



Kendall Bay Sediment Remediation Project

REMEDIATION ACTION PLAN

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EXECUTIVE SUMMARY

Kendall Bay is a bay off the southern side of the Parramatta River, approximately 9 km west of the Sydney CBD, and is situated between the Breakfast Point development (on the site of the former Mortlake Gasworks) and Cabarita Park. The gasworks was operated by the The Australian Gas Light Company (AGL). Responsibility for legacy contamination of the bay subsequently passed with ownership of the company to Alinta and then Jemena.

Kendall Bay is a small, northwards-opening bay on the southern side of the Parramatta River at Mortlake with:

- a small beach at the head of the bay and a small beach on the north-west side;
- a stand of mangroves around the southern edge;
- a sandstone seawall along the southern and western edges;
- large stormwater drains that drain the large surrounding residential catchment; and
- a ferry terminal at the north-east point (Cabarita) which services Rivercats and Harbourcat services.

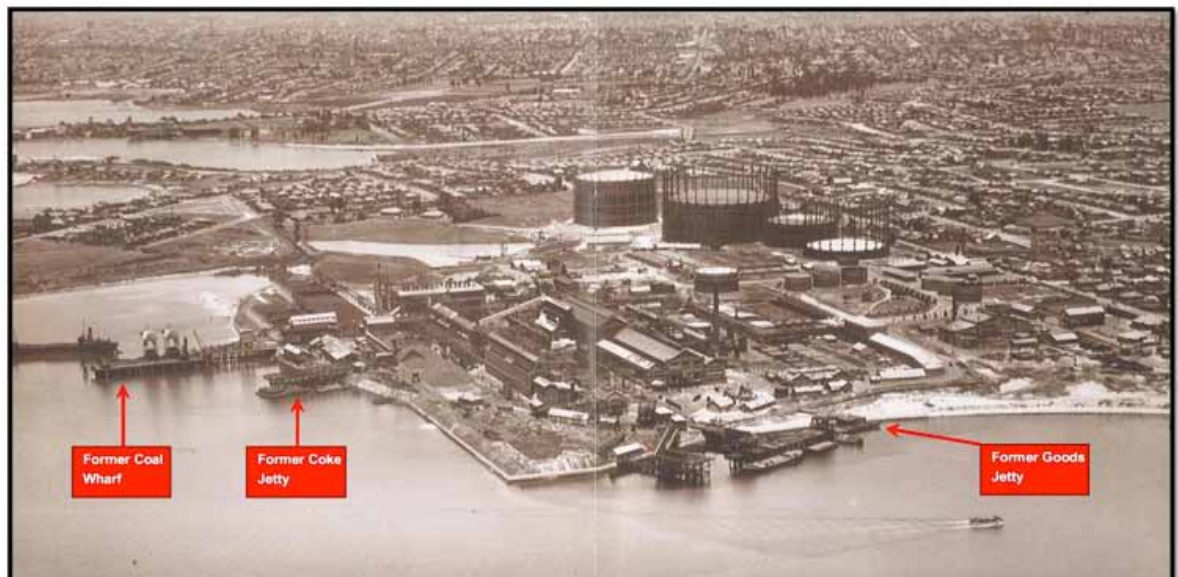
THE HISTORY AND NATURE OF THE CONTAMINATION

The sediments in Kendall Bay (the site) are contaminated with wastes from gasworks operations, primarily from coal gasification (and related processes) which occurred at the Mortlake Gasworks between 1886 and 1971, as well as metals and other pollutants which are at levels comparable with other parts of the Parramatta River (see Figure 1).

The sediments in the main impacted areas of the bay are black and oily and have a strong tar, hydrocarbon or naphthalene odour, characteristic of gasworks contamination. These sediments contain levels of polycyclic aromatic hydrocarbons (PAHs) and total recoverable hydrocarbons (TRH) greatly in excess of sediment quality guidelines. This highly contaminated sediment is present to a maximum depth of more than 4 m in the area to the north-west of the bay, where the coal and coke wharves were located, and to a maximum depth of almost 8 m in parts of the southern end of the bay, where a former stream had cut into the sandstone bedrock.

The contamination on the gasworks site itself was remediated from 1999 to 2002.

Figure 1. 1935-1936 Photo of the Mortlake Gasworks (Kendall Bay is to the left of the Photo)





REMEDIATION REGULATORY HISTORY OF SITE

YEAR	DETAILS
2001	A Voluntary Investigation Proposal was agreed between AGL and the NSW Environment Protection Authority (EPA) on 22 November 2001.
2004	On 25 May 2004, the EPA declared the bed of the Parramatta River and Kendall Bay bordering the former gasworks and within 200 m of the shoreline to be a 'Remediation Site' under Section 21 of the <i>Contaminated Land Management Act 1997</i> (CLM Act).
2005	On 20 September 2005, the EPA approved a Voluntary Remediation Agreement (VRA) (now known as a Voluntary Management Proposal, VMP) prepared by AGL. The VRA provided for additional investigation of Kendall Bay to determine the impacted areas within Kendall Bay and the development and submission of a Risk Assessment, a Remediation Action Plan (RAP), a remediation strategy and various management plans, as well as to undertake and complete the remediation in accordance with those documents.
2007	In early/mid 2007, Alinta submitted to the EPA a Risk Assessment and a Conceptual RAP based on an initial understanding of how remediation would be undertaken.
2007	On 22 June 2007, EPA issued a Remediation Order to the Maritime Authority of NSW, as owners of the seabed of Kendall Bay, the purpose of which was to ensure no one disturbed the sediments of Kendall Bay without EPA approval.
2007	In November 2007, the EPA confirmed that an area in the southern end of Kendall Bay (known as 'Area A') and another area in the north-western part of the bay (known as 'Area B') were the areas of sediments in which remediation activities were required.
2008	The project was declared a 'Major Project' under the former Part 3A of the <i>Environmental Planning & Assessment Act</i> (EP&A Act).
2011	On 10 August 2011, the Department of Planning issued Director General's Requirements for the preparation of an Environmental Assessment for the project under Part 3A EP&A Act.
2013	Following repeal of Part 3A, this project transitioned to a State Significant Development (SSD) under the EP&A Act in April 2013.
2014	Jemena prepared a Remediation Action Plan (RAP) for remediation of areas of Kendall Bay. This was issued on 6 June 2014 and subsequently endorsed by the Site Auditor and the EPA (2014 RAP).
2014	On 19 September 2014, a new SSD was gazetted to integrate the proposed sediment treatment works (to occur at the Tennyson Road property purchased by Jemena in December 2013 as a staging site for the remediation works) with the remainder of the project.
2014	On 2 December 2014, following the new SSD declaration, the Department of Planning & Environment (DP&E) issued Secretary's Environmental Assessment Requirements (SEARs) for the project. These SEARS were updated and reissued in March 2017.
2015	Jemena undertook a comprehensive review of the 2014 RAP, found aspects of this document to be deficient, and initiated additional scientific and engineering investigations. An update, including summary details of the revised remediation strategy, was provided to the EPA on 4 December 2015.
2016	On 7 January 2016, the EPA wrote to Jemena addressing a number of technical matters pertaining to the revised RAP, including the need to update the Human Health Risk Assessment (HHRA), to address odour issues and conduct some further investigations. That work has now been completed.

REVIEW OF 2014 REMEDIAL ACTION PLAN

A Remedial Action Plan (RAP) was prepared in 2014, which documented a program of remedial works employing wet dredging methods to remove very large volumes of sediments from the bay.

A review and analysis undertaken by Jemena, together with a specialist remedial contractor and its expert advisors, found the 2014 RAP to be deficient in the following areas:

- sampling density was insufficient and sampling for volatiles had been carried out incorrectly so that the concentration of volatile components of contaminated sediments may have been underreported. This may have resulted in unforeseen impacts to the Breakfast Point community during the course of the remedial works by excessive odours, as well as difficulty in the proposed treatment of contaminants in excavated sediments;
- site-specific remedial criteria were not developed. In particular, the human health remedial criteria and the ecological remedial criteria were not justified by the weight-of-evidence assessment method required;
- the proposed underwater capping of sediments was determined to be not constructible due to its not being supported on a competent surface;
- the proposed wet dredging approach was problematic and would have resulted in an extremely long time for the remedial works;
- sediment treatment was complex and would have become a bottleneck which may have delayed completion of the remedial works for many months, if not years;
- large volumes of contaminated sediments would be required to be treated and an unacceptable number of truck movements from the site to landfill would be required;
- the healthy benthic marine community established in recently-deposited sediment in the bay would be destroyed;
- the healthy mangrove community at the south of the bay would be destroyed; and
- the 2014 RAP did not adequately address the principles of Ecologically Sustainable

Development, which according to the CLM Act require consideration of:

- 'the precautionary principle—namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by (i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment, and (ii) an assessment of the risk-weighted consequences of various options';
- 'inter-generational equity—namely, that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations';
- 'conservation of biological diversity and ecological integrity—namely, that conservation of biological diversity and ecological integrity should be a fundamental consideration'; and
- 'environmental goals, which having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, that enable those best placed to maximise benefits or minimise costs to develop their own solutions and responses to environmental problems'.

In order to adequately address the identified uncertainties and provide reliable data for the development of a revised remedial approach, Jemena contracted consultants Synnot & Wilkinson Pty Ltd, together with EnRiskS and CSIRO Land and Water to conduct a series of comprehensive investigations to:

- conclusively determine the depth and extent of gasworks-derived contamination that posed an unacceptable risk to people who used the beach, mangrove areas and other foreshore areas of Kendall Bay, and to marine organisms in the bay;
- obtain suitable data for revision of the Human Health Risk Assessment and Ecological Risk Assessment;



- determine appropriate and scientifically justifiable site-specific remediation criteria; and
- taking into account the results of the work described above, review the nature and extent of remediation works required, and settle on a revised remediation strategy.

The work program was carried out in four phases in 2015 and 2016:

- Phase 1 – Investigation of nature and extent of contamination within the mangrove, beach and stormwater delta sediments at the southern end of Kendall Bay;
- Phase 2 – Investigation of the environmental condition of surface sediments throughout parts of Kendall Bay where the previous investigations had identified them to be areas of concern, as well as suitable background areas, to obtain the data needed for revision of the Human Health Risk Assessment and preparation of a robust Ecological Risk Assessment and development of scientifically justifiable remediation criteria and strategies;
- Phase 3 – Investigation of the subsurface sediments of parts of Kendall Bay to fill in data gaps and to define the area, depth and volume of gasworks-contaminated sediments; and
- Phase 4 – an excavation trial of some of the most contaminated sediments, to obtain bulk samples for testing of sediment properties and for use in trials of various methods of in situ solidification of the contaminated sediments, plus leachate testing of the stabilised materials and to quantify the nature and extent of odour issues that were likely to be produced during remediation works.

Jemena provided the EPA with a Draft RAP in January 2017 and the EPA provided comment shortly thereafter. The comments required Jemena to address the human health and ecological issues of chronic toxicity of the sediments (Phase 5).

The results of all phases have been used in this RAP (2018) to determine the nature and extent of remediation required to address the risks, both to human health and to the environment, posed by the contaminated sediments in Kendall Bay.

RESULTS OF WORK PROGRAM

Key findings from the 2015/16 work program are indicated below.

Sediment Chemistry

The sediments in the most contaminated parts of Kendall Bay contained:

- total polycyclic aromatic hydrocarbons (PAHs) (normalised to 1% Total Organic Carbon) up to 4500 mg/kg (450 times the Australian sediment guideline value (GV));
- total recoverable hydrocarbon (TRH) up to 100,000 mg/kg (360 times the guidance value); and
- elevated levels of heavy metals and metalloids, although the values found were comparable to the values present elsewhere in the Parramatta River.

In the south-western corner of the bay, and in two areas on the western side of the bay, black oily gasworks-contaminated sediments occurred at the sediment surface. Elsewhere in Kendall Bay the gasworks contamination was overlain by a layer of recently deposited sediment.

Water Quality

The water quality data did not show any significant difference between the levels of contaminants in those areas of Kendall Bay contaminated by gasworks wastes, other parts of Kendall Bay, or the background locations outside the bay.

Oysters and Mussels

The oyster and mussel tissue chemistry data indicated that the PAHs and TRH in the contaminated gasworks sediments in the bay were not being taken up by oysters or mussels.

Marine Benthic Communities

The majority of locations sampled in Kendall Bay contained marine benthic (bottom-dwelling) communities. However, four marine benthic sites (two in each of the Southern and Northern Investigation Areas of the bay) were recommended for remediation as these sites supported no or low numbers of marine benthic infauna together with the acutely toxic sediment contamination.

Bioavailability and Ecotoxicity

CSIRO was engaged to investigate the chemical bioavailability and toxicity of contaminants within the sediments at Kendall Bay and to provide advice on the development of appropriate remediation targets that were protective of benthic communities.

CSIRO concluded that it would be ineffective to target areas of the bay where chronic (non-lethal) toxicity is observed because sediments throughout the Parramatta River are known to exhibit chronic toxicity due to elevated levels of heavy metals and other contaminants. CSIRO also concluded that remediation targeting the gasworks-contaminated sediments likely to cause acute toxicity to benthic organisms could significantly improve the health of benthic communities within Kendall Bay.

Based on the laboratory-based chemical bioavailability and toxicity testing, CSIRO proposed the following remediation criteria (below which no expected adverse effects would be expected) for the Kendall Bay sediments:

- Total PAH concentrations average <25 mg/kg and maximum <55 mg/kg (normalised to 1% Total Organic Carbon); and
- TRH concentrations average <4400 mg/kg and maximum <6000 mg/kg.

CSIRO stated, however, that contaminant chemistry and ecotoxicology are not always sufficient to determine whether sediment contaminants are affecting ecosystem health. CSIRO considered that these lines of evidence may be supported with measures of bioaccumulation and benthic ecology, important indicators of sediment quality, to enable a more complete assessment, using a weight-of-evidence framework that considers all of the lines of evidence together.

The bioaccumulation and benthic ecology data were used, along with sediment chemistry and toxicity data derived by CSIRO, in the weight-of-evidence assessment to define the remediation areas and their boundaries.

DETERMINING SITE-SPECIFIC REMEDIATION CRITERIA

Contamination in the Sediments of Kendall Bay

The areas of Kendall Bay to be remediated will be those areas where contamination in near-surface sediments (0-300 mm) exceeds the CSIRO-derived chemical criteria and:

- the sediments were found to be acutely toxic; or
- the sediments were found to contain no benthic fauna; or
- oily gasworks contamination was present in surface sediments or within 50 mm of the surface.

Where the gasworks contamination is overlain by at least 50 mm of recently deposited mud containing benthic infauna comparable to the fauna found in areas of the bay uncontaminated by gasworks wastes (as evidenced by background levels of PAHs (Figure 5.4)), the sediments will not be remediated as this would involve removing a viable benthic community, cause environmental harm and be contrary to the objective of the CLM Act which is for contaminated land to be managed with regard to the principles of Ecologically Sustainable Development, namely minimising, mitigating or addressing environmental impacts.

It would also be contrary to the principles of sediment remediation endorsed by the United States Environment Protection Agency (USEPA) for many years:

'If impacts of the remediation alternative are determined to cause more environmental harm than leaving the contaminants in place, EPA may not proceed with a cleanup at that time' (USEPA 1998).

Contamination on the Foreshores of Kendall Bay

Following the 2015/16 investigations, the Human Health Risk Assessment was updated to include:

- reassessment of the exposure scenarios used for the site to allow calculation of site-specific human health-based remediation criteria;
- an update of toxicity considerations;
- a review and screening of all recent surface water monitoring data;
- a review and screening of recent biota tissue monitoring data; and



Figure 2. Southern Remediation Area

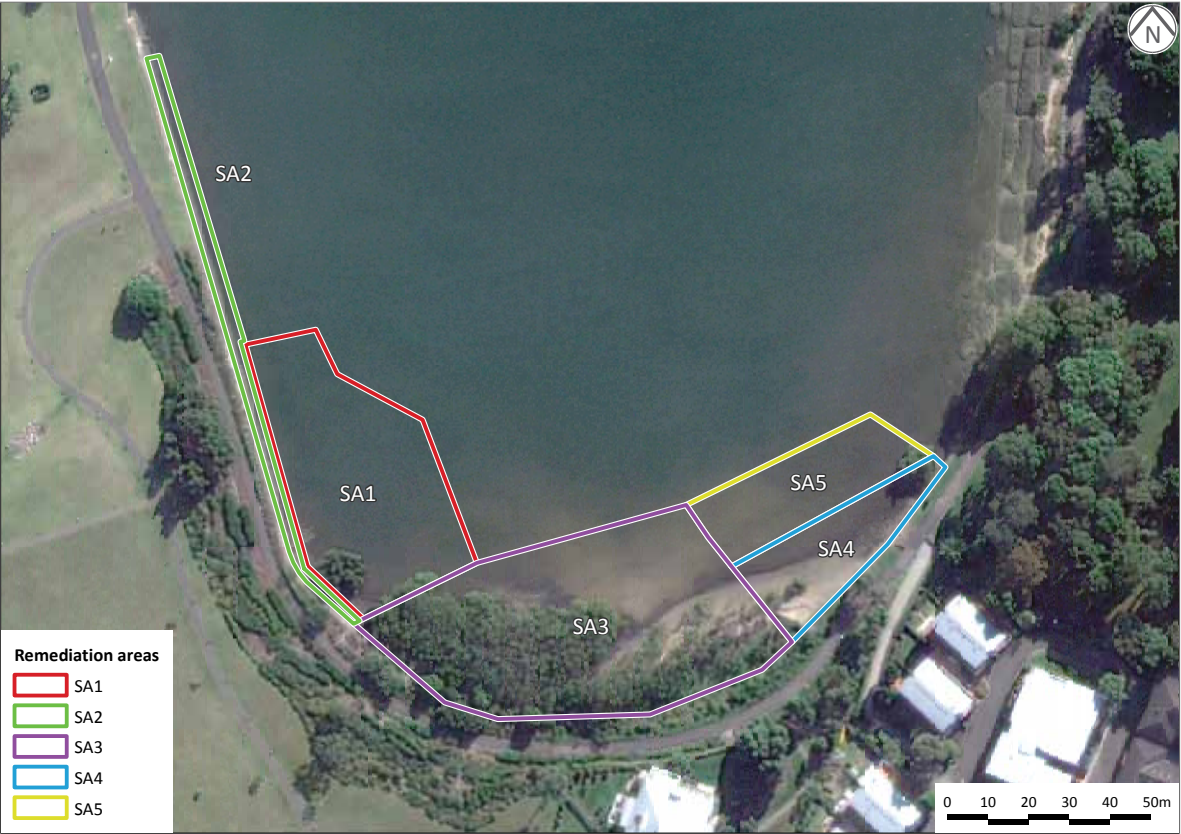


Figure 3. Northern Remediation Area



- a review of odour and air quality modelling and monitoring during excavation of sediments.

The 2018 Human Health Risk Assessment determined the following site-specific remediation criteria for the Kendall Bay foreshore, based on total PAHs:

- accessible foreshore areas and western end of mangrove area 1 mg/kg;
- rest of mangrove area 120 mg/kg;
- wading areas 60 mg/kg; and
- heavily contaminated submerged areas – apply ecological criteria.

PROPOSED REMEDIATION AREAS

Based on the above criteria, the proposed Remediation Areas and remediation Staging Site are defined below.

Southern Remediation Area

Five sub-areas have been defined: Areas SA1, SA2, SA3, SA4 and SA5, as indicated in Figure 2.

Northern Remediation Area

Three sub-areas have been defined: Area NA1 and Areas NA2 and NA3—joined together and referred to as 'NA2+NA3', and shown as the blue dotted line in Figure 3.

Staging Site

The remediation will also include use of the Jemena premises at 140 Tennyson Road, Mortlake, as a staging site for mobilising remediation plant and equipment and receiving stabilised excavated material from Kendall Bay, for transport to a licenced waste disposal facility.

REMEDIATION OPTIONS

In evaluating the remediation options, guidance was provided by the NSW EPA and the USEPA. Consideration of options also took account of the stated objectives of the overall program:

- provide a 'safe' bay for stakeholders;
- provide a suitable environment for benthic communities;
- minimise disturbance to surrounding residents;

- meet regulatory guidelines such as National Environment Protection Measures (NEPMs); and
- preserve the integrity of the existing seawall.

In relation to remediation of contaminated materials, the NSW EPA's policies and the CLM Act require that:

- remediation should not proceed in the event that it is likely to cause a greater adverse effect than leaving the site undisturbed. This principle is of special relevance to the remediation of sediments, the disturbance of which:
 - has a high potential to mobilise contaminants into the water column; and
 - necessarily completely destroys any existing ecosystem located on or within the sediments;
- the preferred order of options for remediation and management of contaminated soil, which also applies to sediment, is:
 1. Onsite treatment of the soil so that the contaminant is either destroyed or the associated hazard is reduced to an acceptable level;
 2. Offsite treatment of excavated soil so that the contaminant is either destroyed or the associated hazard is reduced to an acceptable level, after which the soil is returned to the site;
 3. Removal of contaminated soil to an approved disposal site or facility, followed where necessary by replacement with clean fill; and
 4. Consolidation and isolation of the soil onsite by containment within a properly designed barrier.

The USEPA has for many years evaluated methods for dealing with soils and sediments associated with gasworks, which are referred to in the United States of America as manufactured gas plants (MGP). Many of these sites have been investigated and remediated, using a variety of methods including excavation, treatment and landfilling of the wastes, onsite encapsulation and containment, in situ solidification and capping.

The USEPA (2012) stated that 'solidification and stabilization have been selected or are being used



in clean-ups at over 250 Superfund sites across the country'. Since then the use of this method has increased both on land and in sediments, and is now viewed as the preferred method, particularly where MGP sites are located immediately adjacent to residential areas.

To validate the technique, the USEPA has developed a series of laboratory leach testing methods known as the Leaching Environmental Assessment Framework (LEAF). This method has been used in assessing laboratory trials conducted on contaminated sediments excavated from the bay.

The remediation options considered for contaminated sediments in SA1 and NA2+NA3 were:

- Monitored Natural Recovery;
- Enhanced Monitored Natural Recovery;
- contaminated sediment removal and treatment (ex situ):
 - at an adjacent on-shore facility for disposal at an offsite licensed disposal site, and
 - in a facility located offsite for treatment and then disposal at a licensed disposal site;
- capping of contaminated sediments:
 - without any contaminated sediment removal; and
 - with some contaminated sediment removal; and
- in situ treatment of contaminated sediments:
 - without any contaminated sediment removal; and
 - with some contaminated sediment removal.

The remediation options considered for contaminated sediments in SA2 and NA1 were:

- contaminated sediment removal and treatment (ex situ):
 - at an adjacent on-shore facility for disposal at an off-site licensed disposal site, and
 - in a facility located off-site for treatment and then disposal at a licensed disposal site;
- capping of contaminated sediments:
 - without any contaminated sediment removal; and

- with some contaminated sediment removal; and
- in situ treatment of contaminated sediments:
 - without any contaminated sediment removal; and
 - with some contaminated sediment removal.

The remediation options considered for Areas SA3, SA4 and SA5 were:

- do nothing;
- clean surface rubbish and contamination; and
- clean surface rubbish and contamination and enhance the mangrove, beach and offshore areas with clean sands.

Based on a detailed assessment, the preferred remediation options are:

- in areas where contaminated sediment requires remediation to protect human or ecological health (SA1, NA2+NA3), in situ stabilise columns down to a competent surface, create a raft of stabilised material across the area, excavate 0.5 m of the top of the solidified raft and install a permeable cap in the area excavated in the top of the raft;
- where intertidal areas near the seawall require remediation to protect human or ecological health (SA2, NA1), carefully remove stained rock/rubble and associated contaminated sediment and replace with clean sandstone to restore site aesthetics, and interstitial sand to support a benthic community; and
- remediation activities in the mangroves (SA3) and beach area (SA4, SA5) to restore visual and public amenity and site aesthetics.

REMEDATION OBJECTIVE

SA1 and NA2+NA3

The adopted remediation objective for sites SA1 and NA2+NA3 is to remediate, to the extent practicable, the surface sediments that pose an unacceptable risk to human health, and pose an acute risk to the marine ecosystem.

The areas will be in situ cement-stabilised, creating a raft of immobilised material in the top layer of sediments, supported by columns. This is depicted in Figure 4.

The top of the raft will then be excavated to below the level of Lowest Astronomical Tide (LAT) and topped with a 0.5 m thick capping layer for benthic re-colonisation.

The removed, stabilised material will be barged to the Staging Site for processing and offsite disposal, as required.

SA2 and NA1

The adopted remediation objective for sites SA2 and NA1 is to remove or stabilise:

- contaminated sediments that present a human health risk and/or an acute ecological risk, and remediate stained surfaces;
- sediments giving rise to emission of odours when exposed at low tides; and
- rubbish in accessible areas of the mangroves and along the foreshore, adjacent to the seawall.

The seabed will be lowered such that the final level is below the level of LAT and will incorporate a 0.3 m thick capping layer for benthic re-colonisation. This will prevent human access to the contaminated rubble along the base of the seawall at low tide and improve the marine ecosystem within the bay.

Stained rock/rubble will be removed and replaced with clean sandstone to restore site aesthetics and to provide habitat for intertidal fauna.

SA3

The adopted remediation objectives in area SA3 are to:

- manage sediments that pose an unacceptable risk to human health for users of the beach and mangrove areas; and
- install control measures to ensure stormwater discharge to Kendall Bay does not impact the remediated and managed parts of the Southern and Northern Remediation Area.

In the mangroves, the ground will be hand-excavated to remove visually contaminated material (while minimising damage to the mangroves by using careful excavation procedures) to a nominal 0.2 m and replaced with clean sand to restore site aesthetics. Stormwater controls will also be provided.

North of the mangroves, sand will be removed and replaced to a depth of 0.3 m to restore site aesthetics.

SA4

The adopted remediation objective for area SA4 is to improve the public amenity of the beach.

The remediation strategy in this area is to clean up the existing beach area by removing coke and coal from the sand surface to a nominal depth of 0.2 m and to replace the material with clean sand.

The beach nourishment sand will be retained by an approximately 30 m long seaward extension of the existing sandstone wall.

SA5

The adopted remediation objective in area SA5 is to provide a clean, firmer underfoot, offshore wading area that on occasions may be accessed from the beach.

The remediation strategy in this area involves shallow excavation of existing seabed material to 0.3 m depth followed by placement of a 0.3 m layer of clean sand to match the existing bed level.

Beneficial reuse of the excavated fine grained material would be achieved by blending it with sand used for capping of other Remediation Areas (e.g. SA1).

Sediment Treatment

Excavated solidified material from the Northern and Southern Remediation Areas will be barged to the Staging Site in sealed bins. It is proposed that the material be transported offsite in sealed bins to a facility licensed by the EPA for solidification, and then disposed of in a landfill licensed by the EPA to receive the treated materials.

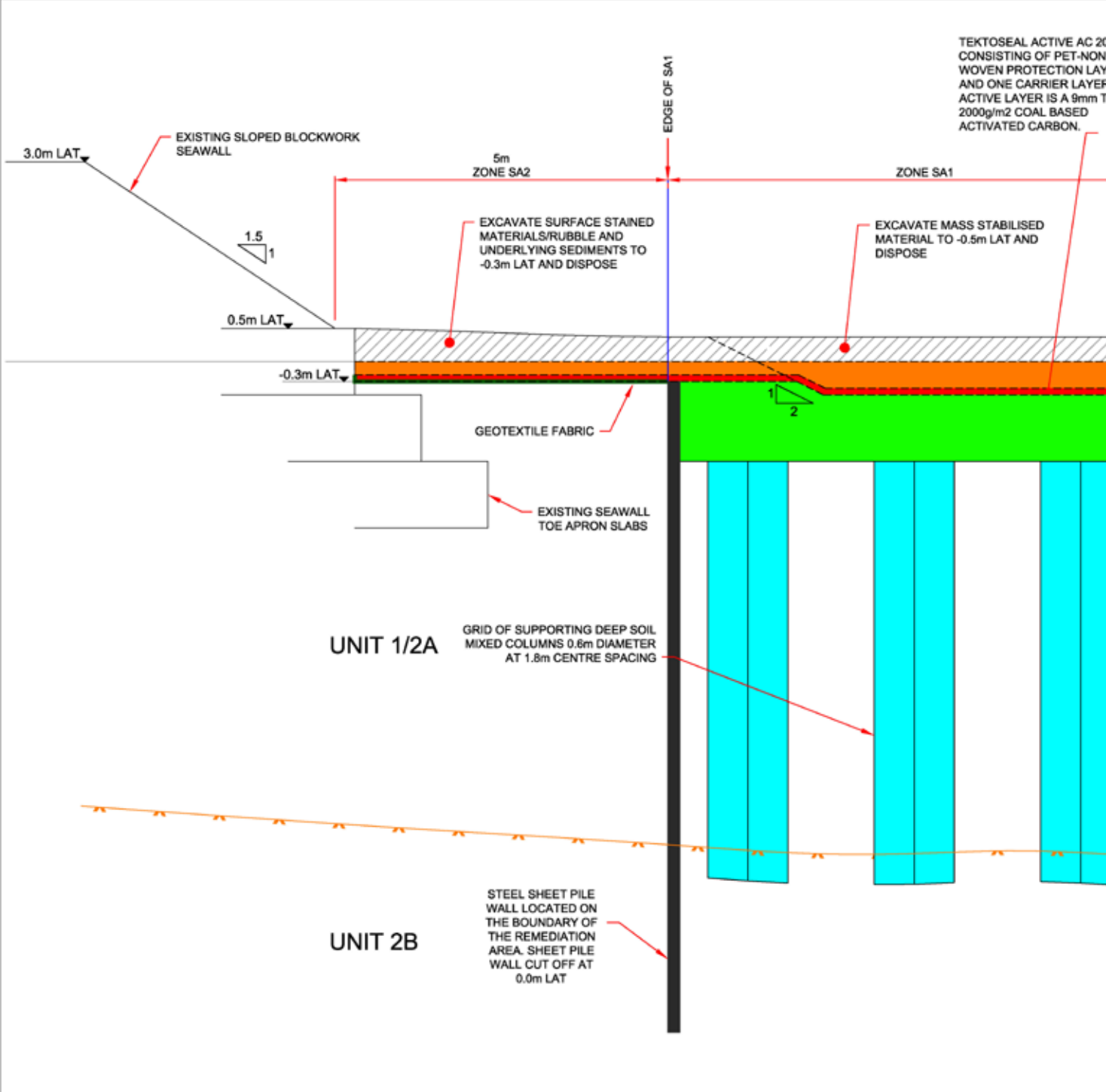
PROJECT MANAGEMENT

This RAP describes:

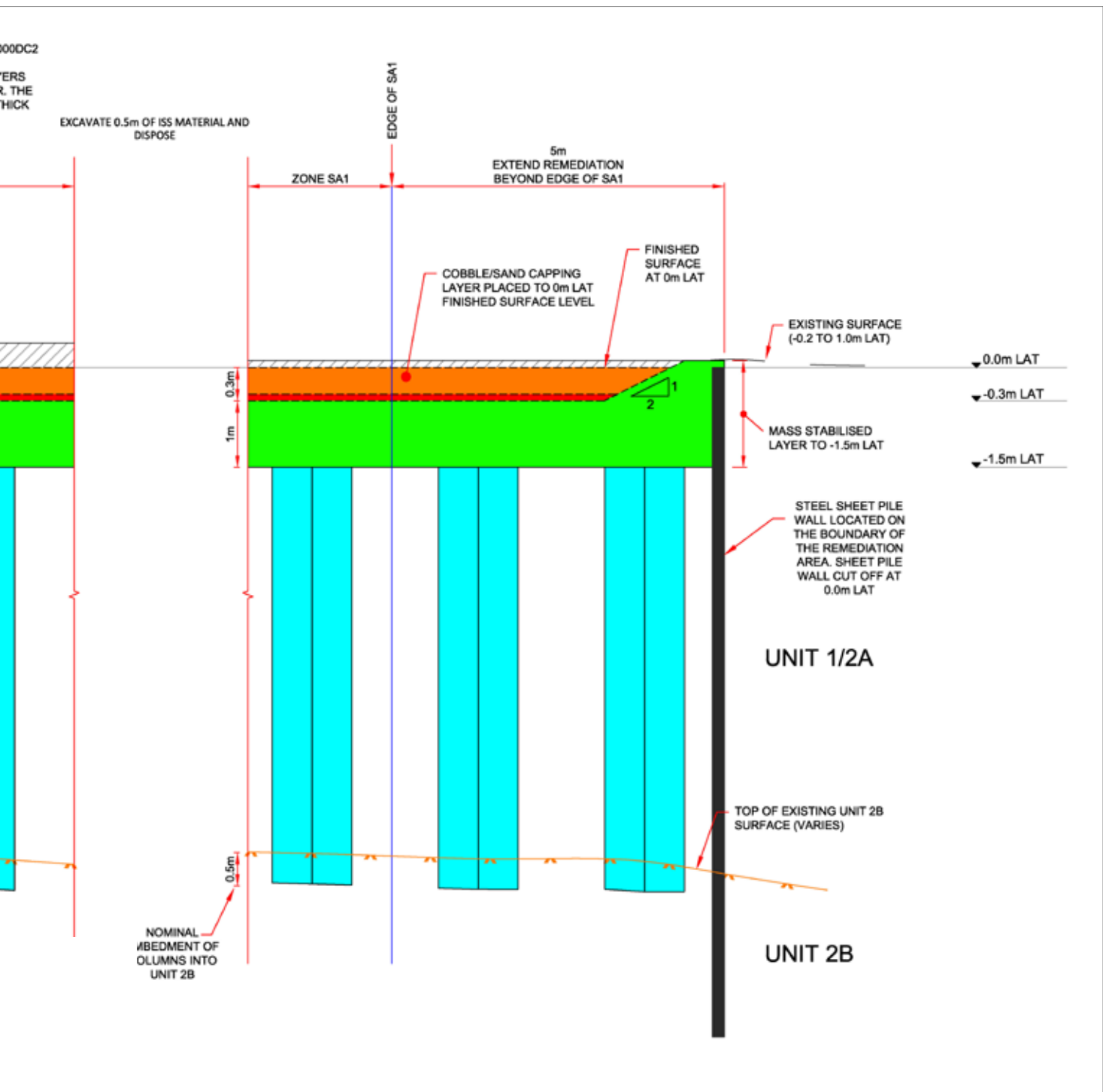
- the approach to managing the project;
- a management structure to control remediation activities;
- preparatory works;
- proposed construction techniques;
- environmental controls;



Figure 4. Cross Section of the Proposed Column and Raft Solidification.



Source: Royal HaskoningDHV, 2016a





- a site management plan that describes the long term monitoring program to ensure the solidification outcomes are durable;
- work health and safety management;
- contingency plans;
- regulatory reporting;
- stakeholder consultation;
- the validation plan; and
- post-remediation site management.

Jemena will, where practicable, adopt best practice in all areas.

CONCLUSION

This RAP offers the following benefits:

- it is robust and supported by the best available science;
- it deals with the contamination in accordance with NSW EPA and USEPA guidelines and best practice;
- it deals with the issues that concern the public, in particular:
 - contamination and the resulting odours along the foreshore;
 - the human health of those who use the bay, beach and mangrove area;
 - the amenity of the beach;
 - preservation of the mangroves; and
 - odour generation during remediation;
- it immobilises the contamination in the most contaminated areas and restores a suitable habitat for benthic communities; and
- it does not destroy existing viable benthic communities.

The following facts provide support for the proposed remediation strategy:

- other sediment solidification projects have been successfully completed in NSW;
- in situ solidification is an globally-established technique for soil improvement;
- the in situ solidification approach for remediation has become best practice in the USA where there are thousands of contaminated former manufactured gas plants and have been tested to show they are a long term solution;
- USEPA quality assurance and control methods will be adopted;
- mix tests have been successfully conducted on stabilising Kendall Bay sediments; and
- best practice project and environmental management approaches will be adopted.

In addition, laboratory trials are underway to establish the best mix of cement and other additives to solidify the Kendall Bay sediments and then an in situ trial will be conducted in the bay to prove the performance of the mix and construction methodology.

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ABBREVIATIONS

ACV	Acid volatile sulphide	EPA	NSW Environment Protection Authority
AGL	The Australian Gas Light Company	EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Cth)
AHD	Australian Height Datum (a level of 0.925 m on the Fort Denison tide gauge)	EPL	Environment Protection Licence (administered by the EPA under the POEO Act 1997)
ANZECC	Australian and New Zealand Environment and Conservation Council	ERA	Ecological risk assessment
ARI	Average recurrence interval	ERP	Emergency Response Plan
ASC NEPM	The National Environment Protection (Assessment of Site Contamination) Measure 1999	ESA	Environmental site assessment
ASS	Acid sulphate soil	ESD	Ecologically sustainable development
AASS	Actual acid sulphate soil	GAC	Granulated activated carbon
ASSMAC	Acid Sulphate Soils Management Advisory Committee	GCL	Geosynthetic clay liner
ASSMP	Acid Sulphate Soil Management Plan	GEL	Generally expected levels
BGS	Below ground surface	GPS	Global positioning system
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes	GSW	General Solid Waste
B(a)P	Benzo(a)pyrene	GV	Guidance value
BC	Black Carbon	HAT	Highest astronomical tide
CBD	Central Business District	HHRA	Human health risk assessment
CD	Chart Datum	HHRA	Human Health and Ecological Risk Assessment
CEMP	Construction and Environmental Management Plan	HOC	Hydrophobic organic contaminants
CLG	Community Liaison Group	ISQG	Interim Sediment Quality Guideline
CLM Act	<i>Contaminated Land Management Act 1997</i> (NSW)	ISS	In situ solidification or in situ stabilisation
COCs	Contaminants of Concern	ITRC	Interstate Technology and Regulatory Council (USA)
COPCs	Contaminants of Potential Concern	LAT	Lowest Astronomical Tide (corresponds to approximately 0 m on the Fort Denison tide gauge15)
CSIRO	Commonwealth Scientific and Industrial Research Organisation	LEAF	Leaching Environmental Assessment Framework
CSM	Conceptual Site Model	LEP	Local Environment Plan
DCP	Dynamic cone penetration	LGA	Local Government Area
DEC	former NSW Department of Environment and Conservation (functions of DEC now within the EPA)	LNAPL	Light Non-Aqueous Phase Liquid
DECC	Department of Environment and Climate Change (NSW)	LOE	Lines of evidence
DECCW	former NSW Department of Environment, Climate Change and Water (functions of DECCW now within the EPA)	MHW	Mean High Water (corresponds to a level of 1.469 m on the Fort Denison tide gauge16)
DGRs	Director General's Requirements (DP&E, NSW)	MGP	Manufactured gas plants
DLWC	former Department of Land and Water Conservation (NSW)	MLWS	Mean Low Water Spring tide
DNAPL	Dense Non-Aqueous Phase Liquid	MNR	Monitored natural recovery
DNR	former Department of Natural Resources (NSW)	MRL	Maximum residue limit
DO	Dissolved oxygen	MTL	Mean tide level
DP&E	NSW Department of Planning and Environment	MTMP	Marine Traffic Management Plan
DQO	Data Quality Objective	NAPL	Non-aqueous phase liquid
EIL	Environmental Investigation Level	NATA	The National Association of Testing Authorities Australia
EIS	Environmental impact statement	NEHF	National Environment and Health Forum
EMP	Environment Management Plan	NEPM	National Environment Protection Measure
EMNR	Enhanced Monitored Natural Recovery	NHMRC	National Health and Medical Research Council
EP&A Act	<i>Environmental Planning and Assessment Act 1979</i> (NSW)	NOAA	National Oceanic and Atmospheric Administration (USA)
		NSOC	Natural sedimentary organic carbon
		NSW	New South Wales
		OCP	Organochlorine Pesticide
		OPP	Organophosphorus Pesticide



OH&S	Occupational Health and Safety	SREP	Sydney Regional Environmental Plan
PAHs	Polycyclic Aromatic Hydrocarbons	SSD	State Significant Development
PASS	Potential acid sulphate soils	S&W	Synnot & Wilkinson Pty Ltd
PCBs	Polychlorinated biphenyls	SSD	State Significant Development (NSW)
PID	Photo-ionisation Detector	TCLP	Toxicity characteristics leaching procedure
PIRMP	Pollution Incident Response Management Plan	TEF	Toxicity equivalency factor
POEO Act	<i>Protection of the Environment Operations Act 1997</i> (NSW)	TOC	Total Organic Carbon
PPE	Personal protective equipment	TPH	Total Petroleum Hydrocarbons
PQL	Practical Quantitation Limits	TPMP	Traffic and Pedestrian Management Plan
QA/QC	Quality Assurance/Quality Control	TRH	Total Recoverable Hydrocarbons
RAP	Remediation Action Plan	TRV	Toxicity reference value
RMS	NSW Roads and Maritime Services	TSS	Total suspended solids
RPD	Relative Percentage Difference	UCL	Upper Confidence Limit
RWCP	Remediation Works Contingency Plan	USA	United States of America
RWEMP	Remediation Works Environmental Management Plan	USEPA	USA Environment Protection Agency
RWP	Remediation Works Plan	VENM	Virgin Excavated Natural Material
SEARs	Secretary's Environmental Assessment Requirements (DP&E)	VMP	Voluntary Management Proposal
SEPP	State Environment Protection Policy (NSW)	VOCs	Volatile Organic Compounds
SEPP 55	State Environment Protection Policy No. 55-Remediation of Land	VRA	Voluntary Remediation Agreement
SMP	Site Management Plan	VSAQP	Validation Sampling, Analysis and Quality Plan
SPOCAS	Suspension Peroxide Oxidation Combined Acidity & Sulphur	WHO	World Health Organisation
SQG	Sediment quality guidelines	WHS	Work health and safety
		WOE	Weight-of-evidence
		WQO	Water quality objectives

Chapter 1

INTRODUCTION

1.1 BACKGROUND TO THIS REMEDIATION ACTION PLAN

1.1.1 Summary of Corporate Ownership and Responsibility for Contamination

Production of gas by coal gasification processes was carried out by The Australian Gas Light Company (AGL) at the Mortlake Gasworks from 1886 to 1971.

As a consequence of corporate transactions in 2006 and 2007, responsibility for legacy contamination of Kendall Bay subsequently passed from AGL to Alinta and then to Jemena Limited (Jemena) in 2008.

In 2004, the NSW Environment Protection Authority (EPA) declared 'the sediments of the bed of Kendall Bay and the Parramatta River in the area adjacent to the former Mortlake gasworks which fall within 200 metres from the land-based boundary of the former Mortlake gasworks' as a Remediation Site under the then Section 21 of the *Contaminated Land Management Act 1997* (NSW) (CLM Act) (see Figure 1.1).

In 2005, AGL proposed a Voluntary Remediation Agreement (VRA) in relation to the Kendall Bay sediments, which was accepted by the EPA. The VRA provided for additional investigation of Kendall Bay to determine the impacted areas within Kendall Bay and the development and submission of a Risk Assessment, a Remediation Action Plan (RAP), a remediation strategy and various management plans, as well as to undertake and complete the remediation in accordance with those documents.

In June 2007, the EPA issued a Remediation Order to the then Maritime Authority of NSW, as owners of the seabed of Kendall Bay (the primary purpose of which was to ensure that no one disturbed the sediments of Kendall Bay without EPA approval). Alinta's responsibility for the contamination was also noted in the order.

In November 2007, the EPA confirmed that an area in the southern end of Kendall Bay (known as 'Area A') and another area in the north-western part of the bay (known as 'Area B') were the areas of sediments in which remediation activities were required.

In 2008, the project was declared a Major Project under the EP&A Act, and then was transitioned to a State Significance Development (SSD).

Jemena prepared a Remediation Action Plan (RAP) in 2014 which was endorsed by the EPA.

In 2015 and 2016, Jemena undertook a detailed engineering feasibility assessment for the implementation of the 2014 RAP and advised the EPA that they intended to prepare a new RAP which would address problems identified with the 2014 RAP.

In January 2016, the EPA provided comments on the proposed scope of the new RAP. These comments were accepted by Jemena and a draft RAP was prepared and submitted on 31 January 2017. The EPA responded to Jemena on 4 April 2017 with comments on the draft RAP and a number of technical reports attached to it.

Subsequent to the receipt of the EPA letter, Jemena held meetings to discuss the comments received from the EPA and in July 2017 confirmed to the EPA an intention to undertake additional field work to provide evidence of the presence and nature of chronic toxicity in sediments inside Kendall Bay and in reference bays upstream and downstream in the Parramatta River.

In addition, the EPA requested some additional bioaccessibility testing for human health risk assessment, to meet new EPA requirements.

The EPA also noted that any revisions to the draft RAP would need to address the fact that "the risk to the natural environment will be required to be assessed by the EPA in order for the declaration of remediation site under the Contaminated Land Management Act 1997 (the CLM Act) to be ultimately removed."

This RAP addresses the Areas A and B within Kendall Bay as was the scope in the previous draft RAP (2017). Jemena has indicated to the EPA that the RAP process is a two-stage process and that the second stage will address areas outside Kendall Bay in the Declared Area.

These regulatory instruments are all more fully described in Section 2.1 of this RAP.

The works proposed in this RAP will be regulated under a new Voluntary Management Proposal (VMP) agreed between the EPA and Jemena and formally issued in August 2017.

Figure 1.1. Location of 'Remediation Site' Declared Area



Source: Figure 1, URS (November 2007)

1.1.2 Summary of Efforts to Identify the Optimum Remediation Methodology

Contaminated sediments within Sydney Harbour and the Parramatta River have only been remediated in a few locations, and a limited range of remediation methods have been employed to date. To assess world best practice for the remediation of sediments in urban locations, the Jemena Remediation Project Team travelled to the USA in September 2016.

In addition, Jemena sponsored a team member's attendance at the Deep Foundations Institute Conference in New York in October 2016, where he conferred with world experts in the treatment and remediation of sediments, the use of traditionally-employed geotechnical equipment for the treatment of sediments and soils, and the containment and in situ stabilisation of contaminated sediments. Such equipment has been used on land successfully in Australia and globally for the rehabilitation of soft soils, and for foundation engineering in poor soils. More recently it has been used in the remediation of contaminated sediments. Methods included those used to stabilise contaminated sediments in a sustainable and durable manner.

Several USA remediation sites associated with former gasworks (referred to as manufactured gas plants (MGP)) were inspected, and meetings were held with consultants and contractors undertaking such investigations and remediation in New York and Delaware. In Delaware, meetings included the Delaware Environment Department. Contact was also made with experts from the USEPA Office of Superfund Remediation and Technology Innovation located at Arlington, Virginia, to discuss the USEPA's approach to the remediation of wastes at former MGP sites, especially where the contaminants are found in sediments.

These discussions confirmed that the preferred remediation method for gasworks-contaminated sediment is by in situ solidification (ISS). These methods have been used for many decades to stabilise soft soils and sediments on construction sites, both overseas and in Australia. Details of the methodologies considered for the Kendall

Bay Remediation Project and the preferred remediation options are presented in Chapters 8 and 9 of this RAP.

1.1.3 Summary of Inability to Implement the 2014 Remediation Action Plan

As part of the pre-commencement planning for the implementation of the 2014 RAP, Jemena engaged a specialist remediation contractor to provide advice on staging, methods and costings for the remediation approach adopted in the 2014 RAP. The outcome of this process determined that the remediation method and strategy set out in the 2014 RAP was not practically constructible and, if attempted, would fail to achieve the remediation objectives. Further detail and discussion on the 2014 RAP and the identified constructability issues is provided in Section 5.1 of this RAP.

Given the above, Jemena has undertaken consultation with the EPA and the Site Auditor and has completed a range of detailed investigations and extensive further works to determine a revised remediation approach that is technically feasible and environmentally justifiable.

This RAP has been prepared based on the outcomes of the further investigations and works completed by Jemena since the 2014 RAP and has been prepared to replace the 2014 RAP.

The remediation works to be undertaken at the Remediation Areas will be conducted in accordance with the requirements of the NSW legislative and regulatory frameworks in place at the time that the works are to take place. When this RAP was prepared, the core elements of this framework were provided by the:

- *Environmental Planning and Assessment Act 1979* (EP&A Act);
- *Contaminated Land Management Act 1997* (CLM Act);
- *Protection of the Environment Operations Act 1997* (POEO Act), and
- their associated regulations and planning instruments.



1.2 SITE IDENTIFICATION

Kendall Bay is an embayment extending off the southern side of the Parramatta River at Cabarita, NSW. It lies approximately 9 km west of the Sydney Central Business District (CBD) and is situated between the Breakfast Point development (on the site of the former Mortlake gasworks) and Cabarita Park, immediately west of Hen and Chicken Bay. The location of Kendall Bay is shown on Figure 1.2.

1.2.1 Areas of the Site that are Subject to this RAP

Two areas of Kendall Bay, each of which contains several discrete sub-areas, are subject to this RAP, as follows:

Southern Remediation Area

- Mangroves and stormwater delta (SA3);
- Beach (SA4 and SA5);
- South-western foreshore (SA2); and
- Sediments in the south-western corner of the bay (SA1).

Figure 1.2. Location of Kendall Bay



Figure 1.3. Remediation Areas in the Northern and Southern Remediation Area.





Northern Remediation Area

- Foreshore (NA1); and
- Sediments located in deeper water to the east of the foreshore (NA2+NA3).

These areas are referred to collectively in this RAP as 'the Remediation Areas' and each area is referred to individually as a 'Remediation Area'. The locations of the Remediation Areas are shown on Figure 1.3.

1.3 PERSONS AND ENTITIES REFERRED TO IN THIS REMEDIATION ACTION PLAN

Within this RAP the following persons and entities are referred to:

- Department of Planning and Environment – NSW Government Department representing the Minister for Planning who is the Consent Authority for the remediation works;
- EPA – the primary regulatory authority for the remediation works;
- EPA Accredited Site Auditor, Mr Graeme Nyland of Ramboll Environ - to provide certification to the EPA;
- NSW Roads and Maritime Services - responsible for Kendall Bay;
- Jemena – company responsible for undertaking the remediation;
- Jemena Project Manager – the person employed by Jemena to oversee the remediation works specified in this RAP;
- City of Canada Bay Council – Local Council responsible for lands adjacent to Kendall Bay;
- Remediation Contractor – the contractor engaged by Jemena to undertake the remediation works described in this RAP;
- Validation Consultant – the consultant engaged by Jemena, or its representative, to undertake the validation of the remediation works specified in this RAP; and
- Independent Technical Expert – the consultant engaged by Jemena, or its representative, to provide technical advice to the community and other nontechnical stakeholders during the course of the remediation works specified in this RAP.

1.4 GOALS AND OBJECTIVES OF THE REMEDIATION WORKS

1.4.1 Goals

The goals of the remediation works are to:

- ensure long-term protection from potential impacts from gasworks-related contamination of the health of users of the foreshore of Kendall Bay, including the southern beach and adjacent mangrove area where gasworks-contaminated sediments are exposed at low tides;
- improve the health of the marine ecosystem of Kendall Bay in areas where it is adversely affected by acutely toxic gasworks-contaminated sediments;
- improve the amenity of readily accessible areas of Kendall Bay;
- ensure that a durable outcome is achieved that satisfies the requirements of the VRA (as amended, or any replacement VMP); and
- provide a remediation solution that is technically sound, environmentally justifiable and meets EPA requirements and community expectations.

1.4.2 Objectives

Specific objectives have been developed for each Remediation Area and the overall remediation works.

Southern Remediation Area

Remediation works in the Southern Remediation Area will be undertaken to:

- remediate to the extent practicable gasworks-contaminated sediments that pose an acute toxicity risk to the marine ecosystem;
- remediate gasworks-contaminated sediments that pose an unacceptable risk to the health of users of the mangrove area and of areas of sediment that pose an unacceptable risk to human health when exposed so as to be accessible at low tides;
- remediate stained surfaces, gasworks-contaminated sediments giving rise to emission of odours when exposed at low tides, and rubbish in accessible areas of the mangroves, on the southern beach and in the foreshore adjacent to the seawall; and

- install a physical barrier to control discharge of stormwater from the large outfall at the southern end of the bay to ensure stormwater discharge to Kendall Bay does not impact the remediated parts of the Southern and Northern Remediation Areas and to minimise ingress of mangroves onto the beach area.

Northern Remediation Area

Remediation works in the Northern Remediation Area will be undertaken to:

- remediate to the extent practicable gasworks-contaminated sediments that pose an acute toxicity risk to the marine ecosystem; and
- remediate stained surfaces, gasworks-contaminated sediments giving rise to emission of odours when exposed at low tides, and rubbish in accessible areas of the foreshore adjacent to the seawall.

Standard of Work

The remediation works will be designed and carried out to ensure:

- durable, robust and conservative remediation outcomes;
- no unacceptable impacts to the amenity of the community in terms of odours, noise or impact to the waters of Kendall Bay during the course of the remediation works; and
- maintenance of the integrity of the seawall adjacent to the Southern and Northern Remediation Areas during and after the remediation works.

Management of Remediation Works

Management of the remediation works will be undertaken in accordance with the requirements of this RAP by:

- having a Jemena project manager who has extensive experience in complex remediation works;
- engaging a Remediation Contractor who has extensive experience in in situ solidification of sediments in waterways within urban environments;
- engaging a Validation Consultant and an Independent Technical Expert who have extensive experience in complex remediation works;

- continuing to implement the community consultation plan prior to, during and after completion of the remediation works;
- implementing an Operational Site Management Plan for the conduct of the remediation works to ensure the protection of the environment and human health of users of Kendall Bay and the adjacent residential community, and workers undertaking the remediation works; and
- validating achievement of the goals of the remediation measures in the Southern and Northern Remediation Areas.

Post-remediation works

After the remediation works have been completed, post-remediation studies will be done to:

- verify the durability of the remediation measures through periodic monitoring, to assess any need for rehabilitation of remediation measures, or further monitoring or management measures;
- continue engagement with and reporting to the community and regulatory authorities during the remediation program, and throughout the implementation of post-remediation verification and management; and
- implement a Site Management Plan (SMP) to ensure the ongoing integrity of the remediation measures once the works have been completed.

1.5 OBJECTIVES OF THE REMEDIATION ACTION PLAN

The objectives of this RAP are to document the:

- remediation goals;
- remediation strategy;
- required regulatory approvals and licences;
- specific remediation works that are to be carried out;
- validation strategy; and
- contingency, environmental management and occupational health and safety procedures to be implemented during and following completion of the remediation works.



1.6 SCOPE OF THIS REMEDIATION ACTION PLAN

The scope of this RAP is to:

- document why the 2014 RAP could not be implemented;
- summarise the previous environmental investigations conducted on the site;
- detail the recent environmental investigations conducted on the site;
- identify areas and contaminants of concern that require remediation;
- evaluate the feasible remediation option/s;
- detail the preferred remediation option/s;
- detail the remediation approach and strategy;
- detail the scope of the remediation works;
- describe operational procedures to be undertaken by the Remediation Contractor, such as excavation, stockpiling of material, materials management and handling;
- set out the requirements for the following plans, which will be developed and implemented by the Remediation Contractor; during the remediation works:
 - a Remediation Works Contingency Plan (RWCP);
 - an Environmental Management Plan (EMP); and
 - a Work Health and Safety (WHS) Plan.
- define the Validation Sampling, Analysis and Quality Plan (VSAQP) to be developed and implemented by the Validation Consultant to demonstrate the successful completion of the remediation works; and
- set out the requirements for the Site Management Plan (SMP), which will be implemented following completion of the remediation works.

1.7 LIMITATIONS OF THIS REMEDIATION ACTION PLAN

This RAP was prepared by Synnot & Wilkinson Pty Ltd (S&W) for Jemena, solely for the purposes set out herein and it is not intended that any other person(s) or Companies or Government use to rely on the contents of the report. Reliance of other parties on this report is subject to agreement in writing by S&W.

S&W otherwise disclaims responsibility to any person other than Jemena arising in connection with this RAP. S&W also excludes implied warranties and conditions, to the extent legally permissible.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. S&W has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The information contained in this report is based on a number of reports and data provided by other parties contracted by S&W and other reports and data from parties not contracted to S&W. The data presented in this report is to the best of our endeavours accurate and reflective of condition in Kendall Bay and surrounding areas at the time of collection.

Whilst the information contained in the RAP is accurate to the best of our knowledge we cannot guarantee the completeness or accuracy of any of the descriptions or conclusions based on the information supplied or obtained during the investigations and site surveys.

Furthermore, conditions can change within limited periods of time, and this should be considered if the RAP is to be used after any elapsed time period subsequent to its issue. In particular, subsurface conditions may change over time due both to natural processes and human activities. For example, groundwater levels may rise and fall, contaminants may migrate from one place to another, chemical changes may occur over time, the ground may be excavated or filled, sediments may accumulate, be eroded, infilled or excavated. Management decisions should not be based on a report where time has elapsed and conditions may have changed.

The sampling reported herein categorises the actual surface and subsurface conditions only at those points where samples were taken, and only at the time they were taken, and cannot be interpolated to describe surface or subsurface

conditions between those points because the nature of the conditions is unknown, and may rely on geological factors which are not apparent, and may change over time.

The RAP, as a whole, represents the findings of the site investigations and should not be copied in part, nor altered in any way. Data, figures, logs, tables etc. have been prepared based on interpretation of field and laboratory data and should not be redrawn or recast for inclusion in other reports, or separated from this report.

S&W has exercised reasonable care, skill and diligence in preparation of the RAP. However, except for any non-excludable statutory provision

or as set out in S&W's terms of engagement by Jemena, S&W gives no warranty in relation to its services or the RAP, and is not liable for any loss, damage, injury or death suffered by any party (whether caused by negligence or otherwise) arising from, or relating to, the services or the use or otherwise of this RAP.

All distances and measurements are subject to accurate survey prior to any works being undertaken. Any measurements quoted in this RAP are nominal only at this stage.

Remediation concepts in this RAP may change in the future with the consent of the Auditor and NSW EPA.





Chapter 2

PLANNING, ASSESSMENT AND APPROVAL PROCESS

2.1 REGULATORY AND LEGISLATIVE FRAMEWORK

The remediation works require that numerous regulatory and legislative requirements be satisfied prior to, during and after completion of the remediation works, and this information will be presented in detail in an Environmental Impact Statement (EIS) prepared for the project. A general overview of key regulations and legislation applying to the works is provided below.

2.1.1 Contaminated Land Management Act 1997

The CLM Act is the primary NSW Act under which contaminated land in NSW is regulated. The regulatory authority under the CLM Act is the NSW EPA.

The following CLM Act regulatory instruments currently apply to the sediments in Kendall Bay:

- 25 May 2004 – The EPA issued a Declaration of Remediation Site that applies to the sediments of Kendall Bay located in the seabed of Kendall Bay and the Parramatta River in an area that extended 200 m from the entire foreshore boundary of the former Mortlake Gasworks site into the bay and river (see Figure 1.1). This declaration was made under the then Section 21 of the CLM Act;
- 20 September 2005 – The EPA issued an approval for a Voluntary Remediation Agreement (VRA) prepared by AGL (2005). The 2005 VRA provided for additional investigation of Kendall Bay to determine the impacted areas within Kendall Bay and the development and submission of a Risk Assessment, a RAP, a remediation strategy and various management plans, as well as to undertake and complete the remediation in accordance with those documents; and

- 22 June 2007 – The EPA issued a Remediation Order under Section 23 of the CLM Act to the Maritime Authority of NSW, as owners of the seabed of Kendall Bay (the primary purpose of which was to ensure that no one disturbed the sediments of Kendall Bay without EPA approval).

In November 2007, the EPA wrote to Jemena and approved two areas of Kendall Bay to be targeted for remediation (Figure 2.1). These areas were derived based on data presented in investigations and associated risk assessments that had been completed at the time pursuant to the VRA (URS, 2008; URS, 2009 – see Section 3.2). The two areas were referred to as Area A, located at the southern end of Kendall Bay and comprising a surface area of approximately 8340 m², and Area B located within part of the footprint of the former coal wharf on the north-western side of Kendall Bay and comprising a surface area of approximately 957 m².

It is envisaged that the works proposed in the current RAP will be regulated under the 2005 VRA, a modification to the 2005 VRA or a new Voluntary Management Proposal to be agreed between the NSW EPA and Jemena.

2.1.2 Protection of the Environment Operations Act 1997

The Protection of the Environment Operations (POEO) Act 1997 is a key piece of environment protection legislation administered by the NSW EPA. The POEO Act has various functions, however, in relation to the remediation works, Schedule 1 of the Act sets out the types of activities that constitute a ‘Scheduled Activity’ and as such require licensing by NSW EPA under the POEO Act. Licences may also be issued for activities that are not listed in Schedule 1 of the POEO Act but are likely to cause pollution of water. These activities are referred to as ‘non-scheduled activities’.



Figure 2.1. Extent of Areas A and B, as approved by EPA in 2007



Aspects of the remediation works set out in this RAP are likely to require licensing under the POEO Act. These works include, but may not be limited, to the following:

- treatment of sediments to enable them to be disposed offsite and/or retained in situ; and
- treatment of excess waters to enable them to be discharged offsite.

Prior to the commencement of any works relating to the remediation, Jemena will determine if any of the activities to be undertaken require a licence and if needed, will apply to the NSW EPA for approval and be issued with an Environmental Protection Licence for those works.

Protection of the Environment Operations (Waste) Regulation 2014

The remediation works will require the removal and disposal of some excess sediments and/or waters offsite and as such the provisions of the *Protection of the Environment Operations (POEO)*

(Waste) Regulation 2014 will apply. All material to be removed from the site will be required to satisfy the requirements of the POEO (Waste) Regulation. These requirements include ensuring that:

- waste is classified appropriately and in accordance with relevant guidelines (NSW EPA (2014) *Waste Classification Guidelines. Part 1: Classifying Waste* (or as superseded);
- waste materials are transported from the site by an appropriately licensed transporter to a landfill facility licensed to accept the type of waste;
- other materials are removed to facilities lawfully able to accept such materials; and
- waste tracking records are kept for the remediation works, including copies of the waste transport and disposal certificates.

2.1.3 Environmental Planning and Assessment Act 1979

All development in NSW is assessed in accordance with the *Environmental Planning and Assessment Act 1979* (EP&A Act). Part 4 of the Act provides for the control of development that requires development consent from a consent authority. Depending on the circumstances of the project, the consent authority may be the local council, the Minister for Planning or in some cases another body such as the Planning Assessment Commission.

The EP&A Act requires that development consent must be obtained before the remediation of Kendall Bay may occur. Due to the nature and location of the proposed remediation works, this work has been declared by the Minister for Planning to be a State Significant Development under the EP&A Act.

Part 4, Division 4.1 of the EP&A Act establishes an approval regime for developments declared to be State Significant Development by either a State Environmental Planning Policy or Ministerial Order. In accordance with Section 89E of the EP&A Act, the Minister for Planning is the consent authority for State Significant Development. Section 23 of the EP&A Act permits the Minister to delegate this consent authority function to the Planning Assessment Commission, the Secretary of DP&E or to another public authority.

Under Section 78A (8A) of the EP&A Act, an EIS is required to support a development application for an State Significant Development. Before preparing the EIS, the applicant must request SEARs from DP&E. The request for SEARs must be accompanied by supporting information which includes details of the location, nature and scale of the proposal as well as a preliminary environmental assessment to identify key issues for further assessment in the EIS. DP&E then consults with relevant public authorities when preparing the SEARs, before issuing them to the proponent.

The proponent must prepare an EIS which meets the requirements specified in:

- the SEARs; and
- Schedule 2 of the *Environmental Planning and Assessment Regulation 2000* (NSW).

The EIS is submitted to DP&E, which reviews the information provided to ensure that adequate detail is available for members of the community and other stakeholders to understand the proposal and its potential impacts. Once DP&E is satisfied the EIS is adequate, it is placed on public exhibition for at least 30 days to allow public and agency submissions to be lodged, after which the proponent may be requested to respond to issues raised in the submissions.

Accordingly, the development application process for State Significant Development requires that Jemena prepare an EIS that is submitted with its development application for the remediation works. This RAP will form part of the EIS. In order to prepare an EIS that will be accepted for assessment by the Department of Planning and Environment (DP&E), in 2014 Jemena prepared a submission to the DP&E to obtain the Secretary's Environmental Assessment Requirements (SEARs). The SEARs were issued in December 2014. These were updated and re-issued in March 2017 and the updated SEARs are provided in Appendix 1. Jemena's EIS must address the subject areas specified in the SEARs.

2.1.4 State Environment Planning Policy No. 55 – Remediation of Land

State Environment Planning Policy No. 55 – Remediation of Land (SEPP55) specifies when remediation work does and does not require development consent from the consent authority. Remediation works that require development consent are classified as Category 1 remediation works and remediation works that do not require development consent are Category 2 remediation works.

2.1.5 Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005

Sydney Regional Environmental Plan (SREP) (Sydney Harbour Catchment) 2005 covers the area of Sydney Harbour, including the Parramatta River and its tributaries, and the Lane Cove River. The aim of the plan is to establish a balance between a prosperous working harbour, maintaining a healthy and sustainable waterway environment and promoting recreational access to the foreshore and waterways. It establishes planning principles and controls for the catchment as a whole.

Kendall Bay is located within the W1-Maritime Waters Zone, which encompasses the main navigation channel between Sydney Heads and Parramatta.

The W1 Zone objectives address effective and efficient movement of commercial shipping, public water transport and maritime industrial operations, and promote equitable use of waterways including by passive recreation craft.

The area of mangroves within Kendall Bay is designated as a Wetlands Protection Area under the SREP. Clause 62 of the SREP provides that development within a Wetlands Protection Area may only be carried out with development consent.



Historical Cadastral Map of Kendall Bay

Chapter 3

SITE HISTORY AND BACKGROUND INFORMATION

3.1 HISTORY OF THE MORTLAKE GASWORKS SITE AND KENDALL BAY

AGL operated a coal gasification facility at Mortlake between 1886 and 1971. It became the largest gasworks in the southern hemisphere, at its height processing approximately a million tonnes of coal a year.

During operation of the gasworks, a number of wharves were built from the northern and eastern foreshores of the gasworks site into the Parramatta River and Kendall Bay. These were used for loading and unloading coal, coke, by-products and other materials. A tar oil pipeline ran along one of the wharves extending from the foreshore into the Parramatta River to the north of Kendall Bay, to allow for direct loading of tar oil onto ships.

During the period of operation of the gasworks, sediments beside the wharves were dredged from time to time in order to maintain access for shipping. A number of the smaller wharves were removed from the northern shoreline from the 1950s, as was the coke jetty on the north-eastern side of the gasworks. However, the larger coal wharf to the south of the coke jetty remained as the primary loading facility until after the gasworks closed.

The layout of the gasworks was subject to various changes over its operation, with significant land reclamation occurring along its northern, eastern and south-eastern shorelines until the mid-1940s. Of relevance to Kendall Bay was the presence of a large water supply dam, waste storage areas and retention ponds on reclaimed land to the west of the south-western foreshore of Kendall Bay. After the site was connected to mains water supply, the dam was progressively infilled with waste materials and used as a repository for tar and other wastes. It is understood that a large drainage channel in this area discharged waters

(likely to have contained waste waters, sediments, surface runoff and other liquid wastes from the gasworks sites, and likely from the ponds), via a large outlet pipe into the south-western part of Kendall Bay.

From 1971 to the mid 1980s, the Mortlake facility produced gas from naphtha. Production then ceased but the works was retained as a hub for odourising and distributing natural gas from Central Australia until it finally closed down in 1990.

Between 1999 and 2002 the former gasworks site was remediated and subsequently redeveloped primarily for medium to high-density residential use, creating the suburb now known as Breakfast Point. In the mid-2000s the coal wharf was removed. Some of the supporting piles were cut off at or near the bay bed and the lower sections remain in the sediments.

The original configuration of Kendall Bay and the eastern boundary of the gasworks site is shown on a 1913 map (Figure 3.1). At the time, Kendall Bay was considerably larger and extended further to the south-west, where the map shows two streams flowing into the head of the bay. The streams eroded channels into the underlying Hawkesbury Sandstone bedrock, where the deepest extent of contaminated sediments has been identified, in the south-western part of Kendall Bay in Remediation Area SA1.

The 1935-1936 oblique aerial photo (Figure 3.2) shows the layout of the gasworks, including the water supply dam, associated structures in Kendall Bay and the southern bay shoreline before reclamation was completed.

The 1958 map (Figure 3.3) shows the dam (at this stage a repository for tars and other wastes) in the south. Adjacent to it, in the former valley and bay end, are storage areas for contaminated materials such as spent oxide, as well as coal, coke and other materials.



Figure 3.1. 1913 plan showing Kendall Bay



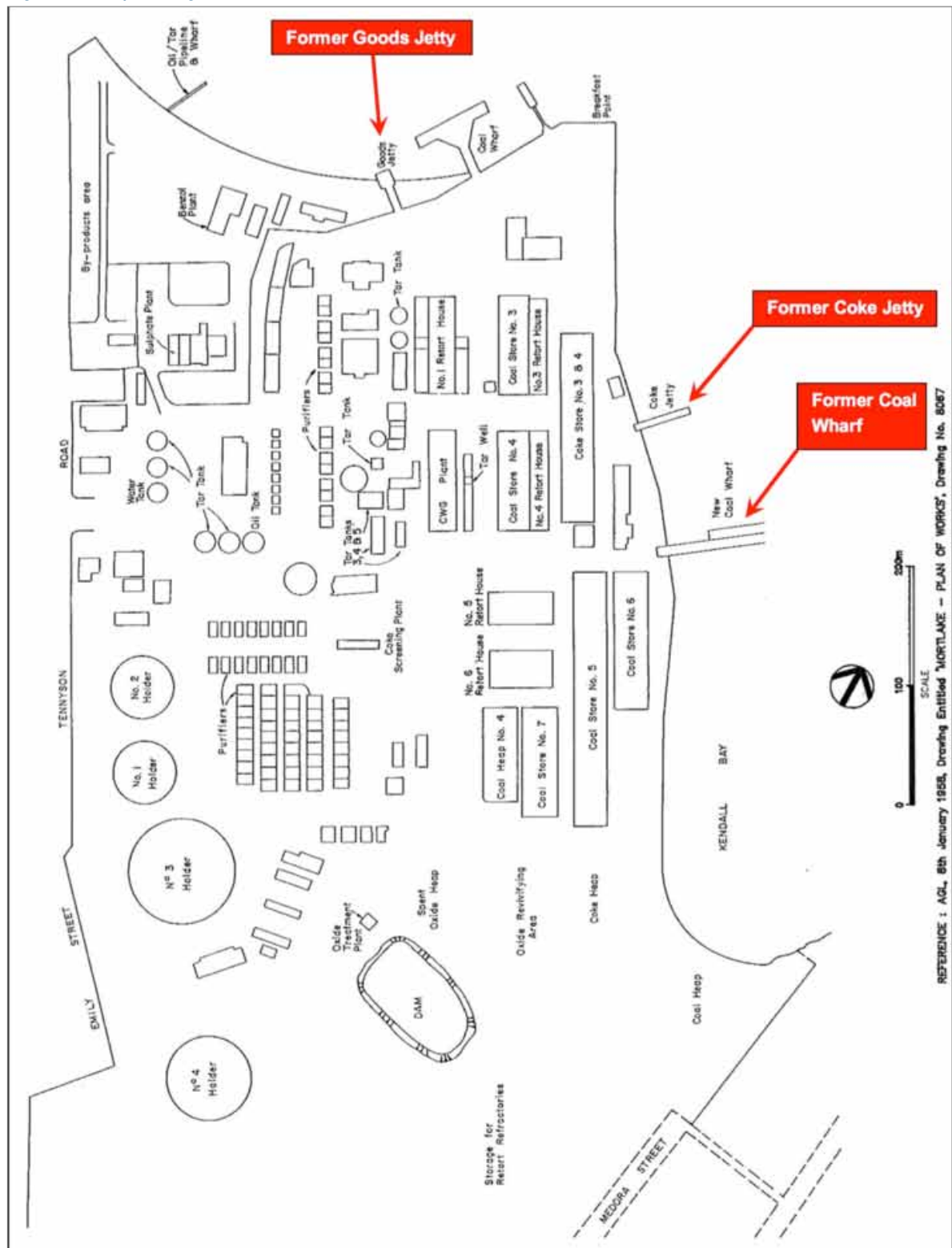
Source: Golders, 2015

Figure 3.2. 1935-1936 aerial photo of the Mortlake gasworks.



Source: AGL, 1986

Figure 3.3. Layout of gasworks in 1958



Source: Figure 3.4, Dames & Moore (May 1996) EIS



The 1972 aerial photo (Figure 3.4) shows the gasworks and the waste dam. The coke jetty has been removed. Note turbidity north and south of the coal wharf, assumed to be from loading operations. No beach, mangroves or a stormwater delta are present at the head of the bay.

The 2014 aerial photo (Figure 3.5) shows considerable redevelopment of the former gasworks site for housing. The coal wharf has been removed and the beach, mangroves and stormwater delta at the head of the bay have established and expanded.

The pits identified on the photo form part of the area where non-tar-containing gasworks waste was buried in a lined containment cell excavated into Hawkesbury Sandstone bedrock where a large gasholder was formerly located.

A large dam which was a repository for gasworks wastes including tarry wastes from the 1940s onwards was located on the southern area of the site (Figure 3.6). This waste dam lay on the reclaimed bedrock valley which drained into Kendall Bay.

3.2 PREVIOUS INVESTIGATIONS

Numerous studies of Kendall Bay and adjacent parts of the Parramatta River were carried out between 1989 and 2014. A number of investigations of Kendall Bay between 1989 and 2002 identified that the sediments were contaminated with gasworks waste, metals and other pollutants. These early investigations are briefly summarised below.

Dames & Moore, 1989

Dames & Moore (1989) sampled 12 sub-tidal locations and concluded that the upper 0.1 – 0.5 m layer of sediment along the foreshore of the gasworks site was contaminated with oil and grease and trace metals in higher concentrations than those found in other locations within Sydney Harbour. The fine-grained sediments below the surface layer of (silty) sands were found to be contaminated by oil and grease to a depth of between 0.6 – 1.0 m below the estuary bed. Visual observations suggested that coal tar was the primary component of the oil and grease.

Dames & Moore, 1996

Dames & Moore (1996) assessed aquatic ecology and sediment quality. Sediments adjacent to the gasworks site (thickness 0.5 – 1.4 m, average thickness 0.8 m) were identified as contaminated by heavy oils, which were concentrated around the former wharves in the Parramatta River and Kendall Bay. The presence of these heavy oils contributed to the elevated concentrations of PAHs in near-shore sediments.

Dames & Moore, 1999

Dames & Moore (1999) collected 17 samples of surface sediments from 12 locations along the foreshore boundary of the former gasworks. The acid volatile sulphide and simultaneously extracted metal ratios indicated potential for specific trace metals to be bound by sulphides in the surface sediment resulting in low toxicity and low potential availability of these contaminants to biota. Fish populations were also assessed for bioaccumulation of the Contaminants of Concern. PAHs were identified in whole fish species but not in the filleted portions. This was thought due to the PAHs preferentially accumulating in the liver and organs of the fish.

URS, 2002

URS (2002) indicated that PAH concentrations in sediments exceeded adopted health-based soil screening guidelines, but were considered unlikely to pose an unacceptable risk to human health. It was also identified that the work method used during this investigation may have contributed to the impacts visually observed on the surface sediments. Visible contamination was observed to a maximum depth of 3.5 m during this investigation.

More detailed sediment investigations were carried out in Kendall Bay by a number of consultants between 2005 and 2013. These investigations, detailed in the referenced reports and summarised in the 2014 HHERA, included:

- Sediment sampling by URS in 2005, 2006 and 2007, to obtain additional data on the distribution of contamination in surface and near-surface sediments in the mangroves and across the bay, and for use in the 'environmental risk assessment' report (URS 2006) (not an ERA as it only assessed



Figure 3.4. 1972 aerial photo of Mortlake gasworks and Kendall Bay.



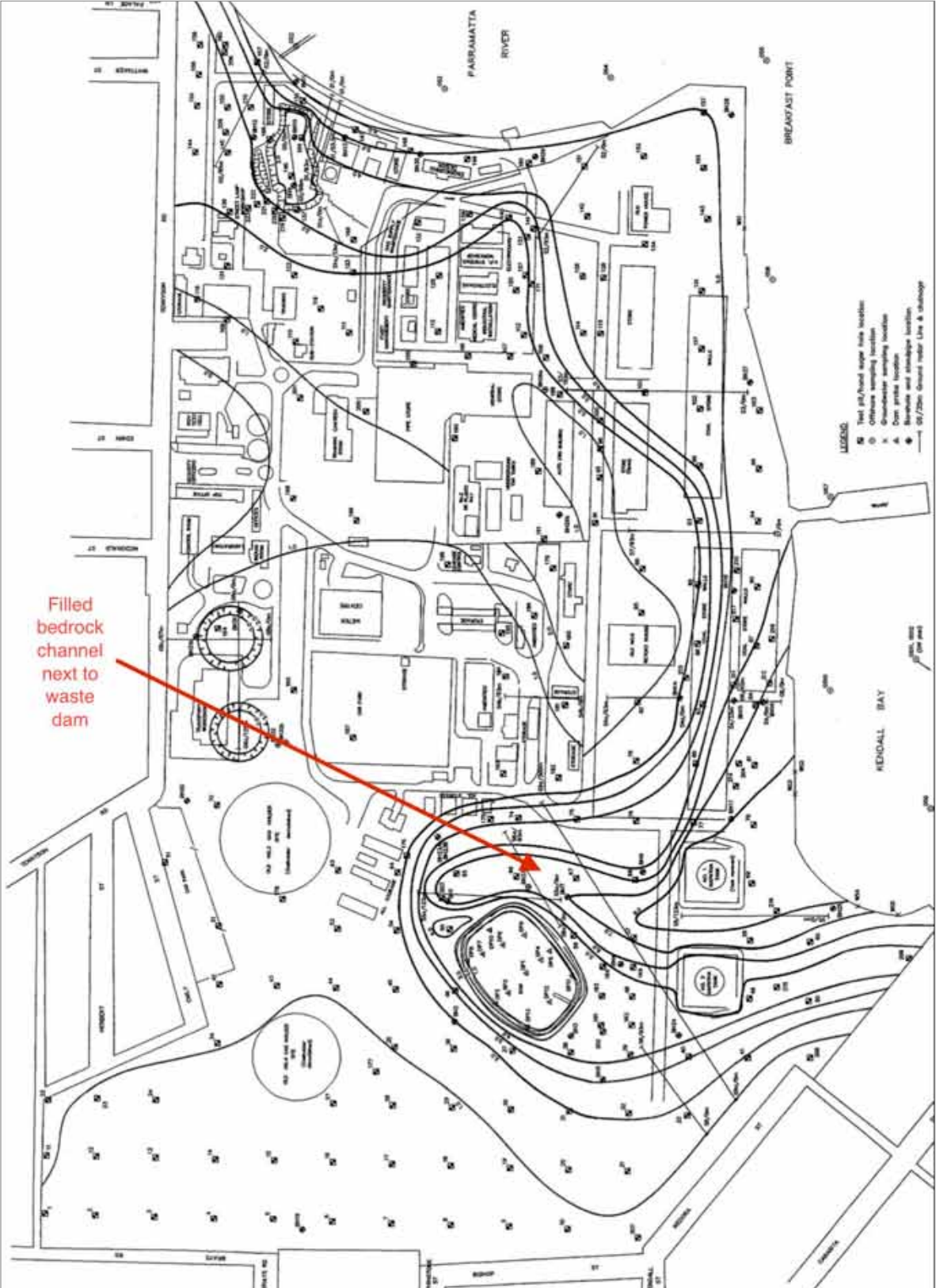
Figure 3.5. 2014 aerial photo



Source: Golders 2015



Figure 3.6. Contours on former bay end bedrock channel



Source: Figure 3.9, Dames & Moore (May 1996) EIS



potential contaminant mobilisation), the Human Health Risk Assessment (URS, 2007), the preliminary environmental assessment (URS, 2008), and the conceptual RAP (URS, 2009). These investigations delineated two areas of contaminated sediments that were stated to require remediation because they represented human health risks, principally due to the levels of carcinogenic PAHs. These areas included one at the southern end of the bay (designated Area A) and one in the middle of the western side of the bay (Area B). Area A did not include the mangroves (though potential human health impacts had been identified from the mangrove area), and URS carried out little sampling in the mangroves.

- Sediment sampling by AECOM (2009) at the site of a proposed large marina on the western side of the bay, encompassing the remediation Area B plus the bay south, east and north of Area B. Data from this report are summarised in the 2014 Human Health and Ecological Risk Assessment, however the original report could not be accessed.
- Sediment sampling by E3 Consulting (2011) in remediation Areas A and B. The purpose of this work was to provide sediment contamination and geotechnical data for remediation planning. The sampling was carried out by push coring from a barge-mounted rig, to refusal. However, in the great majority of cores the upper 2-4 m of soft fine sediment, which is believed to contain most of the contamination, was not recovered. Grab sampling was also undertaken using a Petite Ponar sampler however this only sampled the top 100-150 mm of sediment.
- Sediment sampling by SKM (2013) in the mangroves at the southern end of the bay, using a hand auger.

Based on the investigations carried out between 2009 and 2013, in 2014 SKM prepared a refined Human Health and Ecological Risk Assessment, altered the extent of the Remediation Areas and prepared the 2014 RAP. In particular, Remediation Area A was enlarged to include the mangroves which were present at the south-western end of Kendall Bay (Figure 3.7).

Key investigations, including the 2014 HHERA and RAP, are reviewed in Section 5.1.

3.3 CURRENT INVESTIGATIONS

Since the 2005 VRA was approved, Jemena has engaged consultants to carry out numerous investigations, principally by URS (2007, 2008, 2009), EnviroPacific Services (2010, 2013) and E3 Consulting (2011), of the contaminated sediments in order to derive a remediation approach based on:

- identifying and delineating the extent of contaminated sediments in the southern and northern parts of Kendall Bay that pose a significant risk of harm to human health and/or to the environment, and therefore require remediation action be taken; and
- determining remediation methods that can be demonstrated to be technically feasible, constructible, robust, durable, conservative, environmentally justifiable and commercially viable.

Based on these investigations, a RAP was prepared and submitted to the NSW EPA in 2014 (the 2014 RAP). In the 2014 RAP, Remediation Areas A and B were expanded (Figure 3.7).

