risk Based Criteria for Groundwater / Seepage Water Adjoining Basement (mg/L)

Constituent	Groundwater / Seepage Water Criteria Adjoining Northern Basement (mg/L)
Acenaphthene	3.69
Acenaphthylene	8.36
Ammonia	5.26
Anthracene	9.57
Arsenic	2340
Benzo(a)pyrene	$3.51*10^{-2}$
Benzene	$4.44*10^{-3}$
Chromium	14.7
Copper	>SOLUBILITY
Cyanide	0.751
Dibenzofuran	0.118
2,4-dimethylphenol	2170
Ethylbenzene	0.253
Fluoranthene	154
Fluorene	8.03
Lead	41 100
2-methylnaphthalene	1.46
Cresols	7600
Naphthalene	$2.73*10^{-2}$
Phenanthrene	9.61
Phenol	9.73
Pyrene	9.01
Toluene	0.319
TPH C_6-C_8 (ali)	8000
TPH C_8-C_{16} (ali)	>SOLUBILITY
TPH $C>_{16}$ (ali)	>SOLUBILITY
TPH C_8-C_{16} (aro)	543

Constituent	Groundwater / Seepage Water Criteria Adjoining Northern Basement (mg/L)
TPH $C_{>16}$ (aro)	117
Trimethylbenzene	0.226
Xylenes	$6.77*10^{-2}$

Levels of impact in groundwater adjoining the proposed northern basement do not exceed these levels, and these criteria do not require to be considered further.

5.5 JBS (2012c) Criteria for Protection of On-Site Ecological Receptors

JBS (2012c) provides criteria for soils proposed to be used as growing media on the site as summarised in **Table 5.7**.

Table 5.7: JBS (2012c) Criteria to be Used for Soils to be used as Growing Medium

Constituent	Ecological Criteria
	Ecological Investigation Level Protective of Potential Phytotoxicity Effects
	mg/kg
Arsenic	20
Cadmium	3
Chromium (total)	190
Copper	60
Lead	1100
Mercury	1
Nickel	30
Zinc	200
Cyanide (free)	0.9
Ammonia	20
Benzene	0.2
Toluene	0.3
Ethylbenzene	0.8
Acenaphthene	29 (sum)
Acenaphthylene	
Anthracene	
Fluorene	
Naphthalene	
Phenanthrene	
Benz(a)anthracene	18 (sum)
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(g,h,i)perylene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Fluoranthene	
Indeno(1,2,3-c,d)pyrene	
Pyrene	
Phenol	3.8
Cresols	3.8
2,4-dimethylphenol	3.8
TPH C_6-C_9	210
TPH C_{10}-C_{14}	150
TPH C_{15}-C_{36}	300

JBS (2012c) required maximum concentrations of constituents to be compared to these criteria.

5.6 JBS (2012c) Criteria for Protection of Off-Site Ecological Receptors

JBS (2012c) provides criteria for unsaturated soils and saturated soils for the protection of off-site ecological receptors. The most potentially sensitive ecological receptor was identified as Darling Harbour. The criteria are based on potential leaching of constituents from soils to impact groundwater which will potentially discharge to Darling Harbour. The criteria are summarised in **Table 5.8**.

Table 5.8: Summary of Ecological Risk Based Criteria for Imported Fill to be Used at Barangaroo Central

Constituent	Ecological Investigation Level Protective of Surface Water	
	Saturated Soils	Unsaturated Soils
	mg/kg	mg/kg
Arsenic	4.6	18
Cadmium	0.1	0.2
Chromium (VI)[1]	18	70
Cobalt	1.7	6.7
Copper	6.8	27
Lead	46	190
Mercury	0.2	0.9
Nickel	210	850
Vanadium	300	1200
Zinc	20	79
Cyanide (free)	0.4	1.6
Ammonia	<LOR	<LOR
Benzene	0.1	0.3
Toluene	<LOR	0.1
Ethylbenzene	<LOR	0.1
Xylene	<LOR	0.1
Styrene	<LOR	0.4
Acenaphthene	0.4	1.5
Acenaphthylene	0.7	2.7
Anthracene	<LOR	<LOR
Fluorene	1.2	4.7
Naphthalene	1.6	6.4
Phenanthrene	0.1	0.5
2-methylnaphthalene	<LOR	<LOR
Benzo(a)pyrene	0.2[1]	0.7[1]
Fluoranthene	1.2	4.7
Pyrene	<LOR	0.1
Dibenzofuran	<LOR	<LOR
Cresols	<LOR	<LOR
2,4-dimethylphenol	<LOR	<LOR
TPH C_6-C_9	<LOR	<LOR
TPH C_{10}-C_{14}	<LOR	<LOR

1. To be assessed as per equivalent toxicity equivalence factor (TEF) to benzo(a)pyrene. Sum of carcinogenic PAHs to be summed, with multiplication of TEF, and assessed to benzo(a)pyrene criteria. As per WHO (2003) 'Polynuclear aromatic hydrocarbons in Drinking-water' relative potencies of Benz(a)anthracene – 0.1; Benzo(a)pyrene – 1.0; Benzo(b)fluoranthene – 0.1; Benzo(g,h,i)perylene – 0.01; Benzo(k)fluoranthene – 0.1; Chrysene – 0.01; Dibenz(a,h)anthracene – 1.0; and Indeno(1,2,3-c,d)pyrene – 0.1.

The criteria were intended to be applied to imported soils only. Existing groundwater data was used to assess the potential impact of existing soils and associated leachates to groundwater. The existing groundwater data did not indicate a potentially unacceptable level of impact in groundwater that would pose an ecological risk to Darling Harbour. The average concentration of soil constituents is required to comply with the risk based criteria. The extent of fill materials relative to the existing mass of soils as already present in the nominated zone, as considered with the existing leachability of the soils, may also be considered in the application of the criteria and estimation of potential average leachability.

5.7 JBS (2012d) Air Quality Criteria

Fill materials as sourced from other areas of the Barangaroo site are potentially malodorous, consequent of the part of the site's historical use as a gasworks. Consequently, fill materials to be imported to the site have a potential be malodorous. The malodorous potential may be increased by the spreading and compaction of materials as proposed with the emplacement of the fill materials. JBS (2012d) derived soil criteria that would be protective of potential malodorous impacts of soils as summarised in **Table 5.9** following.

Table 5.9: Summary of Allowable Levels of Malodorous Constituents to Prevent Offensive Odours – 'Protection of Construction Odours Soil Criteria'

Constituent	Maximum Criteria	Daily Mean Criteria
Benzene	5.2	2.8
Ethylbenzene	10	2.8
Toluene	12	3.3
Xylene (total)	43	12
2-methylnaphthalene	200	55
Acenaphthene	19	5.2
Naphthalene	170	160
Phenol	3	0.8
Dibenzofuran	53	15
Trimethylbenzenes	30	8
Styrene	7	2
Cyanide	2	0.6

The decision rules for the application of the criteria are summarised in **Table 5.9** following. The criteria do not relate to potential human health effects, but instead potential odours as generated during construction works.

5.8 Driscoll (2013) Asbestos Criteria for Barangaroo Site

Driscoll (2013) has nominated asbestos criteria to be applied across the soils on the Barangaroo Site as may be potentially accessible during construction phases of works. These criteria are summarised following:

- No free asbestos or asbestos fibres (i.e., no fibrous asbestos or asbestos fines);
- Less than 0.001% asbestos / less than 0.006% asbestos containing material (ACM); and
- No visible ACM.

This criteria requires to be applied to all imported soils and all potentially accessible soils with the proposed extent of excavation / construction works on the Barangaroo Central site. Soils which exceed this criteria require remediation for asbestos impact. The criteria is proposed to be complied with on the basis of an average concentration.