The guidelines made or endorsed by NSW EPA under the CLM Act have been applied in undertaking various phases of investigations on the sediments, culminating in the preparation of site-specific quantitative human health and environmental risk assessments (see Chapter 5). These risk assessments, via the derivation of site-specific criteria, have identified the locations of sediments that pose a risk. These results, derived from the risk assessments, have been utilised to determine the nature and extent of contaminated sediments that require remediation. This approach to addressing the declaration under the CLM Act is in accordance with the guidelines made, or endorsed, by NSW EPA under the CLM Act. The Site Auditor engaged for the remediation works, Mr Graeme Nyland of Ramboll Environ, has been accredited by the NSW EPA under the CLM Act and will issue relevant Site Audit Statements for this RAP and subsequent reports on the remediation and validation works under the relevant provisions set out in the CLM Act. Each

Site Audit will be undertaken in accordance with the guidelines made by the NSW EPA for the Site Audit Scheme under the CLM Act.

At the completion of remediation works described in this RAP and any stage two investigations (and any associated RAP), and after the issue of a

relevant Site Audit Statement, Jemena will request the NSW EPA to determine whether the current declaration of the sediments under the CLM Act can be revoked or whether ongoing regulation will be required in respect of all or part of the current Declared Area, under an alternative mechanism than that of the current declaration.

Figure 3.7. The 2014 RAP Remediation Areas.



Source:SKM 2014

Chapter 4

SITE CONDITIONS AND SURROUNDING ENVIRONMENT

The existing environment of Kendall Bay and its surrounds is described in detail in the report, Kendall Bay Sediment Remediation Project, Description of

Existing Marine Environment by Royal HaskoningDHV (2016a). Key features of the environs of Kendall Bay are shown on Figure 4.1.

Figure 4.1. Key features of Kendall Bay in 2016





4.1 SITE DESCRIPTION

Kendall Bay is located on the southern side of the Parramatta River, approximately 9 km west of the Sydney CBD and within the Canada Bay local government area to the north of the suburb of Cabarita. The Breakfast Point residential development is located along the western and southern shoreline and Cabarita Park is along the eastern shoreline of the Kendall Bay.

A corridor of open space including a paved pedestrian pathway runs around the foreshore of the bay from the Cabarita Ferry Wharf to Breakfast Point. The pedestrian pathway continues along the foreshore from Breakfast Point to the end of Tennyson Road, Mortlake. Garden beds are located between parkland/residential areas and the foreshore at the head of Kendall Bay.

The terrain within the land adjacent to Kendall Bay is relatively level with higher ground located along Cabarita Road to the east and the Country Club on Village Drive to the southwest. Overland flow paths for stormwater include shallow gullies along the northern and eastern edges of Waterfront Park, and surface runoff down the western slope of Cabarita Park. Land adjacent to the western foreshore is relatively flat. Groundcover on the slopes of Cabarita Park is patchy with areas of exposed soil and gravel. All remaining open space areas are protected from erosion as a result of well-maintained lawns/grass in parklands or gardens stabilised with mulch.

The former River Quays site at 140 Tennyson Road, Mortlake was a marina but has been acquired by Jemena and is proposed to be used at the Staging Site to facilitate the treatment and transport of materials to and from the Remediation Areas, as required. This site is located on the southern shoreline of Fairmile Cove within the Parramatta River and situated approximately 1 km north-west of the Remediation Areas in Kendall Bay. For the purpose of this RAP, this site is referred to as the Staging Site.

Further details can be found in Royal HaskoningDHV (2016a).

4.1.1 Project Area

Collectively, the project area (Figure 4.2) includes the proposed:

- Remediation Areas;
- Staging Site; and
- Declared Area.

Remediation Areas

The project will involve the remediation of gasworks-contaminated sediments within two defined areas within Kendall Bay (see Chapter 7) referred to in this document as the Southern and Northern Remediation Areas.

Staging Site

Treatment of contaminated sediment, if required, will occur at the Staging Site at 140 Tennyson Road. The Staging Site provides direct access to the Parramatta River, which is strategically important as it enables ready access to Kendall Bay, without the reliance on adjoining public or other land. All plant and equipment to be utilised as part of the project will be transported to and from the Staging Site and subsequently from the Staging Site to and from the Remediation Areas.

Existing facilities at the Staging Site include several large warehouses (previously used for ship repair), a foreshore hardstand area, a concrete piled wharf structure, a number of mooring piles and several gangways providing access to floating pontoons.

The terrain around the site is relatively level and developed, with the Mortlake – Putney car ferry access and an adjacent repair yard to the immediate west, and several other businesses occupying the western side of Tennyson Road. Housing associated with the Breakfast Point development adjoins the eastern boundary of the Staging Site, which also marks the end of the foreshore reserve area and pedestrian pathway. The foreshore in the immediately vicinity of the Staging Site is protected by a facing of mortared sandstone blocks with rock toe protection, which appears to be of similar construction to the older seawall structure found around the head of Kendall Bay.



Declared Area

The EPA Declared Area encompasses the route vessels will take to facilitate the transport of sediments and other materials removed from the Remediation Areas to the Staging Site and solidification materials and clean sand and rocks to the site. Excavated materials will be transported via barges to the Staging Site for onshore transfer, treatment, storage and disposal, where required.

A rock platform extending along the eastern side of Kendall Bay is gradually covered with sandy sediments to the south, forming a shallow beach in the south-eastern corner of the bay. The nearshore beach slope at this location is around 1V:8H. The sandy sediments continue into the eastern side of the stand of mangroves at the head of the bay. Within the mangroves area the bed transitions into silty sand with shell and gravel of coal and fill (Figure 4.3).

4.1.2 Shoreline Conditions

The foreshore areas of Kendall Bay are relatively shallow and intertidal with seabed levels above LAT. At the head of the bay the foreshore slopes through the intertidal zone at a gradient of around 1V:20H (vertical to horizontal) and then flattens to slopes of up to 1V:100H throughout the middle of the embayment.

Several foreshore protection structures exist behind the shallow intertidal area of Kendall Bay. A low-level sandstone block wall in the south-eastern corner of the bay acts as a retaining wall adjacent to the promenade along the foreshore. This structure is terminated by a concrete wall on the eastern side of the mangrove stand. Beyond this point the mangroves are backed by a 1V:1H revetment formed by a facing of mortared

Figure 4.2. Staging Site and Declared Area



Source: URS 2007a



Figure 4.3. View from the eastern foreshore to the head of Kendall Bay looking west, showing the beach and mangroves. Note outcrops of Hawkesbury Sandstone on which green alga have developed.



Figure 4.4. View of sloped revetment located to the west of the mangrove stand (located within Proposed Remediation Areas SA1, SA2 and SA3).



sandstone blocks (Figure 4.4). The toe of the revetment appears to be protected by rip-rap, generally less than 100 mm in diameter, while bricks have been deposited along its base in the south-western corner of the bay.

The sloped revetment transitions into a near-vertical sandstone block seawall at the location of a stormwater outlet extending through the seawall along the western foreshore of the bay (Figure 4.5). This structure continues north to the site of the former coal wharf. Angular basalt rip-rap has been placed along the toe of the seawall at a slope of between 1V:3H and 1V:5H and sized from 50 mm to 200 mm. At the site of the former coal wharf (Figure 4.6) the rip-rap mound appears to comprise larger rock of between 200 mm and 400 mm diameter. Remnants of the demolished coal wharf structure (rubble and cut off concrete piles) are visible below the water surface.

The vertical seawall transitions into a sloped rock revetment of relatively recent construction approximately 250 m south of the tip of Breakfast Point (Figure 4.7). At the tip of Breakfast Point a vertical blockwork seawall has been constructed to retain a terraced pedestrian walkway (Figure 4.8). This structure appears to be built on a foundation formed by a bedrock outcrop and continues around the tip of Breakfast Point before transitioning back to a sloped rock revetment similar to the one on the western side of Kendall Bay.

4.2 CURRENT AND FUTURE USE OF KENDALL BAY

4.2.1 Navigation

The primary navigation route in the area is the main channel of the Parramatta River, located to the north of Kendall Bay and within Fairmile Cove, which has depths generally between 5 m and 20 m. A port hand mark is located approximately 20 m to the north-east of Breakfast Point, and an east cardinal mark is located within Kendall Bay, both delineating shallow bathymetry of typically less than 2 m below LAT.

A floating pontoon ferry wharf (Cabarita Ferry Wharf) and a single lane public boat ramp are located at Cabarita Point on the eastern side

of Kendall Bay. A Roads and Marine Services (RMS) slipway to service vehicular ferries, plus the Mortlake vehicular ferry landing and the former River Quays marina (now referred to as the Staging Site), are located on the western side of Fairmile Cove. Twenty commercial swing moorings within Fairmile Cove are leased to a private company. About 50 m downstream of the old River Quays marina, and 20 m from shore, a wreck (the *Lady Edeline*) is partly visible at lower tides, and is marked with white marker buoys (Figure 4.9).

4.2.2 Vessel Use

Existing vessel and small craft use within Fairmile Cove includes:

- public passenger ferry;
- Mortlake ferry;
- rowing boats;
- dragon boats;
- sail boats;
- kayaks;
- recreational power boats; and
- swing moorings.

The shallow waters of Kendall Bay and the exposure of sediments at low tides preclude the use of most of the bay other than for occasional use by kayakers and some other shallow-draft vessels. Use of the deeper water within Kendall Bay is restricted by the movement of ferries, as described below.

Ferries

The Sydney Ferries service between Circular Quay and Parramatta stops at Cabarita Wharf and uses Rivercat and Harbourcat class ferries. These vessels are around 35 m in length, and have a service speed of 22 knots and a displacement of 58 tonnes. The downstream ferry route starting at Parramatta follows the main channel until it passes Breakfast Point, and then cuts across outside the mouth of Kendall Bay into the Cabarita Wharf. From the wharf, the ferry continues downstream towards Circular Quay via the main channel. Ferries travelling upstream (Circular Quay to Parramatta) follow a similar route.

Other harbour-based passenger cruise vessels also use this stretch of river but generally do



Figure 4.5. View of sloped seawall in Southern Remediation Area.



Figure 4.6. Rip-rap and rubble at location of demolished former coal wharf located within the proposed Remediation Area NA2+NA3.



Figure 4.7 Transition between sandstone block seawall and sloping rock revetment looking north towards Breakfast Point. Note small beach midway.



Figure 4.8 Vertical block seawall at Breakfast Point.

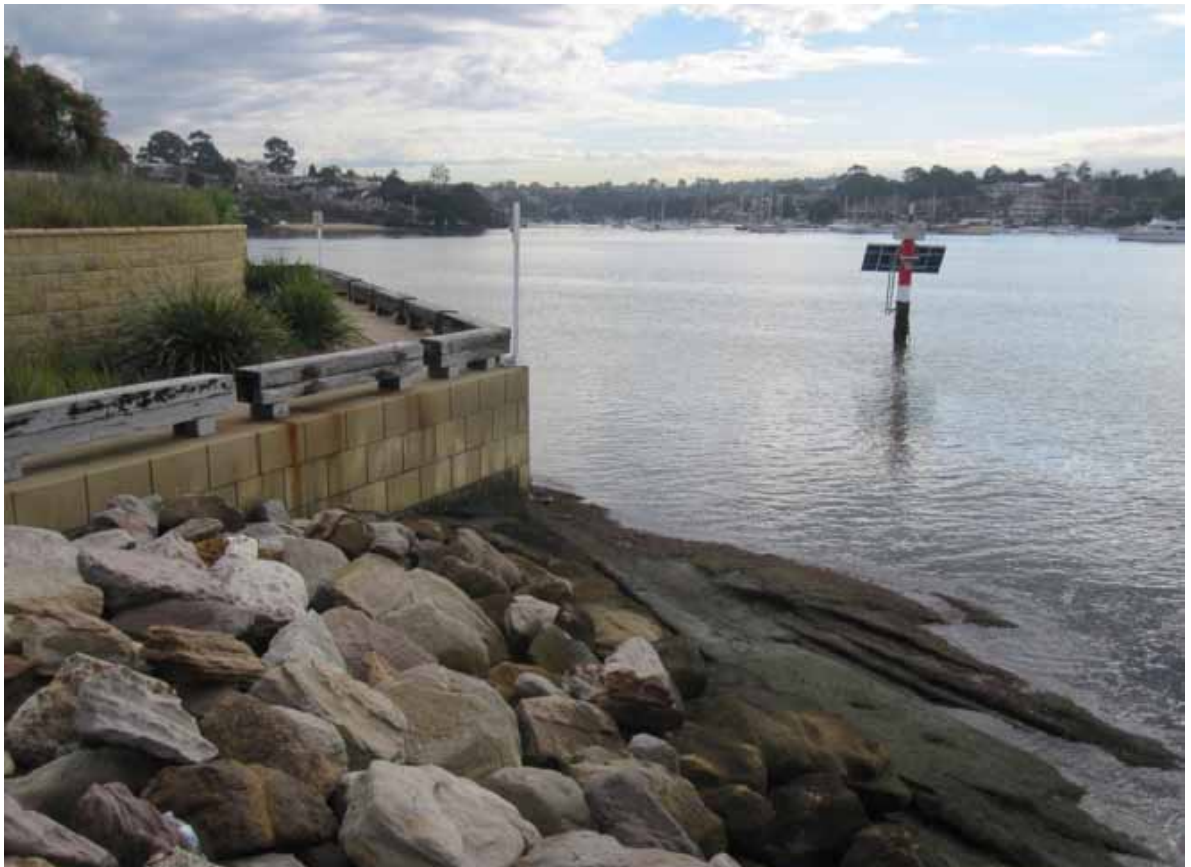




Figure 4.9 Old River Quays Marina (while still in operation) with the Lady Edeline wreck in the foreground.



not deviate from the main channel due to the generally shallow waters of Kendall Bay.

The Mortlake Ferry (known to locals as the Putney Punt), a vehicular ferry operated by RMS, began operating in the 1920s and is the only remaining punt in the Sydney metropolitan area. It crosses the Parramatta River from Hilly Street, Mortlake to Pellisier Road, Putney, taking 5 minutes to make the 300 m crossing. The ferry has a capacity of 15 cars, accepts passengers and does not charge for its service. The ferry is approximately 35 m in length, has a displacement of 71 tonnes and is operated on twin cables from its respective landings. A speed limit of 4 knots applies to all vessels within 100 m of the ferry and its cables while in operation.

A slipway located immediately downstream of the Mortlake approach ramp is used for the maintenance of all the RMS-owned vehicular ferries operating in the greater Sydney area and surrounds.

Other Vessels

The Sydney Rowing Club, and several school rowing sheds, are located downstream of Kendall Bay in the Abbotsford and Gladesville areas. The Sydney Rowing Club confirmed that their rowing routes do not enter Kendall Bay and Fairmile Cove, but stay within the main channel.

The Sydney Dragon Boat Club Association (based at Rhodes) confirmed that they rarely venture as far downstream along the Parramatta River as Kendall Bay.

Abbotsford 12 ft Sailing Club is situated on the Parramatta River at the end of Great North Road, Abbotsford and generally operates every Saturday. The Vice President of the sailing club advised that the sailing club does not use Kendall Bay or Fairmile Cove.

Kayakers are known to enter Kendall Bay and Fairmile Cove from time to time but these waterways are not considered to be popular kayaking areas as no known kayak rental locations are close by and sediments are exposed at low tides. Jolly Roger Kayaks, who run kayak tours across Sydney (including the Parramatta River) state on their website that the general area around Kendall Bay and Fairmile Cove is a restricted zone for their tours due to the potential danger presented by the Mortlake Ferry.

Recreational power boats are known to enter the Kendall Bay and Fairmile Cove from time to time but these locations are not considered to be popular boating areas. In discussions with a local resident, it is understood that power boats launched at the public boat ramp at Cabarita Park tend to head directly to the deeper water within the main channel.

The River Quays swing moorings are located immediately downstream of the old River Quays marina. They cover an area of around 200 m by 100 m, and are approximately 50 m from shore in water depths of 3-10 m. The vessels on the moorings are a mixture of small sailing and powered vessels, and are rarely used.

4.3 SURROUNDING LAND USE

The land immediately surrounding Kendall Bay comprises a constructed western shoreline consisting of a walkway, with a medium density residential backdrop situated on the former gasworks site (the development forming Breakfast Point). The southern shoreline area consists of an intertidal beach and mangroves and is more 'natural' in comparison to the western shoreline. The eastern shoreline largely consists of rock outcrops and smaller pockets of mangroves.

Cabarita Park is located to the immediate east of Kendall Bay with internal access roads and picnic areas extending throughout the parkland.

The Parramatta River is located to the north of Kendall Bay. A mixture of both powered private and commercial vessels is used on the waterway along with unpowered craft such as kayaks, row boats and small yachts. Large passenger ferries also operate along the river between the Sydney CBD and Parramatta.

Breakfast Point is situated to the immediate west of Kendall Bay and consists of residential dwellings, predominately attached medium-density dwellings and residential apartment buildings.

Kendall Bay can be accessed by pedestrians utilising the shared pathway that leads from Cabarita Point to Breakfast Point, and there is a public boat ramp adjoining the public wharf towards the north-western corner of Cabarita Park.

The Staging Site is adjoined by the Parramatta River to the north and north-east, light industrial buildings to south and west, and residential dwellings generally located slightly beyond the marina site to the north-west and south-east.

4.4 BATHYMETRY, TIDES, CURRENTS AND WAVES

4.4.1 Bathymetry

Kendall Bay is a shallow embayment on the southern foreshore of the Parramatta River. The head of Kendall Bay faces north and the bay itself is formed by Breakfast Point on its western foreshore and Cabarita Park and Cabarita Point on its eastern foreshore (Figure 4.10).

The main channel within the Parramatta River runs across the entrance to Kendall Bay and, according to the current Admiralty Chart (Aus 203), has depths adjacent to Kendall Bay ranging between 6.0 and 8.4 m below chart datum (CD). The Parramatta River channel has several deeper areas with depths between -16.1 m CD and -15.6 m CD between Breakfast Point and Raven Point, and down to -21.1 m CD opposite Cabarita Point.

Within Kendall Bay the bathymetric levels are typically less than -2 m CD except in the vicinity of the former coal wharf on the western foreshore, where a channel and berthing areas were dredged to provide shipping access from the wharf to the main channel of the Parramatta River.

The detailed bathymetry of Kendall Bay (Figure 4.11), which comes from a hydrographic survey by Hydrographic & Cadastral Survey Pty Ltd on 5 June 2014, shows surveyed depths relative to CD. The location of the former wharf is marked by a prominent elongated mound rising up to 2.5 m above the dredged areas to the north, south and east.

4.4.2 Tides, Storm Surge, Sea Level Rise and River Flooding

Tides

Water levels within Kendall Bay vary primarily in response to astronomical tides, although storm surge (barometric and wind set-up) and freshwater flooding may also influence water levels from time to time. Sea level rise will have a long-term effect on water levels.

Kendall Bay is subject to semi-diurnal tides (i.e. two high tides and two low tides per day) that propagate along the Parramatta River from the estuary mouth at Sydney Harbour. The predicted tides for Cabarita (near Kendall Bay) derived by the MSB Sydney Ports Authority in 1995 are provided in Table 4.1.

Table 4.1. Predicted tidal planes for Cabarita.

Tidal Plane	Water Level (m CD)
Highest Astronomical Tide	2.1 (Fort Denison)
Mean High Water Springs	1.64
Mean High Water	1.51
Mean High Water Neaps	1.38
Mean Tide Level	0.98
Mean Low Water	0.39
Mean Low Water Springs	0.27
Lowest Astronomical Tide	-0.003 (Fort Denison)

Source: Royal HaskoningDHV 2016a



Figure 4.10. Admiralty chart for Project Area (Aus 203) Note location of former wharf (demolished) near Remediation Area NA1.

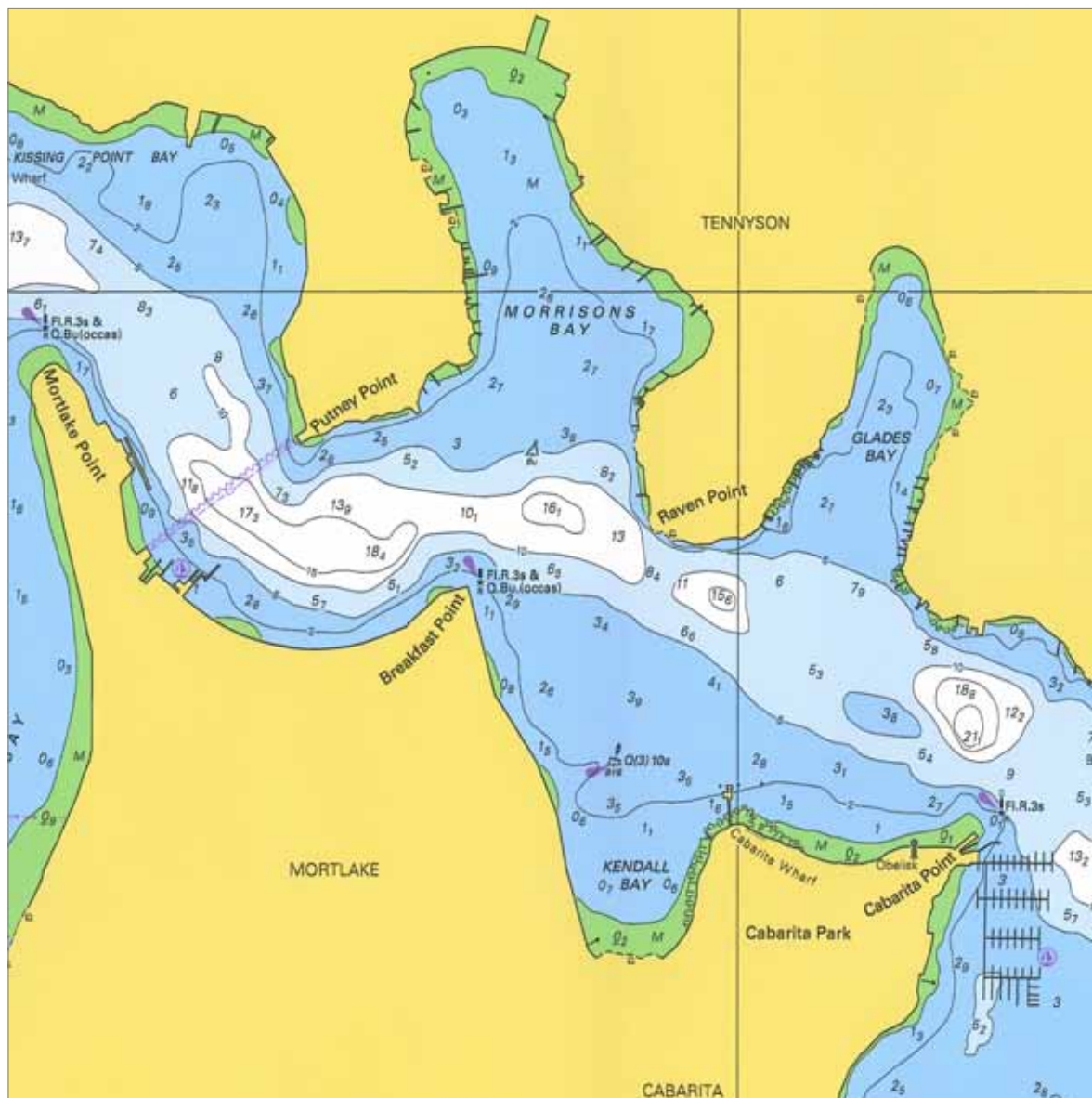


Chart Datum is approximately the level of Lowest Astronomical Tide (LAT) and is approximately 0.9 m below Australian Height

High and low tides at Cabarita were reported to lag the corresponding high and low tides at Fort Denison by approximately 9 and 7 minutes respectively.

Storm Surge and Wave Setup

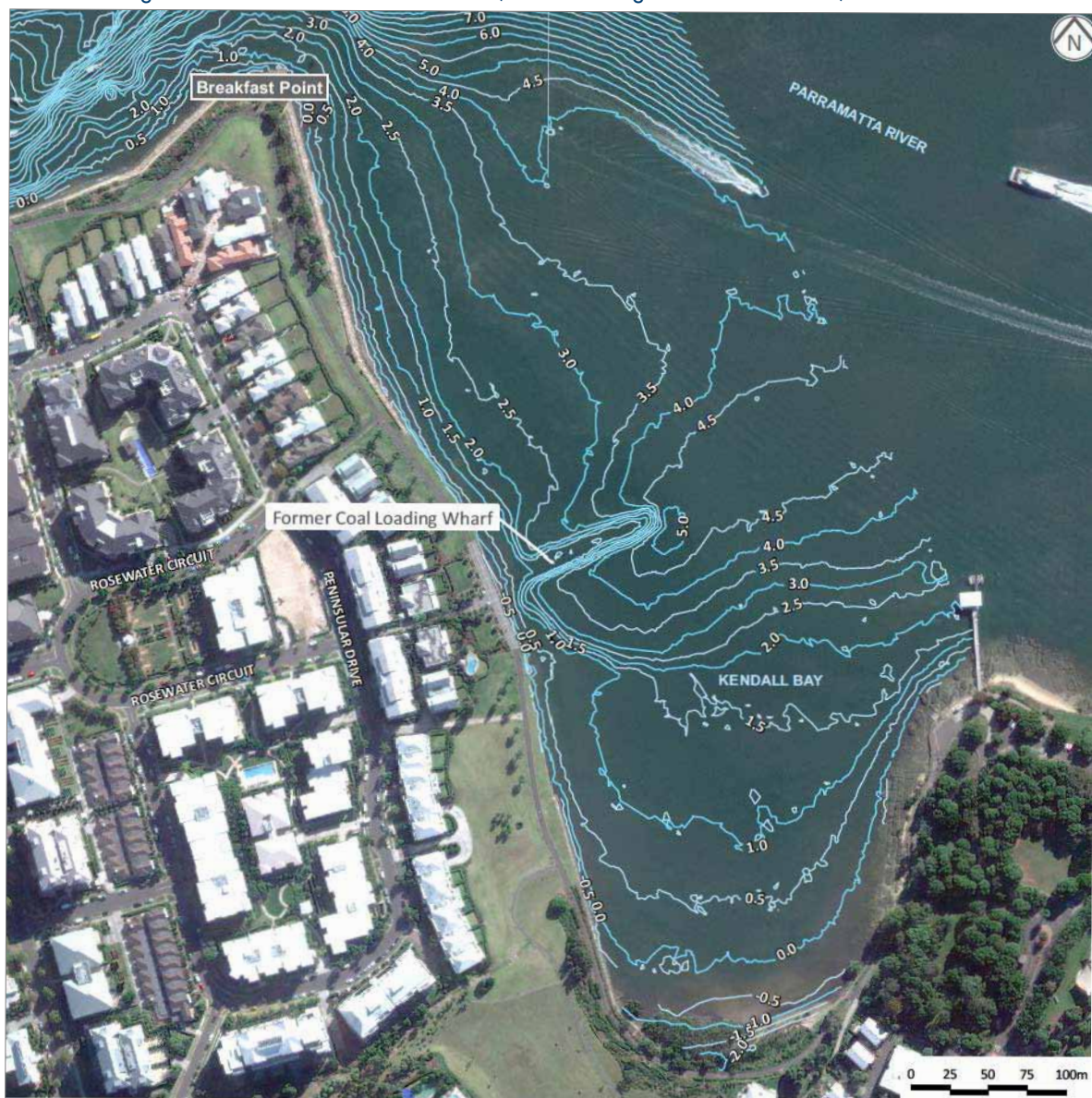
The combined effect of barometric pressure setup and wind stress setup is referred to as storm surge. Barometric pressure setup refers to the increase in mean sea level caused by a drop in atmospheric pressure, such as when a low-pressure system is centred over an area. Wind stress setup is the increase in mean sea level caused by the 'piling up' of water on a shoreline by wind action acting on the water surface.

DECCW (2010) has provided design ocean still water levels for the NSW coast at 2010, 2050

and 2100 (for various average recurrence interval (ARI) events, Table 4.2). These water levels include allowances for astronomical tide, design barometric setup and wind setup, and future sea level rise. (Note, the values adopted for sea level rise between 2010 and 2050, and 2010 and 2100, were 0.34 m and 0.84 m respectively and remain suitable for adoption for current planning purposes.) Given the similarity of the tidal levels between Cabarita and Fort Denison, these values are considered to be reasonable for application at the Kendall Bay remediation site.

The above water levels exclude the effects of wave setup, which have to be assessed separately from a consideration of the wave climate at the particular site of interest.

Figure 4.11. Bathymetry of Kendall Bay and nearby Parramatta River, 2014 (depths in metres). Note the prominent mound marking the location of the former coal wharf, and the dredged areas to the north, south and east.



Source, Hydrographic & Cadastral Survey Pty Ltd, 2014

Table 4.2. Design still water levels at Fort Denison (DECCW, 2010)

Average Recurrence Interval	2010		2050		2100	
	m AHD	m CD	m AHD	m CD	m AHD	m CD
Years						
0.02	0.97	1.90	1.31	2.24	1.81	2.74
0.05	1.05	1.98	1.39	2.32	1.89	2.82
0.1	1.00	1.93	1.44	2.37	1.94	2.87
1	1.24	2.17	1.58	2.51	2.08	3.01
10	1.35	2.28	1.69	2.62	2.19	3.12
50	1.41	2.34	1.75	2.68	2.25	3.18
100	1.44	2.37	1.78	2.71	2.28	3.21

Source: Royal HaskoningDHV 2016a



Wave setup at the shoreline is approximately 10-15% of the breaking significant wave height. For the worst case 20-year ARI wind wave conditions the wave setup is estimated to be between 0.09 m and 0.13 m. For the worst case 1-year ARI wind wave conditions the wave setup is estimated to be between 0.07 m and 0.10 m.

Freshwater Flooding

The Lower Parramatta River Flood Study (PWD, 1986 as cited in Royal HaskoningDHV 2016a) reported that flood levels between the Silverwater Bridge and Ryde Bridge (downstream limit of the study area) were determined by the adopted storm tide level and were not influenced by river discharge. A similar approach was adopted in the subsequent update to the flood study completed in 2005 (SKM, 2005).

4.4.3 Currents

Currents within Kendall Bay and surrounding areas can be generated by:

- tides;
- freshwater flows;
- wind;
- boat wash; and
- stormwater inflows.

Tidal Currents

An investigation into tidal currents was undertaken as part of the Environmental Risk Assessment (URS, 2006), which included an Acoustic Doppler Current Profiler survey of several transects across the Parramatta River including areas of Kendall Bay and Fairmile Cove. It was reported that water velocities are generally low and complex at high (slack) tide with velocities less than 0.2 metres per second (m/s). During the peak ebb tide, currents of up to 0.7 m/s were measured in an east south east direction off the end of Breakfast Point and were expected

to be of a similar magnitude during flood tides. Tidal currents were observed to be confined to the main channel through the Parramatta River and the higher velocity ebb tide currents recorded off Breakfast Point did not extend into the shallow waters of Kendall Bay. Tidal currents within Kendall Bay were generally recorded between 0.2 – 0.3 m/s on the ebb tide. Ebb tide currents within Fairmile Cove were around 0.15 m/s.

Freshwater Flows

Currents resulting from freshwater flows are expected to be confined to the main channel of the Parramatta River and would not exceed peak tidal flows.

Wind-Induced Currents

Wind-induced currents can be generated by the action of surface shear (unidirectional currents) or wave action (oscillatory currents).

Unidirectional surface currents can be induced by surface shear of winds up to 7 m/s before the surface response becomes oscillatory and wind waves are generated (Limnology and Oceanography, 1951). These unidirectional surface currents can reach 1 to 2% of the wind speed, giving a maximum potential velocity of around 0.15 m/s.

Oscillatory currents from wind wave action vary according to the water depths within the bay. Table 4.3 summarises the calculated near bed (50 mm above the bed) horizontal velocities generated by the worst-case north north west wind wave conditions for water depths of 3 m, 2 m and 1 m.

Boat Wash

Oscillatory currents generated by boat waves have been determined using the wake typically

Table 4.3. Maximum horizontal wind wave-induced currents at the bed

Design Event	Wave Height (m)	Wave Period (s)	Maximum Nearbed Current Speed (m/s) at Water Depth		
			3m	2m	1m
1-year ARI (NNW)	0.56	2.15	0.11	0.25	0.57
20-year ARI (NNW)	0.72	2.34	0.20	0.38	0.78

Source: Royal HaskoningDHV 2016

produced by Rivercat vessels passing the site on a daily basis. If a wave height of 0.3 m and wave period of 7 seconds is adopted, then at water depths within the bay of 3 m, 2 m and 1 m the corresponding near-bed (50 mm above the bed) currents would be 0.27 m/s, 0.37 m/s and 0.63 m/s respectively.

Stormwater Inflows

There are a number of stormwater outlets flowing into Kendall Bay. These have the potential to generate localised currents from the entry of strong freshwater flows into the shallow water environment of Kendall Bay.

The main stormwater inflow is at the head of the bay where a 1650 mm diameter pipeline exists (Figure 4.12). The catchment of this drain is approximately 75 hectares. However, this pipeline flows into a large basin constructed from gabion baskets which would act to dissipate the energy of stormwater flow. During a site inspection under low flow conditions, a shallow incised channel was observed leading from the outlet through the sandy substrate within the mangrove stand (Figure 4.13).

During a site inspection after a major storm event in June 2016, significant erosion of the channel sediments was observed along the channel between the outfall and the shoreline, including excavation of pools more than 0.6 m deep and 2-4 m long. The inspection noted that despite the very large volumes of water that discharged in to the mangrove stand during the rainfall event of June 2016, the mangroves were not undermined (Figures 4.13 and 4.14).

The north-easterly channel across the tidal flat was also enlarged after the storm event, and much of the sediment surface covered in a mat of wood fibres (Figure 4.15).

Other stormwater outlets discharging into Kendall Bay include one located at the northern end of the revetment on the western side of the bay and two outlets in the seawall on the eastern side of Kendall Bay which discharge onto the sandy beach area. Additional stormwater outlets enter the bay and the Parramatta River from Cabarita Park.

At the Staging Site, several minor stormwater pipes protrude through the seawall structure located at the eastern side of the site and are understood to drain rainwater collected from the roof of the warehouse building. Five surface inlet pits exist over the hardstand area which are likely to have been part of a first flush drainage system (draining to a central sump) for the former marina. A drain protruding through the seawall at the eastern boundary of the Staging Site is part of the public drainage network and receives stormwater runoff from inlet pits along Tennyson Road.

4.4.4 Waves

The wave climate within Kendall Bay is influenced by wind waves and boat-generated waves.

Wind Waves

Kendall Bay is exposed to overwater wind directions (i.e. wind fetches) in the sector between the north-north-west and easterly directions. A selection of worst case wind fetches within this sector have been defined to develop design wind wave conditions for 1-year ARI and 20-year ARI wind speeds. The 1-year ARI wave provides an indication of conditions that may occur at least once during the construction period. The 20-year ARI wave represents the design condition for 'temporary works' in accordance with Australian Standard *AS 4997 - 2005 Guidelines for the Design of Maritime Structures*.

The wind wave climates for the 1-year ARI and 20-year ARI design events are summarised in Table 4.4 for the critical wind fetches into Kendall Bay. The wave climates have been calculated using the procedures for shallow water wind wave prediction within the *Shore Protection Manual* (SPM, 1984 as cited in Royal HaskoningDHV 2016a) with input wind data from *AS 1170.2 - 2011 Structural Design Actions - Part 2: Wind Action*.

The above results indicate that the worst-case wind wave would be generated from a NNW wind, giving a significant wave height (H_{m0}) of around 0.56 m and peak wave period (T_m) of around 2.15 seconds in the case of a 1-year ARI design event.

Figure 4.12. 1650 mm stormwater outlet at the head of Kendall Bay



Figure 4.13. Shallow channel leading from 1650 mm stormwater outlet



Figure 4.14. Erosion around mangroves below stormwater outlet after major storm event, June 2016 (Remediation Area SA 3)



Figure 4.15. Enlarged channel below stormwater outlet after major storm event, June 2016 (Remediation Area SA3)





Boat-Generated Waves

Waves generated by boat traffic provide a significant contribution to the daily wave climate experienced within Kendall Bay. This is particularly relevant to the Rivercat and Harbourcat ferries that run services through the main channel of the Parramatta River and pass Kendall Bay a number of times each day. The typical magnitude of waves generated by passing boat traffic was reported in an assessment by gbaCOASTAL Pty Ltd (GBAC, 2009 as cited in Royal HaskoningDHV 2016a) as part of an environmental assessment submitted for the proposed Inner West Marina at Breakfast Point. A compilation of wave conditions was presented in this report and is reproduced in Table 4.5.

Review of the 2016 ferry timetable determined Cabarita Ferry Wharf receives 25,608 ferries annually. Recreational boat ownership in Sydney Harbour has been reported to have increased by 1.3 % annually between 1999 and 2009 (NSW Maritime, 2010 as cited in Royal HaskoningDHV 2016a) which would increase the number of passings from this type of craft. However, this is not considered to be material for the current assessment as ferries pass closer to Kendall Bay on a regular basis to service the Cabarita Ferry Wharf and are considered to be the main source of boat-generated waves within Kendall Bay

Table 4.5 indicates that the height of waves generated by passing vessels is similar to those from more regular wind wave events. However, the wave period generated by Rivercat and Harbourcat vessels is much longer and would therefore impart more wave energy into Kendall Bay. Although the near-field boat wave conditions would reduce with distance from the sailing line (or path) of vessels, the near-field wave energy generated from ferries would effectively be delivered unattenuated into Kendall Bay when these vessels access Cabarita Ferry Wharf.

4.5 GEOLOGY AND HYDROGEOLOGY

4.5.1 Geology and Geomorphology

Sydney Harbour lies in the Sydney Basin, an elongated structural basin consisting of sedimentary rocks of Permian and Triassic age. The main rock types present along the harbour are the Hawkesbury Sandstone and the overlying Ashfield Shale of the Wianamatta group. Only the Hawkesbury Sandstone outcrops at Kendall Bay, although a small patch of Ashfield Shale is present in the south-western corner of the Breakfast Point site (Dames & Moore, 1996). Quaternary alluvium also occurs in and near many of the bay ends of the Parramatta River.

Table 4.4. Wind wave climate

Wind Direction	Fetch Description	Fetch	Average Depth	1-year ARI		20-year ARI	
		m	m	HmO ¹ (m)	Tm ² (s)	HmO (m)	Tm (s)
NNW	From head of Kendall Bay into Morrisons Bay	1600	5	0.56	2.15	0.72	2.34
N	From Northern Remediation Area into Morrisons Bay	1250	5	0.51	1.99	0.65	2.18
NNE	From head of Kendall Bay into Glades Bay	1300	5	0.51	2.02	0.67	2.20
NE	From Northern Remediation Area to Gladesville foreshore	800	5	0.42	1.75	0.54	1.91
E	From Northern Remediation Area to Looking Glass Point	1050	5	0.47	1.89	0.61	2.07

¹ HmO is the spectrally based significant wave height and is four times the square root of the variance of the sea surface variation. HmO is approximately equal to the significant wave height (Hs) in deep water.

² Tm is the period of the peak of the wave energy spectrum.

Source: Royal HaskoningDHV 2016

The original Mortlake gasworks site was greatly enlarged by reclamation up to the 1940s. Figure 4.16 shows the approximate original shoreline. Kendall Bay originally extended south-west into the gasworks for more than 150 m but the creek was dammed for water supply and the bay end subsequently reclaimed.

4.5.2 Hydrogeology

The hydrogeology of the former gasworks site was described in the EIS for the Mortlake Rehabilitation Project (Dames & Moore, 1996), based on data from many monitoring wells. The following information has been summarised from that EIS, however, it should be noted that rehabilitation works since that report are expected to have modified local disturbances in the groundwater flow field that resulted from local historical recharge sources associated with the former gasworks at the site.

A more uniform groundwater flow field would be currently expected across the Breakfast Point redevelopment site. The overall groundwater flow direction will have remained the same, with discharge occurring to Kendall Bay in the area of interest. Only targeted groundwater information has been collected at the site following the redevelopment and on that basis a site-wide assessment of the current status of groundwater is not possible.

Permeability

The permeability of both the fill materials and sandstone bedrock was described as 'highly variable' (Dames & Moore, 1996). The permeability of the placed fill materials largely depends on the type and layering of materials within the fill, while the permeability of the sandstone bedrock is likely to be controlled by the presence of structural defects within the rock mass in the form of fracture zones, joints and faults. The permeability of the fill materials is several orders of magnitude higher than the sandstone.

Tests in the fill material showed a range of permeability from 0.007 m/day to 56.3 m/day, with an average of 19.2 m/day. The results from wells screened in sandstone or drawing water only from sandstone ranged from 0.00003 m/day to 0.4 m/day, with an average of 0.09 m/day. The vertical permeability of the sandstone is likely to be considerably lower than the measured horizontal values due to the strong bedding in the sandstone.

Groundwater Levels

The general features of the interpreted groundwater flow regime were as follows:

- groundwater levels ranged from close to, or slightly below mean sea level, in the foreshore area, to a maximum of 17.5 m Australian Height Datum (AHD) on the southern up-

Table 4.5. Design near-field boat wave climate

Boat Type	No. Passings per Year	Typical Maximum Wave Conditions		Root-Mean-Square Typical Maximum Wave Conditions	
		H max (m)	T (s)	H max (RMS)	T (s)
Recreational Power Craft	71,000	0.2 – 0.4	1.5 – 2.5	0.27	2.0
Ferries (Rivercats and Harbourcats)	25,000	0.25 – 0.35	6 - 8	0.3	7
Charter Vessels	3,500	0.3 – 0.4	2.0 – 2.5	0.35	2.2
Work Boats	3,600	0.2 – 0.4	1.5 – 2.5	0.30	2.0

1 Based on Parramatta River boating surveys reported in 2001, scaled up to 2009 according to trends in NSW boating registrations 1991-2006. Ferry movements from April 2009 Sydney Ferries timetable for Parramatta River service.

2 Typical maximum wave conditions interpreted from GBAC database including WA (2001) and Blumberg et al (2003). Typical operating speeds are assumed.

3 Root Mean Square (RMS) wave conditions assessed by GBAC. These related to average wave energy conditions. H max(RMS) for recreational power craft based on an assessment of waves generated by the expected range of actual vessel sizes and their distribution within the traffic profile, simulated using registration statistics.

Source: Royal HaskoningDHV 2016a

[illegible]

40

gradient boundary of the Breakfast Point site near Tennyson Road;

- the general direction of groundwater flow was from south to north, discharging along the foreshore zone;
- the groundwater level in two foreshore wells on the Breakfast Point site was less than mean sea level reflecting tidal influences in the foreshore region. Foreshore groundwater levels were found to fluctuate according to local tidal levels;
- groundwater levels around the former dam were controlled primarily by the water level in the dam;
- groundwater levels in the south-western portion of the Breakfast Point site may have been influenced by high levels of water stored in the annuli of the former Gasholders 1 to 4;
- groundwater levels around the carburetted water gas building towards the centre of the gasworks site may have been influenced by fluids contained in three underground tanks; and
- the hydraulic gradient was relatively low in the foreshore area, and steepened towards the south. The hydraulic gradient in the foreshore area (0 to 1 m AHD contour range) was in the range 1/50 to 1/100 or less. The hydraulic gradient across the central site area (1 to 10 m AHD) was typically 1/30 to 1/50.

Groundwater Flow Velocity

The velocity of groundwater flow has been estimated from the observed permeability and flow gradients. The flow velocity of groundwater in the fill is estimated to range between 1 to 2 m/day in the foreshore area where the flow gradient is lowest, to possibly locally 5 to 10 m/day in central and southern sections of the site where the flow gradient is steepest. The average flow velocity in the fill is estimated to be approximately 4 m/day. On this basis, the theoretical transit time for groundwater to flow through the fill, 600 m across the former gasworks site, would be about 150 days. Inferred groundwater level contours, based on monitoring in November 1995, are shown on Figure 4.17.

Theoretical groundwater discharge to the Parramatta River along the foreshore zone of a length of 1200 m and assumed average saturated

thickness of 1 m, would be approximately 5 L/sec (450 m³/day). In practice, other factors such as variations in fill compaction or low-permeability inclusions could limit groundwater discharges from the fill to the harbour to perhaps 1 to 2 L/sec (90 to 180 m³/day).

The groundwater flow velocity in the sandstone is estimated to be in the range of 0.1 m/day in the foreshore zone where the flow gradient is lowest, to a maximum of 2 to 3 m/day in the central and southern areas of the site where the gradient is steepest. The average flow velocity is approximately 0.2 m/day. On this basis, the theoretical transit time for groundwater to flow through the sandstone, 600 m across the site, would be approximately 8 years. The theoretical groundwater discharge would be 0.5 L/sec (45 m³/day) along a 1200 m foreshore boundary.

Groundwater Flow Regime

The main features of the groundwater flow regime within the fill materials at the former gasworks site are:

- groundwater in the fill does not form part of the regional groundwater table in the Mortlake area, and up-gradient inflows are not significant;
- groundwater levels in the fill are maintained by recharge from onsite rainfall, and from onsite sources, particularly the (former) dam and gasholders. Groundwater levels in the fill are locally 'perched' above the regional water level in the bedrock;
- outflows of groundwater from the fill occur at the foreshore, and groundwater levels in the fill are tidally influenced in the foreshore zone; and
- the fill is highly heterogeneous and the permeability is generally high. Groundwater velocities and flows in the fill are high relative to the bedrock.

4.6 SEDIMENTOLOGY OF KENDALL BAY

Numerous sediment sampling and testing programs have been carried out for Kendall Bay between 1989 and the present day. Sampling programs up to 2014 have been summarised in SKM (2014a, b). Recent investigations are described in Section 5.3.

THE AUSTRALIAN GAS LIGHT COMPANY
ENVIRONMENTAL IMPACT STATEMENT
MORTLAKE REHABILITATION PROJECT
SYDNEY, NSW

FIGURE 3.13
GROUNDWATER LEVELS

DAMES & MOORE 08051-038-371

FILE: AGL-ENV/ENG
DATE: 14/5/95

LEGEND:
Monitoring Well
Groundwater Collection Tank
Groundwater level (m AHD)
Inferred Contour of Groundwater Level (m AHD)

Screened in Fill
Screened in Sandstone/Sludg
Screened in Fill and Sandstone/Sludg

0 100 200m

42

4.6.1 Surface Sediments

Foreshore and Intertidal Areas

The foreshore areas in front of the seawall on the southern and western sides of Kendall Bay are covered in sandstone rip-rap, bricks, masonry and rubble. In the south-western corner of the bay, close to what was interpreted to have been a constructed drain discharging waste materials from the former dam to the south-western end of Kendall Bay, in the proposed SA1 and SA2 Remediation Areas, the seawall also contains scattered crusts of weathered tar.

On the mid-western side of the bay, at the location of the NA1 Remediation Area, the foundations of the former coal wharf are visible at the base of the seawall. Intertidal sediments in these areas are generally gravelly sands or gravelly muddy sands, the gravel-sized materials being comprised of shell, coal, coke and fill materials.

From the southern end of the bay eastward to the exposed rock platform in front of Cabarita Park, the foreshore is sandy and scattered with pieces of coal and other debris. A stormwater delta has formed north of the mangroves and consists of sands and silty sands.

The surface sediments in the mangroves are sands and muddy sands, often shelly, with gravel-sized coal, coke, rock fragments and, in places, fill materials.

Subtidal Sediments of Kendall Bay

Surface sediments throughout the majority of Kendall Bay are typically soft and structureless, olive grey or grey coloured muds or sandy muds, often containing small bivalve shells or shell fragments. The top few millimetres of sediment often comprises a pale brown floc which was easily disturbed and not always able to be recovered in grab or core samples. Sediments near the western shoreline are coarser, typically being muddy sands or sandy muds which often have a significant gravel fraction made up of shell, coal, coke, rock fragments and sometimes fill materials.

At some locations within the 2014 RAP Area A and Area B sites, gasworks-contaminated

sediments, comprising black coloured oily gravelly muds or muddy sands with a strong tar or hydrocarbon odour are present at the surface.

4.6.2 Subsurface Sediments

JK Geotechnics (2012, 2016) have reported on the stratigraphy of Kendall Bay sediments. The sequence from surface to depth is as follows:

- Unit 1 – Marine Muds, very soft clay to sandy clay, usually dark grey/black to green, includes ‘recent’ surface sediment of ‘jelly like’ hydrous brown to green sediment to about 0.2 m depth. Sometimes contaminated with gasworks wastes;
- Unit 2A – Silty Sands to Silty Clays, very loose to loose (sands) or very soft to soft (clays), black or dark grey where tar-contaminated, grading to lighter grey with depth:
 - the Unit 2A Sands and Silty Sands have formed in the intertidal zone at the south end of the bay and have a maximum thickness of approximately 1.2 m; and
 - the Unit 2A Silty Clays underlie the marine muds elsewhere in the bay and can be many metres thick in some south-western parts of the bay. The upper sections are often black and contaminated with gasworks wastes;
- Unit 2B – Clay to Clayey Sand, stiff grading to very stiff or hard with a firm surface zone, light grey with orange and red brown mottles; and
- Unit 3 – Sandstone Bedrock, with shale/laminate beds, some low to medium rock strength with occasional clay seams.

JK Geotechnics (2016) notes that sometimes the Unit 1 muds are overlain by Unit 2A sands. These sands (in the beach and stormwater delta areas) are not visible in the 1972 aerial photo (Figure 3.4) and have mostly been deposited since the gasworks closed. JK Geotechnics (2016) also notes that the Unit 1 and Unit 2A very soft clays are very similar in character and geotechnical characteristics, and it is appropriate to treat them as a combined material for geotechnical analysis. In some of the south-western parts of the bay the combined material is up to 10 m thick.



The upper 2-4 m of sediment, including the marine muds of Unit 1 as well as the soft silty clays in the upper part of Unit 2A, is often oily and has proven difficult to collect using push tube corers as it slides out through the core catcher. The nature and extent of these sediments within Kendall Bay has not been well documented in reports of investigations carried out prior to 2015.

4.6.3 Sediment Transport, Erosion and Deposition

Sediment Transport

As noted in Section 4.4.3, Kendall Bay is regularly subjected to boat wake waves made by Rivercat and Harbourcat movements along the Parramatta River and is also exposed to wind from the north west to the east, creating local wind-generated waves from these directions. Currents generated by this wave action are considered capable of mobilising the bed sediments. This is evidenced by the surface distribution of sediments in the bay – wave action at the shoreline margins has caused finer sediments to be winnowed out, carried offshore and deposited in the deeper, lower energy, environment leaving behind a sandy beach. Wave action, particularly from Rivercats and Harbourcats which is of longer wave period, is also capable of transporting sand-sized material alongshore in the shallow littoral zone.

Currents from tides and freshwater flooding are very low in magnitude (Section 4.4.3) and are not considered to have any significant influence on sediment transport within Kendall Bay.

Review of historical aerial photographs (Figures 3.1, 3.2, 3.4, 3.5 and 4.18) indicates that the beach and stormwater delta at the head of the bay have formed since the south-western end of the bay was enclosed after the late 1930s. These sediments are likely to be a combination of coarser sandy marine sediments transported to the head of the bay by wind and boat wake wave action, and sand-sized sediments from catchment sources delivered into the bay by stormwater discharges.

The south-western corner of the bay contains coarse sediment including an area of cobbles in the intertidal zone (Figure 4.4 and Figure 4.18). This area does not appear to support sediment deposition, probably due to the high wave energy and incident wave direction. The western shoreline is exposed to frequent ferry wake waves, which roll at an angle along the exposed face of the seawall and propagate into the south-western corner of the bay.

Figure 4.18. Aerial photographs of Kendall Bay in 1943 (left) and 2015 (right)

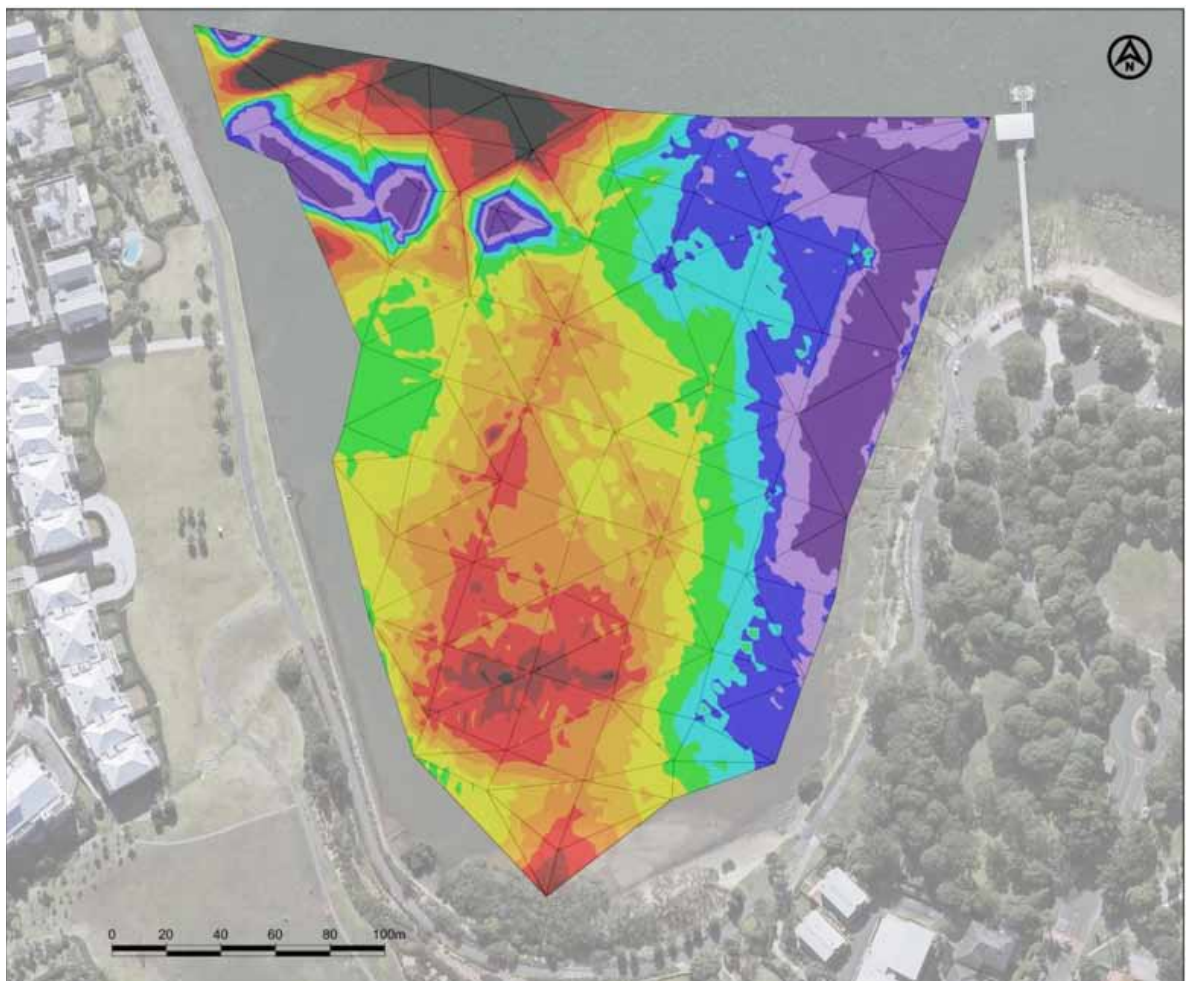


Sedimentation and Erosion

Comparison of historical hydrographic surveys indicates that the maximum average rate of sedimentation between 1956 and 2014 within the central subtidal areas of the bay was in the order of 10 mm to 14 mm per year. A plot of the depth differences between these surveys (Royal HaskoningDHV, 2016a) (Figure 4.19), indicates that deposition over this period had generally occurred in the central portion of the bay, whilst bed levels had become shallower along the eastern side of the bay.

This map provides a broad indication of sedimentation patterns, however the estimated sedimentation rates determined from hydrographic survey comparison are indicative only. Factors such as the accuracy of historic survey techniques, dredging, wharf and jetty demolition, construction of seawalls and stormwater outlets, and introduction of Rivercats and Harbourcats on the Parramatta River are likely to confound sedimentation estimates and result in variable sedimentation rates over time. The available hydrographic survey data does not have

Figure 4.19. Depth difference between 1956 and 2014 hydrographic surveys. Positive depth difference and warmer colours indicates sedimentation, cooler colours indicate erosion.



Source: Royal HaskoningDHV 2016a.



sufficient time resolution to capture this variability. Furthermore, the 1956 survey data provided by RMS was reported to comprise a compilation of several surveys completed pre-1995 (details of these surveys were not available).

The Parramatta River Estuary Data Compilation and Review Study (Cardno Lawson Treloar, 2008) reported that there was a paucity of information relating to infilling in the Parramatta River Estuary. Available data includes the documents following.

Irvine, 1980

Irvine (1980) reported that the average distribution of the Holocene (i.e. since the end of the last Ice Age) estuarine deposit in Sydney Harbour was 7 m, and this had accumulated over the 9000 years since most of the harbour flooded as sea level rose. This gave an average sedimentation rate of 0.8 mm per year, though before dewatering and compaction the annual rate would be considerably higher, and the author noted that sedimentation rates would have been higher in upper river channels.

The thickness of Holocene sediments in Kendall Bay (i.e. those sediments occurring above the distinctive firm, red- and yellow-mottled sandy clay that marks the erosion surface when sea level was low in the last Ice Age), based on the push-coring done, typically ranged from 2.5 to 11.5 m in the Southern Investigation Area and averaged around 7 m, excluding foreshore areas where bedrock outcropped. The Northern Investigation Area was dredged for the coal wharf and possibly the coke wharf as well so true depths of Holocene sediments cannot readily be determined.

Taking an average of 7 m of sediment deposition in the bay since it filled, which would have been around 8000 years ago when sea level reached within a few metres of its current level (Couriel et al., 2014), implies a deposition rate of 0.9 mm/year, although recently deposited sediments have a very high water content and before dewatering and compaction the annual rate would be considerably higher, up to 5 mm/year.

Irvine and Birch, 1998

Irvine and Birch (1998) inferred rates of sedimentation from analysis of sediment cores by identifying the depth of low heavy metal

concentrations and assuming that this represented the thickness of sediment deposited from the start of anthropogenic impact 150-200 years ago. This approach determined that sedimentation rates within Sydney Harbour were between 1.5 and 3.5 mm/year. These rates would be higher than the long-term rates reported above, because dewatering and compaction would be much less.

Other studies of sedimentation rates in Sydney Harbour have determined typical rates in the bays of 5 to 15 mm/year, and up to 25 mm/year near the mouth of stormwater canals entering bays (Dr Stuart Taylor 2016, pers. comm., 24 November 2016).

Having regard to the above, it is considered that the rates of sedimentation within subtidal areas of Kendall Bay, away from the immediate vicinity of stormwater outlets, are likely to be variable and lie in the range of 5-15mm/year.

4.7 SEDIMENT CHEMISTRY

4.7.1 Contaminants

Contamination in Parramatta River Sediments

Sydney Harbour is a drowned valley system and has deep channels, including the Parramatta River channel, but a shallow entrance. Because streams flowing into the harbour are small, flood flow has had little impact on the bed sediments. The sediments upstream of the harbour tend to be fine grained silts and muds which have acted as a pollution trap during more than two centuries of urbanisation and industrialisation.

It is known (Irvine, 1980; Irvine and Birch, 1998; Birch and Taylor, 2004) that the sediments of the Sydney Harbour system are contaminated with metals and organics from a wide range of historical industrial and urban sources. Contamination by metals extends to a depth of half a metre or more throughout much of the harbour, and much deeper in some places. Contamination, by a variety of heavy metals particularly mercury, copper, lead, zinc and chromium, in many locations greatly exceeds the ANZECC/ARMCANZ (2000) sediment quality guidelines as revised by Simpson et al. (2013a). The contamination tends to be highest in the ends of the many shallow bays away from the main channel, particularly on the south side, where fine

sediments accumulate, as well as next to long-term industrial pollution sources and stormwater inlets.

Other widespread contaminants in the Parramatta River, sometimes present at levels greatly exceeding the sediment quality guidelines, include organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), PAHs, TRH and dioxins. Due to stormwater flow and tidal action, these contaminants, which are largely attached to the fine fraction of the sediments, can be resuspended into the water column and transported both upstream and downstream of their original sources and points of deposition.

Previous work by Birch and others has also indicated that large areas of Parramatta River sediments show toxicity to aquatic organisms, however, attributing toxicity to any particular industry when there are so many potential sources, known and unknown, is extremely challenging (Birch et al., 2008).

Contamination in Kendall Bay Sediments

Numerous sediment studies of Kendall Bay and adjacent parts of the Parramatta River were carried out between 1989 and 2014, as part of the gasworks remediation investigations. Sediment studies of Kendall Bay between 1989 and 2002 showed that the sediments are contaminated with gasworks wastes, metals and other pollutants (Section 3.3 above and SKM 2014a, b).

The studies found that sediments in parts of the Remediation Areas A and B of the 2014 RAP were often black and oily, had a strong tar, hydrocarbon or naphthalene odour, and were characteristic of gasworks contamination. These sediments contained levels of PAHs and TRH greatly in excess of sediment quality guidelines. These highly contaminated sediments were found to be present to a maximum depth of more than 4 m in parts of Area B and a maximum of almost 8 m in parts of Area A (E3 Consulting, 2011, SKM 2014a).

The contamination in Area A of the 2014 RAP could have come from surface discharge or seepage down the bedrock valley that had been the former western end of the bay, which was partly reclaimed during the early history of the Mortlake gasworks and completely reclaimed by

filling with industrial waste and other materials in the late 1930s or early 1940s (Figure 4.16) (SKM 2014b). As described previously, the former large dam on the gasworks site subsequently became a repository for toxic wastes including tarry wastes from the 1940s onwards. This waste dam lay on the reclaimed bedrock valley and could have been a source of contamination to the bay until the gasworks site was remediated between 1999 and 2002. Figure 3.6 shows bedrock contours overlain over the gasworks site.

Contamination in Area B of the 2014 RAP could have come from loading operations at the former coal and coke wharves on the western side of the bay, including loading of tar barges from a tar pipeline which had (according to anecdotal reports from a former gasworks employee) overflowed into the bay on at least one occasion. The contaminants identified in Area B were notably more odorous than the contaminants identified in Area A.

The bay sediments also contain other contaminants, including heavy metals and metalloids, though in general the levels are not higher than levels in comparable background locations in the Parramatta River.

Between 2005 and 2007, investigations by URS (2006, 2007) delineated two areas of contaminated sediments that were stated to require remediation because they represented human health risks, principally due to the levels of carcinogenic PAHs. These areas included one at the southern end of the bay (Area A of the 2014 RAP) and one in the middle of the western side of the bay (Area B of the 2014 RAP). At the time of the investigations by URS, Area A did not include the mangroves (though potential human health impacts had been identified from the mangrove area).

Further investigations between 2009 and 2014 by SKM (2013, 2014a, b) and others obtained additional sediment data, refined the human health risk assessment, carried out an ecological risk assessment, and developed remediation criteria to mitigate the identified human health and ecological risks. Using these criteria, remediation Area A was enlarged from 8340 m² to 10 017 m² to include the mangroves, and Area B



enlarged from 957 m² to 3,604 m² to encompass a much larger area where sediments exceeded the ecological remediation criteria.

4.7.2 Acid Sulphate Materials

Acid sulphate soils (ASS) are naturally occurring soils and sediments which contain iron sulfide. On oxidation of the iron sulfides through disturbances such as excavation, dredging and dewatering, chemical changes occur which can result in the generation of sulfuric acid. It is common for fine estuarine sediments to contain significant amounts of iron sulfides, and the sediments of Sydney Harbour are known to be sulphur-rich (Irvine, 1980).

The DLWC (1997) ASS risk map for Prospect/Parramatta River indicates a 'High Probability' of occurrence of ASS within the 'Bottom Sediments' and there is a potential for severe environmental risk if bottom sediments are disturbed by activities such as dredging and subsequently exposed to the atmosphere. The NSW Natural Resource Atlas also classifies the sediments of the Parramatta River as having a high probability of ASS risk (from 2014 RAP).

Two classes of ASS have been identified, including highly acidic Actual Acid Sulphate Soils (AASS), which have previously been oxidised, and Potential Acid Sulphate Soils (PASS) containing iron sulfides that have not been oxidised. Typically, there is a risk of environmental degradation and/or contamination from disturbance to PASS unless sufficient acid-neutralising capacity is available in the material (e.g. through the presence of fine carbonates such as shell) or neutralising additives (e.g. lime or cement) are blended with the soil soon after initial disturbance.

Preliminary sampling and testing of samples of sediments collected from Kendall Bay were undertaken by URS (2007b) using the Suspension Peroxide Oxidation Combined Acidity and Sulphate (SPOCAS) test suite. Three samples were taken from Remediation Area A at a depth of 0.5 to 1 m below bed level. The results were compared to the action criteria trigger values for greater than 1000 tonnes of fine textured materials, as specified in the NSW Acid Sulphate Soils Management Advisory Committee (ASSMAC)

(1998) *Acid Sulphate Soil Manual*. The three samples collected reported peroxide oxidisable sulphur, titratable peroxide acidity and titratable sulfidic acidity exceeding the action criteria.

The presence of acid sulphate soils in the western and central areas of Kendall Bay was also investigated by AECOM (2009) as part of the proposed development of the Inner West Marina, which was near the former wharf within Area B of the 2014 RAP. SPOCAS tests were undertaken on five samples collected from 0.1 to 0.5 m depth. Test results determined that all samples exceeded the ASSMAC action criteria.

The above results indicate the likely presence of PASS within Kendall Bay sediments, which needs to be considered when handling and managing these sediments. The ASSMAC (1998) guideline provides strategies for the excavation and management of such sediments so as to mitigate these risks.

4.8 WATER QUALITY

4.8.1 Water Quality Objectives

The adopted criteria for the assessment of water quality in Kendall Bay and adjoining bays are based on the Sydney Harbour and Parramatta River Water Quality Objectives (NSW Government, 2006). The Upper Parramatta River is classified as Upper Estuary (Figure 4.20). In relation to toxicants, the ANZECC/ARMCANZ (2000) marine water quality guidelines for ecological protection apply.

4.8.2 Marine Water Quality

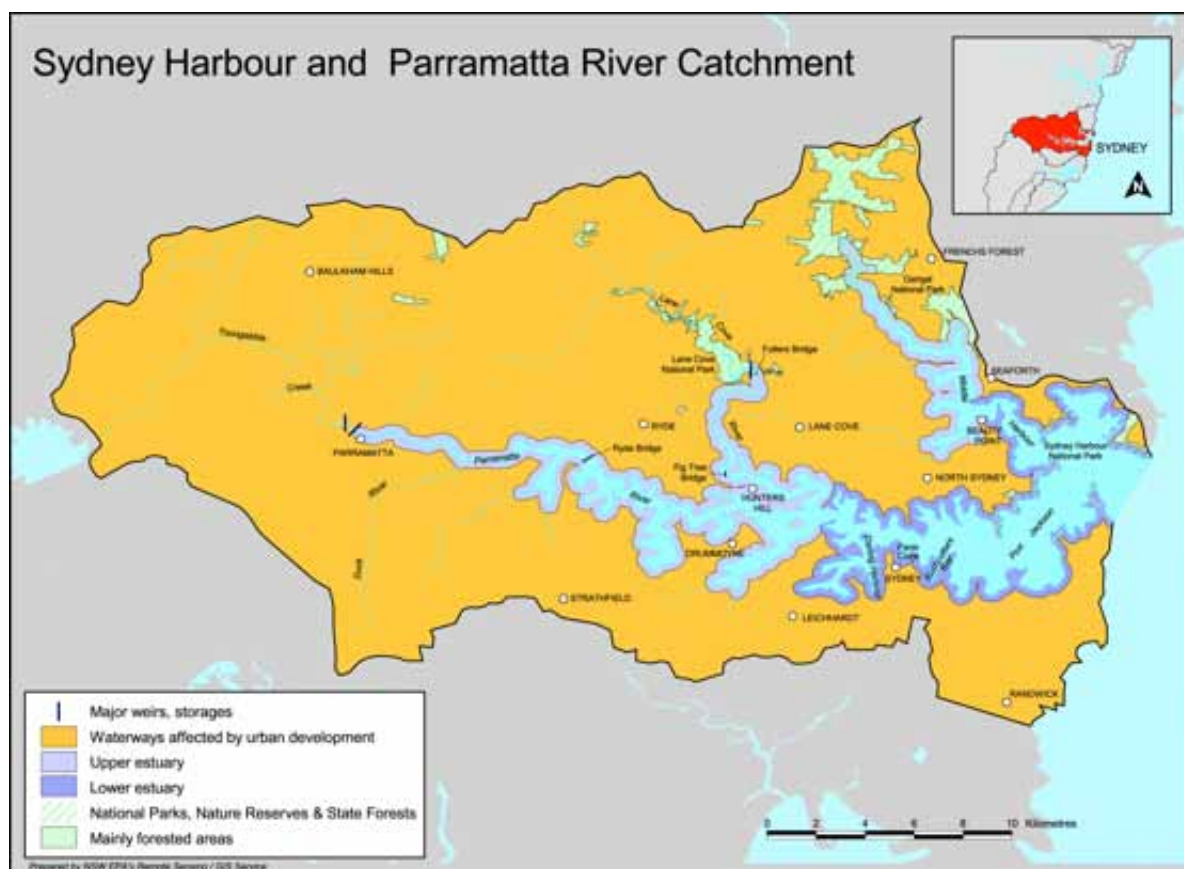
2006

Water quality monitoring was carried out for the Kendall Bay area by URS in 2006. URS reported concentrations of total petroleum hydrocarbons (TPH), PAHs, benzene, toluene, ethylbenzene and xylenes (BTEX) and cyanide. The concentrations of the substances analysed were all less than the relevant ANZECC/ARMCANZ (2000) 95% Trigger Values (Marine).

2012 and 2014

Baseline water quality monitoring was also carried out for the Kendall Bay area (at three bay locations and two background locations)

Figure 4.20. Sydney Harbour and Parramatta River catchment zoning



Source: Sydney Harbour and Parramatta River Water Quality Objectives (NSW Government, 2006).

by Royal HaskoningDHV in two stages, Stage 1 being from August to October 2012 and Stage 2 from November 2013 to February 2014 (Figures 4.21 and 4.22). The objectives of the baseline monitoring were to:

- characterise site-specific water quality conditions at Kendall Bay and Fairmile Cove under normal conditions (i.e. in the absence of proposed remediation activities); and
- establish a suitable reference (or background) location(s) that would be used during the construction period to define 'natural' water quality conditions.

Note that the Remediation Areas and activities referred to on Figure 4.21 were those proposed at the time of sampling, and have since been superseded.

Baseline monitoring during Stage 1 was undertaken from the three nearfield locations and the two background locations shown in Figure 4.21.

The purpose of the Stage 2 monitoring program was to provide baseline data for Fairmile Cove, and a new upstream background monitoring location. Additional baseline data were also collected at the remaining Stage 1 monitoring locations to supplement the Stage 1 dataset.

Stage 2 monitoring was undertaken at the three locations around the Stage 1 locations and two background locations shown in Figure 4.22.

The purpose of the nearfield locations was to collect data in the immediate vicinity of Area A (Nearfield 1), Area B (Nearfield 2), and near the potential return water discharge point (Nearfield 3A). The nearfield locations would be positioned outside any proposed silt curtains.

The purpose of the background monitoring locations was to provide reference data for the nearfield sites during the remediation period. Therefore, the background monitoring locations were positioned in areas subject to similar conditions as the nearfield locations (i.e. similar water depth, exposure to wind waves, boat wake) but sufficiently removed from the areas of potential disturbance that project activities would not affect water quality at the background sites.

The Mortlake (Background 1A) and Cabarita (Background 2) monitoring locations were considered to be appropriate background monitoring sites during ebb and flood tides respectively. That is, during an outgoing (ebb) tide, water quality conditions at monitoring location Background 1A would be independent of the effects of any activities being undertaken



Figure 4.21. Water quality monitoring locations – Stage 1 (indicative only)



Source: Royal HaskoningDHV, 2014.

Figure 4.22. Water quality monitoring locations – Stage 2 (indicative only) (locations approximate)



Source: Royal HaskoningDHV, 2014.



inside Kendall Bay and at the discharge location as part of the remediation project. This would also be the case at monitoring location Background 2 during an incoming (flood) tide.

Water Quality

At each location, samples were taken from just below the surface and 0.5 m above the bay bed, and analysed for total suspended solids (TSS), dissolved metals, Total Cyanide, TPH (C6-C36), BTEX and PAHs. The results were documented in the report *Kendall Bay Sediment Remediation Project – Baseline Water Quality Report* (Royal HaskoningDHV, 2014) and summarised in Royal HaskoningDHV, 2014, 2016:

'Summary of Results – Chemical Contaminants/Toxicants'

Results for chemical contaminants/toxicants were generally very low throughout the entire baseline monitoring period (i.e. Stages 1 and 2), with the majority of samples having contaminant concentrations below the relevant LOR values. Overall, the results for chemical contaminants/toxicants indicated that existing water quality conditions in Kendall Bay and Fairmile Cove are typically benign.

There were isolated instances where elevated concentrations were detected for arsenic, copper, zinc, total cyanide and PAHs, however such results were not consistently recorded. In addition, these elevated results were not confined to any particular monitoring location.

It is noted that a number of the elevated concentrations exceeded the relevant ANZECC trigger values, with several results up to around 10 times greater than the trigger value, most notably for copper, zinc and total cyanide. This indicated that Kendall Bay and Fairmile Cove may be occasionally characterised by poor water quality for these parameters under normal conditions.

Elevated PAH concentrations were recorded for three samples during the baseline monitoring period, with PAH values (sum of individual PAHs) varying between 3.3 µg/L and 49.2 µg/L. These samples contained a very high proportion of bed sediments, with TSS values of 346 mg/L and 1,420 mg/L recorded

for these samples. These results indicated that the mobilisation of bed sediments can result in elevated PAH concentrations within Kendall Bay.

Summary of Results – Physical and Chemical Stressors

It was evident that water quality conditions in Kendall Bay and Fairmile Cove during the entire baseline monitoring period (i.e. Stages 1 and 2) were indicative of a typical estuary, and can be summarised as follows:

- *Dissolved Oxygen (DO): DO values were typically in the order of 6 to 10 ppm throughout the water column at each monitoring location, and were generally within the default ANZECC trigger limits of 80 to 110%.*
- *Electrical Conductivity (EC): EC values were generally in the order of 40 to 52 mS/cm throughout the water column at each monitoring location, with lowest EC levels observed following rainfall events. These results indicate a relatively high degree of ocean water mixing due to tidal flows, with reductions in salinity associated with catchment runoff following rainfall events.*
- *pH: pH values were typically in the order of 7.1 to 8.2 throughout the water column at each monitoring location, while the average pH from depth-averaged results was around 7.8. pH results were therefore within the default ANZECC trigger limits of 7.0 to 8.5.*
- *Turbidity: Average turbidity values were lowest at the surface (4 to 6 NTU) and highest near the bed (8 to 32 NTU), while depth-averaged values were around 7 to 13 NTU. Turbidity results were therefore typically within the default ANZECC trigger limits of 0.5 to 10 NTU, except near the bed where turbidity measurements above 10 NTU were occasionally recorded. However, relatively elevated turbidity measurements would be expected near the bed under normal conditions, and these results were not considered to be indicative of poor water quality at the site.*
- *Temperature: Temperature values were strongly influenced by prevailing air temperatures due to the relatively shallow*



water at the site, with water temperatures ranging between 14 and 26°C during Stages 1 and 2.

In addition, it was evident that water quality conditions were relatively similar at each monitoring location, which indicated that the background monitoring locations were suitable reference locations for monitoring during the remediation project’.

Algal Blooms

Eutrophication has led to numerous outbreaks of the toxic blue-green algae within the Parramatta River Estuary (WSROC, 2006). Red algal blooms have also been a problem in the upper estuary in the past (Cardno, 2008). The causes of the blooms are unclear but appear to be related to high nutrients, low oxygen levels and poor flushing of the system (WSROC, 2006).

Well-flushed sections of the Parramatta River Estuary, such as Kendall Bay and surrounding areas, are not likely to be affected by algal blooms. DO levels in the Remediation Area are generally within the default ANZECC trigger limits of 80 to 110 %, which indicates that low oxygen levels do not affect the site. Indeed, WSROC (2006) noted that the weirs, culverts and detention basins located throughout the Parramatta River Estuary catchment are most likely to be affected by algal blooms (i.e. areas where little or no water flow occurs).

Hence, algal blooms are more likely to occur in the upper Parramatta River Estuary. Revelante and Gilmartin (1978) assessed phytoplankton levels within the estuary and determined that the three basic characteristics of phytoplankton

communities (rates of primary production, chlorophyll-a standing crops, and cell densities) all increase with progression up the estuary (Table 4.6).

4.8.3 Stormwater

No data has been found on the quality of stormwater entering Kendall Bay. Stormwater quality will be monitored as part of the baseline water quality monitoring program.

4.9 MARINE ECOLOGY

Several studies in Kendall Bay have investigated ecology in relation to sediments and gasworks contamination. These include studies by The Ecology Lab (1989, 1996, 1999) and Cardno Ecology Lab (2009). These studies are summarised in Section 5.2 of the HHERA (SKM, 2014a).

The following information on marine ecology has been sourced from the report *Inner West Marina Sydney – Aquatic Environmental Assessment* (Cardno Ecology Lab, 2009), for the proposed Inner West Marina to be built in the western half of Kendall Bay. The proposal failed to gain approval.

4.9.1 Flora

Cardno Ecology Lab (2009) reported that hard surfaces in the bay (the sea walls, piles and rocks) supported a number of algal species, including a green alga, a red alga, a brown alga, a blue-green alga, and green and brown filamentous algae. A small, sparse patch of the seagrass *Halophila ovalis* was found off the rock platform near Cabarita Wharf.

Table 4.6. Phytoplankton characteristics within Parramatta River estuary

Location	Mean rate of primary production (mg C m ⁻³ h ⁻¹)	Mean standing crop of chlorophyll-a (mg chl-a m ⁻³)
Lower Estuary	11	1.8
Middle Estuary	54	8
Upper Estuary	127	17

Source: (Revelante and Gilmartin, 1978 as cited in Royal HaskoningDHV 2016a)

4.9.2 Fauna

Hard Surfaces

Fauna identified on hard surfaces in the bay included the Sydney Rock Oyster, Blue Mussel, several species of barnacles and gastropods, and a limpet. Other organisms included a finger sponge, an encrusting bryozoan and two species of crabs.

Soft Sediments

Benthic Infauna

Sediments in grab samples from the footprint of the proposed Inner West Marina (eight sites) – which was in the vicinity of the former (2007) Remediation Area B – contained 30 taxa (17 polychaete, 5 crustacean, 5 mollusc and 3 others), with mactrid bivalves, capitellid, nephtyid, sabellid, spionid and lumbrinerid polychaete worms being the most abundant. Sediments in grab samples from two sites in the southern part of the bay – in the vicinity of the former (2007) Remediation Area A – contained 17 taxa (8 polychaetes, 3 crustaceans, 4 molluscs and 2 others) and were dominated numerically by nephtyids and nemerteans (ribbon worms). The difference in number of taxa at these locations probably reflected a difference in sampling intensity, but did not appear to be linked with the concentrations of the major contaminants at the proposed marina location.

The mean number of taxa within samples from the proposed marina location was similar to that at both reference locations (elsewhere in the bay and outside in the Parramatta River) but the mean number of animals was similar to that at only one reference location. The overall structure of the assemblages at the proposed marina location, however, was significantly different from that at both reference locations. This suggested that the infaunal assemblages at the proposed marina location are not typical of that region of the estuary.

Benthic Epifauna

Benthic fish and mobile macroinvertebrates were sampled by beam trawling within and adjacent to the location of the proposed Inner West Marina – the vicinity of the former (2007) Remediation Area B. A total of 64 taxa (11 polychaete, 25 crustaceans, 16 mollusc, 6 fish and 6 other taxa)

were collected at these sites with the mactrid bivalve *Spisula trigonella*, mysid *Haplostylis dakini*, amphipod *Corophium* sp. and shrimp *Philocherus* sp. being the most abundant. The mean numbers of taxa and animals, and overall structure of the epibenthic assemblages in Kendall Bay were similar to those at the reference locations combined. This suggested that the epibenthic assemblage at the location of the proposed Inner West Marina was typical of that region of the estuary.

The fish component of the epibenthic assemblages at Kendall Bay North and Kendall Bay South were significantly different from that at Kendall Bay Mid and Kissing Point Bay. The exquisite goby (*Favonigobius exquisitus*) accounted for most of the dissimilarity in these assemblages and was more abundant on average at Kendall Bay Mid and Kissing Point Bay.

Mobile Fish and Invertebrates

Fish and mobile macroinvertebrates associated with nearshore soft sediments at the location of the proposed Inner West Marina, Sydney Rowing Club and Kissing Point Bay were sampled using a beach seine net. Fifteen taxa (1 jellyfish, 6 crustacean and 8 fish) were caught off the sandy beach near the location of the proposed Inner West Marina (in the vicinity of the former (2007) Remediation Area B), with the transparent goby *Gobiopterus semivestitus*, mysid *Haplostylis dakini* and glassfish *Ambassis jacksoniensis* being the most abundant. Significantly fewer taxa were caught at the location of the proposed Inner West Marina than at either reference location. Intermediate numbers of taxa were caught at Kendall Bay South. There was some indication of a difference in the structure of these assemblages among sites, with that at the proposed marina location being distinct from that at Kendall Bay South.

4.9.3 Aquatic Habitats, Flora and Fauna of Conservation Significance

Cardno Ecology Lab (2009) did not identify any critical habitats in Kendall Bay. No threatened marine invertebrate or algal species were listed in the area, and no critically endangered or endangered species have been recorded in



the area. A vulnerable species, Black Cod, is known to occur in Sydney Harbour but has not been recorded within Kendall Bay. None of the threatened populations or threatened ecological communities listed as occurring in the Sydney Metro Area have been found in Kendall Bay or its immediate vicinity. Six threatened marine mammal species are known to occur within the Sydney Metro Area Marine Zone.

No protected fish have recently been reported in the Canada Bay local government area. A Hairy Pipefish was reported at the southern end of Kendall Bay in 1988 (The Ecology Lab, 1988) but has not been reported since.

Protected wetlands (saltmarsh communities) are present at the southern end of Kendall Bay and to the east around Cabarita Wharf and Cabarita Point. None of these communities are affected by the proposed remediation activities.

A total of 13 marine species and 15 migratory species listed under the Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999 occur within Canada Bay local government area, however, these are all birds.

4.10 CONTAMINANTS IN MARINE TISSUES

4.10.1 Parramatta River

The biota of Sydney Harbour has been studied for many decades in relation to the risks of human consumption of fish and shellfish and impacts on environmental systems. A summary of the relationship between metal-contaminated sediments and impact on biota is presented in Hedge et al., 2013:

'Contaminated sediments have been collected from water column sediment traps within the harbour, bedded sediments and from tissue analysis of deployed Sydney rock oysters (Dafforn et al., 2012). All three monitoring tools are highly correlated suggesting localised resuspension processes are important.'

Changes in the distribution of sessile invertebrates that live above sediments are associated with metal contamination (Dafforn

et al., 2012) as are changes to seaweed tissue contamination and their associated herbivores (Roberts et al., 2008a). Increased tissue concentrations of metals are observed in small toothed flounder and are associated with lower growth rates (McKinley et al., 2012). Two flounder collected from Woolloomooloo Bay had lead concentrations that exceeded food health guidelines (McKinley et al., 2012).'

An advisory is in place across Sydney Harbour due to the dioxin contamination present in Homebush Bay, and dioxins found at high levels in seafood from Sydney Harbour. The advisory recommends no seafood be consumed if collected west of the Harbour Bridge and only a limited amount should be consumed if caught east of the Harbour Bridge.

4.10.2 Kendall Bay

Studies of PAH contamination of oysters and mussels in Kendall Bay and surrounding reference bays were carried out in 2006 by URS: 'Contaminant levels in oysters growing within the Declared Area were investigated by URS in January 2006. The investigation involved the collection of oysters from three locations (O1 – O3) that were situated along the northern shoreline in the Parramatta River (O1), near the boat ramp at the south-eastern end of Kendall Bay (O2), and near the former coal wharf in Kendall Bay (O3). Samples from two reference sites were also collected (R1 & R2), these being situated at Bedlam Point and Abbotsford Bay'.

URS concluded that:

- 'both low and high molecular weight PAHs were detected in all samples, including the samples collected from the two reference sites;
- oysters in the Declared Area had significantly higher PAH concentrations compared to the reference sites. Total PAH concentrations in the Declared Area were 0.907 - 8.146 mg/kg, which was 16 – 54 times higher than at the reference site (0.057 – 0.152 mg/kg);
- the maximum PAH concentrations were measured in sample O3 located along the shoreline near the former coal wharf in Kendall Bay; and
- there is a correlation between PAH concentrations in sediments and in oysters, which indicates that the main source of contamination in the oysters is contamination in the sediments.'

Chapter 5

RECENTLY COMPLETED STUDIES

5.1 CRITIQUE OF PREVIOUS INVESTIGATIONS

5.1.1 Sediment Contamination Investigations

Mangrove and Stormwater Delta Area

Due to the growth of the Kendall Bay mangrove stand from the late 1990s to the present day and rapid sediment accumulation in the southern part of the bay, as well as wave-induced erosion in the south-western corner of the bay, it was considered that chemical data obtained by Dames & Moore from 1979 to 1998, and URS up to 2006, could not be demonstrated to be presently representative for this area.

Sampling by AECOM in 2009 for the proposed Inner West Marina, and by E3 Consulting in 2011 (for EnviroPacific Services) did not include sampling within the mangroves. SKM carried out additional sediment sampling in 2013 (SKM, 2013), including 14 locations within and adjacent to the mangroves, however the samples were collected by hand augering and hence were disturbed samples which were likely to have lost volatile and semi-volatile contaminants. Additionally, the samples analysed were taken from the auger flights from three small depth intervals (representing either 10 or 20 cm of sediment).

None of the investigations carried out between 1989 and 2013 followed the Australian Standard (AS 4482-1, 2005) for sampling for volatiles and semi-volatiles, which requires collection of undisturbed samples, and therefore the chemical analyses obtained from these samples cannot be proven to be reliable for these contaminants, which include low molecular weight TRH, BTEX and naphthalene.

As the chemical data collected in the earlier investigations might not have been representative of current conditions, and because none of the samples were subsampled correctly for volatiles, a clear need for a more thorough sampling of the mangrove area, and the adjacent beach and stormwater delta, was identified.

Kendall Bay Offshore and Deep Sediment Sampling

Due to sediment disturbance at and in the vicinity of the former coal wharf on the western side of the bay during removal of the wharf, and subsequent erosion and partial infilling of the channels on the northern and southern sides of the wharf, chemical data collected for the sediments in this area between 1989 and 2010 may not be representative of current conditions.

Most of the early coring studies collected samples of sediment from Kendall Bay for analysis from narrow depth intervals, often 2 cm to 10 cm, and left much of the upper section of the core unsampled. While these studies provided much valuable data and established the broad areas where contamination was present, in a study for potential remediation it is more appropriate to collect samples over a broader depth interval, 30 cm or more, since this is the minimum depth that can be selectively handled in dredging.

Also for remediation planning, it is vital to have data on the full depth of contamination in the sediments, and to understand the sediment chemistry, stratigraphy and geotechnical characteristics. The E3 Consulting study (E3, 2011), using a push-core rig, obtained valuable information on contamination at depth, however due to the soft, oily nature of the heavily contaminated upper sediment layers, sediment was seldom recovered for the top 2-4 m of the profile. This was a critical data gap; much better data was needed for the upper 2-4 metres of sediments to adequately characterise them for ecological risk assessment (ERA), and for remediation planning.

None of these investigations followed the Australian Standard (AS 4482-1, 2005) for sampling for volatiles and semi-volatiles, and therefore the data obtained cannot be proven to be reliable for these contaminants, which include low molecular weight petroleum hydrocarbons, BTEX and naphthalene. Therefore, a clear need for a more thorough sampling of these sediments was identified.



Due to uncertainties and data gaps in the previous investigations, further data were needed to determine the extent and depth of contamination, and determine whether the contamination prevented or limited colonisation by benthos in the upper part of the sediment profile.

5.1.2 Marine Tissue Analyses

Oyster tissue analyses carried out by URS in 2006 identified significant PAH contamination, however it was not clear from the methods used if the gills had been cleaned of suspended sediment. If not, this could have accounted for the elevated levels of PAHs. Additionally, the former coal wharf, which would have been a significant source of PAH contamination, has been removed since 2006. For these reasons, and to obtain data on an additional species, a new tissue sampling and analysis study was needed.

5.1.3 Marine Biological Studies

Several ecological investigations have been carried out in Kendall Bay, including studies by The Ecology Lab (1989, 1996, 1999 as cited in Royal HaskoningDHV 2016a) and Cardno Ecology Lab (2009), as described above.

However, the earlier studies may not be representative of current conditions in the bay and none of these studies were designed to investigate benthic communities as part of a weight-of-evidence (WOE) assessment of the gasworks-contaminated sediments, in accordance with the ANZECC/ARMCANZ 2000 Sediment Quality Guidelines, as revised by Simpson et al. (2013). Accordingly, a new benthic ecology study was required.

5.1.4 Ecological Risk Assessment

The 2014 ERA (included in the 2014 HHERA) was stated to be a definitive or detailed ERA under the new National Environment Protection Measures (NEPM) ERA guidelines (NEPC, 2013, Schedule B5a Guideline on Ecological Risk Assessment). The 2014 HHERA contains much valuable data, however some of the procedures set out in NEPM 5a Table 3 were not carried out, in particular for exposure assessment and toxicity assessment. Issues with the 2014 HHERA were:

1. According to the ANZECC/ARMCANZ 2000 sediment quality assessment decision tree (Figure 3-1 in the 2104 HHERA), after the levels of contaminants are found to exceed both the lower sediment quality guideline and the background levels, the next step is to carry out toxicity and bioavailability testing. Assessment of the results of such testing generally demonstrate the toxicity of the sediments and help to justify any need to remediate.

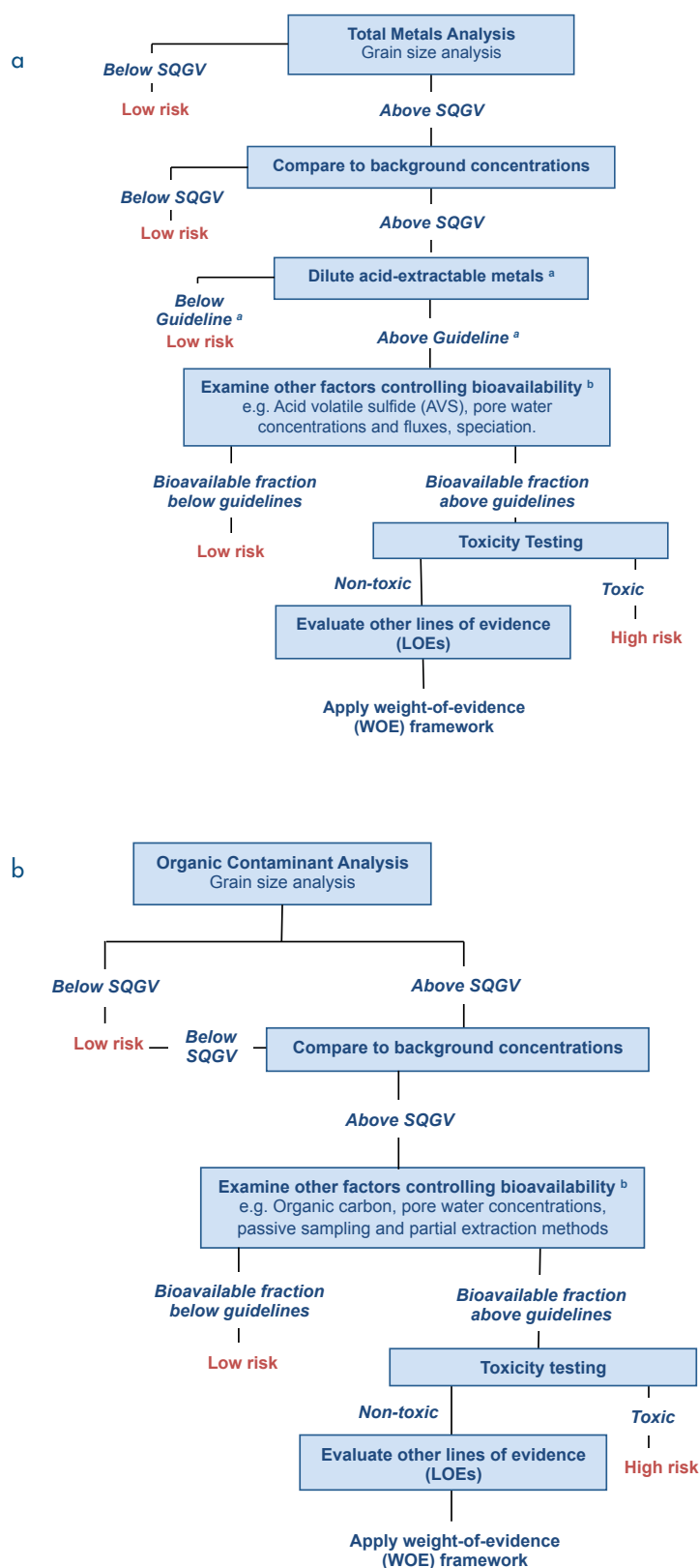
Without such data, the proponent would be committing to huge costs without any proof that remediation is required on ecological protection grounds, or what the appropriate remediation criteria were. The ANZECC/ARMCANZ (2000) sediment quality guidelines (SQGs) are, by definition, not remediation criteria, but are criteria which, if exceeded, lead to toxicity and bioavailability testing to identify whether an unacceptable risk is posed by the contaminants.

No bioavailability or toxicity testing was done. The 2014 HHERA states that 'A weight-of-evidence (WOE) framework that followed CSIRO (2010) recommendations was used to assess the ecological risks posed by contaminated sediments in the Declared Area.' However, the work done was not a scientifically robust WOE assessment because no data was collected on the bioavailability or toxicity of the sediments; the assessment largely relied on conclusions drawn from sediment ecology studies and old bioaccumulation data which could have had a number of causes.

2. The WOE framework that should have been followed is set out in the Revision of the ANZECC/ARMCANZ 2000 Sediment Quality Guidelines (Simpson et al. 2013) in Figure 5.1.

The 2014 HHERA concluded, 'sediment contamination adjacent to the former Mortlake gasworks site has adversely affected the population and diversity of benthic organisms, with contaminant concentrations in the tissues of these animals also elevated.'

Figure 5.1. Framework for assessment of sediments for metals (a) and organics (b)



GV = Guideline Value. SQG = Sediment Quality Guidelines

Source: [Simpson et al., 2013]



The conclusions were based on:

- significantly elevated levels of PAHs in the sediments of the bay, in the 2014 Remediation Areas A and B. Though significantly elevated levels of TPHs and metals were also found, the assessment did not rely on them, nor adequately justify why they were not considered;
 - significantly elevated levels of PAHs in oysters, correlated to sediment PAH levels;
 - reduced species diversity and populations in contaminated areas; and
 - the ecological risk assessment was based on the Total PAH contamination in the top 0.5 m of sediment. The data were compared to the CSIRO (2010) SQG-High Ecological Investigation Level (EIL) of 50 mg/kg normalised to 1 % TOC, because: 'Ecological effects are negligible to possible for concentrations less than or equal to SQG-High criteria ecological, while ecological effects can be expected at concentrations above the SQG-High level. These criteria have hereafter been referred to as the EIL.'
3. The 2014 HHRA failed to demonstrate unequivocally that the contaminated sediments posed an ecological risk to exposed organisms in Remediation Areas A and B of the 2014 RAP, because the crucial steps that demonstrate cause and effect, i.e. bioavailability and toxicity testing, had not been carried out. Ecological differences in the mangrove area, for instance, could be influenced by stormwater discharge. The bioaccumulation observed in by URS (2006) might have been due to contaminants in the large stormwater outfall nearby, or to the presence of the former coal wharf, and does not demonstrate that the sediments are toxic.

The gasworks-contaminated sediments also contain enormously high Total Organic Carbon (TOC) levels (up to 60%), much of which is Black Carbon (BC) (i.e. pyrogenic carbon of anthropogenic origin, comprising coke, coal, oils and tars). BC is known to bind organic contaminants such as PAHs far more strongly than natural organic materials that

report as TOC, and therefore a significant proportion of the PAHs in the sediments are likely to be presently bound-up in biologically unavailable forms and to thereby pose a reduced risk to marine organisms.

4. The assessment process that should have been followed is set out in Section 3.2 of the Revision of the ANZECC/ARMCANZ 2000 *Sediment Quality Guidelines* (Simpson et al., 2013):

'3.2 Application of the WOE Assessment Framework

If the conclusions from the evaluation of chemical and ecotoxicological evidence are ambivalent and further investigations are required, this will involve the application of the WOE assessment framework. The WOE investigation should combine assessments of:

- a) sediment chemistry to measure contaminant concentrations, compare to Guideline Values (if available) and identify COPCs [Contaminants of Potential Concern]. These measurements may include chemistry-based bioavailability tests (e.g. pore water measurements, AVS, or biomimetic approaches for hydrophobic organic contaminants).*
- b) toxicity testing (e.g. multiple species, varying exposure pathways, acute and chronic endpoints such as mortality, reproduction, development, growth, avoidance).*
- c) bioaccumulation/biomagnification, and*
- d) benthic community structure (e.g. ecological malfunction).*

The WOE framework allows decisions to be reached when a single line of evidence (LOE) is insufficient for making decisions, e.g. if Guideline Values (GVs) do not exist for the contaminants, if there are no appropriate toxicity tests that are sensitive to the contaminants of concern.

The WOE approach tabulates and ranks the results of all individual Lines of Evidence (LOEs) used, such as sediment chemistry (e.g. exceedance of trigger values), elutriate and bioavailability testing (exceedance of the relevant criteria), toxicity testing (elevated toxicity compared to controls), bioaccumulation (significant differences compared to controls), and benthic community structure (reduced benthic diversity or abundance relative to controls)'.

5. The ERA used the Simpson et al. (2013) SQG-High value of 50 mg/kg Total PAH (normalised to 1% TOC) as a remediation criterion, however SQGs are expressly not remediation criteria as they do not take into account bioavailability, and exceedences of the SQGs require additional studies to identify whether identified chemical substances give rise to unacceptable impacts to biota.
6. Site-specific PAH remediation criteria need to be determined for Kendall Bay sediments, to identify whether an unacceptable risk is posed by the contaminants in the sediments, as they have been for other similar projects, such as BHP's remediation of PAH-contaminated sediments in the Hunter River, Port of Newcastle.
7. Another issue in relation to normalisation of organics to % TOC is that the normalisation procedure was designed for typical marine sediments which typically contain TOC in the approximate range of 0.5 % to 5 % TOC, and mainly of natural organic origin. The method was not designed for sediments containing extremely high levels of TOC much of which is BC of industrial origin. The issue of normalisation to forms of carbon needs further consideration.

5.1.5 Human Health Risk Assessments

The potential for the sediments adjacent to the site of the former Mortlake Gasworks site to impact human health has been assessed on a number of occasions over the last decade. Reports detailing this work include:

- URS, 2007, *Human Health Risk Assessment of Estuarine Sediments Adjacent to the Former AGL Mortlake Site*; and
- SKM, 2014a. *Updated Human Health and Ecological Risk Assessment, Kendall Bay Remediation Project, Sydney*.

URS, 2007

The URS (2007) HHRA assessed the potential for risks to human health for three life stages – young child, older child and adult. For each life stage, exposure while at the beach, in the mangrove area and in rocky areas along the seawall was estimated. Exposure was estimated assuming average and maximum exposure assessment assumptions – such as time spent in an area, consumption rates for fish and oysters caught in Kendall Bay, and skin surface area relevant for dermal exposure.

The URS HHRA was detailed and used scenarios (and exposure assumptions) that were agreed with NSW Health and EPA.

The conclusions of the URS HHRA were that potential non-threshold risks to human health from contact with sediments in the beach, mangrove and intertidal rocky areas were elevated even under average exposure scenarios and remediation was necessary to minimise exposure. The drivers of the elevated non-threshold risks were the carcinogenic PAHs.

Site-specific remediation criteria for the protection of human health were not prepared during this work. The extent of remediation works proposed by URS was developed from evaluation of the 2007 ERA undertaken at the same time, along with consideration of aesthetic issues at the site, such as areas where odours were present or tar-like material was released when disturbed. Criteria for the protection of ecological systems were more stringent than those for the protection of human health so the use of the findings of the 2007 ERA for the development of the 2007 RAP was also protective of human health.

SKM, 2014

SKM (2014a) carried out an HHRA for the sediments by reviewing all the chemical data collected after 2007 to assess which areas were



above sediment quality guidelines for ecological protection. In regard to human health, the SKM HHERA updated the findings from the URS (2007) HHRA using changes in guidance that had occurred between 2007 and 2014.

The detailed assessment approach used by the URS (2007) HHERA was not reviewed or updated. The calculated risks determined in URS (2007) were multiplied by a factor to correct for a change in the toxicity reference value (TRV) recommended in the updated *National Environment Protection (Assessment of Site Contamination) Measure 1999* (ASC NEPM) (NEPC, 1999) and a change in the approach to estimating exposures via dermal contact.

The change in toxicity reference value recommended in the updated ASC NEPM was due to a change in the toxic equivalence/potency factors used for the set of PAHs that are considered carcinogenic (i.e. heavy molecular weight PAHs). This change reduced the overall non-threshold risk estimate by 1.3 for the ingestion pathway.

International agencies that provide guidance on the toxicity of chemicals, such as the World Health Organisation and USEPA, have noted that the carcinogenic PAHs may have effects specific to exposure via the dermal pathway. As a result, they have flagged that the use of a TRV developed from studies via the oral pathway may not be sufficiently protective. Neither of these agencies

have proposed a dermal-specific TRV, although Health Canada has attempted to develop such a value. This is referred to as the Knafla approach. This approach was used by URS in 2007 to ensure a conservative assessment. The ASC NEPM update provided an additional review of this approach, and recommended that for most sites the Knafla approach was not appropriate as it applied specifically to situations where people could come into contact with tars and other materials where the carcinogenic PAHs were readily bioavailable. The SKM (2014) HHERA corrected the URS (2007) risk estimates for dermal exposure by reducing the risk by a factor of 67 to change from the Knafla approach to the more common approach used for other contaminants, as recommended by the USEPA.

Using these corrections and the average scenarios from the URS (2007) HHRA, the risks from direct contact with the sediments are reduced to acceptable levels as shown in Table 5.1. The risks from consumption of fish and oysters were not re-evaluated in the SKM (2014) HHERA but have been corrected in Table 5.1 for the change in toxicity reference value discussed above.

Due to the reduction in risk estimates for human health, the focus of the conclusions of this SKM (2014) HHERA, were the sediment quality criteria based on ecological protection. The areas for remediation were based on the updated SQG-High of 50 mg/kg for total PAHs normalised to 1% organic carbon published in 2013 (Simpson et al. 2013).

Table 5.1. Summary of calculated risks for average exposure assumptions

Life Stage/Pathway	Non-threshold Risk	Threshold Risk
Adult		
Consumption of Fish/Oysters	2×10^{-5}	0.006
Direct Contact with Sediments	5×10^{-6}	0.06
Older Child		
Consumption of Fish/Oysters	5×10^{-6}	0.008
Direct Contact with Sediments	5×10^{-6}	0.4
Young Child		
Consumption of Fish/Oysters	3×10^{-5}	0.1
Direct Contact with Sediments	8×10^{-6}	0.8
Target Risk	1×10^{-5}	1

Source: SKM, 2014.

Again, site-specific human health-based remediation criteria were not determined in the SKM (2014) HHERA.

In 2015, during planning for the remediation and consultation with the community, issues were raised that triggered further investigation before engineering plans for the remediation works could be finalised. In regard to human health risk assessment, this additional work included:

- development of site-specific human health based remediation criteria;
- consideration of potential risks from exposure to surface waters and biota (based on recent data); and
- consideration of potential risks during excavation works that might form part of the remediation to inform development of risk mitigation measures.

This work is described in Section 5.8.

5.1.6 2014 Remediation Action Plan

Ventia Utility Services Pty Ltd (Ventia – formerly Thiess Services) reviewed the 2014 RAP to assess constructability of the impermeable membrane and the sand cover that was proposed in the 2014 RAP to be placed over the sediments that remained in situ after removal of the upper 60 cm of contaminated sediments. Ventia concluded that the engineered cap proposed within the RAP was not constructible in consideration of a number of geotechnical characteristics of the sediments, most importantly, the lack of a competent (load-bearing) surface to withstand the bearing pressure from the impermeable cap that was proposed to be placed over the remediated areas. This would have resulted in the cap sinking unpredictably through the soft marine muds that underlie, to considerable depths, the areas proposed to be remediated.

As part of their review, Ventia sought advice from geotechnical engineers, JK Geotechnics, who had previously reviewed geotechnical data at the site. To allow the impermeable cap to be placed so that it remained stable, JK Geotechnics identified that the cap would need to be placed on a geotechnically competent surface, which was identified as the stiff clay layer, referred to as Unit 2B (see Section 4.6.2, above), which ranges

in depth from 4-10 m below the current surface of the sediments in Area A.

The requirement to install the cap on a competent surface would have required excavation of an extremely large volume of sediments, which would have greatly increased the time taken to complete the remediation works and the volume of sediments and contaminated water that would have been required to be treated at the Staging Site and ultimately be disposed to landfill.

These previous studies included a range of shortcomings or were conducted before updated assessment techniques were available. Given the range and importance of the shortcomings, a revised investigation program was formulated with the objective of generating a suite of studies from which a revised RAP could be produced.

5.2 PURPOSE AND DESIGN OF STUDIES CARRIED OUT SINCE 2014

5.2.1 Overview

Because of the issues identified above, Jemena commissioned Synnot & Wilkinson Pty Ltd (S&W) to carry out the necessary investigations of surface and subsurface sediments to:

- determine the depth and extent of gasworks-derived contamination that posed an unacceptable risk to:
 - people who used the beach, mangrove areas and other foreshore areas of the bay; and/or
 - marine organisms in the bay.
- obtain reliable data for revision of the HHRA and ERA;
- determine appropriate and scientifically justifiable remediation criteria;
- identify the extent of remediation works required; and
- identify the preferred and feasible remediation method/s.

Investigations to address these issues were carried out in stages between April 2015 and September 2016, with the results of each stage being used to refine the objectives and the sampling and analytical plans for later investigations. The work program was designed using the USEPA's seven-



step Data Quality Objectives process as set out in Appendix B of NEPC (2013) Schedule B2, *Guideline on Site Characterisation*. The process is described in the Sediment Investigation Data Report (S&W, 2018a).

The sediment investigations were carried out in five phases.

Phase 1

Phase 1 entailed investigation of the mangrove, beach and stormwater delta sediments at the southern end of Kendall Bay.

Phase 2

Phase 2 involved investigation of the surface sediments throughout Kendall Bay, and suitable background areas, to obtain the data needed for:

- revision of the HHRA (including chemical testing, specialist bioaccessibility testing and odour assessment);
- preparation of an ERA using a WOE approach to assessment of the contaminated sediments in accordance with the latest revision of the ANZECC/ARMCANZ 2000 Sediment Quality Guidelines (Simpson et al. 2013). This included investigation of:
 - sediment bulk chemistry and volatiles chemistry to measure contaminant concentrations, compare to SQG values where available, and identify COPCs; bioavailability testing including dilute acid extraction, acid volatile sulphide: simultaneously extracted metals ratio (AVS:SEM) analysis, pore water and elutriate testing, analysis of BC content and evaluation of USEPA models; and specialised chemical analysis of volatiles.
 - toxicity testing including multiple species, varying exposure pathways, and acute and chronic endpoints;
 - bioaccumulation studies on oysters and mussels; and
 - assessment of benthic community structure.
- Development of scientifically justifiable remediation criteria and strategies.

Phase 3

Phase 3 investigated the subsurface sediments of Kendall Bay to fill in data gaps, particularly for the

soft oily clays in the top 2–4 m of the sediment column, which had previously proven difficult to sample, and to define the areas, depths and volumes of gasworks-contaminated sediments.

Phase 4

Phase 4 consisted of a bulk dredging trial to:

- monitor water quality, air quality and odour release during a trial dredging of some of the most contaminated sediments; and
- obtain bulk samples for testing of sediment properties and for use in trials of various methods of in situ solidification of the contaminated sediments, plus leachate testing of the stabilised materials.

The main sediment investigation work program, comprising 10 separate sampling episodes, was carried out between April 2015 and April 2016. Phases 2 and 3 overlapped. The bulk excavation trial was carried out in September 2016.

Phase 5

EPA assessed the draft RAP in February 2017 and requested consideration of levels of chronic toxicity of surface sediments in Kendall Bay, and also in bays upstream and downstream of Kendall Bay, outside of the Declared Area in the Parramatta River. Sampling for this assessment of chronic toxicity was carried out in October 2017 and considered the existing benthic communities, chemical status of the sediments, chronic toxicity of the sediments and also the water quality at the sampling sites.

The additional testing sought to (i) more clearly assess the level of residual chronic toxicity of the sediments that will remain in Kendall Bay following the proposed remediation, and (ii) re-assess whether it was possible to derive remediation criteria relevant to the gasworks contamination based on the chronic toxicity contaminant-effects data.

5.2.2 Investigation Areas

The Investigation Areas for the sediment investigations were progressively refined on the basis of data collected in the 11 sampling episodes. Five Investigation Areas were defined (three of them being background areas):

Figure 5.2. Northern Investigation Area. Note the location of the former coal wharf and the wake of the Rivercat to/from Cabarita wharf.



- Northern Investigation Area – including 2014 RAP Area B plus surrounding areas (Figure 5.2);
- Southern Investigation Area – including the 2014 RAP Area A plus surrounding areas (Figure 5.3);
- those parts of Kendall Bay identified in the 2014 RAP as having background levels of PAHs (Figure 5.4);
- Southern Reference Area - initially this was Exile Bay, a nearby bay not exposed to gasworks wastes. In the October 2017 sampling, Canada Bay was added (Figure 5.5); and
- Northern Reference Area - initially this was Majors Bay, a nearby bay not exposed to gasworks wastes. In the October 2017 sampling, Brays Bay and Yaralla Bay were added (Figure 5.6).
- water quality sampling and analysis for the COPCs and other parameters throughout Kendall Bay and in suitable reference areas (S&W, 2018b);
- a survey of marine benthic communities throughout Kendall Bay and in suitable reference areas, plus analysis of the sediments for the COPCs (Alison Hunt & Associates, 2016, 2018);
- a bioavailability and ecotoxicity study of sediments from Kendall Bay and suitable reference areas by CSIRO, plus analysis of the sediments for the COPCs (Simpson et al., 2016, Simpson and Spadaro 2018);
- a human health risk assessment of PAHs in sediments to which people could be exposed (EnRisks, 2017, 2018);
- an ecological risk assessment of the gasworks-contaminated sediments in Kendall Bay (S&W, 2018c); and
- a bulk sampling trial excavation of sediments from some of the most contaminated areas.

5.2.3 Studies Carried Out

The specific investigations carried out to support this RAP are described in a series of reports by S&W, and consultants to S&W, as follows:

- surface and subsurface sediment sampling and analysis for COPCs and other parameters throughout Kendall Bay and in suitable reference areas (S&W, 2018a);
- oyster and mussel tissue sampling for key contaminants throughout Kendall Bay and in suitable reference areas (S&W, 2018a);

The results of these investigations are briefly described in Sections 5.3 to 5.10.

Several other investigations were also carried out, including:

- an odour assessment of the gasworks-contaminated sediments;
- odour chemistry of the gasworks-contaminated sediments;



Figure 5.3. Southern Investigation Area

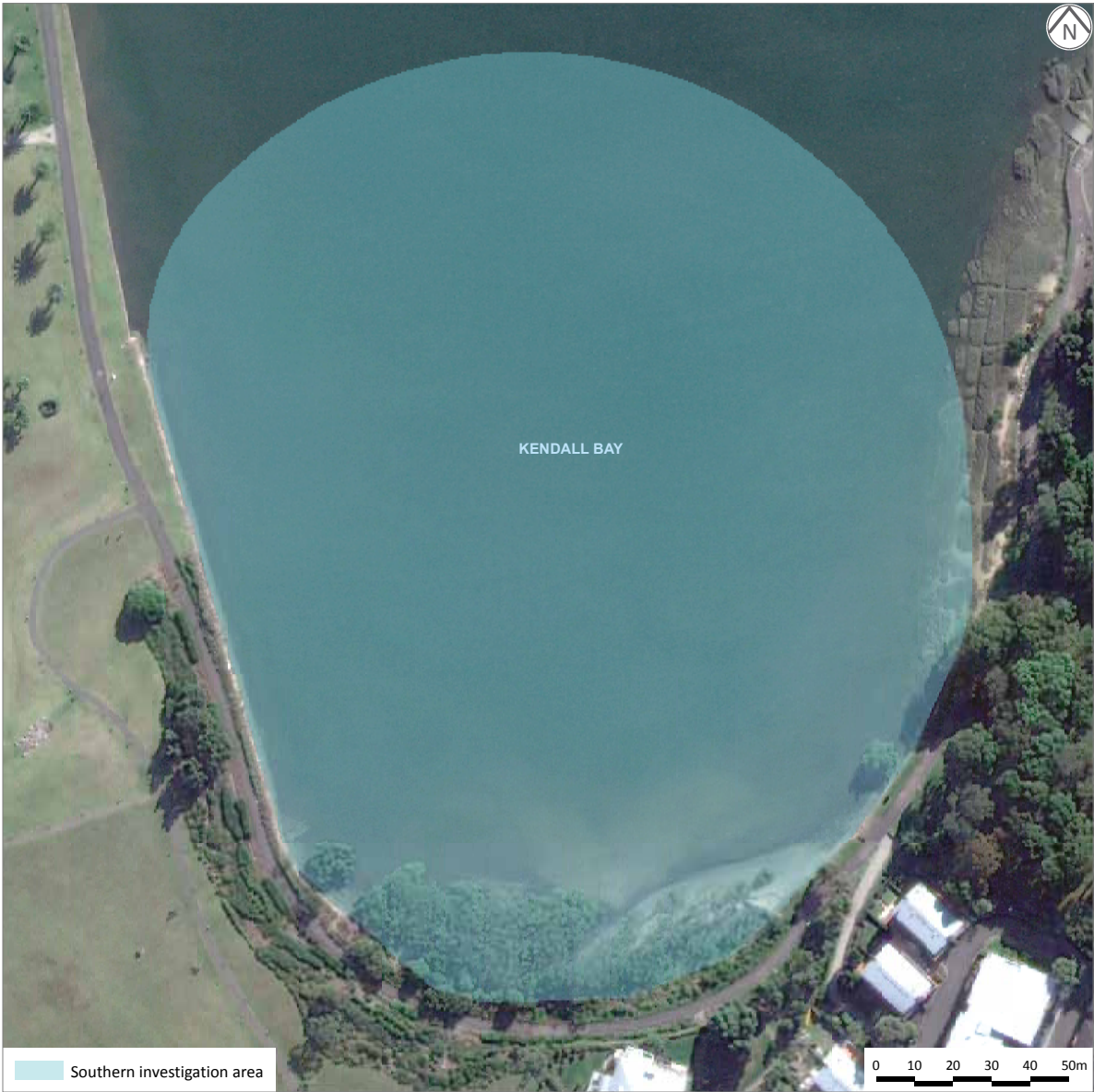


Figure 5.4. Kendall Bay areas with background PAH levels





Figure 5.5. Southern Reference Area



Figure 5.6. Northern Reference Area



- geotechnical studies of the sediments in Kendall Bay; and
- a review of remediation options and a strategy and work plan for the preferred options.

The results of these investigations are briefly outlined in Section 5.11.

5.3 SEDIMENTS OF KENDALL BAY AND BACKGROUND AREAS

The sampling methodologies and results are presented in the *Kendall Bay Remediation Project Sediment Contamination Studies Data Report* (S&W, 2018a) with summaries provided below.

5.3.1 Observations on the Sediments

Intertidal Areas

The beach sediments in the south-eastern corner of the bay were generally clean sands or silty sands containing little visible contamination apart from coal particles.

The sediments of the eastern side of the mangroves and stormwater delta were generally sands and silty sands to a depth of more than 1 m. In the central and western parts of the mangroves and delta the sediments were typically sandy or gravelly at the surface, with coal particles, underlain by fine sediment with an oily appearance and a strong tar odour, to a depth of greater than 1 m.

The surface sediments adjacent to the south-western seawall were typically gravelly sands with shell, coal and coke and rock fragments, and rubble or rip-rap, and often had an oily sheen. Below this layer, a black oily clay with a strong tar odour was typically present and extended to a depth of greater than 1 m. The sea wall in this area contained hard tar encrustations of historical age and sometimes after heavy rain seepage through the wall had an oily sheen.

The intertidal sediments in the Northern Investigation Area were similar to the surface sediments adjacent to the south-western seawall.

Sediments of Kendall Bay

Surface Sediments

Surface sediments throughout the majority of Kendall Bay were typically soft grey muds or sandy muds. Sediments near the western shoreline were coarser, typically being muddy sands or sandy muds with a significant gravel fraction. The elongated mound marking the location of the former coal wharf was topped with a firm layer of very gravelly mud, the gravel comprising shell, coke and coal.

Oily gasworks sediments were present at the surface in three small areas of the bay (Figure 5.7 and Figure 5.8):

- in the south-western corner of the bay, the surface sediments often comprised black oily gravelly sands with a strong tar or hydrocarbon odour;
- midway up the western side of the bay in the Northern Investigation Area, surface sediment near the western side of the former coal wharf mound consisted of a black oily gravelly mud with a strong and unpleasant odour; and
- further north on the western side of the bay in the Northern Investigation Area a black oily mud with a strong and unpleasant odour was present at the surface.

Subsurface Sediments

Southern Investigation Area

Push coring showed the black oily sediment layer occurring at the surface in many cores from the south-western side of the bay (Figure 5.7). In cores from the south-central part of the bay, the black oily layer was typically covered by a mud deposit between 0.05 and 0.25 m deep, as measured in cores, that has accumulated since the gasworks contamination entered the bay. Due to dewatering during sampling the in situ depth would be considerably greater.

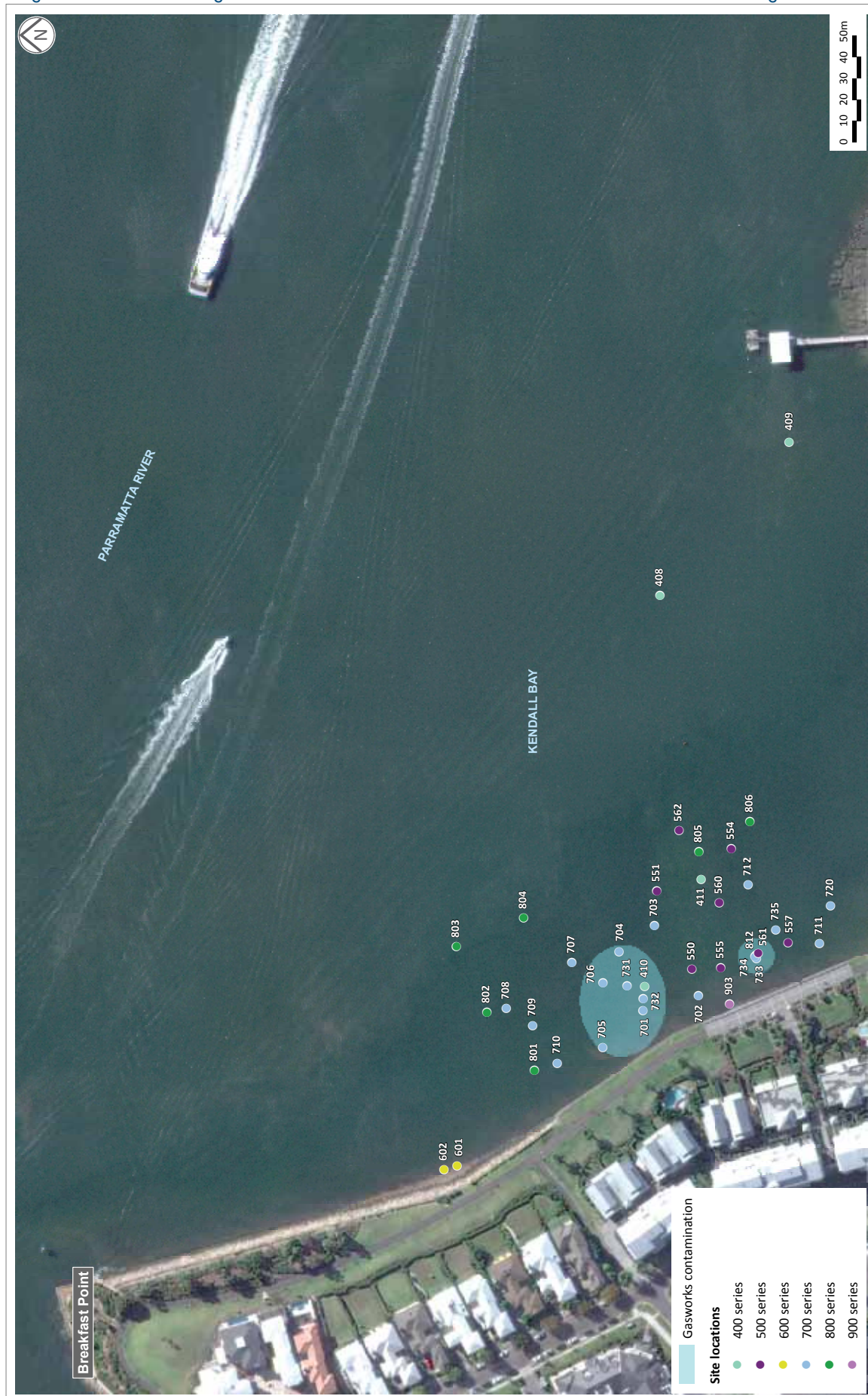
Below the black clay, which had a thickness of 1.5–2.0 m or more in parts of the south-western section, the sediment was a dark clay or shelly clay, often with veins or blobs of Dense Non-Aqueous phase liquid (DNAPL) and a tarry odour.



Figure 5.7. Areas where gasworks contamination is found in surface sediment – Southern Investigation Area



Figure 5.8. Areas where gasworks contamination is found in surface sediment – Northern Investigation Area





The total thickness of contaminated material, based on visual evidence and odour, was typically 4-6 m in the south-western part of the bay, but thinned to 2 m or less to the south, east and north. In several cores in the south-western corner of the bay observable contamination was present throughout, to a depth of approximately 8 m.

Cores taken towards the south-eastern shore of Kendall Bay sometimes contained more than a metre of recent sediment. The visually contaminated layer tended to be dark grey rather than black, occurred at a greater depth, and was thinner with a less pronounced tar odour. In the two easternmost cores, no visual contamination was observed.

Northern Investigation Area

Push coring showed the black oily sediment occurring at the surface in two small areas (Figure 5.8). Elsewhere the black oily layer was covered with a layer of mud, 0.1 – 0.3 m in thickness (as measured in cores). The in situ depth of recent mud would be considerably greater due to dewatering. The black oily sediment had a strong, unpleasant odour.

The thickness of this layer ranged from less than 1 m to 4.7 m, increasing from low values along the western shoreline to the highest values towards the eastern side of the area.

5.3.2 Sediment Chemistry

Initial Investigations

The analytical data for the sediments is summarised in Table 5.2. The full data set is provided in S&W, 2018a.

The locations of sediment sampling sites are shown on Figures 5.9 and 5.10.

The results provide considerably more information on the distribution of contamination by area and depth throughout the bay, particularly in relation to volatile contaminants. The results also provide a better definition of gasworks contamination in the Southern Investigation Area. These results confirm the conclusions of previous investigations that high levels of the gasworks contaminants TRH and PAHs, greatly exceeding GVs, are likely to cause adverse effects on organisms exposed to these sediments.

Outside the Northern and Southern Investigation Areas, the sediments of Kendall Bay typically contained much lower levels of TRH and PAHs (often more than an order of magnitude lower than the levels inside the Investigation Areas).

The heavy metal levels in the sediments, while often elevated above the GVs, were generally comparable to levels found in the background areas and elsewhere in the Parramatta River.

October 2017 Investigations

These samples were collected from (a) eastern and northern parts of Kendall Bay, where previous data (see above) indicated that the sediments generally contained background levels of gasworks contaminants (TRH and PAH) typical of the Parramatta River in the vicinity of Kendall Bay, and from (b) bays in the Northern and Southern Reference Areas. The sample locations are shown on Figures 5.9, 5.10 and 5.26 and the key analytical data in Table 5.3, below.

The data showed that the TRH levels in outer Kendall Bay were generally low and not significantly different from the levels found in the five bays in the Reference Areas.

The levels of Total PAH were, with one exception, low and well below the ANZECC sediment quality Screening Level of 10 mg/kg. The levels found in Kendall Bay were comparable to the levels in the five bays in the Reference Areas. The one exception was sample KBR12, from the northern part of Kendall Bay. This sample, as noted above, was very shelly and had an unusually low TOC level, which raised the PAH level via the normalisation process.

The arsenic, chromium, nickel and zinc levels in Kendall Bay were comparable to the levels in the Reference Bays. The levels of cadmium tended to be higher outside Kendall Bay. The levels of copper in Kendall Bay were comparable to the levels in the bays of the Northern Reference Area but lower than the levels in the Southern Reference Area. The levels of lead in the Southern Reference Area showed a tendency to be higher than in the other locations.

Table 5.2. Key sediment chemical data summary, 0-300 mm (mg/kg except where noted otherwise)

Southern Investigation Area Sites – 0 to 300 mm										
Analyte	TRH Sum C10-C40	Total PAH	TOC %	PAH Norm 1%	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Samples	94	92	88	90	94	94	94	94	94	94
Mean	6402	411	16	80	145	49	110	0.6	50	309
Min	<250	0.12	0.06	1.3	3	2	6.1	0.01	1	10
Max	57900	3600	57	2650	530	143	660	8.5	230	820
GV	280	–	–	10	80	65	50	0.15	21	200
Northern Investigation Area Sites – 0 to 300 mm										
Analyte	TRH Sum C10-C40	Total PAH	TOC%	PAH Norm 1%	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Samples	53	52	51	51	54	54	54	54	54	54
Mean	9475	720	13	82	89	165	205	1.2	14	375
Min	<250	2	1.5	0.3	9	3	8.4	0.02	4	15
Max	100500	13000	44	1300	210	2800	860	3.2	40	706
Kendall Bay Background Sites – 0 to 300 mm										
Analyte	TRH Sum C10-C40	Total PAH	TOC %	PAH Norm 1%	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Samples	16	16	16	16	16	16	16	16	16	16
Mean	594	22	4.8	3.3	66	63	122	0.7	10	253
Min	<250	0.2	0.08	0.64	6.9	6.7	22	0.01	4	50
Max	2320	130	15	13	130	130	240	1.4	17	570
Exile Bay Background Sites – 0 to 300 mm										
Analyte	TRH Sum C10-C40	Total PAH	TOC %	PAH Norm 1%	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Samples	6	6	6	6	6	6	6	6	6	6
Mean	219	7.3	1.5	4.2	53	82	115	0.4	6.5	250
Min	<250	1.2	0.6	1.9	10	30	30	0.06	1.0	50
Max	785	21	2.9	7.2	120	260	300	1.2	14	580
Majors Bay Background Sites – 0 to 300 mm										
Analyte	TRH Sum C10-C40	Total PAH	TOC %	PAH Norm 1%	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Samples	11	11	11	11	11	11	11	11	11	11
Mean	526	10	2.9	7.4	124	91	182	0.6	13	426
Min	<250	1.3	0.44	1.02	15	19	41	0.1	2	70
Max	1215	22	6.3	49.5	230	140	250	0.84	24	760

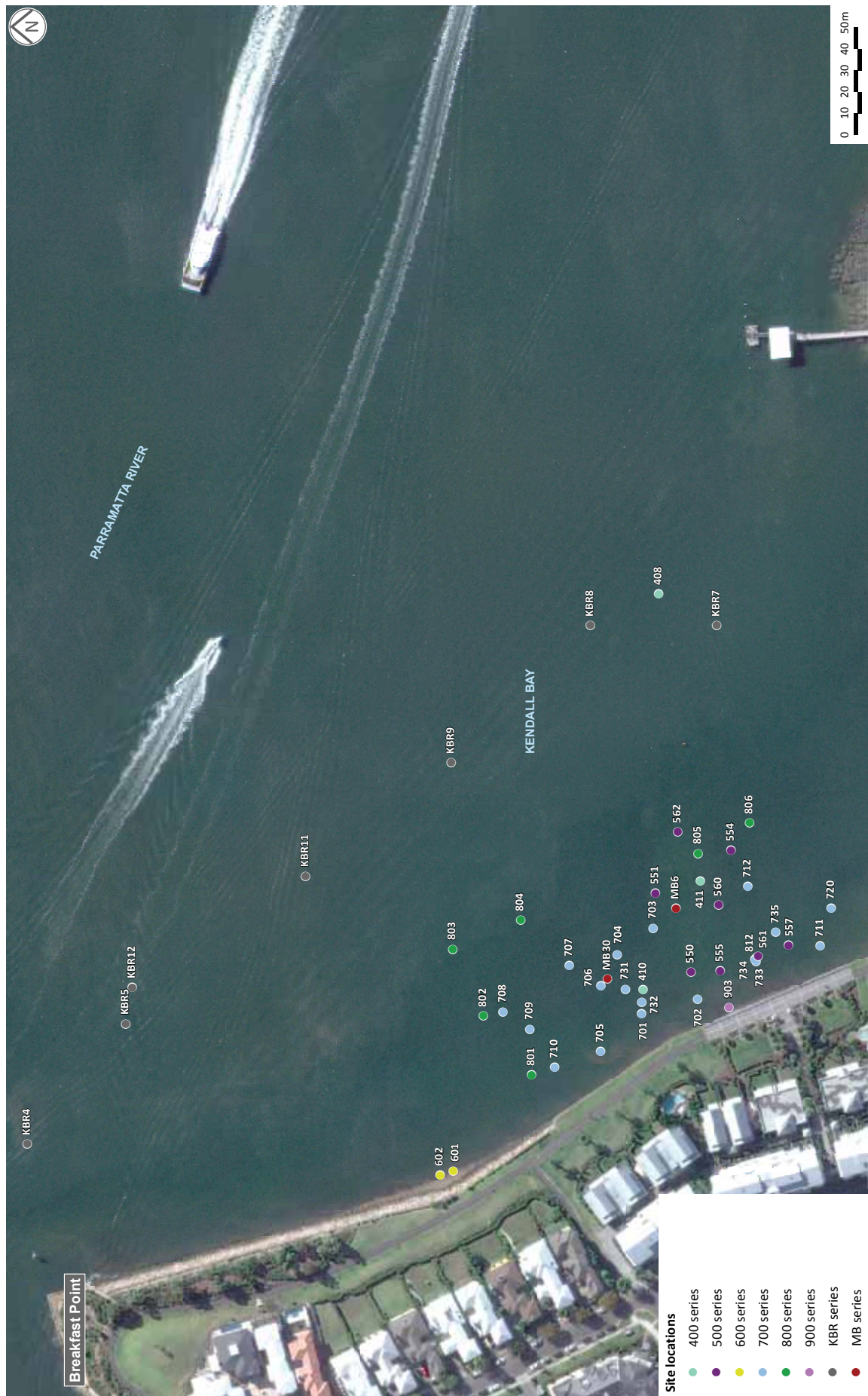
GV: ANZECC Sediment Quality Guideline Value (Simpson et al., 2013)



Figure 5.9. Sediment sampling locations, Southern Investigation Area



Figure 5.10. Sediment sampling locations, Northern Investigation Area



**Table 5.3. Key sediment analysis data, chronic toxicity study, October 2017 (mm/kg unless stated).**

Sample Site No.	Site Location	Sum C10-C40	Total +ve PAHs	PAHs Norm 1%	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc	TOC (%)	Fines <0.63mm (%)
PQL			0.05		4	0.4	1	1	1	0.1	1	1		1
GV*		280#	NA	10	20	1.5	80	65	50	0.15	21	200	NA	NA
KBR1	Brays Bay	125	2.5	1.8	17	<0.4	76	74	110	0.5	10	270	1.4	78
KBR2A	Brays Bay	125	1.8	1.3	15	<0.4	69	72	100	0.5	9	250	1.4	61
KBR2B	Brays Bay	195	2.5	2.1	16	<0.4	65	70	97	0.5	8	230	1.2	60
KBR3	Majors Bay	125	7.8	2.4	15	0.8	84	81	110	0.5	10	310	3.2	64
KBR4A	Kendall Bay	385	24	3.0	14	<0.4	62	88	100	0.8	8	230	7.9	54
KBR4B	Kendall Bay	745	42	5.5	17	<0.4	89	120	140	1.1	12	340	7.6	52
KBR4C	Kendall Bay	1510	37	4.1	18	<0.5	92	100	150	1.1	14	440	9	
KBR5A	Kendall Bay	125	9.2	2.0	21	<0.4	100	130	160	1.2	13	380	4.5	63
KBR5B	Kendall Bay	355	20	3.4	20	<0.4	89	110	140	1.1	12	340	5.8	33
KBR6	Kendall Bay	355	16	3.4	24	<0.4	110	140	180	1.3	16	420	4.7	80
KBR7	Kendall Bay	235	9.2	3.4	21	<0.4	130	170	200	1.4	17	480	2.7	95
KBR8A	Kendall Bay	125	5.2	1.8	15	<0.4	93	130	150	1	12	350	2.9	98
KBR8B	Kendall Bay	840	5.1	1.6	25	<0.5	160	190	270	1.5	23	740	3.1	
KBR9	Kendall Bay	365	18	6.9	24	<0.4	100	140	170	1.5	13	380	2.6	75
KBR10A	Yaralla Bay	125	2.9	1.0	17	1	100	110	140	0.6	12	400	2.8	83
KBR10C	Yaralla Bay	610	0	0.0	19	1.4	120	110	160	0.68	15	570	3.3	
KBR11	Kendall Bay	295	16	5.7	22	<0.4	120	150	180	1.4	15	440	2.8	89
KBR12	Kendall Bay	385	20	30.8	20	<0.4	87	110	140	1.2	12	340	0.65	13
KBR13	Yaralla Bay	125	0.97	0.5	8	<0.4	23	27	41	0.2	3	94	1.8	61
KBR14	Majors Bay	125	2.7	1.1	16	<0.4	93	100	130	0.6	11	310	2.5	100
KBR15	Canada Bay	245	5.3	1.7	23	0.4	150	540	280	0.9	15	580	3.2	97
KBR16	Canada Bay	125	5.4	2.3	18	<0.4	100	330	180	0.8	11	400	2.3	96
KBR16B	Canada Bay	770	6.4	2.1	28	<0.5	150	370	260	0.93	18	680	3	
KBR17	Exile Bay	185	6.4	2.8	26	0.7	130	380	290	1.3	16	570	2.3	95
KBRMB18	Majors Bay	125	2.4	1.0	17	0.7	160	150	190	0.8	16	470	2.5	95

Note:

* Guideline Value, Simpson et al., 2013. Values exceeding the guideline are shaded.

Low quality guideline (Simpson et al., 2013).

NA Not applicable

Overall, the metal levels in the Southern Reference Area (Exile and Canada Bays) were significantly higher than in Kendall Bay or the Northern Reference bays. This is not surprising – the bays of Hen and Chicken Bay are known to contain high levels of metals, particularly copper.

5.4 WATER QUALITY

Full details of sampling and analytical methods, quality assurance and quality control, and data validation are provided in the *Kendall Bay Remediation Project Seawater Seasonal Monitoring Data Report* (S&W 2018b).

Two sampling events were carried out, in January and April 2016. Locations are shown on Figures 5.11 to 5.13.

5.4.1 Results

The data obtained from analysis of water samples are provided by S&W (2018b). Key data are summarised in Table 5.4.

Petroleum hydrocarbons were below or at the detection limit for all samples.

The levels of PAHs in water were very low, generally below or near detection limits. There was no significant difference between the values found in the Northern and Southern Investigation Areas compared to the background locations.

The dissolved metal levels were typical of those found in urbanised estuaries and in the Parramatta River. As is commonly found, copper was typically several times higher than the ANZECC/ARMCANZ

Figure 5.11. Water quality sampling locations, Kendall Bay and Parramatta River





Figure 5.12. Water quality sampling locations, Southern Reference Area



Figure 5.13. Water quality sampling locations, Northern Reference Area



2000 marine water quality criterion (95% protection) in all areas. There was no elevation of heavy metals in the Investigation Areas compared to the Background Areas.

Overall, the water quality data did not show any significant difference between the levels of contaminants in the areas of Kendall Bay contaminated by gasworks wastes, other parts of Kendall Bay, or the background locations outside the bay.

5.5 MARINE BIOTA TISSUE CHEMISTRY

Full details of sampling and analytical methods, quality assurance and quality control, and data validation are provided in the Biological Tissue Report (S&W 2018a).

5.5.1 Sampling Locations and Methods

Oysters, *Saccostrea glomerata*, and mussels, *Mytilus edulis*, were collected from three locations,

Table 5.4. Key contaminants in water, Kendall Bay and Reference Areas

January 2016	Total PAH	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
PQL	NA	0.1	1	1	1	0.05	1	1
Assessment Criteria	NA	0.7	27	1.3	4.4	0.1	7	15
Kendall Bay Northern Investigation Area	NIL – 0.14	<0.1	<1	2	<1	<0.05	<1	<1-2
Kendall Bay Southern Investigation Area	NIL – 1.1	<0.1	<1	2-3	<1	<0.05	<1	<1-1
Kendall Bay Background	NIL – 0.26	<0.1	<1	2-3	<1	<0.05	<1	<1-1
Exile Bay Background	NIL -0.43	<0.1	<1	2-3	<1	<0.05	<1	<1
Majors Bay Background	NIL – 0.06	<0.1	<1-5	2-6	<1-7	<0.05-0.08	1-2	<1-16
April 2016								
Kendall Bay Northern Investigation Area	NIL – 1.2	<0.1	<1	2-5	<1-2	<0.05	<1-2	6-17
Kendall Bay Southern Investigation Area	NIL	<0.1	<1	2-6	<1	<0.05	<1-2	6-11
Kendall Bay Background	0.11-0.14	<0.1	<1	5-11	<1	<0.05	1	7-8
Exile Bay Background	0.02-0.14	<0.1	<1	3-8	<1	<0.05	<1-2	6-8
Majors Bay Background	µg/L	<0.1	<1	1-2	<1	<0.05	<1	6
October 2017								
Kendall Bay Northern Investigation Area	NIL-0.02	<0.1	<1	3-4	<1	<0.05	<1-2	
Kendall Bay Southern Investigation Area	0.1-0.46	<0.1	<1	3-5	<1	<0.05	<1-4	
Kendall Bay Background	NIL-0.08	<0.1	<1	2-5	<1	<0.05	<1-2	
Southern Reference Area	NIL-0.02	<0.1	<1	4-5	<1	<0.05	1-2	
Northern Reference Area	NIL	<0.1-0.1	<1	2-4	<1	<0.05	<1-1	

Note: Results that exceed the Assessment Criteria are shaded.



one on the western side of Kendall Bay, one in Exile Bay near the sediment collection area, and one near the entrance of Majors Bay. Selection of sampling sites depended on the availability of suitable substrates for oysters and mussels. Mussels were sparse in distribution and those found were generally extremely small with little flesh inside. Oysters were also generally small.

The sample locations for biological tissues are shown on Figure 5.14.

5.5.2 Results

The data obtained from analysis of oyster and mussel tissue samples are summarised in Table 5.5.

Figure 5.14. Mussel and oyster sampling locations



There are no Australian assessment criteria for petroleum hydrocarbons in tissues. Samples from Kendall Bay did not show elevated levels of petroleum hydrocarbons compared to the background bays.

There are no Australian assessment criteria for PAHs in tissues. Samples from Kendall Bay did not show any significant difference in PAH levels compared to samples from background areas; the PAHs were all below or near detection limits.

Of the metals analysed, Australian assessment criteria are only available for cadmium, copper and zinc. Metals were not detected in mussels except for zinc, where the values were well below the generally expected levels (GEL). The zinc values showed no significant differences between Kendall Bay and the two background bays.

Only cadmium, copper and zinc were detected in the oyster samples. The cadmium values were well below the maximum residue limit (MRL). The copper values, however, were more than an order of magnitude higher than the GEL, and the zinc levels approximately an order of magnitude higher than the GEL. The copper values were comparable in the three bays. The zinc and cadmium values were higher in Majors Bay oysters than in the oysters from Kendall and Exile Bays. Samples from Kendall Bay did not show elevated levels of metals compared to the background bays.

From the data obtained (S&W, 2018c), there is no evidence that the PAHs or TRH in the contaminated gasworks sediments in the bay are being taken up by oysters or mussels.

Table 5.5. Key contaminants in oyster and mussel tissue, Kendall Bay and Reference Areas (mg/kg)

	Total PAH	TRH C10-C40	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
	mg/kg	Mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PQL	NA	250	0.2	1	1	1	0.1	1	1
Assessment Criteria	NC	NC	MRL 2.0 mg/ kg		GEL 5 mg/kg Median 30 mg/kg 90% UCL				GEL 130 mg/kg Median 290 mg/kg 90% UCL
KBM Kendall Bay Mussels	NIL (+)VE	625	<0.2	<1	<1	<1	<0.1	<1	17
EBM Exile Bay Mussels	NIL (+)VE	675	<0.2	<1	<1	<1	<0.1	<1	14
MBM Majors Bay Mussels	NIL (+)VE	625	<0.2	<1	<1	<1	<0.1	<1	18
KBO Kendall Oysters	0.06	765	0.7	<1	180	<1	<0.1	<1	1100
EBO Exile Bay Oysters	NIL (+)VE	985	0.6	<1	190	<1	<0.1	<1	1000
MBO Majors Bay Oysters	NIL (+)VE	605	1	<1	170	<1	<0.1	<1	1900

Notes:

GEL – Generally Expected Levels

MRL – Maximum Residue Limit

Results that exceed the Assessment Criteria are in bold and shaded.

NC – No Criteria

UCL – Upper Confidence Limit



5.6 MARINE BENTHIC COMMUNITIES

Alison Hunt & Associates Pty Ltd (AH&A) was commissioned by S&W to undertake an assessment of marine benthic infauna for the Kendall Bay Sediment Remediation Project. Forty-five samples were collected in Kendall Bay in two stages, the first on 20-21 January 2016, and the second on 7 April 2016.

The location of the benthic sampling sites are shown in Figure 5.15.

The findings of the study are detailed in the Marine Benthic Infauna Assemblages report (AH&A 2016). Conclusions are summarised below.

NSW EPA advised in its 2007 Remediation Order that contamination in the Declared Area (including the Northern and Southern Investigation Areas)

Figure 5.15. Benthic fauna sampling locations.



had resulted in environmental harm in that there is a 'lack of benthic biota' in the area and that although 'cause and effect' had not been established it is reasonable to assume based on the scientific literature that the nature and degree of the contaminants resulted in the 'lack of benthic biota'. EPA's broad statement has been shown to be inconsistent with the findings of this current study, and studies by Cardno Ecology Lab (1988, 1996, 2009).

The majority of samples (both within the Investigation Areas and background locations) collected for the Kendall Bay Remediation Project continue to support a range of benthic taxa. In effect, samples of marine benthic infauna collected from within the Investigation Areas were not significantly different from the background locations in adjoining bays unaffected by gasworks contaminants, in terms of numbers, diversity or relationships among abiotic factors and benthic infauna. Instead, this study found that the differences amongst the Investigation Areas and background sites were typically small-scale differences in the number of animals rather than substantial differences in the number of taxa.

Only four sites were identified (three with the Northern Investigation Area and one within the Southern Investigation Area) from the 28 samples collected from the Northern and Southern Investigation Areas that lacked identifiable benthic biota. The remaining 24 samples from the Investigation Areas and 17 samples from the background sites, except Exile Bay, all contained similar arrays of infauna taxa and abundance of these taxa, although Exile Bay sites did contain more animals and taxa than any of the sampling sites. This may be related to the sandy sediments of Exile Bay.

The criteria used to recommend areas for remediation were developed using multiple lines-of-evidence (LOE) including ecotoxicity testing, sediment chemistry and marine benthic communities. When these multiple LOE were considered, four marine benthic sites were recommended for remediation (see Figure 5.16, Northern Investigation Area: MB1, MB3 and Figure 5.17, Southern Investigation Area; MB14, MB20) as these sites supported low numbers of marine benthic infauna as well as gasworks contamination

at levels considered to be acutely toxic to marine benthos.

Additional sampling carried out in October 2017 for the chronic toxicity investigation comprised 23 samples, including 6 locations sampled previously and 3 additional bays (Brays Bay, Yaralla Bay and Canada Bay) within the Reference Areas. The findings of this investigation (Alison Hunt and Associates, 2018) supported the results of the previous investigations.

5.7 BIOAVAILABILITY AND ECOTOXICITY

5.7.1 Introduction and Methods

CSIRO Land and Water investigated the chemical bioavailability and toxicity of contaminants within the sediments at Kendall Bay. The results are reported in Simpson and Spadaro (2015) and Simpson et al. (2016) and Simpson et al. (2017).

Bulk sampling for toxicity and chemical testing was carried out in four phases, in May 2015, July 2015, February 2016 and October 2017. Forty-seven samples were collected and tested to provide corresponding chemistry and toxicity data for the purpose of examining contaminant effects relationships that were used to derive remediation criteria that would eliminate the majority of the toxicity attributable to gas work contamination. Samples from the May and July samplings were also subjected to bioavailability testing. Four samples from the May sampling were also sent for bioaccessibility testing.

Assessment of sediment toxicity to benthic organisms was undertaken using an amphipod survival and reproduction test (*Melita plumulosa*) and a harpacticoid copepod reproduction test (*Nitocra spinipes*), with survival added as an endpoint for the copepod in Phase 3.

The 21 sample locations selected in Phases 1 and 2 were intended to represent the full range of gasworks-contaminated sediments in Kendall Bay, from locations distant from the gasworks as well as locations where visible tars and oils were present, plus background locations beyond the influence of the gasworks.



Figure 5.16. Benthic fauna sites for remediation in Northern Investigation Area

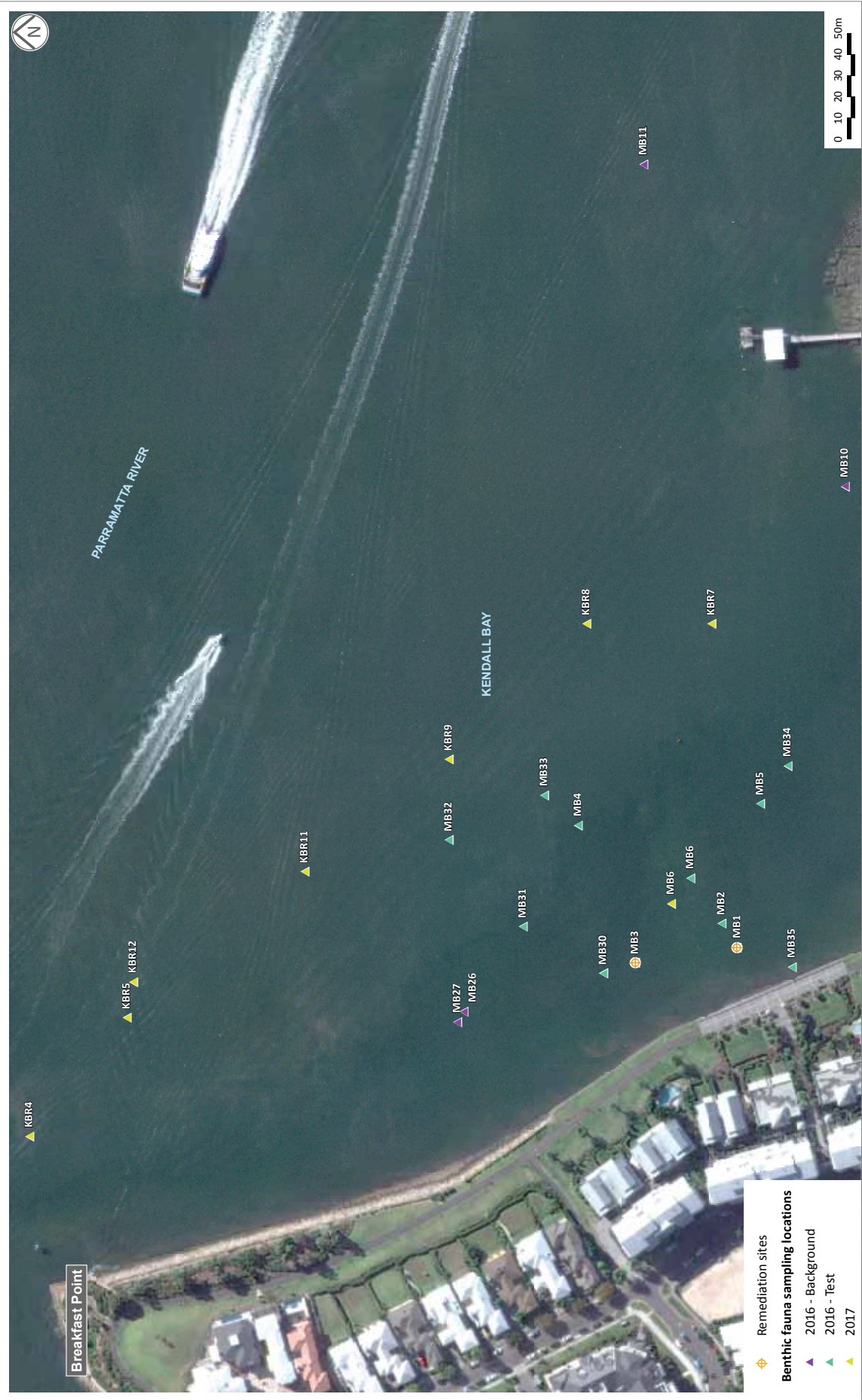
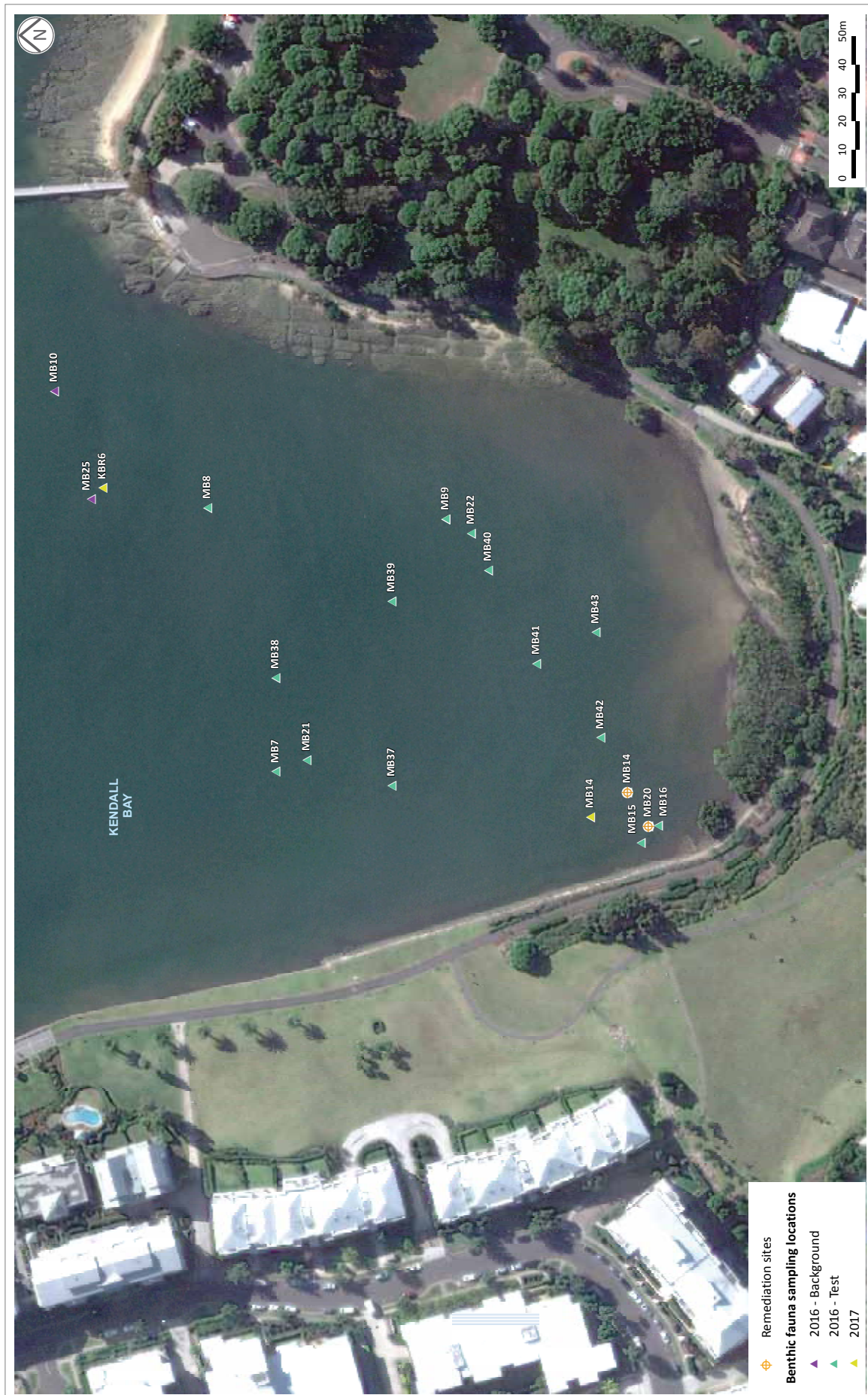


Figure 5.17. Benthic fauna sites for remediation in Southern Investigation Area





The 10 sample locations in Phase 3 were chosen to provide further information on sediments that could cause acute toxicity to benthic organisms, and therefore samples were collected from areas where gasworks contamination was known to be present at the sediment surface.

In October 2017 a further 16 locations were sampled and tested. This testing was carried out to obtain further information on chronic toxicity of sediments in the outer parts of Kendall Bay as well as sediments from bays outside Kendall Bay which have background levels of metals, TRHs and PAHs but are not exposed to gasworks contamination. Accordingly, samples were collected from the eastern and northern sides of Kendall Bay, away from the areas of heavy gasworks contamination sampled previously, as well as from Brays, Yaralla and Majors Bays to the north-west, and Canada and Exile Bays to the south-east.

Chemical and ecotoxicology tests using the amphipod were undertaken on sixteen additional samples to improve the assessment of the level of residual chronic toxicity of the sediments that may remain in Kendall Bay.

With respect to the ecotoxicology assessment, the additional testing sought to (i) more clearly assess the level of residual chronic toxicity of the sediments that will remain in Kendall Bay following the proposed remediation, and (ii) re-assess whether it was possible to derive remediation criteria relevant to the gasworks contamination based on the chronic toxicity contaminant-effects data.

Other aspects of sampling, subsampling, sample handling, preservation and decontamination are described in S&W (2018a) and Simpson and Spadaro, (2018).

5.7.2 Results

Bioavailability

Lead and zinc were considered metals of potential concern in most sediments, and copper for some sediments. It is likely that the mixed metal contamination would result in chronic toxicity for some of these sediments.

The bioavailability of hydrophobic organic contaminants (HOCs), such as PAHs, is influenced by the concentration of total organic carbon (TOC) in sediments. Both natural sedimentary organic carbon, which includes diagenetic organic carbon such as plant material, and also forms of pyrogenic or Black Carbon (BC, e.g. soot, coal tars and coal and coke particles) are present. The sorption of PAHs to BC is typically 10-1000 times stronger than the sorption to natural sedimentary organic carbon (Koelmans et al., 2006; Maruya et al., 2010; USEPA, 2012 as cited in Simpson et al., 2016).

All of the Kendall Bay sediments tested for bioavailability had a high proportion of BC. These observations were consistent with the presence of a large amount of coal tar and coal and coke particles present in many sediments. The risk of toxicity posed by PAHs in sediments is predicted to be considerably less for sediments that contain high BC concentrations, however, the existing models appear to provide poor predictions for Kendall Bay sediments.

Toxicity

Four of the fifteen Kendall Bay sediment samples from Phase 1 and 2, and nine of ten sediment samples from Phase 3, resulted in acute toxicity to at least one test species (mostly the amphipod). Fifteen of the samples from Phases 1-3 also showed high-chronic toxicity to at least one test species. Acute and high-chronic toxicity was almost always associated with black, oily sediments visually contaminated with gasworks wastes.

None of the samples from the outer parts of Kendall Bay, or the bays of the Reference Areas, caused either acute or high chronic toxicity. Some of the samples from these areas did, however, have low or moderate chronic toxicity.

The Phase 5 investigations strengthened the chemistry-ecotoxicology data, but did not significantly alter conclusions and recommendations made from the earlier phases of testing. The additional data (Simpson et al., 2017) confirms that organism survival is adversely affected only for sediments from sites within the proposed remediation area, but also occurs at

sites investigated in other studies by CSIRO in the inner bays 2-4 km east of Kendall Bay that have been impacted by contaminants in stormwater discharge. Organism reproduction is adversely affected in sediments from all areas (within and beyond Kendall Bay). The incidence of chronic effects to organism reproduction is lower for outer Kendall Bay than for other inner bay sites east or west of Kendall Bay.

5.7.3 Conclusions

For the Kendall Bay sediments, the earlier studies (Simpson et al., 2016) found that the concentrations of total PAHs provided the strongest relationship with the observed acute toxicity (e.g. organism survival), and the concentrations of metals and total PAHs expressed in the form of a SQGQ provided the strongest relationship with the observed chronic toxicity (e.g. organisms reproduction).

Many of the sediments tested caused chronic toxicity to both benthic invertebrate species, and acute toxicity was observed for some of the sediments that were very highly contaminated with hydrocarbons.

The joint contributions of metals and total PAHs best explained the observed chronic toxicity to organism reproduction (Figure 5.18). In general, the TRH concentrations did not improve

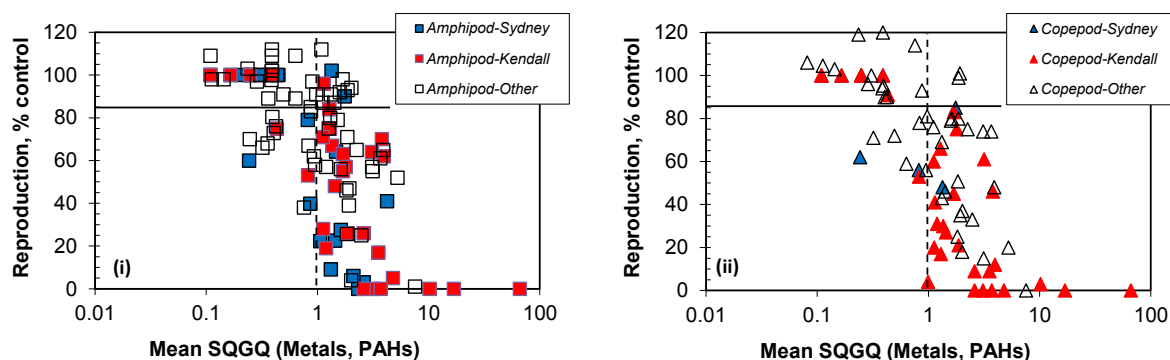
the prediction of the risk of chronic effects compared to considering solely the total PAH concentrations. A mixture of bioavailable metals and PAHs represented a risk of chronic toxicity to benthic organisms. A large portion of the chronic toxicity to organisms may be attributed to metals alone, however the whole Parramatta River is contaminated with metals, derived from many historic sources, and these sediments are regularly resuspended due to regular boat traffic (e.g. Rivercat ferry).

Acute toxicity to organism survival was well predicted by concentrations of total PAHs and TRH, but poorly by metals. This was consistent with hydrocarbon contaminants derived from the Kendall Bay gasworks being the primary cause of acute toxicity. PAHs and TRH are likely to contribute jointly to the observed effects on survival.

Concentration-response relationships based on the PAH and TRH concentrations were developed for the purpose of establishing remediation targets for Kendall Bay sediments (Figure 5.19).

The Phase 5 investigations indicate that remediation based on the proposed criteria would eliminate the acute toxicity and high chronic toxicity in Kendall Bay (Figure 5.20). The residual moderate to low chronic toxicity may be attributed to metals and PAHs (Table 5.6),

Figure 5.18. Relationship between toxicity to amphipod and copepod reproduction and exceedances of sediment quality guideline values (SQGVs) for metals and total PAHs (1% TOC), as represented by mean sediment quality guideline quotient (SQGQ) values. .



Note: The filled symbols represent the data for Kendall Bay (red), Sydney Harbour (Parramatta River, blue), and open symbols for other sediments in NSW or Tasmania using these tests



Figure 5.19. Relationship between toxicity to survival of the amphipod *M. plumulosa* and the concentrations in the Kendall Bay sediments of TPHs, total PAHs (1% TOC).

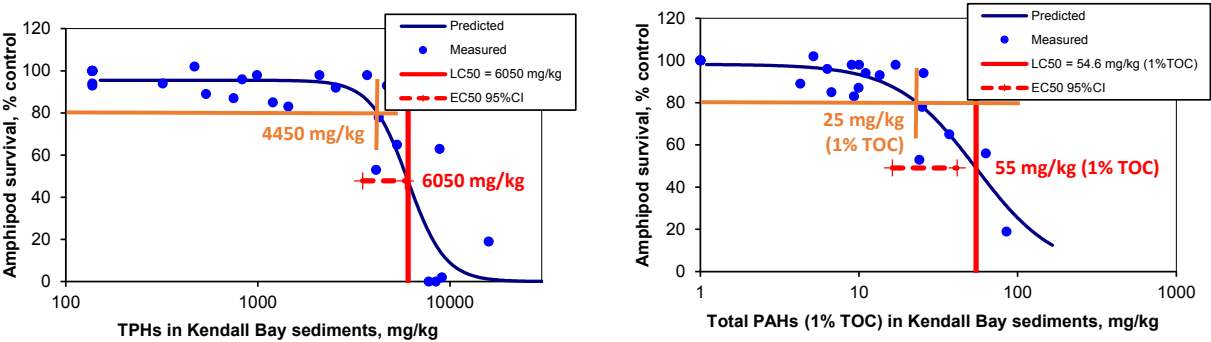
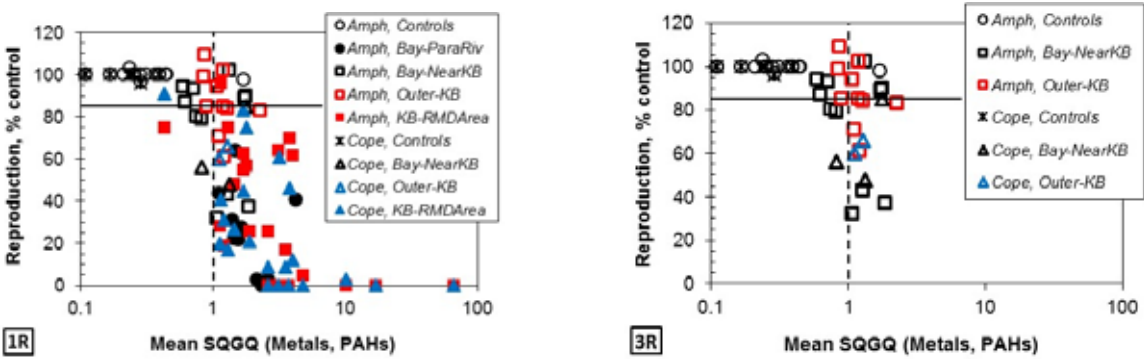


Figure 5.20. Relationship between toxicity to reproduction of the amphipod and copepod and the mean sediment quality guideline quotient (SQGQ) values derived using GV and SQGQs based on the concentrations of total metals and total PAHs (1% TOC).



Note: The left figure shows all data and the right figure is the comparison of data for Kendall Bay only (i.e. removed data within the proposed remediation and sites 2-4 km away from Kendall Bay). Descriptions of the SQGQs are provided in Simpson et al. (2017) along with 6 other Figures. The horizontal solid line indicates 85%. The vertical dashed line represents SQGQ = 1.

Table 5.6. Proposed remediation criteria

Location	Site-Specific Remediation Criteria
Beach Area (or areas similar)	60 mg/kg
Central Mangrove Area (or areas similar)	120 mg/kg
Western Corner of Kendall Bay (areas with coal tars at or near surface)	1 mg/kg

where inner bay sites throughout much of the southern side of this region of the Parramatta River are impacted by legacy and ongoing stormwater contaminant inputs. Due to the combined effects of what may be described as ‘background contamination’ within the region (comprising metals and organic contaminants), it is not possible to derive remediation criteria to eliminate all chronic toxicity. In the longer term the remediated areas within the bay are expected to become re-contaminated as sediment from the surrounding environment is redeposited and also from future stormwater inputs.

Those studies indicated that there would be a low risk of acute toxicity to benthic organisms for Kendall Bay sediments when:

- total PAH concentrations: average <25 mg/kg (1% TOC) (representing effects thresholds) and maximum <55 mg/kg (1% TOC) (representing effects occurring frequently).
- TRH concentrations: average <4400 mg/kg and maximum <6000 mg/kg.

The results for the 0-300 mm depth interval, to which benthic organisms could be directly exposed, are shown on Figures 5.21 to 5.24. Results for the 300-600 mm depth interval, and for sediments below 600 mm depth, are reviewed in detail in S&W 2018a.