Appendix F:
EnRiskS Review of HHERA Documents for Barangaroo Central (extracts)

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25 June 2013

Environ
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Attention: Graeme Nyland, Rowena Salmon

Re: Review of HHERA Documents for Barangaroo Central

Introduction

Environmental Risk Sciences Pty Ltd (enRiskS) has been commissioned to provide review of a number of reports outlining risk assessments undertaken for the Barangaroo Central development. The reports reviewed are:

- Human Health and Ecological Risk Assessment for Proposed Imported Soils, Barangaroo Central, Hickson Rd, Sydney, NSW, July 2012 (JBS 2012a)
- Human Health Risk Assessment, Barangaroo Central, Hickson Rd, Sydney, NSW, July 2012 (JBS 2012b)
- Additional Human Health Risk Assessment Calculations – Basement Exposures, Barangaroo Central Residential Development, Hickson Rd, Sydney, NSW, January 2013 (JBS 2013).

All these documents were prepared by JBS Environmental.

Additional documents were received also prepared by JBS Environmental:

- Human Health Risk Assessment, Barangaroo Central, Hickson Rd, Sydney, NSW, May 2013 (JBS 2013b)
- Remedial Action Plan, Barangaroo Central, Hickson Rd, Sydney, NSW May 2013 (JBS 2013c)

This review includes comments on each of these documents followed by recalculations of the various remediation criteria developed in these documents for consideration by the auditor.

Background

In 2011 a range of risk assessments were prepared by JBS Environmental for the Headland Park part of the Barangaroo development in Sydney, NSW. An extensive range of remediation criteria were developed in these documents to support a variety of land uses proposed for Headland Park. The contamination present across much of the Barangaroo site is due to the historical infilling of the site and the presence of a gasworks in part of the overall development area. Many of the remediation criteria developed for Headland Park are also appropriate for use in Barangaroo Central where similar land uses are proposed and similar key chemicals are present.

One major difference between the two parts of the site is the proposal for multi-storey residential buildings with basements in Barangaroo Central. Such buildings are not proposed for Headland Park. The smaller buildings that may be part of Headland Park will be placed above the existing hardstand within the constructed headland. It is appropriate to develop remediation criteria for Barangaroo Central that cover this additional land use.

Another major difference is the removal of the existing hardstand in the Barangaroo Central area. This will make a difference to the potential for groundwater to be affected by infiltration through the existing soils and any fill placed at the site and to the potential for vapours to migrate from the fill material.

Comments on Reports

JBS 2012a – Human Health and Ecological Risk Assessment for Proposed Imported Soils

This HHERA has addressed the issue of the quality of soils to be imported onto the site for the fill required to modify the topography of the site. It is estimated that 80 000 to 150 000 m^3 of fill will be brought onto the site. This risk assessment has looked at the scenarios that describe how people may come into contact with the imported soils and also at the scenarios where the ecology (terrestrial or aquatic) may be impacted. Both types of assessment have been back calculations rather than forward ones to estimate the concentrations that would be acceptable in the imported soils, which is the appropriate approach.

Human Health

The scenarios covered by this assessment are appropriate for the land uses proposed for the site. The scenarios include:

- Recreational user – adults and children who breathe vapours and come into direct contact with imported fill
- Gardener – adult who breathes vapours, dust and comes into direct contact with imported fill
- Intrusive Worker – adult who breathes vapours inside excavations, dust and comes into direct contact with imported fill
- Basement car park user – breathes vapours from imported fill next to basement walls and floor; breathes vapours from groundwater seepage and is dermally exposed to groundwater seepage
- Resident – breathes vapours from basement diluted 10 fold and uses car park
- Commercial/retail/cultural space user – breathes vapours from imported fill next to basements or from soil adjoining walls of cultural space.

The car park user for the temporary surface car park is not calculated separately. It is agreed that this is covered by the scenario for the recreational user.

Given that this report covers the imported fill to be brought onto the site, groundwater sources of exposure such as seepage into the basements in the basement car park user scenario should not have been included in these calculations. However, the criteria, for soil in areas that groundwater impacts might be present, may be affected by the additional exposure from groundwater sources so may need to be modified to take this into account at the end of the calculations.

The calculations undertaken in the assessment are difficult to follow and not all the steps are included in the appendices. The output pages from the BP RISC program for the vapour modelling are not included in the report nor is the appendix from BP RISC describing how the model calculates outdoor concentrations. The input pages for the vapour modelling and the input and output pages for the modelling of risk from direct contact with soil are included. Summary spreadsheets that take the outputs from the vapour modelling and the direct contact modelling and convert them to risk estimates and then criteria to define acceptable quality are also included.

Check calculations for the vapour modelling from soil contamination have identified that JBS has not included the CRC CARE HSLs 10 fold factor for modelling vapour emissions from soil for the relevant key chemicals. This means the vapours are estimated to be 10 fold higher than they are likely to be and results in a soil criteria 10 fold lower than it needs to be – a conservative error that would result in a higher level of protection.

Check calculations for the vapour modelling from groundwater seepage have identified that one step in the calculations has been left out. The WATER 9 model includes a calculation of C_L. This value is a concentration but it is the equilibrium concentration that is reached in the surface of the puddle given the surface area of the puddle, the seepage flow, the initial bulk concentration of the key chemicals in the groundwater, the relevant mass transfer coefficient and the equilibrium that is reached in the puddle once it has been there for a while. The calculations undertaken in this assessment have been based on estimating risk posed by unit concentrations (i.e. 1 mg/L in the case of the groundwater). C_i is the initial bulk concentration and is the parameter that should have been held at 1 mg/L. Instead the calculations have assumed C_L is equal to C_i and is set at 1 mg/L which overestimates the concentration of the key chemicals in air inside the basement. Again a conservative error which would result in a higher level of protection but which is not necessary or appropriate.

The calculations for vapours from seepage of impacted groundwater have also included an unusual addition. Leaching from unsaturated soil has also been estimated and that water from infiltration has then been assumed to seep into the basement and potentially generate vapours. This is not a normal part of these calculations. Given the amount of water that might infiltrate through the unsaturated soil in a way that might seep into the building rather than mixing into the groundwater that then seeps into the building and the estimated size of the puddle that will form from the seepage inside the basement, it is entirely unrealistic.

JBS has assumed all the TPH contamination is covered by the risk calculations for the speciated compounds which is not correct. No separate risk estimates have been undertaken for TPH although criteria are developed for these categories of compounds.

JBS has used the US EPA definition of a volatile compound rather than the NSW EPA definition. The US EPA definition only includes consideration of the Henry's Law Constant for a compound where the NSW EPA definition includes consideration of both Henry's Law Constant and the vapour pressure of the compound. The NSW EPA definition is also the one used in the new NEPM revision and the CRC Care HSLs documents. If the vapour pressure is considered as well as the Henry's Law constants then all the PAHs are not volatile and do not need to be considered in the vapour calculations. This includes naphthalene but it is normal practice to include naphthalene (the most volatile PAH) in these calculations so this will be undertaken below.

There is a lack of consistency in development of criteria for Zone 1. For a couple of chemicals it is assumed they are not present in soil (e.g. ammonia) and so don't contribute to the oral and dermal pathways. For most of the chemicals these pathways are assumed to exist. This leads to criteria that are difficult to check.

Ecological

The ecological risk assessment undertaken in this report focuses on ensuring that the imported soil brought onto the site will not pose an unacceptable risk. This risk assessment does not estimate the risk posed by the site currently.

The assessment covers appropriate scenarios for the ecological systems relevant to this site. The scenarios include:

- Soil suitable for terrestrial plants
- Soil protective of aquatic systems.

The calculations of criteria that cover these scenarios are provided in Appendix D of this HHERA. The criteria developed are the same as those developed for Headland Park in 2011 as would be expected. These criteria are generally much lower (i.e. more restrictive) than the human health criteria.

JBS 2012b – Human Health Risk Assessment – July 2012

The human health risk assessment looks at the risks posed by the site in its current form to people.

This report does not include any consideration of ecological risk at the site in its current form.

A shorter list of key chemicals is included in this document as the maximum concentrations present in the Barangaroo Central area have been compared to conservative screening criteria. The risk assessment has covered a range of scenarios relevant to the land uses proposed for the site. The scenarios include the same scenarios as listed for the HHERA for imported soil with the addition of the following:

- Recreational user – adults and children who breathe vapours from groundwater outdoors
- Gardener – adult who breathes vapours from groundwater outdoors
- Intrusive Worker – adult who breathes vapours inside excavations from groundwater

This assessment has also removed direct contact with soil from the recreational user and gardener scenario as on site soils would be covered by imported soil so there would be no direct contact with on site soils.