Figure 5.21. PAHs in sediments, 0-300 mm, Southern Investigation Area (mg/kg, 1% TOC)





Figure 5.22. PAHs in sediments, 0-300 mm, Northern Investigation Area (mg/kg, 1% TOC)

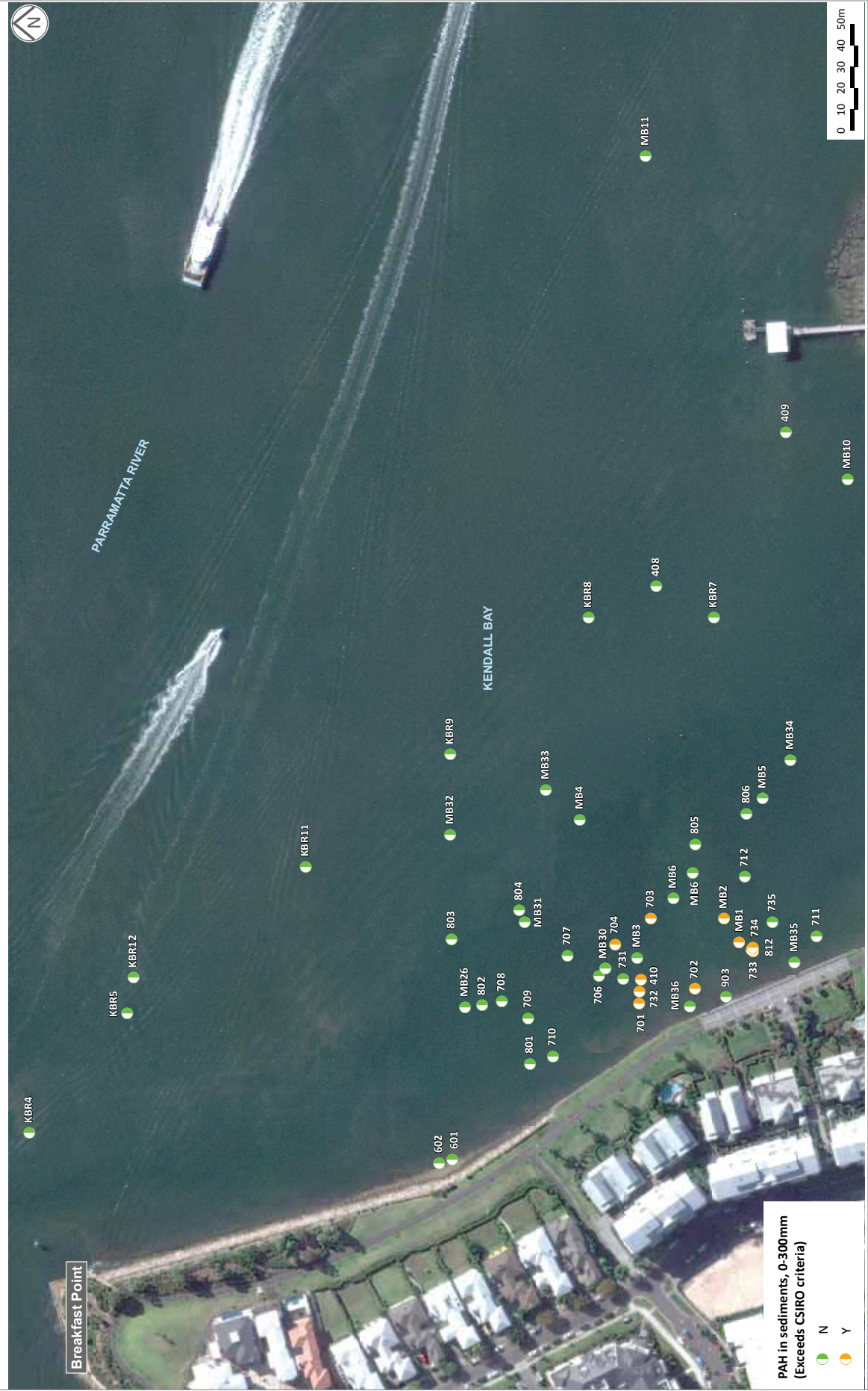
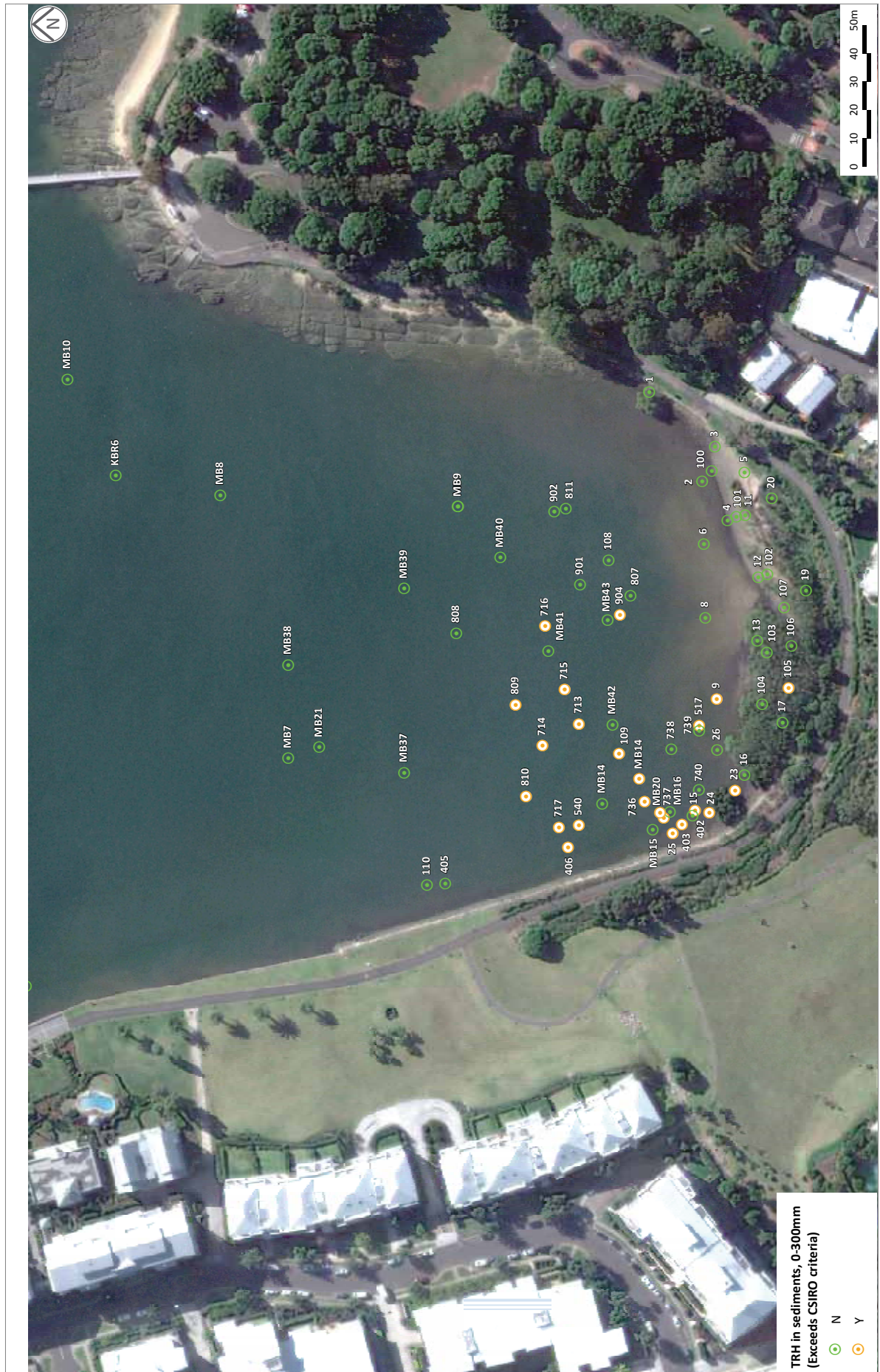


Figure 5.23. TRHs in sediments, 0-300 mm, Southern Investigation Area



[illegible]

Reducing the risk of toxicity to benthic organisms from gasworks contamination.

A strong contaminant effects data set has been generated for chronic effects (amphipod and copepod), however, due to the joint contributions of metals and PAHs to the observed toxicity, it is not considered possible to use these data to effectively develop separate remediation targets. However, it is considered useful to use the available data for surface sediments to calculate and compare mean and 95% Upper Confidence Limits (95%UCL of the mean) for SQGQs and chronic effects to the amphipod (Figure 3, Appendix B of Simpson et. al, 2018).

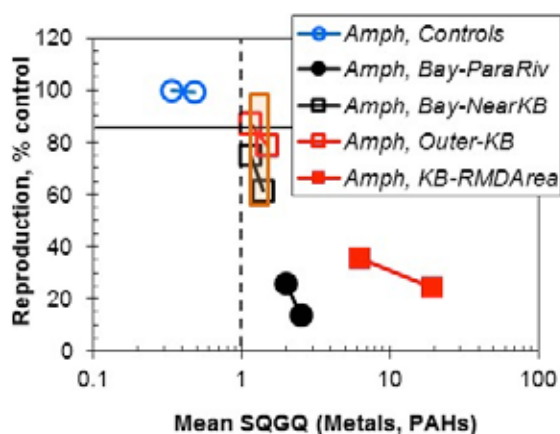
The predictive ability of these values must be considered in relation to the relative small size of the data sets, and also the selection of sites for testing, but they do provide another perspective how the proposed remediation will considerably reduce the likelihood of adverse effects to benthic organisms. In addition to the analysis of the effects data, we calculated a mean and 95%UCL of the SQGQ of 1.4 and 1.6, respectively, for surface sediments within inner Kendall Bay that lie outside of the proposed remediation area. We don't have effects data specifically for this inner Kendall Bay area, but based on the

effects relationships for the other areas and the calculated SQGQs we have indicated where we expect this area to lie in Figure 5.25.

Overall, the results are consistent with the earlier studies, and indicate that significant improvements in ecosystem health may be expected to be achieved by removal or isolation of sediments that caused acute toxicity to benthic organisms. The results continue to indicate that remediation targeting areas where chronic toxicity is observed may be ineffective at eliminating chronic toxicity of the sediments in the longer term as remediated areas within the bay will be expected to become re-contaminated as sediment from the surrounding environment is redeposited, and also from future stormwater inputs.

Remediation that targets the acute toxicity of the Kendall Bay sediments that exists within the proposed remediation areas (i.e. intended to result in the remaining surface sediments having total PAHs with mean <25 mg/kg (1% TOC) and none with >55 mg/kg (1% TOC)) should eliminate acute toxicity and result in few instances of chronic toxicity to benthic organisms in Kendall Bay.

Figure 5.25. Comparison of the mean and 95% Upper Confidence Limits (95%UCL) of toxicity to reproduction of the amphipod versus the sediment quality guideline quotient (SQGQ for metals + total PAHs).



Note: The orange box indicates the inner Kendall Bay area that lie outside of the proposed remediation area, where SQGQ data exists without effects data. Descriptions of the SQGQs are provided in Appendix A. The horizontal solid line indicates 85% reproduction. The vertical dashed line represents SQGQ = 1. Other lines join the mean and 95%UCL pairs (calculated using ProUCL 5.1).



The toxicity status of sediments from Reference Areas is shown on Figure 5.26, and details for the Southern and Northern Areas respectively on Figures 5.27 and 5.28 Table 5.7 summarises the chemistry and toxicity of all 47 samples tested. This table shows that acute and high chronic toxicity is largely due to gasworks

contaminants, is essentially confined to the proposed Remediation Areas and will be removed by remediation, and that low-moderate toxicity is largely due to background levels of metals and is found in some samples elsewhere in Kendall Bay as well as throughout the Parramatta River.

Figure 5.26. Toxicity of sediment samples from Reference Areas (acute, chronic or non-toxic)



Figure 5.27 Toxicity of sediment samples, Northern Investigation Area (acute, chronic or non-toxic)

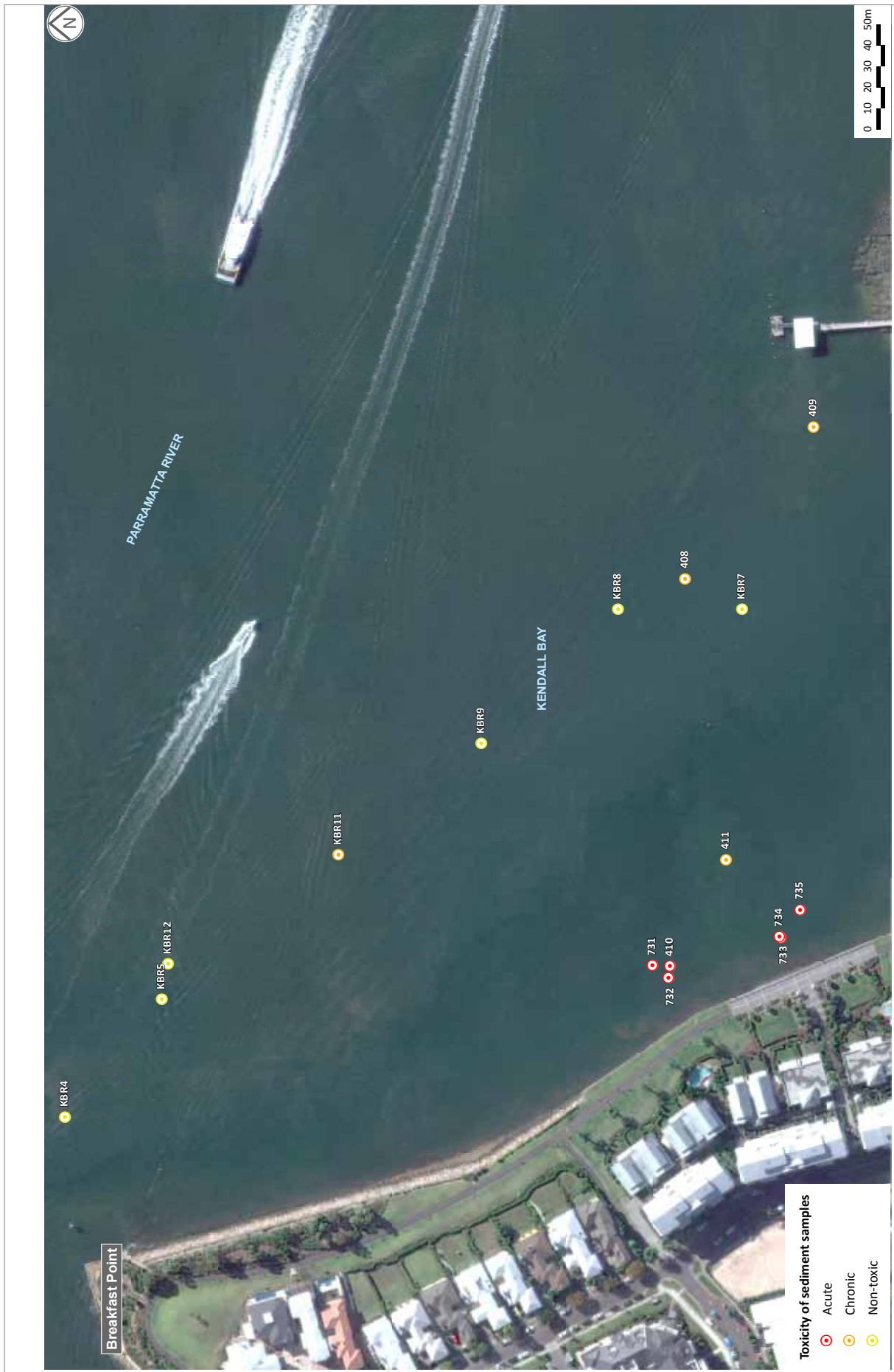




Figure 5.28. Toxicity of sediment samples, Southern Investigation Area (acute, chronic or non-toxic)



Table 5.7. Sediment toxicity and chemistry summary

Sample No/Location	Toxicity (highest found)		Sediment Quality Guideline Quotients (SQGQ)		TRH (mg/kg)
	Acute	Chronic	Metals	Total PAHs	
Southern Remediation Area					
100 (S beach – sand)	No	Moderate	0.5	1.1	285
101 (S beach – sand)	No	Moderate	0.2	2.5	125
102 (edge mangroves – sand)	No	No	0.2	0.6	745
103 (in mangroves)	No	High	1.5	0.9	1,310
104 (in mangroves)	No	High	1.6	0.7	1,060
108 (near boundary of RA)	No	High	1.6	1.0	1,740
109	No	Moderate	1.3	6.3	11,100
110	No	Moderate	1.7	1.7	3,190
402 (coarse: sandy & gravelly)	Very High	High	0.8	1.2	1,610
403	High	High	2.8	18	33,150
405	No	High	1.5	1.4	4,700
406	Low	High	1.5	5.6	8,815
407	No	Moderate	2.0	1.6	2,540
KB736	Very High	High	1.3	3.9	7,740
KB737	Very High	High	2.6	4.8	8,440
KB738	Moderate	High	1.3	2.4	4,120
KB739	Low	High	1.5	3.7	5,290
KB740	High	High	3.7	2.5	4,260
Northern Remediation Area					
410	Moderate	High	1.7	6.2	16,600
KB731	High	High	1.5	4.8	9,070
KB732	Very High	No data (no survival)	1.7	32	51,100
KB733	Very High	No data (no survival)	2.4	130	101,000
KB734	High	High	1.1	8.5	15,900
KB735	Low	Moderate	1.4	0.9	990
Elsewhere in Kendall Bay					
408	No	Low	2.1	0.4	538
409	No	Low	1.7	0.5	468
411	No	Moderate	2.4	1.0	748
KBR4	No	No	1.3	0.4	565
KBR5	No	No	1.5	0.3	240
KBR6	No	No	1.0	0.3	355
KBR7	No	No	2.0	0.3	235
KBR8	No	No	1.5	0.2	125
KBR9	No	No	1.7	1.2	365
KBR11	No	Moderate	1.8	0.6	295
KBR12	No	No	1.4	3.1	385

**Table 5.7. Sediment toxicity and chemistry summary (cont.)**

Sample No./Location	Toxicity (highest found)		Sediment Quality Guideline Quotients (SQGQ)		TRH (mg/kg)
	Acute	Chronic	Metals	Total PAHs	
Northern Reference Area					
401 (Majors Bay, edge mangrove)	No	Moderate	2.8	0.7	138
413 (Majors Bay)	No	Moderate	2.3	0.4	718
KBR3 (Majors Bay)	No	No	1.3	0.2	125
MB18 (Majors Bay)	No	Moderate	2.0	0.2	125
KBR14 (Yaralla Bay)	No	No	1.3	0.1	125
KBR1 (Brays Bay)	No	No	1.1	0.1	125
KBR2 (Brays Bay)	No	No	1.0	0.2	160
Southern Reference Area					
404 (Exile Bay, edge mangrove, sand)	No	Moderate	1.2	0.4	138
412 (Exile Bay – sandy)	No	No	0.3	0.2	798
KBR17 (Exile Bay)	No	No	3.2	0.3	185
KBR16 (Canada Bay)	No	Moderate	2.3	0.2	125
KBR15 (Canada Bay)	No	Moderate	3.6	0.2	245

Source Data: Simpson et al., 2016; Simpson and Spadaro, 2018; Synnot & Wilkinson, 2018e.

- Acutely toxic or highly chronically toxic.
- Exceeds ANZECC SQGQ for metals/PAH, SQG-High for TRH (Simpson et al., 2013).
- Exceeds CSIRO PAH remediation criterion (max. 55 mg/kg).
Exceeds CSIRO TRH remediation criterion (max. 6000 mg/kg).

RA: Remediation Area.

5.8 HUMAN HEALTH RISK ASSESSMENT

EnRisks (2018) updated the previous Human Health Risk Assessment (HHRA). The main purpose of the HHRA update was to calculate site-specific human health remediation criteria for use in the RAP. The updated HHRA has addressed the presence of PAH contamination in sediments at the southern end of Kendall Bay.

Additional studies were undertaken between 2015 and 2017 to refine the remediation design including:

- chemical analysis of sediments, surface waters, biota and odours;
- ecotoxicity testing of the sediments;

- bioaccessibility analysis;
- benthic ecology survey; and
- black carbon (and other chemical analyses) related to ecological assessment.

Using these additional data, recent updates to national risk assessment guidance and consideration of the need (where possible) to retain mangroves, calculations have been undertaken to determine remediation criteria to be used in designing the remediation across Kendall Bay. The additional investigations have also resulted in changes to the areas to be remediated (formerly known as Areas A and B).

Based on the exposure scenarios and the toxicity assessment in the updated HHRA, remediation

criteria have been determined that are protective of human health (Table 5.8). The basis of each of the proposed criteria has been assessed to determine the most appropriate criteria to apply in each of the newly identified areas to be remediated.

Along with these remediation criteria, the remediation design will need to ensure that discoloured or odorous sediments are not present at the surface where people may come into direct contact with them, or near the surface where normal disturbance during wading may allow people to come into contact with contaminated sediments.

Surface water sampling has demonstrated that concentrations for relevant chemicals are all well below relevant screening criteria.

Biota SAMPLING has found that oysters and mussels collected in Kendall Bay did not contain any PAHs relevant to gasworks waste. The oyster samples did contain copper, cadmium and zinc. The concentrations were the same in the samples from all three bays indicating that the contamination was not related to the gasworks contamination.

The levels of copper and zinc were above those that would be acceptable to consume on a regular long-term basis. There is already an advisory in place for Sydney Harbour that recommends no

seafood collected west of the Harbour Bridge should be consumed and a prohibition on the collection of oysters and mussels from the entire shoreline of Sydney Harbour. No further restrictions need to be implemented.

Odour modelling and modelling of evaporation of volatile chemicals has shown that during excavation of the sediments, none of the chemicals relevant to the gasworks waste are predicted to be present in shoreline locations even under worst-case dispersion conditions at concentrations that are above conservative ambient air guidelines (protective of lifetime exposures). Odours have been predicted to be present, particularly under worst-case dispersion conditions if no odour control measures are used.

The bulk sediment excavation trial supported the findings of the modelling of odours and volatilisation of chemicals.

A range of odour control measures are proposed to be included in the project design. Additional odour control measures will be considered, if needed.

Proposed Remediation Criteria

Based on the exposure scenarios and the toxicity assessment as outlined in the HHRA, remediation criteria have been determined that are protective of human health (Table 5.8).

Table 5.8. Application of proposed remediation criteria for carcinogenic PAHs

Location	Site-Specific Remediation Criteria
Southern Investigation Area	
SA1	1 mg/kg
SA2	1 mg/kg
SA3	1 mg/kg
SA3	120 mg/kg
SA4	60 mg/kg
SA5	60 mg/kg
Northern Investigation Area	
NA1	1 mg/kg
NA2	Area submerged so ecological criteria more relevant
NA3	Area submerged so ecological criteria more relevant



Application of Proposed Remediation Criteria

The basis of each of these proposed criteria has been assessed to determine the most appropriate criteria to apply in each of the newly identified remediation areas.

Application of 1 mg/kg Criterion

It is proposed that the most stringent criterion is applied to areas with coal tars at or near the surface. This includes SA1, SA2, and NA1. The RAP for the project outlines the intended remediation to be undertaken in SA1, SA2 and NA1. It includes in-situ stabilisation and capping.

Application of 60 and 120 mg/kg Criteria – Western edge of SA3

In the western end of the mangroves, there are several sites where the levels of PAHs exceed the adopted Human Health criteria of 1 mg/kg. Some of these are in Remediation area SA1 and will be remediated using in situ solidification. Several others are located in the western end of Remediation Area SA3 (such as sampling locations 16 and 23) but the highest levels in these areas are covered by the mangrove root mass which in this area can reach half a metre in depth. The driver of risk in the calculation of the remediation criteria is dermal contact with the contaminated materials. It is assumed that a child may come into direct contact with the sediments 20 days per year for 6 years in this part of the Bay and on each occasion lower arms, hands, lower legs and feet will be covered by the sediments. If such contact is prevented by the mangrove root mass or is, at least, greatly reduced due to the physical difficulty in reaching the contaminated materials, then the risk is much reduced and compliance with the remediation criteria is not strictly required.

Given the thickness of the overlaying dense root mat, the risk of human exposure in this western end of SA3 is deemed to be low and hence the adopted treatment in this area is to leave the mangrove root mass in place and ensure that any materials on the surface of the root mass are cleaned of any coke and coal washed onto the surface of the area as discussed below.

Application of 60 and 120 mg/kg Criteria – SA3, SA4 and SA5

Given the discussion above, the central mangrove area criteria can be applied to SA3 and the beach area criteria can be applied to SA4 and SA5.

The RAP for the project outlines the intended remediation to be undertaken in SA3, SA4 and SA5. It is intended that all surface rubbish and weathered coal contamination will be removed to a nominal depth of 0.2 -0.3 m. The stormwater drain will be reengineered to better manage flow. Clean sand will be brought in to nourish all these areas and to provide a sufficient capping layer. As a result, little material currently at the surface will remain at the surface after the remediation is complete.

Remaining Areas

None of the health-based criteria need to be applied in areas NA2 and NA3 as these areas are submerged at all times and are not readily accessible to people. If people do access these areas, then any materials will be washed off immediately minimising any potential for dermal exposure. Remediation in these areas should be based on the ecological criteria developed by the CSIRO.

5.9 ECOLOGICAL RISK ASSESSMENT

The ecological risk assessment (S&W, 2018c) used data from the sediment contamination studies (Section 5.3), water quality monitoring (Section 5.4), biological tissue monitoring (Section 5.5), marine benthic community studies (Section 5.6), and the bioavailability and ecotoxicology studies (Section 5.7) to assess the risks to organisms exposed or potentially exposed to the gasworks-contaminated sediments of Kendall Bay.

5.9.1 Potential Effects on Water Column Biota

The dissolved PAH levels in water from Kendall Bay were very low, mostly below the detection limits or in a few cases at or slightly above the detection limits. There are no Australian marine water quality guidelines for PAHs, due to insufficient data, however the very low PAH values found are considered unlikely to affect aquatic organisms.

The metal levels were also low and generally below the water quality guideline values except for copper, which consistently exceeded the guideline, and zinc, which occasionally exceeded the guideline. This indicates potential for adverse effects on some organisms, however the metal levels were no higher in the contaminated areas of Kendall Bay than at the background locations in and outside the bay, and therefore any toxic effects of metals cannot be attributed to the gasworks contamination.

5.9.2 Potential Bioaccumulation

There was no evidence that the PAHs or TRH in the gasworks-contaminated sediments of Kendall Bay were being taken up by oysters or mussels.

Mussels were found to contain elevated levels of zinc, and oysters contained high levels of copper and zinc. The copper values were comparable in the three bays. The zinc and cadmium values were higher in Majors Bay oysters than in the oysters from Kendall and Exile Bays. Samples from Kendall Bay did not show elevated levels of metals compared to the background bays, and for this reason it does not appear that the gasworks-contaminated sediments in the Southern and Northern Investigation Areas are significantly contributing to the levels of metals in oysters or mussels.

5.9.3 Potential Effects on Benthic Biota

Sediment distribution

The sediment investigations showed that the gasworks contamination, distinguished by black or dark grey oily sediments with a strong tar or hydrocarbon odour, was only present at the surface in the south-western corner of Kendall Bay, and in two patches on the western side in the vicinity of the former coal wharf.

Elsewhere, gasworks contamination, where present, was covered by a layer of estuarine mud deposited since the gasworks contamination entered the bay.

Sediment Chemistry

The sediment chemical data showed that some areas of Kendall Bay contained gasworks contaminants (PAHs and TRH) greatly exceeding

the GVs and therefore indicative of a risk to benthic organisms exposed to these sediments. These areas included parts of the 2014 Remediation Areas A and B, as well as parts of the bay adjacent to these areas.

Ecotoxicology and Bioavailability Studies

The CSIRO bioavailability studies (above) indicated that the elevated mixed-metal burden in some Kendall Bay sediments was likely to cause chronic toxicity, although similar metal burdens occur throughout the Parramatta River and its bays, beyond the influence of the gasworks.

Total sediment PAH and porewater PAH data both indicated a potential for adverse effects on exposed organisms, although because of the high BC concentrations, the models provided poor predictions of toxicity from total PAH (normalised to 1% TOC).

All 14 sediment samples which CSIRO found to cause acute and high chronic toxicity were oily or had an oily sheen, and were generally black, with a tar odour. The sediments causing chronic toxicity or no toxicity were distinctly different, typically grey or grey brown, with either a 'marine' odour, no odour or, occasionally a slight hydrocarbon or slight tar odour.

The CSIRO studies identified the Contaminants of Concern to be PAHs and TRH. CSIRO indicated that remediation targeting sediments that may cause acute toxicity to benthic organisms could significantly improve the ecosystem health within Kendall Bay. Based on the chemical bioavailability and toxicity testing, CSIRO proposed the following chemical remediation criteria for the sediments:

- Total PAH concentrations: average <25 mg/kg (1% TOC) (representing effects thresholds) and maximum <55 mg/kg (1% TOC) (representing effects occurring frequently); and
- TPH concentrations: average <4400 mg/kg and maximum <6000 mg/kg.

CSIRO also indicated that targeting areas where chronic toxicity is observed may be ineffective at eliminating chronic toxicity of the sediments in the longer term, because remediated areas within the



bay will be expected to become re-contaminated as sediment from the surrounding environment is redeposited.

Benthic Community Studies

The majority of samples, both in Investigation Areas and background sites, supported marine benthic communities. The differences among sampling locations were typically small-scale differences in the number of animals rather than substantial differences in the number of taxa. Some samples contained no fauna; these were generally in areas where gasworks contaminants were exposed at the surface and were, or were likely to be, on the basis of the CSIRO criteria, acutely toxic.

Throughout the majority of the bay the layer of black oily gasworks-contaminated sediment was overlain by 50-300 mm of recent silt containing benthic infauna comparable to that found at other sites, distant from gasworks contamination, in the Parramatta River and its bays.

All available LOE are considered in defining remediation areas and boundaries (Chapter 7).

No risk was identified to organisms outside Kendall Bay.

5.10 BULK EXCAVATION TRIAL

5.10.1 Sampling

A bulk excavation trial was undertaken on 22 September 2016 in order to obtain large volume sediment samples for engineering testing, including testing for in situ solidification.

The trial was carried out using an excavator on a barge, surrounded by silt curtains, to excavate samples of gasworks-contaminated sediment from the most contaminated parts of both the Northern and Southern Investigation Areas. The working arrangement is shown on Figure 5.29. An excavator bucket full of the black oily contaminated sediment is shown in Figure 5.30.

Sediment was collected from three locations, NA3 and NA2 in the Northern Investigation Area, and SA1 in the Southern Investigation Area (Figure 5.31). At each location, the excavator, using a large

but narrow bucket, sampled the sediment from the surface to a depth of approximately 1 m. At SA1 a second sample was collected from a depth of approximately 1.5 – 2.5 m. It had been hoped to sample a second area in SA1 but this was not possible in this shallow area because the falling tide left insufficient depth for the barge's tender boat.

At each site, the excavator operator carefully tipped sediment from each sampling location into one or more 220 L drums. Contaminated sediment was also collected from the excavator bucket and placed into 20 L containers.

Six 220 L drums, each half full of sediment, were collected, plus 18 buckets of 20 L capacity. Sediment subsamples were also collected from each drum and bucket for bulk chemical testing, volatiles testing and grainsize testing. The sediment samples were collected and analysed by the same procedures as had been used in the previous sediment investigations (S&W, 2018a). It was not appropriate or possible to homogenise the sediment in the drums or buckets before sampling, and therefore the samples may not be fully representative of the material in the drums and buckets.

Water quality monitoring was carried out in Kendall Bay before the bulk excavating began, during bulk excavation at each location, and after sampling was completed. The monitoring conducted during sampling was carried out both within and outside the silt curtains.

Air quality measurements were undertaken by SGS Australia Pty Ltd (SGS) up- and down-wind during the excavation works, from a small rowboat to eliminate interferences from fuels and exhaust emissions. Ektimo Pty Ltd carried out an odour assessment at the same time.

5.10.2 Results

Sediment Chemistry

Overall, the chemistry of the bulk samples was comparable to the results of the main sediment sampling program (Section 5.3), with the following exceptions:

- the bulk samples from NA2 and NA3 were low to very low in Total Cyanides compared to the

Figure 5.29. Barge-mounted excavator and silt curtains.



Figure 5.30. Excavator bucket full of gasworks-contaminated sediment. Note oily sheen on water within silt curtain.





Figure 5.31. Location of bulk excavation trial sites, September 2016.



Maximum Values from the large amount of data for the Northern Investigation Area; and the two bulk samples from SA1 were very low in volatiles (BTEX and Naphthalene), and somewhat low in TRH and Total PAH compared to the Maximum Values from the large amount of data for the Southern Investigation Area.

Water Quality

Water quality samples were taken during the bulk sampling trial, immediately adjacent to the excavator operations inside the silt curtain and also immediately outside the silt curtain that enclosed the work area at each sampling location. Background samples were also taken before the work barges located to Kendall Bay, and hours after the barges left the bay.

The results indicated that, compared to background values:

- dissolved oxygen, temperature and conductivity levels did not vary significantly inside or outside of the silt curtain; and
- turbidity levels rose in the work area inside the silt curtain but rapidly dropped to background levels after the works were finished.

Chemical analyses of water samples indicated that:

- the levels of naphthalene and toluene were elevated inside the silt curtain (but not outside) during excavation;
- the levels of total and dissolved PAHs including Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene and

Pyrene were slightly elevated inside the silt curtain surrounding the work area, but not outside the curtain; and

- these elevated levels rapidly returned to background levels after excavation ceased.

Minor increases in the levels of total chromium, lead and zinc were observed inside the excavation works areas, but not immediately outside, presumably due to elevated suspended sediment values. These metal levels were short-lived in the water column and returned to background after the excavation ceased.

Levels of suspended solids in the immediate areas of the excavation inside the silt curtain increased during excavation, but rapidly returned to background levels after the excavation works were completed.

Odour assessment

Air monitoring did not identify any individual chemicals down-wind of the excavation to be present above levels normally found in urban air. Some odour was identified, however, supporting the need for mitigation measures proposed after the modelling was completed. The results are reported in two separate reports, *Air Sampling and Analysis During Kendall Bay Dredge Trial, September 2016* (SGS, 2016), and *Emission Testing Report, SGS Australia Ltd, Mortlake* (Ektimo, 2016).

5.11 OTHER STUDIES CARRIED OUT FOR THE REMEDIATION ACTION PLAN

5.11.1 Odour Modelling

Todoroski Air Sciences were commissioned to undertake air dispersion modelling to estimate odours and ambient air concentrations of PAHs and other chemicals that may be emitted from an excavation surface during remediation works on the sediments in Kendall Bay (Todoroski Air Sciences 2016). The sampling was carried out in February 2016.

The results are summarised in Section 5.8 above and the full report is included in Appendix D of the HHRA.

5.11.2 Volatiles Chemistry

SGS Australia Ltd was contracted in March 2016, to carry out chemical testing of volatile compounds released from the gasworks-contaminated sediments. The work was carried out in March 2016, and used in the HHRA (summarised in Section 5.8).

5.11.3 Remediation Strategy Review

Royal HaskoningDHV were commissioned to carry out a remediation technology screening and prepare a remediation strategy and work methods. The strategy and methods are described in Royal HaskoningDHV (2016b), *Kendall Bay Sediment Remediation Project Preferred Strategy and Work Methods for Remediation Action Plan (RAP)*, which is presented in Appendix 2. Relevant sections from the report are included in Chapter 8 and 9 of the RAP.

5.11.4 Geotechnical Assessment

JK Geotechnics (2016) prepared a report for Jemena, *Revised Geotechnical Assessment and Design and Construction Advice for Proposed Kendall Bay Remediation Project at Kendall Bay, NSW*. This report updated two reports JK Geotechnics had prepared in 2012, one being a geotechnical model for the sediments of Kendall Bay and the other presenting a construction methodology for the remediation proposed at that time.

The 2016 report updates the geotechnical model using additional data collected since 2012, and describes the geotechnical conditions and sets out construction conditions and recommendations for each of the Remediation Areas defined in Chapter 7 of this RAP. The report is presented in Appendix 3.



Chapter 6

CONCEPTUAL SITE MODEL

An important function of a Conceptual Site Model (CSM) is to identify a complete link between a contaminant source, contaminant release, contaminant transport pathway to sediment, presence of the contaminant in sediment, and exposure of the contaminant (above established risk levels) to receptors (Washington Dept. of Ecology, 2015).

An initial CSM was developed in the work program planning stage as a guide to the studies that would be required. The CSM and work program were developed using the USEPA's seven-step DQO process as set out in Appendix B of NEPC 2013b, Schedule B2, Guideline on Site Characterisation. The process is fully described in S&W, 2018a.

The CSM was progressively refined with the results of the individual investigations in 2015-2016. The purpose of the CSM was to

- document the sources of contamination in the study area, the COCs, and the areas contaminated by gasworks wastes;
- show how contaminants already contained in the sediments of Kendall Bay, or released into the bay, might move under certain circumstances in the aquatic environment;
- identify the potential human and ecological receptors that could be exposed to COCs; and
- list the potential and complete exposure pathways (e.g. exposure to contaminated water, uptake from water, ingestion of contaminated sediment, direct contact with sediment, uptake from suspended sediment in water column) for each receptor.

The draft CSM is shown in Figure 6.1.

6.1 CONTAMINATION SOURCES

6.1.1 Historic Contamination Sources

Mortlake Gasworks

The principal source of the sediment contamination by gasworks wastes in the Declared Area was operations at the Mortlake gasworks site prior to its closure and remediation.

It is not known how the tarry oils, now present in some of the sediments of Kendall Bay, entered the bay. The Mortlake gasworks had multiple sources of tarry oils including tar wells and tanks, tar pipelines (one of which is reported to have extended along the former coke wharf into Kendall Bay), coke stockpiles (particularly large stockpiles on land reclaimed from the former bay end in the south-eastern part of the former gasworks site), waste piles such as oxide-revivifying areas and spent oxide dumps, also present in the south-eastern area and the large deep waste dam formed from the former water supply dam, which, sometime after the 1940s became a repository for tar and other wastes. Contamination from these sources could have entered the southern part of the bay down stormwater drains or by subsurface flow, and the mid-western side of the bay from tar pipeline releases and spilled coke.

However, this contamination is considered to be historic rather than ongoing because:

- the former gasworks site has been remediated and certified as being suitable for residential use and open space/parkland by the site auditor, all NSW EPA notices were removed more than a decade ago and the site has been redeveloped into the residential suburb of Breakfast Point;
- throughout the majority of the Declared Area, where gasworks-contaminated sediments are present, those sediments are overlain by 50-300 mm of recently deposited silt that is characterised by significantly lower levels of the COCs, and contains benthic infauna. Over much of the bay, the black oily clay layer which has a high level of gasworks-derived contamination occurs as a distinct layer with a relatively sharp upper boundary below the recent silt;
- given the low sedimentation rate in Kendall Bay (Section 4.6.3) the layer of recently deposited silt, which would have accumulated over decades, indicates that the gasworks contamination is historic, not currently occurring;
- the recent silt depth measurements are considerable underestimates of the true in

The flowchart illustrates the waste management pathway from Gasworks Wastes to various receptors. The process is divided into four main stages: Primary Source, Primary Release Mechanism, Secondary Sources, and Exposure Route. The receptors are categorized into Fish, Benthic Fauna, Transient Marine Invertebrate (crustacean), Human Consumption, and Intertidal Invertebrates (oysters and mussels).

Primary Source: Gasworks Wastes

Primary Release Mechanism: Historic Point Source Emissions, Solid Wastes, Liquid/Tarry Wastes

Secondary Sources: Intertidal Surface Sediments and Seawater, Groundwater, Surface Waters, Subtidal Sediment, Porewater

Exposure Route: Direct Contact, Ingestion

Receptor: Fish, Benthic Fauna, Transient Marine Invertebrate (crustacean), Human Consumption, Intertidal Invertebrates (oysters and mussels)

Legend:

- Pathway is not complete; no evaluation required
- Pathway is complete, but judged to be minor; qualitative evaluation
- Pathway is complete and might be significant; insufficient data available for qualitative evaluation
- Pathway is complete and might be significant; sufficient data available for qualitative evaluation

- the sandy sediments in the mangrove area and the stormwater delta immediately north of the mangroves, which from aerial photos of the bay were largely deposited since the 1970s and also immediately overlie the black oily clays, support this time estimate; and
- although gasworks-contaminated sediments are found at the surface in part of the Southern Investigation Area and at two places in the Northern Investigation Area (see Section 5.3.1.1), the presence of the

Other Historic Sources

- the former Dulux paint factory at Cabarita, to the south-east of Kendall Bay, which operated from 1921 to the 1990s and produced white lead (lead oxide) and a range of paints (although wastewater discharge was to France Bay on Hen and Chicken Bay). This site was also remediated in the late 1990s (Figure 4.18) and redeveloped for residential purposes;
- a number of stormwater outfalls, particularly the large stormwater outfall that discharges through the mangroves at the southern end of Kendall Bay;

- resuspension and redeposition of contaminated sediment from the Parramatta River upstream and downstream of Kendall Bay by tidal and wind currents;
- urban runoff and airborne fallout;
- groundwater movement; and
- vessels using the bay.

6.1.2 Current Contamination Sources

Current contamination sources to the bay include:

- resuspension of contaminated gasworks sediments exposed at the sediment surface and redeposition elsewhere in the bay;
- a number of stormwater outfalls, particularly the large stormwater outfall that discharges through the mangroves;
- resuspension and redeposition of contaminated sediment from the Parramatta River upstream and downstream of Kendall Bay by tidal and wind currents;
- urban runoff and airborne fallout;
- groundwater movement; and
- vessels using the bay.

6.1.3 Areas of Kendall Bay Contaminated by Gasworks Waste

The surface areas contaminated by gasworks wastes are shown on Figures 5.7 and 5.8.

6.2 CONTAMINANT TRANSPORT

Since Kendall Bay is largely a depositional environment, the majority of the historic gasworks contamination is buried beneath recently deposited silt, as noted above. Therefore, over most of the bay direct exposure to the gasworks contamination will only occur to organisms that burrow deep into the sediments.

The majority of the infauna in estuarine muds occupy only the top 50-100 mm of the sediment (Dr Alison Hunt, pers. comm.; USEPA, 2015) and infauna and epifauna will not be directly exposed to gasworks-contaminated sediment except where biotic processes (such as bioturbation) have moved contamination up into the overlying silt. However, infauna and epifauna will be exposed to contaminants in the sediment porewater, or released from the sediments into the immediately overlying water.

In those parts of the bay where erosion, lack of sedimentation or human activities have exposed the gasworks contamination, organisms dwelling in or on the mud will be directly exposed to high levels of PAHs, TRH and other gasworks contaminants. The ecotoxicology and benthic community studies showed these areas to be acutely toxic to the test organisms and the sediments sometimes contained no fauna.

6.3 RECEPTORS

The potential receptors for the contaminated sediments in Kendall Bay are defined in the NSW EPA Water Quality Objectives for the Parramatta River (Section 4.8.1). The receptors are the aquatic organisms and ecosystems of Kendall Bay (e.g. fish, crabs, oysters, mussels, prawns, benthic infauna and epifauna, seagrasses), and recreational users of the bay.

6.4 EXPOSURE PATHWAYS

The main environmental media of concern for this RAP are the gasworks-contaminated sediments, porewater in the sediments and possibly, contaminants released from the sediments or porewater into the immediately overlying water.

Water quality monitoring has shown that the chemistry of Kendall Bay waters is not significantly different to the chemistry of waters in Exile Bay and Majors Bay, which are beyond the influence of gasworks contamination.

Biological tissue monitoring has shown that tissue concentrations in the organisms monitored (oysters and mussels) are not significantly different to those of the same organisms from Exile Bay and Majors Bay, which are beyond the influence of gasworks contamination.

The principal completed exposure routes for organisms in the bay are:

- ingestion of and direct contact with contaminated sediments;
- ingestion of and direct contact with contaminated pore water and, possibly, water immediately overlying the contaminated sediments; and
- ingestion of organisms contaminated with sediment, and possibly ingestion of



benthic organisms that have accumulated contaminants in their tissues.

Exposure routes for recreational users of the bay include:

- direct dermal contact of contaminated sediments;
- consumption of contaminated organisms;
- odours; and
- ingestion of contaminated sediments.

6.5 POTENTIAL FOR RECONTAMINATION OF REMEDIATED AREAS

Before taking a decision to remediate, it is necessary to ensure that the source of the COCs has been removed or isolated, as there would be no point remediating the gasworks-contaminated sediments in Kendall Bay if contamination from this source was continuing. Accordingly, the potential for the remediated areas to be re-contaminated has been assessed, in consideration of:

- migration of groundwater from the Breakfast Point development;
- discharge of stormwater into Kendall Bay; and
- mobilisation of sediments from other parts of Kendall Bay and the Parramatta River.

6.5.1 Migration of Groundwater from the Breakfast Point Development

The Breakfast Point residential development occupies the site of the former Mortlake gasworks, which as described in Section 3.1 of this RAP, was remediated in the period 1999 to 2002. As part of the remediation works, some contaminated materials were contained in areas on the site:

- a containment cell, located in the south-western part of the Breakfast Point site, over which the Village Green was established. The cell is located approximately 350 m from the southern part of Kendall Bay and was:
 - placed within the location of former gasholders and excavated into sandstone bedrock;
 - lined with a synthetic low-permeability liner;
 - infilled with contaminated materials that met leaching criteria that were

protective of groundwater quality and, therefore, the quality of water in Kendall Bay. (no tars were placed in the cell); and

- capped with clean fill materials over which lime and clean fill were placed and completed with grass cover.
- an entombment zone in which coal tars were retained in underground tanks located in the north-eastern part of the Breakfast Point site (Figure 3.5) and which at the nearest point is approximately 200 m from Kendall Bay near the location of the former coal wharf; and
- contaminated fill that remains behind the sea wall, particularly in the former bay end and filled valley on the south-eastern side of the Breakfast Point site. This fill is known to contain gasworks contaminants but not tar.

The integrity of the containment cell and the entombment zone, as well as the areas in which contaminated fill remains, are all monitored on a regular basis as follows:

- the containment cell is subject to monitoring several times a year for groundwater by consultants engaged by Jemena from five pits located close to the perimeter of the cell (see Figure 3.8) and from five groundwater monitoring wells, three of which are located close to the down-gradient side of the cell and two of which are located on land near the seawall bounding the southern part of Kendall Bay. Although occasional low concentrations of benzene, C18 to C28 petroleum hydrocarbon fractions and naphthalene have been identified in some monitoring events in some wells, no tar DNAPLs have been identified;
- the entombment zone is subject to periodic monitoring of groundwater by consultants engaged by the Breakfast Point community (i.e. this is a property owner obligation) from four groundwater monitoring wells located close to the down-gradient side of the cell entombment zone; and
- low-concentration contaminated fill remains behind the sea wall along its entire length, however six monitoring wells installed from the former bay end almost to Tennyson Road, close to the seawall, have not reported significant concentrations of contaminated

groundwater. Neither have these wells reported high concentrations of petroleum hydrocarbons, naphthalene or cyanide that would (if present) indicate migration of non-aqueous phase liquids from this material.

No significant concentration of components of gasworks waste have been identified in groundwater.

The results of groundwater monitoring events are reviewed by a Site Auditor engaged by Jemena and are provided to the EPA. No issues have been raised based on the results of the monitoring events.

Based on the results of groundwater monitoring, the risk of recontamination of remediated areas proposed in this RAP by migration of groundwater from the Breakfast Point site is considered to be insignificant.

2014 Remediation Plan Assessment of Recontamination Risk

The risk of recontamination of remediated areas within Kendall Bay was also examined in the 2014 RAP (2014). Excerpts from the findings by SKM (which remain applicable) are included below:

'The former gasworks site has been remediated, certified as being suitable for residential and open space/parkland uses by a Site Auditor, and all NSW EPA notices were removed approximately 10 years ago'.

'Investigations have shown that sediments in the Declared Area are mainly contaminated by high molecular weight PAHs and heavier-end TPH fractions compared to the low molecular weight PAHs and light-end TPH fractions (Section 4.1.6). This indicates that the hydrocarbon contamination remaining in these sediments is historic and that the sources of contamination (51) have been removed or reduced to such an extent that they are having no measurable (sic) impact on sediment contamination;'

(51) Examples of these contaminant sources include spills, discharges and the migration of contaminated groundwater from the former gasworks operation/site' (p87).

'At Kendall Bay, submarine groundwater flows would be occurring from the former Mortlake Gasworks site towards Kendall Bay. A major remediation program of the gasworks site was completed several years ago, which was approved by a Site Auditor and the NSW EPA. This was followed by the redevelopment of the land for a major residential development referred to as Breakfast Point.

Consequently, it can be reasonably assumed that there is a low risk of any significant amount of contaminated groundwater migrating from the land into Kendall Bay' (p163).

Assessment of Risk of Recontamination of Proposed Remediated areas

There is potential for low-level sediment and soil contamination to remain below and behind the seawall. The presence of the seawall will have prevented assessment of those materials. Any contaminated sediment occurring beneath the seawall is expected to have been leached in a similar manner to the sediments within the bay and as a result, any residual contamination would likely comprise low solubility PAH and TRH fractions. These residual contaminants are therefore unlikely to be significantly mobile in the groundwater environment and therefore very unlikely to re-contaminate remediated areas.

Anecdotal information has indicated that low-level gasworks wastes have been placed as backfill behind the seawall. Infiltration through contaminated soil materials located behind the seawall has the potential to leach contaminants to groundwater and thus to the marine water column. The area immediately behind the seawall is covered in permanent pavement or vegetated areas. The volume of infiltration that might enter the zone behind the seawall is considered to be low as a result of the surface coverings and so the potential for significant leaching of contamination as a result is also considered to be low. Direct seepage through the seawall could also occur but any such seepage would be expected to be minor and would enter the marine water column and be dispersed. Therefore, any seawall seepage waters would be unlikely to re-contaminate remediated areas.



The groundwater monitoring conducted within the Breakfast Point site, targeting the key residual contamination risks, has indicated that negligible contamination of the groundwater is occurring. Based on the results of groundwater monitoring and the consideration of potential risks associated with residual sediment and soil contamination in the vicinity of the seawall, the risk of re-contamination of remediated areas proposed in this RAP by migration of groundwater from the Breakfast Point site is considered to be insignificant.

However, as a conservative measure, to avoid migration of any possible gasworks contamination into the remediated areas, it is proposed to enclose Remediation Areas SA1 and NA2+NA3 in a continuous piled structure, such as sheet piling or a cement-stabilised cut-off wall (Chapter 8). This measure will effectively isolate the Remediation Areas from the Breakfast Point site and from non-gasworks contaminants which could possibly migrate in stormwater into Kendall Bay and from other contaminated sediments likely to migrate in currents from the Parramatta River. The cut-off wall will also prevent sediment contamination occurring within the remediated area from migrating beyond the remediated area. The proposed cut-off wall and stabilised raft structure (See Figure 9.2) will essentially entomb the contaminated sediment materials within the designated remediation zones.

6.5.2 Mobilisation of Sediments from Other Parts of Kendall Bay and the Parramatta River

Kendall Bay is largely a depositional area for sediment (Section 4.6.3), and once remediation has been completed natural processes (tidal and wave currents) will transport suspended and bed sediment from surrounding areas of the bay and the adjacent Parramatta River, and begin to deposit this sediment in the Remediation Areas. As previously noted, the whole Parramatta River is contaminated with heavy metals and a range of other substances, and therefore over time the composition of surface sediments in the remediated areas will change to reflect background contamination in the Parramatta River.

6.5.3 Discharge of Stormwater into Kendall Bay

Stormwater will continue to be discharged into the bay from the large drain at the head of the bay and from other smaller discharges, however the catchment areas are not exposed to unremediated gasworks wastes and therefore any contamination coming from the drains will be comparable to the urban contamination which currently discharges into the Parramatta River from other stormwater drains. Given the existing contamination of the Parramatta River by heavy metals and other substances, input from the stormwater drains is not expected to cause any increase in this background.

6.6 CONCEPTUAL MODEL OF GASWORKS CONTAMINATION WITHIN KENDALL BAY

A conceptual model of gasworks contamination was developed for the bay. The model was based on the sedimentology observed in core logs as well as the chemical data obtained during the investigations, and observations made in relevant previous studies of the sediments. The model shows the distribution with depth of gasworks contamination in the bay, as well as the depth of recent silt overlying the contamination, and the depth at which firm sediments occur below the contamination. The model was used in design of the Remediation Action Plan.

Figures 6.2 and 6.3 are cross-sections through the sediments of the Southern and Northern Investigation Areas, respectively. Note that due to dewatering, compaction and plastic flow during coring, depths shown on the figures are approximate.

In the Southern Investigation Area, typically a thin layer of recent estuarine mud (0.05 – 0.25 m thick) overlies a layer of black or dark grey soft oily gasworks-contaminated sediment, commonly around 1 m in thickness, occasionally 2 m or more thick, sometimes containing gravel of coal or coke. In the south-western corner this dark oily sediment occurs at the surface. Below it is a layer of soft silty clay, typically 2 to 5 m thick, which can contain veins and blobs of black oil or DNAPL. The lowest layer encountered was a firm sandy

Figure 6.2. Cross section through Southern Investigation Area

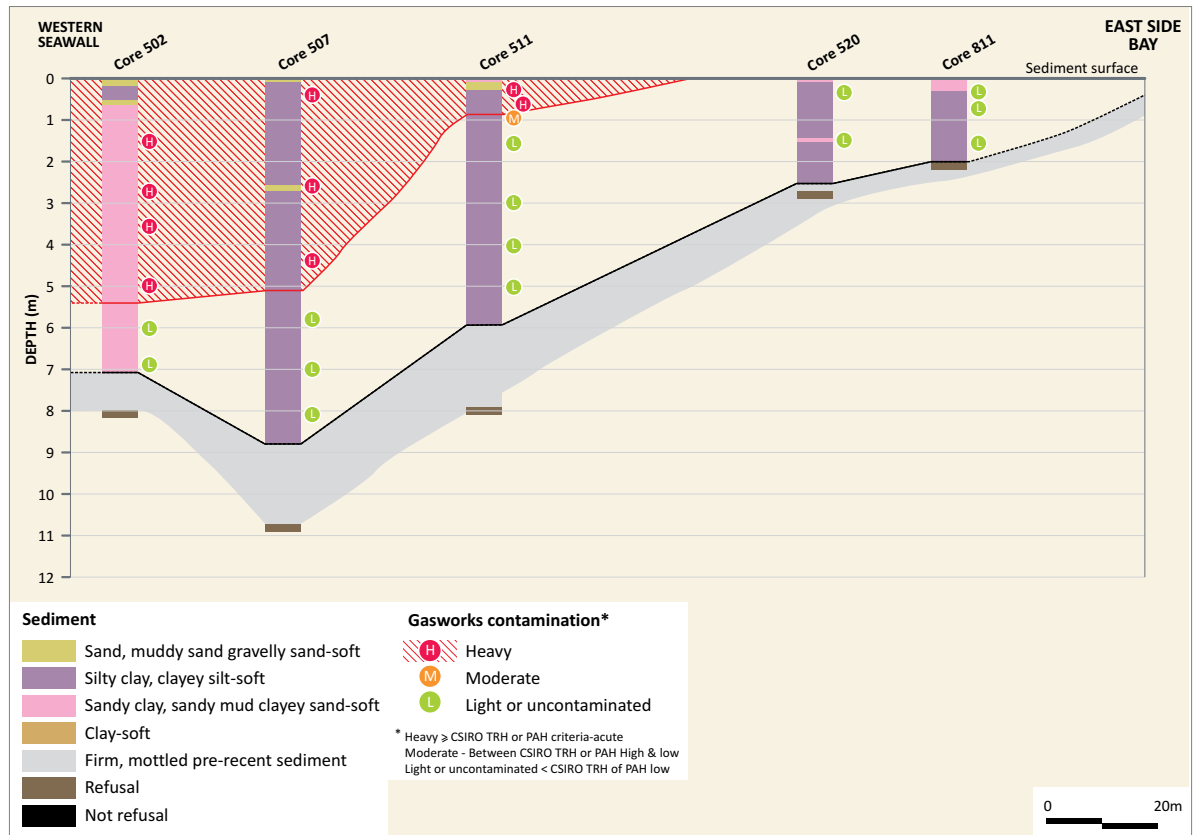
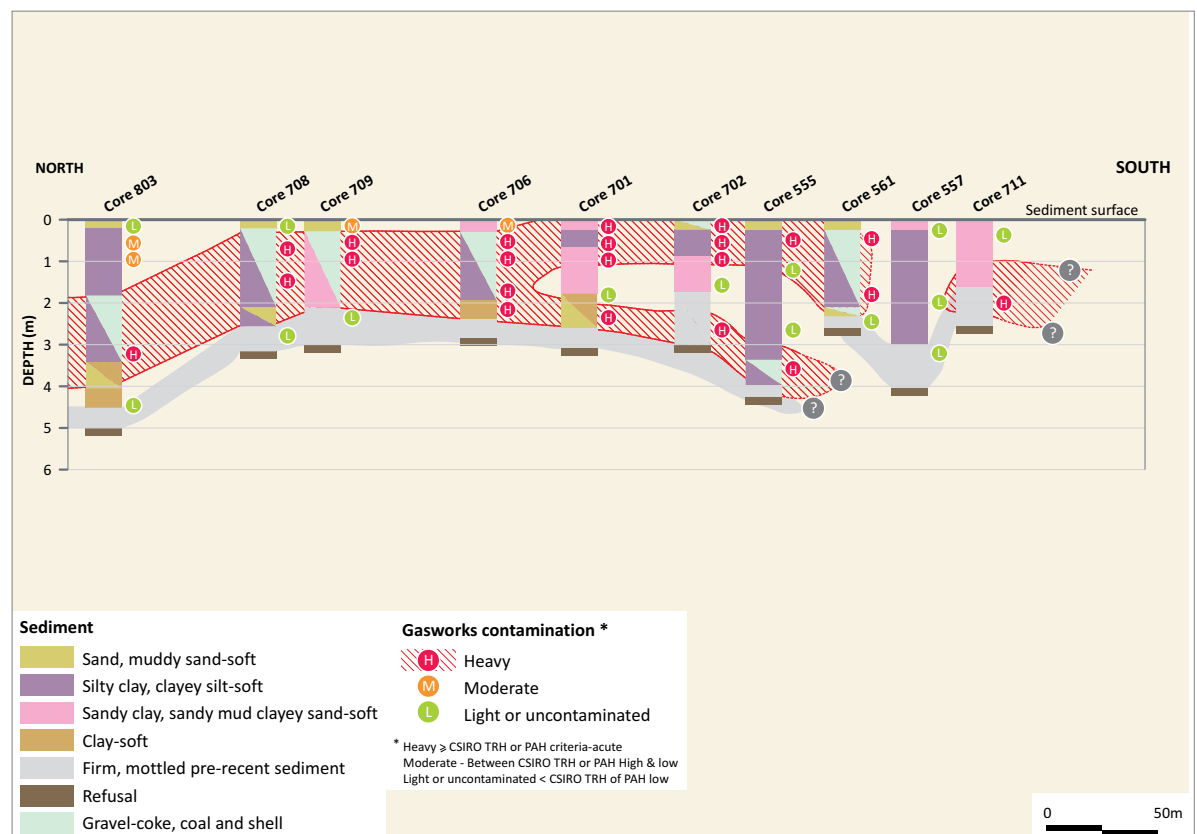


Figure 6.3. Cross section through Northern Investigation Area





clay or clayey sand, mottled orange and yellow, which was uncontaminated in most cores, though several cores on the south-western side of the bay did contain contamination in this layer.

Based on the chemical data, the typical thickness of heavy gasworks contamination (defined as exceeding the CSIRO Acute criteria for TRH or normalized PAH) in the south-western corner of the bay was 5 m (maximum 8 m), though to the north and east the contaminated layer thinned rapidly and was absent in some cores on the eastern side of the bay.

In the Northern Investigation Area, typically a thin layer of recent estuarine mud (0.05 – 0.3 m thick) overlies a layer of black or dark grey soft oily gasworks-contaminated sediment, commonly around 1 m in thickness, occasionally 3 m or more thick, often containing gravel of coke or coal. In two areas, near and north of the former coal wharf mound, this dark oily sediment occurs at the surface. Below it is a layer of soft silty clay, sometimes gravelly, typically around 1 m thick, which was sometimes oily or contained veins and blobs of DNAPL. The lowest layer encountered was a firm sandy clay or clay, mottled orange and yellow, which was sometimes contaminated.

Based on the chemical data, the typical thickness of heavy gasworks contamination (defined as exceeding the CSIRO Acute Criteria for TRH or

normalized PAH) in Northern Investigation Area was 2 – 4 m. In cores near and north of the former coal wharf, two heavily contaminated layers were often present, separated by sediment that was relatively clean. This pattern may be due to removal of the former coke and coal wharves, dredging, or sediment slumping into dredged channels.

The sedimentological and chemical data strongly suggest that the majority of the gasworks contamination entered Kendall Bay via surface disposal, release or discharge of tar or tarry wastes many decades ago, and that heavy tarry oils and DNAPL subsequently migrated downwards into the sediments. It is not possible to tell whether contamination was due to a single pollution discharge or release, or to a number of such events at one location in Kendall Bay or in a number of locations. However, it is known that in the early 1930s, the gasworks began dumping of 'non-specification coal tar, CWG tar-water emulsions and other toxic and inert gas manufacturing residuals and wastes, at a site on the foreshores of Homebush Bay' (Hathaway, AW, 2010). Release of similar wastes into Kendall Bay could also have occurred at that time.

Chapter 7

DEFINITION OF REMEDIATION AREAS

7.1 REQUIREMENT FOR REMEDIATION

Based on the evidence presented in the preceding sections, a clear case has been made for remediation of gasworks-contaminated sediments in parts of the Southern and Northern Investigation Areas, in order to protect human health and/or to protect the aquatic environment from acutely toxic sediments. The boundaries of the individual Remediation Areas are defined in Section 7.3.

7.2 REMEDIATION OBJECTIVES

The specific objectives in this RAP have been developed for each Remediation Area within Kendall Bay and the overall remediation works, and these are detailed below.

Southern Remediation Area

Remediation works in the Southern Remediation Area will be undertaken to:

- remediate to the extent practicable gasworks-contaminated sediments that pose an acute toxicity risk to the marine ecosystem;
- remediate gasworks-contaminated sediments that pose an unacceptable risk to human health of users of the mangrove area and of areas of sediment that pose an unacceptable risk to human health when exposed so as to be accessible at low tides;
- remediate stained surfaces, gasworks-contaminated sediments giving rise to emission of odours when exposed at low tides, and rubbish in accessible areas of the mangroves, on the southern beach and in the foreshore adjacent to the seawall; and
- install a physical barrier to control discharge of stormwater from the large drain at the southern end of the bay to ensure stormwater discharge to Kendall Bay does not impact the remediated parts of the Southern and Northern Remediation Areas.

Northern Remediation Area

Remediation works in the Northern Remediation Area will be undertaken to:

- remediate to the extent practicable gasworks-contaminated sediments that pose an acute toxicity risk to the marine benthic communities; and
- remediate stained surfaces, gasworks-contaminated sediments giving rise to emission of odours when exposed at low tides, and rubbish in accessible areas of the foreshore adjacent to the seawall.

7.3 GENERAL METHODOLOGY FOR DEFINITION OF REMEDIATION AREAS

7.3.1 Human Health Risk

The boundary definitions to protect human health are based on the criteria set out in Section 5.8 Table 5.5.

7.3.2 Ecological Risk

The following methodology has been used to produce defensible and scientifically robust remediation boundaries for ecological risk, based on the reports and studies presented in Chapter 5:

1. Plot sediment chemistry for the 0-300 mm interval, flagging points that exceed either CSIRO's acute toxicity criteria for PAH of 55 mg/kg @1% TOC or for TRH of 6000 mg/kg:
 - where there are areas with few samples in the Northern Investigation Area, plot the sediment chemistry data from the 2014 HHERA for the areas where PAHs exceeded 55 mg/kg @1% TOC; and
 - this resultant map shows sediment chemistry indicative of acute risk to benthic organisms.
2. Plot AH&A's benthic infauna data (Section 5.6), highlighting locations exceeding the above chemical criteria where:
 - no benthic fauna was present, or any benthic fauna present was impoverished compared to areas of Kendall Bay uncontaminated by gasworks wastes (as evidenced by background levels of PAHs, Figure 5.18);
 - the existing benthic fauna was comparable to the fauna found in areas of the bay uncontaminated by gasworks wastes (background PAH contamination); and



- plot the thickness of recent sediment overlying the black oily contaminated layer, flagging the minimum depth of recent sediment that can contain a viable community. A depth of 50 mm has been used, as measured in push cores, which equates to a true in situ depth of 100 mm or greater (Section 5.3).

The areas to be remediated will be those areas where contamination in near-surface sediments (0-300 mm) exceeds the above CSIRO chemical criteria and:

- the sediments were found to be acutely toxic; or
- the sediments were found to contain no benthic fauna; or
- oily gasworks contamination was present in surface sediments or within 50 mm of the sediment surface.

Where the gasworks contamination is overlain by at least 50 mm of recently deposited sediment containing benthic infauna comparable to the fauna found in areas of the bay uncontaminated by gasworks wastes (Figure 5.18), the sediments will not be remediated as this would remove a viable benthic community, cause environmental harm and be contrary to the principles of environmental sustainability, and USEPA policies for remediating contaminated sediments.

7.3.3 Amenity

Remediation Areas SA4 and SA5 were defined largely on improving public amenity. Remediation measures proposed in these areas will remove surface contamination that could give rise to odours when the sediments are exposed at low tides, will remove rubbish and rocks that are stained with tar, and replace surface sediments with clean sand.

7.4 FUTURE SEDIMENT ACCUMULATION IN KENDALL BAY

7.4.1 Recent Silt Accumulation

Kendall Bay is regularly subjected to boat wake waves from Rivercat and Harbourcat movements along the Parramatta River and is also exposed to wind waves from the north-west to the east

creating local wind-generated waves from these directions. The currents generated by waves are capable of mobilising the bed sediments. This is evidenced by the distribution of sediments where wave action at the shoreline margins has caused finer sediments to be winnowed out, carried offshore and deposited in the deeper, lower energy, environments leaving behind a sandy beach and delta to the south, a cobble area in the south-west corner, and gravelly muds near the western shoreline of Kendall Bay. Wave action, particularly from Rivercats and Harbourcats, which is of longer period than generated from conventional vessels and wind, is also capable of transporting sand-sized material alongshore in the shallow littoral zone.

A review of historical aerial photographs (Figure 7.1) indicates that sediment has accumulated over time at the beach area at the head of the bay. These sediments are likely to be a combination of coarser sandy marine sediments transported to the head of the bay by wind and boat wake wave action, and sand-sized sediments from catchment sources delivered into the bay by stormwater discharges.

7.4.2 Forecast Future Sedimentation Rates in Kendall Bay

Section 4.6.3 indicates that sedimentation rates in the central part of the bay are in the range 5-15 mm per year. Over the past 50 years, erosion has occurred along the eastern side of the bay and the presence of cobbles and gravelly sediment exposed in the south-western corner of the bay provide evidence that erosion is occurring along parts of the western side as well.

Assessment of current sedimentation rates in the Northern Investigation Area is hindered by the presence of the mound formed beneath the former coal wharf, and by past dredging and the effects of removal of the wharf around 2006, however it is expected that the dredge channels will gradually fill in by preferential deposition in deeper areas, and by erosion and possibly slumping of the edges of these channels. The top of the mound, which is armoured with a shell and coke layer 100-300 mm thick, appears resistant to erosion, however the edges of the mound could be subject to failure by slumping into the dredge basins.

Figure 7.1. Aerial photographs of Kendall Bay in 1943 (left) and 2015 (right)



Using a sedimentation rate of 5-15 mm per year, the depositional parts of Kendall Bay are expected to accumulate 50-150 mm of additional sediment over the next ten years, and 250-750 mm of sediment over the next fifty years, which would bury the gasworks contamination more deeply. However, areas subject to wave erosion or erosion at the edges of the former dredged channels, and where contaminated gasworks sediment is currently exposed at the surface in the south-western part of the bay, are not expected to accumulate significant depths of sediment in the near future.

7.5 SPECIFIC DEFINITION OF REMEDIATION BOUNDARIES – SOUTHERN REMEDIATION SUBAREAS

Based on the data presented in Sections 5.3 to 5.7 and the methodology in Section 7.3, five Remediation Areas were defined for protection of human and/or ecological health, or for other reasons (aesthetic, odour, public amenity) in the Southern Remediation Area. These areas are shown on Figure 7.2.

The definition of each Remediation Area within the Southern Remediation Area is set out below.

7.5.1 Southern Remediation Area – SA1

The boundaries of Remediation Area SA1 were defined using the process outlined in Section 7.3 and are shown on Figure 7.3 .

In the western end of the mangroves, there are several sites where the levels of PAHs exceed the adopted Human Health criteria of 1 mg/kg. Some of these are in Remediation area SA1 and will be remediated using in situ solidification. Several others are located in the western end of Remediation Area SA3 but are covered by the

mangrove root mass which in this area can reach half a metre in depth.

The driver of risk in the calculation of the remediation criteria is dermal contact with the contaminated materials. It is assumed that a child may be come into direct contact with the sediments 20 days per year for 6 years in this part of the bay and on each occasion lower arms, hands, lower legs and feet are covered by the sediments. If such contact is prevented by the mangrove root mass or is, at least, greatly reduced due to the physical difficulty in reaching the contaminated materials then the risk is much reduced and compliance with the remediation criteria is not strictly required.

Given the thickness of the overlaying dense root mat, the risk of human exposure in this western end of SA3 is deemed to be negligible and hence the adopted treatment in this area is to leave the mangrove root mass in place and ensure that the surface of the root mass is cleaned of any coke and coal washed onto the surface of the area.

The remediation boundary of SA1 along the seawall has been set out at least 5 m from the wall to avoid potential disturbance of the seawall during remediation, and preserve the integrity of the seawall.

The area between SA1 and the seawall requires remediation based on both human health risk and ecological risk, however this area will have to be remediated differently to protect the sea wall and, accordingly, this area has been identified as SA2.

7.5.2 Southern Remediation Area – SA2

The boundaries of Remediation Area SA2 (Figure 7.3) have been defined by the potential for human contact with contaminated sediments along the intertidal section of the seawall between the



Figure 7.2 Boundaries of the remediation areas in the Southern Remediation Area.

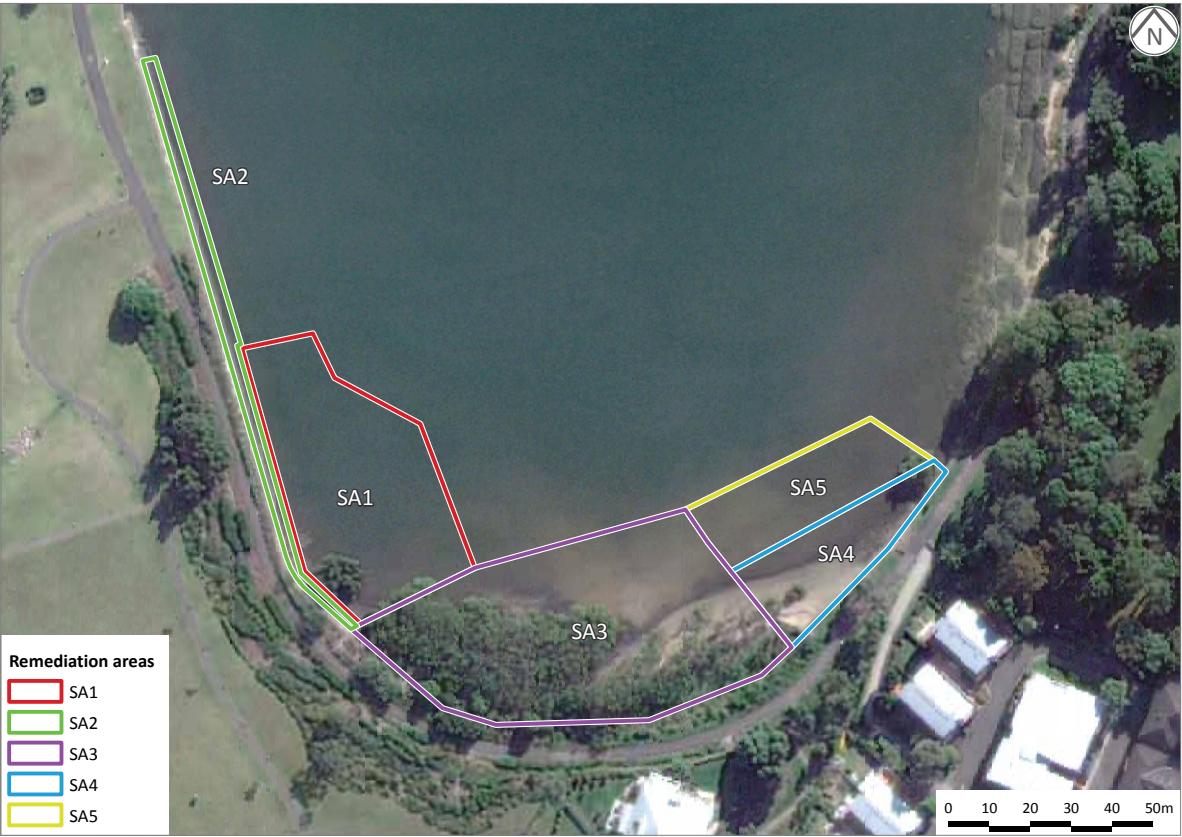


Figure 7.3. Boundaries of Remediation Area SA1 and SA2



southern boundary of SA1 and north along the seawall to where the 0.0 m LAT contour and the seawall coincide. The precise location of this coincidence will need to be determined by survey at the time of the remediation actions being taken.

The proposed remediation reduces the human health risk by removing the surface sediments to below the LAT mark, then adding clean rock and sand to a surface level also below the LAT mark. This eliminates the risk of people coming in contact with contaminated sediments as they will always be well below LAT, and also reduces the possibility of the contaminated sediments warming in sunshine at low tide and emitting odours. The addition of clean rock and sand also addresses the second remediation objective of providing clean sediments for the establishment and development of benthic communities.

7.5.3 Southern Remediation Area – SA3

The Remediation Area SA3 is shown in Figure 7.4.

This area will be remediated to eliminate any human health risk from contaminated sediments (including tars, coal and coke) in the mangroves. The rubbish, debris, coke and coal will be manually removed and a layer of clean sand will be placed over the existing mangrove sediments.

The boundaries are defined as abutting SA1 and SA2 to the west and Areas SA4 and SA5 to the east. The inner boundary of the area is set at the landward side of the mangroves and the northern boundary set at the -0.5 CD tide level in the delta extending out from the major stormwater drain outlet.

Figure 7.4. Boundaries of Remediation Area SA3





Area SA3 has notionally been subdivided into two sub areas. The northern part of SA3 is the exposed intertidal flats with no mangroves (SA3 North), and the southern part which includes all the mangroves in this area (SA3 South).

7.5.4 Southern Remediation Areas – SA4 and SA5

The boundaries of Remediation Areas SA4 and SA5 are shown in Figure 7.5.

The boundaries of Remediation Area SA4 are defined by the landward sea wall and the outer boundary by the anticipated boundary of a stable beach profile after construction of an extended rock wall along the western boundary. Within SA4, the beach contains coal, coke and other rubbish, and low levels of PAHs in the subsurface. It is proposed to remove the debris and replace the surface of the beach with clean sand.

The boundaries of Remediation Area SA5 are defined as a rectangular extension of the proposed new beach in SA4, and extends out almost to LAT. The purpose of SA5 is to provide new clean sand and sediments so any human contact with sediments offshore from the beach will be in clean materials.

7.6 DEFINITION OF REMEDIATION BOUNDARIES – NORTHERN REMEDIATION AREA

The methodology presented in Section 7.3 was used to determine the boundaries of Remediation Areas comprised within the Northern Remediation Area for human health and ecological protection.

Based on the data presented in Sections 5.3 to 5.7 and the methodology in Section 7.3, two Remediation Areas were defined for protection

Figure 7.5. Boundaries of Remediation Area SA4 and SA5





Figure 7.6. Boundaries of the remediation areas in the Northern Remediation Area



Figure 7.7. Northern Remediation Area NA1





of human and/or ecological health as well as for other reasons (aesthetic, odour, public amenity) in the Northern Remediation Area. These areas are shown on Figure 7.6.

7.6.1 Northern Remediation Area – NA1

Area NA1 (Figure 7.7) has been defined on the same criteria as Area SA2 in the Southern Remediation Area, i.e. protection of human health by exposure to contaminated sediments and rubble in the intertidal area, ecological protection, protection of the integrity of the seawall and prevention of odours generated by sunshine-based heating of the intertidal sediments at low tide.

7.6.2 Northern Remediation Area – NA2+NA3

Areas NA2 and NA3 were defined using the process defined in Section 7.3 for ecological protection. Data on sediment PAH levels from the 2014 RAP was used to supplement the 2015-2016 sediment chemistry data. Consideration of these data indicated that the two areas previously identified as having oily gasworks wastes at the surface, and being acutely toxic to benthic organisms (NA2 and NA3), should form part of one area, NA2+NA3, shown on Figure 7.6.

The joining of the two areas NA2 and NA3 and the intervening area between them was based on the similarities of conditions within and between the areas and the dispersed nature of the sampling sites, with exposed contamination at the surface, often surrounded by non-contaminated sediments. The intervening area is defined as the area between NA2 and NA3, from the shoreline and around the LAT -2 m CD contour.

Chapter 8

REMEDIATION OPTIONS

8.1 EPA REGULATORY GUIDANCE

The evaluation of remediation options for a site located in NSW must be undertaken with respect to the following:

- Section 9 of the CLM Act, Requirement for the need to have regard to the principles of ecologically sustainable development (ESD);
- EPA's policy for site remediation as set out in Section 4.3.2 of NSW Department of Environment and Conservation (DEC) (2006) *Guidelines for the Site Auditor Scheme* – 2nd Edition; and
- the *National Environment Protection Measure Guideline for Soil Sampling and Assessment* (NEPC 2013).

The principles of ESD that apply to the proposed remediation works set out in this RAP specifically relate to:

- 'the precautionary principle – namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:
 - careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment, and
 - an assessment of the risk-weighted consequences of various options';
- 'inter-generational equity – namely, that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations';
- 'conservation of biological diversity and ecological integrity – namely, that conservation of biological diversity and ecological integrity should be a fundamental consideration'; and
- 'environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, that enable those best placed to maximise benefits or minimise costs to develop their

own solutions and responses to environmental problems'

The preferred order of options for remediation and management of contaminated soil is set out in guidelines endorsed by the EPA, as follows:

1. Onsite treatment of the soil so that the contaminant is either destroyed or the associated hazard is reduced to an acceptable level;
2. Offsite treatment of excavated soil so that the contaminant is either destroyed or the associated hazard is reduced to an acceptable level, after which the soil is returned to the site;
3. Removal of contaminated soil to an approved disposal site or facility, followed where necessary by replacement with clean sediment; and
4. Consolidation and isolation of the soil on site by containment within a properly designed barrier.

It is considered that the EPA's remediation policy with respect to soils is also applicable in the consideration of the options for the remediation and management of sediments of Kendall Bay.

With respect to contaminated sediments that pose no risk to humans, the policy of the EPA has been directed mostly to ensuring that the contaminated sediments are not disturbed so they do not mobilise contaminants into the water column allowing contaminants to be transported to other, sometimes more sensitive environments. This approach was applied to contaminated sediments adjacent to Cockatoo Island and Garden Island in Sydney Harbour, in Berrys Bay and in the northern part of Lake Macquarie.

In some instances, the EPA may issue, under s28 of the CLM Act, a maintenance order requiring the owner of the land (including the bed of a river, lake or harbour) to manage the land so that the sediments are not disturbed.

In specific instances where high concentrations of contaminants, particularly contaminants that bioaccumulate in fish tissue and have been



identified to impact the health of consumers of the fish caught some distance from the source sediments, the NSW EPA has required remediation of sediments by excavation and their replacement with virgin excavated natural materials (VENM) that are compatible with the marine ecosystem at the source site. For example, the sediments in Homebush Bay that reported the highest concentrations of dioxins, together with other chlorinated compounds, were excavated, the contaminants destroyed, and the sediments were replaced with compatible VENM.

The preferred remediation option adopted in this RAP must be justified in accordance with the above guidance and policy adopted by the EPA and must be appropriate for implementation technically, environmentally and in compliance with existing policies and guidelines.

Application of the principles of ESD requires that soil remediation and management should not proceed if the remediation works are likely to cause a greater adverse effect than leaving the site undisturbed. This principle is of special relevance in Kendall Bay, where the remediation of contaminated sediments:

- has a high potential to mobilise contaminants into the water column; and
- necessarily completely destroys any existing ecosystem.

Application of the principles of ESD also requires that the remediation works should be pursued in the most cost-effective way and should minimise the generation of waste to be deposited to landfill.

In addition, the remediation works will be designed to minimise impact to the amenity of the Mortlake community by adopting a method that minimises movement of trucks through streets and minimises volumes of materials that are excavated so as to reduce odours and the time for completion of the works.

8.2 USEPA REGULATORY GUIDANCE

The USEPA has for many years evaluated methods for remediating soils and sediments contaminated by the operations of manufactured gas plants

(MGP) and other industries. It is estimated that there are tens of thousands of MGP sites in the USA, many of which have not yet been subjected to a preliminary site investigation to determine the extent and degree of contamination.

However, many MGP sites have been remediated, by a variety of methods. These include excavation, treatment and landfilling of the wastes, onsite encapsulation and containment, in situ solidification (ISS), and capping. Each method has advantages and disadvantages, depending on the nature of the site and its location in relation to surrounding land uses. Recent site investigations of major USA MGP plant sites have had to deal with residential developments in close proximity. This has placed additional constraints on remediation methods that are likely to generate odours, and where contaminated wastes must be transported through residential areas.

Additionally, excavation of contaminated sediment and its disposal in landfills is becoming increasingly difficult for a number of reasons, including a scarcity of suitable landfill space, the risk of future leaching from the site, and legal issues associated with ownership of any relocated environmental problems should they arise in the future.

In 2012, the USEPA stated that 'Solidification and stabilization have been selected or are being used in clean-ups at over 250 Superfund sites across the country'. Since then the use of this method has increased on land and in sediments and it is now viewed as a method of choice, particularly where MGP sites (including sites in sediments) are located immediately adjacent to residential areas (USEPA 2012).

Selected examples of the use of ISS for remediating contaminated land and sediment sites are presented in Appendix 4.