Also the intrusive worker scenario laid out in JBS 2012a is confirmed for this HHRA given that these workers are not expected to have to work in trenches that extend deeper than 0.5 m at the site which removes direct contact with groundwater as a pathway of exposure. Groundwater is assumed to be at 1.9 m bgl across the site.

The same errors as described above are included in this report with regard to C_L (where the maximum concentration at the site is used for C_L instead of 1 mg/L) and the CRC CARE soil factor.

An additional input to the calculations of vapours from a puddle in the basement where chemicals leaching from soil in the unsaturated zone into water that then seeps into the basement has been included. This is not considered likely as the seepage is most likely to occur where the floor of the basement connects to the walls of the basement which will be well within the saturated zone. It is also not normal practice to do this.

The calculations for determining vapour emissions from the groundwater into outdoor areas assumes there is no clean capillary fringe at the site. Given that the contamination of the groundwater has arisen from the leaching from the fill over time and the tidal influence on the salinity of the groundwater and its effect on the mixing of groundwater and rainfall at the surface of the groundwater table, it is likely that there is (at least) a small clean capillary fringe present at the site and this should be included in the calculations.

Vapour emissions to outdoor areas are calculated from soil (with and without paving) and from groundwater (with and without paving). From these 4 scenarios only the maximum concentration from one of these is included in the risk calculations – usually emissions from unpaved soil. However, given that the contamination levels are not high enough to cause saturation of the vapour phase in the soil profile the concentrations derived from a soil and a groundwater scenario should have been added to give the appropriate values for use in the risk calculations.

JBS has assumed all the TPH contamination is covered by the risk calculations for the speciated compounds which is not correct. No separate risk estimates have been undertaken for TPH.

Seepage calculations use the actual size of basement in the calculations of concentration in the basement while the vapour modelling from soil sources uses a small room inside the basement. The same scenario should be used in both calculations so they can be compared appropriately. Also in the vapour modelling from soil sources the air exchange rate used is based on the air movement through the whole basement whereas the likely rate of air exchange in the small room is likely to be lower.

JBS has used the US EPA definition of a volatile compound rather than the NSW EPA. The US EPA definition only includes consideration of the Henry's Law Constant for a compound where the NSW EPA definition includes consideration of both Henry's Law Constant and the vapour pressure of the compound. If the vapour pressure is considered all the PAHs are not defined as volatile and so don't need to be considered in the vapour calculations. This includes naphthalene but it is normal practice to include naphthalene in these calculations so this will be undertaken in the revised calculations below.

JBS 2013a – Additional Human Health Risk Assessment Calculations – Basement Exposures

Some changes have been made to the some of the building design parameters that impact on the criteria previously calculated. The parameters that have changed include the size of the basements, the depth of the basements, the air exchange rate for the basements, the dilution of basement air as it moves into the ground floor and the size of the puddle likely from groundwater seepage. These changes affect the vapour modelling calculations but not the direct contact calculations. This report provides the revision of the modelling of vapours from groundwater seepage and from soil based on unit concentrations in both types of sources.

The same errors as described above are included in this report with regard to C_L and the CRC CARE soil factor. Given the large size of the puddle in these recalculations the missing C_L calculation makes a significant difference to the calculations.

In addition in the puddle calculations the windspeed has been calculated as 0.0012 m/s but I get 0.09 m/s (**Attachment 1**).

The calculations involve determination of a flux from the seepage puddle. In determining this flux, the emission rate has been divided by the surface area of the entire basement instead of the size of the puddle. The flux only occurs from the puddle not the full floor area so using the wrong area value in the calculation has resulted in a lower flux than would actually be occurring.

The basement seepage scenario has been adjusted to consider a more reasonable amount of seepage water entering the basement. In JBS 2013a it has been assumed that 800m^2 of water is present in the basement. This is based on 5% of the basement being wet. This is an appropriate assumption for a small basement but is not as appropriate for a large basement.

JBS 2013b - Human Health Risk Assessment – May 2013

This report is almost the same as the version from July 2012. The only change is in some of the calculations and the executive summary and the conclusions. The risk estimates have not been updated in **Table 9.2** despite the changes in the calculations.

The changes in the calculations mainly affect determination of the concentration of chemicals in seepage water from rainfall leaching from soil in the unsaturated zone into water that then seeps into the basement. This is not considered likely as the seepage is most likely to occur where the floor of the basement connects to the walls of the basement which will be well within the saturated zone. It is also not normal practice to do this.

Comments on JBS Conclusions

Current Situation Risk Estimate

Tables 6.1 and 6.2 in JBS 2013b (and 2012b) list the chemicals of potential concern at the site.

The data listed for soil represents the maximum value for the unsaturated soil data from all relevant investigations (JBS, ERM and AECOM).

The data listed for the groundwater are from studies by ERM, AECOM and JBS between 2008 and 2012. A couple of differences between the groundwater data listed in JBS 2013b and the review of data by the auditor. The chemicals that are different include lead (0.014 reported by JBS but maximum value found 0.004 mg/L); nickel (0.08 reported by JBS but maximum value found 0.09 mg/L); ammonia (42 reported by JBS but maximum value found 90 mg/L); acenaphthene (0.034 reported by JBS but maximum value found 0.158 mg/L); naphthalene (1.9 reported by JBS but maximum value found 1.92 mg/L); and styrene (0.007 reported by JBS but maximum value found 0.194 mg/L). The calculations in the Attachment are based on the values in the JBS table below. These differences have been assessed and they make no significant difference to the outcome of the calculations so the attachment has not been revised.

No details are provided on how the screening step was undertaken in the JBS report although the text mentions that it has been undertaken. Further screening is possible as follows:

Table 1 Soil Results Screening (mg/kg)

Constituent	Maximum Concentration	Screening Criteria
Lead	1000	600[N]
Acenaphthene	1.9	3 400[R]
Acenaphthylene	8.7	3 400[R]
Anthracene	11	17 000[R]
Benz[a]anthracene	24	30[N]
Benzo[a]pyrene	30	3[N]
Benzo[b&k]fluoranthene	37	30[N]
Benzo[ghi]perylene	10	300[N]
Chrysene	22	300[N]
Dibenz[ah]anthracene	2.8	3[N]
Fluoranthene	5.9	2 300[R]
Fluorene	64	2 300[R]
Indeno[123cd]pyrene	12	30[N]
Naphthalene	4.2	3[R]
Phenanthrene	33	1 700[R]
Pyrene	61	1 700[R]

N = NEPM HIL C (2013)
R = US EPA RSL (2013)

Table 2 Groundwater Results Screening (mg/L)

Constituent	Maximum Concentration	Screening Criteria
Arsenic	0.14	0.01[A]
Lead	0.014	0.01[A]
Nickel	0.08	0.02[A]
Ammonia	42	0.5 (aesth)[A]
Acenaphthene	0.034	0.4[R]
Acenaphthylene	0.097	0.4[R]
Anthracene	0.056	1.3[R]
Benz[a]anthracene	0.05	0.0001[A]
Benzo[a]pyrene	0.05	0.00001[A]
Benzo[b&k]fluoranthene	0.061	0.0001[A]
Benzo[ghi]perylene	0.017	0.001[A]
Chrysene	0.04	0.001[A]
Dibenz[ah]anthracene	0.0039	0.00001[A]

Fluoranthene	0.081	0.63 [R]
Fluorene	0.12	0.22 [R]
Indeno[123cd]pyrene	0.018	0.0001 [A]
Naphthalene	1.9	0.17 (Csat from CRC Care HSLs) [C]
Phenanthrene	0.17	0.087 [R]
Pyrene	0.12	0.087 [R]
Benzene	4.3	0.001 [A]
Toluene	1.9	0.8 [A]
Ethylbenzene	0.078	0.3 [A]
Xylenes	0.76	0.6 [A]
Trimethylbenzenes	0.115	0.015 [R]
Styrene	0.007	1.1 [R]

A = Australian Drinking Water Guidelines (2011)
R = US EPA RSL (2013)
C = CRC CARE HSLs (2011)

The results of this additional screening step indicate that for soil only lead, carcinogenic PAHs (assessed on the basis of all compounds contributing to the benzo[a]pyrene TEFs even though some individual compounds were less than the specific screening value) and naphthalene need to be further assessed.