8.2.1 In Situ Solidification Validation

To validate the technique of in situ solidification and capping, the USEPA has developed a series of laboratory leach testing protocols, referred to as the Leaching Environmental Assessment Framework (LEAF) (Garraabrants, et. al., 2011),

‘An integrated set of testing methods, data management tools, and report support.’ The methods comprise a suite of available leaching tests, including batch, column and tank tests, which may be interpreted individually or integrated to provide characteristic leaching behaviour of a solid material over a range of potential release scenarios. The LEAF tests form part of USEPA’s methods.

The LEAF test methods are to be applied to the proposed trial methods assessment, remediation works and validation of the remediation proposed for sediments in Kendall Bay.

8.3 REMEDIATION OPTIONS

Remediation options for contaminated sediments, and remediation alternatives within each option, have been reviewed at length in the recent US Interstate Technology and Regulatory Council (ITRC) Guidance Document *Contaminated Sediments Remediation, Remedy Selection for Contaminated Sediments* (ITRC, 2014), and also in USEPA (2013), *Use of Amendments for In situ Remediation at Superfund Sediment Sites*. April 2013.

The key remediation options for contaminated sediments are:

- No Action – the base case;
- Monitored Natural Recovery (MNR) and Enhanced Monitored Natural recovery (EMNR);
- in situ treatment and solidification (ISS);
- contaminated sediment removal and treatment (ex situ):
 - in a facility located at an adjacent onshore facility for disposal at an offsite licensed disposal site; or
 - in a facility located adjacent to an offsite licensed disposal site;
- capping of contaminated sediments:
 - without any contaminated sediment removal; or
 - with some contaminated sediment removal; and
- in situ treatment of contaminated sediments;
 - without any contaminated sediment removal; or
 - with some contaminated sediment removal.

The options, including applicable technologies, available to remediate the contaminated sediments within the Remediation Areas have been assessed in detail below.

8.3.1 No Action

A remediation options review should always begin with the No Action case. However, no action is not acceptable for the sediments of Kendall Bay because there are clearly identified risks to both human health and benthic communities. These risks are unlikely to naturally decrease or be eliminated in any reasonable time frame if no action is taken to address them. Therefore, active remediation is required.

8.3.2 Monitored Natural Recovery and Enhanced Monitored Natural recovery

The application of MNR and/or EMNR in the remediation of sediments requires consideration of the mechanisms of sorption, sequestration, degradation, deposition (reducing exposure) and dilution and dispersion that maybe occurring within the contaminated sediments and their surrounding environment. In assessing the applicability of MNR and/or EMNR to the remediation of sediments in the Remediation Areas the key factors to be considered are:

- sediment characteristics/conditions;
- timeframes for demonstration of success;
- mechanisms to demonstrate success;
- scouring/deposition rates within Kendall Bay;
- durability of method;
- ESD principles; and
- regulatory acceptance.

MNR is a remediation option that uses naturally occurring processes in sediment to reduce the toxicity or bioavailability of contaminants. Careful consideration must be given to ensuring that these natural processes achieve this reduction without increasing the levels of toxic by-products of natural processes.

Natural processes that can reduce risk include the following, in order of preference:

- processes that convert contaminants to less toxic forms (e.g. biodegradation);
- processes that bind contaminants more tightly to the sediment (e.g. sorption); and



- processes that bury contaminated sediment beneath clean sediment (e.g. sedimentation). MNR is most effective in bays and inlets where the water is relatively deep and slow moving, and is usually a very slow process.

The USEPA (2004) describes general site conditions that are especially conducive to MNR, which include:

- 'risk is low to moderate;
- anticipated land uses or new structures are not incompatible with natural recovery;
- natural recovery processes have a reasonable degree of certainty to continue at rates that will contain, destroy, or reduce the bioavailability or toxicity of contaminants within an acceptable time frame;
- expected human exposure is low and/or reasonably controlled by institutional controls;
- site includes sensitive, unique environments that could be irreversibly damaged by capping or dredging;
- sediment bed is reasonably stable and likely to remain so;
- sediment is resistant to resuspension, e.g., cohesive or well-armoured sediment;
- contaminant concentrations in biota and in the biologically active zone of sediment are moving towards risk-based goals;
- contaminants readily biodegrade or transform to lower toxicity forms;
- contaminant concentrations are low and cover diffuse areas; and
- contaminants have low ability to bioaccumulate.'

The USEPA's (2004) *Presenter's Manual for Remediation of Contaminated Sediments* states: 'Two key limitations of MNR may be that it generally leaves contaminants in place without engineered containment and that it can be slow in reducing risks in comparison to active remedies. As with any risk reduction approach that takes a period of time to reach remediation goals, remedies that include MNR frequently rely upon institutional controls, such as fish consumption advisories, to control human exposure during the recovery period.'

EMNR consists of an engineered amendment, such as placement of a thin-layer cap or injection of a carbon-based sorbent into the surface sediments.

The objective of EMNR is to accelerate the process of physical isolation, which is continued over time by natural sediment deposition. EMNR also enhances ongoing natural recovery processes (such as burial and sorption) and minimizes more invasive impacts on the aquatic environment (for example, aquatic habitat that would be lost with dredging and filling) (ITRC, 2014).

Parallel natural or enhanced processes, taken together with observed and predicted reductions of contaminant concentrations in fish tissue, sediments and water, provide multiple lines of evidence to support the selection of MNR/EMNR (Magar et al. 2009). The success of MNR/EMNR also depends on adequate control of contributing sources of contamination (see Section 2.3) so that the recovery processes can be effective. MNR is not viable as a stand-alone remediation technology if it does not achieve the remediation objectives.

The advantages and disadvantages of MNR and EMNR are set out in Table 8.1.

8.3.3 Removal of Contaminated Sediments

The removal of contaminated sediments can be undertaken via a range of different physical methods that can be generally described as dredging or excavation. Either of these methods requires that physical controls be utilised, such as temporary batters, temporary walls, permanent walls and/or sediment control curtains. In assessing the applicability of the removal of contaminated sediment from the Remediation Areas the primary factors to be considered include, but may not be limited to, the following:

- sediment characteristics/conditions;
- depth of removal required;
- sediment handling and transport;
- requirement for treatment to allow for disposal offsite;
- volume of water and sediment generated that would require treatment;
- ex situ treatment methods;
- scale of environmental controls;
- ESD principles; and
- durability of method.

The advantages and disadvantages of dredging and wet excavation are set out in Table 8.1.

8.3.4 Capping of Contaminated Sediments

Capping of contaminated sediments involves the placement of a clean material over the contaminated sediments.

Simple capping involves placement of a clean material such as sand, gravel, rocks or sediments dredged from elsewhere. More complex capping can include membranes and additions to the layers placed over the membranes. The membranes can be permeable or impermeable and the additional materials could include organoclays, activated carbon and other reactive materials.

The role of the additional materials is to modify the movement of any contamination through the cap, to eliminate such movement, or to react with contaminants if they do move through the cap.

USEPA (2005) discusses types of capping used, and states that these 'may reduce risk in the following ways:

- by physically isolating the contaminated sediment from the overlying water;
- by stabilizing the contaminated sediment and protecting it from erosion and transport to other areas; and
- by chemically isolating the contaminants or reducing their movement into the water body (e.g. a reactive cap or one that prevents upwelling groundwater from flowing through the contaminated sediment).'

The advantages and disadvantages of capping are set out in Table 8.1.

8.3.5 In Situ Treatment of Contaminated Sediments

In situ treatment of contaminated sediments involves a process where stabilising chemicals are mixed with the sediments where they occur. The most common type of chemical is cement, but other chemicals are also commonly used as additives to cement, including fly ash, slag, bentonite and flowing agents.

The function of in situ solidification is to create stabilised sediment which both retains the contamination and provides a significant increase

in strength that renders the contamination immobilised for long-term retention where it occurs, and provides a robust remediation solution.

This method is suitable for areas where physical disturbance is required to be minimised (e.g. shallow bays and estuaries) and can be used to stabilise a variety of organic contaminants such as PAHs derived from gasworks plants. In situ solidification has been used extensively in the USA since the 1980s for control of PCBs, PAHs, Metals, TCE, VOCs and other contaminants in soils and sediments.

By the early 1990s ISS of soils and sediments was the recommended treatment method for half of the USEPA's Priority contaminated sites (Garraabrants et al., 2011).

The long-term effectiveness of ISS of sediments can be determined by using mandated leachate testing procedures developed by the USEPA (the LEAF test suite, Section 8.2.1).

The advantages and disadvantages of ISS are set out in Table 8.1.

8.4 REMEDIATION TECHNOLOGY ASSESSMENT

Potential remediation options for remediation of the contaminated sediments of Kendall Bay were assessed by consideration of the technical constraints and advantages and disadvantages of each methodology. The assessment was used to determine the applicability of each option to remediation of sediment contamination, and whether inclusion in a more detailed assessment was warranted to determine the preferred site remediation options. High-level assessment of the following remediation options was undertaken:

- monitored natural recovery (MNR);
- enhanced MNR;
- capping;
- excavation (wet process);
- dredging (wet process);
- in situ treatment; and
- institutional controls.

These remediation options were assessed using

**Table 8.1. Summary of assessment of remediation options**

Technology	Considerations	Advantages	Disadvantages/limitations	Retained for further consideration?
Monitored Natural Recovery (MNR)	MNR relies on natural processes (such as sedimentation or biodegradation) to decrease sediment concentrations and reduce bioavailability or toxicity of chemicals following accretion of clean suspended sediment in a reasonable timeframe. Contamination is left in place and monitored for ongoing physical effects MNR is not viable unless it achieves remediation objectives. Generally applicable to low concentrations over large areas rather than source zones.	Low capital cost compared to more aggressive technologies. Less impact on the local community in terms of odour, noise, truck movements compared to more aggressive technologies.	Natural recovery, whilst occurring in Kendall Bay, is not occurring in a reasonable timeframe over the entirety of the Remediation Areas. Long-term monitoring is required to ensure processes are continuing and achieving remediation goals.	No - processes are not occurring at a reasonable rate over the entire Remediation Area.
Enhanced MNR (EMNR)	EMNR applies material or amendments to enhance natural recovery processes (such as the addition of a thin-layer cap or carbon amendment). As with MNR a decrease in sediment concentrations and reduction in bioavailability or toxicity of chemicals following accretion of clean suspended sediment needs to occur in a reasonable timeframe. Differs from conventional capping in that sediment amendments do not completely isolate chemically impacted sediment.	Placement of a thin sand cap or equivalent could provide adequate habitat for benthic community and remove acute risk to ecosystems. Non-invasive technique and does not disrupt or destroy biologically active zones. Low capital cost compared to more aggressive technologies. Less impact on the local community in terms of odour, noise, truck movements compared to more aggressive technologies. A thin cap without an impermeable layer is not subject to hydrostatic uplift.	Dissolution of contaminants from contamination at depth may occur into the pore space of the clean cap. EMNR will not reduce source contamination in a reasonable timeframe. Bathymetry will not remain without excavation/dredging prior to placement of thin cap. Long-term monitoring is required to ensure processes are continuing and achieving remediation goals. Scouring of the thin cap may occur during storm events.	Yes – as a provisional technology pending further assessment of contaminant dissolution and assessment of cap robustness during storm events.
Capping	Involves the following primary functions: - physical separation of the contaminated sediment to reduce exposure to humans and ecology and to reduce the ability of burrowing organisms to move contaminants to the surface; - stabilisation of contaminant sediment and erosion protection of sediment; and/or - chemical isolation of contaminated sediment sufficient to reduce exposure from dissolved or colloiddally-bound contaminants transported into the water column.	Reduces exposure to contamination without the need to remove contaminant mass. Reduces the volume of sediment requiring excavation and treatment compared to other options. Eliminates the requirement for treatment of contaminated water.	Bathymetry will not remain without excavation/dredging prior to placement of thin cap. Long-term maintenance of the cap may be required. Similar capping projects have only been implemented for 10-15 years so long-term data on cap performance does not exist. Caps will require sediments to have an adequate bearing capacity to reduce settlement. Slip-circle failure around the leading edge of emplaced cap material can occur.	Yes

Table 8.1. Summary of assessment of remediation options (cont.)

Technology	Considerations	Advantages	Disadvantages/limitations	Retained for further consideration?
Excavation (wet process)	Involves containing the Remediation Area with a structural retaining wall (sheet pile) or cut-off wall. Requires earthmoving equipment to operate over the sediments. Significant ESD issues.	Excavation removes contamination and associated risks. Minimises the volume of contaminated water that must be treated before disposal to landfill. Excavation (undertaken in the wet) would minimise the likelihood of significant vapours/odour being emitted.	Construction of retaining walls would be expensive but feasible. High energy consumption in carrying out remediation works.	Yes
Dredging (wet process)	Involves mechanically dredging sediment whilst maintaining a cover of water. Dredging could be by mechanical excavation or hydraulic dredging (such as cutter suction). Significant ESD issues.	Efficient method of removing and transporting sediment. Odour is minimised as a cover of water is maintained. Precise, surgical removal of contaminated sediments can be achieved.	Hydraulic dredging cannot efficiently handle large debris. Surrounding sediments can flow into the dredged zone as a gradient is created resulting in sediment beyond the Remediation Area being drawn in. Where existing sea bed levels are above RL 0 m AHD, excavation down by 0.5 m for capping will result in batters and excavation bases being exposed during low tides, with consequent odour issues. Excessive water treatment requirements to allow discharge back into Kendall Bay or for disposal. Excessive energy consumption in carrying out remediation works. Excessive quantities of contaminated sediments to landfill. Excessive time for completion due to treatment of excessive volumes of water which limit the rate of excavation of contaminated sediments.	No

**Table 8.1. Summary of assessment of remediation options (cont.)**

Technology	Considerations	Advantages	Disadvantages/limitations	Retained for further consideration?
In situ stabilisation (ISS)	Includes reactive caps, additives to enhance biotic degradation and cement stabilisers that are mixed into sediments. There are no known technologies capable of destroying in situ the primary COC present in Kendall Bay. In situ treatment technologies exist that can solidify/stabilise sediments. ISS has been successfully undertaken as a wet process for solidification of soils and sediments in poor ground conditions. Extensive experience in countries overseas in using this method for the solidification of a range of organic and inorganic contaminants in sediments.	ISS can be used to: - Enable more efficient cap design, reduce settlement of caps and improve seabed stability. - Improve the in-situ strength of sediment to allow earthmoving equipment to track in a wet or dry excavation process. - Assist with meeting landfill criteria and avoiding the need for offsite treatment. - Eliminate ex situ treatment and disposal of contaminated sediment left in situ. - Eliminate the requirement to treat excessive volume of contaminated water.	Only partially reduces contaminant loads in the bay. High Energy use during works.	Yes
Institutional controls	Non-engineering measures to reduce exposure by humans or human activities in the contaminated areas. Existing signs around Kendall Bay have been destroyed and required replacement. Existing fishing bans in Sydney Harbour are not often observed.	Cost effective.	Does not reduce contaminant concentrations. Existing signs around Kendall Bay have been destroyed and required replacement. Existing fishing bans in Sydney Harbour are not often observed.	No

the terminology presented in USEPA (2005) and ITRC (2014). The assessment is presented in Table 8.1.

The assessment concluded that the following options should be retained for further consideration:

- enhanced MNR;
- capping;
- excavation (wet process); and
- in situ treatment.

8.5 EVALUATION OF OPTIONS AND TECHNOLOGIES

An assessment of the options and technologies available for the remediation of sediments within the Remediation Areas is provided in Table 8.2.

8.5.1 Short List of Potential Options

The feasible remediation options for the site include the following technologies:

- enhanced MNR for areas that present an acute risk at depth but where enhanced deposition is adequate to create a suitable habitat for benthic communities;
- installation of a cap over contaminated areas that present an acute risk to benthic communities;
- excavation as a means of maintaining bathymetry and providing a foundation to support a cap; and
- in situ treatment as a means of providing an improved foundation to support a cap.

8.5.2 Rating of Options

The shortlisted remediation options were assessed and rated considering the objectives of remediation, which are to:

- reduce as far as practicable the generation of oily releases from the sediments and the generation of hydrocarbon sheens in the river water;
- minimise the generation of odours that could impact the amenity of the nearby community;
- ensure the remediation approach provides a robust and durable solution and there is a low risk of maintenance work being required;
- negate the need for long-term management of sediments after the completion of the

remediation work and adopt a commercially practicable defects liability period;

- ensure the benefits of long-term mitigation exceed the short-term nuisance/amenity impacts of the remediation work;
- comply with ESD principles;
- minimise waste generation and the unnecessary use of resources;
- minimise the time taken to complete the remediation works and thereby reduce impact to the amenity of the nearby community; and
- reinstate the seabed in remediated areas to the existing bathymetry.

The assessment and ranking (presented numerically in brackets) of shortlisted options is presented in Table 8.2. Ratings are relative to other technologies and are on a scale of 1 (worst) to 5 (best).

Based on the screening assessment undertaken, the preferred option for sediment remediation at the site is: Option 4 – in situ solidify columns below the raft to a competent surface, create a raft of stabilised material across the area and install a permeable cap in the area excavated in the top of the raft.

8.6 PREFERRED REMEDIATION OPTIONS

Based on the screening assessment presented in Table 8.2, the preferred options for sediment remediation at the site are:

- Option 4 - In areas where contaminated sediment requires remediation to protect human or ecological health (SA1, NA2+NA3), in situ solidify sediments into columns down to a competent surface, create a raft of solidified material across the area and install a permeable cap in the area wet excavated in the top of the raft; or
- Option 2 - where intertidal areas near the seawall require remediation to protect human or ecological health (SA2, NA1), carefully remove (wet excavate) stained rock/rubble and associated contaminated sediment and replace with clean crushed sandstone to restore site aesthetics, and interstitial sand to support a benthic community.



Table 8.2. Evaluation of remedial options rated by cumulative rating (1 = least favourable rating; 5 = most favourable rating)

OPTION	OPTION 1 – ENHANCED MNR (Thin cap plus enhanced MNR)	OPTION 2 – CAPPING (Mechanically excavate to competent surface and install permeable cap)	OPTION 3 – DREDGING (Mechanically dredge to depth of acutely toxic sediment and treat sediment ex situ)	OPTION 4 – IN SITU TREATMENT (In situ solidified columns and raft to form competent surface, install permeable cap and excavate (wet process) inshore areas)
Technology	- Excavate areas exceeding acute toxicity criteria to 0.5 below surface. - Install capping layer with enhancements. - MNR for areas with natural sediment cover.	- Excavate areas exceeding acute toxicity criteria to a depth required to support cap. - Install capping layer. - MNR for areas with natural sediment cover.	- Dredge areas exceeding acute toxicity criteria. - MNR for areas with natural sediment cover.	- In situ stabilised columns to stable geotech layer below raft of stabilised sediment in acutely toxic areas. Columns may not be required in areas of shallow sediment depth where stabilised material extends to geotechnically suitable unit (Unit 2B). - Excavate shallow area in top of raft. - Install capping layer of geotextiles, activated carbon and clean sand and crushed rock to existing bathymetry. - MNR for areas with natural sediment cover.
Description	1. Sheet pile and support geotextile and geogrid from top of piles. 2. Excavate to 0.5 m. 3. Removal and treatment of contaminated sediments ex situ. 4. Install 0.5 m thick cap of sand or equivalent and enhanced materials to artificially accelerate sedimentation process. 5. Cut geotextile from sheet piles to allow cap to evenly settle.	1. Excavate all areas exceeding acute toxicity criteria except areas with clean sediment cover. 2. Depth of excavation to unit 2B. 3. Install 0.5m cap. 4. With or without retaining wall around excavation area. 5. Removal and treatment of contaminated sediments ex situ.	1. Dredge all areas exceeding acute toxicity criteria (PAH and TRH criteria) except areas with clean sediment cover. 2. Depth of dredge to base of acutely toxic sediment. 3. Retaining wall constructed around dredge areas. 4. Removal and treatment of contaminated sediments ex situ.	1. Construct in situ cement-stabilised raft and columns of contaminated sediment in areas identified as having surface sediments classified as toxic. Columns may not be required in areas of shallow sediment depth. 2 Construct sheet pile wall around Remediation Areas SA1 & NA2+NA3 (if required). 3 Avoid areas with clean sediment cover. 4. Depth of columns to stable geotech layer. 5 Construct stabilised layer above columns across area. 6 Excavate shallow area on top of raft. 7 Install capping layer of geotextiles, activated carbon and clean sand and crushed rock to existing bathymetry.
Technology status	1. Is unproven for gas works waste and would take many decades to confirm success. 2. Long-term performance data for capping solutions is limited and does not extend beyond 10-15 years. (Rating 1)	1. Mechanical dredging is proven and utilised routinely. 2. Long-term performance data for capping solutions is limited and does not extend beyond 10-15 years. 3. MNR is unproven for gas works waste and would take decades confirm success. (Rating 2)	1. Dredging is proven and utilised routinely. 2. MNR is unproven for gas works waste and would take many decades to confirm success. (Rating 2)	1. In situ solidification below water or in estuarine sediments has been proven on a full-scale in Australia for ground stabilisation, and in USA, Europe, UK, Japan, Korea, Hong Kong and other countries for both ground stabilisation and contaminant solidification. (Rating 4)

Table 8.2. Evaluation of remedial options rated by cumulative rating (1 = least favourable rating; 5 = most favourable rating) (cont.).

OPTION	OPTION 1 – ENHANCED MNR (Thin cap plus enhanced MNR)	OPTION 2 – CAPPING (Mechanically excavate to competent surface and install permeable cap)	OPTION 3 – DREDGING (Mechanically dredge to depth of acutely toxic sediment and treat sediment ex situ)	OPTION 4 – IN SITU TREATMENT (In situ solidified columns and raft to form competent surface, install permeable cap and excavate (wet process) inshore areas)
Technical considerations	PROS: 1. A minimum volume of material is removed. 2. Supporting the geotextile off the sheet piles attempts to eliminate the problem of the cap sinking into the soft sediments as it is placed. CONS: 1. Complex construction technique. 2. Differential settlement of the cap still a possibility when the geotextile is untied from the sheet piles. 3. Integrity of sediment and thin cap over the long-term needs to be proven.	PROS: 1. Potentially shallower excavation than Option 3 so engineering complexity may be reduced. 2. Potentially less source mass is removed. CONS: 1. If bathymetry is to be maintained sufficient bearing capacity of underlying sediment is required to prevent excess settlement. 2. Source contamination remains. 3. Where MNR is applied, natural sediment cover needs to be static and durable. 4. Requires ex situ treatment of significantly larger volumes of contaminated sediments and seawater.	PROS: 1. A large proportion of source mass is removed. CONS: 1. Requires a retaining wall constructed around dredge area to minimise over-excavation of sediment. 2. Requires a retaining wall, or a large untreated section along western boundary would be required to maintain integrity of sea wall. 3. Where MNR is applied, natural sediment cover needs to be static and durable. 4. Dredging to 10-12m in parts will be required so complexity of engineering is increased and stability of the barge and excavator potentially compromised. 5. Requires significant volume of clean sand backfill. 6. Requires ex situ treatment of significantly larger volumes of contaminated sediments and seawater.	PROS: 1. Minimum volume of material is removed and any sediment removed is stabilised underwater before removal. 2. Stabilised sediment expected to be removed to landfill as non-hazardous waste, reduces transport and decreases risks associated with transport. 3. Minimises the amount of sediment requiring removal as compared to Option 3. CONS: 1. Contamination remains in solidified form or at depth.
	(Rating 3)	(Rating 3)	(Rating 1)	(Rating 4)
Robustness of solution	1. Least robust solution as largest proportion of the source mass is being left behind.	1. As contamination remaining after remediation will be >1-2m, there is less chance compared to Option 4 that future exposure could occur post-remediation. Similar robustness to Option 3.	1. All contamination that presents a health risk and is acutely toxic to organisms is being removed so no ongoing future exposure risks.	1. Less source mass removed than Options 2 and 3 but remaining contamination in defined areas is solidified in situ.
	(Rating 2)	(Rating 4)	(Rating 5)	(Rating 4)



Table 8.2. Evaluation of remedial options rated by cumulative rating (1 = least favourable rating; 5 = most favourable rating) (cont.).

OPTION	OPTION 1 – ENHANCED MNR (Thin cap plus enhanced MNR)	OPTION 2 – CAPPING (Mechanically excavate to competent surface and install permeable cap)	OPTION 3 – DREDGING (Mechanically dredge to depth of acutely toxic sediment and treat sediment ex situ)	OPTION 4 – IN SITU TREATMENT (In situ solidified columns and raft to form competent surface, install permeable cap and excavate (wet process) inshore areas)
Logistical considerations	1. Placement of enhanced cap can be problematic. (Rating 2)	1. Placement of enhanced cap can be problematic. (Rating 2)	1. Hydraulic dredging would require a water/ sediment treatment system of a size larger than would fit at the Tennyson Rd Staging Site. 2. Mechanical dredging equipment of the scale needed for a 10-12m dredge may have significantly longer lead times and disruption to surrounding communities. (Rating 1)	1. In situ solidification equipment is available in Australia and contractors are experienced in using it in ground improvement applications on land. (Rating 4)
Community impact (odour, truck movements, noise etc.)	1. Some community impact as odourous material is being removed, offsite treatment is occurring. (Rating 3)	1. As the amount of sediment requiring treatment is reduced compared to Option 3, odour, truck movements and associated impact on community will also be reduced but still highly significant. 2. Significant odour problems from large volume of wet excavation. (Rating 1)	1. As the majority of contaminated sediment is being removed there will be a larger and longer impact on the community compared to other options. 2. Significant odour problems from large volume of wet dredging. (Rating 1)	1. As the amount of sediment requiring treatment is significantly reduced compared to Option 3, odour, truck and associated impacts on community will also be reduced. 2. Odour will largely be eliminated by the cement solidification. (Rating 4)
Ongoing management / robustness	Ongoing management for indefinite period required by implementation of an SMP. (Rating 2)	1. Ongoing management may be required depending on depth of excavation. Monitoring of residual sediments required over the short- term by implementation of an SMP. (Rating 3)	1. No ongoing management apart from monitoring of residual sediments required for a defined period. (Rating 4)	1. No ongoing management apart from monitoring of integrity of cap and residual sediments required over the short-term by implementation of an SMP. (Rating 4)
Time considerations	1. Shorter programme. (Rating 4)	1. Programme dependent on depth of excavation required. (Rating 3)	1. Longest treatment program of all options (depending on depth of dredging required). (Rating 2)	1. Programme time comparable to other options. (Rating 3)
Financial considerations	1. Lower cost. (Rating 4)	1. Solution should cost less than Option 3 but is assumed to be more than Option 1 and 4. (Rating 3)	1. Dredging of all acutely toxic material will result in highest treatment costs. (Rating 1)	1. Solution costing comparable to other options - less than Option 3 but is assumed to be slightly lower than Option 1 and 2. (Rating 3)

Table 8.2. Evaluation of remedial options rated by cumulative rating (1 = least favourable rating; 5 = most favourable rating) (cont.).

OPTION	OPTION 1 – ENHANCED MNR (Thin cap plus enhanced MNR)	OPTION 2 – CAPPING (Mechanically excavate to competent surface and install permeable cap)	OPTION 3 – DREDGING (Mechanically dredge to depth of acutely toxic sediment and treat sediment ex situ)	OPTION 4 – IN SITU TREATMENT (In situ solidified columns and raft to form competent surface, install permeable cap and excavate (wet process) inshore areas)
ESD Considerations	1. May require the most ongoing management. (Rating 2)	1. A cap provides a viable option to remove less than Option 3 material but volume still significant. 2. Requires ex situ treatment of significant volumes of contaminated sediment and water. (Rating 2)	1. Potentially least sustainable option (depending on depth of Option 2) as the largest amount of sediment requires treatment. 2. Requires ex situ treatment of significant volumes of contaminated sediment and water. (Rating 1)	1. Solidification is a way to create a solid foundation without the need for sediment removal and hence a more robust and durable option. (Rating 5)
Data gaps	1. Dissolution of underlying contamination into pore space of the cap needs to be investigated. 2. Integrity of thin sand cap over long-term needs to be assessed. (Rating 2)	1. Depth of excavation largely dependent on need to maintain bathymetry. 2. Settlement may not be uniform across Remediation Areas and requires geotechnical investigation. (Rating 3)	1. Detailed contamination model required to define depth of excavation. 2. Additional data needed to define exact dredging areas and depths. (Rating 3)	1. In situ solidification will require pilot testing prior to full-scale implementation. (Rating 3)
Engineering constructability	Feasible - Settlement and bearing capacity dependent on the thickness of cover required. Complex construction technique. Long-term viability of the cap problematic. Disappearance of the cap into the soft sediments below remains a possibility. (Rating 2)	Feasible - Bearing capacity, settlement, shoring and seawall stability need investigation and design. (Rating 3)	Feasible - Although significant shoring considerations. (Rating 2)	Feasible - Required depth of solidification to provide adequate bearing capacity needs investigation. (Rating 4)
Acceptability to regulatory authorities	Yes - if long-term diffusion and integrity of an adequate thickness of deposited sediment and enhancements can be maintained. (Rating 3)	Yes - benthic habitat restored and bathymetry restored if backfilled adequately. (Rating 4)	Yes - contaminant mass removal, however significant offsite waste disposal required, benthic habitat restored and bathymetry restored if backfilled adequately. (Rating 3)	Yes - contamination treated onsite, benthic habitat restored and bathymetry restored with accurate backfilling. Best practice in the US for MGPs but trial to be undertaken to demonstrate effectiveness in Kendall Bay. (Rating 4)
Minimisation of adverse environmental outcomes	Minor movement and associated silt and water management requirements. (Rating 4)	Significant material movement and associated silt and water management requirements. (Rating 2)	Significant material movement and associated silt and water management requirements. (Rating 2)	Minimal material disturbance and associated silt and water management requirements. (Rating 4)



Table 8.2. Evaluation of remedial options rated by cumulative rating (1 = least favourable rating; 5 = most favourable rating) (cont.).

OPTION	OPTION 1 – ENHANCED MNR (Thin cap plus enhanced MNR)	OPTION 2 – CAPPING (Mechanically excavate to competent surface and install permeable cap)	OPTION 3 – DREDGING (Mechanically dredge to depth of acutely toxic sediment and treat sediment ex situ)	OPTION 4 – IN SITU TREATMENT (In situ solidified columns and raft to form competent surface, install permeable cap and excavate (wet process) inshore areas)
Compliance with ecologically sustainable development principles	High (Rating 4)	Moderate (Rating 3)	Low (Rating 2)	Moderate (Rating 3)
Requirement for long-term monitoring till objectives met	Yes, to assess cap integrity. (Rating 2)	Yes, to assess cap integrity and for residual sediment monitoring. (Rating 1)	Yes, for residual sediment monitoring only. (Rating 3)	Yes, for residual sediment monitoring only. (Rating 3)
Overall assessment	Potential impacts of odour-generating works in Kendall Bay and impacts associated with the offsite treatment and transport of contaminated sediments. Potential issues associated with stability and durability of capping.	Potentially an option for consideration, however it has significant offsite impacts associated with odour-generating works in Kendall Bay and impacts associated with the offsite treatment and transport of contaminated sediments. Assessment of this solution is highly dependent on required depth of dredging.	The solution is robust as the majority of contamination is being removed but is the most intrusive, has the largest impact on the community and is potentially the most expensive. Option is retained but is not favoured and considered least favourable. Significant sediment stability issues.	The most favoured option. Least impacts of odour- generating works in Kendall Bay and least impacts associated with the offsite treatment and transport of contaminated sediments. Most stable in situ treatment of contaminated sediments.
Cumulative Rating	41	39	33	46

8.6.1 Southern Remediation Area 1 – SA1

The boundaries of SA1 are shown on Figure 7.3.

Remediation Objective

The objective in remediation of area SA1 is to remediate to the extent practicable the surface sediments that pose an unacceptable risk to human health and pose an acute risk to the marine ecosystem and in which no viable marine community has been identified.

Remediation Strategy

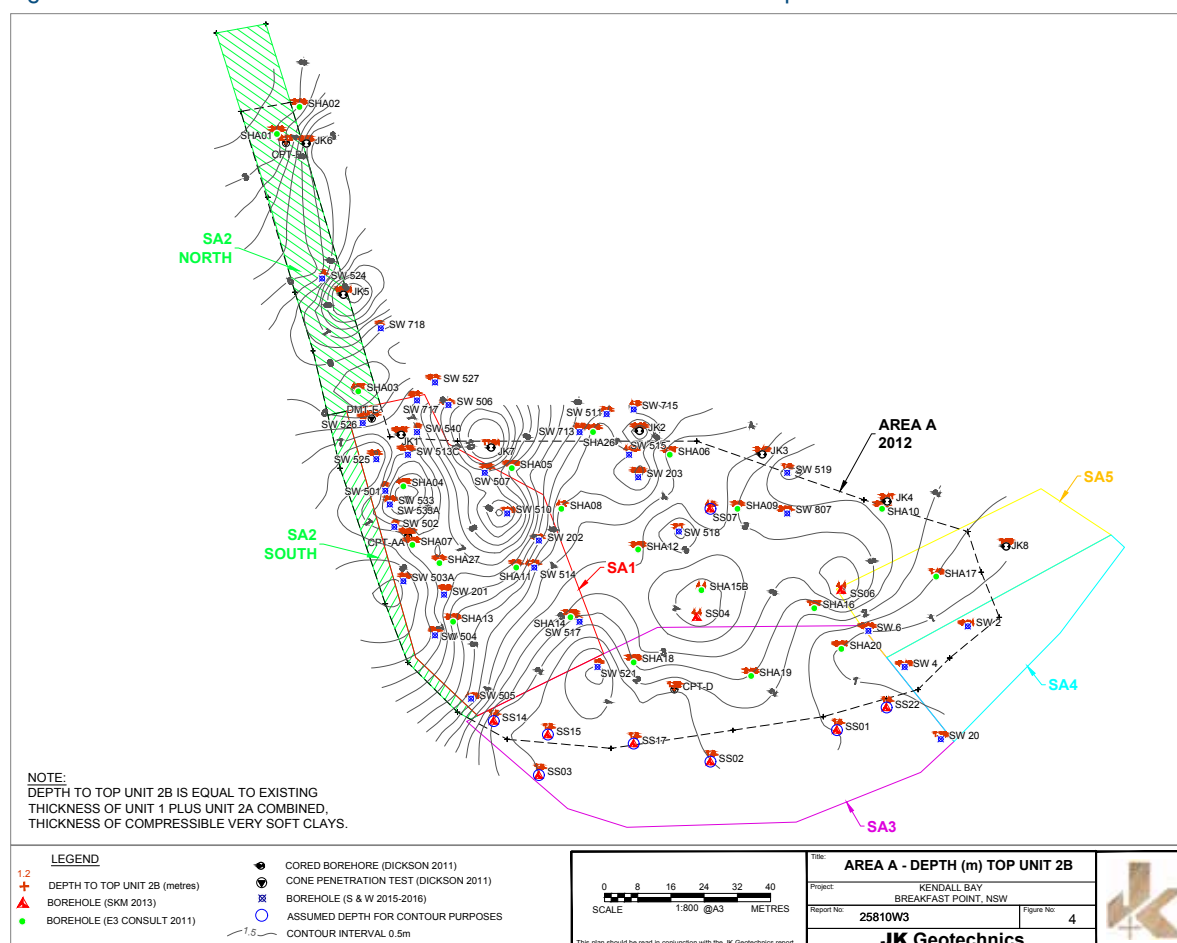
The proposed remediation strategy in this area is to solidify the sediments into columns to support a cemented raft over the top. The installation of columns may not be required in areas of shallow sediment depth where the stabilised material extends to a geotechnically suitable unit (Unit 2B). The top of the raft will then be excavated down to 0.5 m below LAT. The excavated cemented material will be classified in accordance with the NSW EPA (2014) Waste Classification Guidelines. Part:1 Classifying Waste and taken to landfill. Secondary treatment of the ISS materials at an EPA licensed offsite waste facility may be considered before the waste materials are

transported to landfill. A 0.3 m thick capping layer suitable for re-establishment of viable benthic communities would be placed on top of the raft. This strategy would prevent human access to the contaminated sediments and improve the marine ecosystem within the bay.

The thickness of soft contaminated sediments (i.e. Unit 1A and Unit 2A) down to the underlying clean competent material (i.e. Unit 2B) has been mapped by JK Geotechnics (2016) and varies from 3 to 10 m along the eastern perimeter, to 6.5 m in the central area, to 9 m on the western perimeter and is up to 6 m along the southern perimeter of SA1 (Figure 8.1).

To minimise excavation and generation of waste, it is proposed to use cement-based mass solidification techniques to create a 'raft' structure over the Remediation Area to support the overlying capping material that is to be placed to a finished level at LAT. The cement-solidified layer would be supported on deep sediment mixed columns extending down to the level of competent Unit 2B material to minimise

Figure 8.1. Southern Area. locations of SA2-North and SA2-South and depths to Sediment Unit 2B



Source: JK Geotechnics, 2016

settlement. The detailed remediation strategy and methodology for Remediation Area SA1 (and NA2+NA3) is described in Section 9.5.1.

8.6.2 Southern Remediation Area 2 – SA2

The boundaries of SA2 are shown on Figure 7.3 and a view of the Remediation Area on Figure 8.2

Remediation Objective

The objective in remediation of area SA2 is to remove contaminated sediments that present a human health risk and/or an acute ecological risk, and remediate stained surfaces, sediments giving rise to emission of odours when exposed at low tides, and rubbish in accessible areas of the mangroves and along the foreshore, adjacent to the seawall.

Remediation Strategy

The remediation strategy in area SA2 is to remove stained rock/rubble and sediments to a depth of 0.3 m between the seawall and to a nominal distance of 5 m seaward or to the surveyed LAT contour in the northern part of the area and between the seawall and the edge of SA1 in the southern section of the area.

It is proposed to lower the seabed such that the final seabed level is below LAT and incorporates a 0.3 m thick capping layer suitable for re-establishment of viable benthic communities. Geotechnical considerations, such as avoiding undermining founding material associated with the seawall, will also be considered when determining the depth of excavation adjacent to the seawall. This would prevent human access to the contaminated rubble material along the base of the seawall at low tide and improve the marine ecosystem within the bay.

As noted earlier, seawall stability is an important consideration for remediation of SA2. The remediation is located immediately adjacent to the seawall, extends over a nominal 5 m width adjacent to SA1 and may vary beyond the northern limit of SA1. As previously noted, the 5 m width adjacent to SA1 allows hydrostatic uplift pressures from surrounding groundwater levels to be released rather than being applied to the base of the mass solidified layer within SA1.

It is proposed that careful excavation of surface-stained materials and rubble be completed at the toe of the seawall down to a level of -0.3 m LAT or



Figure 8.2. Sloped seawall and rubble along SW side of Kendall Bay



the level of the seawall toe apron slabs, whichever is reached first. Beyond the extent of seawall toe apron slabs, careful excavation can be completed to -0.3 m LAT.

The westernmost mangroves in the southern area of SA2 will be removed to allow for accurate removal of contaminated sediment and replacement of clean material to achieve the human health risk objectives.

Excavation will be followed by placement of a layer of geotextile fabric and 0.3 m thick layer of cobble sized rock to a finished level of 0 m LAT. Geotechnical considerations for the existing seawall may impact the finished level that can be obtained adjacent to the seawall. Sand would be subsequently placed over the rock layer to provide substrate within the interstitial spaces of the rocks for benthic recolonisation.

8.6.3 Southern Remediation Area 3 – SA3

The boundaries of SA3 are shown on Figure 7.4.

Remediation Objectives

The objectives in remediation of area SA3 are:

- managing sediments that pose an unacceptable risk to human health to users of the beach and mangrove areas; and
- installing control measures to ensure

stormwater discharge to Kendall Bay will not impact the remediated and managed parts of the Southern and Northern Remediation Areas.

Remediation Strategy

The remediation strategy in the northern part of SA3 is to remove any coke and coal from the intertidal sand surface to a nominal depth of 0.2 m. A layer of clean, imported sand (VENM, compatible with the existing natural material) will be placed over the area as required to restore the existing sand surface where removal of material was required.

The remediation strategy in the southern part of SA3 is to retain the existing established mangrove vegetation and clean up the area due to it being accessible to humans. This would involve removal of coke and coal from the sand surface amongst the mangroves to a nominal depth of 0.2 m using small excavators (Figure 8.3). A layer of clean, imported sand (VENM, compatible with the existing natural material) will be placed over the area as required to restore the existing sand surface where removal of material was required.

Management of the stormwater flow from the large 1650 mm diameter outlet discharging behind the mangroves at the head of Bay will be carried out. This discharge occurs periodically during rainfall

Figure 8.3. Small excavators with screening buckets deployed on beach areas



events and creates a scour channel through the mangroves and over the sand shoal further out into the bay, as shown on the photographs in Chapter 4 and this occurred after a major storm event in June 2016.

During the June 2016 storm event, the scour channel migrated to the east and extended across the beach area in the south-eastern corner of the bay, and was still evident during a site inspection in July 2016.

The June 2016 storm demonstrated that the mangroves are resilient to localised scour that occurred around their base, with no evidence of trees falling over due to undermining of the root system. The storm discharge carried a significant amount of woody debris and rubbish, which was strewn throughout the mangroves and beach area. The discharge also entrained some of the coke and coal found within the mangroves and distributed it along the channel alignment across the sand shoals.

Stormwater discharge is not considered to pose a significant risk to the stability of the mangroves and clean-up of coke and coal would prevent remobilisation of these materials in stormwater flows. However, any migration of the existing scour channel to the east would impact on the amenity of the adjacent beach area in SA4 and SA5. The impact on the beach area will be limited by the proposed seaward extension of the existing sandstone wall (discussed below). However, eastward-migrating stormwater flows running alongside the wall may cause localised scour and undermining of the structure. To address these issues, stormwater flows will be redirected away from the wall by the installation of a series of spur walls along an alignment through the mangrove area. These low-level rock mound structures (example shown on Figure 8.4) would train stormwater discharge away from the wall extension whilst allowing the flow to spread over the sand shoals without scouring a deep channel.

8.6.4 Southern Remediation Area 4 – SA4

The boundaries of SA4 are shown on Figure 7.5.

Remediation Objectives

The objective in remediation of area SA4 is to improve the public amenity of the beach.

Remediation Strategy

The remediation strategy in this area is to clean up the existing beach area by removing coke and coal from the sand surface and to a nominal depth of 0.2 m (screened sand would be returned to the beach profile). The natural rocks shown over the beach on Figure 8.5 could also be collected as part of beach clean-up activities and beneficially reused in the construction of the spur walls proposed within area SA3.

The public amenity of the beach is to be improved by the placement of an additional 0.5 m layer of clean sand (VENM) over the area. The grading of the imported sand material would be compatible with the existing beach sand and placed at the same slope and alignment. This would minimise readjustment of the beach profile and/or loss of sand offshore under wave action. The nearshore beach slope is around 1V:8H before it flattens significantly to a slope of 1V:100H beyond a bed level of +0.4 m LAT, which is around the Mean Low Water mark. It is estimated that the volume of sand placement would be in the order of 500 m³.

The quantity of sand on the existing beach fluctuates. Figure 8.6 shows a relatively elevated beach level in August 2012 compared to Figure 8.5, showing the exposed rock material seen in July 2016. This fluctuation occurs in response to prevailing wind wave action and the regular action of boat wake waves from Rivercats and Harbourcats, which may cause beach sand to move alongshore and be captured within the sand shoal that has been established in the mangrove area.



Figure 8.4. Example of low-level rock mound structure used to deflect flows for riverbank protection



Figure 8.5. Surficial materials on eastern side of beach area in July 2016



Figure 8.6. Sand covering underlying rock and partly blocking stormwater outlet in August 2012



For this reason, it is necessary to retain any beach nourishment sand within the SA4 area to maintain beach amenity. This will be achieved by a seaward extension of the existing sandstone wall (which is approximately 0.5 m wide by 0.5 m high (Figure 8.7) located on the western side of the beach. This will act as a groyne to retain sand within the embayment created on its eastern side and will also act to prevent scouring of the beach area by meandering stormwater discharge from the head of the bay (although the proposed spur walls would be the primary means to mitigate this process). The sandstone wall will extend offshore beyond the limit of sand placement, which would result in a wall extension length of around 30 m.

It is expected that in high rainfall events, the existing stormwater outlet located towards the eastern end of the beach (Figure 8.8) would discharge across the beach creating a scour channel and deposition of debris and rubbish from the catchment. The associated impacts on beach amenity could be resolved by diversion of the outlet to a location further to the east, where stormwater could discharge out on to the existing rock platform. Should this not prove technically feasible or not be approved by Council and RMS, other measures could include installation of a gross pollutant trap(s) upstream in the system and

construction of an energy dissipation structure at the outlet.

Management of and improvements to the storm water outlet will be negotiated with Council and RMS prior to completion of the Remediation Work Plan by the Remediation Contractor, as set out in Section 9.3.8 of this RAP.

8.6.5 Southern Remediation Area 5 – SA5

The boundaries of SA5 are shown on Figure 7.5.

Remediation Objective

The remediation objective in Remediation Area SA5 is to provide a clean, firmer underfoot, offshore wading area to be accessed from the beach.

Remediation Strategy

The remediation strategy in this area involves shallow excavation of existing seabed material to 0.3 m depth followed by placement of a 0.3 m layer of clean sand to match the existing bed level. The sand placement would provide a clean, firmer underfoot, offshore wading area to be accessed from the beach and mangrove area and would extend to the limit of SA5. The offshore boundary of SA5 is located around the 0.2 – 0.3



Figure 8.7. Existing cement-covered sandstone wall on western side of beach (SA4)



Figure 8.8. Stormwater outlet discharging onto beach in July 2016



Figure 8.9. Seawall and rubble along SW side of Kendall Bay near former coal wharf (NA1)



m LAT contour, which is around the position of the waterline at MLWS (0.27 m LAT). The grading of the imported sand material (VENM) would be compatible with the existing beach sand further inshore. It is estimated that the volume of excavation (and subsequent sand placement) would be in the order of 200 m³. Beneficial reuse of the excavated fine grained material would be achieved by supplementing it with sand used for capping of other Remediation Areas (e.g. SA1).

8.6.6 Northern Remediation Area 1 – NA1

The boundaries of NA1 are shown on Figure 7.7 and a view of the area in Figure 8.9.

Remediation Objective

The primary objective of remediation in NA1 is to protect human health by preventing people using the area from being exposed to contaminated sediments.

Remediation works in NA1 will remove stained surfaces, sediments giving rise to emission of odours when exposed at low tides and the presence of rubbish in accessible areas and in the foreshore, adjacent to the seawall.

Remediation Strategy

The remediation strategy in this area is to remove stained rock/rubble and any contaminated sediment to 0.3 m within the designated area adjacent to the vertical seawall and replace with clean sandstone to restore site aesthetics.

The process used will be similar to that employed for SA2. That is, to lower the seabed to below the level of LAT and to provide a 0.3 m thick capping layer for establishment of viable benthic communities. Geotechnical considerations for the existing seawall may impact the finished level that can be obtained adjacent to the seawall. This treatment will prevent air exposure of contaminated rubble material and sediments along the base of the seawall at low tide and improve the marine ecosystem within the bay. Exposure of material along the toe of the seawall at low tide is reported to be a significant odour generation issue for Breakfast Point residents.

It is proposed that careful excavation of surface stained materials and rubble should be completed at the toe of the seawall down to a target level of -0.3 m LAT whilst preserving the existing toe support along the seawall structure. Excavation



would be followed by placement of a layer of geotextile fabric and a 0.3 m thick layer of cobble sized rock to a finished level of 0 m LAT where possible. Sand would be subsequently placed over the rock layer to provide substrate within the interstitial spaces of the rocks for benthic recolonisation.

8.6.7 Northern Remediation Area 2 – NA2+NA3

Remediation Objective

The objective in Remediation Areas NA2+NA3 is to remediate to the extent practicable the surface sediments that pose an unacceptable risk to human health, and that pose an acute risk to the marine ecosystem.

The boundaries of NA2+NA3 are shown on Figure 7.6.

Remediation Strategy

The remediation strategy in this area is to establish a surficial layer of material on the seabed for re-establishment of viable benthic communities. This would initially involve removal of surficial loose contaminated materials over hard surfaces associated with operation and demolition of the former wharf. Cement-based mass solidification techniques would then be used to create a 'raft' structure over the Remediation Area to support the overlying capping material that is to be placed to a finished level equivalent to the existing natural surface. The raft in NA2 + NA3 is to be constructed through the full depth of sediments to the competent Unit 2B – Stiff Clay material as the sediment thickness appears to be much shallower than in remediation area SA1 and as such columns are not required. A geotechnical investigation will be completed to confirm the depth of the Unit 2B - Stiff Clay material.

A detailed explanation of this technique is presented in Chapter 9.

The depth of mass solidification is to be completed up to a depth of approximately 3.0 m. Following the in situ stabilisation of contaminated sediments the surface of the stabilised raft is to be excavated to a depth of 0.5 m below LAT and to a minimum depth of 0.5 m from the surface of the in situ stabilised sediments.

A 0.3 m thickness of cobble-sized rock capping material would be placed directly on to the excavated surface cut into the solidified material. As proposed for Remediation Area SA1, an activated carbon impregnated geotextile would be placed as an initial layer incorporated into the base of the 0.3 m capping material thickness. Sand would be placed over the rock layer to form a suitable substrate within interstitial spaces of the rocks for benthic community colonisation. The rock would be placed first, followed by the sand layer to ensure that the sand is able to be distributed throughout the entire interstitial space.

It is proposed to enclose Remediation Areas NA2 + NA3 in a continuous sheet pile wall to provide environmental control during remediation and contamination containment within the Remediation Areas post remediation will be determined following remediation trial works.

8.7 DESIGN LIFE AND PERFORMANCE CRITERIA

The NSW EPA has advised that one of their key requirements for the remediation of Kendall Bay is that the proposed treatments are 'durable' and 'robust'. These requirements relate to performance criteria that ensure that the remediation treatments are effective for an extended period of time and are resistant to the action of natural processes and anthropogenic influences.

The proposed remediation strategy involves either:

- addressing human health risks by:
 - reducing seabed levels to below LAT to limit access and generation of odour; and
 - capping areas with a layer of clean material to prevent exposure to contact with contaminated materials and generation of odour; or
- improvement of the marine ecosystem by capping areas identified to be acutely toxic to benthic communities with a layer of clean material suitable for re-establishment of viable benthic communities.



Figure 8.10. Cobble beach adjacent to mangroves in south-west corner of Kendall Bay (Remediation Area SA1)



This remediation strategy generally involves excavation of existing materials to reduce seabed levels, and placement of a capping layer over the lowered seabed to achieve the remediation objectives defined for specific areas. The Remediation Areas have been defined on the basis of an extensive program of sediment sampling undertaken by S&W. The results of this investigation were used to delineate specific areas within the Southern Remediation Area (i.e. SA1) and Northern Remediation Area (i.e. NA2+NA3) that require remediation due to low numbers or the absence of viable benthic communities in acutely toxic seabed sediments as a result of gasworks contamination being present in surface sediments.

It should be noted that in the case of Remediation Area SA1, the remediation objectives were to address human health risks associated with physical contact and improve marine ecosystem health.

The other Remediation Areas which are largely defined on human health risks associated with physical contact and odour generation are SA2, SA3, SA4, SA5 and NA1.

A 0.3 to 0.5 m layer of clean material is considered to be suitable for limiting human access to underlying contaminated material and providing substrate suitable for re-establishment

of viable benthic communities. To satisfy the robustness requirement, this layer has been designed to withstand the near-bed velocities generated by 100-year recurrence wind wave conditions as well as near-bed velocities from regular boat-generated waves. To satisfy the durability requirement this layer has been designed to be constructed from competent material that would not break down over time in the marine environment.

Royal HaskoningDHV (2016a, b) has estimated that near-bed velocities under 100-year recurrence wind wave conditions and regular boat generated waves are approximately 1 m/s. Cobble-sized rock is considered to be the most appropriate capping material. The median rock size (D50) within a graded rip-rap blanket placed on the seabed required to withstand these near-bed velocities is around 110 mm (sieve size), based on the use of sandstone with a density of 2.3 t/m³.

The rip-rap blanket would have a grading envelope which ranges between 60 mm and 180 mm (sieve size). This sizing is similar to rock found over the existing cobble beach area adjacent to the mangroves in the south-west corner of the bay (Figure 8.10). The rock would need to be placed in a layer a minimum of two rocks thick to be effective, which is achievable given the target placement thickness of 0.3 m to 0.5 m.



Chapter 9

REMEDIATION MANAGEMENT AND METHODS

9.1 REMEDIATION MANAGEMENT

9.1.1 Jemena

The remediation works will be managed by Jemena and its appointed Project Manager. The Jemena Project Manager will manage the Remediation Contractor with respect to time, cost and quality and also other contractors and consultants engaged during the project. The Project Manager will liaise with the regulatory authorities and the public on Jemena-related issues.

9.1.2 Remediation Contractor

The remediation works will be delivered by the Remediation Contractor who will be engaged by Jemena. Monitoring of the remediation works including review and/or collection of environmental monitoring data, and all sampling works required for the delivery of the remediation works, will be delivered by the Remediation Contractor. Jemena will manage day-to-day community relations during the course of the remediation works. The Remediation Contractor will support Jemena in the management of the community.

9.1.3 Site Auditor

The EPA-accredited Site Auditor is engaged by Jemena and is responsible for certifying that the RAP, if implemented, will meet the objectives of the remediation works and satisfy the requirements of the 2005 VRA or replacement VMP (as applicable). The Site Auditor will be responsible for review of the preparatory documents, detailed works plans and the progress of the remediation works to ensure that all works are being completed in accordance with the RAP requirements, which at the completion of the remediation/validation works and satisfactory review of the Validation Report, will enable the Site Auditor to produce a Site Audit Statement certifying that the remediation works have satisfied the objectives of the remediation works, subject to implementation of the Site Management Plan (see Chapter 15).

9.1.4 Validation Consultant

A Validation Consultant will be engaged by Jemena to manage analytical works and document the construction quality assurance and quality control measures described in Chapter 14, Validation Plan.

9.2 REMEDIATION ENVIRONMENTAL MONITORING

9.2.1 Pre-Remediation Baseline Monitoring Event

A program of pre-remediation baseline monitoring will be undertaken by the Jemena's Validation Consultant to assess environmental conditions in the work area and Kendall Bay, and obtain a baseline data set that can be compared to monitoring during and post-remediation, to assess the changes to conditions as a result of the remediation works. The conditions that will be monitored are:

- water quality;
- tidal fluctuations;
- wave climate;
- turbidity;
- currents;
- weather conditions; and
- stormwater flow and quality.

Prior to undertaking the monitoring works the Jemena's Validation Consultant will prepare a detailed sampling, analysis and quality plan (SAQP) for the pre-remediation monitoring event in accordance with the relevant guidelines made or endorsed by NSW EPA. This SAQP must be endorsed by the Site Auditor prior to its implementation. The methodologies adopted during the pre-remediation monitoring event will be consistent with the methodologies to be adopted for during the remediation and post-remediation monitoring events.

The results of the pre-remediation monitoring event will be presented to Jemena by Jemena's Validation Consultant in a report that will be prepared in general accordance with the



requirements of the relevant guidelines made or endorsed by NSW EPA. This report will be provided to the Site Auditor for acceptance as appropriate.

9.2.2 Remediation Works Monitoring Events

The Remediation Contractor will undertake monitoring for the following conditions during the remediation works:

- water quality;
- tidal fluctuations;
- wave climate;
- turbidity; and
- weather conditions (visual).

The Remediation Contractor will report the result of the monitoring on a regular basis to Jemena during remediation works.

Full details of the monitoring to be undertaken during the remediation works program will be presented in the Remediation Works Environmental Management Plan (RWEMP (see Chapter 11 of this RAP).

9.3 PREPARATORY WORKS

9.3.1 Licences and Approvals

The project requires an extensive approval process prior to the commencement of any remediation works. The approvals required for the works will include, but may not be limited to:

- development consent under the EP&A Act as State Significant Development;
- landowner's consent from RMS (the owner of the bed of Kendall Bay), together with obtaining any other permits, licences or similar required by RMS to conduct the works in the bay;
- specific immobilisation approval for solidified sediments that are excavated and removed from the site for offsite disposal issued in accordance with Part 10 of the *Protection of the Environment Operations (Waste) Regulations 2014*;
- Part 7 Permit issued under the *Fisheries Management Act 1994*; and
- construction approval/certificate and accompanying stamped plans.

9.3.2 Geotechnical Assessment

The Remediation Contractor will need to engage a suitably qualified and experienced geotechnical engineer to provide advice on the selected remediation methods and designs for each Remediation Area.

9.3.3 Seawall Dilapidation Survey

Prior to commencement of remediation work, the Remediation Contractor will engage a suitably qualified marine engineer specialising in the design of sea walls and the structural assessment and repair of dilapidated sea walls to undertake an initial dilapidation survey of the existing sea wall. The sea wall was built by various methods at different times and has been subject to some degradation, e.g. from the surges created by passing Rivercat ferries.

The report of the initial dilapidation survey will record any existing damage and the state of particular aspects of the wall that are likely to be affected by the nearby remediation work. The report will include date-stamped photographs, notes, measurements, photographs and diagrams which give an accurate picture of the state of the sea wall. It will include recommendations with respect to the monitoring of identified defects or the repair of defects considered serious enough to require repair prior to the commencement of remediation.

Upon completion of the remediation works a final dilapidation survey will be undertaken to ascertain whether there has been any degradation of the wall during the works. Copies of the dilapidation reports will be provided to, as a minimum, RMS, the City of Canada Bay Council and the strata manager for the Breakfast Point community.

9.3.4 Laboratory Trials

There is a high degree of confidence in the proposed ISS approach for the following reasons:

- the approach has been used for many years in Australia for geotechnical, not remediation, purposes and contractors are well versed in the methodology, it has been used in Australia for remediation in swampy areas and it has been successfully used overseas in

- underwater contamination applications (for example in Hong Kong harbour);
- three Australian soil mixing contractors have conducted solidification trials on Kendall Bay sediments using cement-based mixtures and produced samples of consistent quality;
- Ventia and its consultant Hazchem have conducted successful ex situ stabilisation trials on Kendall Bay sediments for the purposes of obtaining landfill approval; and
- ISS is the preferred method in the USA for MGP contamination.

Nevertheless, Jemena proposes to conduct an early in-situ trial in Kendall Bay before proceeding to engage a contractor to carry out the remediation.

First, a series of laboratory trials will be conducted on Kendall Bay sediments with various mixes of cement, bentonite, blast furnace slag and chemical fixation reagents.

The testing organisation will be NATA-accredited to the USEPA SW846 1315 Monolith Leach method, known as the LEAF test. Other required NATA accredited tests are for TCLP to USEPA SW846 1311 and UCS to AS1012.

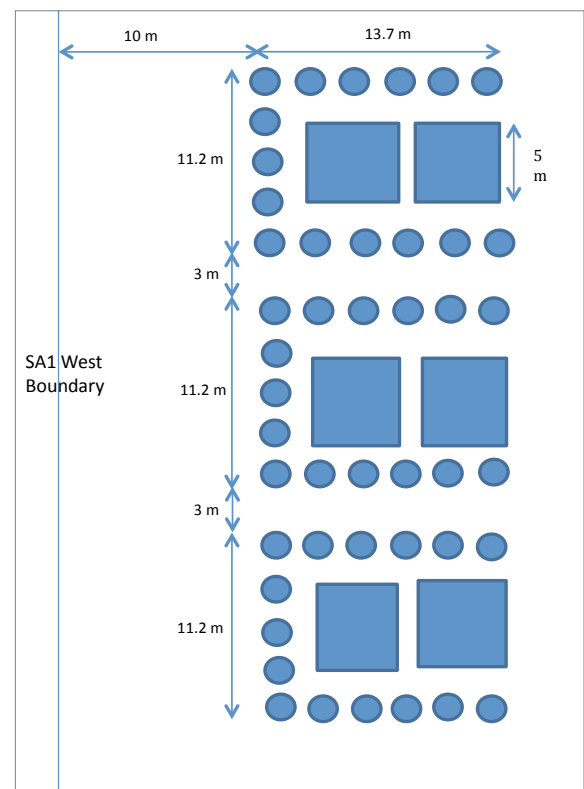
The solidified sediment samples (approximately 200) will be tested for:

- TRH;
- PAH;
- 8 Metals; and
- Unconfined Compressive Strength.

9.3.5 Field Scale Trials

The results of the laboratory tests will be analysed and it is proposed to select the best mix for in situ trials in the bay. The trials will be conducted first in a cleaner area to the north of Remediation Area SA1 and then within remediation area SA1. The plan is to construct 24 columns, nominally 0.6 m diameter at 1.8 m centres down to the top of Unit 2B, and 110 m² of raft in two trial phases in Kendall Bay. The first phase, the clean sediment commissioning phase, will construct a raft slab with dimensions of approximately 8.4 m by 8.4 m by up to 1.5 m deep in cleaner sediments North of remediation area SA1. The second phase, the contaminated sediment commissioning phase

Figure 9.1. Layout of solidification trials



will construct a raft slab with dimensions of approximately 3.0 m by 12.6 m by up to 3.0 m deep.

The chosen contractor will trial different methods (equipment, speeds, injection rates, etc.) for construction of the columns and for the rafts and take grab samples for each method.

On completion, the contractor will provide a detailed map of the locations of all columns and rafts and the depths of all columns so these structures can later be incorporated into the full-scale solidification arrangement.

The results of the trials will be shared with the EPA and then the next steps determined.

9.3.6 Detailed Design and Specifications

The detailed designs and specifications for a range of remediation elements including, but not



limited to, the cement-stabilised 'raft' structure and associated supporting columns; the in situ solidification works; all capping works and all stormwater diversion structures, as presented in this RAP, are to be finalised by the Remediation Contractor prior to the establishment on the Site. The detailed design and specifications will be included in the RWP after endorsement by the Site Auditor.

A range of assessments and trialling works will be undertaken in order to inform the detailed design and specifications. These assessments will include, but may not be limited to, the following:

- geotechnical assessment to confirm conditions at the toe of the seawall, and address data gaps in existing geotechnical information necessary for detailed design;
- field solidification trials to confirm the mechanical mixing methodology, including mix components, mix proportions, density, moisture content, gradations and hydraulic conductivity to achieve the requirements set out in this RAP;
- field trialling of the supporting columns to confirm the methodology and other elements to meet the structural requirements set out in this RAP;
- bench-scale and field trialling to determine whether stabilised materials excavated from the raft structure will meet immobilisation approval requirements, or whether additional treatment will be required to allow for disposal offsite and the nature of any such additional treatment required;
- field trials of environmental and human health control measures such as odour controls and water quality controls;
- detailed design of the sediment treatment plant and water treatment plant (if required);
- detailed design, modelling or other engineering assessments for the construction of all stormwater diversion structures and diversion of stormwater during the works; and
- detailed design of all capping structures.

The scope of any additional assessments and trialling works will be determined by the Remediation Contractor and will be approved by Jemena prior to their implementation. It is noted that the results of previous trialling works, pre-remediation monitoring works and any

other existing information will be utilised in the scoping and completion of the detailed design and specifications.

9.3.7 Remediation Works Plan

On completion and issue of the detailed design and specification works to Jemena, the Remediation Contractor will prepare a Remediation Works Plan (RWP) that describes in detail the remediation works, management requirements and mitigation measures required for the over-water works, land-based works and operational works required at the Staging Site. The RWP will be required to demonstrate that:

- the design, specifications and methodologies for construction of the remediation works will meet the requirements set out in this RAP;
- the detailed design and specifications set out the measures to be undertaken to minimise the volume of excess spoil and waters generated during construction;
- sufficient measures are to be undertaken to mitigate potential impacts on the environment and human health as a result of the works;
- the program of works is designed to minimise impacts to the amenity of Kendall Bay and to minimise the duration of the works at the Remediation Areas, during transport of materials to and from the Remediation Areas and at the Staging Site;
- the appropriate approvals, licences and permits for the remediation works have been obtained and are current for the life of the project; and
- the quality control and quality assurance plan that will be implemented during construction to demonstrate that the constructed elements will meet the required specifications.

The RWP will provide all necessary engineering design information required to undertake the remediation works, and the commissioning and proof of performance requirements, and will contain a comprehensive contingency plan to address unexpected conditions that could arise during the remediation works. Unexpected conditions may include the discovery of unknown types of contamination, an increase in the expected volume of contaminated material, adverse weather conditions, and/or difficulties associated with undertaking the treatment or containment of contaminated materials.

The wharf at the Staging Site has recently been upgraded and the existing structural and loading capacity of the wharf will be considered in relation to marine transportation options and the use of the wharf structure for the storage and movement of heavy plant, materials and equipment and its capacity will be confirmed via the completion of an assessment by a suitably qualified engineer. Should rectification or other works be required to improve existing capacity this would be undertaken prior to the establishment of the Remediation Contractor.

9.3.8 Auditing

The RWP will be required to be endorsed by the Site Auditor.

9.4 SITE ESTABLISHMENT

On finalisation of the detailed design and specification and on receipt of the required planning and other required approvals, permits and licences, the Remediation Contractor will establish to the Staging Site and will provide necessary amenities sufficient for the project requirements, a designated car parking area, site offices (as required) and installation of site security and signage. Designated areas with required controls will be established for materials storage, handling, treatment and loading and unloading at the Staging Site. The Remediation Contractor will also determine any need for protection, termination and/or diversion of services on the Staging Site prior to the commencement of any works.

The Staging Site is the only land-based operational area for the remediation works. It will be used for loading and unloading of general goods and materials required for the remediation works, and will also be the receiving area for excavated materials.

Prior to the commencement of the Remediation Contractor's site establishment works, the layout and capacity of the Staging Site will be assessed for operation during the remediation works. This will include:

- determination of how excavated materials will be received at the wharf and moved safely from the wharf into the Staging Site; and

- how existing buildings will be utilised to receive excavated materials and to manage odour and fugitive emissions during excavated materials handling, treatment (if required) and loading for offsite disposal.

Loading and unloading areas for trucks and other vehicles within the Staging Site will need to be assessed and then established. Outside the Staging Site trucks and other vehicles associated with the movement of goods and materials will use Tennyson Road to access the wider road network. Other roads in proximity to the Staging Site will not be used.

The load capacity of the wharf will also be confirmed via the completion of an engineering assessment.

Site establishment also requires the installation of environmental and occupational health management controls at both the Staging Site and the Remediation Areas including measures for the control of water quality, odour, dust, surface water and sediment runoff and other control measures including, but not limited, to those set out in Chapter 11 of this RAP and the establishment of all relevant health and safety measures required to be undertaken during the remediation works as set out in Chapter 12 of this RAP. The requirement for any infrastructure will be set out in the RWP (as set out in Section 9.3.7 above).

Heavy duty plant and equipment for operations in Kendall Bay – barges, excavators, etc. – will be mobilised to the site from a commercial wharf such as is available at White Bay or Rozelle Bay.

9.4.1 Environmental Controls

Site establishment also requires the installation of environmental and occupational health management controls at both the Staging Site and the Remediation Areas including measures for the control of water quality at the remediation sites in the bay and at the Staging Site, as well as fugitive emissions, odour, dust, surface water and sediment runoff, the designated loading and unloading areas on the wharf at the Staging Site and other control measures. These may include, but not be limited, to those set out in Chapter 11



of this RAP and the establishment of all relevant health and safety measures required to be undertaken during the remediation works as set out in Chapter 12 of this RAP. Such works may require the establishment of sediment receiving areas, treatment plants, odour control enclosures and emission control systems, water holding and treatment plants. The requirement for this infrastructure will be set out in the RWP (as set out in Section 9.3.7 above).

9.5 REMEDIATION WORKS

The remediation works are required to be conducted in a staged sequence that addresses the Remediation Areas that require the most significant construction works and contain the most significant contamination first, with Remediation Areas that require only minimal works to be completed last. The preferred staging of the remediation works is as follows:

- Stage 1
 - Remediation Areas SA1, NA1 and NA2+NA3;
- Stage 2
 - Remediation Areas SA2 and SA5; and
 - Remediation Areas SA3 and SA4.

Should the Remediation Contractor consider alternative staging, justification will be required to be provided to Jemena and its approval sought prior to commencing the works.

The general methodology for the works to be undertaken for the completion of the staged remediation is provided below.

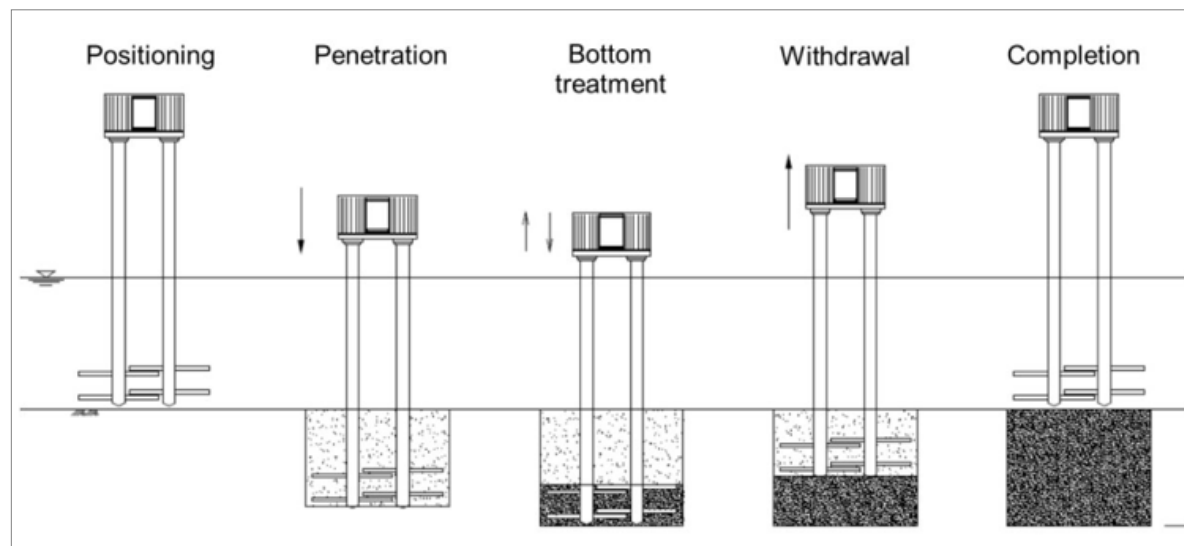
9.5.1 In Situ Treatment Works

Installation of Raft Structure in SA1 and NA2+NA3

The raft structure in SA1 is to be installed by the Remediation Contractor and is to be constructed as a cement-based structure that is supported by cement-based columns across the lateral extent of SA1. This process adopts the remediation method of chemical solidification in which chemicals or cementing agents 'fix' or 'stabilise' and immobilise the contamination within the sediment.

Construction of the supporting columns will be undertaken first. They are proposed to be constructed as either cement-based columns that are keyed into a component strata unit, referred to as Unit 2B material, or as otherwise determined by the detailed design. The process of creating columns is shown schematically on Figure 9.2.

Figure 9.2. Deep sediment mixed column construction sequence



Source: Taguchi, 2015

The works would be undertaken utilising barge-mounted equipment, comprising a drill rig, binder silo, mixing plant and grout pump. A single or multi-shaft hollow-stem auger is gently lowered through the water column and into the sediment to the desired depth. The cement binder is then carefully injected into the sediment whilst raising and rotating the mixing apparatus. Mixing of the cement through the sediment column is achieved by rotating mixing paddles while cement is released through ports at the base of the auger. The injected cement reacts with the pore water within the saturated sediment and replaces it with a sediment and cement matrix upon curing. Cement hydration (i.e. reaction with water) has the effect of increasing the density of the in situ material and its strength. The methodology for construction of the columns, including their width, depth, adequacy of the key, mix design and lateral configuration will be determined as an outcome of the development of the detailed design and specification work as set out in Section 9.3.6 of this RAP and will be documented in the RWP.

The construction of the raft structure will commence only after the supporting columns have been installed and validated to meet the detailed design requirements. It is proposed that the raft will be constructed using cement-based mass solidification methods and would likely be completed from the surface of the existing sea bed level to approximately -1.5 m LAT. As existing seabed levels range between around 0 m LAT at the eastern perimeter and around +0.5 m LAT along the western perimeter, the depth of mass solidification could generally range from 1.5 m to 2 m. Over the 2200 m² Remediation Area, this equates to mass solidification of around 3900 m³ of in situ material on an average solidification depth of 1.75 m. When using dry cement, as proposed, there is no significant bulking of materials, whereas if wet grout is used bulking of up to 20% can be expected.

Differential GPS controls on the excavator and mixing attachment will be used during the solidification works to ensure accurate positioning, that solidification depths are achieved and that over-solidification is minimised.

The process of creating deep sediment mixed columns is shown schematically on Figure 9.2.

This comprises the careful lowering of a single or multi-shaft hollow-stem auger into the sediment to the desired depth and injecting the cement binder into the sediment whilst slowly raising and rotating the mixing apparatus. A number of Australian contractors have experience in using this technique in marine and estuarine sediments, and in the use of the necessary equipment.

The remediation sequence will initially involve construction of the supporting columns followed by mass solidification of surface material down to the defined depth. The cement solidification would also make excavation of sediments less problematic, by improving the in situ strength and allowing steeper temporary excavation batters of say 1V:1H to 1V:2H.

The proposed method is to encircle the relevant area with a ring of overlapping sheet piles before the construction of the inner matrix of columns. After the columns have been completed, the raft will be constructed atop the columns. Any bulking of the sediments occurring as a result of the solidification processes for columns and raft will result in a mounding of the solidified surface which will be removed when the top of the raft is excavated.

Following mass solidification and curing of the raft, excavation of the solidified material down to -0.5 m LAT will be carried out to enable placement of a 0.5 m thick capping layer to 0 m LAT. Based on the above seabed variation, the depth of excavation could range from 0.5 to 1.0 m. Over the 2200 m² Remediation Area, this equates to excavation of around 1700 m³ (dry method with no bulking) or 2100 m³ (wet method with 20% bulking) of solidified material based on an average excavation depth of 0.75 m.

The depths of solidification and excavation will be measured using precise GPS to ensure adequate solidification and excavation to the surveyed depths are achieved.

To ensure that the entire area of SA1 receives a consistent 0.3 m thick capping, the extent of mass solidification will extend 5 m outside of the defined boundary of the Remediation Area to provide a buffer that allows for the width of the excavation batter. The width of the excavation



batter will vary according to the existing seabed level. If a temporary excavation batter of 1V:2H was adopted, the width of the excavation batter would generally range from 1 to 2 m. Excavation through the perimeter buffer will leave a 'rim' of solidified material around SA1 that will prevent sediments from adjacent areas from slumping into the capping area.

Based on discussions with local contractors who have experience in solidification of low-strength soils and sediments, the consistency of the solidified material, which achieves a strength gain to several hundred kPa, allows ready excavation and the area could be walked on after a few days of curing.

The capping layer will be placed directly onto the excavated surface cut into the solidified material to a level of -0.5 m LAT and would comprise cobble-sized rock. Sand would be subsequently placed over the rock layer to provide substrate within the interstitial spaces of the rocks for benthic recolonisation. The rock will be placed first to ensure that the sand is able to be distributed throughout the entire interstitial space.

Preliminary testing to determine the strength of the solidified sediments has been undertaken and the preliminary results show that strengths of up to 1 MPa could be achieved using a simple cement additive. A laboratory program of mix testing, using a range of additives, at a range of relative concentrations, based on the USA experience of solidification of MGP contaminated marine sediments is planned for early 2018 to confirm the range of unconfined compressive strengths and permeabilities that could be expected during major project solidification works. It is also proposed to conduct a trial on site solidification using typical solidification equipment to solidify trial columns and rafts in and around Area SA1. This in-field trial will allow for testing of methods, using the best mixes from the laboratory trials.

Unconfined compressive strength testing will be undertaken according to Australian Standards, and the leachability and permeability of the samples will be testing using the appropriate USEPA test methods specifically designed for solidified samples containing organic contaminants.

Although the solidified material is expected to have a low permeability (hydraulic conductivity in the order of 10^{-8} m/s, similar to a layered clay or fresh cemented sandstone), in order to enhance the robustness of the remediation treatment, an activated carbon material will be incorporated into the capping layer as a conservative method to contain any contaminants that may migrate through the solidified material. A review of available activated carbon products was completed by CSIRO (Appendix 5). For economic and practicability reasons activated carbon material will be placed in a geofabric mat at the base of the 0.5 m capping material thickness.

The construction of SA2 adjacent to SA1 will allow hydrostatic uplift pressures from surrounding groundwater levels to be released rather than being applied to the base of the mass solidified layer within SA1. The proposed mass solidification within SA1 would form a raft and pile structure of solidified material adjacent to SA2 and would be surrounded by a continuous sheet pile wall on the boundary of the remediation area. As a precautionary measure, remediation of SA2 will be undertaken after SA1 so that any unintended mass solidified buffer material from SA1 will be excavated and replaced with capping material as per the remediation strategy for SA2 (Section 8.6.2). The construction sequence for the proposed capping layer is shown in Figure 9.3

The performance of different binders and dose rates for solidification will be determined based on dosing trials completed on representative samples of excavated material at a NATA-accredited laboratory. This involves preparation of a number of different binder/soil mixes in a laboratory and strength testing at different intervals (i.e. 1 day, 7 days, 14 days, 28 days, etc.) to establish the rate of strength gain and relative performance of different binders. Several contractors have expressed interest in completing cement dosing trials on material obtained from the trial excavation activity completed on 22 September 2016 (Section 5.10).

Preliminary testing to determine the strength of the solidified sediments has been undertaken and the preliminary results show that strengths of up to 1 MPa could be achieved using a simple cement

additive. A laboratory program of mix testing, using a range of additives, at a range of relative concentrations, based on the USA experience of solidification of MGP contaminated marine sediments is planned for early 2018 to confirm the range of unconfined compressive strengths and permeabilities that could be expected during major project solidification works. It is also proposed to conduct a trial on site of solidification using typical solidification equipment to solidify trial columns and rafts in and around Remediation Area SA1. This in-field trial will allow for testing of methods, using the best mixes from the laboratory trials.

The Remediation Contractor will supervise the installation works to monitor that the depth and alignment of these structures meet the requirements of the detailed design and specifications that will be prepared in accordance with Section 9.3.8 of this RAP.

9.5.2 Construction Considerations

SA1 and NA2+NA3

The following work methods will be implemented:

- construction of supportive columns nominally 0.6 m diameter and at 1.8 m centres (exact details to be determined in the detailed design phase of the project) using barge-mounted equipment comprising a drilling rig, binder silo and mixing plant and grout pump and positioned using GPS control. An example setup is shown in Figures 9.4 to 9.6, and is used for offshore applications by TOA Corporation, Tokyo, Japan;
- in situ cement solidification of the upper sediment layer in SA1 using a barge-mounted excavator with a mixing attachment (Figure 9.7) linked via a supply hose to a cement batch plant mounted on a floating barge and positioned using GPS control. Several Australian-based contractors (including Menard Oceania, Keller Ground Engineering and Wagstaff Piling) own amphibious excavators with proprietary mixing attachments and GPS control, and have experience in mass cement mixing applications in environments with poor ground conditions including in marine

environments (Appendix 4). The cobble material in the south-west area of SA1 will be removed to enable access for mass mixing as the tracks on amphibious excavators are damaged by hard or rocky ground conditions;

- excavation of cement stabilised material to a depth of 500 mm with barge-mounted excavator and placement into an adjacent hopper barge or a barge carrying smaller hoppers or skip bins;
- transfer of excavated material overwater by barge to the Staging Site for treatment (if necessary) and disposal by truck to a licensed waste facility;
- placement of an activated carbon mat and then cobble-sized rock using small earthmoving equipment (e.g. Bobcat or small excavator) gradually tipping rock over the edge of a floating barge containing stockpiled material (Figure 9.8); and
- placement of sand over the cobble layer in a similar manner to rock.

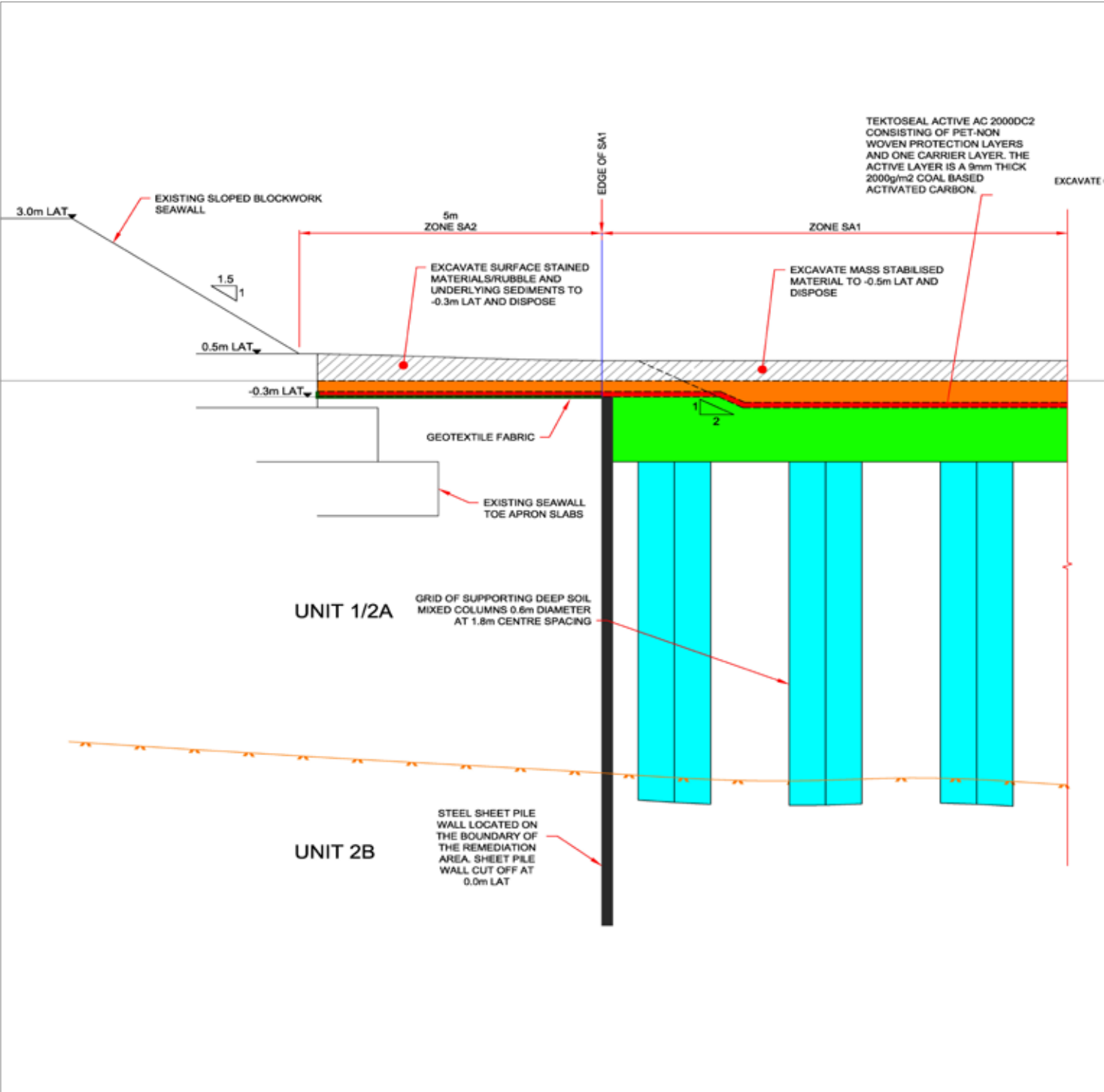
Areas SA2 and NA1

The following work methods are proposed for these areas:

- careful excavation of surface materials with a barge-mounted excavator with GPS control at high tide and placement of materials into an adjacent hopper barge or flat barge carrying smaller sealed hoppers or skip bins;
- transfer of excavated material overwater by barge to the Staging Site for treatment (if required) and disposal by truck to a licensed waste facility;
- placement of panels of geotextile fabric and geogrid from floating barges to achieve a minimum 0.9 m overlap between adjacent panels - use of polyester non-woven geotextile fabric would facilitate underwater deployment as polypropylene geotextile fabric is buoyant; and
- placement of capping materials using small earthmoving equipment (e.g. Bobcat or small excavator) gradually tipping material over the edge of a floating barge containing stockpiled material, or capping materials placed and groomed by barge-mounted excavator with GPS control.