For groundwater arsenic, nickel, ammonia, carcinogenic PAHs (assessed on the basis of benzo[a]pyrene TEFs), naphthalene, phenanthrene, pyrene, benzene, toluene, ethylbenzene, xylenes and trimethylbenzenes need further assessment. Ethylbenzene is included as it acts via the same mechanism as the other BTEX components and has been included to cover the risk posed by the mixture.

The risk estimates for these key chemicals given the current concentrations at the site, the proposed development and the various exposure scenarios are as follows:

Table 3 Risk Estimates for Current Soil and Groundwater Data

Exposure Scenario	Non-threshold Risk	Threshold Risk
Recreational User		
Ingestion	$4x10^{-6}$	1.0
Dermal	$6x10^{-6}$	2.2
Dust Inhalation	$9x10^{-7}$	0.008
Vapour Inhalation	$2x10^{-9}$	0.0004
Total	*$1x10^{-5}$*	*3*
Resident		
Vapour Inhalation – soil (top floor basement only)	NA	0.0002 + 0.0004 *
Vapour Inhalation – groundwater	$5x10^{-7}$ + $1x10^{-6}$ *	0.03 + 0.06*
Dermal	$4x10^{-9}$	0.00008
Total	*$2x10^{-6}$*	*0.09*
Commercial Worker/Car Park Attendant		
Vapour Inhalation – soil (top floor basement only)	NA	0.0009
Vapour Inhalation – groundwater	$3x10^{-6}$	0.16
Total	*$3x10^{-6}$*	*0.2*
Gardener		
Ingestion	$9x10^{-7}$	0.1
Dermal	$1x10^{-5}$	1.0
Dust Inhalation	$2x10^{-5}$	0.04
Vapour Inhalation	$3x10^{-8}$	0.001
Total	*$3x10^{-5}$*	*1*
Intrusive Worker		
Ingestion	$2x10^{-8}$	0.09
Dermal	$5x10^{-8}$	0.2
Dust Inhalation	$3x10^{-8}$	0.002
Vapour Inhalation	$4x10^{-7}$	0.02
Total	*$5x10^{-7}$*	*0.3*

Acceptable Risk	$\leq 1x10^{-5}$	≤ 1

* = the two values represent the risk estimate for the basement and the risk estimate for the ground floor in each of these situations where vapours intrude into a building through the basement and then mix into the air in the rest of the building

These results indicate that remediation criteria are needed for the outdoor scenarios but not for the indoor ones as the pathways that drive the risk are those associated with ingestion and dermal contact rather than inhalation.

Remediation Criteria for Existing Soil (current situation)

Threshold Chemicals

The main contributor to the risks posed by ingestion and dermal contact for soil is lead. It is recommended that the HIL C for lead (600 mg/kg) is used as a remediation criteria for these scenarios. A more site specific value would require modelling using the IEUBK model and there are not really any standout parameters that would be different enough at this site from those used in the HIL calculations to justify redoing the modelling. The other chemical that contributes to the threshold risk posed by ingestion and dermal contact with soil is naphthalene. The risk posed by the maximum naphthalene concentration is low enough (<0.01) that no remediation criteria is needed.

Non-threshold Chemicals

The non-threshold chemicals in soil at the site are the carcinogenic PAHs. The maximum concentration found at the site is 41 mg/kg BaP equivalents. In the gardener scenario this gives a risk of $3x10^{-5}$ so a remediation criteria of 13 mg/kg BaP equivalents would bring the risk back to acceptable levels.

Remediation Criteria for Imported Fill

Imported fill will be brought onto the Barangaroo Central to landscape the public open space area. This imported fill will need to be of an appropriate quality to ensure the protection of both human health and ecological systems. Criteria have been developed for all the chemicals that may be present in fill from other areas of the Barangaroo development. More chemicals are listed here than in the forward risk assessment described above because while these chemicals may not currently be found in the Barangaroo Central part of the site they have been found in the other parts of the site and materials from these areas may be brought to Barangaroo Central.

The calculations to determine the human health criteria for the imported fill have been undertaken using the same scenarios as used for the forward risk assessment described above. This is because the various uses of the site are the same, it is just the potential sources of contamination that are different between the two sets of calculations.

The imported fill criteria are just relevant for soil. However, the calculations cover both exposure to potential contamination in soil and in groundwater. Both types of criteria have been included in the table as the calculations in the JBS reports were a bit confused.

Given the use of the same scenarios as those used in the forward risk assessment, these criteria apply to both the imported fill, the existing soil at the site and the existing groundwater at the site. The listed criteria provide an additional line of evidence about the existing risk posed by the site as they show that concentrations would need to be much higher before the existing contamination at the site would pose a risk with the exceptions discussed above.

enRiskS has recalculated the remediation criteria for imported fill taking into account the errors discussed above and adjusting the scenarios (**Attachment 2**).

Particularly, the basement seepage scenario has been adjusted to consider a more reasonable amount of seepage water entering the basement. In JBS 2013a it has been assumed that 800m^2 of water is present in the basement. This is based on 5% of the basement being wet. This is an appropriate assumption for a small basement but is not as appropriate for a large basement. In these calculations it has been assumed a 5 cm wide drain has 2 cm of water in it along the entire length of 2 sides of the basement.

Table 4 Recalculated Criteria for Imported Fill

Key Chemicals	Recreational User	Resident	Resident	Commercial	Commercial	Gardener	Intrusive Worker
	SSTL Soil (mg/kg)	SSTL Soil (mg/kg)	SSTL GW (mg/L)	SSTL Soil (mg/kg)	SSTL GW (mg/L)	SSTL Soil (mg/kg)	SSTL Soil (mg/kg)
2,4-dimethylphenol	440	NA	NC	NA	NA	2 000	9 300
2-methylnaphthalene	300	NA	51 000	NA	NA	1 200	6 200
Acenapthene	910	NA	160 000	NA	NA	3 800	18 800
Acenapthylene	910	NA	155 000	NA	NA	3 800	18 800
Ammonia	450	400 000	4 050	250 000	2 300	1 200	1 200
Anthracene	4 500	NA	500 000	NA	NA	18 900	94 000
Arsenic	190	NA	NC	NA	NA	1 500	4 700
Benzene	120	45	29	19	17	32	2 000
Benzo[a]pyrene TEFs	16	NA	70	NA	NA	6	1570
Chromium	320	NA	NC	NA	NA	2 600	4 500
Copper	10 200	NA	NC	NA	NA	240 000	290 000
Cresols	2 200	NA	NC	NA	NA	10 000	46 700
Cyanide	100	NA	NC	NA	NA	2 500	3 000
Dibenzofuran	76	NA	12 000	NA	NA	320	1 500
Ethylbenzene	520	1 100	180	430	100	600	5 500
Fluoranthene	600	NA	30 000	NA	NA	2 500	12 500
Fluorene	600	NA	85 000	NA	NA	2 500	15 000
Lead	600 (HIL-C)	NA	NC	NA	NA	600 (HIL-C)	600 (HIL-C)
Naphthalene	250	1 600	7	910	4	320	320
Phenanthrene	450	NA	50 000	NA	NA	1900	9 400
Phenol	5 200	NA	NC	NA	NA	24 000	112 000
Pyrene	2 300	NA	35 000	NA	NA	9 500	47 000
Styrene	6 500	28 000	2 100	16 000	1 200	21 000	151 000
Toluene	1 400	10 400	4 400	5 200	2 500	3 500	22 900
Total Trimethylbenzenes	1 000	3 000	470	1 700	270	2 000	14 000
TRH C10-C14 Aliphatic	1 450	9 000	1 500	5 100	850	3 000	2 500
TRH C10-C14 Aromatic	620	13 100	280	7 500	160	2 100	3 150
TRH C15+ Aliphatic	31 500	NA	NC	NA	NA	140 000	670 000
TRH C15+ Aromatic	470	NA	NC	NA	NA	2 200	10 000
TRH C6-C9 Aliphatic	9 800	12 300	24 000	7 000	13 800	7 500	4 200
Xylenes	930	850	160	390	95	660	7 100

NA – criteria not calculated as only volatile chemicals relevant to scenario
NC – criteria very high so not listed as not likely to occur

Some differences exist between the values calculated by enRiskS and those calculated by JBS. In most cases the enRiskS values are higher than the JBS values.

Some of the criteria recalculated by enRiskS are lower than the ones calculated by JBS. The differences arise for the following reasons:

- Ammonia – the JBS calculations do not include any ingestion or dermal contact with ammonia in soil for the recreational and other outdoor scenarios. There is no explanation as to why this would be

the case. For every other chemical listed ingestion and dermal contact with the chemical in soil in these outdoor scenarios are included.

- Cyanide – the toxicity assessment section of the report lists the oral TDI for cyanide as 0.012 mg/kg/d derived from the DWGs. The input pages for RISC show that the TDI entered for cyanide was 0.02 mg/kg/d.
- Dibenzofuran – The US EPA RSLs derived RfD is 0.001 mg/kg/d. This is the value quoted in the summary table in the toxicity assessment section in the JBS reports but the value entered into RISC was 0.06 mg/kg/d.
- Lead – a bioavailability factor of 50% was applied at the end of the calculation of the SSTLs by JBS. This factor should only apply to the ingestion pathway not all the pathways as it relates to how much lead crosses the gut and so should have been applied earlier in the calculations just to the ingestion pathway. Regardless the approach adopted by JBS to calculate risk from lead is not appropriate (a blood lead model should have been used).

Proposed Human Health Criteria for the Site

In the RAP (JBS 2013c) for the site Chapter 5 lists the criteria to be used for the site and in which situations they are to be used.

The criteria for ***Open Space areas*** calculated by JBS are listed in **Table 5** for comparison with the recalculated values listed in **Table 4**.

Table 5 JBS Criteria for soil in open spaces

Constituent	JBS – Risk Based Soil Criteria 0-0.5 m (mg/kg)	JBS – Risk Based Soil Criteria >0.5 m (mg/kg)
Acenaphthene	900	49 000
Acenaphthylene	900	170 000
Ammonia	5 200	16 000
Anthracene	4 500	NC
Arsenic	190	NC
Benzene	0.9	4.8
Benzo[a]pyrene TEFs	2.0	NC
Chromium	630	NC
Copper	6 400	NC
Cyanide	310	14 000
Dibenzofuran	4 400	150 000
2,4-dimethylphenol	1 800	NC
Ethylbenzene	130	130
Fluoranthene	610	NC
Fluorene	600	250 000
Lead	480	NC
2-methylnaphthalene	60	9 600
Cresols	4 300	NC
Naphthalene	33	170
Phenanthrene	4 500	NC
Phenol	25 000	25 000
Pyrene	460	NC
Toluene	92	92
TPH C6-8	890	4 400
TPH C8-14	830	4 500
TPH C15+	5 100	NC
Trimethylbenzenes	6.3	215
Xylenes	33	33

The criteria for ***soils near the building basements*** calculated by JBS are listed in **Table 6** for comparison with the recalculated values in **Table 4**.

Table 6 JBS Criteria Soils adjoining the Northern Basement

Key Chemical	Risk Based Soil Criteria (Soil within 10 m of Basement Car Park) (mg/kg)	Risk Based Soil Criteria (Unsaturated Soil within 30 m and greater than 10 m from Basement Car Park) (mg/kg)	Groundwater/Seepage Water Criteria Adjoining Northern Basement (mg/L)
Acenaphthene	470	17 000	3.69
Acenaphthylene	1 400	31 000	8.36
Ammonia	<LOR	5 300	5.26
Anthracene	49 000	NC	9.57
Arsenic	NC	NC	2 340
Benzo[a]pyrene	62	NC	0.0351
Benzene	<LOR	0.8	0.00444
Chromium	59 000	NC	14.7
Copper	NC	NC	>solubility
Cyanide	75	5 300	0.751
Dibenzofuran	3.2	24 000	0.118
2,4-dimethylphenol	3 300	NC	2 170
Ethylbenzene	<LOR	120	0.253
Fluoranthene	180 000	NC	154
Fluorene	750	45 000	8.03
Lead	NC	NC	41 100
2-methylnaphthalene	2.5	1 900	1.46
Cresols	7 200	NC	7 600
Naphthalene	0.6	31	0.0273
Phenanthrene	41 000	NC	9.61
Phenol	88	25 000	9.73
Pyrene	99 000	NC	9.01
Toluene	<LOR	90	0.319
TPH C6-8 (aliphatic)	210	910	8 000
TPH C8-16 (aliphatic)	160	690	>solubility
TPH C16+ (aliphatic)	NC	NC	>solubility
TPH C8-16 (aromatic)	290	1 200	543
TPH C16+ (aromatic)	NC	NC	117
Trimethylbenzenes	<LOR	70	0.226
Xylenes	<LOR	33	0.0677

ECOLOGICAL CRITERIA

The ecological criteria proposed for Barangaroo Central are the same as previously approved for use at Headland Park. This makes sense as it is the same receptors that are relevant for protection.

The Root Zone Soils EILs apply to all surface soils where grass or gardens are likely (i.e. excluding locations were buildings will be placed) – to 0.5m over much of the site and to 1.5m for places where the trees are planted.

The EILs for the protection of surface waters apply to all fill brought onto the site.

Table 7 Ecological Criteria for Barangaroo Central

Key Chemical	Ecological Criteria		
	EILs for Root Zone Soils (ie protective of phytotoxicity) (mg/kg)	EILs for Saturated Soils protective of surface waters (mg/kg)	EILs for Unsaturated Soils protective of surface waters (mg/kg)
Arsenic	20	4.6	18
Cadmium	3	0.1	0.2
Chromium (VI)	-	18	70
Chromium (total)	190	-	-
Cobalt	-	1.7	6.7
Copper	60	6.8	27
Lead	1100	46	190
Mercury	1	0.2	0.9
Nickel	30	210	850
Vanadium	-	300	1200
Zinc	200	20	79
Cyanide (free)	0.9	0.4	1.6
Ammonia	20	<LOR	<LOR
Benzene	0.2	0.1	0.3
Toluene	0.3	<LOR	0.1
Ethylbenzene	0.8	<LOR	0.1
Xylenes	-	<LOR	0.1
Styrene	-	<LOR	0.4
Acenaphthene	29 (sum)	0.4	1.5
Acenaphthylene		0.7	2.7
Anthracene		<LOR	<LOR
Fluorene		1.2	4.7
Naphthalene		1.6	6.4
Phenanthrene		0.1	0.5
2-methylnaphthalene	-	<LOR	<LOR
Benz[a]anthracene	18 (sum)	-	-
Benzo[a]pyrene		0.2	0.7
Benzo[b]fluoranthene		-	-
Benzo[ghi]perylene		-	-
Benzo[k]fluoranthene		-	-
Chrysene		-	-
Dibenz[ah]anthracene		-	-
Fluoranthene		1.2	4.7
Indeno[123cd]pyrene		-	-
Pyrene		<LOR	0.1
Dibenzofuran	-	<LOR	<LOR
Phenol	3.8	-	-
Cresols	3.8	<LOR	<LOR
2,4-dimethylphenol	3.8	<LOR	<LOR
TPH C6-9	210	<LOR	<LOR
TPH C10-14	150	<LOR	<LOR
TPH C15-36	300	-	-

Conclusions

In most areas of the Barangaroo Central site, it is likely that the ecological criteria will apply to the surface soils and the imported fill.

For the existing soils in open space areas, the ecological criteria for the carcinogenic PAHs are similar to the criteria for the protection of human health – either will be appropriate. For lead in these soils the human health protective criteria is more stringent than the ecological one so should be preferred. For existing soils at depth and near the proposed basements there are no concentrations of contaminants that are at levels that would pose unacceptable risk.

For imported fill, in most cases the ecological criteria will be the most stringent criteria. For lead the HIL-C should be applied to all materials that could be near the surface.

Limitations

Environmental Risk Sciences has prepared this report for the use of Environ P/L in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report.