Figure 9.3 Construction sequence SA1 and SA2 capping



Source: Royal HaskoningDHV, 2016a

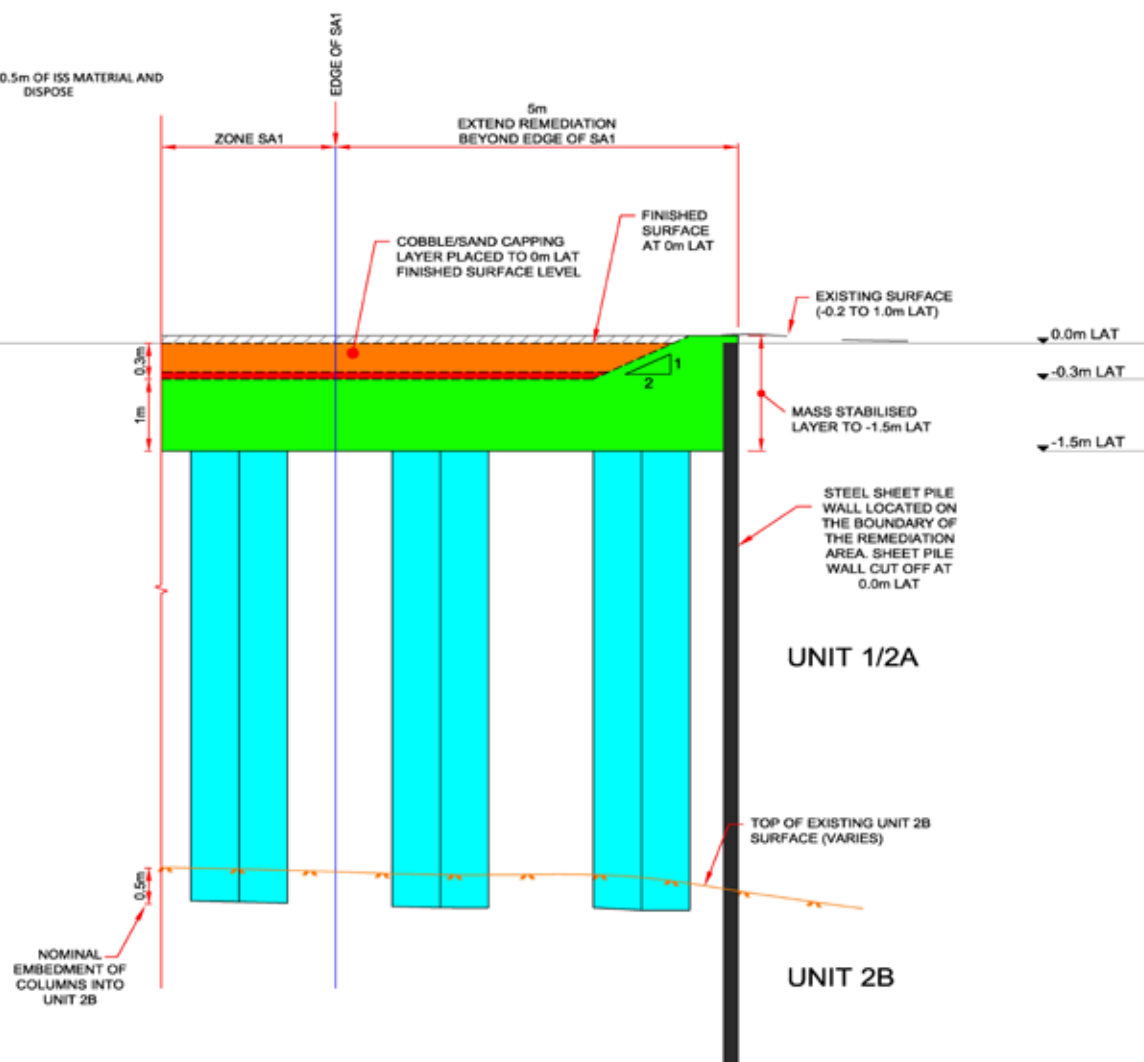
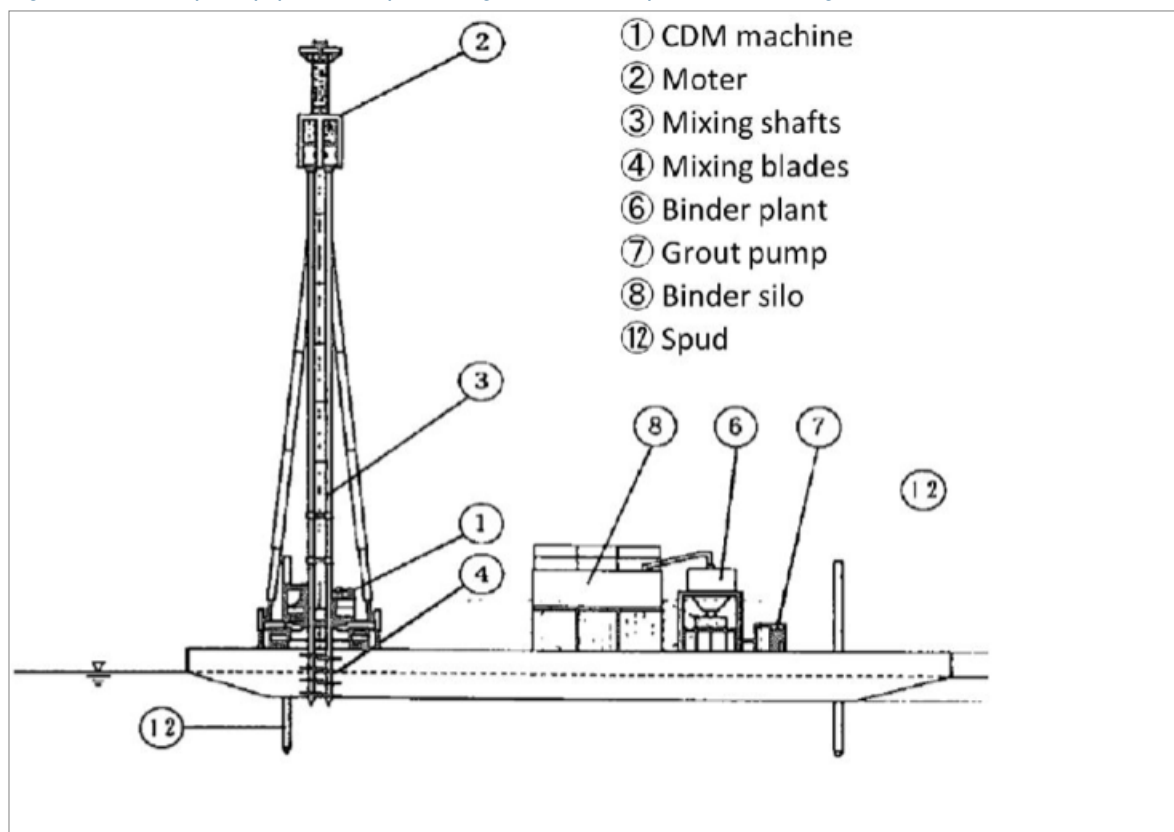


Figure 9.4. Barge-mounted drilling rig for deep sediment mixed columns



Figure 9.5. Example equipment setup for barge-mounted deep sediment mixing



Source: Taguchi, 2015

Figure 9.6. Barge-mounted deep sediment mixing



Source: Taguchi, 2015

Figure 9.7. Amphibious excavator with mass mixing attachment



Source: Keller Ground Engineering, 2016



Figure 9.8. Small excavator tipping rock from floating barge



Area SA3

The following work methods are proposed for this area:

- removal of surficial material where practicable over the nearshore sand shoal by small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge;
- removal of surficial material within the mangroves by hand with labourers wearing appropriate personal protective equipment (PPE), as set out in Chapter 12;
- waste material placed into skip bins positioned on the nearshore sand shoal and within reach of floating barges at high tide;
- transfer of waste material overwater by barge to the Staging Site for treatment (if required) and disposal by truck to a licensed waste facility;
- sand placed hydraulically via a small pipeline (e.g. 100 mm diameter, able to be shifted by hand) extending from a floating barge fitted with a slurry pump box and displacement pump for delivery of sand slurry into the pipeline or alternatively, sand will be stockpiled on the beach by small earthmoving equipment deployed on to the beach at low tide by a landing barge, profiled/graded by small earthmoving equipment over the unvegetated shoal area, and distributed

throughout the mangroves by hand using wheelbarrow, spades and rakes;

- spur walls constructed with rock placed with small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge; and
- if small equipment access into mangroves is problematic, the spur walls could be constructed with smaller rock that is able to be transported and lifted into place by hand.

Area SA4

The following work methods are proposed for this area:

- construction of the sandstone wall extension over beach and intertidal area will be undertaken by small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge;
- construction materials will be delivered to the site by barge and an amphibious excavator may be required in areas where weak ground conditions exist;
- removal of surficial material from the beach area by small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge, utilising a screening bucket or similar);
- waste material would be placed into skip bins positioned on the nearshore sand shoal and within reach of floating barges at high tide;

- transfer of waste material overwater by barge to the Staging Site for treatment and disposal by truck to a licensed waste facility;
- placement of sand layer over beach by small earthmoving equipment deployed on to the beach at low tide by a landing barge; and
- alternatively, hydraulic sand placement could be achieved as per the method described for SA3 and profiling/grading of placed sand undertaken by small earthmoving equipment.

Area SA5

The following work methods are proposed for this area:

- an amphibious excavator will track over intertidal/subtidal areas to excavate material;
- an amphibious excavator will place sand from stockpiles located on the beach (SA4) or floating barges;
- excavated material will be placed into skip bins positioned on the nearshore sand shoal and within reach of floating barges at high tide; and
- blending of excavated material with sand using earthmoving equipment for beneficial re-use in capping of other Remediation Areas.

9.5.3 Installation of Capping Layers

Installation of Capping Layer on Raft Structures in SA1 and NA2+NA3

The capping layer that forms the raft structure in SA1 will be installed by the Remediation Contractor only after the raft structure has been validated to have been installed to meet the detailed design requirements. Once this is confirmed, excavation of the upper part of the raft from the top of the solidified material to a depth of approximately -0.5 m LAT will be undertaken, with excavation batters formed at the boundaries of the raft that will be offset at a sufficient width from the edge of the solidified material to prevent slumping of the surrounding soft sediments into the capping area. Based on the variation in depth of the seabed, the depth of excavation of the raft could range from 0.5 m to 1.0 m. Excavation works will be undertaken using a barge-mounted excavator with excavated materials placed directly into hoppers mounted on a barge.

The capping layer would be placed directly onto the excavated surface cut into the solidified

material to a level of approximately -0.5 m LAT. The capping layer will comprise cobble-sized rock, activated carbon impregnated geotextile mat and sand. The activated carbon mat and cobble-sized rock would be placed first, followed by the sand. This work will be undertaken using barge-mounted small earthmoving equipment (e.g. Bobcat or small excavator) that would gradually tip rock over the edge of the floating barge containing stockpiled material. The rock would be placed in at least two layers to ensure that the sand is able to be distributed throughout the entire interstitial space. The activated carbon impregnated geotextile mat would be placed as a continuous geofabric layer at the base of the capping material.

The Remediation Contractor will supervise the installation works to validate that the depth and alignment of this structure meets the requirements of the detailed design and specifications that will be prepared in accordance with Section 9.3.5 of this RAP.

Installation of Capping Layers in SA2 and NA1

Capping layers will be installed on a number of Remediation Areas after the completion of excavation/dredging works (SA2 and NA1). Where required, the capping layer would be placed directly onto the excavated surface cut to achieve pre-existing levels and/or thickness of cap required. The capping layer will comprise the placement of a geotextile fabric and then the placement of cobble sized rock and sand. Where placement of geotextile fabric and cobble sized rock is required, this work would be undertaken first and then sand would be subsequently placed.

The placement works for the geotextile fabric will be undertaken by sinking panels of these materials from a barge-mounted excavator with GPS controls. The other materials will be placed by barge-mounted small earthmoving equipment (e.g. Bobcat or small excavator) that will gradually tip rock over the edge of the floating barge containing the stockpiled/stored material.

Where rock is required to be placed it would be placed first followed by the sand to ensure that the sand has been distributed throughout the interstitial spaces.



Where only sand is required to be placed, this will be undertaken hydraulically using a small pipeline extending from a barge that will contain a slurry pump box and displacement pump for delivery of sand slurry into the pipeline for distribution where required. Alternatively if weather or environmental or safety conditions dictate, sand could be placed directly from barges in low tide conditions using small earthmoving equipment (e.g. Bobcat or small excavator) and where required by hand using wheelbarrows, spades and rakes. Placement of sand on beach areas (SA3, SA4 and SA5) is to be undertaken at the same slope and areal alignment as the existing beach.

GPS controls will be utilised during the capping works to ensure that capping thicknesses are achieved.

The Remediation Contractor will supervise these installation works to validate that the depth and alignment of this structure meets the requirements of the detailed design and specifications that will be prepared in accordance with in Section 9.3.5 of this RAP.

9.5.4 Excavation Works

Excavation works are required to be undertaken across a number of Remediation Areas to varying vertical and lateral extents. Where excavation is required from areas not subject to in situ treatment, dredging depths are limited to between 0.3 and 0.5 m, which negates the need for engineering excavation support. Where limited excavation depths are required, the formation of batters during excavation will be used along the boundaries of the excavation area to preclude the movement of sediments from surrounding areas onto the excavated surface.

Excavation will be undertaken with either a barge-mounted excavator or amphibious excavator, using mechanical dredging buckets. Excavation near the seawall and apron toe of the seawall will be conducted using appropriately sized excavators and buckets to ensure protection of the seawall.

Where excavation can be conducted on land (such as on the beach and in the intertidal zone during low tides) this will be completed using

appropriately sized excavators, amphibious excavators and bobcats or similar equipment, and by hand where required. Where possible, GPS control will be used during excavation to ensure that excavation depths and lateral extents are achieved and over- excavation is minimised.

Excavated sediments will be transferred directly from excavation into dedicated hoppers equipped with close-fitting covers for transfer by barge to the Staging Site for dewatering, stockpiling, screening, assessment and treatment where required, then disposed offsite to an appropriately licenced facility.

In order to limit the volume of materials to be disposed offsite, efforts must be undertaken by the Remediation Contractor to limit the volumes of excess sediments generated during the remediation works, by application of detailed excavation methods and GPS controls.

The stockpile, materials tracking and waste management measures are detailed in the Remediation Works Environmental Management Plan (RWEMP), the requirements for which are set out in Chapter 11 of this RAP. Excavation works will require:

- implementation of necessary environmental protection measures in accordance with the requirements of the RWEMP; and
- documenting and recording the works.

The Remediation Contractor will conduct and document inspections at the following stages of the works:

- following setting out, but prior to the commencement of any excavations;
- following the implementation of environmental control measures;
- periodically during any major excavation activity;
- periodically where excavation is being conducted proximal to seawall to assess for visual signs of instability along seawall;
- during and after installations of columns and capping layers; and
- at the completion of the excavation.

9.5.5 Transportation Works

Transport Quantities and Movements

Preliminary estimates suggest that the quantities of materials to be imported to, and exported from, the Staging Site via Tennyson Road will be as indicated in Table 9.1.

Over an estimated construction period of 14 months, at 20 working days per month and a 30 tonne load for a truck and trailer, this translates to an average of 2.63 trucks, or 5.26 truck movements (in plus out) per day. It is expected that there will be peaks of truck movements during the construction period and times with fewer movements.

By way of comparison, there are 5 buses arriving and then leaving Mortlake per hour, i.e. 10 bus movements per hour, or 100 bus movements in a 10-hour working day.

When other construction in the Mortlake area is also considered, the traffic impact of the project is therefore considered negligible.

Transport of Excavated Materials to the Staging Site

Transport of excavated materials will be via barge direct to the Staging Site. Once the barge-mounted hopper is loaded, a close-fitting cover will be drawn over the top to minimise odour emissions and the barge will move to the wharf at the Staging Site for unloading. Sediments within the hoppers will be covered to minimise the sediment surface area potentially exposed to the ambient air, thereby minimising generation of odours.

It is anticipated that during excavation of sediments approximately three barges would

be operating as transport vessels to ensure maximum production rates. The hoppers would be transferred from the barge to the wharf using mechanical lifting equipment located within the Staging Site.

Once unloaded at the wharf, the containers holding the excavated sediments will be placed directly onto haulage vehicles or otherwise moved to the designated sediment and materials receiving area within part of the existing building on the Staging Site, which will be equipped with mechanisms to control emissions of odour.

The movement of all excavated materials will be undertaken in accordance with the materials-tracking requirements of the RWEMP.

Transport of Materials used in Capping Layers and other Works to the Remediation Areas

Transport of materials to be used in capping layers to the specific Remediation Areas will be via barge or boat from the wharf at the Staging Site direct to the Remediation Areas. The materials will be delivered to the Staging Site and then prepared for use and loaded from the wharf to the barge. It is anticipated that these materials will comprise a number of different types including, but not limited to rock, crushed rock, cobbles, sands, activated carbon mat and geotextile materials.

The materials will be stored on the barge in stockpiles or in storage units that best provide for the distribution of these materials to the Remediation Areas.

9.5.6 Installation of Erosion Abatement Structures in SA3 and SA4

An erosion abatement structure is required to retain sand placement within SA3 and will comprise spur walls constructed along a specified alignment through the mangrove area. The spur walls will be constructed of rock placed with small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge. If small-equipment access into the mangroves is problematic, spur walls will be constructed with smaller rock that can be moved and placed by hand. Construction materials will be delivered by barge.

Table 9.1. Materials transported

Material	Tonnes
Imported Cement and Additives	4800
Imported Rocks	5400
Imported Sand	2300
Exported Waste	9600
Total	22 100



An erosion abatement structure is required to protect SA4 and will comprise a seaward extension of the existing sandstone wall located on the western side of the beach. The extension of the wall will be approximately 30 m in length, and construction over the beach and intertidal area will be undertaken by appropriately sized earthmoving equipment (e.g. Bobcat or excavator) deployed onto the beach at low tide by a landing barge. Construction materials will be delivered by barge and an amphibious excavator may be required in areas where weak ground conditions exist.

9.5.7 Excavated Materials Handling, Offsite Treatment and Disposal

Where sediments are required to be removed from the Remediation Areas they will ultimately be disposed to a licensed offsite facility. Given that the excavated sediments are likely to contain significant concentrations of PAHs and other compounds, the options for disposal of excavated sediments comprise either onsite treatment at the Staging Site to meet a Specific Immobilisation Approval and then offsite disposal to landfill, or the transport of excavated sediments to a facility licenced to treat the sediments and then to dispose of the treated materials to landfill.

Offsite treatment is preferred for reasons of environmental sustainability:

- less traffic;
- less volume of excavated materials;
- less odour;
- less climate change gases emitted; and
- less disruption time on surrounding residents.

In summary, it is wasteful to build a temporary facility at the Staging Site if a perfectly suitable fixed facility exists offsite and there will be a significantly reduced EPA licensing burden with no discharges to air or water to regulate.

It is planned that materials removed from the Remediation Areas will be barged in sealed skips to the Staging Site and then treated offsite as follows:

- the top layer of material removed from NA2+NA3 and SA1 will have been cement-stabilised in situ and it is envisaged that it will be tested according to the General Approval

of the immobilisation of Contaminants in Waste No. 2005/14 and, when demonstrated to meet the requirements will be sent to an EPA-licensed landfill;

- the untreated material from NA1, SA2, SA3, SA4 and SA5, will be sent offsite in sealed skips to an EPA-licensed solidification facility and from there to an EPA-licensed landfill; and
- the offsite treatment and landfilling will be carried out in accordance with the Environment Protection Licences of the respective facilities.

The receiving area at the Staging Site will be designed to receive excavated materials in sealed skips on barges from Kendall Bay.

Facilities, details of which will be determined by the Remediation Contractor, will be provided for transfer of the material for transporting, in sealed containers, from the Staging Site to a licensed offsite treatment facility.

An appropriate facility is, for example, owned by Toxfree at St Marys, which is set up to treat solids. The liquid decanted there is sent to a separate treatment facility at South Windsor.

Options for handling the materials at the Staging Site include:

- using sealed skips on the barges and then, on arrival at the Staging Site, pumping the sediment into sealable containers which are then loaded on trucks for transport off site, and/or
- excavating straight into the sealable containers on the barges and loading them by crane or dragging them on rails off the water onto trucks at the Staging Site.

If necessary to comply with the receiving offsite facility's requirements, some large rocks, concrete, metal materials and rubbish may need to be removed from the sediments for stockpiling, classification and subsequent disposal.

Such materials that are generated as a result of the remediation work and that require disposal offsite must be classified in accordance with NSW EPA (2014) Waste Classification Guidelines. Part 1: Classifying Waste.

Assessment of the waste classification of excavated sediment and materials will be documented in the RWP.

Free waters decanted and pumped off the barges and potentially contaminated water from the Staging Site will be stored within marked, untreated water holding tanks. These waters are expected to contain suspended and dissolved constituents. A program of sampling and analysis of these waters will be undertaken by the Remediation Contractor to classify the waters for offsite disposal.

9.5.8 Remediation Constraints

Remediation works to be conducted within the Remediation Areas will be subject to a number of physical constraints due to the location and environment of Kendall Bay:

- access onto the land and foreshore that surrounds Kendall Bay for the purposes of any sediment remediation works is not permitted by the owners of the land and foreshore. Consequently, all activities relating to remediation of the sediments within the Remediation Areas must be undertaken over water and within the Staging Site;
- the foreshore of Kendall Bay that forms the western boundary of the Northern and Southern Remediation Areas is formed by a constructed seawall. The integrity of the seawall must be maintained throughout the duration and after completion of any remediation works;

- Kendall Bay is located within a dynamic environment that is subject to tidal movement and variable current and wave climates. The remediation works must be designed such that they can be undertaken within this environment and that they will be sufficiently durable and robust to withstand variations in this environment over time;
- Kendall Bay receives large volumes of stormwater, discharged via a number of large stormwater pipes located along the foreshore and beach areas. The stormwater outlets must be maintained during and after remediation, and remediation works must be designed to withstand the impacts of stormwater discharges to the bay;
- the navigable channel of the Parramatta River runs past the entrance of Kendall Bay. The remediation works must be undertaken in a manner that does not impact the use of the navigable channel by other marine craft, especially near the seawall in the Northern Remediation Area; and
- boating is an existing and future use of the bay and hence the remediation works must be designed to maintain existing bathymetry wherever possible, or possible in the near future after allowing for predicted settlement.

The selected remediation option/s for the Remediation Areas (Chapter 8) must ensure that the remediation objectives are achieved, within the constraints set out above.



Chapter 10

REMEDICATION WORKS CONTINGENCY PLAN

The purpose of the Remediation Works Contingency Plan (RWCP) is to outline procedures for the identification and management of unexpected issues or events that may occur during the remediation works.

10.1 KEY RISKS

The key risks that have the potential to arise during the remediation works include:

- in situ solidification trial is unsuccessful;
- construction issues in the Remediation Areas;
- unexpected contamination or obstructions;
- offsite sediment treatment is not viable;
- heritage items are discovered and/or disturbed;
- unfavourable weather conditions;
- unfavourable wave conditions, including Rivercat wake;
- water quality issues due to spills of fuel and/or disturbed or excavated sediment;
- generation of excessive odours; and
- remediation works fail to achieve the remediation criteria and goals.

The contingency measures that will be implemented to ensure that the key risks are mitigated are discussed below.

10.1.1 In Situ Solidification Trial is Unsuccessful

As discussed in Section 9.5.3, there is a high degree of confidence in the proposed in situ solidification (ISS) approach but, to prove the performance of ISS, Jemena proposes to conduct an in situ trial in Kendall Bay before proceeding to engage a contractor to carry out the remediation.

If a trial does not demonstrate the effectiveness and robustness of ISS, Jemena will revert to Option 1 in Table 8.2 – capping by mechanically dredging to a competent surface and installing a permeable cap and provide a revised Remediation Works Plan.

10.1.2 Construction Issues in the Remediation Areas

Areas SA1 and NA2+NA3

If cement dust generation is found to be problematic during mass mixing, the use of wet grout rather than dry cement will prevent release of cement dust at the surface during mixing.

In the event that use of an amphibious excavator for mass soil mixing is restricted due to odour generation, other measures that could be implemented include:

- use of floating equipment for mass solidification, working the tides, which would involve drilling of shallow cement-mixed columns in an overlapping pattern to achieve the desired thickness; or,
- excavation of a shallow thickness of contaminated material with a barge-mounted excavator and hopper barge, and placement of a geotextile and geogrid layer to support capping material, which would be designed to settle over time to a desired finished level below LAT.

If not available on short lead time, all equipment to implement the contingency measure will be maintained on the Staging Site during these works and personnel will be trained in the operation of equipment and installation of the contingency measure.

Areas SA2 and NA1

Due to seawall stability concerns, excavation along the toe of the seawall should be completed in limited lengths of maximum 10 m, followed by placement of capping material before the adjacent excavation is started. The seawall would be monitored visually for signs of instability during the works, conducted daily. Pre-remediation and post-remediation dilapidation surveys would be conducted.



If excavation of surface material uncovers underlying soft sediments, placement of geotextile fabric and geogrid may be required to limit the loss of capping layer material by it punching through the soft underlying material upon placement.

If not available on short lead time, all equipment to implement the contingency measure will be maintained on the Staging Site during these works and personnel will be trained in the operation of equipment and installation of the contingency measure.

Area SA3

No contingency measures are considered necessary for this area.

Area SA4

If works need to be undertaken in shallow waters or at low tide, an amphibious excavator could be used to enable operation on weak ground conditions.

Poor foundation conditions for the wall extension are likely to exist further offshore from the existing beach berm. In this case the wall may need to be constructed on a bridging layer formed by geotextile fabric, geogrid and a rock layer. Alternatively, a supportive platform for the wall extension could be created with mass solidification techniques using equipment mobilised for SA1.

If not available on short lead time, all equipment to implement the contingency measure will be maintained on the Staging Site during these works and personnel will be trained in the operation of equipment and installation of the contingency measure.

Area SA5

An amphibious excavator could be used to enable operation where weak ground conditions are encountered.

10.1.3 Unexpected Contamination or Obstructions

The approach for the remediation works set out in this RAP has been developed through a review of the previous investigations and historical

activities undertaken on the site to determine the COPCs and CoCs. However, it is possible that unanticipated contamination and/or potential submerged structures or obstructions will be encountered.

The nature of residual material and the associated hazards are generally detectable through visual or olfactory means such as:

- construction/demolition associated waste through visual observation; and
- waste material associated with illegal dumping through visual observation.

In the event that one or more of the above-mentioned substances are encountered, the Remediation Contractor is to undertake the following steps:

- **STEP 1:** Immediately notify Jemena;
- **STEP 2:** Segregate suspect materials and set out exclusion zone if required to prevent access and exposure to workers;
- **STEP 3:** Contact Remediation Consultant to arrange for inspection of encountered material/conditions;
- **STEP 4:** Remediation Consultant to undertake detailed inspection and conduct an assessment to determine appropriate management of conditions encountered;
- **STEP 5:** Remediation Consultant to provide instruction and advice to Jemena and Remediation Contractor as to approach to rectify/manage conditions encountered;
- **STEP 6:** If deemed required, Remediation Consultant to supervise any active 'remediation' or other rectification/management works if they are required;
- **STEP 7:** Once any rectification/management works are completed Remediation Contractor to remove any exclusion zone; and
- **STEP 8:** Where required, Remediation Consultant to prepare a report to Jemena on the unexpected find and the works undertaken to rectify/manage the conditions encountered. This report would be included in the Validation Report for the remediation works.

10.1.4 Off-Site Sediment Treatment Not Viable

For reasons outlined in Section 9.5.7, it is desirable to carry out sediment treatment off-site. If this is not viable due to commercial, technical, regulatory or logistics reasons, a treatment facility will be constructed at the Staging Site.

The treatment facility would include:

- sealed enclosures under negative pressure ventilating through a dual activated carbon bed emission control system and discharging to air via a stack;
- stockpile areas for receipt and classification of excavated materials, including provisions for collection and management of leachates;
- screening equipment such as a vibrating scalping screen or grizzly/screen combination, the underflow being transported to a temporary storage area for treatment and the oversize being assessed and, if suitable, disposed directly off-site, or crushed or shredded and transported to a temporary storage area ready for treatment;
- a mixing plant comprising a feed hopper, conveyors, reagents silo, pug mill and associated equipment;
- facilities for temporary storage and load-out of treated materials;
- a water treatment plant, typically consisting of storage tanks, reaction tanks for the addition of chemicals, clarifier, multi-media filters, centrifuge, granular activated carbon filters, pumps, piping and associated equipment.

Treatability trials have already been conducted on the sediments and the water, in case this option is adopted.

10.1.5 Heritage Items are Discovered or Disturbed

Cultural heritage sites are easily damaged or destroyed by natural processes such as erosion, as well as by disturbance. While it is not possible to prevent the slow destruction of cultural heritage sites, it is possible to prevent unnecessary damage by the implementation of careful work practices.

Due to the location and historical use of the site, it is considered unlikely that heritage items will be encountered during the remediation works.

However, given the nature of the disturbing activities that will be undertaken during these works, should potential heritage items be encountered unexpectedly, the following contingency measures should be implemented:

- **STEP 1:** Immediately cease all activities that could in any way interfere with, or disturb, the encountered site and/or object(s);
- **STEP 2:** Promptly report the discovery to the Remediation Contractor who will in turn notify Jemena and (if directed to do so by Jemena) the relevant regulatory authorities. Until further instructions are received:
 - DO NOT disturb the area of the site in which the item was uncovered;
 - DO NOT collect any artefacts as this may alter the scientific value;
- **STEP 3:** Details of the find should be documented including:
 - location of find;
 - person(s) who encountered the find;
 - time and date of find;
 - description of find including number of objects, shape, colour etc.;
 - actions taken; and
 - without touching or interfering with the site and/or objects, photograph them for a record of the find.

10.1.6 Unfavourable Weather Conditions

The Remediation Contractor will be contractually required to allow in the construction schedule for typical inclement weather conditions but, in any case, it can be expected that work will be interrupted by unfavourable weather conditions. In this case, the work will have to be suspended or efforts directed to work unaffected by the weather, for example, to clean up the surface of SA3 if it is not safe or viable to work on SA1, NA2+NA3.

10.1.7 Unfavourable Wave Conditions, Including Rivercat Wake

The Remediation Contractor will be contractually required to undertake the works in Kendall Bay in a manner which allows for the continuance of the works during normal operations of the Rivercat Ferries and any reasonably expected wave conditions. In the event of extreme wave



conditions which result from extreme weather conditions, works will need to cease and plant and vessels be secured.

10.1.8 Water Quality Issues

The Remediation Contractor will be required to monitor water quality according to the specifications agreed in the Remediation Works Environmental Management Plan. If water quality conditions outside the agreed levels of screening and booming exceed agreed criteria, works will cease and appropriate corrective actions will be taken before works recommence.

10.1.9 Generation of Excessive Odours

The Remediation Contractor will be required to monitor odour according to the specifications agreed in the Remediation Works Environmental Management Plan. If odour levels exceed the agreed levels or public complaints are received concerning odour which are not frivolous or vexatious, works will cease and appropriate corrective actions (including confirmatory odour monitoring) will be taken before works recommence.

10.1.10 Remediation Works Fail to Achieve Validation Criteria

Where the remediation works and the contingency remediation works result in the Remediation Acceptance Criteria, the Validation Criteria and the objectives of the RAP not being met, the following contingency measures should be implemented:

- review the results of the validation works;
- determine the lateral and vertical extent of the failure of the installed remediation measures;
- determine the requirements for rectification or replacement of the remediation measures in order to achieve the remediation objectives as specified in the Validation Plan;
- document these requirements in a report that is provided to the Site Auditor for acceptance as appropriate;
- mark out the spatial boundaries onsite and communicate the rectification requirements to Remediation Contractor;
- upon completion of the additional works, undertake validation works in accordance with this RAP or subsequent plan; and
- where the validation works returns successful results, remediation is considered to have been completed.

10.2 ENDORSEMENT OF THE REMEDIATION WORKS CONTINGENCY PLAN

The Remediation Contractor will prepare and provide a copy of the Remediation Works Contingency Plan to the Jemena Project Manager for endorsement, either separately or as part of the Remediation Contractor's standard workplace management documentation.

10.3 TRAINING OF PERSONNEL IN APPLICATION OF THE REMEDIATION WORKS CONTINGENCY PLAN

The Remediation Contractor will train all project personnel in the application of the Remediation Works Contingency Plan and individual roles and responsibilities.

10.4 ACCESS TO THE REMEDIATION WORKS CONTINGENCY PLAN

A hard copy of the Remediation Works Contingency Plan or the Remediation Contractor's equivalent standard workplace management documentation will be kept in the Remediation Contractor's site office.

Chapter 11

REMEDIATION WORKS ENVIRONMENTAL MANAGEMENT PLAN

Disturbance of environments for the purpose of remediation brings with it the potential of risk to the surrounding environment, associated with migration of contamination from the Remediation Areas or within the Remediation Area, as well as to site personnel. To ensure protection of the environment, measures need to be implemented during the remediation works within Kendall Bay, the Staging Site and the waters in between.

A Remediation Works Environmental Management Plan (RWEMP) will be prepared by the Remediation Contractor prior to commencement of physical remediation works to ensure that the appropriate control measures are in place to protect the environment at the Remediation Areas, along the transport corridor in Kendall Bay and at the Staging Site, and that appropriate monitoring is implemented to identify any improvements or repair to control measures required.

The sections below provide guidance for preparation of the RWEMP and set out the minimum requirements to be adopted in the RWEMP. Where development consent, licence or permit conditions vary from the information set out below, these conditions take precedent and must be included in the RWEMP.

11.1 OBJECTIVE

The objective of the RWEMP is to set out the environmental management measures that are required to be implemented during remediation works in order to manage identified risks to site personnel and the environment to ensure that:

- comprehensive control measures are implemented to prevent the migration of potentially contaminated materials or waters from the over-water remediation works areas

and from the Staging Site and within these areas;

- works that require disturbance of sediments are undertaken in a manner that protects the health of the workers and users of the areas adjacent to the remediation works areas;
- any potentially contaminated materials excavated are appropriately stored, handled, treated and disposed of offsite: and
- appropriate monitoring is undertaken to identify compliance with the RWEMP and corrective actions, if required.

11.2 TIMING OF IMPLEMENTATION OF THE REMEDIATION WORKS ENVIRONMENTAL MANAGEMENT PLAN

No sediment disturbance works or other intrusive works are to be undertaken until the RWEMP is endorsed by the Site Auditor and by the Jemena Project Manager, and until the environmental management measures set out in the RWEMP are installed and functional to the satisfaction of the Jemena Project Manager.

11.3 RESPONSIBILITIES

The Remediation Contractor is responsible for the overall implementation and maintenance of the RWEMP and for ensuring that the local community and contractors working on the remediation works have been informed of the requirements of the RWEMP prior to commencement of works.

The RWEMP is required to be prepared by the Remediation Contractor and provided to Jemena for approval prior to the commencement of any remediation works.

Indicative responsibilities of Jemena and the Remediation Contractor as regards the RWEMP are outlined in Table 11.1

**Table 11.1. RWEMP responsibility matrix**

Position and Company or Entity	Responsibilities
Jemena Project Manager	- Provide approval of the RWEMP; - Provide direction as required by the RWEMP; - Monitoring the Remediation Contractor's implementation of the RWEMP requirements; - Undertake regular inspections to ensure Remediation Contractor compliance with RWEMP; - Ensure appropriate planning and environmental consents, permits and licences (as required) are obtained for the works;
Remediation Contractor	- Prepare the RWEMP and obtain approval of the RWEMP from Jemena and from the Site Auditor; - Procure the training and induction of employees and sub-contractors before and during the works, as appropriate and relevant; - Advise persons occupying and working on the remediation works of the requirements of the RWEMP; - Implement the RWEMP to ensure compliance, including all applicable reporting requirements; - Provide a copy of the RWEMP to any sub-contractors who are engaged to undertaking works; - Ensure relevant and appropriate site personnel and contractors comply with the requirements of the RWEMP; and - Ensure relevant and appropriate site personnel and contractors clearly understand the requirements of the RWEMP and ensure that compliance with the RWEMP is a condition of any agreement with these parties. - Ensure consents, approvals and licenses are obtained (other than those for which Jemena is responsible); - Complete the registers, databases and records required by the RWEMP; - Conduct works in an environmentally responsible manner; - Meet relevant Work Health and Safety regulatory requirements; - Implement the works in a safe and responsible manner; - If unexpected conditions are encountered during excavation works, notify Jemena in accordance with the RWCP; - Complete non-conformance and corrective action reports as required and undertake follow-up corrective actions, as required; - Ensure monitoring is conducted as required in the RWEMP; - Where required, engage a suitably qualified Occupational Hygienist to conduct any required monitoring; - Undertake audits of activities in accordance with the requirements of the RWEMP; - Ensure non-conformance and/or complaints are reported to Jemena as soon as practicable; - Undertake corrective actions in response to requests made by Jemena regarding specific environmental or safety issues; - Ensure all works comply with relevant regulatory requirements; and - Inform Jemena if conditions change significantly from those documented in the RWEMP.

The Project Manager's role will be defined by the relevant terms of the construction contract. In general, the Project Manager's role will be to 'administer' the contract and ensure the Remediation Contractor performs its contractual obligations.

The specific functions of the Project Manager may include:

- issuing directions to the contractor on behalf of the principal;
- approving programs;
- approving subcontractors;
- controlling employees;
- resolving contract disputes;
- examining and testing materials;
- postponement and suspension of work; and
- ordering variations.

11.4 GENERAL SITE OPERATIONS

11.4.1 Hours of Operation

The hours of construction, including the delivery of materials to and exported from the Staging Site, will be set out in the development consent and are likely to be restricted as follows:

- between 7:00 am and 6:00 pm, Mondays to Fridays inclusive;
- between 8:00 am and 5:00 pm, Saturdays; and
- no work on Sundays and public holidays.

Works may be undertaken outside these hours where:

- the delivery of materials is required outside these hours by regulatory authorities; or
- it is required in an emergency to avoid the loss of life, damage to property and/or to prevent environmental harm.

11.4.2 Traffic and Pedestrian Management

Safe traffic and pedestrian management are the responsibility of the Remediation Contractor. Prior to the commencement of remediation works a Traffic and Pedestrian Management Plan will be prepared in accordance with the relevant standards. The plan is required to address, but not be limited to, the following components:

- ingress and egress of vehicles to the Staging Site;
- loading and unloading, including construction zones;

- predicted traffic volumes, types and routes;
- pedestrian and traffic management methods and controls; and
- any required controls on management of water traffic during over-water works.

The Traffic and Pedestrian Management Plan must be provided to Jemena for its approval prior to the commencement of works by the Remediation Contractor.

11.4.3 Site Access and Protection

During the remediation works effective site signage and security that will prevent the exposure of the general public to contaminated or potentially contaminated materials, and/or to hazards that may exist during the course of the works, and prevent damage to environmental control structures, is to be established and maintained by the Remediation Contractor. During works, barriers will be installed which will restrict access to the designated works area. Only authorised persons will be permitted to enter the work area.

Staging Site

Appropriate hoarding or fencing will be erected by the Remediation Contractor between the Staging Site and areas accessed by the public, during the works when the works are likely to cause obstruction or inconvenience to pedestrian or to vehicular traffic in that public place, or if the works require the enclosure of a public place. Enclosure of a public place will be only by approval of the appropriate regulator.

The installation, maintenance, management and removal of any required hoarding or fencing is the responsibility of the Remediation Contractor.

Over-Water Works

The over-water remediation works are not to interfere with the movement of seagoing ships/commercial vessels unless agreed in advance with the Harbour Master. Should the Remediation Contractor anticipate that the over-water works could interfere with seagoing ships/commercial vessels or that Harbour Master Approval is required for the over-water works then the Remediation Contractor is required to prepare a Marine Traffic Management Plan for submission



to Jemena and the Harbour Master for approval prior to the commencement of works by the Remediation Contractor.

The over-water remediation works are required to comply with the following:

- buoys are not to be laid in or adjacent to the shipping channels unless agreed in advance with the Harbour Master;
- all buoys are to be fitted with lights;
- all vessels associated with the construction works are to have Response Plans for emergencies and spills;
- the Remediation Contractor must provide the Harbour Master with an 'All Hours' contact number during construction of the facility;
- any marine spill (whether the spill occurs on water or occurs on land and subsequently enters the water) is to be immediately reported to RMS; and
- any material associated with the construction of the development that enters the water is to be immediately retrieved. Should the material not be retrieved, the Port Authority of NSW must be notified and will organise for its removal and recover the cost from the Remediation Contractor.

An incident report should be completed and forwarded to Jemena as soon as practicable after any materials have been observed to have entered the water and after appropriate corrective measures have been implemented.

11.4.4 Noise and Vibration

The Remediation Areas and the Staging Site are located near to residential areas and therefore the noise that the works generate should be controlled by the Remediation Contractor by the following means:

- ensure works are undertaken only within appropriate hours of operation set out above or as required by the planning approval;
- ensure that no vehicles, machinery or equipment generate noise levels beyond applicable guidelines; and
- ensure that all equipment and machinery is operated in an efficient manner to minimise the emission of noise.

The remediation work will be undertaken to comply, where relevant, with the guidance provided in the NSW Department of Environment and Climate Change (DECC) (2009) *Interim Construction Noise Guideline* and the Australian Standard 2436-2010 *Guide to Noise Control on Construction Maintenance and Demolition Sites* for the control of construction site noise. The Remediation Contractor is required to notify Superintendent of Works of any activities that could exceed the construction noise management levels, and how the noise generated from these activities will be managed. Where relevant, such noise mitigation measures must be presented by the Remediation Contractor in a Construction Noise and Vibration Management Plan that is provided to and approved by the Jemena Project Manager prior to commencement of works.

The Remediation Contractor will use advanced technology and the best practicable means to prevent or mitigate the effects of noise emissions from the works, and shall be prepared to demonstrate that plant, equipment and methods comply with these requirements at all times.

It is anticipated that the proposed works will not generate vibration such that any control measures will be required. However, any vibration caused by construction at any residence or structure outside the Remediation Areas and Staging Site must meet:

- for structural damage vibration: German Standard DIN 4150 Part 3 *Structural Vibration in Buildings. Effects on Structures*; and
- for human exposure to vibration: the evaluation criteria presented in British Standard BS 6841 *Guide to Evaluate Human Exposure to Vibration in Buildings* (1Hz to 80 Hz) for low probability of adverse comment.

These limits apply unless otherwise detailed by the Remediation Contractor in the Construction Noise and Vibration Management Plan that is provided to and approved by Jemena prior to commencement of works on the site by the Remediation Contractor.



11.4.5 Occupational Health and Safety

The Remediation Contractor will prepare a detailed Work Health and Safety Plan that is prepared and implemented in accordance with all relevant and applicable health and safety legislation, regulations, codes and guidelines, applicable Jemena policy, and the requirements of Chapter 12 of this RAP. This plan must set out the personal protective equipment and control measures that ensure the protection of worker health due to the potential for contaminated materials to be exposed and handled during the remediation works. The Work Health and Safety Plan will be provided to and approved by Jemena prior to the commencement of works by the Remediation Contractor.

11.5 ENVIRONMENTAL MANAGEMENT

The RWEMP will be prepared to meet and/or exceed the requirements for the sediment, materials and water management measures outlined in this section. The RWEMP must set out control measures that are designed to mitigate discharges of sediment, nutrients and other pollutants to the land and/or waters and to mitigate discharges of odour, vapours, dust or other emissions to the air.

11.5.1 Protection of Air Quality – Odour, Vapour and Dust

The remediation works require the excavation/dredging and subsequent handling, assessment and treatment of contaminated sediments and associated waters. These activities have a high potential to generate some organic vapours, significant odour and dusts. Organic vapours and odours are likely to be most significant during excavation/dredging of contaminated sediments and during their transfer to the Staging Site. Once at the Staging Site the activities associated with handling, assessment, stockpiling and any treatment are to be undertaken within an odour control structure which will operate to prevent to the extent practicable the emission of vapour, odour or dust to the atmosphere.

The RWEMP is to set out the control measures to be undertaken at each stage of remediation works to mitigate emissions to the air as follows:

- the RWEMP must set out the control measures for remediation works to be undertaken on the Staging Site, and must include the installation and operation of systems and work methods designed to control odour, air and dust emissions from the works including, but not limited to, odour control structures, emission controls systems and monitoring requirements; and
- the RWEMP will set out control measures for remediation works to be undertaken over water and will include the installation and operation of systems and work methods designed to control odour, air and dust emissions from the over-water works including, but not limited to:
 - excavation and storage of the sediments/waters;
 - methods that reduce the sediment surface area exposed to the atmosphere and the duration of this exposure;
 - odour control and suppression measures; and
 - monitoring requirements.

The requirements of the RWEMP will be implemented by the Remediation Contractor to ensure that adequate measures are undertaken to adequately prevent odour, vapours and dust from the Remediation Areas and the Staging Site affecting the amenity of the neighbourhood during the remediation works.

11.5.2 Protection of Water Quality of Kendall Bay and Parramatta River

Stormwater, Surface Water, Excess Water, Remediation Area Waters, Sediments, Other Materials

The remediation works require the excavation/dredging and subsequent handling, assessment and treatment of contaminated sediments and associated waters. These activities have a high potential to generate contaminated waters, sediments and other materials that present a risk of migrating to the waters of Kendall Bay and the Parramatta River.



To minimise the risk of contamination of waters of Kendall Bay and Parramatta River, the RWEMP will set out the control measures to be undertaken at each stage of remediation works to prevent discharges of contaminated sediments, waters or other materials as follows.

The RWEMP will set out the control measures for remediation works to be undertaken over water outside of the Remediation Areas and will include the following:

- installation, operation and maintenance of in-water control systems, including silt curtains and booms around works areas in which sediments are being disturbed for remediation works. These systems must operate to prevent the migration of suspended sediments and waters within the work area to the waters of Kendall Bay and the Parramatta River;
- installation and operation of control systems on barges and other marine craft to prevent migration/spillage of waters/sediments/materials located on these craft to the waters of Kendall Bay and the Parramatta River; and
- installation, operation and maintenance of equipment control measures comprising over-water decontamination areas, washing facilities or similar to preclude the migration of contaminated sediments and waters to the waters of Kendall Bay and the Parramatta River.

The RWEMP will set out the control measures for remediation works to be undertaken on the Staging Site and will include the following:

- installation, operation and maintenance of a stormwater detention basin, covers over stormwater pits, bunding, silt fences, straw bale barriers and oil absorbents to prevent migration of waters/sediments from the Staging Site to the stormwater system and/or to the Parramatta River;
 - installation and maintenance of perimeter control barrier measures along the boundaries of the Staging Site, in particular along the line of the seawall and along the wharf that form the boundary of the Staging Site with the Parramatta River. These control measures must be constructed to minimise migration of sediments, primarily as a component of surface run-off to Parramatta River and/or to neighbouring properties. These measures should be constructed as silt fences constructed of filter fabric or mesh. Should conditions require it, straw bales will be installed;
 - installation and maintenance of perimeter control barrier measures around designated sediment receiving areas, handling areas, stockpile areas and water retention areas located within the Staging Site for the duration of the works. These control measures will be constructed to minimise migration of sediment and waters, primarily as a component of run-off from the surface of the Staging Site to the surrounding areas including to the Parramatta River;
 - installation and operation of excess water collection and retention system to collect and store waters generated from surface water runoff, dewatering of sediments, dewatering/washing of barges and other equipment to prevent migration of waters from the Staging Site to the stormwater system and/or to the Parramatta River;
 - installation, operation and maintenance of equipment control measures comprising wheel wash and truck and other machinery wash facilities; and
 - if necessary, the installation, operation and maintenance of a water treatment plant that will treat waste waters generated on the Staging Site to allow for discharge of treated waters to the Parramatta River.
- installation, operation and maintenance of a materials-handling system that sets out the procedures to be adopted to prevent discharges to the Parramatta River during a range of activities including, but not limited to:
 - the loading and unloading of marine vessels at the wharf and within the Staging Site;
 - the establishment and maintenance of stockpiles; and
 - the management of potential for generation of acid-sulphate soils from the excavated materials;



11.5.3 Acid Sulphate Soils

It is anticipated that excavated sediments will be classified as potentially acid sulphate soils (PASS). The Remediation Contractor must include in the RWEMP an Acid Sulphate Soil Management Plan. This Plan will include the procedures to be implemented for the handling, transfer, stockpiling, treatment and disposal of the sediments generated during the over water works, such that oxidation of PASS is avoided, that any impacts from oxidation of PASS sediment through effective management measures and to ensure no impact on surrounding properties or the environment as a result of the PASS handling. The Acid Sulphate Soil Management Plan will include any treatment works that will be undertaken in order managed the PASS.

11.6 MATERIALS HANDLING AND TRACKING

The movement of materials during the remediation works will be tracked and the Remediation Contractor will prepare a Materials Tracking Plan for inclusion in the RWEMP, in which records of the following must be kept and maintained:

- any materials imported onto the Staging Site;
- any movement and placement of materials within the Staging Site;
- any movement of materials from the Remediation Areas to the Staging Site;
- any movement of materials from the Staging Site to the Remediation Areas; and
- any materials disposed of offsite.

Records of all materials imported onto, placed within and disposed of offsite from the Staging Site will be maintained by the Remediation Contractor and will be provided to the Superintendent of Works on a monthly basis.

The RWEMP will set out that all loading and unloading associated with the remediation works must be accommodated on the Staging Site, unless relevant approvals have been sought by the Remediation Contractor from the local council or other relevant authorities to conduct these works outside the Staging Site.

11.7 WASTE MANAGEMENT

11.7.1 Waste Stream Management and Handling

The Remediation Contractor is responsible for the management and handling of the different waste streams that may be generated during the remediation works, and the processes for this activity must be set out in the RWEMP.

The RWEMP will set out that materials sourced from different areas or from different sources must be subject to segregated and marked stockpiling to ensure that contaminated materials are not mixed with uncontaminated materials. The segregation of stockpiled materials will be managed by the Remediation Contractor and assessed periodically during the remediation works.

11.7.2 Waste Classification and Disposal

The RWEMP will include a process for waste classification and disposal including nominated haul routes, nominated waste disposal facilities and other relevant consignment details. The RWEMP will set out any materials (solid or liquid) that are required to be disposed of offsite and are required to be classified by the Remediation Contractor according to the requirements of current waste classification groundwater made by NSW EPA. Waste classification information must be documented by the Remediation Contractor prior to any material being disposed of offsite. Details of offsite disposal of soil or other materials from the Staging Site during the remediation works will be recorded by the Remediation Contractor in the Materials Tracking Plan and must be provided to the Superintendent of Works on a monthly basis.

11.8 IMPORTED MATERIALS APPROVAL

The RWEMP will set out that materials to be imported onto the Staging Site by the Remediation Contractor must be subject to assessment to determine whether certification documentation supplied with the materials is deemed to appropriate or whether confirmation



sampling and analysis is required. Materials to be imported on the Staging Site for the purposes of capping works, for stormwater abatement structures or other rectification works must satisfy the following criteria:

- only Virgin Excavated Natural Materials (VENM) are to be imported to the Site;
- VENM must satisfy the criteria stated in NSW EPA (2014) and NSW DEC (2006) guidelines and be demonstrated to be:
 - natural material (such as clay, gravel, sand, soil or rock fines);
 - materials that has been excavated or quarried from areas that are not contaminated with manufactured chemicals or process residues, as a result of industrial, commercial, mining or agricultural activities; and
 - materials that do not contain any sulfidic ores or soils or any other waste.

Materials will not be imported until the Jemena Project Manager has provided written approval to the Remediation Contractor. If materials are imported on the Staging Site, then their use and placement is to be recorded in the Materials Tracking Plan.

11.9 ENVIRONMENTAL INCIDENT REPORTING

The Remediation Contractor will include in the RWEMP a Pollution Incident Response Management Plan (PIRMP) for the remediation works. This plan will set out the procedures to be undertaken during the works to:

- ensure timely reporting about a pollution incident to the Jemena Project Manager and where relevant to the NSW EPA, Fire and Rescue NSW, NSW Ministry of Health, WorkCover NSW, local councils and surrounding properties that may be affected by a pollution incident;

- minimise and control the risk of a pollution incident during the works by identifying the risks and the development of planned actions to minimise and manage those risks; and
- ensure that the plan is properly implemented by personnel, identifying persons responsible for implementing it, and ensuring that the plan is tested for accuracy, currency and suitability, and that monitoring and corrective action procedures are implemented and are appropriate.

11.10 COMPLAINT REPORTING AND RESOLUTION

The RWEMP must provide a protocol for the process to be followed in the event of complaints by members of the public and by regulatory authorities. This process will need to be determined by Jemena and the Remediation Contractor such that the appropriate party is notified of complaints and that the complainant will be investigated and remedied as required.

The RWEMP will also set out the party responsible for maintaining a detailed record of any complaints received and their resolution.

11.11 ACCESS TO THE REMEDIATION WORKS ENVIRONMENTAL MANAGEMENT PLAN

A hard copy of the RWEMP will be kept in the Remediation Contractor's site office.

Chapter 12

WORK HEALTH AND SAFETY PLAN

12.1 OBJECTIVES

The project work health and safety (WHS) objectives are to:

- comply with legislation and in particular, the *NSW Work Health and Safety Act 2011*, *Work Health and Safety Regulation 2011*;
- establish and maintain site-specific requirements to manage risks to the health and safety of workers;
- deliver an incident-free project;
- support compliance with relevant legislation and Codes of Practice;
- foster acknowledgement by all parties of their responsibilities;
- communicate clearly the safety requirements for the project; and
- encourage the involvement of workers in the review, improvement and implementation of safety systems.

These objectives will be achieved through:

- leadership and commitment;
- competent workers;
- fit-for-purpose plant, equipment and facilities; and
- providing all necessary information and instruction.

12.2 RESPONSIBILITIES

The Remediation Contractor will be the Principal Contractor under the WHS legislation and will be responsible for:

- developing a site-specific WHS Plan;
- identifying and observing all legal WHS requirements;
- ensuring that all works are conducted in a manner without risk to workers;
- planning to do all work safely;
- participating in the planning and design stages of construction trade activities;
- identifying WHS training required for an activity;
- ensuring workers undertake identified WHS training;
- communicating and consulting with workers;
- investigating hazard reports and ensuring that corrective actions are undertaken;

- assisting in rehabilitation and return to work initiatives;
- dispute resolution;
- providing appropriate signage for the construction project; and
- managing risks associated with the following:
 - the storage, movement and disposal of construction materials and waste;
 - the storage of plant that is not in use;
 - traffic in the vicinity of the workplace that may be affected by construction work; and
 - essential services at the workplace.

The Remediation Contractor will prepare the WHS Plan and will be required to have the plan endorsed by a qualified and experienced occupational health and safety expert.

The Jemena Project Manager is responsible for:

- project requirements as set out in the Validation Plan;
- liaison with the various levels of government and with the relevant statutory authorities; and
- review of the WHS Plan.

No physical work on the Remediation Areas or the Staging Site will be permitted until approval is granted by the Jemena Project Manager.

All workers on the project, including those employed by contractors, are responsible for:

- taking reasonable care of their own health and safety;
- taking reasonable care that their conduct does not adversely affect others;
- complying with instruction, so far as they are reasonably able; and
- cooperating with reasonable notified policies or procedures.

12.3 PROTECTION OF WORKER HEALTH

EnRiskS (2016) has assessed the potential for health risks of staff and subcontractors during the remediation works. This Human Health Risk Assessment has also provided the basis for the



design of some parts of the remediation to ensure that the remediation addresses all potential long-term health risks.

12.4 PROTECTION OF HEALTH OF SURROUNDING COMMUNITY

EnRiskS (2016) has assessed the potential for health risks to the community during the remediation works. This Human Health Risk Assessment has also provided the basis for the design of some parts of the remediation to ensure that the remediation addresses all potential long-term health risks. The remediation design has been undertaken so as to ensure all potential risks to the community are appropriately mitigated by the works.

During the remediation, the community will not be permitted to access areas where works are occurring, so they will not be able to come into direct contact with the contaminated sediments or other materials used during the remediation.

Evaporation of volatile chemicals from the sediments could increase levels of such chemicals in ambient air. This pathway of exposure was evaluated in the risk assessment. It was found that the concentration of these chemicals would be extremely low in areas such as the footpath on the shoreline and at the houses closest to the bay. This evaluation made conservative assumptions about how much of the sediments would be open to the air (not under water) at any one time. The surface area assumptions in these calculations are very conservative so it is likely that the concentrations in ambient air will be even lower than those assessed.

12.5 ANTICIPATED HAZARDS AND PREVENTION

At this stage of the project, the hazards in Table 12.1 below have been identified. Further work on hazard identification and prevention will be undertaken when the Remediation Contractor is engaged. All hazards identified by the Remediation Contractor and by Jemena will be addressed in the WHS Plan.

12.6 PERSONAL PROTECTIVE EQUIPMENT

12.6.1 General Outside Operations

The concentrations of the various chemicals to which an outside worker will be exposed are well below health guidelines which are based on lifetime exposure, not just exposure over a few hours. Therefore, risks to workers are expected to be low and acceptable. However, the material is odorous and can cause nausea.

The recommended personal protection equipment for workers is long pants, long sleeves, steel-capped boots and nitrile gloves. P2 respirators can also be used to avoid exposure to odour.

The prime focus is to prevent sediments and any additives coming into contact with skin. Should any spills onto skin or clothes occur they need to be washed off as soon as possible.

12.6.2 On Water Operations

The concentrations of the various chemicals at the barge immediately adjacent to the excavations will be higher than those estimated to be present on the footpath or near the houses, however, they are still expected to be well below the health guidelines based on lifetime exposure. Odours will be more likely on the barge.

The recommended personal protection equipment is long pants, long sleeves, steel-capped boots and nitrile gloves (and any other requirements for boating operations). P2 respirators can also be used to avoid exposure to odour.

The prime focus is to prevent sediments and any additives coming into contact with skin. Should any spills onto skin or clothes occur they need to be washed off as soon as possible.

Should the option of onsite sediment solidification be adopted, to prevent odour release to the community, the solidification work will be done inside an enclosure which is ventilated under negative pressure to an activated carbon emission control system.

Table 12.1. Project hazards, risks and proposed control measures

Project Area / Activity	Identified Hazard	Risk	Control Measures
Staging Site – processing plant and Water Treatment Plant	Odours/fumes: diesel fumes from plant machinery	Odour impact on neighbours Health impact to neighbour	Well ventilated building Doors remain open CO ₂ monitoring Equipment risk assessment/site approval (plant inspection to ensure acceptable noise and odour levels) Remediation Works Environmental Management Plan (RWEMP) Prestart operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Distance to neighbours (70 m for public and 20 m for industrial).
	Odours/fumes: Diesel fumes from plant machinery	Impact on personnel in confined areas	Well ventilated building Doors remain open CO ₂ monitoring Equipment risk assessment/site approval (plant inspection to ensure acceptable noise and odour levels) Construction and Environmental Management Plan (CEMP) Prestart operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions
	Vehicle impacts offsite (entry and exit to site). Local pedestrians and vehicles	Vehicle collisions/ accidents potentially causing fatality	Traffic management (site-specific). Toolbox talks and site inductions Study in more detail prior to mobilisation
	Vehicle impacts onsite (human plant interface)	Vehicle collisions/ accidents potentially causing fatality	Spotters for plant machinery movements Physical separation of personnel and machinery Reversing lights / beepers Traffic management (site-specific) 3rd party specialist Equipment risk assessment/ site approval (plant inspection) Toolbox talks and site inductions Trained plant machinery operators Study in more detail prior to mobilisation
	Noise	Noise impact on neighbours	Equipment risk assessment/ site approval (plant inspection) Exclusion zones Prestart operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Working within designated hours (detailed in the development consent and CEMP) Noise monitoring (as part of CEMP) Distance to neighbours Incident Management
	Dust generation	Dust impact on neighbours	Dust suppression Sealed off area
	Spills (diesel, paint, hydraulic oil)	Contamination to a water run off	Spill kits Designated refuelling area Designated service area Bunded fuel oil storage Bunded paint storage (cabinet) Inspection Toolbox talks / inductions
	Storm water run off	Contamination to a water run off	Silt fencing Diversion bunds Drains On site storm water drain maintenance
	Waste disposal	Disposal of general waste causing environmental issues	CEMP Housekeeping inspections Tool box and Inductions Mechanical dredging from barge into skips on other barges

**Table 12.1. Project hazards, risks and proposed control measures (cont.)**

Project Area / Activity	Identified Hazard	Risk	Control Measures
Placement of capping material.	Noise	Noise impact on neighbours	Equipment risk assessment/ site approval (plant inspection) Prestart operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Working within designated hours (detailed in the development consent and CEMP) Noise monitoring CEMP Acoustic assessment to be performed
	Odour	Odour impact on neighbours	Odour study Equipment specification based on odour study results Avoiding work in near calm easterly winds Foam or water covering excavated material in skips Minimising drop height from excavator Daily cleaning of soiled surfaces Restricting the rate of excavation if necessary Odour suppressants Water Sprays On-shore odour monitoring Community awareness campaign
	Public disturbance / light nuisance	Nuisance to neighbours	CEMP Use of directional lighting Keep community informed
	Barges and vessel movement	Collision resulting in spill	Navigational management plan Exclusion zones Professional, licensed operators All equipment in exclusion zone Study in more detail prior to mobilisation
	Use of plant and equipment on barges.	Impact with operators on barges.	Equipment maintenance (prestart checks of machinery) Exclusion zones Equipment risk assessment/site approval (Plant inspection) Prestart Operator checks Routine maintenance Toolbox talks and site inductions Trained plant machinery operators Contractor Safe Work Method Statements Study in more detail prior to mobilisation
	Aquatic environmental issues	Damage of equipment causing leaks.	CEMP Double booms with silt curtains Primary boom around equipment Gates/locks in boom
	Aquatic environmental issues	Mobilisation of contaminants in sediments	CEMP Double booms with silt curtains Primary boom around equipment. Gates/locks in booms
	Sea bed excavation	Undermining of the adjacent sea wall	Dilapidation survey to be undertaken prior to operations Work undertaken carefully and methodically in accordance with CEMP
	Beach excavation	People impacted by equipment used Public interface	Fencing (restricting access to the beach) Spotter Shade cloth 600 mm depth of excavation Short duration (1 week)
	Waste disposal	Disposal of general waste causing environmental issues	CEMP Housekeeping inspections Tool box and Inductions

Table 12.1. Project hazards, risks and proposed control measures (cont.)

Project Area / Activity	Identified Hazard	Risk	Control Measures
Barging of material in skips on barges	Noise	Workboats pushing the barges	Equipment risk assessment/site approval (plant inspection) Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Noise monitoring CEMP Acoustic assessment to be performed
	Odour	Exposed material on barge	Odour study Equipment specification based on odour study results Foam covering excavated material in skips Daily cleaning of soiled surfaces Restricting the rate of excavation if necessary Odour suppressants On-shore odour monitoring Community awareness campaign
	Aquatic environmental issues	Spillage from barge causing contamination	Navigational management plan Exclusion zones Professional, licensed operators All equipment in exclusion zone Study in more detail prior to mobilisation
	Aquatic environmental issues	Barge or spillage from barge causing turbidity	Navigational management plan Exclusion zones Professional, licensed operators All equipment in exclusion zone Study in more detail prior to mobilisation
	Aquatic environmental issues	Barge or spillage from barge causing turbidity	Navigational management plan Exclusion zones Professional, licensed operators All equipment in exclusion zone Study in more detail prior to mobilisation
	Barges and vessel movement	Collision resulting in spill	Navigational management plan Exclusion zones Professional, licensed operators All equipment in exclusion zone Study in more detail prior to mobilisation
	Barges and vessel interactions with the public	Vessel collisions / accidents potentially causing fatality	Navigational management plan Exclusion zones Professional, licensed operators All equipment in exclusion zone Study in more detail prior to mobilisation
	Waste disposal	Disposal of general waste causing environmental issues	CEMP Housekeeping inspections Tool box and Inductions
Mechanical transfer of material from barge to land	Noise	Crane lifting skips from barge to shore	Equipment risk assessment/ site approval (plant inspection) Prestart operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Working within designated hours (detailed in the development consent and CEMP) Noise monitoring (as part of CEMP) Distance to neighbours Incident management
	Odour	Odour impact on neighbours	Odour study Equipment specification based on odour study results Foam or water covering excavated material in skips Daily cleaning of soiled surfaces Restricting the rate of excavation if necessary Odour suppressants On-shore odour monitoring Community awareness campaign

**Table 12.1. Project hazards, risks and proposed control measures (cont.)**

Project Area / Activity	Identified Hazard	Risk	Control Measures
	Aquatic environmental issues	Spillage during transfer causing contamination	Navigational management plan Exclusion zones Professional, licensed operators All equipment in exclusion zone Study in more detail prior to mobilisation
	Waste disposal	Disposal of general waste causing environmental issues	CEMP Housekeeping inspections Tool box and Inductions
Sediment and water treatment	Noise	Noise impact on neighbours	Equipment risk assessment/site approval (Plant inspection) Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions CEMP Working within designated hours (detailed in the CEMP) Distance to neighbours (70 m to residential neighbours) Noise monitoring Noise study conducted Modifications to buildings to reduce noise
	Odour	Odour impact on neighbours	Emission Control System Equipment risk assessment/site approval (Plant inspection) Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions CEMP (including odour study) Distance to neighbours (70 m)
	Public disturbance/ Light nuisance	Light pollution/ visual impact on neighbours/ the public	Distance to neighbours Directional lighting Working within designated hours (detailed in the CEMP)
	Dust generation	Dust impact on neighbours	Dust control Housekeeping/spillage control Filters on the air system maintained and inspected regularly Dust monitoring (CEMP) Distance to neighbours (70 m to residential neighbours)
	Spills (diesel, paint, hydraulic oil)	Contamination to a water runoff/to the bay	Housekeeping/spillage control Inspections Bunded storage Spill kits provided on site Inductions/training Equipment maintenance
	Storm water run off	Contamination to a water run off	Silt fences Monitoring and inspections of system Stormwater runoff collection and treatment system Housekeeping/spillage control
	Security	Theft, sabotage, break in. Loss/damage of equipment. Potential harm to unauthorised persons on site (fall from heights)	Fenced off area. Security patrol Equipment / vehicles/buildings locked Housekeeping 'No unauthorised personnel' signs Locked chemical storage (fuel)
Discharge into Parramatta River (treated wastewater) (if applicable)	Odour	Odour to nearby properties and recreational users and others of waterway	Water treatment plant (filters) Inspection and maintenance Testing/monitoring of wastewater before discharge (daily checks at first, followed by weekly testing/monitoring as part of CEMP)

Table 12.1. Project hazards, risks and proposed control measures (cont.)

Project Area / Activity	Identified Hazard	Risk	Control Measures
	Aquatic environmental issues	Impacts on benthic organisms and aquatic fauna/flora	Water treatment plant (filters) Inspection and maintenance Testing/monitoring of wastewater before discharge (daily checks at first, followed by weekly testing/monitoring as part of CEMP)
	Stormwater run off	Pollution of waterways and increased turbidity	Water treatment plant (filters) Inspection and maintenance Testing/monitoring of wastewater before discharge (daily checks at first, followed by weekly testing/monitoring as part of CEMP) Housekeeping/spillage control
	Fire	Damage to equipment/injury to personnel	Inspections Bunded storage Spill kits provided on site Inductions/training Equipment maintenance Chemicals (e.g. fuel) locked away
Discharge into Parramatta River (treated wastewater) (If applicable)	Health issues due to contaminated material from site	Health issues due to contaminated material from site	Procedures for use of equipment PPE Housekeeping Equipment maintenance Environmental controlled treatment areas.(segregated from general public) Toxicity Study (impact on humans, potential disease, and environment covered in study)
	Personal threat by member of public to personnel working on site	Personal threat by member of public to personnel working on site	Fenced off area Signs Community survey completed Public engagement Training/Inductions (e.g. how to deal with members of public)
Material transported by truck to licensed landfill	Odour	Odour impact on neighbours	Material stabilised prior to transport Equipment risk assessment Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Cement will neutralise odour components Covering up the sediments Chemical fixation reduces the odour Traffic management plan Emergency Response Plan
	Odour	Odour impact on neighbours	Unstabilised material transported Equipment risk assessment Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Cement will neutralise odour components Covering up the sediments Chemical fixation reduces the odour Traffic management plan Emergency Response Plan
	Noise	Noise impact on neighbours	Equipment risk assessment Prestart Operator checks Routine maintenance Traffic management plan (use of noncompression braking) Speed limits

**Table 12.1. Project hazards, risks and proposed control measures (cont.)**

Project Area / Activity	Identified Hazard	Risk	Control Measures
	People interaction	Vehicle accidents, run over, hit by falling objects (from vehicle)	Traffic Management Plan Equipment risk assessment Prestart Operator checks Routine maintenance. Speed limits Community consultation Transport during daylight hours (working hours) Truck load limits Cover using tarps Housekeeping in loading area to minimise contamination of wheels
	Vehicle accidents leading to spillage	Sediment impact on drains and running into waterways. Roll over. Slip and slide. Vehicle to vehicle.	Equipment risk assessment/site approval (Plant inspection) Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions. Truck load limits Cover using tarps Cooling of cement prevents fluoridisation of material Traffic management plan Emergency Response Plan Toxicity study concludes material has low toxicity Appropriately licenced drivers Drive to conditions policy
	Dust generation	Dust impact on neighbours	Equipment risk assessment Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions. Cement will neutralise odour components Cover the sediments Chemical fixation reduces the odour Traffic management plan Emergency Response Plan
Demobilise Staging Site, processing plant and WTP	Odours/fumes: Diesel fumes from plant machinery	Odour impact on neighbours Health impact to neighbours	CO ₂ monitoring Equipment risk assessment/site approval (plant inspection to ensure acceptable noise and odour levels) CEMP Prestart Operator checks. Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Distance to neighbours (70 m for public and 20 m for industrial)
	Odours/fumes: Diesel fumes from plant machinery	Impact on personnel in confined areas	Well ventilated building Doors remain open CO ₂ monitoring Equipment risk assessment/site approval (plant inspection to ensure acceptable noise and odour levels) CEMP Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions
	Vehicle impacts offsite (entry and exit to site). Local pedestrians and vehicles	Vehicle collisions accidents potentially causing fatality	Traffic management (site-specific) Equipment maintenance (prestart checks of trucks) Equipment risk assessment/site approval (Plant inspection) Prestart Operator checks Routine maintenance Toolbox talks and site inductions Trained plant machinery operators Study in more detail prior to mobilisation.

Table 12.1. Project hazards, risks and proposed control measures (cont.)

Project Area / Activity	Identified Hazard	Risk	Control Measures
	Noise	Noise impact on neighbours	Equipment risk assessment/site approval (Plant inspection) Prestart Operator checks Routine maintenance Equipment maintenance (from prestart checks) Toolbox talks and site inductions Working within designated hours (detailed in the development consent and CEMP) Noise monitoring (as part of CEMP) Distance to neighbours Incident Management
	Dust generation	Dust impact on neighbours	Dust suppression Sealed off area
	Spills (diesel, paint, hydraulic oil)	Contamination to a water run off	Spill kits Designated refuelling area Designated service area Bunded fuel oil storage Bunded paint storage (cabinet) Inspection Toolbox talks/inductions
	Stormwater run off	Contamination to a water run off	Silt fencing Diversion bunds Drains On-site storm water drain maintenance
	Waste disposal	Disposal of general waste causing environmental issues	CEMP Housekeeping inspections Tool box and Inductions

In this case, the required levels of personal protection equipment and respiratory protective equipment will be subject to study and the recommendations of an occupational hygienist and could include Tyvek suits, chemical-resistant suits and supplied air respirators.

12.7 EMERGENCY RESPONSE

An emergency is defined as any hazardous or potentially hazardous situation presenting danger to personnel, property, ongoing business operations or the environment.

Effective emergency management is achieved by:

- identifying potential foreseeable scenarios and define appropriate actions and responses relevant to the type of emergency and resources available;
- providing a basis for training personnel in the handling of emergencies, so that a high level of preparedness can be continually maintained, and to provide a model for plant emergency procedures; and
- outlining a coordinated response and communications in the event of a foreseeable emergency and to provide for appropriate assistance from external emergency services (Police, Fire & Rescue and Ambulance).

A detailed Emergency Response Plan (ERP) will ultimately be prepared by the Remediation

Contractor. To ensure a coordinated and systematic response to an emergency situation, it is envisaged that the Remediation Contractor will have the following management hierarchy:

- Chief Warden (the contractor's Site Manager);
- Area Warden – On Shore (the manager of the treatment facilities);
- Area Warden – On Water (the supervisor of the dredging, barges); and
- Emergency Warden – a person to whom responsibilities are delegated to assist the Chief Warden.

The Chief Warden is in charge of managing an emergency for the facility and has overall responsibility for all functions performed by facility personnel during an emergency.

The responsibilities of the Chief Warden during the period of any emergency are to prioritise and then coordinate the following activities:

- assign persons to assist as required;
- protect people on site;
- search and rescue of missing people;
- first aid and medical attention for those who require it;
- protect people off site;
- control access;
- facility emergency response;
- damage control;
- communications to Emergency Services (Fire & Rescue/Ambulance/Police);
- protect the environment;



- traffic control;
- evacuation; and
- all clear.

The Area Wardens will provide assistance and specific knowledge to the Chief Warden for their particular geographic area and will have tasks delegated to them as required.

Once the Emergency Services (NSW Fire & Rescue / Police) arrive on site control/command passes to their Emergency Services Controller unless otherwise directed by Fire & Rescue/ Police. The Chief Warden will then provide assistance and support.

Jemena will be responsible for the management of communications to:

- the media;
- external government authorities, such as NSW Fire & Rescue, the Police, Safe Work NSW and the EPA, except as required during the event, where communication will be managed by the Remediation Contractor; and
- neighbours (residents and commercial), except as required during the event, where communication will be managed by the Remediation Contractor.

The Remediation Contractor will develop a full range of emergency scenarios but the following have been identified at this stage (Table 12.2).

12.8 EMERGENCY CONTACT DETAILS

Contact details for all relevant authorities will be provided in the WHS Plan, as listed below.

The emergency responsibilities of NSW State Authorities and their contact details are:

NSW Police Force (000)

The Police Force is the authority responsible for the command, control and coordination of all offsite actions in the event of a declared emergency with offsite implications.

The Police Force is responsible for:

- the establishment of a liaison communications centre in, or near to, the existing emergency control centre;
- the setting-up of roadblocks to control all entry/exit points on the periphery of the declared danger area; and
- evacuation and registration of persons deemed to be at risk from the incident.

NSW Fire & Rescue (000)

In addition to its normal fire fighting role, NSW Fire & Rescue is responsible for minimising the impact of hazards and emergency incidents on the people, environment and economy.

NSW Ambulance Service (000)

The NSW Ambulance Service is responsible for the provision of transport and medical assistance for injured persons.

Other regulators that may be called to assist after the emergency is reported include:

NSW EPA (13 15 55)

The EPA is responsible for managing environmental issues, responding to pollution incidents and emergencies and enforcing environmental regulations.

Safe Work NSW (13 10 50)

Safe Work NSW is responsible for responding to occupational health and safety injuries and serious near-misses.

Roads & Maritime Services (RMS) (13 12 36)

RMS is responsible for regulation of the waterways and safety and environmental management services, and is the owner of the sediments in Kendall Bay on behalf of the Government of NSW.

Department of Health (9391 9000)

The Department of Health is responsible for safeguarding the health of the public and for instituting, under NSW Police control, any necessary control measures. In particular, the Department is responsible for:

- providing independent radiological and/or toxicological surveys;

Table 12.2. Emergency scenarios

Scenario	Immediate Action	Further Action
Person down. Person(s) seriously injured and cannot or should not be moved until specialised medical aid is available.	Raise alarm. Dial '000'. Apply first aid if safe to do so. Chief Warden to take charge. Other Emergency Services to be called, as required. Assist Emergency Services.	PPE of patient(s) may need to be removed to commence CPR - assess potential exposure first. Ambulance brought to most convenient location, patient(s) transferred to ambulance.
Person down. Person(s) seriously injured but able to walk.	Raise alarm. Dial '000'. Apply first aid if safe to do so. Relocate the person to a safer location. Chief Warden to take charge. Other Emergency Services to be called, as required. Assist Emergency Services.	Ambulance brought to most convenient location, patient(s) transferred to ambulance.
Fire. Mobile plant or equipment, building, flammables or combustibles catch fire.	Raise alarm and establish exclusion zone Dial '000' if fire not small and easily controllable locally. Chief Warden to take charge. Emergency Services to be called. If safe to do so, fight fire with appropriate fire retardant, use breathing apparatus if necessary.	If safe to do so, remove other combustible and flammable materials and items away from affected area. Maintain exclusion zone.
Boating related incident. Incident involving injury or death, damage over \$5000 or damage or risk of damage to the environment.	Stop the vessel immediately. Give any assistance which may be necessary. Raise alarm and establish exclusion zone. Dial '000' if injury or damage to the environment e.g. oil spill. Deploy containing measures, e.g. booms, if a spill. Chief Warden to take charge. Emergency Services to be called.	Report to RMS within 24 hours.
Loss of containment of fuel or oil from plant or equipment at Tennyson Road.	Raise alarm. Chief Warden to take charge. Use spill kits to protect drains. Contain spillage with soil or absorbent material. Remove all possible ignition sources from the area. Ensure that no contaminated water is allowed to run off the work site.	Sweep up contaminated materials. Place into drums or other suitable receptacles. Avoid washing down. Personnel should use appropriate PPE.
Unplanned shutdown of Emission Control System (assuming an enclosure under negative pressure is required to contain odorous material at Tennyson Road).	Alarm should be raised automatically from plant control system. Treatment plant manager to take charge initially, then the Chief Warden. Organise orderly shutdown on operating plant and retreat of personnel to a safe location (if the risks to personal harm are significant the plant can be kept running until it is safe to turn it off). Personnel to assemble in decontamination area. Conduct roll call. Do not re-enter the building unless performing a recovery operation or given the all-clear by the Chief Warden.	Advise EPA as soon as possible. Conduct repairs as required Institute corrective actions.



- providing advice to the NSW Police on decontamination measures offsite; and
- providing any necessary medical care for persons affected by the emergency.

Further to the above, the remediation contractor's ERP will provide emergency contact details for the contractor's and Jemena's key project personnel.

12.9 INCIDENT REPORTING

Pollution incidents where material harm to the environment is caused or threatened will be immediately reported to the EPA by Jemena via the EPA hotline on 13 15 55.

Under Workplace Health & Safety legislation a 'notifiable incident' must be reported immediately to Safe Work NSW on 13 10 50. Jemena or the Remediation Contractor, will report any such incidents. These are:

- the death of a person;
- a serious injury or illness of a person; and
- a potentially dangerous incident.

As urgent investigations may be needed, the incident site must be preserved until an Inspector attends (or the inspector or regulator directs otherwise).

All incidents, including actual or potential (near miss), for injury, damage to equipment and property and damage to the environment will be reported internally.

Jemena, with assistance of the Remediation Contractor, will investigate the incident, implement appropriate preventive action, prepare a report and then audit that permanent and appropriate corrective actions are instituted.

The risk which contributed to the incident is then managed under a 'Hierarchy of Controls':

- elimination (get rid of it);
- substitution (use something else);
- isolation (separate it or move it somewhere else);
- engineering (make something new);
- administration (instructions, signage, safe work practices); and
- personal protective equipment (e.g. use gloves, masks).

This is the same hierarchy of controls considered when developing the WHS plans when the project is in the planning phase.

12.10 TRAINING OF PERSONNEL IN APPLICATION OF THE WORK HEALTH AND SAFETY PLAN

The Remediation Contractor will train all project personnel in the application of the WHS Plan and individual roles and responsibilities.

12.11 ACCESS TO THE WORK HEALTH AND SAFETY PLAN

A hard copy of the WHS Plan will be kept in the Remediation Contractor's site office.

Chapter 13

STAKEHOLDER ENGAGEMENT

13.1 GENERAL APPROACH

13.1.1 Background

Given the nature of the remediation works, the issues involved and the potential for community interest and concern, an open communications and consultation program with all stakeholders has been implemented by Jemena since late 2012. The program of stakeholder engagement will be continued for the duration of the remediation works and, where applicable, in the period following completion of those works.

For the purpose of this document, ‘stakeholder’ means an individual, group, organisation or other entity that may be interested in, or affected by, the remediation project.

Stakeholders include local residents, businesses, government regulatory authorities, public health officials, media, environmental or other action/interest groups, and staff and contractors working on the project.

This section outlines the various methods of communication that have been, and will be, implemented during the project considering:

- the location of the remediation works and the neighbouring community; and
- the need for the general public and the regulators to be informed of the progress of the remediation works and to have their questions and concerns responded to in a timely manner.