The methodology adopted and sources of information used are outlined in this report. Environmental Risk Sciences has made no independent verification of this information beyond the agreed scope of works and assumes no responsibility for any inaccuracies or omissions. No indications were found that information contained in the information provided by Environ P/L for use in this assessment was false.

This report was prepared in May and June 2013 and is based on the information provided and reviewed at that time. Environmental Risk Sciences disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Attachment 1 – Windspeed Calculations

JBS 2013a

Windspeed in basement calculation

The northern basement has a floor area of 16 650 m^2. While it is not rectangular it can be approximated by a rectangle. The length of the basement is 215 m while the width ranges from 70 to 85 m. If the width is assumed to be 77.5 m then the floor area is essentially the same. The volume of the space is 16 650 x 2.5 = 41 625 m^3.

With 4.3 air exchanges per hour then a volume of 178 987 m^3 of air moves through the basement every hour. The cross sections are 215 x 2.5 m^2 or 77.5 x 2.5 m^2. So the volume crosses an area of 537.5 m^2 or 193.75 m^2. So the velocity is 333 m/hour or 924 m/hour which convert to 0.09 m/s or 0.26 m/s. The smaller value is used in the calculations.

The value used in the JBS 2013a report was 0.0012 m/s.

Attachment 2 – Modelling and Risk Calculations

SSTLs for the Recreational User - Outdoor Scenarios only

	Ingestion		Dermal		Dust Inhalation		Vapour Inhalation		T Total	NT Total	Target Risk	SSTL NT mg/kg	SSTL T mg/kg	
TRH C6-C9 Aliphatic	--	1.22E-06	--	1.32E-05	--	0.00000000018	--	0.0000060	0.0000204		0.2			**9791**
TRH C10-C14 Aromatic	--	1.53E-04	--	1.65E-04	--	0.00000001681	--	0.0000069	0.0003246		0.2			**616**
TRH C10-C14 Aliphatic	--	6.11E-05	--	6.59E-05	--	0.00000000336	--	0.0000107	0.0001378		0.2			**1452**
TRH C15+ Aromatic	--	2.04E-04	--	2.20E-04	--	0.000000032	--	--	0.0004235		0.2			**472**
TRH C15+ Aliphatic	--	3.06E-06	--	3.30E-06	--	0.0000000005	--	--	0.0000064		0.2			**31480**
Benzene	1.7E-8	1.53E-03	1.8E-8	1.65E-03	1.6E-12	0.0000001120	1.4E-8	0.001040	0.0042162	4.87E-08	0.5	**2.05E+02**		**119**
Toluene	--	2.50E-05	--	2.70E-05	--	0.0000000006	--	0.00000200	0.0000540		0.075			**1389**
Ethylbenzene	--	5.67E-05	--	6.12E-05	--	0.0000000116	--	0.00002522	0.0001431		0.075			**524**
Xylenes	--	3.40E-05	--	3.66E-05	--	0.0000000168	--	0.00003648	0.0001071		0.1			**934**
Acenapthene	--	9.17E-05	--	1.29E-04	--	--	--	--	0.0002203		0.2			**908**
Acenapthylene	--	9.17E-05	--	1.29E-04	--	--	--	--	0.0002203		0.2			**908**
Anthracene	--	1.83E-05	--	2.57E-05	--	--	--	--	0.0000441		0.2			**4540**
Benzo[a]anthracene	9.8E-9	--	1.4E-8	--	2.3E-9	--	--	--		2.58E-08				
Benzo[a]pyrene	9.8E-8	--	1.4E-7	--	2.3E-8	--	--	--		2.58E-07		**1.67E+01**		
Benzo[b&k]fluoranthene	9.8E-9	--	1.4E-8	--	2.3E-9	--	--	--		2.58E-08				
Benzo[ghi]perylene	9.8E-10	--	1.4E-9	--	2.3E-10	--	--	--		2.58E-09				
Chrysene	9.8E-10	--	1.4E-9	--	2.3E-10	--	--	--		2.58E-09				
Dibenz[ah]anthracene	9.8E-8	--	1.4E-7	--	2.3E-8	--	--	--		2.58E-07				
Fluoranthene	--	1.38E-04	--	1.93E-04	--	--	--	--	0.0003304		0.2			**605**
Fluorene	--	1.38E-04	--	1.93E-04	--	--	--	--	0.0003304		0.2			**605**
Indeno[123cd]pyrene	9.8E-9	--	1.4E-8	--	2.3E-9	--	--	--		2.58E-08				
Naphthalene	--	2.75E-04	--	3.86E-04	--	0.0000010	--	0.00012432	0.0007861		0.2			**254**
Phenanthrene	--	1.83E-04	--	2.57E-04	--	--	--	--	0.0004405		0.2			**454**
Phenol	--	1.83E-05	--	1.98E-05	--	0.0000000151	--	--	0.0000381		0.2			**5245**
Pyrene	--	1.83E-04	--	2.57E-04	--	--	--	--	0.0004405		1			**2270**
Arsenic	--	3.93E-03	--	1.27E-03	--	0.0000043216	--	--	0.0052048		1			**192**
Chromium	--	3.06E-03	--	--	--	0.0000336124	--	--	0.0030893		1			**324**
Copper	--	9.82E-05	--	--	--	--	--	--	0.0000982		1			**10181**
Lead	--	2.62E-03	--	2.83E-03	--	0.0000100837	--	--	0.0054452		1			**184**
Total Trimethylbenzenes	--	1.10E-04	--	1.19E-04	--	0.0000000138	--	0.00002043	0.0002491		0.25			**1003**
Cyanide	--	9.17E-03	--	--	--	0.0000037814	--	--	0.0091708		1			**109**
Dibenzofuran	--	5.50E-03	--	7.72E-03	--	0.0000008643	--	--	0.0132162		1			**76**
2-methylnaphthalene	--	1.38E-03	--	1.93E-03	--	0.0000002161	--	--	0.0033041		1			**303**
Ammonia	--	1.90E-04	--	2.05E-03	--	0.0000000303	--	0.00000202	0.0022382		1			**447**
Styrene	--	2.75E-05	--	8.90E-06	--	0.0000000030	--	0.00000200909	0.0000384		0.25			**6508**
Cresols	--	5.50E-05	--	5.93E-05	--	0.0000000086	--	--	0.0001144		0.25			**2186**
2,4-dimethylphenol	--	2.75E-04	--	2.97E-04	--	0.0000000432	--	--	0.0005718		0.25			**437**
	2.4E-7	**0.047**	**3.2E-7**	**0.02010**	**5.2E-8**	**0.00005420**	**1.4E-8**	**0.00127583**						

SSTLs for the Resident - Indoor Scenarios Only

	Vapour Inhalation Soil Basement		Vapour Inhalation Soil Gd Floor		Vap Inh GW Basement		Vap Inh GW Gd Floor		Dermal Seepage		NT Total - Soil	T Total - Soil	Target Risk	SSTL NT - Soil mg/kg	SSTL T- Soil mg/kg	NT Total - GW	T Total - GW	Target Risk	SSTL NT - GW mg/L	SSTL T- GW mg/L
TRH C6-C9 Aliphatic	--	0.00001	--	0.00001	--	0.0000027	--	0.00001	--	0.0000001		0.0000162	0.2		**12342**		0.0000083	0.2		**24066**
TRH C10-C14 Aromatic	--	0.00001	--	0.00001	--	0.00024	--	0.00047	--	0.0000016		0.0000152	0.2		**13132**		0.0007085	0.2		**282**
TRH C10-C14 Aliphatic	--	0.00001	--	0.00001	--	0.00004	--	0.00009	--	0.0000007		0.0000220	0.2		**9074**		0.0001348	0.2		**1483**
TRH C15+ Aromatic									--	0.0000102			0.2				0.0000102	0.2		**19627**
TRH C15+ Aliphatic									--	0.000000021			0.2				0.000000021	0.2		**9358700**
Benzene	2.2E-8	0.0003	2.0E-7	0.0029	1.1E-7	0.0016	2.3E-7	0.0033	1.9E-10	0.000004	2.24E-07	0.0032232	0.5	**4.47E+01**	**155**	3.4E-7	0.0049179	0.5	**2.9E+1**	**102**
Toluene	--	0.00000176	--	0.000005	--	0.0000057	--	0.000011	--	0.00000012		0.0000072	0.075		**10402**		0.0000171	0.075		**4391**
Ethylbenzene	--	0.00000048	--	0.000067	--	0.000138	--	0.000277	--	0.00000043		0.0000673	0.075		**1115**		0.0004152	0.075		**181**
Xylenes	--	0.00001648	--	0.0001	--	0.0002	--	0.0004	--	0.0000002		0.0001142	0.1		**876**		0.0006063	0.1		**165**
Acenapthene									--	0.0000012			0.2				0.0000012	0.2		**164321**
Acenapthylene										0.0000013			0.2				0.0000013	0.2		**155293**
Anthracene									--	0.00000040			0.2				0.0000004	0.2		**497593**
Benzo[a]anthracene									4.2E-9	--						4.2E-9			**2.4E+3**	
Benzo[a]pyrene									5.4E-8	--						5.4E-8			**1.9E+2**	
Benzo[b&k]fluoranthene									3.2E-9	--						3.2E-9			**3.1E+3**	
Benzo[ghi]perylene									8.5E-10	--						8.5E-10			**1.2E+4**	
Chrysene									4.5E-10	--						4.5E-10			**2.2E+4**	
Dibenz[ah]anthracene									7.2E-8	--						7.2E-8			**1.4E+2**	
Fluoranthene										0.0000066			0.2			0.0E+0	0.0000066	0.2		**30391**
Fluorene									--	0.0000023			0.2				0.0000023	0.2		**85646**
Indeno[123cd]pyrene									7.9E-9							7.9E-9			**1.3E+3**	
Naphthalene	--	0.00004170	--	0.0001	--	0.0099	--	0.0198	--	0.0000020		0.0001251	0.2		**1598.6**		0.0297724	0.2		**7**
Phenanthrene									--	0.0000040			0.2				0.0000040	0.2		**50470**
Phenol									--	0.000000012			0.2				0.0000000	0.2		**16280688**
Pyrene									--	0.0000057			0.2				0.0000057	0.2		**35329**
Arsenic									--	0.000000607			1				0.0000006	1		**1648691**
Chromium									--	0.000000944			1				0.0000009	1		**1059873**
Copper									--	0.000000015			1				0.0000000	1		**65947640**
Lead									--	0.000000040			1				0.0000000	1		**24730365**
Total Trimethylbenzenes	--	0.000027	--	0.0000550	--	0.0001738	--	0.000348	--	0.000001455		0.0000825	0.25		**3032**		0.0005228	0.25		**478**
Cyanide									--	0.000000053			1				0.0000001	1		**18842183**
Dibenzofuran									--	0.000082793			1				0.0000828	1		**12078**
2-methylnaphthalene									--	0.000019467			1				0.0000195	1		**51369**
Ammonia	--	0.00000076	--	0.0000015	--	0.00008	--	0.0002		0.000000029		0.0000023	1		**438747**		0.0002471	1		**4047**
Styrene	--	0.000002966	--	0.0000059328	--	0.00003957	--	0.00007914	--	0.000000158		0.0000089	0.25		**28092**		0.0001189	0.25		**2103**
Cresols									--	0.000000065			0.25				0.0000001	0.25		**3843461**
2,4-dimethylphenol									--	0.000000463			0.25				0.0000005	0.25		**540200**
	2.2E-8	**0.0004**	**2.0E-7**	**0.0033**	**1.1E-7**	**0.012191**	**2.3E-7**	**0.02**	**1.4E-7**	**0.0001464**										

SSTLs for the Commercial User - Vapour Inhalation Only

	Vap Inh GW Basement		Vapour Inhalation Soil Basement		T Total - Soil	NT Total - Soil	Target Risk	SSTL NT - Soil mg/kg	SSTL T - Soil mg/kg	T Total - GW	NT Total - GW	Target Risk	SSTL NT - GW mg/L	SSTL T - GW mg/L
TRH C6-C9 Aliphatic	--	0.00001	--	0.00003	0.0000284		0.2		**7038.7**	0.00001		0.2		**13830**
TRH C10-C14 Aromatic	--	0.00124	--	0.00003	0.0000267		0.2		**7489.1**	0.00124		0.2		**161**
TRH C10-C14 Aliphatic	--	0.00024	--	0.00004	0.0000386		0.2		**5175.1**	0.00024		0.2		**850**
TRH C15+ Aromatic							0.2					0.2		
TRH C15+ Aliphatic							0.2					0.2		
Benzene	6.0E-7	0.00862	5.3E-7	0.00763	0.0076319	5.30E-07	0.5	**1.89E+01**	**65.5**	0.00862	6.0E-7	0.5	**1.7E+1**	**58**
Toluene	--	0.00003	--	0.00001	0.0000143		0.075		**5230.9**	0.00003		0.075		**2522**
Ethylbenzene	--	0.00073	--	0.00018	0.0001756		0.075		**427.0**	0.00073		0.075		**103**
Xylenes	--	0.00106	--	0.00026	0.0002570		0.1		**389.2**	0.00106		0.1		**94**
Acenapthene							0.2					0.2		
Acenapthylene							0.2					0.2		
Anthracene							0.2					0.2		
Benzo[a]anthracene														
Benzo[a]pyrene														
Benzo[b&k]fluoranthene														
Benzo[ghi]perylene														
Chrysene														
Dibenz[ah]anthracene														
Fluoranthene							0.2					0.2		
Fluorene							0.2					0.2		
Indeno[123cd]pyrene														
Naphthalene		0.05220		0.00022	0.0002194		0.2		**911.7**	0.05220		0.2		**3.8**
Phenanthrene							0.2					0.2		
Phenol							0.2					0.2		
Pyrene							1					1		
Arsenic							1					1		
Chromium							1					1		
Copper							1					1		
Lead							1					1		
Total Trimethylbenzenes		0.00091		0.00014	0.0001446		0.25		**1729.1**	0.00091		0.25		**273**
Cyanide							1					1		
Dibenzofuran							1					1		
2-methylnaphthalene							1					1		
Ammonia		0.00043		0.0000040	0.0000040		1		**250222.8**	0.00043		1		**2308**
Styrene		0.00020816		0.0000156	0.0000156		0.25		**16021.4**	0.00021		0.25		**1201**
Cresols		--					0.25					0.25		
2,4-dimethylphenol		--					0.25					0.25		
	6.0E-7	**0.0657**	**5.3E-7**	**0.0086**										