13.1.2 Key Stakeholders

Members of Parliament

Members of Parliament include Mr John Sidoti MP (State Member for Drummoyne) and Mr Craig Laundy MP (Federal Member for Reid). MPs will be interested in amenity and other potential impacts on residents and businesses (e.g. noise, odour, visual, traffic management), resident or business complaints and the successful completion of the remediation project.

Local Government

The Declared Area is located adjacent to the City of Canada Bay (Council) Local Government Area. Council's requirements for the management of contaminated land are described in the City of Canada Bay (June 2016) Contaminated Land Policy. The Council defers to the EPA in relation to contaminated land which poses a significant risk of harm to human health or the environment (as is the case with this project) but will be a reference agency when the EIS for the remediation project is lodged. The Council can then be expected to consider the project against its Contaminated Land Policy. The Council will particularly be interested in potential amenity impacts on residents and businesses (e.g. noise, odour, visual, traffic management) and resident or business complaints.

NSW Health

NSW Health will have an interest in the potential long-term health benefits associated with completion of the remediation project and the minimisation of health impacts during works.

NSW Environment Protection Authority

The EPA has legislative oversight of the remediation of the site, and is empowered to issue orders for remediation and contamination management. The EPA will have an interest in the resolution of the Voluntary Remediation Agreement (or any successor Voluntary Management Proposal), the successful achievement of the remediation objectives, and the minimisation of environmental and health impacts during works.

NSW Department of Planning and Environment

The Kendall Bay Sediment Remediation Project has been classified as a State Significant Development for assessment by the Minister for Planning (or delegate, such as the Planning Assessment Commission), with SEARs for the environmental assessment of the project issued in 2014, and re-issued in March 2017. As the consent authority for the project, the Minister (and DP&E) will be primarily interested in the assessment of the project from an environmental planning perspective, including processes prescribed



under the EP&A Act, Regulations and applicable environmental planning instruments.

Roads & Maritime Services

NSW Roads and Marine Services (RMS) is the owner of the bed of Kendall Bay (and Sydney Harbour more broadly), as well as road and ferry infrastructure.

As the owner of the bed of Kendall Bay, RMS has a direct interest in the remediation outcomes, approval processes for the project and maritime issues such as barge movements in and around existing ferry routes.

RMS will also be interested in potential impacts on the Mortlake Ferry and local roads.

NSW Office of Environment & Heritage

The NSW Office of Environment and Heritage (OEH) is responsible generally for the protection of NSW's environment and heritage. OEH provides scientific evidence and knowledge to underpin environmental decision making, regulation and service delivery.

NSW Department of Primary Industry – Fisheries Branch

Fisheries is responsible for administering laws relating to the protection of fishing habitat, and therefore will be interested to ensure that conduct of the remediation works does not impact significantly on the health of the marine ecosystem, and that the completed remediation works provide increased amenity for the marine ecosystem of Kendall Bay.

Local Residents and Community Groups

Local residents and community groups in Cabarita and Breakfast Point – including Bay and Park Communities Alliance (BAPCA), the Mortlake and Majors Bay Resident Action Group (MMBRAG), the Friends of Cabarita Park and Wharf, and the various strata groups and community associations (e.g. Kendall Inlet, Breakfast Point, Edgewood) – will be interested in a range of issues including:

- potential amenity impacts associated with the works (noise, odour, visual, traffic etc.);
- potential health impacts associated with the works (perceived and real);
- potential impacts on property values associated with the works (perceived and real);

- preservation of the integrity of the seawall in proximity to the Remediation Areas; and
- potential impacts on access to the waterfront during works.

Local businesses and the Majors Bay Chamber of Commerce

Local businesses and the Majors Bay Chamber of Commerce will have a key interest in how the project and the works might affect patronage (both positive and negative impacts). This will include an interest in potential amenity impacts (noise, odour, visual, traffic etc.).

Media

Local newspapers include the *Inner West Courier* and the *Burwood Scene*.

13.1.3 Stakeholder Engagement Objectives

It is essential to the overall success of the project that open communication occurs during all stages of the project. Open communication, allowing all stakeholders access to relevant information, is necessary during the course of the remediation works and it is essential that stakeholders have a means of providing feedback and having any questions responded to in a timely manner.

The key goal of the stakeholder engagement process is the dissemination of clear and factual information that meets the needs of the various stakeholders in order to minimise the generation of misinformation, to encourage and respond to feedback and to reduce the potential for uninformed objections to the works. In this regard, the following stakeholder engagement objectives have been identified for the project:

- to help the local community develop an understanding of the project objectives, benefits and works proposed (including an understanding of potential short-term impacts, and mitigations);
- to provide up-to-date information to stakeholders on the progress of the project on a regular basis;
- to provide opportunities for all stakeholders to provide feedback and air concerns during the course of the project;
- to respond to comments and requests for information in a clear and timely manner; and

- to pass on information relating to stakeholder issues and concerns to the remediation team so that they can be adequately addressed.

The scope of information provided includes the following:

- progress of remediation works;
- any changes in key components of the site works proposed during the course of the remediation works;
- any changes in the timetable and timeframes proposed over the course of the remediation works;
- expected impacts of the proposed works on the surrounding community;
- measures to be taken to manage and mitigate these impacts; and
- realistic project outcomes.

13.2 PRE-REMEDIATION STAKEHOLDER ENGAGEMENT

13.2.1 Communications and Consultation with the Community

Jemena has been communicating and consulting with stakeholders since late 2012 regarding this project. The focus of pre-remediation communications and consultation has been on providing updates to stakeholders as the remediation planning progresses and seeking feedback on issues relation to proposed remediation strategies. Specific consultation activities are listed below.

Website

The website at <http://jemena.com.au/about/projects/remediation-project/kendall-bay> provides ready access to information about the Kendall Bay remediation project and Jemena's remediation activities. There are links to relevant technical documents, frequently asked questions, all newsletters distributed during the project, Community Liaison Group meeting minutes, recent project updates and a contact phone number and an email address to provide feedback or request further information about the project.

Intercept surveys

Intercept surveys of residents and businesses in the local area have been undertaken to gain feedback on the project and highlight key issues

for consideration. To date, surveys have been undertaken as follows:

- Survey 1 – November 2013;
- Survey 2 – April 2014;
- Survey 3 – January 2015; and
- online survey – available to complete at any time on the website.

Feedback collected during surveys is available on the website.

Mailing list and email updates

Mailing list subscription is made though the website. Each time a newsletter is sent out, the same information is sent to those who are subscribed. To date, 19 email updates have been provided, in line with the timing and content of each newsletter (see below).

Local project office

Jemena has established a project office at 140 Tennyson Road (the Staging Site). Local residents will be encouraged to visit the project office when full scale remediation works commence to speak to members of the project team.

1800 number, project email address

An 1800 number and a project email address are available during business hours for stakeholders to provide feedback and ask questions:

- phone: 1800 571 972; and
- email: kendallbay@jemena.com.au.

Issues and response Log

All queries and comments received through the 1800 number and email address are collated in an Issues and Response Log. All questions are referred to Jemena for review and response. In some cases, Jemena has referred questions to regulatory agencies.

Community Newsletters

Newsletters have been sent out as project updates become available and will be sent out during the course of the remediation works. The newsletters are distributed to a local catchment of over 4000 houses and are also made available on the website.

- Newsletter 1 – March 2013
- Newsletter 2 – July 2013
- Newsletter 3 – September 2013



- Newsletter 4 – October 2013
- Newsletter 5 – November 2013
- Newsletter 6 – December 2013
- Newsletter 7 – February 2014
- Newsletter 8 – May 2014
- Newsletter 9 – July 2014
- Newsletter 10 – October 2014
- Newsletter 11 – December 2014
- Newsletter 12 – March 2015
- Newsletter 13 – April 2015
- Newsletter 14 – June 2015
- Newsletter 15 – September 2015
- Newsletter 16 – November 2015
- Newsletter 17 – February 2016
- Newsletter 18 – August 2016
- Newsletter 19 – December 2016
- Newsletter 20 – December 2017

Further newsletters will be distributed as the project goes through the statutory approvals phase, prior to the commencement of remediation.

Community Information And Feedback Sessions

Community information and feedback sessions (CIFS) have been run at key stages of the project to provide a detailed information display, a question and answer session with key members of the project team and to invite feedback. The materials presented at these sessions are accessible through the website.

To date, the following CIFS have occurred:

- CIFS 1 – November 2013;
- CIFS 2 – February 2014; and
- CIFS 3 – July 2014

It is anticipated that a fourth CIFS will be held during the statutory approvals phase of the project.

Community Liaison Group meetings

A Community Liaison Group (CLG) has been established to maintain regular dialogue between Jemena and the community during the remediation project, both at the planning and implementation stages. Interested members of the community were invited to apply to the CLG through a publicly advertised expression of interest process. Nominations were also put forward by the Bay and Park Communities Alliance (BAPCA) and Mortlake and Majors Bay Residents Action Group (MMBRAG).

The CLG operates under agreed terms of reference, available on the website. Meeting minutes from each CLG meeting are also available on the website.

To date the following CLG meetings have occurred:

- CLG 1 – October 2013
- CLG 2 – November 2013
- CLG 3 – December 2013
- CLG 4 – March 2014
- CLG 5 – July 2014
- CLG 6 – August 2015
- CLG 7 – December 2014
- CLG 8 – March 2015
- CLG 9 – June 2015
- CLG 10 – December 2015
- CLG 11 – August 2016; and
- CLG 12 – December 2016
- CLG 13 – February 2018

Further CLG meetings will be undertaken during the statutory approvals phase.

Community information stalls

Community information 'pop-up' stalls have been established at key stages of the project at the Concord Markets. The stalls have provided an opportunity for local residents to find out information about the project and to provide feedback.

To date, the following stalls have been held:

- Community info stalls 1 & 2 – May 2014;
- Community info stalls 3 & 4 – December 2014;
- Community info stalls 4 & 5 – February 2015; and
- Community Info stall during the September 2017 Breakfast Point Spring Fair.

Stakeholder Briefings

A number of stakeholder briefings with community groups have been held, including four initial discussions with various community groups in the first consultation phase between December 2012 and March 2013. A series of additional one-on-one stakeholder briefings with community groups has been undertaken as requested by these groups throughout the communications and consultation program.

A number of stakeholder briefings have also been undertaken with Canada Bay Council and State Government Agency stakeholders throughout the program.

Invitations to Community Information and Feedback Sessions have also been published in local newspapers the Burwood Scene and Inner West Courier.

On 4 December 2015, a presentation on the project was given at the Mortlake project office to representatives of the following statutory approval authorities who will be regulating the project or who will be reference agencies in the approval process:

- EPA
- DP&E
- OEH
- RMS
- City of Canada Bay; and
- Fisheries.

A further update was provided to the EPA on 20 June 2016 at their offices.

On 28 July 2016, a briefing was given to the State Member for Drummoyne at his office.

On 29 July 2016, a presentation was made to the same statutory approval authorities as the December 2015 meeting.

A copy of the July 2016 presentation was provided to a representative of NSW Health, who could not attend the meeting, and he then visited the Mortlake office on 3 August 2016 to discuss the project.

Media

Local media have been engaged at key stages during the project.

13.3 STAKEHOLDER ENGAGEMENT DURING THE REMEDIATION WORKS

13.3.1 Communications and Consultation with the Community

Communications and consultation with the community during remediation works will focus

on providing regular updates. Activities will include:

- community relations representative available at the project office;
- quarterly CLG meetings;
- website updates;
- regular community newsletters (print and email);
- targeted works notifications (as required);
- 1800 number and email address (published on website, newsletters, notifications and site signage); and
- established complaints recording and handling system, including agreed timeframes and responsibilities for responding.

13.3.2 Communications and Consultation with the Statutory Regulators

Jemena will hold communication sessions with the statutory regulators as required during the remediation works.

It is expected that the EPA and DP&E will also require formal monthly reports.

13.4 POST-REMEDIATION STAKEHOLDER ENGAGEMENT

13.4.1 Communications and Consultation with the Community

Detailed requirements are expected to be outlined in the Site Management Plan (see Chapter 15), to be agreed with the EPA. At this stage is anticipated that the following activities will be undertaken:

- a meeting (or meetings) with the CLG;
- a community newsletter; and
- a website update, publishing contact details going forward.

13.4.2 Communications and Consultation with the Statutory Regulators

Jemena will hold a communication session with interested statutory regulators after the remediation works are complete to discuss the project outcomes and any future remediation management requirements.



Chapter 14

VALIDATION SAMPLING ANALYSIS AND QUALITY PLAN

14.1 VALIDATION SAMPLING ANALYSIS AND QUALITY PLAN

Successful completion of the remediation works will be demonstrated by outcomes of monitoring under the Validation Sampling Analysis and Quality Plan (VSAQP). This plan will adopt criteria based on the multiple-lines-of-evidence approach adopted by the USEPA for verifying the successful completion of complex remediation projects as the out in Suter and Cormier (2011).

The objective of the VSAQP is to demonstrate that the remediation goals have been achieved and the site has been remediated according to the requirements of this RAP.

The VSAQP will be prepared and implemented by the Validation Consultant following guidance provided in Chapter 14 of the RAP. Prior to its implementation, the VSAQP will be provided for endorsement by the Site Auditor.

The VSAQP is based on a combination of various physical measurements, which will be made by qualified professionals, and by a program of sampling and chemical analyses, which will be undertaken by the Validation Consultant.

The VSAQP will set out the requirement for assessing and reporting:

- the lateral and vertical extents of excavation and removal of existing sediments;
- the source/s and environmental condition of imported materials used as backfill in a number of Remediation Areas, including establishing capping layers and rehabilitation of the beach and mangrove areas and areas adjacent to the seawall;
- the lateral and vertical extents and the condition of materials treated in situ;
- the condition of any materials treated ex situ at the site; and
- the classification of any materials that required offsite disposal at landfill, and records provided by the landfill operator.

Validation testing of the in situ- and ex situ-treated materials may also be modified or optimised based on results of bench-scale and/or pilot testing to be undertaken prior to remediation of the site.

Details of bench scale and/or pilot testing, treatment methodologies and associated modifications to the validation sampling (if any), including required construction quality control measures and inspection and test plans will be prepared and presented to the Site Auditor for review and endorsement prior to the commencement of remediation works.

The following sections outline the methodology for validation of the site that will be documented in the VSAQP.

14.2 MATERIALS TRACKING

Tracking of material movements will be a key part of demonstrating compliance with the RAP and effectiveness of the remediation strategy. A detailed material tracking procedure will be developed by the Remediation Contractor and will be set out in the Remediation Work Plan, including all movements onsite and offsite, documenting material source, type, description and final destination as well as interim movements and any treatment and testing undertaken.

Decision processes and authorisation for movement will form part of the material tracking procedure and validation requirements.

The Remediation Contractor will provide all relevant documentation relating to transport of contaminated materials and receipt of these materials at the licensed landfill.



14.3 VALIDATION OF THE REMEDIATION WORKS

Validation of the remediation works will be undertaken to ensure and to document that the objectives of the RAP have been achieved in relation to the parameters set out in Section 14.3.2.

Validation of the remediation measures installed in the Remediation Areas will be required to be undertaken in a staged approach, and to demonstrate that the construction and performance of the measures meet the detailed design and specification requirements in accordance with the validation approach set out in Chapter 14 of this RAP, including the requirement for the preparation of a detailed VSAQP.

A Site Management Plan will be required to set out the maintenance and monitoring requirements for the measures installed, and to provide measures to ensure the adequate protection of the health of future users of Kendall Bay and for the protection of the benthic communities of Kendall Bay. The Site Management Plan requirements are set out in Chapter 15 of this RAP.

14.3.1 Post-Remediation Environmental Monitoring Event

A post-remediation monitoring event will be undertaken by the Validation Consultant to assess the conditions after the completion of the works within the Remediation Areas and to obtain a data set that can then be compared to the pre-remediation monitoring to assess the changes to conditions during, and as a result of the remediation works. The conditions that will be monitored are as follows:

- water quality;
- tidal fluctuations;
- wave climate;
- currents;
- weather conditions; and
- stormwater flow and quality.

Prior to undertaking the monitoring works the Validation Consultant will prepare a detailed VSAQP for the post-remediation monitoring event in accordance with the relevant guidelines

made or endorsed by EPA. The VSAQP must be endorsed as appropriate by the Site Auditor prior to its implementation. The methodologies adopted during the pre-remediation monitoring event undertaken on the site must be consistent with the methodologies to be adopted during the pre-remediation monitoring event.

The results of the post-remediation monitoring event are to be presented by the Validation Consultant as part of the Validation Report for the works as detailed in Chapter 14 of this RAP.

14.3.2 Validation of Excavations and Removal of Surface Contamination and Foreign Materials

Remediation Areas SA1 and NA2+NA3

The following actions in these Remediation Areas will be validated as follows:

- placement of solidified columns - by survey and GPS records;
- strength of the solidified materials- by Unconfined Compression Strength testing;
- placement and dimensions of the raft structure - by survey and GPS records;
- excavation of contaminated sediments (validate lateral extent and depth of excavation - by survey);
- excavation of raft surface (validate lateral extent and depth of excavation - by survey) ;
- validate capping geofabric, activated carbon layer, rocks and sand (lateral and vertical extents by measurement and survey);
- validation of solidified columns and raft by sampling and laboratory testing for Unconfined Compression Strength, permeability and leachate behaviour; and
- validate the cleanliness of imported materials with laboratory testing against EPA standards.

Remediation Areas NA1 and SA2

The surfaces of areas NA1 and SA2 will be water blasted and/or scraped of tarry and foreign material and excavated back as described in Sections 7.3 and 7.4. Validation will be assessed against the following parameters:

- validation of the extent of excavation will be by survey;
- validation that the surface contamination and foreign materials have been removed will be by visual inspection, documented by photographic evidence;

- validate capping geofabric, activated carbon layer, rocks and sand (lateral and vertical extents by measurement and/survey;
- validate final surface levels in relation to LAT by survey; and
- validate the cleanliness of imported materials.

Remediation Areas SA3, SA4 and SA5

The surfaces of SA3 and SA4 will be scraped of foreign material and excavated, and the bay bed of area SA5 will be excavated to levels described in Section 7.4. Validation will be assessed against the following parameters:

- validation of the extent of excavation will be by survey;
- validation that the surface, and just sub surface foreign materials have been removed will be by visual inspection, documented by photographic evidence;
- validate capping geofabric, activated carbon layer, rocks and sand (lateral and vertical extents by measurement and survey; and
- validate the cleanliness of imported materials.

14.3.3 Imported Materials

Material will be imported to fill all the Remediation Areas.

Imported fill material must comply with the following validation criteria:

- the material must be Virgin Excavated Natural Material (VENM) - only bring in VENM compatible with the local environment, such as Hawkesbury Sandstone or sand derived from Hawkesbury Sandstone

Prior to importing material to site, the following fill sampling plan will be implemented;

- a visual inspection of the source site and the proposed fill material (if exposed);
- collection and laboratory analysis of the minimum number of samples of the fill material per source, as required by the *Sampling Design Guidelines* (NSW EPA 1995) or NSW OED (2012) *Excavated Natural Material Exemption*, whichever is greater.

Imported materials will also have to comply with physical characteristics specified by a marine engineer for hydrological purposes or a benthic biology specialist, and by DPI Fisheries,

for the purpose of establishing marine benthic communities. These materials are to be signed off by the project environmental consultant as fit for purpose.

Other imported materials are cement, cement additives, powdered activated carbon and geotextile to be placed in NA2+NA3 and SA1, and potentially any chemicals that may be needed for solidification or water treatment at the Staging Site. These materials are to be certified to a recognised industry standard.

14.4 IN SITU TREATMENT

14.4.1 Introduction

The sediments and underlying material in NA2+NA3 and SA1 will be treated in situ to form a capping system, as described in Sections 7.3 and 7.4.

The in situ treatment mix design will be developed during bench scale testing and presented to the Site Auditor prior to commencement of remediation work.

For the purposes of understanding the validation sampling program:

- the cap consists of an approximate 1.5 m thick cement-stabilised raft supported by a grid of approximately 1.2 m diameter cement-stabilised columns at approximately 2.5 m spacing;
- the rafts in NA2+NA3 and SA1 will both be approximately 3000 m² in area resulting in approximately 300 to 400 columns in each area, but the number of supporting columns in each area will depend on how close the raft and the columns can be installed to the sea wall and any remnant underwater structures;
- the target performance criteria are:
 - Unconfined Compressive Strength of 1.0 MPa at 14 days;
 - leachability using the USEPA LEAF 1315 cumulative release test for the 90 - day interval on the solidified sediment to reduce by more than 90 per cent compared to mass releases from the untreated native sediment;
 - hydraulic conductivity of 10⁻⁵ cm/sec or less;



- Toxicity Characteristics Leaching Procedure to comply with EPA acceptance standards.

14.4.2 Grab Sampling

During construction, when the mix is still fluid (typically up to 1 day from production), grab samples will be taken by remediation contractor using a sampling tool, such as a pneumatically operated syringe-like cylinder on the end of a steel beam suspended from the mast of the soil mixing machine. The tool is inserted into the mix to a predetermined depth and opened up to take a sample. The tool is then extracted and the samples pressed out of the cylinder into a bucket by the pneumatic ram that took the sample, but operating in reverse. The bucket is decanted into plastic sample cylinders which are then capped.

Sampling and analysis programme:

- a minimum of 8 sample cylinders (also known as monoliths) will be cast for each grab sample;
- when the samples have sufficiently cured (minimum 7 days from production), the cylinders will be split and the hardened cylindrical samples will be placed under water collected from Kendall Bay to continue curing;
- three of the samples will undergo conduct Unconfined Compression Strength tests (in accordance with RMS Test Method T131 or T116) nominally at 14, 28 and 56 days from production;
- one sample will be tested to the USEPA SW846 1315 Monolith Leach method, known as the LEAF test, involving monolith leach, TRH in leachate (tested 9 times each monolith), PAHs in leachate (tested 9 times each monolith) and metals in leachate (tested 9 times each monolith); and
- four of the samples will be tested using the Toxicity Characteristics Leaching Procedure method as specified in the NSW EPA Waste Classification Guidelines for TRH/PAH/metals, TRH in leachate, PAHs in leachate and metals in leachate.

The proposed sampling density is:

- 1 grab sample per 200 m² of raft area, taken 1 m below the surface, with a minimum of 1 sample for each day's production, and

- 1 grab sample per 20 columns, taken half way down the column, with a minimum of 1 sample for each day's production.

14.4.3 Compliance with Design Dimensions

The soil mixing machines installing the raft and the columns will be fitted with instrumentation to determine the depth at which the mixing heads are operating. The location of the columns and the outside dimensions of the rafts will be determined by GPS reference.

Daily production logs will be produced showing the above dimensional information as well as the volume of added cement, operating time, etc.

Copies of daily production logs and a data file with all the dimensional information will be provided to the Jemena Project Manager and the Validation Consultant.

14.4.4 Core Sampling

After the capping system has cured (typically after 28 days), core samples will be cut through the raft to verify the data obtained from the grab sampling and dimensional measurements.

The complete cores will be inspected and photographed.

If any anomalies are evident in the cores, additional analyses or coring will be considered.

The proposed core sampling density is four cores evenly spread across both SA1 and NA2+NA3, the full depth of the raft, taken in between the columns.

Any core holes made during sampling will be reinstated using the same mix of cement and additives mixed with surrounding sediments.

14.5 OFFSITE TREATMENT AND DISPOSAL

Where sediments are required to be removed from the Remediation Areas they will be transported to an offsite treatment facility and from there to a licensed landfill.



Offsite disposal is guided by the NSW waste classification framework, NSW EPA General Immobilisation Approval 2005/14 Coal tar contaminated soil from former gasworks sites and by previous specific immobilisation approvals and experience from other gasworks projects.

The suitability of the waste for landfill will be validated by the EPA's acceptance of disposal at the landfill.

Any other materials that are generated as a result of the remediation work and that require disposal offsite must be classified in accordance with NSW EPA (2014) *Waste Classification Guidelines. Part 1: Classifying Waste*. Again, validation will be by way of acceptance at the landfill.

14.6 QUALITY ASSURANCE AND QUALITY CONTROL

All remediation validation works requiring chemical analyses of samples collected from within the Remediation Areas will be completed using strict field and laboratory quality control (QA/QC) protocols, which will include the collection and analysis of quality control samples. A description of the quality control samples to be used during the validation programme is provided as follows.

14.6.1 Field Quality Control Samples

Field quality control

The specific field data quality indicators are shown in Table 14.1.

Quality control of samples for chemical analysis

Specific laboratory data quality indicators are shown in Table 14.2.

Intra-Laboratory Duplicates: These are prepared in the field by splitting the original sample and placing two equivalent portions of samples into two separate containers. The blind duplicate sample is sent anonymously to the project laboratory. Duplicate samples are analysed for the identical set of parameters requested for the corresponding original sample. For the intra-laboratory duplicate sample pair, relative

percentage differences are calculated. Intra-laboratory duplicates provide an indication of the analytical precision of the project laboratory, but may also be affected by factors such as sampling methodology or inherent heterogeneity of the sample medium.

Inter-Laboratory Duplicates: These are prepared as with intra-laboratory duplicates in the field. However, the blind duplicate sample is sent anonymously to a secondary project laboratory. Duplicate samples are analysed for the identical set of parameters requested for the corresponding original sample. For the inter-laboratory, duplicate sample pair, relative percentage differences are calculated. Inter-laboratory duplicates provide an indication of the precision of the sampling methodology but may also be affected by factors such as inherent heterogeneity of the sample medium.

Trip Blanks: These samples provide a check to detect any cross-contamination during transport.

Trip Spikes: These samples provide a check to assess loss of volatile compounds from samples during transport.

The QA/QC samples will be collected and analysed for Contaminants of Potential Concern (COPCs) at the following density:

- duplicate samples will be collected and analysed at a frequency of no less than 1 in 20 samples for blind and split duplicates each; i.e. a combined frequency of 1 per 10 samples;
- rinsate samples will be collected and analysed at a frequency of one sample per sampling day where sampling equipment (other than nitrile gloves) is used; and
- trip blanks or spikes will be collected and analysed at a frequency of one sample per sample batch sent to the laboratory.

14.6.2 Laboratory Quality Assurance

The analytical laboratories will utilise their own internal procedures and test methods (for which they are NATA accredited) and in accordance with their own quality assurance system which forms part of their NATA accreditation. Laboratory quality control procedures to be used include:

**Table 14.1. Field data quality indicators**

Indicator	Frequency	Acceptance Criteria
PRECISION (a quantitative measure of the data variability)		
Sampling methodologies	All samples	Appropriate and complied with
Intra-lab duplicates/splits	5% of samples	<+/- 50% RPD*
Inter-lab duplicates/splits	5% of samples	<+/- 50% RPD*
Trip blanks/spikes (volatiles only)	1 per sampling	<= LOR for blanks, as per lab spec for spikes
ACCURACY (a quantitative measure of the closeness of reported data to the true value)		
Collection of rinsate blanks for re-used equipment	Where equipment re-used	COPCs below detection limit
Sampling methodologies	All samples	Appropriate and complied with
REPRESENTATIVENESS (qualitative confidence that data obtained are representative of each sampled medium)		
Sampling, subsampling, sample handling and storage appropriate for the history and contamination status of the sediments, the study objectives and the media/analytes	All media & all analytes	All samples analysed according to VSAQP
COMPARABILITY (qualitative confidence that data collected in separate sampling events is equivalent)		
VSAQP for sample collection, subsampling and handling. Same methods used each day; same types of samples collected	All samples	All samples collected and handled in accordance with VSAQP, by experienced professionals
COMPLETENESS (the amount of useable data, as a % of total data collected. Goal is 95% valid data)		
Chain-of-Custody forms, sample descriptions and sample location data complete	All samples	All samples
All critical locations sampled; all samples collected	All samples	All samples collected & analysed according to VSAQP
Completeness objective met (percentage of data suitable for use, 95% of all data)	All data	Minimum 95% of all data on submitted samples validated as suitable for use
Methodologies	All samples	Sampling in accordance with NEPM, 2011 and other relevant standards for marine sampling

* Contaminant concentrations become increasingly uncertain as they approach the method detection limit, and therefore DQOs may not be met for analytical values close to LORs. Laboratories often use the following approach (or a variation of it) to assess replicates:

- Result < 5 times the LOR – no limit to RPD or RSD.
- Result > 5 times the LOR – RPD or RSD should be <= 50%.

Table 14.2. Laboratory data quality indicators

Objective	Frequency	Data Quality Objective
PRECISION (a quantitative measure of the data variability)		
Lab duplicates (separate subsamples from jar, not aliquot splits)	1 per batch or 20 samples	<5 x LOR = no limit on RPD. >5 x LOR = 0-50% RPD *
ACCURACY (a quantitative measure of the closeness of reported data to the true value)		
Matrix spikes Matrix spike duplicates	1 per lab batch or 20 samples 1 per lab batch or 20 samples	Recovery 70% - 130% for inorganics/ metals, 60-140% for organics, or as per lab requirement## RPDs should be less than 35%
Surrogate spikes	All organic analyses	Recovery 70% - 130% for inorganics/ metals, 60-140% for organics, or as for lab requirement##
Lab method and reagent blanks	1 each per batch	< /= LOR
Control samples	1 per lab batch or 20 samples	Recovery 70% - 130% or as for lab requirement##
Analysis of CRMs (for metals) or in-house standards certified against CRMs	All sediment metal analyses, 1 per batch	< +/- 35% RPD, recovery 70% - 130% or as per lab requirement
REPRESENTATIVENESS (qualitative confidence that data obtained are representative of each medium sampled)		
Sample handling and storage appropriate for media/ analytes	All media, all analytes	All samples
Holding times (HTs)	All samples	All samples extracted and analysed within HTs
COMPARABILITY (qualitative confidence that data collected in separate sampling events can be directly compared)		
Standard analysis methods	All samples	All samples subsampled, extracted/ digested & analysed at NATA-certified labs, by standard methods
LORs consistent between labs and batches	All samples	All samples
LORs met for all analytes**	All samples	All samples
Outliers and inter-lab discrepancies resolved	Affected samples	Affected samples re-extracted and analysed in replicate.
COMPLETENESS (the amount of useable data, as a % of total data collected – minimum of 95%)		
All critical locations sampled, all required samples collected, and all samples analysed according to this SAQP	All samples	All required data obtained
Chain-of-Custody forms (COCs), field logs, sample descriptions and sample location data complete	All samples	All samples
Samples received at laboratory as specified on COC forms	All samples	All bottles and jars received and unbroken, seals intact and samples cool
QC samples sufficient, and acceptable results	All QC/QAs	100%
SENSITIVITY (ability of analysis methods to reliably determine the analytes at lowest environmental concentrations)		
Analysis methods and LORs appropriate for media, expected background levels of analytes and adopted site assessment criteria	All media, all analytes	All samples
SECONDARY DATA (quality assessment of any pre-existing data to be used in this project)		
All secondary data	All data	Establish DQOs and assess data quality

Certain inhomogeneous samples, e.g. fine, clayey or organic-rich sediments, samples through mangrove root zones, algal mats etc, as well as samples for analysis of volatiles and semi-volatiles, must not be homogenised in the field prior to subsampling. Therefore, sample replicates are distinct samples rather than splits. Such replicates may not meet this DQO.

Lower recoveries may be recorded for some semi-volatile organics, such as phenols. Recoveries may also be lower, and the spread wider, on some sediments and soils due to matrix interference from high water content, high salinity, plant waxes, sterols, lipids etc.

* Contaminant concentrations become increasingly uncertain as they approach the method detection limit.

Criteria:

- Result < 5 times the LOR – no limit to RPD or RSD.
- Result > 5 times the LOR – RPD or RSD should be < /= 50% (or < /= 35% for lab replicates).

** Occasionally, matrix effects may prevent this. Any such incidences must be documented by lab.



Laboratory Duplicate Samples: Analysis of duplicate sub-samples from one sample submitted for analytical testing and analysis of the samples in the one batch. A laboratory duplicate provides data on the analytical precision (repeatability) of an analytical batch;

Spiked Samples: A sample is spiked by adding an aliquot of known concentration of the target analyte(s) to the sample matrix prior to sample extraction and analysis. A spike documents the effect of the sample matrix on the extraction and analytical techniques;

Laboratory Blank: Usually an organic or aqueous solution that is as free of analyte as possible and contains all the reagents in the same volume as used in the processing of the samples. The reagent blank must be carried through the complete sample preparation procedure and contains the same reagent concentrations in the final solution as in the sample solution used for analysis. The reagent blank is used to correct for possible contamination resulting from the preparation or processing of the sample;

Laboratory Surrogates: Laboratory surrogates are used to assess the effect of the matrix and the precision of each individual sample preparation. The surrogate consists of a compound that is chemically similar to the target compound; and

Laboratory Control Samples: Laboratory control samples consist of a well characterised clean matrix (e.g. sand, clay or reagent water) that has been spiked with a known quantity of a compound. Laboratory control samples are used to measure the method accuracy and analytical precision.

14.6.3 Evaluation of QA/QC

The WSAQP to be prepared by the Remediation Contractor following completion of the remediation works will include an evaluation of the field and laboratory quality control procedures (as outlined in Appendix V of the NSW DEC (2006) Guidelines for the NSW Site Auditor Scheme) implemented during the course of the remediation. It will consider the following key quality criteria:

- representativeness of the validation sampling program;
- completeness of the validation sampling program;
- comparability of the validation results;
- precision of the validation data;
- accuracy of the validation data; and
- overall evaluation of the data quality and fit for purpose.

14.7 VALIDATION REPORT

Following implementation of the VSAQP the Remediation Contractor and the Validation Consultant will prepare Validation Reports documenting in full the processes carried out to demonstrate the goals of this RAP have been achieved.

The Validation Report will be prepared in accordance with requirements of relevant guidelines endorsed by EPA under the CLM Act.

14.8 CERTIFICATION BY THE SITE AUDITOR

The Validation Report(s) will be provided to the Site Auditor for review and prior to issuance of a Site Audit Statement (B4) confirming compliance with the VMP (2017).

Chapter 15

SITE MANAGEMENT PLAN

15.1 INTRODUCTION

Following completion of the remediation works, a Site Management Plan (SMP) will be implemented to provide on-going monitoring and management of the Remediation Areas and surrounding parts of the bay to ensure that the objectives of the RAP have been maintained after remediation is completed, and in the longer term.

The SMP will be prepared by Jemena to the satisfaction of the Roads and Maritime Services, the owner of the bed of Kendall Bay), the EPA and the Site Auditor in accordance with the requirements of EPA. The SMP will be written in plain English to be understood by non-professionally trained personnel who may be involved in maintenance activities on the site and will contain sufficient details so that assessment of the data obtained during the execution of the SMP can be interpreted in the context of the objectives of the RAP.

The SMP will address the following:

- why the SMP is required;
- who is responsible for implementing the SMP;
- where the SMP applies;
- how the SMP will be implemented, including corrective actions and reporting requirements; and
- when the SMP is required to be implemented and its duration.

The SMP will include the following information:

- the objectives of the SMP;
- description of the remediation works undertaken at the site, including all the volumes of contaminated materials remediated or removed from the site, a summary of the treatment/solidification of fill materials and crushed rock, results of leach tests of stabilised materials (including the appropriate methods used), details of compaction tests of stabilised materials, of any structure(s) installed, geotextiles and activated carbon layers installed in caps, clean fill materials placed for capping, storm water diversion, and bathymetry;

- a survey plan at A3 scale (detail to be shown on separate drawings) showing the locations of the:
- cadastral boundaries of the site;
- existing sea walls;
- stormwater drains;
- points of human access to the bay in proximity to the Remediation Areas;
- works in the Remediation Areas; and
- the areas where in situ solidification of sediments were completed;
- drawings, including cross-sections, of the as-built:
- in situ sediment solidification areas;
- geosynthetic fabrics, AC layers, clean fill materials placed over the geotextile membranes; and
- placed capping layer;
- description of the residual contamination issue(s) required to be managed, including the nature and extent of contaminated sediments remaining within the Remediation Areas;
- description of the environmental controls to manage the residual contamination issues, including the requirements for periodic inspections, maintenance and reporting;
- description of responsibilities for persons implementing various elements of the SMP and the person/s responsible for ensuring its overall management;
- timeframe for implementing various elements of the provisions contained in the SMP;
- measures to be implemented if any parts of the remediated areas are required to be physically disturbed;
- a specific Environmental Management Plan to ensure no unacceptable impact to the environment whilst undertaking any intrusive works on the site; and
- health and safety requirements of each relevant activity required by the SMP.

15.2 OBJECTIVES OF THE SMP

The objectives of the SMP are to provide guidance for the inspections, sampling and testing to ensure the objectives of the RAP will be maintained for each Remediation Area, as set out in the following sections.



Southern Remediation Area – SA1

Visual inspection of cap surface and areas peripheral to capped area to assess:

- integrity of cap;
- presence/absence of marine biota;
- presence/absence of sheens or seeps;
- survey of cap perimeter and of cap elevation;
- testing;
- frequency of inspections and testing;
- collection and chemical analysis of samples of water from above and peripheral to capped area; and
- triggers for rehabilitation and/or repair.

Southern Remediation Area – SA2

Visual inspection of area and peripheral areas to assess:

- integrity of placed materials;
- presence/absence of marine biota;
- presence/absence of sheens or seeps;
- testing;
- frequency of inspections and testing;
- collection and chemical analysis of samples of water from above and peripheral to area; and
- triggers for rehabilitation and/or repair.

Southern Remediation Area – SA3

Visual inspection of area and peripheral areas to assess:

- integrity of placed materials;
- presence/absence of marine biota;
- presence/absence of sheens or seeps;
- testing;
- frequency of inspections and testing;
- collection and chemical analysis of samples of water from above and peripheral to area; and
- triggers for rehabilitation and/or repair.

Southern Remediation Area – SA4 and SA5

Visual inspection of area and peripheral areas to assess:

- integrity of placed and cleaned materials;
- presence/absence of marine biota;
- testing;
- frequency of inspections and testing;
- collection and chemical analysis of samples of water from above and peripheral to area; and
- triggers for rehabilitation and/or repair.

Northern Remediation Area – NA1

Visual inspection of area and peripheral areas to assess:

- integrity of placed materials;
- presence/absence of marine biota;
- presence/absence of sheens or seeps;
- testing;
- frequency of inspections and testing;
- collection and chemical analysis of samples of water from above and peripheral to area; and
- triggers for rehabilitation and/or repair.

Northern Remediation Area – NA2+NA3

Visual inspection of cap surface and areas peripheral to capped area to assess:

- integrity of cap;
- presence/absence of marine biota;
- presence/absence of sheens or seeps;
- survey of cap perimeter and of cap elevation;
- testing;
- frequency of inspections and testing;
- collection and chemical analysis of samples of water from above and peripheral to capped area; and
- triggers for rehabilitation and/or repair.

15.3 PERIODIC HYDROGRAPHIC SURVEY

Following completion of the remediation works, a bathymetric survey will be conducted of the Remediation Areas to validate final levels. This will be conducted as part of the Validation Sampling Analysis and Quality Plan. It is proposed that the SMP will require a follow-up survey of the bathymetry after a three-year interval, to confirm the predicted bathymetric levels.

If no significant changes have occurred after three years, no further bathymetric surveys will need to be conducted. If significant changes have occurred after three years, a further survey of the bathymetry will be required after another three-year interval.

15.4 PERIODIC WATER QUALITY MONITORING

It is proposed that seasonal water quality monitoring of the Remediation Areas and Kendall Bay and established background sites in Exile and Majors Bays will be undertaken as a part of the SMP for three years after completion of the remediation works. The results will then be assessed to determine if any additional water quality monitoring is required.

If no significant changes have occurred after three years, no further water quality monitoring surveys will need to be conducted. If after three years, significant changes have occurred as a consequence of the remediation works, a further three-year period of seasonal monitoring will be undertaken.

15.5 CAP INSPECTION AND SAMPLING TO TEST INTEGRITY

The robustness and chemical quality of the capping materials used in the remediation will be sampled annually at all Remediation Areas for three years, post-completion of the remediation works, to confirm that no gasworks-related contaminants have migrated through the capping materials.

The sediment sampling will also occur at nominated background locations to establish the environmental condition of sediments in the Parramatta River to enable assessment of the nature and extent of impact from gasworks waste in Kendall Bay. After three years, the data will be reassessed to determine if any further sampling is required.

15.6 BIOTA RECOLONISATION ASSESSMENT

The capping materials have been designed to facilitate the settling and recolonisation of benthic communities in the Remediation Areas.

It is proposed that benthic sampling of the benthic communities in the Remediation

Areas and established background sites and analyses of the benthic fauna present will occur annually for three years, commencing one year post-completion of remediation works. It is anticipated that colonisation will have occurred in these first three years and trends will indicate the establishment and sustainability of these communities. The sampling will occur at the same time as the chemical analyses of the capping materials.

After three years, analyses of the benthic fauna will be undertaken to establish if the newly settled biota is representative of the background and adjacent benthic communities in terms of abundance and species diversity.

If the analyses demonstrate that there is no significant difference in terms of abundance and species diversity, then sampling and analysis of benthic communities can cease.

15.7 REPORTING

It is proposed that reporting of the surveys will be made to Roads and Maritime Services, the Site Auditor and EPA on an annual basis. Any recommendation concerning cessation or modification of the monitoring will be discussed with the relevant parties prior to any change to the SMP being approved.

15.8 RESPONSIBILITIES

Jemena is to report annually to Roads and Maritime Services, the Site Auditor and the EPA on the results of the monitoring and any actions required or outcomes of any actions undertaken.

15.9 CRITERIA TO BE MET FOR SIGNOFF

The criteria to be met for sign off will be agreed with the EPA at the outset of the remediation works. The criteria will reflect the objectives of the remediation proposed i.e., that the works will deliver a robust and durable outcome to reduce human health risk to acceptable levels and provide a stable benthic environment for the development and long-term establishment of



Chapter 16

CONCLUSIONS

The sediments in Kendall Bay are contaminated with wastes from operations of the former Mortlake gasworks, as well as metals and other pollutants derived from many industrial and urban sources.

The sediments have been sampled extensively and compared to background areas. The sediments in parts of Kendall Bay contain levels of polycyclic aromatic hydrocarbons (PAHs) and petroleum hydrocarbons (TRHs) greatly in excess of sediment quality guidelines.

Site-specific studies of sediment toxicity and benthic community diversity studies were carried out to develop criteria and used to define areas that require remediation to meet the project objectives.

Once the Remediation Areas were defined, a world-wide review of potential remediation methods has resulted in the adoption of in situ solidification for the main areas and a mixture of this method plus removal of contaminated sediments for ex situ treatment and lowering the finished surface to below tidal levels in the inshore areas.

The data and technical inputs accumulated over the past two years have been used to develop this detailed RAP.

This RAP offers the following benefits:

- it is robust and supported by the best available science;
- it deals with the contamination in accordance with NSW EPA and USEPA guidelines;

- it immobilises the contamination in the most contaminated areas and restores a suitable habitat for benthic communities; and
- it does not destroy existing viable benthic communities.

The RAP addresses specifically the issues that concern the public, in particular:

- contamination and the resulting odours along the foreshore;
- the human health of those who use the bay, beach and mangrove area;
- the amenity of the beach;
- preservation of the mangroves; and
- odour generation during remediation.

The proposed in situ solidification approach for the sediments in the bay:

- is an established technique for soil improvement;
- has become best remediation practice in the US where there are thousands of former manufactured gas plants;
- will be subject to NSW EPA and USEPA quality assurance and control methods;
- has been demonstrated as effective by preliminary mix tests on Kendall Bay sediments;
- will be trialled in Kendall Bay during the project approval stage;
- will be closely regulated by the EPA and other statutory authorities;
- will be conducted under best-practice project and environmental management approaches; and
- provides a high degree of confidence of a robust and durable solution to the defined contamination.



Chapter 17

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Appendix 1

SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS (SEARS)



Our ref: SSD-6701

Jemena Asset Management Pty Ltd
Kendall Bay Project Office
99 Walker Street
North Sydney NSW 2060

By email: peter.odea@jemena.com.au

Dear Peter

**Kendall Bay Sediment Remediation (SSD-6701)
Secretary's Environmental Assessment Requirements**

The Department of Planning and Environment (the Department) has reviewed your letter of 14 February 2017 re-consulting the Secretary on the above project, given two years has passed since the Secretary's Environmental Assessment Requirements (SEARs) were issued.

The Department has reviewed the SEARs issued in December 2014 in consultation with key agencies and the City of Canada Bay Council. Following this review, the Department has reissued the SEARs with only minor changes. The changes reflect the revised description of the development and remediation methodology. The changes include:

- Amending the development description as follows:
Remediation of the contaminated sediments within two areas of Kendall Bay (the Southern and Northern areas, formerly called Areas A and B), including:
 - *immobilisation of contaminated sediments;*
 - *excavation of contaminated sediments and materials along the shoreline;*
 - *transportation of sediments and other contaminated materials to a land-based 'staging site' at 140 Tennyson Road, Mortlake via barge;*
 - *treatment of the sediments at a licensed waste facility; and*
 - *capping of excavated areas and reinstatement with clean soil.*
- Removing the following point from the 'Biodiversity' section
 - *a mangrove rehabilitation plan, including monitoring requirements and performance measures; and*
- Updating various technical guidelines in Attachment 1.

Please note that the Department may alter the SEARs at any time. You must consult further with the Department if you do not lodge a development application and Environmental Impact Statement (EIS) for the development within two years of the date of issue of the revised SEARs.

I wish to emphasise the importance of effective and genuine community consultation and the need for the proposal to proactively respond to the community's concerns. Accordingly, you must undertake a comprehensive, detailed and genuine community consultation and engagement process during the preparation of the EIS. This process must ensure that the community is informed of the development and engaged with issues of concern to them. Sufficient information must be provided to the community to enable a good understanding of the development and any potential impacts.

Your development may require separate approval under the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). If an EPBC Act approval

is required, please advise the Department accordingly, as the Commonwealth assessment process may be integrated into the NSW assessment process, and supplementary SEARs may need to be issued.

Please contact the Department at least two weeks before you intend lodge the EIS and any associated documentation for the development. This will enable the Department to determine the:

- applicable fee (under Division 1AA, Part 15 of the Environmental Planning and Assessment Regulation 2000); and
- consultation and public exhibition arrangements, including copies and format requirements of the EIS.

If you have any enquiries about these SEARs, please contact Deana Burn on the above details.

Yours sincerely



Chris Ritchie

Director

Industry Assessments

as delegate of the Secretary

7/3/17.

Secretary's Environmental Assessment Requirements

Section 78A(8A) of the *Environmental Planning and Assessment Act 1979*
Schedule 2 of the *Environmental Planning and Assessment Regulation 2000*

Application Number	SSD 6701
Development	Remediation of the contaminated sediments within two areas of Kendall Bay (the Southern and Northern areas, formerly called Areas A and B), including: • immobilisation of contaminated sediments; • excavation of contaminated sediments and materials along the shoreline; • transportation of sediments and other contaminated materials to a land-based 'staging site' at 140 Tennyson Road, Mortlake via barge; • treatment of the sediments at a licensed waste facility; and • capping of excavated areas and reinstatement with clean soil.
Location	Kendall Bay and 140 Tennyson Road Mortlake
Applicant	Jemena Limited
Date of Issue	March 2017
General Requirements	The Environmental Impact Statement (EIS) for the development must meet the form and content requirements in Clauses 6 and 7 of Schedule 2 of the <i>Environmental Planning and Assessment Regulation 2000</i>. In addition, the EIS must include: • a detailed description of the development, including: – need for the proposed development; – justification for the proposed development, including alternatives considered; – a Remedial Action Plan, which includes: - o characterisation of the nature and extent of contaminated material; - o details of the proposed remediation process, including the process to treat contaminated material; - o details of proposed remediation management measures, including justification of the remediation criteria and proposed disposal of treated sediments and waste, and management of wastewater; - o a site validation plan; and - o details of compliance with the <i>Contaminated Land Management Act 1997</i>; – final landform following remediation and the suitability of fill material; – final revegetation plan and process for on-going management following remediation works. • consideration of all relevant environmental planning instruments, including identification and justification of any inconsistencies with these instruments; • risk assessment of the potential environmental impacts of the development, identifying the key issues for further assessment; • detailed assessment of the key issues specified below, and any other significant issues identified in this risk assessment, which includes: – a description of the existing environment, <u>using sufficient baseline data</u>;

	– an assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant guidelines, policies, plans and statutes; and – a description of the measures that would be implemented to avoid, minimise and if necessary, offset the potential impacts of the development, including proposals for adaptive management and/or contingency plans to manage any significant risks to the environment; and • consolidated summary of all the proposed environmental management and monitoring measures, highlighting commitments included in the EIS. The EIS must also be accompanied by a report from a qualified quantity surveyor providing: • a detailed calculation of the capital investment value of the proposal (as defined in clause 3 of the <i>Environmental Planning and Assessment Regulation 2000</i>), including details of all assumptions and components from which the CIV calculation is derived; • a close estimate of the jobs that will be created by the development; and • certification that the information provided is accurate at the date of preparation.
Key Issues	The EIS must address the following specific matters: • Air Quality and Odour – including: - an assessment of odour from the excavation, dredging, transport, treatment and storage of contaminated sediments; - an air quality impact assessment of each stage of the remediation works and treatment facility including details of the emission control measures at the treatment facility, odour/dust suppressants and stockpile management; - details of the proposed odour and air emissions controls for each stage of the remediation process, including the proposed treatment site at 140 Tennyson Road; and - details of an air quality monitoring program including the identification of air quality criteria. • Human Health and Ecological Risk Assessment – including an assessment of the health implications of the development (including from the extraction of sediments, treatment and disposal of treated material), during and following remediation, including details of exposure scenarios and demonstration that the development will not have unacceptable acute or chronic health effects on humans or ecological resources. • Traffic – including: - details of the land based and water based traffic that would be generated by the project; - transport routes; - traffic management procedures for the staging site and parking requirements, including a construction traffic management plan and measures to manage and repair any damage to the local road network; and - navigation and safety impacts on other water based traffic and ferry commuter services from any piping or barging of contaminated material, including details of any proposed measures to manage navigational conflicts. • Water Quality and Sediments – including: - erosion and sediment controls during excavation, dredging, transport and treatment of sediments, stockpiling and backfilling of the bay;

	- details of a water quality monitoring program for Kendall Bay, with a focus on turbidity and key contaminants; - management of stormwater and treated wastewater discharges from the treatment facility; - management of wastewater generated during dewatering of extracted sediments; - impacts on surface water and groundwater, including potential impacts on bed and bank stability of Kendall Bay and the Parramatta River; - assessment and management procedures for acid sulfate soils. • Waste Management – including details of the classification, treatment, handling and disposal of all waste materials, including wastewater generated by the development. • Noise and Vibration – including an assessment of construction and operational noise from excavation, dredging, traffic and operation of the treatment facility; • Biodiversity – including: - an assessment of any impacts on critical habitats, threatened species, populations or ecological communities and their habitats; - measures to minimise harm to mangrove habitat and details of proposed biodiversity offsets for impacts on aquatic habitat; and - details of backfill material that supports the re-establishment of aquatic flora and fauna. • Hazards – including: - a Preliminary Hazard Analysis (PHA) of the treatment facility including a detailed assessment of the potential off-site risks; - an Emergency Management Plan detailing the measures to be put in place to minimise risks and respond to incidents and emergencies. • Visual – including an assessment of the visual impact of all aspects of the development, particularly on any adjoining landowners and significant vantage points in the public domain. • Heritage – including an assessment of non-Aboriginal and Aboriginal heritage impacts. • Cumulative Impacts – particularly in relation to air, noise and traffic associated with other nearby industrial or commercial operations.
Plans and Documents	The EIS must include all relevant plans, architectural drawings, diagrams and relevant documentation required under Schedule 1 of the <i>Environmental Planning and Assessment Regulation 2000</i>. These documents should be included as part of the EIS rather than as separate documents.
Consultation	During the preparation of the EIS, you must consult with the relevant local, State or Commonwealth Government authorities, service providers, community groups and affected landowners. In particular you must consult with: • Environment Protection Authority; • City of Canada Bay Council; • NSW Health; • SafeWork NSW; • Department of Primary Industries (DPI) including DPI Water and DPI Fishing; • NSW Roads and Maritime Services; • Office of Environment and Heritage; • Transport of NSW (Sydney Ferries); and • local community and other stakeholders.

	The EIS must describe the consultation process and the issues raised, and identify where the design of the development has been amended in response to these issues. Where amendments have not been made to address an issue, a short explanation should be provided.
Further consultation after 2 years	If you do not lodge an EIS for the development within 2 years of the issue date of these SEARs, you must consult with the Secretary in relation to the requirements for lodgement.
References	The assessment of the key issues listed above must take into account relevant guidelines, policies, and plans as identified. While not exhaustive, Attachment 1 contains a list of some of the guidelines, policies, and plans that may be relevant to the environmental assessment of this development.

ATTACHMENT 1

Technical and Policy Guidelines

The following guidelines may assist in the preparation of the Environmental Impact Statement. This list is not exhaustive and not all of these guidelines may be relevant to your proposal.

Many of these documents can be found on the following websites:

<http://www.planning.nsw.gov.au>,
<http://www.bookshop.nsw.gov.au>,
<http://www.publications.gov.au>

Policies, Guidelines & Plans

Plans and Documents

The EIS must include all relevant plans, architectural drawings, diagrams and relevant documentation required under Schedule 1 of the Environmental Planning and Assessment Regulation 2000. Provide these as part of the EIS rather than as separate documents.

In addition, the EIS must include the following:

1. An existing site survey plan drawn at an appropriate scale illustrating:
 - the location of the land, boundary measurements, area (sq. m) and north point;
 - the existing levels of the land in relation to buildings and roads;
 - location and height of existing structures on the site;
 - location and height of adjacent buildings and private open space; and
 - all levels to be to Australian Height Datum (AHD).
2. A locality/context plan drawn at an appropriate scale should be submitted indicating:
 - watercourses including nearby rivers and creeks, and dams;
 - significant local features such as heritage items;
 - the location and uses of nearby buildings, shopping and employment areas, hospitals and schools; and
 - traffic and road patterns, pedestrian routes and public transport nodes.
3. An indication of the location of the site with respect to the relevant Land Zoning Map within the *Canada Bay Local Environmental Plan 2013*.
4. Drawings at an appropriate scale illustrating:
 - detailed plans, sections and elevations of the existing building, which clearly show all proposed internal and external alterations and additions.

Documents to be submitted

Documents to submit include:

- 1 electronic copy of all the documents and plans for review prior to exhibition; and
- other copies as determined by the Department once the development application is lodged.

Policies, Guidelines & Plans	
Aspect	Policy /Methodology
Contamination	
	<i>Contaminated Land Management Act 1997</i>
	<i>State Environmental Planning Policy 55 – Remediation of Land</i>
	Guidelines for Consultants Reporting on Contaminated Sites (EPA, 2011)
	Guidelines for the NSW Site Auditor Scheme – 2 nd edition (DEC, 2006)
	Sampling Design Guidelines (EPA, 1995 and National Environment Protection (Assessment of Site Contamination) Measure 1999 (April 2013)
Human Health	
	Work Health and Safety Regulation 2011 (WHS Regulation)
	Managing risks of hazardous chemicals in the workplace (Safe Work Australia, July 2014)
	Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards (2012)
Waste	
	Waste Avoidance and Resource Recovery Strategy 2010-2021 (EPA)
	The National Waste Policy: Less Waste More Resources 2009
	Waste Classification Guidelines (DECC)
Air Quality	
	<i>Protection of the Environment Operations (Clean Air) Regulation 2010</i>
	Approved Methods for the Modelling and Assessment of Air Pollutants in NSW (EPA 2016)
	Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (DEC)
Odour	
	Assessment and Management of Odour from Stationary Sources in NSW: Technical Framework and Technical Notes (2006)
Noise and Vibration	
	Assessing Vibration: a Technical Guide (DEC, 2006)
	NSW Road Noise Policy (EPA, 2011)
	Interim Construction Noise Guideline (DECC, 2009)
	NSW Industrial Noise Policy (EPA, 2000)
Soil and Water	
<i>Soil</i>	Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC & NHMRC)
	National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC)
	Draft Guidelines for the Assessment & Management of Groundwater Contamination (DECC)
	Acid Sulfate Soils Manual (Stone et al. 1998)
	NSW Guidelines for Controlled Activities on Waterfront Land (NOW, 2012)
<i>Surface Water</i>	National Water Quality Management Strategy: Water quality management - an outline of the policies (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Policies and principles - a reference document (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Implementation guidelines (ANZECC/ARMCANZ)
	National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ)

	National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ)
	Using the ANZECC Guideline and Water Quality Objectives in NSW (DEC)
	NSW State Rivers and Estuaries Policy(1993)
	State Water Management Outcomes Plan
	NSW Government Water Quality and River Flow Environmental Objectives (DECC)
	Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DEC)
	Managing Urban Stormwater: Soils & Construction (Landcom)
	Managing Urban Stormwater: Treatment Techniques (DECC)
	Managing Urban Stormwater: Source Control (DECC)
	Technical Guidelines: Bunding & Spill Management (DECC)
	NSW Floodplain Development Manual 2005
	NSW Floodplain Development Manual 2005
<i>Groundwater</i>	National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC)
	Australian Groundwater Modelling Guidelines (NWC, 2012)
	NSW State Groundwater Policy Framework Document (DLWC)
	NSW State Groundwater Quality Protection Policy (DLWC)
	NSW State Groundwater Dependent Ecosystems Policy (2002)
	NSW State Groundwater Quantity Management Policy (DLWC) Draft
	Guidelines for the Assessment and Management of Groundwater Contamination (DEC, 2007)
	Draft Guidelines for the Assessment & Management of Groundwater Contamination (DECC)
Wastewater	
	National Water Quality Management Strategy - Guidelines For Water Recycling: Managing Health And Environmental Risks (Phase1) 2006 (EPHC, NRMCC & AHMC)
	National Water Quality Management Strategy – Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2): Augmentation of Drinking Water Supplies 2008 (EPHC, NRMCC & AHMC)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems - Effluent Management (ARMCANZ/ANZECC)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems - Use of Reclaimed Water (ARMCANZ/ANZECC)
	National Water Quality Management Strategy: Guidelines for Sewerage Systems - Use of Reclaimed Water (ARMCANZ/ANZECC)
Transport	
	Guide to Traffic Generating Developments (RMS)
	Road Design Guide (RTA)
Biodiversity	
	NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014)
	Principles for the use of Biodiversity Offsets in NSW (OEH);
	Policy & Guidelines - Aquatic Habitat Management and Fish Conservation (NSW Fisheries)
	The NSW State Groundwater Dependent Ecosystem Policy (DLWC)
Hazards	
	State Environmental Planning Policy No. 33 – Hazardous and Offensive Development
	Applying SEPP 33 – Hazardous and Offensive Development Application Guidelines (DUAP)
	Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis
Visual	

	Control of Obtrusive Effects of Outdoor Lighting (Standards Australia, AS 4282)
Heritage	
	Guide to investigating, assessing and reporting on Aboriginal cultural heritage in NSW (OEH, 2011)
	Code of Practice for the Archaeological Investigation of Aboriginal Objects in New South Wales (DECCW, 2010)
	Draft Guidelines for Aboriginal Cultural Impact Assessment and Community Consultation (Department of Planning, 2005)
	Aboriginal Cultural Heritage Consultation Requirements for Proponents 2010 (DECCW, 2010)

Appendix 2

PREFERRED STRATEGY AND WORK METHODS

Note / Memo

**Haskoning Australia PTY Ltd.
Maritime & Aviation**

To: Russell Synnot
From: Matt Potter / Greg Britton
Date: 08 November 2016
Copy:
Our reference: M&APA1388N002F1.0
Classification: Project related

**Subject: Kendall Bay Sediment Remediation Project
Preferred Strategy and Work Methods for Remediation Action Plan (RAP)**

Dear Russell,

The following memorandum provides a narrative to support the conceptual design of the preferred remediation strategy and work methods for the Kendall Bay Sediment Remediation Project. Other aspects relating to environmental monitoring/controls, contingency measures, works validation and ongoing management are also covered. It is understood that the content of this memorandum will be used in the preparation of the Remediation Action Plan (RAP) by others.

Section 1 of the memorandum outlines general considerations that influence the selection of remediation strategies and work methods. The proposed remediation strategies and work methods for each of the 5 sub areas within the Southern Area and 3 sub areas within the Northern Area are discussed in turn within **Section 2**. This discussion includes the primary objectives, remediation strategy, work methods, schedule, contingency measures, and works validation.

Suggested environmental monitoring and control measures associated with the project are outlined in **Section 3**. Monitoring and maintenance activities associated with a post-remediation environmental management plan are discussed in **Section 4**. References are listed in **Section 5**.

Drawings showing the extent of the remediation areas and concept designs for remediation strategies are provided in **Attachment A**. A technology brief for activated carbon products prepared by CSIRO is provided in **Attachment B**.

1 General Considerations

1.1 Remediation Objectives

The overarching objectives of the project are to ensure long-term protection of human users of the foreshore of the Bay and improvement of the health of the marine ecosystem of the Bay. Synnot & Wilkinson (S&W) have provided the following list of objectives to achieve this:

- remediating to the extent practicable the surface sediments that pose an unacceptable risk to human health in the Southern Area and that pose an acute risk to the marine ecosystem;
- managing sediments that pose an unacceptable risk to human health to users of the beach and mangrove areas in the Southern Area;

- remediating stained surfaces, sediments giving rise to emission of odours when exposed at low tides and the presence of rubbish in accessible areas of the mangroves and in the foreshore adjacent to the seawall in the Southern and Northern Areas;
- ensuring durable and robust remediation/management outcomes;
- ensuring the integrity of the seawall adjacent to the Southern and Northern Areas during and after the remediation works;
- implementing an Operational Site Management Plan for the conduct of the remediation and management works, including minimising and monitoring odours at the boundaries of the remediation site and protecting the quality of water in Kendall Bay outside the Southern and Northern Areas;
- implementing a Human Health Management Plan for the operational phase of the remediation and management works to protect the health of the community and of remediation workers;
- installing control measures to ensure stormwater discharge to Kendall Bay does not impact the remediated and managed parts of the Southern and Northern Areas;
- validating the achievement of the remediation goals of the remediation and management works in the Southern and Northern Areas;
- developing a Post-Remediation Environmental Management Plan that is to be implemented within the Southern and Northern Areas to verify the durability of the remediation/management measures through periodic monitoring of the effectiveness of the measures, aesthetic issues and water quality over a five-year period and to assess if further remediation, management or monitoring needs to be implemented; and,
- continuing engagement with and reporting to the community and regulatory authorities during the remediation and management programs and throughout the period of the Post-Remediation Environmental Management Plan.

For each remediation area, several of the above objectives may be relevant and dictate the remediation strategy and work method applied. This is discussed further in **Section 2**.

1.2 Physical Environment

The physical environment has a significant influence on the remediation strategies and work methods applied in different areas. These site conditions are described within the *Description of Existing Marine Environment* report (RHDHV, 2016), which should be read in conjunction with this memorandum.

Relevant physical environment factors include:

- existing seabed levels;
- water level variation;
- wave climate (wind and boat generated waves);
- currents;
- sediment characteristics (physical and chemical properties);
- sediment transport; and,

- existing structures (e.g. seawalls, stormwater outlets).

1.3 Design Life and Performance Criteria

The NSW EPA has advised that their key requirements for the remediation of Kendall Bay are that the proposed treatments are 'durable' and 'robust'. These requirements relate to performance criteria that ensure that the remediation treatments are effective for an extended period of time and are resistant to the action of natural processes and anthropogenic influences.

The proposed remediation strategy involves either:

- addressing human health risks by:
 - reducing bed levels to below Lowest Astronomical Tide (LAT) to limit access and generation of odour; and,
 - capping of areas with a layer of clean material to prevent contact with contaminated materials and generation of odour; or,
- improvement of the marine ecosystem by:
 - capping of areas with a layer of clean material for recolonisation by benthic communities.

As such, the remediation strategy generally involves excavation of existing materials to reduce seabed levels and placement of a capping layer over the lowered seabed to achieve the remediation objectives defined for specific areas. The remediation areas have been defined on the basis of an extensive program of sediment sampling undertaken by Synnot & Wilkinson. The results of this investigation were used to delineate specific areas within the Southern Area (i.e. SA1) and Northern Area (NA2 and NA3) that require remediation due to the absence of viable benthic communities in seabed sediments as a result of contamination levels. It should be noted that in the case of remediation area SA1, the primary objective was to address human health risks associated with physical contact and a secondary objective was to improve marine ecosystem health. Other remediation areas that were defined to primarily address human health risks associated with physical contact and odour generation comprise SA2, SA3, SA4, SA5 and NA1. The extent and location of each of these remediation sub areas within the Northern and Southern Areas is shown on Drawing 1 and Drawing 2 respectively (refer **Attachment A**).

A 0.3m to 0.5m thick layer of clean material has been advised by Synnot & Wilkinson as being suitable for limiting human access to underlying contaminated material and providing substrate for benthic recolonisation. To satisfy the robustness requirement, this layer should be able to withstand the near-bed velocities generated by 100 year recurrence wind wave conditions. In addition, this layer would need to withstand near-bed velocities from regular boat generated waves. To satisfy the durability requirement the layer should be constructed from competent material that would not break down over time in the marine environment.

It is estimated that near-bed velocities under 100 year recurrence wind wave conditions and regular boat generated waves are approximately 1m/s. Cobble sized rock is considered to be the most appropriate capping material. The median rock size (D_{50}) within a graded rip rap blanket placed on the seabed required to withstand these near-bed velocities is around 110mm (sieve size), based on the use of sandstone with a density of 2.3t/m^3 . The rip rap blanket would have a grading envelope which ranges between 60mm and 180mm (sieve size). It is noted that this sizing is similar to rock found over the existing cobble beach area adjacent to the mangroves in the south-west corner of the Bay (refer **Figure 1**). The rock would need to be placed in a layer that is a minimum of two rocks thick to be effective, which is achievable given the target placement thickness of 0.3m to 0.5m.



Figure 1: Cobble beach adjacent to mangroves in south-west corner of Kendall Bay

The following rock acceptance properties are considered to provide the required durability for sedimentary rock (i.e. sandstone) in the marine environment:¹

- Dry Density greater than 2.3t/m³;
- Compressive Strength greater than 25Mpa;
- Point Load Strength Index (I_{s50}) greater than 1.5Mpa;
- Wet/dry Strength Variation less than 25%;
- Sodium Sulphate Weight Loss less than 9%; and,
- Water Absorption less than 1.5%.

The above properties should be established on representative samples of the proposed rock tested at a NATA registered laboratory.

In addition to the above properties obtained from physical testing of rock material, visual inspection of the rock should verify that individual rocks are hard, durable and clean and should be free from cracks, cleavage planes, joints, seams, chemical alteration or weathering and other defects which would result in the breakdown of the rock in the marine environment.

Rock that satisfies the above criteria can be expected to have an indefinite life.

Sandy material would need to be placed in the interstices of the rock cobbles to provide a suitable substrate for benthic recolonisation.

¹ Similarly, a set of durability criteria could be established for igneous rock such as basalt.

1.4 Site Access

Access to the remediation areas from land is not available for the project due to the proximity of the Breakfast Point development located immediately adjacent to the western seawall and due to Canada Bay Council prohibiting access through Cabarita Park on the eastern shoreline. As such, access for plant, equipment, personnel and materials would need to be achieved via waterborne transport.

Jemena own a waterfront property located around 1km further upriver in Fairmile Cove (140 Tennyson Road, Mortlake), which would function as a staging area for implementation of the remediation strategy as well as a processing site for material removed from Kendall Bay. The existing wharf at the site would be used for shore transfer of plant, equipment, personnel and materials that would need to be transported overwater to Kendall Bay by barges, tugs or work boats. The restriction of water only access to the site influences the plant and equipment and work methods proposed for the remediation works.

1.5 Geotechnical Conditions

Geotechnical conditions are a significant consideration for the remediation strategies and work methods applied in most of the proposed remediation areas. This is due to the presence of very soft to soft clays and very loose to loose sands within geotechnical units referred to as Unit 1 and Unit 2A (JK Geotechnics, 2012). These materials have low shear strength, are highly compressible and extend over a thickness of several metres above more competent Unit 2B material comprising stiff clay to clayey sand. As such, relevant considerations include design and constructability, stability of excavated batters, bearing capacity for tracked equipment, local failure of soft sediments, and long term settlement under loads applied by capping layers.

1.6 Seawall Stability

There are two different types of seawalls in the vicinity of the remediation areas.

A sloped seawall (refer **Figure 2**) formed by a facing of mortared sandstone blocks at a slope of around 1V:1H (vertical:horizontal) is located behind the mangroves at the head of the Bay and runs alongside remediation area SA2 on the western side of the Bay. It is understood that the seawall is likely to be founded on a layer of rock fill that was placed into soft ground. Exploratory probing completed along the toe of the seawall has indicated that a layer of rubble material exists over flat apron slabs. Careful excavation in this area is required to avoid removal or damage to seawall foundations.



Figure 2: Sloped seawall along western side of Kendall Bay

A vertical sandstone block seawall (refer **Figure 3**) exists along the frontage of the Breakfast Point development and is located immediately adjacent to remediation area NA1. Rip rap and rubble/debris exist at the toe of the wall at this location and are exposed at low tides. Recent inspections of the seawall identified signs of existing seawall instability, indicated by lateral separation of pavers behind the seawall and a localised step in the seawall level at the southern end. This is a potential concern and, accordingly, an assessment of the existing seawall stability issues should be undertaken prior to the design of any remediation works associated with the project. This assessment may identify works to mitigate existing seawall instability that would need to be completed before remediation works can commence. To manage the risk of damage during the project, a pre-remediation and post-remediation dilapidation survey would need to be undertaken. These reports would need to be accepted and signed off by Jemena and Rose Group.



Figure 3: Vertical seawall along western side of Kendall Bay

1.7 Sequencing of Remediation Activities

The proposed sequence of remediation activities in the various areas would be undertaken to address the areas of highest contamination first and areas of low contamination would be completed last. Where possible, the sequencing should also consider the use of common equipment between work areas.

The suggested sequencing of remediation areas in the Northern Area is as follows:

1. Remediation Area NA3
2. Remediation Area NA2
3. Remediation Area NA1

The suggested sequencing of remediation areas in the Southern Area is as follows:

1. Remediation Area SA1
2. Remediation Area SA2
3. Remediation Area SA5
4. Remediation Area SA3
5. Remediation Area SA4

It is possible that remediation works could be completed in work packages covering both the Northern Area and Southern Area if common equipment/methods are applied. This would be applicable for the following groups of remediation areas:

- NA1, SA2; and,
- NA2, NA3, SA1.

1.8 Climate Change

The main consideration for climate change is sea level rise. The proposed strategies are robust in terms of sea level rise since:

- areas which are proposed to be lowered below LAT to limit human access or mitigate odour would be even deeper or further inundated; and,
- nearbed velocities generated by wind waves and boat wash would be less than existing due to the greater water depth.

2 Remediation Strategy and Work Methods by Remediation Area

2.1 Remediation Area SA1

Primary Objective

The primary remediation objective in remediation area SA1 comprises:

- remediating to the extent practicable the surface sediments that pose an unacceptable risk to human health in the Southern Area and that pose an acute risk to the marine ecosystem.

Remediation Strategy

The remediation strategy in this area is to lower the seabed such that the seabed level is below the level of Lowest Astronomical Tide (LAT) and incorporates a 0.5m thick capping layer for benthic recolonisation. This strategy would prevent human access to the contaminated sediments and improve the marine ecosystem within the Bay.

The thickness of soft contaminated sediments (i.e. Unit 1A and Unit 2A) down to the underlying clean competent material (i.e. Unit 2B) has been mapped by JK Geotechnics (2012) and varies from 3m to 10m along the eastern perimeter, 6.5m in the central area and is up to 6m along the southern perimeter of SA1 (refer Drawing 3 within **Attachment A**).

To minimise excavation and generation of waste, it is proposed to use cement-based mass stabilisation techniques to create a 'raft' structure over the remediation area to support the overlying capping material that is to be placed to a finished level at LAT. The cement stabilised layer would be supported on deep soil mixed columns extending down to the level of competent Unit 2B material to minimise settlement. The process of creating deep soil mixed columns is shown schematically on **Figure 4**. This comprises the lowering of a single or multi-shaft hollow-stem auger into the soil to the desired depth and injecting the cement binder into the soil whilst raising and rotating the mixing apparatus. Mixing of the cement through the soil column is achieved by rotating mixing paddles whilst cement is released through ports at the base of the auger. This is a process of soil replacement where the injected cement reacts with the pore water within the saturated sediment and replaces it with a soil and cement matrix upon curing. Cement hydration (i.e. reaction with water) has the effect of increasing the density of the insitu material and its strength.

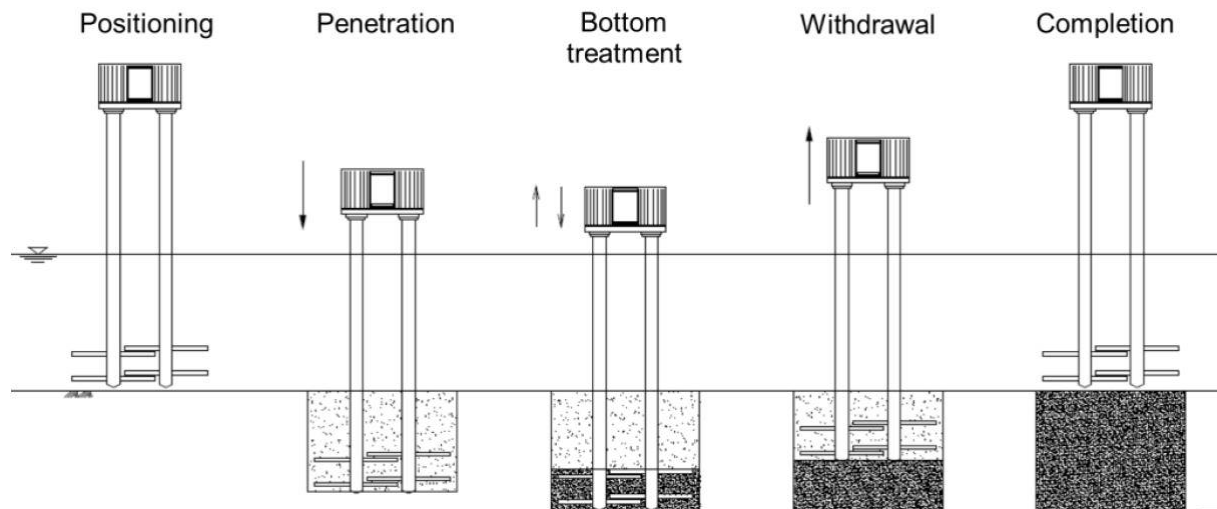


Figure 4: Deep soil mixed column construction sequence (Taguchi, 2015)

The remediation sequence would initially involve the construction of the supporting columns followed by mass stabilisation of surface material down to a defined depth. The cement stabilisation would also make excavation of sediments less problematic, by improving the insitu strength and allowing steeper temporary excavation batters of say 1V:1H to 1V:2H.

The overall depth of mass stabilisation is defined by a 1m thickness of stabilised material that is proposed to be retained to support the capping layer following excavation. To enable placement of the capping layer to a finished level at LAT mass stabilisation would need to extend down from the existing seabed level to a level of -1.5m LAT. As existing seabed levels vary between around 0m LAT at the eastern perimeter and around +0.5m LAT along the western perimeter, the depth of mass stabilisation could generally range from 1.5m to 2m. Over the 2,200m² remediation area, this equates to mass stabilisation of around 3,900m³ of insitu material on an average stabilisation depth of 1.75m.

Mass stabilisation can be achieved by injection of dry cement into the soil, in which case no significant bulking occurs. If a wet method involving injection of a grout is applied, bulking of up to 20% can be expected within the insitu material.

Following mass stabilisation, excavation of the stabilised material down to -0.5m LAT would be required to enable placement of a 0.5m thick capping layer to 0m LAT. Based on the above seabed variation, the depth of excavation could range from 0.5m to 1.0m. Over the 2,200m² remediation area, this equates to excavation of around 1,700m³ (dry method with no bulking) or 2,100m³ (wet method with 20% bulking) of stabilised material based on an average excavation depth of 0.75m. To ensure that the entire area of SA1 receives a 0.5m thick capping, the extent of mass stabilisation would need to extend outside of its defined boundary to provide a buffer that allows for the width of the excavation batter. The width of the excavation batter would vary according to the existing seabed level. If a temporary excavation batter of 1V:2H was adopted, this additional treatment width around the perimeter of SA1 would generally range from 1m to 2m. Excavation through the perimeter buffer would leave a 'rim' of stabilised material around SA1 that would act to prevent sediments from adjacent areas from slumping into the capping area.

Based on discussions with contractors that have experience in mass stabilisation, the consistency of the stabilised material (strength gain to several hundred kPa) allows ready excavation and the area could be walked on after a few days of curing.

The capping layer would be placed directly on to the excavated surface cut into the stabilised material to a level of -0.5m LAT and would comprise cobble sized rock. Sand would be subsequently placed over the rock layer to provide substrate within the interstitial spaces of the rocks for benthic recolonisation. The rock would be placed in at least two layers to ensure that the sand is able to be distributed throughout the entire interstitial space.

Although it is understood that the stabilised material has a very low permeability (hydraulic conductivity in the order of 10^{-8} m/s, similar to a layered clay or fresh sandstone), in order to enhance the robustness of the remediation treatment it is proposed to incorporate activated carbon material into the capping layer to absorb any contaminants that may migrate through the stabilised material. A review of available activated carbon products was completed by CSIRO (refer **Attachment B**). It is considered that activated carbon supplied in a form that is adhered to granular (gravel sized) materials (and later breaks down to form an activated carbon layer when placed underwater) is the most practical way of incorporating this material. The granular activated carbon material would be placed as an initial layer incorporated into the base of the 0.5m capping material thickness.

It is noted that the 3m width of SA2 adjacent to SA1 allows hydrostatic uplift pressures from surrounding groundwater levels to be released rather than being applied to the base of the mass stabilised layer within SA1. The proposed perimeter buffer for mass stabilisation around SA1 would encroach into SA2. However, this buffer is generally not expected to extend over the full 3m width of SA2. Furthermore, if remediation in SA2 is undertaken after SA1 (as recommended in **Section 1.7**) then the mass stabilised buffer material could be excavated and replaced with capping material as per the remediation strategy for SA2 (refer **Section 2.2**).

A typical section of the proposed capping layer arrangement for SA1 is shown on Drawing 4 (refer **Attachment A**).

The performance of different binders and dose rates for stabilisation would be determined based on dosing trials completed on representative samples of excavated material. This involves preparation of a number of different binder/soil mixes in a laboratory and strength testing at different intervals (i.e. 1 day, 7 day, 14 day, 28 day) to establish the rate of strength gain and relative performance of different binders. Several contractors have expressed interest in completing cement dosing trials on material obtained from the trial excavation activity completed on 22 September 2016.

In addition, a full-scale pre-construction trial would be undertaken in SA1 by the preferred remediation contractor to verify the field performance of deep soil mixed columns (if required) and mass stabilisation and to refine work methods prior to complete full execution.

Work Methods

The following work methods are proposed to implement the remediation strategy:

- Construction of supportive columns using barge-mounted equipment, comprising a drilling rig (refer **Figure 5**), binder silo and mixing plant and grout pump. An example setup is shown in **Figure 6** and **Figure 7** and is used for offshore applications by TOA Corporation, Tokyo, Japan.
- Insitu cement stabilisation of upper sediment layer using an amphibious excavator with a mixing attachment (refer **Figure 8**), this would need to be linked via a supply hose to a cement supply silo/tank located on the shoreline or mounted on a floating barge. Several Australian-based contractors (including Menard Oceania, Keller Ground Engineering and Wagstaff Piling) own amphibious excavators with proprietary mixing attachments and GPS control, and have experience in mass cement mixing applications in environments with poor ground conditions. It

is noted that the cobble material in the south-west area of SA1 would need to be removed to enable access for mass mixing as the tracks on amphibious excavators are damaged by hard or rocky ground conditions.

- Excavation of cement stabilised material with barge-mounted excavator and placement into an adjacent hopper barge (refer **Figure 9**) or flat barge carrying smaller hoppers or skip bins (refer **Figure 10**).
- Transfer of excavated material overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Placement of granular activated carbon material and cobble sized rock using small earthmoving equipment (e.g. Bobcat or small excavator) gradually tipping rock over edge of floating barge containing stockpiled material (refer **Figure 11**).
- Placement of sand over the cobble layer in a similar manner to rock.