SSTLs for the Gardener - Outdoor Scenarios only

	Ingestion		Dermal		Dust Inhalation		Vapour Inhalation		NT Total	T Total	Target Risk	SSTL NT mg/kg	SSTL T mg/kg	
TRH C6-C9 Aliphatic	--	0.00000005	--	0.0000050	--	0.00000000066		0.00002179649		0.0000269	0.2			**7448**
TRH C10-C14 Aromatic	--	0.0000065	--	0.0000625	--	0.00000006088		0.00002501488		0.0000941	0.2			**2124**
TRH C10-C14 Aliphatic	--	0.0000026	--	0.0000250	--	0.00000001218		0.00003884001		0.0000665	0.2			**3008**
TRH C15+ Aromatic	--	0.0000087	--	0.0000834	--	0.000000116				0.0000922	0.2			**2169**
TRH C15+ Aliphatic	--	0.0000001	--	0.0000013	--	0.0000000017				0.0000014	0.2			**144604**
Benzene	3.5E-9	0.00007	4.4E-8	0.000813	2.8E-11	0.0000004059	2.6E-7	0.0037664636	3.09E-07	0.0046452	0.5	**3.24E+01**		**108**
Toluene	--	0.0000011	--	0.00001330	--	0.0000000022		0.0000072545		0.0000216	0.075			**3468**
Ethylbenzene	--	0.0000024	--	0.000030	--	0.0000000421		0.0000913722		0.0001240	0.075			**605**
Xylenes	--	0.000001	--	0.0000181	--	0.0000000609		0.0001321665		0.0001517	0.1			**659**
Acenapthene	--	0.000004	--	0.0000488	--	--				0.000052698	0.2			**3795**
Acenapthylene	--	0.000004	--	0.0000488	--	--				0.000052698	0.2			**3795**
Anthracene	--	0.000001	--	0.0000098	--	--				0.000010540	0.2			**18976**
Benzo[a]anthracene	2.1E-9	--	2.6E-8	--	4.1E-8	--			6.90E-08					
Benzo[a]pyrene	2.1E-8	--	2.6E-7	--	4.1E-7	--			6.90E-07			**6.24E+00**		
Benzo[b&k]fluoranthene	2.1E-9	--	2.6E-8	--	4.1E-8	--			6.90E-08					
Benzo[ghi]perylene	2.1E-10	--	2.6E-9	--	4.1E-9	--			6.90E-09					
Chrysene	2.1E-10	--	2.6E-9	--	4.1E-9	--			6.90E-09					
Dibenz[ah]anthracene	2.1E-8	--	2.6E-7	--	4.1E-7	--			6.90E-07					
Fluoranthene	--	0.000006	--	0.0000732		--				0.0000790	0.2			**2530**
Fluorene	--	0.000006	--	0.0000732	--	--				0.0000790	0.2			**2530**
Indeno[123cd]pyrene	2.1E-9	--	2.6E-8	--	4.1E-8	--			6.90E-08					
Naphthalene	--	0.000012	--	0.0001464	--	0.0000037		0.0004504		0.0006121	0.2			**327**
Phenanthrene	--	0.000008	--	0.0000976	--	--				0.0001054	0.2			**1898**
Phenol	--	0.000001	--	0.0000075	--	0.0000000548				0.0000083	0.2			**23973**
Pyrene	--	0.000008	--	0.0000976	--	--				0.0001054	1			**9488**
Arsenic	--	0.000168	--	0.0004825	--	0.0000156556				0.0006659	1			**1502**
Chromium	--	0.000261	--		--	0.0001217656				0.0003827	1			**2613**
Copper	--	0.000004	--	--	--	--				0.0000042	1			**238467**
Lead	--	0.000056	--	0.0010722	--	0.0000365297				0.0011646	1			**859**
Total Trimethylbenzenes	--	0.000005	--	0.0000450	--	0.0000000498		0.0000740020		0.0001238	0.25			**2020**
Cyanide	--	0.000391	--		--	0.0000136986				0.0004051	1			**2469**
Dibenzofuran	--	0.000235	--	0.0029271	--	0.0000031311				0.0031650	1			**316**
2-methylnaphthalene	--	0.000059	--	0.0007318	--	0.0000007828				0.0007913	1			**1264**
Ammonia	--	0.000008	--	0.0007764		0.0000001096		0.0000073062		0.0007919	1			**1263**
Styrene	--	0.000001	--	0.0000034	--	0.0000000110		0.0000072782		0.0000118	0.25			**21114**
Cresols	--	0.000002	--	0.0000225	--	0.0000000313				0.0000249	0.25			**10042**
2,4-dimethylphenol	--	0.000012	--	0.0001126	--	0.0000001566				0.0001245	0.25			**2008**
	5.2E-8	**0.00133848**	**6.5E-7**	**0.008**	**9.5E-7**	**0.0015662**	**2.62E-07**	**0.00462187**						

SSTLs for the Intrusive User - Excavations

	Ingestion		Dermal		Dust Inhalation		Vapour Inhalation		T Total	NT Total	Target Risk	SSTL NT mg/kg	SSTL T mg/kg	
TRH C6-C9 Aliphatic	--	0.000000043	--	0.0000008	--	0.0000000000	--	0.00005	0.0000466		0.2			**4294**
TRH C10-C14 Aromatic	--	0.00001	--	0.0000095	--	0.0000000038	--	0.00005	0.0000631		0.2			**3168**
TRH C10-C14 Aliphatic	--	0.00000	--	0.0000038	--	0.0000000008	--	0.00007	0.0000778		0.2			**2572**
TRH C15+ Aromatic	--	0.00000718	--	0.0000126	--	0.0000000072	--	--	0.0000198		0.2			**10098**
TRH C15+ Aliphatic	--	0.00000011	--	0.0000002	--	0.0000000001	--	--	0.0000003		0.2			**673230**
Benzene	9.7E-11	0.000054	2.2E-10	0.000123	5.9E-14	0.0000000254	1.7E-10	0.00007	0.0002502	4.88E-10	0.5	**2.05E+04**		**1999**
Toluene	--	0.000001	--	0.00000201	--	0.0000000001	--	0.000000372	0.0000033		0.075			**22961**
Ethylbenzene	--	0.000002	--	0.0000046	--	0.0000000026	--	0.00001	0.0000135		0.075			**5555**
Xylenes	--	0.000001	--	0.0000027	--	0.0000000038	--	0.00001	0.0000140		0.1			**7165**
Acenapthene	--	0.000003	--	0.0000074	--	--	--	--	0.0000106		0.2			**18845**
Acenapthylene	--	0.000003	--	0.0000074	--	--	--	--	0.0000106		0.2			**18845**
Anthracene	--	0.000001	--	0.0000015	--	--	--	--	0.0000021		0.2			**94224**
Benzo[a]anthracene	5.8E-11	--	1.3E-9	--	8.5E-11	--	--	--		1.46E-09				
Benzo[a]pyrene	5.8E-10	--	1.3E-10	--	8.5E-10	--	--	--		1.56E-09		**1.57E+03**		
Benzo[b&k]fluoranthene	5.8E-11	--	1.3E-11	--	8.5E-11	--	--	--		1.56E-10				
Benzo[ghi]perylene	5.8E-12	--	1.3E-10	--	8.5E-12	--	--	--		1.46E-10				
Chrysene	5.8E-12		1.3E-11	--	8.5E-12	--	--	--		2.74E-11				
Dibenz[ah]anthracene	5.8E-10	--	1.3E-9	--	8.5E-10	--	--	--		2.74E-09				
Fluoranthene	--	0.000005	--	0.0000111	--	--	--	--	0.0000159		0.2			**12563**
Fluorene	--	0.000005	--	0.0000085	--	--	--	--	0.0000134		0.2			**14966**
Indeno[123cd]pyrene	5.8E-11		1.3E-10	--	8.5E-11	--	--	--		2.74E-10				
Naphthalene	--	0.000010	--	0.0000222	--	0.0000002283	--	0.00059	0.0006227		0.2			**321**
Phenanthrene	--	0.000006	--	0.0000148	--	--	--		0.0000212		0.2			**9422**
Phenol	--	0.000001	--	0.0000011	--	0.0000000034	--		0.0000018		0.2			**112031**
Pyrene	--	0.000006	--	0.0000148	--	--	--		0.0000212		1			**47112**
Arsenic	--	0.000138	--	0.0000730	--	0.0000010	--	--	0.0002124		1			**4708**
Chromium	--	0.000215	--	--	--	0.0000076104	--	--	0.0002229		1			**4487**
Copper	--	0.000003	--	--	--	--	--	--	0.0000035		1			**289051**
Lead	--	0.000092	--	--	--	0.0000022831	--	--	0.0000945		1			**10578**
Total Trimethylbenzenes	--	0.000004	--	0.0000068	--	0.0000000031	--	0.00001	0.0000175		0.25			**14319**
Cyanide	--	0.000323	--	--	--	0.0000008562	--		0.0003238		1			**3089**
Dibenzofuran	--	0.000194	--	0.0004430	--	0.0000001957	--		0.0006370		1			**1570**
2-methylnaphthalene	--	0.000048	--	0.0001108	--	0.0000000489	--	--	0.0001592		1			**6280**
Ammonia	--	0.000007	--	0.0001175	--	0.0000000068	--	0.00067	0.0007957		1			**1257**
Styrene	--	0.000001	--	0.0000005	--	0.0000000007	--	0.00000017	0.0000017		0.25			**151382**
Cresols	--	0.000002	--	0.0000034	--	0.0000000020	--	--	0.0000053		0.25			**46752**
2,4-dimethylphenol	--	0.000010	--	0.0000170	--	0.0000000098	--	--	0.0000267		0.25			**9350**
	1.3E-9	**0.0026**	**3.1E-9**	**0.0010**	**2.0E-9**	**0.00018921**	**1.7E-10**	**0.00152553**						