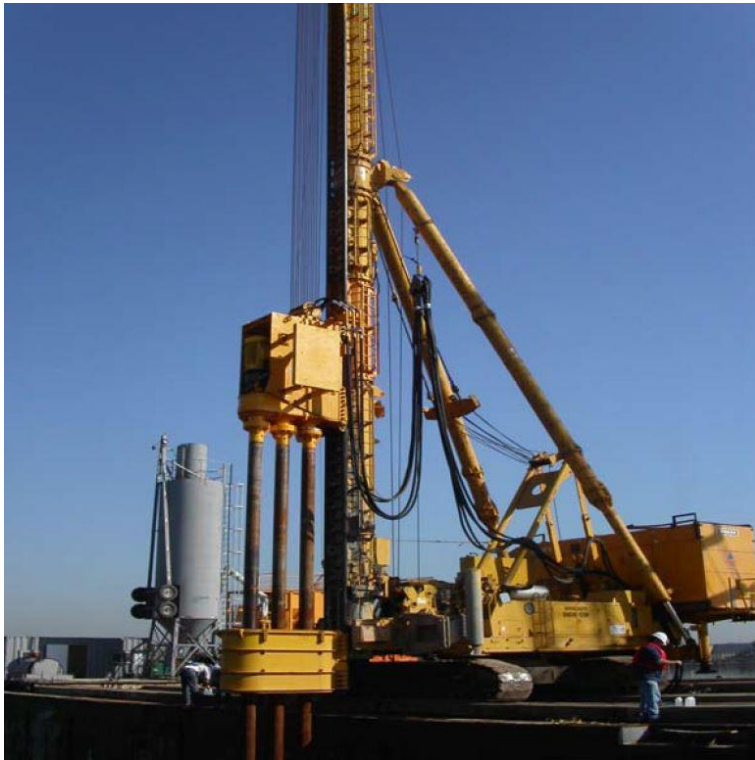


Figure 5: Drilling rig for deep soil mixed columns

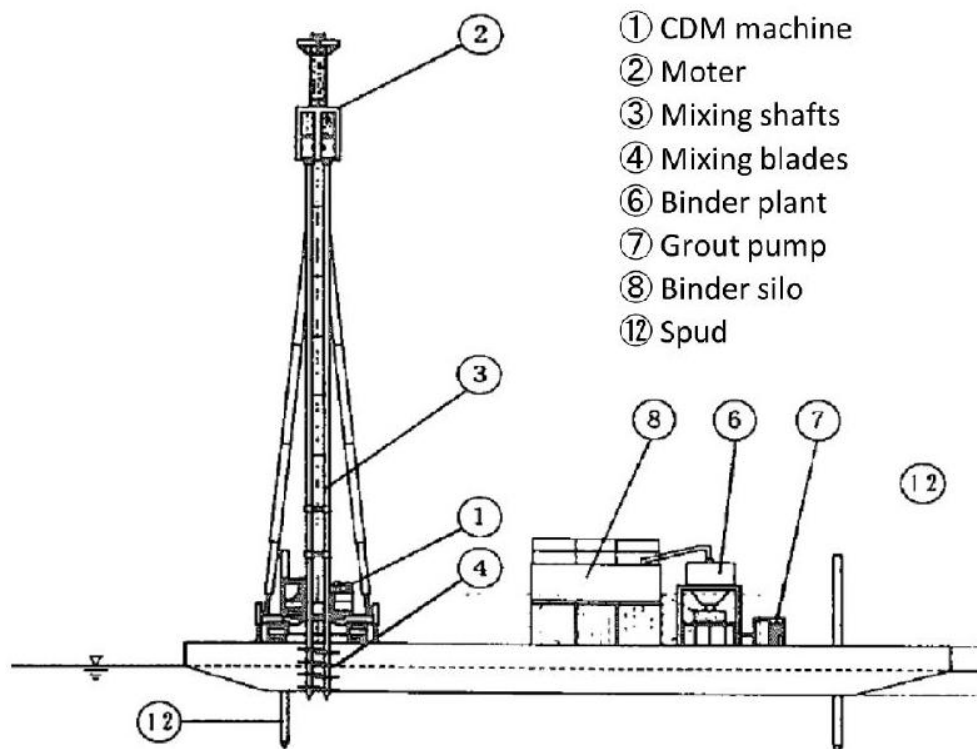


Figure 6: Example equipment setup for barge mounted deep soil mixing (Taguchi, 2015)



Figure 7: Barge mounted deep soil mixing equipment (Taguchi, 2015)



Figure 8: Amphibious excavator with mass mixing attachment (Keller Ground Engineering, 2016)



Figure 9: Barge mounted excavator loading into a hopper barge



Figure 10: Barge mounted excavator loading material into a large skip bin



Figure 11: Small excavator tipping rock from floating barge

Schedule

Mass stabilisation is able to be completed at a rate of approximately 100 to 150 insitu m³/day, which equates to a duration of around 25 to 40 working days for SA1 (based on an insitu treatment volume of 3,900m³). Other activities, including deep soil mixed columns (if required), excavation of stabilised

material and placement of capping material, are expected to result in a construction period of several months for remediation of SA1.

Contingency Measures

If cement dust generation is found to be problematic during mass mixing with an amphibious excavator, the use of wet grout rather than dry cement would prevent release of cement dust at the surface during mixing.

In the event that use of an amphibious excavator for mass soil mixing is restricted due to odour generation, other measures that could be implemented include:

- use of floating equipment for mass stabilisation, working the tides, involving drilling of shallow cement mixed columns in an overlapping pattern to achieve the desired thickness; or,
- excavation of a shallow thickness of contaminated material with a barge mounted excavator and hopper barge, placement of a geotextile and geogrid layer to support capping material, which would be designed to settle over time to a desired finished level below LAT.

Works Validation

Validation of completed works would be achieved at different stages of construction and would include:

- confirmation of the depths and coverage achieved with deep soil mixed columns and mass mixing by records from GPS attached to the mixing equipment;
- coring of stabilised material and testing to confirm strength gain over time;
- hydrographic survey (supplemented by land-based survey in shallow areas) of the surface of stabilised material to determine pre and post excavation levels;
- sampling and testing of sand and rock supply to confirm required material specifications are satisfied;
- confirmation of finished capping levels with GPS attached to placement equipment and hydrographic survey (supplemented by land-based survey in shallow areas);
- verification of capping layer thickness by comparison of pre and post capping surveys;
- underwater photography using a drop camera at high tide; and,
- diver inspection at high tide.

2.2 Remediation Area SA2

Primary Objective

The primary remediation objective in remediation area SA2 comprises:

- remediating stained surfaces, sediments giving rise to emission of odours when exposed at low tides and the presence of rubbish in accessible areas of the mangroves and in the foreshore adjacent to the seawall in the Southern and Northern Areas.

Remediation Strategy

The remediation strategy in this area is to lower the seabed such that the final seabed level is below the level of Lowest Astronomical Tide (LAT) and incorporates a 0.3m thick capping layer for benthic recolonisation. This would prevent human access to the contaminated rubble material along the base of the seawall at low tide and improve the marine ecosystem within the Bay.

As noted earlier, seawall stability is an important consideration for remediation of SA2. The remediation is located immediately adjacent to the seawall and extends over a 3m width adjacent to SA1 and widens to 8m for a length of 30m beyond the northern limit of SA1. As previously noted, the 3m width adjacent to SA1 allows hydrostatic uplift pressures from surrounding groundwater levels to be released rather than being applied to the base of the mass stabilised layer within SA1.

It is proposed that careful excavation of surface stained materials and rubble be completed at the toe of the seawall down to a level of -0.3m LAT or the level of the seawall toe apron slabs, whichever is reached first. Beyond the extent of seawall toe apron slabs, careful excavation can be completed to -0.3m LAT. Excavation would be followed by placement of a 0.3m thick layer of cobble sized rock to a finished level of 0m LAT. Sand would be subsequently placed over the rock layer to provide substrate within the interstitial spaces of the rocks for benthic recolonisation.

Work Methods

The following work methods are proposed to implement the remediation strategy:

- Careful excavation of surface materials with a barge-mounted excavator with GPS control at high tide and placement of materials into an adjacent hopper barge or flat barge carrying smaller hoppers or skip bins.
- Transfer of excavated material overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Placement of capping materials (cobbles and sand) using small earthmoving equipment (e.g. Bobcat or small excavator) gradually tipping material over the edge of a floating barge containing stockpiled material, or capping materials placed and groomed by barge-mounted excavator with GPS control.

Schedule

Remediation of SA2 would need to be undertaken at high tide to facilitate access by floating equipment and to minimise exposure of excavation surface and associated odour generation. It is anticipated that remediation of the area would take several weeks to complete.

Contingency Measures

Due to seawall stability concerns, excavation along the toe of the seawall should be completed in limited lengths of maximum 10m followed by placement of capping material before the adjacent excavation is started. The seawall would be monitored visually for signs of instability during the works, conducted daily. Pre-remediation and post-remediation dilapidation surveys would be conducted.

If excavation of surface material uncovers underlying soft sediments, placement of geotextile fabric and geogrid may be required to limit the loss of capping layer material by it punching through the soft underlying material upon placement.

Works Validation

Validation of completed works would be achieved at different stages of construction and would include:

- confirmation of excavation levels with records from GPS attached to the barge-mounted excavator;
- hydrographic survey (supplemented by land-based survey in shallow areas) to determine pre and post excavation levels;

- sampling and testing of sand and rock supply to confirm required material specifications are satisfied;
- confirmation of finished capping levels with GPS attached to placement equipment and hydrographic survey (supplemented by land-based survey in shallow areas);
- verification of capping layer thickness by comparison of pre and post capping surveys;
- pre-remediation and post-remediation seawall dilapidation surveys; and,
- photographic record taken at low tide.

2.3 Remediation Area SA3

Primary Objective

The primary remediation objectives in remediation area SA3 comprise:

- managing sediments that pose an unacceptable risk to human health to users of the beach and mangrove areas in the Southern Area; and,
- installing control measures to ensure stormwater discharge to Kendall Bay does not impact the remediated and managed parts of the Southern and Northern Areas.

Remediation Strategy

The remediation strategy in this area is to retain the existing established mangrove vegetation and clean up the area due to it being accessible to humans. This would involve removal of coke and coal from the sand surface in amongst the mangroves and over the sand shoal in front of the mangroves to a nominal depth of 0.2m. A layer of clean sand (compatible with the existing natural material) would be placed over the area as required to restore the existing sand surface where removal of material was required.

Management of the stormwater flow from the large 1650mm diameter outlet (refer **Figure 12**) discharging behind the mangroves at the head of Bay is also required. This discharge occurs periodically during rainfall events and creates a scour channel through the mangroves and over the sand shoal further out into the Bay. The meandering of this scour channel to the east has the potential to impact on adjacent remediation areas SA4 and SA5.

The June 2016 storm is a recent example of a significant rainfall event that created a scour channel through the mangroves (refer **Figure 13**) and out over the adjacent sand shoal (refer **Figure 14**). The scour channel migrated to the east and extended across the beach area in the south-eastern corner of the Bay. The scour channel was still evident during a site inspection in July 2016 (refer **Figure 15** and **Figure 16**). The June 2016 storm demonstrated that the mangroves are resilient to localised scour that occurred around their base, with no evidence of plants falling over due to undermining of the root system. The storm discharge carried a significant amount of woody debris and rubbish, which was strewn throughout the mangroves and beach area. The discharge also entrained some of the coke and coke material found within the mangroves and distributed it along the channel alignment across the sand shoals (refer **Figure 16**).

As such, stormwater discharge is not considered to be a threat to the mangroves and clean up of coke and coal would prevent remobilisation of these materials in stormwater flows. However, any migration of the scour channel to the east would impact on the amenity of the adjacent beach area in SA4 and SA5. The impact on the beach area would be limited by the proposed seaward extension of the existing sandstone wall (discussed further in **Section 2.4** below). However, eastward migrating stormwater flows running alongside the wall may cause localised scour and undermining of the structure. To redirect stormwater flows away from the wall it is proposed that a series of spur walls are constructed along a

desired alignment through the mangrove area. These low-level rock mound structures (refer to example shown on **Figure 17**) would train stormwater discharge away from the wall extension whilst allowing the flow to spread over the sand shoals without scouring a deep channel.



Figure 12: 1650mm diameter stormwater outlet behind the mangroves at the head of Kendall Bay (July 2016)



Figure 13: Localised scour around mangroves following June 2016 storm event



Figure 14: Scour channel through sand shoal following June 2016 storm event



Figure 15: Scour channel through mangroves and adjacent sandy areas (July 2016)



Figure 16: Scour channel observed across sand shoals to the east from mangrove area (July 2016)



Figure 17: Example of low-level rock mound structure used to deflect flows for riverbank protection

Work Methods

The following work methods are proposed to implement the remediation strategy:

- Removal of surficial material where practicable over the nearshore sand shoal by small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge.
- Removal of surficial material within the mangroves by hand (with labourers wearing appropriate PPE).
- Waste material would be placed into skip bins positioned on the nearshore sand shoal and within reach of floating barges at high tide.
- Transfer of waste material overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Sand placement could be achieved hydraulically (refer **Figure 18**) via a small pipeline (e.g. 100mm diameter, able to be shifted by hand) extending from a floating barge fitted with a slurry pump box and displacement pump for delivery of sand slurry into the pipeline.
- Alternatively, sand could be stockpiled on the beach by small earthmoving equipment deployed on to the beach at low tide by a landing barge, profiled/graded by small earthmoving equipment over the unvegetated shoal area, and distributed throughout the mangroves by hand (using wheelbarrow, spades, rakes etc.).
- Spur walls could be constructed with rock placed with small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge.
- If small equipment access into mangroves is problematic, the spur walls could be constructed with smaller rock that is able to be transported and lifted into place by hand.



Figure 18: Hydraulic sand placement on beach area with small pipeline

Schedule

It is anticipated that remediation of the area would take several weeks to complete.

Contingency Measures

No contingency measures are considered necessary for this area.

Works Validation

Validation of completed works would include:

- pre-remediation topographic survey of the area to record existing surface levels;
- visual observation to confirm removal of surficial coke and coal materials;
- sampling and testing of sand and rock supply to confirm required material specifications are satisfied;
- post-remediation topographic survey to confirm restoration of existing surface levels and the location and form of spur wall structures; and,
- photographic record taken at low tide.

2.4 Remediation Area SA4

Primary Objective

The primary remediation objectives in remediation area SA4 comprise:

- managing sediments that pose an unacceptable risk to human health to users of the beach and mangrove areas in the Southern Area; and,
- installing control measures to ensure stormwater discharge to Kendall Bay does not impact the remediated and managed parts of the Southern and Northern Areas.

Remediation Strategy

The remediation strategy in this area is to clean up the existing beach area by removing coke and coal material (refer **Figure 19** and **Figure 20**) from the sand surface and to a shallow nominal depth of 0.2m (screened sand would be returned to the beach profile). It is noted that the natural rocks shown over the beach on **Figure 19** could also be collected as part of beach clean up activities and beneficially reused in the construction of the spur walls proposed within area SA3.

The public amenity of the beach is to be improved by the placement of a 0.5m layer of clean sand over the area. The grading of the imported sand material would be compatible with the existing beach sand and placed at the same slope and planform alignment. This would minimise readjustment of the beach profile and/or loss of sand offshore under wave action. The nearshore beach slope is around 1V:8H before it flattens significantly to a slope of 1V:100H beyond a bed level of +0.4m LAT, which is at around the Mean Low Water mark. It is estimated that the volume of sand placement would be in the order of 500m³. The conceptual arrangement for the sand fill placement is shown on Drawing 5 and several cross sections are provided on Drawing 6 (refer **Attachment A**).

It is noted that the quantity of sand on the existing beach fluctuates as demonstrated by **Figure 20**, which shows a relatively elevated beach level in August 2012 when compared to the exposed rock material seen during more recent site inspections in July 2016. This fluctuation occurs in response to prevailing wind wave action and the regular action of boat wake waves from Rivercats and Harbourcats, which may

cause beach sand to move alongshore and be captured within the sand shoal that has been established in the mangrove area.

As such, it is necessary to retain any beach nourishment sand within the SA4 area to maintain beach amenity. This would be achieved by a seaward extension of the existing sandstone wall (which is approximately 0.5m wide by 0.5m high, refer **Figure 21**) located on the western side of the beach. This would act as a groyne to retain sand within the embayment created on its eastern side and would also act to prevent scouring of the beach area by meandering stormwater discharge from the head of the Bay (although the proposed spur walls would be the primary means to mitigate this process). The sandstone wall would need to extend offshore beyond the limit of sand placement, which would result in a wall extension length of around 30m.

It is proposed that existing beach access would be improved by provision of steps in front of the seawall at the eastern end of the beach (refer **Figure 20**). These steps could be created with stacked sandstone blocks. The increase in existing beach level provided by the sand placement may also improve beach access from the seawall.

It is anticipated that ongoing maintenance would include occasional removal of mangrove saplings from the beach to prevent encroachment by adjacent mangrove vegetation.

It is also noted that the existing stormwater outlet located towards the eastern end of the beach (refer **Figure 22**) would discharge across the beach creating a scour channel and deposition of debris and rubbish from the catchment. The associated impacts on beach amenity would be resolved by diversion of the outlet to a location further to the east, where stormwater could discharge out on to the existing rock platform. Should this not prove technically feasible other measures could include installation of a gross pollutant trap (GPT) upstream in the system and construction of an energy dissipation structure at the outlet.



Figure 19: Surficial materials existing over eastern side of beach area in July 2016



Figure 20: Sand covering underlying rock and partly blocking stormwater outlet in August 2012



Figure 21: Existing sandstone wall on western side of beach area



Figure 22: Stormwater outlet discharging onto beach area in July 2016

Work Methods

The following work methods are proposed to implement the remediation strategy:

- Construction of the sandstone wall extension over beach and intertidal area could be undertaken by small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge.
- Construction materials would be delivered to the site by barge and an amphibious excavator may be required in areas where weak ground conditions exist.
- Removal of surficial material from the beach area by small earthmoving equipment (e.g. Bobcat or small excavator) deployed on to the beach at low tide by a landing barge, utilising a screening bucket or similar (refer **Figure 23**).
- Waste material would be placed into skip bins positioned on the nearshore sand shoal and within reach of floating barges at high tide.
- Transfer of waste material overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Placement of sand layer over beach by small earthmoving equipment deployed on to the beach at low tide by a landing barge.
- Alternatively, hydraulic sand placement could be achieved as per the method described for SA3 and profiling/grading of placed sand undertaken by small earthmoving equipment.



Figure 23: Small excavators with screening buckets deployed on beach areas

Schedule

It is anticipated that remediation of the area would take several weeks to complete.

Contingency Measures

Use of an amphibious excavator to enable operation on weak ground conditions.

Poor foundation conditions for the wall extension are likely to exist further offshore from the existing beach berm. In this case the wall may need to be constructed on a bridging layer formed by geotextile fabric, geogrid and a rock layer. Alternatively, a supportive platform for the wall extension could be created with mass stabilisation techniques using equipment mobilised for SA1.

Works Validation

Validation of completed works would include:

- pre-remediation topographic survey of the area to record existing surface levels;
- visual observation to confirm removal of surficial coke and coal materials;
- sampling and testing of sand supply to confirm required material specifications are satisfied;
- post-remediation topographic survey to confirm sand placement profile and the location and form of the sandstone wall extension; and,
- photographic record taken at low tide.

2.5 Remediation Area SA5

Primary Objective

The primary remediation objective in remediation area SA5 comprises:

- managing sediments that pose an unacceptable risk to human health to users of the beach and mangrove areas in the Southern Area.

Remediation Strategy

The remediation strategy in this area involves shallow excavation of existing seabed material to 0.3m depth followed by placement of a 0.3m layer of clean sand to match the existing bed level. The sand placement would provide a clean, firmer underfoot, offshore wading area to be accessed from the beach

and would extend to the limit of SA5. The offshore boundary of SA5 is located around the 0.2-0.3m LAT contour, which is around the position of the waterline at Mean Low Water Spring tide (MLWS, 0.27m LAT). The grading of the imported sand material would be compatible with the existing beach sand further inshore. It is estimated that the volume of excavation (and subsequent sand placement) would be in the order of 200m³. Beneficial reuse of the excavated fine grained material would be achieved by blending it with sand used for capping of other remediation areas (e.g. SA1).

The conceptual arrangement for the excavation and subsequent sand fill placement is shown on Drawing 5 and several cross sections are provided on Drawing 6 (refer **Attachment A**).

Work Methods

The following work methods are proposed to implement the remediation strategy:

- An amphibious excavator would track over intertidal/subtidal areas to excavate material.
- An amphibious excavator would place sand from stockpiles located on the beach (SA4) or floating barges.
- Excavated material would be placed into skip bins positioned on the nearshore sand shoal and within reach of floating barges at high tide.
- Blending of excavated material with sand using earthmoving equipment for beneficial reuse in capping of other remediation areas.

Schedule

It is anticipated that remediation of the area would take several weeks to complete.

Contingency Measures

Use of an amphibious excavator to enable operation on weak ground conditions.

Works Validation

Validation of completed works would include:

- pre-remediation survey of the area to record existing surface levels;
- post-excavation survey of the area to confirm depth of excavation prior to sand placement;
- sampling and testing of sand supply to confirm required material specifications are satisfied;
- post-remediation topographic survey to confirm sand placement profile matches existing surface levels; and,
- photographic record taken at low tide.

2.6 Remediation Area NA1

Primary Objective

The primary remediation objective in remediation area NA1 comprises:

- remediating stained surfaces, sediments giving rise to emission of odours when exposed at low tides and the presence of rubbish in accessible areas of the mangroves and in the foreshore adjacent to the seawall in the Southern and Northern Areas.

Remediation Strategy

The remediation strategy in this area would be similar to that employed for SA2. This is to lower the seabed to below the level of Lowest Astronomical Tide (LAT) and to provide a 0.3m thick capping layer for benthic recolonisation. This treatment would prevent air exposure of contaminated rubble material and sediments along the base of the seawall at low tide and improve the marine ecosystem within the Bay. Exposure of material along the toe of the seawall at low tide is reported to be a significant odour generation issue for Breakfast Point residents.

It is proposed that careful excavation of surface stained materials and rubble should be completed at the toe of the seawall down to a target level of -0.3m LAT whilst preserving the existing toe support along the seawall structure. Excavation would be followed by placement of a 0.3m thick layer of cobble sized rock to a finished level of 0m LAT. Sand would be subsequently placed over the rock layer to provide substrate within the interstitial spaces of the rocks for benthic recolonisation.

Work Methods

The following work methods are proposed to implement the remediation strategy:

- Careful excavation of surface materials with a barge-mounted excavator with GPS control at high tide and placement into an adjacent hopper barge or flat barge carrying smaller hoppers or skip bins.
- Transfer of excavated material overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Placement of capping materials (cobbles and sand) using small earthmoving equipment (e.g. Bobcat or small excavator) gradually tipping material over edge of floating barge containing stockpiled material, or capping materials placed and groomed by barge-mounted excavator with GPS control.

Schedule

It is anticipated that remediation of the area would take several weeks to complete.

Contingency Measures

Due to seawall stability concerns, excavation along the toe of the seawall should be completed in limited lengths of maximum 10m followed by placement of capping material before the adjacent excavation is started. The seawall would be monitored for signs of instability during the works, conducted daily. Pre-remediation and post-remediation dilapidation surveys would be conducted.

If excavation of surface material uncovers underlying soft sediments, placement of geotextile fabric and geogrid may be required to limit the loss of capping layer material by it punching through the soft underlying material upon placement.

Odour generation during excavation may be significant and should be closely monitored. If odour cannot be sufficiently managed by the environmental controls (refer **Section 3**), then work may need to cease until suitable conditions exist to continue (e.g. higher tide level, wind direction away from sensitive receptors).

Alternatively, the contaminated materials along to toe of the seawall may be able to be swept along the seabed into adjacent deeper water areas by a barge-mounted excavator operating at high tide, to

achieve a finished surface below LAT. This would avoid exposure of excavated material to air during remediation activities whilst achieving the human health objective to limit odour generation at low tide.

Works Validation

Validation of completed works would be achieved at different stages of construction and would include:

- confirmation of excavation levels with records from GPS attached to the barge-mounted excavator;
- hydrographic survey (supplemented by land-based survey in shallow areas) to determine pre and post excavation levels;
- sampling and testing of sand and rock supply to confirm required material specifications are satisfied;
- confirmation of finished capping levels with GPS attached to placement equipment and hydrographic survey (supplemented by land-based survey in shallow areas);
- verification of capping layer thickness by comparison of pre and post capping surveys;
- pre-remediation and post-remediation seawall dilapidation surveys; and,
- photographic record taken at low tide.

2.7 Remediation Area NA2

Primary Objective

The primary remediation objective in remediation area NA2 comprises:

- remediating to the extent practicable the surface sediments that pose an unacceptable risk to human health in the Southern Area and that pose an acute risk to the marine ecosystem.

Remediation Strategy

The remediation strategy in this area is to establish a surficial layer of material on the seabed for establishment of viable benthic communities. This would initially involve removal of surficial loose contaminated materials over hard surfaces associated with operation and demolition of the former wharf. Cement-based mass stabilisation techniques would then be used to create a 'raft' structure over the remediation area to support the overlying capping material that is to be placed to a finished level equivalent to the existing natural surface. The depth of mass stabilisation would be around 1.3m to allow subsequent shallow excavation to a depth of 0.3m in order to retain a 1m thickness of stabilised material to support the capping layer. It should be noted that in some areas excavation of stabilised material may not be required if the initial excavation of surficial loose material provides sufficient depth for placement of capping material to a finished level below the existing surface.

A 0.3m thickness of cobble sized rock capping material would be placed directly on to the excavated surface cut into the stabilised material. As proposed for remediation area SA1, a layer of granular activated carbon material would be placed as an initial layer incorporated into the base of the 0.3m capping material thickness. Sand would be placed over the rock layer to form substrate within interstitial spaces of the rocks for benthic colonisation. The rock would be placed in at least two layers to ensure that the sand is able to be distributed throughout the entire interstitial space.

Work Methods

The following work methods are proposed to implement the remediation strategy:

- Excavation of loose surface materials with a barge-mounted excavator with GPS control and placement into an adjacent hopper barge or flat barge carrying smaller hoppers or skip bins.
- Transfer of excavated loose surface materials overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Insitu cement stabilisation of upper sediment layer using barge-mounted equipment, comprising a drilling rig, binder silo and mixing plant and grout pump. A series of overlapping cement stabilised columns would be constructed to the stabilisation depth using a hollow-stem auger in a similar manner to that described for creation of deep soil mixed columns in remediation area SA1.
- Excavation of cement stabilised material (as required to provide a 0.3m depth below the existing seabed level for placement of capping material) with barge-mounted excavator and placement into an adjacent hopper barge or flat barge carrying smaller hoppers or skip bins.
- Transfer of excavated cement stabilised material overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Placement of capping materials to match existing seabed levels using small earthmoving equipment (e.g. Bobcat or small excavator) gradually tipping material over edge of floating barge containing stockpiled material, or capping material placed and groomed by barge-mounted excavator with GPS control.

Schedule

It is anticipated that remediation of the area would take several weeks to complete.

Contingency Measures

Odour generation during initial excavation of loose surface materials may be significant and should be closely monitored. If odour cannot be sufficiently managed by the environmental controls (refer **Section 3**), then work may need to cease until suitable conditions exist to continue (e.g. higher tide level, wind direction away from sensitive receptors).

Although the presence of debris associated with the former wharf is expected to limit settlement of the cement stabilised layer, settlements in excess of tolerable levels could be mitigated by installation of suitably spaced deep soil mixed columns extending down to the level of competent Unit 2B material. These would support the mass stabilised 'raft' in a similar manner to that proposed for remediation area SA1.

Works Validation

Validation of completed works would be achieved at different stages of construction and would include:

- confirmation of the depths and coverage achieved with deep soil mixed columns by records from GPS attached to the mixing equipment;
- coring of stabilised material and testing to confirm strength gain over time;
- hydrographic survey of the surface of stabilised material to determine pre and post excavation levels;
- sampling and testing of sand and rock supply to confirm required material specifications are satisfied;

- confirmation of finished capping levels with GPS attached to placement equipment and hydrographic survey;
- verification of capping layer thickness by comparison of pre and post capping surveys;
- underwater photography using a drop camera at high tide; and,
- diver inspection at high tide.

2.8 Remediation Area NA3

Primary Objective

The primary remediation objective in remediation area NA3 comprises:

- remediating to the extent practicable the surface sediments that pose an unacceptable risk to human health in the Southern Area and that pose an acute risk to the marine ecosystem.

Remediation Strategy

The remediation strategy in this area is to establish a surficial layer of material on the seabed for establishment of viable benthic communities. Cement-based mass stabilisation techniques would be used to create a 'raft' structure over the remediation area to support the overlying capping material that is to be placed to a finished level equivalent to the existing natural surface. The depth of mass stabilisation would be around 1.3m to allow subsequent shallow excavation to a depth of 0.3m in order to retain a 1m thickness of stabilised material to support the capping layer. The mass stabilised 'raft' would be supported on deep soil mixed columns extending down to the level of competent Unit 2B material to minimise settlement.

A 0.3m thickness of cobble sized rock capping material would be placed directly on to the excavated surface cut into the stabilised material. As proposed for remediation area SA1, a layer of granular activated carbon material would be placed as an initial layer incorporated into the base of the 0.3m capping material thickness. Sand would be placed over the rock layer to form substrate within interstitial spaces of the rocks for benthic colonisation. The rock would be placed in at least two layers to ensure that the sand is able to be distributed throughout the entire interstitial space.

Work Methods

The following work methods are proposed to implement the remediation strategy:

- Construction of supportive columns using barge-mounted equipment, comprising a drilling rig, binder silo and mixing plant and grout pump.
- Insitu cement stabilisation of upper sediment layer using the same barge-mounted equipment above. A series of overlapping cement stabilised columns would be constructed to the stabilisation depth using a hollow-stem auger.
- Excavation of cement stabilised material with barge-mounted excavator and placement into an adjacent hopper barge or flat barge carrying smaller hoppers or skip bins.
- Transfer of excavated cement stabilised material overwater by barge to the Tennyson Road site for treatment and disposal by truck to a licensed waste facility.
- Placement of capping materials to match existing seabed levels using small earthmoving equipment (e.g. Bobcat or small excavator) gradually tipping material over edge of floating barge containing stockpiled material, or capping material placed and groomed by barge-mounted excavator with GPS control.

Schedule

It is anticipated that remediation of the area would take several weeks to complete.

Contingency Measures

No contingency measures are considered necessary for this area.

Works Validation

Validation of completed works would be achieved at different stages of construction and would include:

- confirmation of the depths and coverage achieved with deep soil mixed columns by records from GPS attached to the mixing equipment;
- coring of stabilised material and testing to confirm strength gain over time;
- hydrographic survey of the surface of stabilised material to determine pre and post excavation levels;
- sampling and testing of sand and rock supply to confirm required material specifications are satisfied;
- confirmation of finished capping levels with GPS attached to placement equipment and hydrographic survey;
- verification of capping layer thickness by comparison of pre and post capping surveys;
- underwater photography using a drop camera at high tide; and,
- diver inspection at high tide.

3 Environmental Monitoring and Controls

Environmental monitoring would include:

- Water quality monitoring for parameters including turbidity, contaminants of concern and pH;
- Air quality monitoring for odour and dust; and,
- Noise monitoring.

Environmental controls that could be applied include:

- installation of silt curtains and oil absorbent booms around work areas, these barriers would need to incorporate an overlapping gate system to allow passage of floating equipment (with consideration of water quality 'inside' and 'outside' of the enclosure prior to opening) and be able to compensate for tidal water level variation across shallow foreshore areas;
- maintenance of oil absorption equipment and oil spill response kits onboard all floating vessels;
- minimising the use of propellers and anchoring within remediation areas;
- manoeuvring of non-propelled vessels should be undertaken using winches and cables wherever possible within the shallow waters of Kendall Bay in preference to the use of engine propulsion;
- limiting the speed of construction traffic to that which would minimise unnecessary generation of boat wake waves within Kendall Bay;
- use of shallow draft construction vessels to limit bed disturbance;
- no fines content within imported fill materials (e.g. cobbles, sand);
- use of a 'moon pool' (created by hanging a silt curtain from a floating boom attached to the excavator barge) where practicable whilst undertaking excavation from floating equipment (refer **Figure 24**);
- using an environmental clamshell (refer **Figure 25**) where practicable to minimise the entrainment of water into excavated material (an open bucket would need to be used for areas containing significant amounts of debris);
- lashing of hopper barges to the excavator barge so that they are immediately adjacent to the excavator barge during loading operations;
- maintaining a cover of water over excavated materials placed in hopper barges;
- placement of a cover over hopper barges or lids over skip bins during transit of excavated material to the Tennyson Road site;
- odour control with installation of scented sprays around perimeter of work area in vicinity of sensitive receivers;
- cement dust suppression during mass stabilisation activities with water sprays;
- noise control measures including:
 - restricted hours of operation;
 - scheduling of noise generating activities at times to cause the least annoyance to the community (e.g. avoid early morning);
 - regular and effective maintenance of plant and equipment;
 - installation of mufflers and the like on plant and equipment to suppress noise generation; and,
 - selection of the smallest size of equipment necessary to complete activities.
- decontamination of equipment:
 - no equipment is to be cleaned outside of remediation areas;
 - no equipment that has been working in an unremediated area is to access a remediated area without being decontaminated; and,
 - All equipment is to be decontaminated prior to leaving the site.



Figure 24: Excavation within a silt curtain enclosure



Figure 25: Hydraulically controlled environmental clamshell attachment

4 Post-Remediation Environmental Management Plan

4.1 Monitoring

Post-remediation monitoring activities relating to the engineering and physical aspects of the remediation works could include:

- Hydrographic surveys – over remediation areas to monitor settlement or sedimentation;
- Sub bottom profiling (geophysical survey) – over capped areas to monitor cap thickness;
- Sediment sampling and analysis – surficial sediments over capped areas to monitor contaminant migration and sedimentation;
- Water quality monitoring – to verify that site remediation and disturbance has not caused any adverse impacts on water quality; and,
- Beach survey – along several transect lines perpendicular to the shoreline alignment to monitor beach response.

The above monitoring activities could be undertaken every 6 months initially up to 2 years after remediation. After this, subject to findings, monitoring activities would be undertaken on a yearly basis up to 5 years after remediation. At this point, the results of monitoring would be reviewed to determine whether the monitoring frequency could be further reduced or discontinued on the basis of findings.

In addition to scheduled monitoring activities, reactive monitoring would be undertaken following major storm events such as flooding and very strong winds. This monitoring would include hydrographic survey and beach survey, and possibly sub bottom profiling depending on results of the hydrographic survey.

Reports for each monitoring activity would be prepared for submission to the EPA.

Other post-remediation monitoring activities relating to the ecological and environmental performance of the remediation works would also be required.

4.2 Maintenance

Maintenance activities that may need to be completed in response to findings during the post-remediation monitoring period could include topping up of beach sand levels. Other routine maintenance activities could include removal of mangrove saplings and clean up of debris/rubbish (from stormwater outlet discharge) from the beach area.

5 References

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Taguchi, H. (2015), *Application of the cement deep mixing method for shallow water areas using the CDM-FLOAT technique*, Deep Foundations Institute.

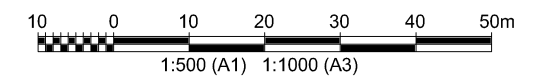
Attachment A: Drawings

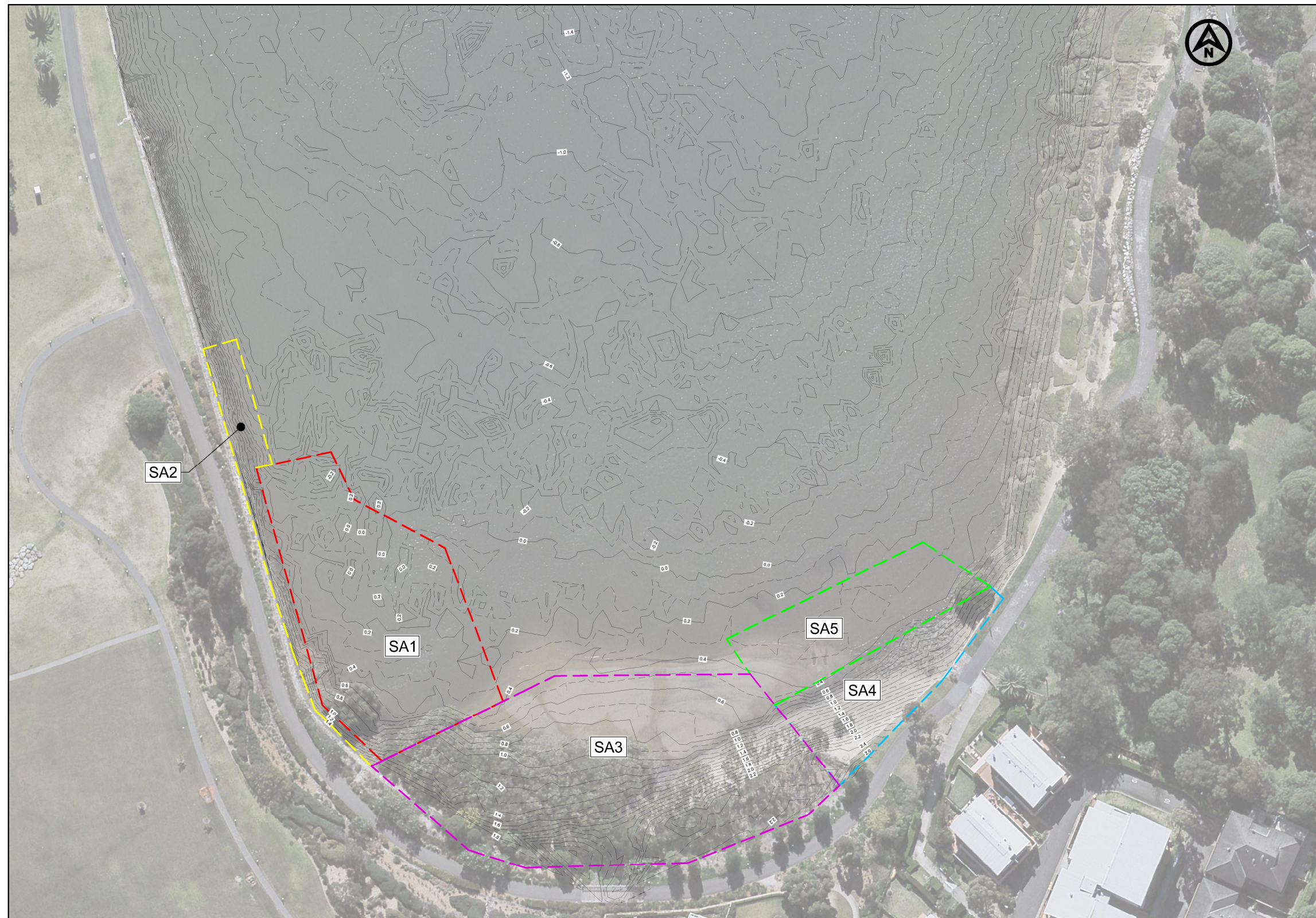


NOTES

1. CHART DATUM IS APPROXIMATELY EQUIVALENT TO LOWEST ASTRONOMICAL TIDE (LAT).
2. REMEDIATION AREA BOUNDARIES PROVIDED BY SYNNOT & WILKINSON.

CHART DATUM

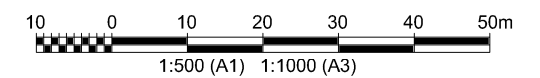


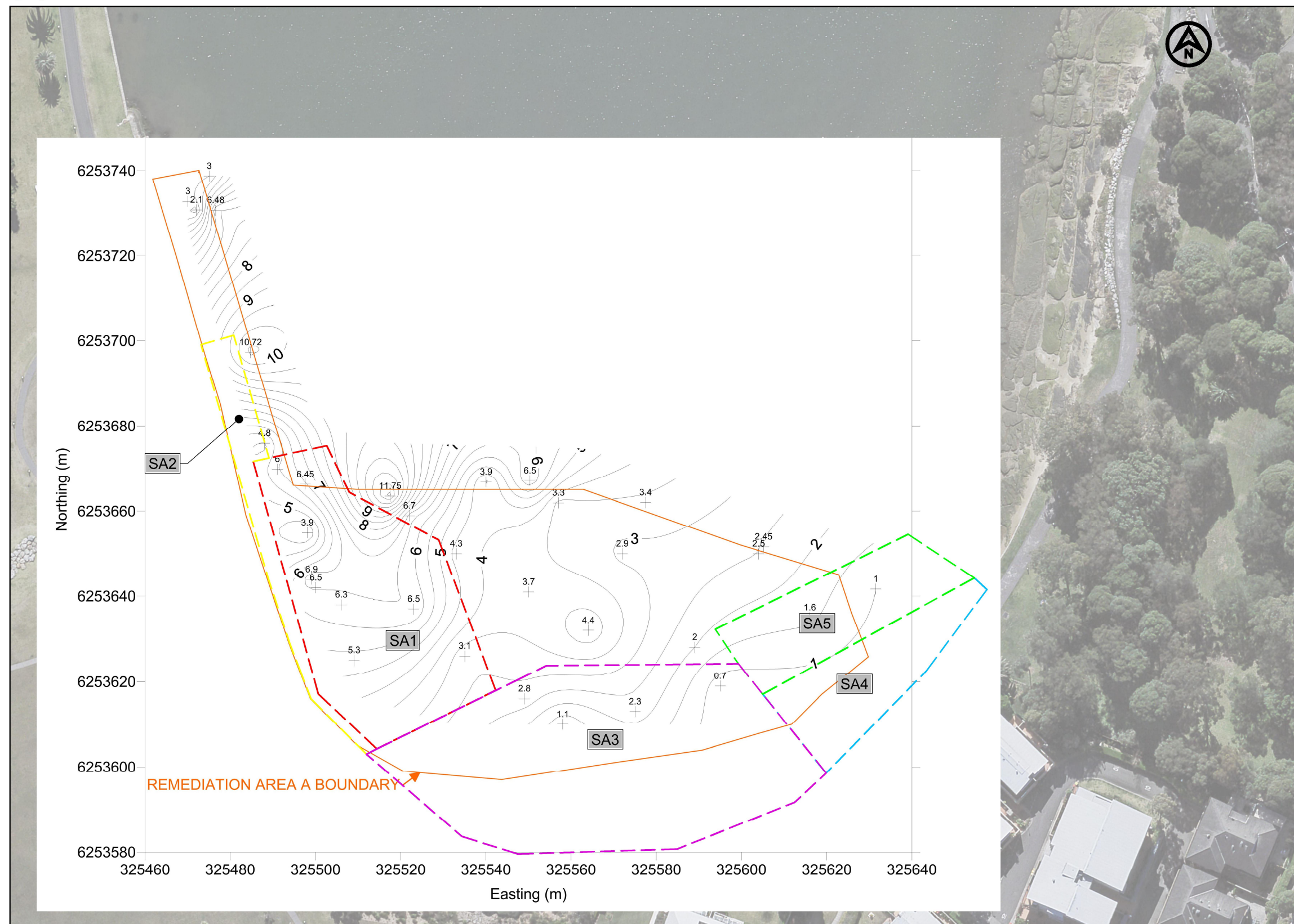


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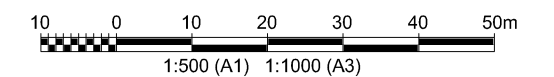
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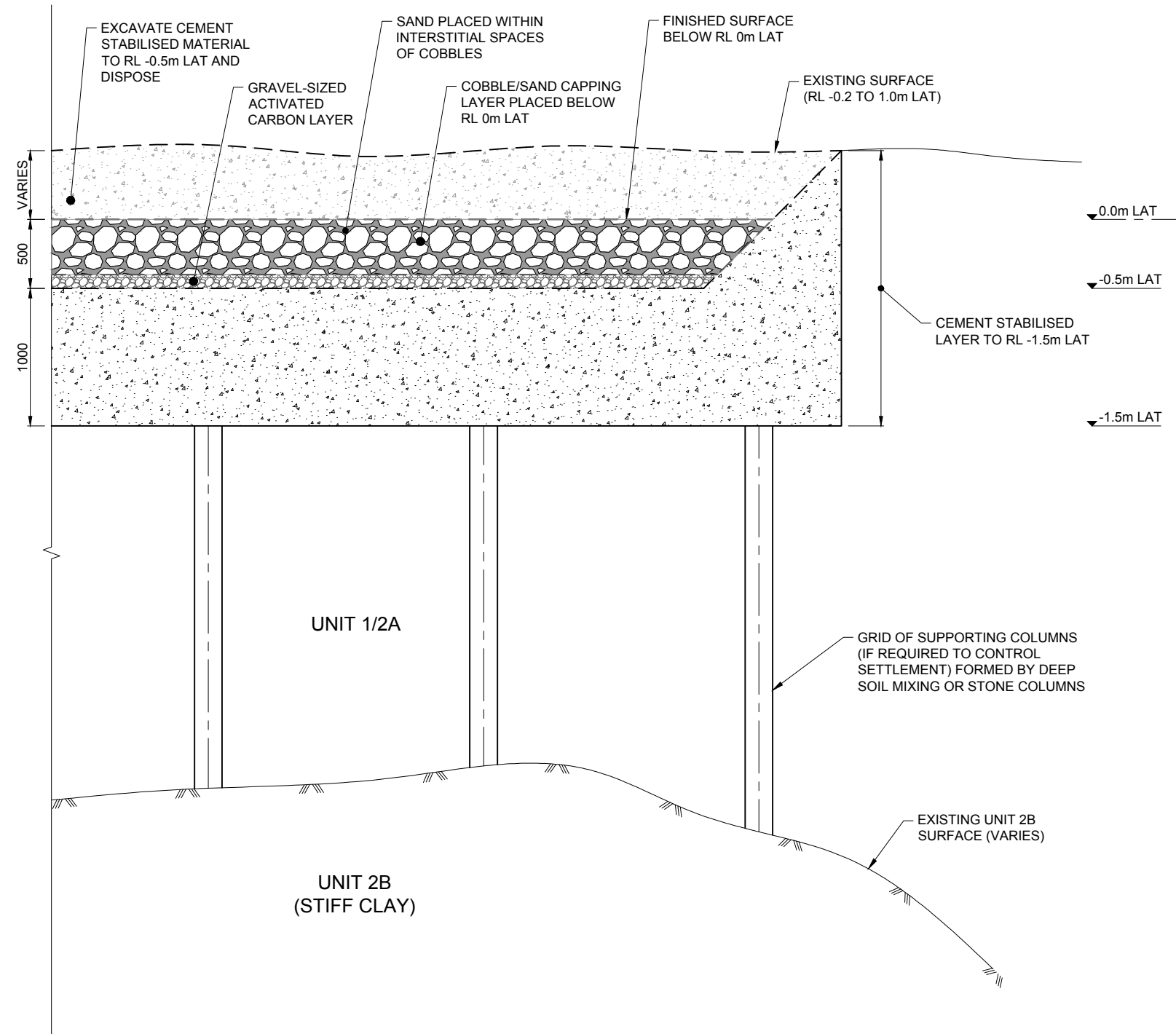
NOTES

1. REMEDIATION AREA A BOUNDARY IS FROM A FORMER REMEDIATION ACTION PLAN.

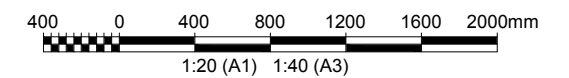


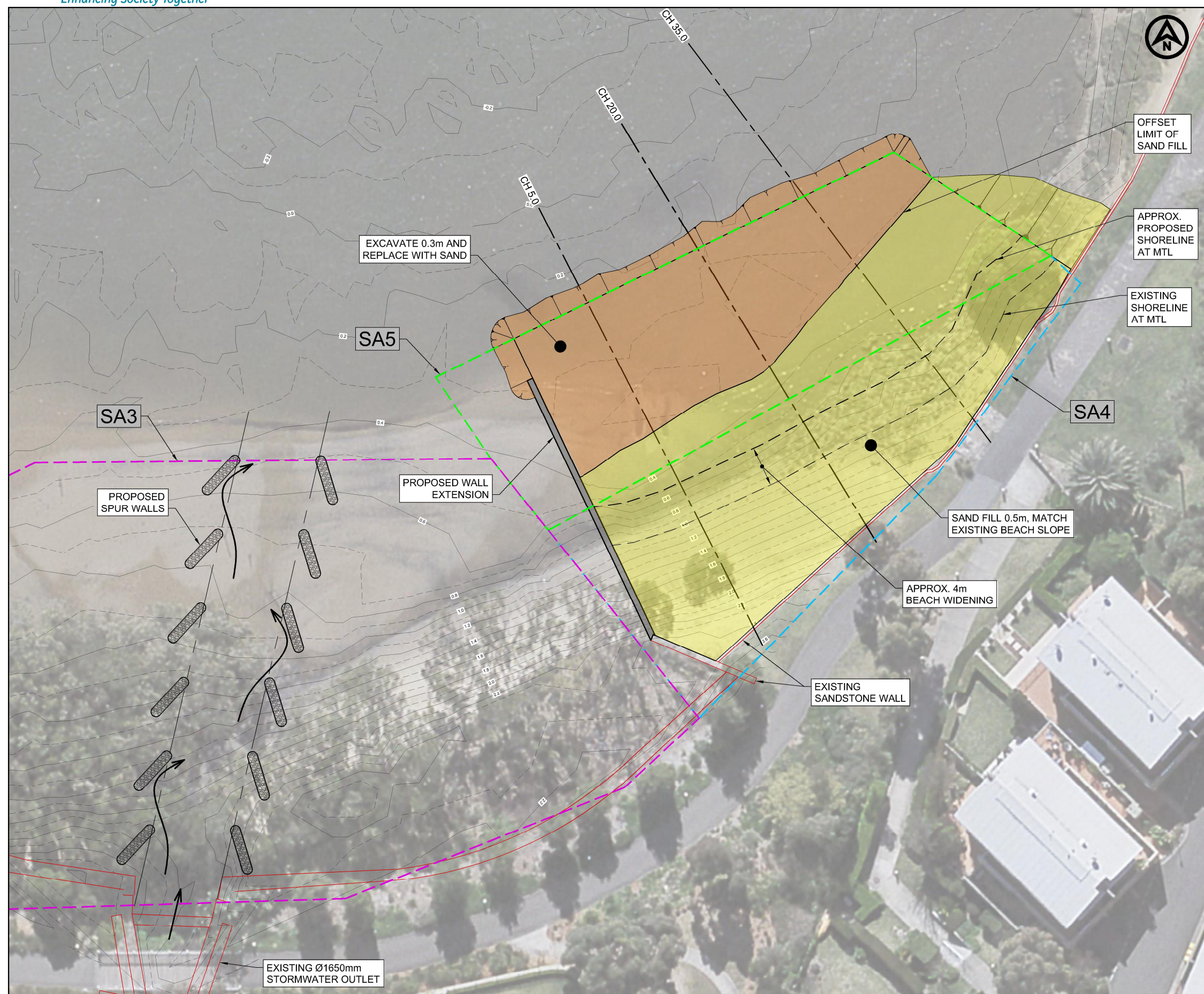
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1. CHART DATUM IS APPROXIMATELY EQUIVALENT TO LOWEST ASTRONOMICAL TIDE (LAT).



TYPICAL SECTION
1:20 (A1)

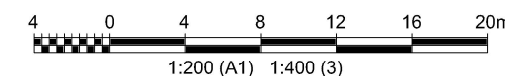


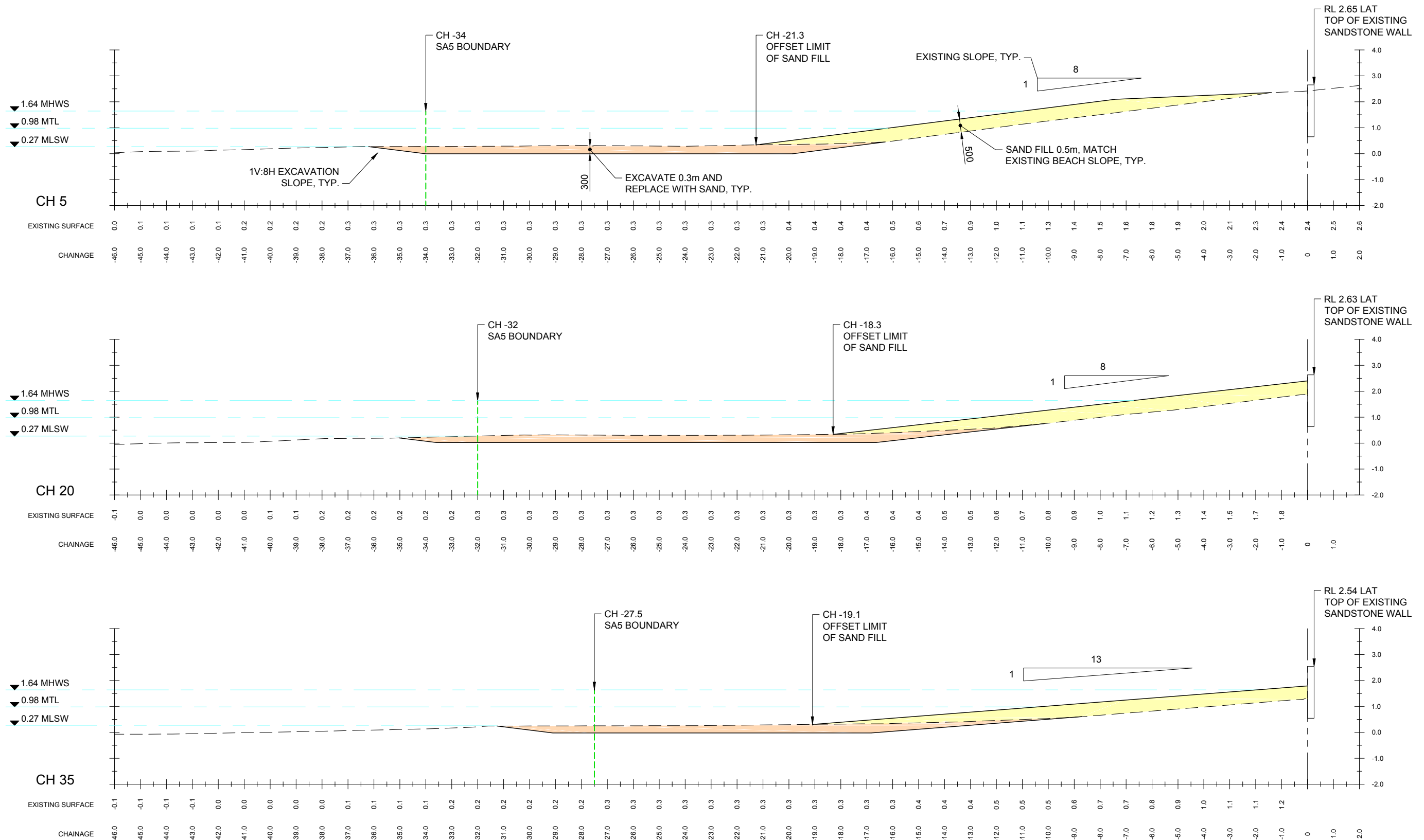


NOTES

1. CHART DATUM IS APPROXIMATELY EQUIVALENT TO LOWEST ASTRONOMICAL TIDE (LAT).
2. RL 0.98 LAT IS APPROX. MEAN TIDE LEVEL (MTL).

CHART DATUM

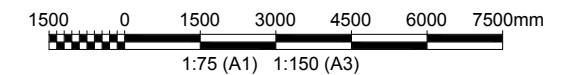




NOTES

- CHART DATUM IS APPROXIMATELY EQUIVALENT TO LOWEST ASTRONOMICAL TIDE (LAT).
- SCREENING OF SURFICIAL BEACH MATERIAL NOT SHOWN.

CHART DATUM



Attachment B: CSIRO Activated Carbon Technology Brief

Technology Brief - Activated carbon (carbonaceous materials) amendment technologies for sediment management (in situ remediation)

INTRODUCTION

Within sediment remediation projects, amendments may be applied into or onto the sediment surface layer, into a sand cap, or within a geotextile mat to reduce the bioavailability of contaminants of concern (COCs). When compared to sand or sediment caps, amended caps have the potential to reduce the thickness of traditional caps and also improve resistance to erosional events. Amended caps are usually designed to be permeable, thus allowing for groundwater flow and tidal fluctuations, and improved advective transport of COCs by ebullition and NAPLs.

Many sorptive treatment amendments that have been trialed for binding contaminants, including activated carbon (AC) and other various carbonaceous amendments (CM, e.g. biochar, coke) organoclays (e.g. bentonite with an organic molecule), apatite (phosphate mineral), zeolites, bauxite, and zero valent iron. The amendments AC, organoclay, and apatite have been found to be the most effective for in situ sediment remediation and AC particularly effective for control dissolved HOCs.

The high degree of sequestration of HOCs (such as PAHs and PCBs) by activated carbon (AC) has been recognized for decades. Applications of AC for remediation purposes have been used for soils since the 1960s. During the 1970-1990 period the science has developed strongly, and practical applications and guidance for sediments from 2000. Numerous demonstrations have been performed in laboratory and the field (freshwater and marine), and many larger scale demonstrations from year ~2004 to present.

Organoclays have been designed to capture NAPL while being permeable enough to permit groundwater advection (minimize swelling) and gas migration, and mixtures of binding phases (e.g. organoclays and AC) can be prepared.

Carbonaceous Materials (CM) and Activated Carbon (AC)

Carbonaceous materials (CM) such as soot and charcoal, often referred to as black carbon (BC) or hard carbon, may bind sediment-bound hydrophobic organic contaminants (HOCs) very strongly, up to one to two orders of magnitude higher than those for natural amorphous organic matter (OM)

Activated carbon (AC) is a porous, manufactured material with a high surface area and affinity for adsorbing contaminants. AC is produced from coal or biomass feedstock and treated at high temperature to produce a highly porous structure with great sorption capacity for HOCs.

The function of AC is to reduce porewater concentrations of HOCs by sequestration and binding to the AC surface. AC has slow kinetics of contaminant desorption.

AC amendment does not decrease total sediment concentrations of contaminants. Rather, it decreases contaminants available for biouptake and transport to surface- and groundwater.

Sustainability

In situ AC sediment treatment remedies may offer significant environmental benefits, while avoiding the environmental impacts often associated with more invasive sediment cleanup technologies (far less disruptive to communities and stakeholders than dredging or many conventional capping remedies).

Increasingly, a combination of sediment cleanup technologies applied specific zones within the sediment cleanup site will provide the best outcomes (long-term protection while minimizing short-term negative impacts and achieving greater cost effectiveness).

Project examples

The field site trials of AC treatments span range of contaminated aquatic environments: tidal creek and marsh and mudflat, freshwater river, marine harbor, deep-water fjord.

Pilot- or full-scale field sediment treatment have been completed or are underway at more than 25 field sites in the United States, Norway, and the Netherlands (see Figure in Patmont, 2015).

It is now quite evident that when applied correctly, in situ treatment of sediment HOCs using sorptive, AC-bearing materials has progressed from an innovative sediment remediation approach to a proven, reliable technology.

Types of AC Materials and Application

There exist multiple providers of AC materials that have been demonstrated as suitable for achieving remediation goals, for example:

- Aquablock (a dense aggregate core, clay agglomerate of clay-sized materials, polymers, and powdered AC additives): <http://www.aquablok.com/in-situ-treatment/>
- Bioblock: http://www.biologge.no/en/bioblok_old/bioblok_sediments_old/
- Sedimite (includes weighting and inert binder, pelletized form that breaks up over time): <http://sedimite.com>
- TOG (Calgon Carbon, water focus): <http://www.calgoncarbon.com/granular-activated-carbon/>
- Rembind: <http://www.ziltek.com.au/>

Green remediation: Life cycle analyses have demonstrated that AC produced from anthracite coal is less sustainable than AC produced from biomass feedstock (plants, e.g. coconut charcoal).

AC form, size, and dose

The AC type, particle size and dosage, sediment characteristics, and properties of contaminants affect the effectiveness of AC amendment to immobilize HOCs in aquatic sediments.

For most applications, a 2 to 4% AC dose (dry weight) provides 60 to >95% reduction in porewater concentrations of the major HOCs, PAHs and PCBs.

Greater surface area increases rate of binding, but more difficult to apply and control fate and effects.

- Powdered Activated Carbon (PAC) (varying definitions: <300 μm ; <180 μm)

- High surface area facilitates fast sorption kinetics.

Granular Activated Carbon (GAC) (varying definitions: >300 μm ; 90% >180 μm)

- >400 μm size range not effective
- 75 to 300 μm size range very effective. Not as effective, being not as fast adsorption kinetics (month-years) as PAC in removing HOCs from dissolved phase, but similar effectiveness in long term.

Generally, a 1-cm-thick AC amendment layer and a 1-m-thick cap of sand have similar ability to isolate contaminated sediments. However, project-specific conditions, such as bioturbation, will require a thicker cap (than 1 cm) to guarantee isolation.

AC application methods

Amendments can be applied as direct amendment (onto or into sediment surface, with or without mixing in the sediment), as blended cover (within a sand cap as a layer or distributed), or contained in a mat (Figure 1). Placements methods include:

1. applying (spraying) an AC slurry as a thin layer to surface sediment (1-2 cm) (AC material may include weighting or binding materials). Mechanical spraying devices used include a pneumatic spreader, bark blower, or hydroseeders etc.
 - may include mixing the material in (e.g. with mechanical mixing equipment such as a tiller)
2. injecting/mechanical mixing an AC slurry into the sediment surface (to 15-30 cm depth) using a mechanical equipment such as a tine sled device.
3. hydraulic spreading from a barge of AC amendment premixed into clean sand or sediment to create a blended cover material (10-20 cm thick layer) over large areas.
4. laying of mats/geotextiles (e.g. 1-2 cm mat laid by crane and anchored in place to counter any mat buoyancy).

Care taken to ensure capping materials are homogenous

When applying to existing sediments, applications have generally sort to achieve %-AC similar to the %-TOC of the native sediments.

Initial mixing of CM with sediment and subsequent remixing can be advantageous because of the more homogenous distribution of CM between sediment particles, which facilitates HOC mass transfer.

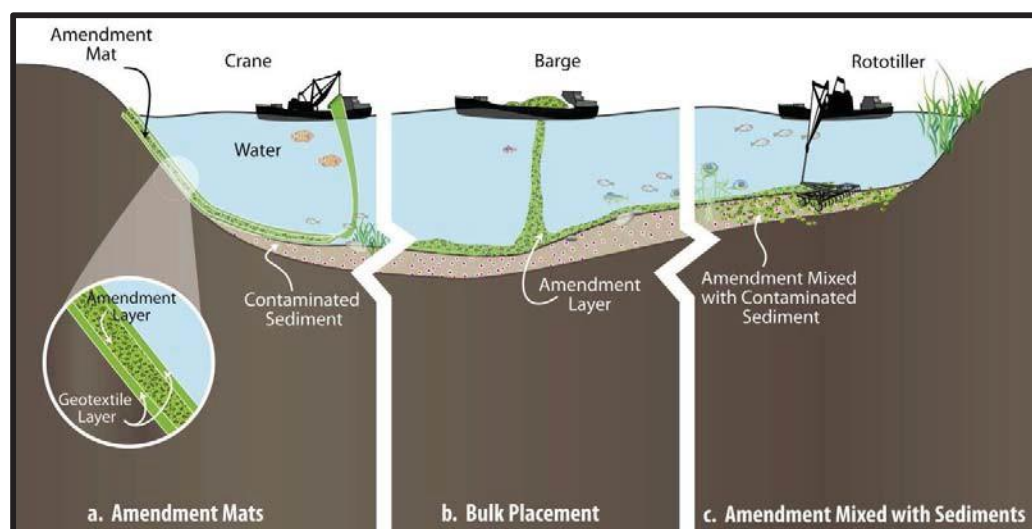


Figure 1: Placement Methods for Sediment Amendments (from USEPA, 2013)

Validation tests and monitoring

The effectiveness of AC treatments may be variable from site to site depending on the properties of the target contaminant, site conditions, and engineering options applied for the treatment. Specific-site and sediment characteristics can reduce the effectiveness of AC application compared to other potential sediment cleanup technologies. These characteristics include (but are not likely limited to) the presence of non-aqueous phase liquids (NAPLs), relatively high concentrations of black carbonaceous particles or tar-like materials that may interfere with HOC sorption to AC, or other factors that result in slow sediment-to-AC transfer rates for relatively large molecular volume HOCs (Choi et al. 2014; 2016).

A range of short- (days-weeks) to medium term screening tests (2-3 months) should be undertaken to optimize AC materials (e.g., grain size or porosity) and dosing based on site-specific conditions (sediment properties etc). Screening assessments will typically include (i) short-term slurry-phase tests being conducted using representative sediment samples collected in the field, with assessment of HOC physicochemical properties, partitioning- and desorption characteristics, AC sorption, and (ii) mid-term validation tests that assess final aqueous HOC concentrations (reduction >70% desired) and effects testing to validate (chronic toxicity of bioaccumulation tests).

Monitoring of amendments is required to evaluate whether reductions in chemical toxicity, bioavailability, or fluxes have been achieved and maintained. In the months to years after AC placement, appropriate field monitoring methods should be used to confirm the success of the in-situ AC amendment. The methodology and schedule should be appropriate to monitor AC placement stability, contaminant (bio) availability, ecosystem health. Typically such post-AC treatment studies would include analyses of porewater HOC concentrations or contaminant flux to water, together with chronic toxicity and bioaccumulation studies.

Effectiveness and Challenges

Up to 100-fold porewater concentration reductions in HOCs and a significantly increased survival of benthic invertebrates in contaminated sediments have been observed from AC-treatments.

The long-term permanence of amendments and their ability to retain contaminants over time are not well understood.

The negative effects of AC itself on benthic species, if any, have been shown to be mild. For GAC amendments/treatments, few negative effects have been observed when GAC <4%. For PAC amendments/treatments, negative effects are more frequently observed. Higher AC dose and smaller AC particle size further reduce bioaccumulation of HOCs but may induce stress in some organisms.

Negative effects, sometimes observed at higher AC concentrations, have generally been quite mild. In a review of 'biological responses to activated carbon amendments in sediment remediation', Janssen and Beckingham (2013), observed effects in ~18% of studies, broken down as effects to organism survival (2%), growth (6%), behavior (5%), and lipid content (5%). Low dose AC amendments generally show no or only mild effects on the diversity and abundance of the benthic community.

Overall, the beneficial effects of reducing toxicity at low AC concentrations most probably outweigh the mild negative effects observed at higher AC concentrations. Numerous studies have also indicated benefits of AC amendments even in uncontaminated sediments.

Some influence on effectiveness of AC-treatments may be attributed to organism behaviour (e.g. dissolved/dietary exposure). AC may either directly sorb nutritive substances or sorb enzymes and other solubilizing agents in the gut, which would be dependent on AC particle size and an organism's feeding behavior. Thus sediment-dwelling organisms that ingest considerable amounts of sediments, such as worms, may be more susceptible to AC amendment because they are exposed to AC not only by direct contact but also by the ingestion of AC particles (effects feeding and lipid content).

Dilution of nutritional content of sediment or changes in bulk density by AC treatment may reduce plant growth and biomass.

Isolation of the AC-amended sediments (active capping layer) with clean sediment/sand (inactive capping layer) may have additional benefits. Additional capping layers may decrease the risk of contaminated AC dispersion and lower footprint of AC-amendment footprint.

AC application complexity and challenges

AC delivery via dosing can be problematic in surface sediments due to near neutral buoyancy of AC, and challenges with obtaining homogeneity (e.g. mixing in, even thickness). Therefore delivering AC-treatment materials as more dense materials (e.g. bound-AC forms – see providers above).

Sediments with high content naturally present black carbon (BC) or oil may sequester HOCs very effectively, thus limiting the effectiveness of CM/AC amendments.

Contaminants may move through the cap due to: dynamic hydrological and topographical conditions, permeability or erosion of capping materials (engineer material to prevent), organisms bioturbating deeper than the thickness of the cap (significant thickness)

Mixed binding layers may have advantages, e.g. organoclays (modified bentonite) for control of non-aqueous phase liquids (NAPLs).

When applying mats or geotextiles (impregnated with AC), care must be taken to minimize potential damage to the mat and provide a more even surface for placement (rocks and debris removed from sediment surface).

If mats or geotextiles lose their permeability, in locations with significant groundwater flow or gas ebullition there is the potential for the mat/geotextile to be lifted.

Periodic maintenance of amended sediments/caps may be necessary to ensure long life.

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Composite Particle System

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TECHNICAL SUPPORT/ENGINEERED SOLUTIONS

At AquaBlok we have the expertise to help you engineer the right solution to meet the special challenges of your project. The company has performed both on-site studies and lab column testing to characterize and test various product and/or treatment material applications for a particular site. Services include:

- Project-Specific Bench Scale/Field Testing & Analysis
- Pilot Application Technical Assistance
- On-Site Observation And Application Assistance Including Oa/Qc

ON-SITE INSTALLATION SUPPORT

AquaBlok works with most standard installation methods. We can package and transport AquaBlok in the configuration that best meets your project needs. AquaBlok offers convenient packaging for easy unloading and placement. We offer flexible transportation arrangements to meet your specific project needs. AquaBlok works with common installation methods:

- Excavator
- Conveyor
- Stone Slinger
- Clamshell Barge
- Helicopter

FLEXIBLE PACKAGING & SHIPPING OPTIONS

AquaBlok packaging and delivery methods are designed to maximize efficiency. AquaBlok can be shipped to your site in easy-to-handle, cost-effective packaging for efficient application to the target area. We can meet your specifications for project volume and preferred delivery method. For very large product volumes we can manufacture product on-site, which reduces costs for transportation and packaging. AquaBlok is available in the following standard packaging sizes:

50 LB. PAILS/BAGS — 1.5-TON SUPERSACKS — 20-TON BLADDER BAGS — ON-SITE PRODUCTION

PROVEN TECHNOLOGY FOR BOTH: CONTAINMENT AND TREATMENT OF CONTAMINATION

+ SEALING IN A WIDE RANGE OF GEOTECHNICAL APPLICATIONS

AQUABLOK ENVIRONMENTAL+GEOTECHNICAL SOLUTIONS

AquaBlok® is a patented material based on a composite-aggregate technology resembling small stones. It is comprised of a dense core, clay or other amendment coating material (the active layer), and polymers. The selection of coating material is based on the application that is being targeted. The use of a bentonite coating layer provides a highly impermeable sealant layer that can be used in sediment remediation and a wide range of upland and aquatic sealing applications.

ENVIRONMENTAL REMEDIATION SOLUTIONS

Includes contaminant sequestration and treatment in a broad range of settings, particularly subaqueous sediments. Other focus areas include addressing nutrient bioavailability and ecological restoration.

GEOTECHNICAL SOLUTIONS/SEALING

Includes seepage reduction and low permeability/containment alternatives in a wide variety of circumstances and settings — ponds, dams, streams, wetlands, manholes, trench dams and wells.

SIMPLE DESIGN, GREAT BENEFITS: AGGREGATE CORE + COATING = AQUABLOK/AQUAGATE+ COMPOSITE PARTICLE





ENVIRONMENTAL REMEDIATION SOLUTIONS.

AquaBlok provides a low-permeability physical **isolation barrier**, while AquaGate+ delivers permeable, **in-situ** chemical and biological treatment materials.

AquaBlok and AquaGate+ are two distinctly different composite material solutions that have been applied successfully in the United States and key locations around the globe. AquaGate delivers amendments in a thin coating around an inner core, allowing movement of water through the matrix for treatment, while limiting the migration of contaminants. Sites where AquaBlok and AquaGate+ materials have been applied have been monitored and studied extensively, including an in-depth evaluation by the U.S. EPA (Superfund Innovation Technology Evaluation).

- AquaGate+ Benefits:
- Uniform delivery through a water column
 - Minimal material separation or loss of high-value, low concentration amendments
 - Creates uniform layers with less material; field mixing or blending not required
 - Installation support; in-house technical support
 - Custom-formulated to your specifications

AquaGate+ (AMENDMENTS)			
ORGANOCLAY	EHC-M™	CLINOPTILOLITE	MICROBES
POWDER ACTIVATED CARBON (PAC)	SULFUR COMPOUNDS	ORGANIC CARBON	
ZERO VALENT IRON (ZVI)	ALUMINUM SULFATE	SORBSTER™	

APPLICATIONS:	AquaBlok	AquaGate+
MGP SITES (COAL TAR)	⊙	⊙
REFINERY SITE (PAH, DIESEL)	⊙	⊙
RIVERINE (PCBS, DIOXIN, PAH)	⊙	⊙
POND (METALS, MERCURY)	⊙	-
UPLAND SEEP ZONE (ARSENIC)	⊙	⊙
INSTALLATION CONFIGURATIONS:		
LOW PERMEABILITY CAP	⊙	-
CUT-OFF WALL	⊙	-
UPLAND PRB	⊙	⊙
LANDFILL CAP REPAIR	⊙	-
FUNNEL & GATE	⊙	⊙
POST-DREDGE BACKFILL	⊙	⊙
IN-SITU TREATMENT	-	⊙
REACTIVE CAPPING	-	⊙
BANK STABILIZATION, RESIDUAL SEQUESTRATION	⊙	-

AquaGate+

GEOTECHNICAL SOLUTIONS/SEALING.

AquaBlok sealing and **delivery system** technology can be successfully applied to a wide range of **geotechnical** applications.

Bentonite is well known for its sealing capability, and our patented bentonite-coated aggregate materials provide a more effective application of this proven sealing material. Our engineered bentonite creates a low hydraulic conductivity and high solids seal that resists erosion and fully hydrates within 24 hours. The superior qualities of AquaBlok have proven to exceed alternative options in results, convenience and ease of implementation—all of which result in lower project costs.

- Key Benefits/Technical Advantages
- Efficient delivery of high-value sodium bentonite at relatively low concentrations
 - Improved uniformity and reliable seal in inches rather than feet
 - No field mixing or blending
 - Low cost handling & installation

AquaBlok (APPLICATIONS)		
POND CONSTRUCTION	FLOOD MITIGATION	WELL SEALANT & GROUT
DAM/BERM CONSTRUCTION (CORE TRENCH)	STRUCTURE BEDDING	WETLAND RESTORATION
ANTI-SEEP COLLARS, TRENCH DAMS	SLOPE STABILIZATION	
TEMPORARY & DIVERSION DAMS	LANDFILL PATCH	

Annular Sealants

HoleBlok & **HoleBlok+**™ are bentonite-coated composite particles that perform better than traditional bentonite pellets at a lower price. HoleBlok+ is the first annular sealant material to include reactive amendments to address sorption and chemical “rebound” or “draw-down” effects in monitoring wells compared to typical coated bentonite pellets.

Wetland Restoration

SubmerSeed® is an alternative to traditional means of plant propagation in wetland/aquatic settings with significant advantages over seed or plugs in many scenarios. The typical formulation of dry product relies on the nutrients available in the surrounding water and underlying sediment to support germination and nourish sustained growth. Fertilizer-amended product formulations can also be made.



better Bentonite

Appendix 3

GEOTECHNICAL DESIGN AND CONSTRUCTION



DRAFT REPORT

TO
JEMENA LIMITED
c/o VENTIA PTY LIMITED

ON
**REVISED GEOTECHNICAL ASSESSMENT AND
DESIGN AND CONSTRUCTION ADVICE**

FOR
**PROPOSED KENDALL BAY SEDIMENT
REMEDIATION PROJECT**

AT
KENDALL BAY, NSW

15 September 2016

Ref: 25810W3 draft REVISED GEOTECHNICAL REPORT.docx



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Date: 15 September 2016
Report No: 25810W3 draft REVISED GEOTECHNICAL REPORT.docx
Revision No: draft

Report prepared by:
B F WALKER
Principal Consultant

For and on behalf of
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TABLE A; SUMMARY OF CAPPING LAYER THICKNESS DESIGN CONSTRAINTS

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APPENDIX A ADDITIONAL LIMITED SCOPE GEOTECHNICAL INVESTIGATION



1 INTRODUCTION

This report presents the results of our revised geotechnical assessment in relation to revised proposed remediation schemes for Kendall Bay Remediation Project being prepared by Ventia Pty Limited (**Ventia**) for Jemena Limited (**Jemena**). The work has been carried out in accordance with the outline scope of work in our email dated 21 July 2016 which was prepared based on our briefing meeting with Ventia on 20 July 2016.

The work has arisen from a revised designation of remediation areas and revised remediation measures required in each remediation area.

In summary, the scope of work completed for this report has included:

- a) Updating the 2012 Geotechnical Model for the site to include the investigations completed since then;
- b) Consideration of geotechnical constraints for each Remediation Area for the proposed remediation applicable for each area;
- c) Providing input to Ventia for preparation of contributions to an updated Remediation Action Plan (RAP).

It is assumed that the reader of this report will be familiar with the site, site history and development of remediation proposals. Many reports have been prepared over the years in relation to these proposals. Only pertinent aspects and reference reports will be mentioned in this report.

The following outlines the relevant previous work.

1.1 Previous Reports and Remediation Schemes

JK Geotechnics (JKG) prepared two reports in 2012 based on available data at that time.

Report Ref 25810W GeotechnicalModel Rev2, dated 30 August 2012 (**JKG 2012 Geotechnical Model Report**) collated the available geotechnical data and provided a Geotechnical Model which characterised the Geotechnical Units for the subsurface conditions at the site. Plots of sea bed levels and depths or Reduced Levels (RL) for the main strata were also presented. Design values for undrained shear strength, compressibility and bulk density were given.

Report Ref 25810W Const Methodology DRAFT 31 Aug12, dated 3 September 2102 (**JKG 2012 Construction Methodology Report**), provided our geotechnical assessment of the constraints arising from the Geotechnical Model. Various treatment methods were being considered at that



time. The impact of the geotechnical constraints was considered in relation to those methods. At that time, the favoured option was for excavation of contaminated material within the designated remediation areas and placement of the required capping layer in the dry. To achieve this methodology, provision of a sheet pile cofferdam was proposed.

After preparing those reports, workshop studies were carried out by the project team. Further consideration was given to alternative methods of treatment, including the use of vacuum consolidation as a step in the remediation process to improve access and method of working. This method was discounted due to practical and cost reasons. Other constraints, such as odour during remediation works, and the availability of a work site to handle contaminated material removed from the site, also lead to revisions to proposed methodologies.

Further geotechnical investigations were carried out by Sinclair Knight Merz (**SKM**) as outlined in Section 2.1 below. SKM also prepared a RAP in 2014 which assessed constraints and available methodologies. In brief, the preferred remediation strategy was for sediment removal from designated areas in Kendall Bay by wet dredging methods. The dredged sediment would be pumped to the nearby Tennyson Road work site for treatment using solidification and stabilisation technologies. The treated sediment would then be taken off site to a licenced landfill. A geocomposite cap of minimum 0.6m thickness would be placed over the dredged surface to reinstate the existing sea bed levels.

Based on the SKM 2014 RAP, Ventia prepared a proposed construction strategy and associated cost estimate for Jemena in 2015. JKG prepared a report on Geotechnical Design and Construction aspects relevant to Ventia and the SKM 2014 RAP, Report Ref 25810W2 Design SKM 2014 RAP dated 27 November 2015 (**JKG 2015 Report**).

1.2 Revised Remediation Scheme

It is understood that since the Ventia 2015 proposal, further characterisation of the sediments has been carried out by Synnot & Wilkinson Pty Ltd (**S&W**), including evaluation of benthic fauna and contamination. In addition, discussions have taken place with various relevant authorities.

Based on those discussions and the additional data from S&W, the designated Remediation Areas have been revised together with the minimum remediation requirements. The Remediation Areas and associated coordinates are defined on the attached Figures 1 and 2. The remediation requirements and proposed methods are summarised in relevant sub sections of Section 4 below.



2 ADDITIONAL INVESTIGATIONS

2.1 SKM 2013 Factual Geotechnical Report

SKM carried out additional geotechnical and environmental (contamination) investigations in July 2013. Results from the geotechnical investigation are presented in SKM 'Geotechnical Factual Report' dated 15 October 2013. The factual report outlines the borehole investigation methods adopted and the laboratory testing completed. This SKM report provides significantly more geotechnical data than was previously available.

Significant features of the investigation and testing include:

- Use of hand auger drilling at 14 locations within the mangrove and near shore areas, but with penetration limited to about 1.3m; hand vane shear tests were completed in five selected boreholes.
- Use of a mini jackup barge for drilling over water, as supplied by Insitu Geotech Services Pty Ltd; 10 geotechnical borehole locations were drilled to depths up to 3.2m.
- Location of boreholes by hand held GPS. Borehole locations are shown on Figure 1 (for those deeper than 0.5m) and Figure 2.
- The sea bed level was not determined at each borehole location. Relevant sea bed level from the sonar survey has been adopted for our analysis.
- For the jack up boreholes:
 - use of a Piston Pneumatic Injection (PPI) sampler to recover 63mm diameter by about 0.6m long tube samples from discrete depth interval using a fixed end cap on insertion. The samples were ejected to form disturbed samples,
 - 63mm diameter tube samples for laboratory testing, and
 - Completion of insitu borehole shear vane tests.
 - Completion of hand penetrometer and hand shear vane tests in the ends of 63mm tube samples.
- Laboratory testing including moisture content, particle size distribution including hydrometer analysis, Atterberg Limits, specific gravity, bulk and dry density, one dimensional consolidation (Oedometer) tests.

2.2 S&W 2015 and 2016 Sediment Sampling

We have only been supplied with borehole logs and plan/schedule of borehole locations from the S&W investigations. We have not been provided with any explanation of investigation methods used.



However, each borehole log includes a brief note on 'Coring Methods' together some supplementary notes on individual logs.

It would appear from the date on each borehole log that the investigations were completed in stages on differing dates. Each stage has a consecutive numbering system with the first digit related to the stage. The stages, investigation dates, borehole numbers and relevant methods of investigation have been summarised as follows, together with our comment where appropriate:

Stage	Date(s)	SW BH Numbers	Method Of Investigation	JKG Comment
1	15/4/15 to 17/4/15	1 to 30	50mm hand cores, toothed on lower end to cut through mangrove roots.	Would appear that no casing was used; fall-in below GWL likely.
2	28/5/15 to 29/5/15	100 to 110	Dormer undisturbed wet soil corer, 35mm for deeper holes and 300mm x 100mm tubes for grab samples	For relatively shallow samples
3	9/7/15	201 to 205	Terratest, 75mm push tube rig + 50mm hand cores	For deeper BHs; significant lengths of core loss particularly at shallow depths; not known if casing used.
4	29/7/15	401 to 412	300mm x 100mm tubes for grab samples	For surface grab samples
5	14/9/15 to 18/9/15	501 to 516	Terratest, 50mm push tube rig + 50mm hand cores	For deep BHs; lengths of core loss particularly at shallow depths; not known if casing used.
	12/10/15 to 16/10/15	517 to 562	Terratest, 75mm push tube rig + 50mm hand cores	For deep BHs; lengths of core loss particularly at shallow depths; not known if casing used.
6	20/1/16 to 21/1/16	MB1 to MB26	Petit Ponar gab samples to 125mm depth	Surface grab samples for marine bio and chem
7	15/2/16 to 19/2/16	701 to 718	Terratest, 75mm push tube rig + 40mm hand cores	For deep BHs; lengths of core loss particularly at shallow depths; not known if casing used.
	16/2/16	731 to 740	Petit Ponar gab samples to 125mm depth	For surface grab samples
8	7/3/16 to 9/3/16	801 to 812	Terratest, 75mm push tube rig + 40mm hand cores	For deep BHs; some lengths of core loss particularly at shallow depths; not known if casing used.
9	7/4/16	901 to 904	40mm hand cores	For relatively shallow samples
	7/4/16	MB30 to MB47	Petit Ponar gab samples to 125mm depth	Surface grab samples for marine bio and chem



On the borehole logs, depths are noted as approximate due to dewatering, compaction and flow of plastic clays into push tubes. In addition, it is also noted that sample and log depths were measured from top of sediment in each tube.

It appears in some cases that the recovery length is more than the sample penetration length which suggests there has been sample fall-in from above the sampled depths. We have adopted the strata depths as shown on the logs with no attempt to rationalise depths with sample recovery. As we understand that the intent of the sampling was to recover undisturbed samples primarily by use of push tube sampling we would expect the materials recovered to be representative of the depth interval sampled.

We do not know what method of penetration for the push tubes was available on the Terratest rig. Therefore the depth of refusal during sampling may be different to that achieved by the other rigs used.

We have assumed that the material descriptions given by S&W are consistent with the geotechnical terminology as set out in 'Appendix A Description and Classification of Soils and Rocks for Geotechnical Purposes' in AS1726 'Geotechnical Site Investigations'. In particular, the use of 'firm' by S&W in relation to undrained strength or consistency is assumed to be consistent with the AS1726 terminology as shown on the top of Figure 9. A summary of the geotechnical logging terms is given on the Explanatory Notes in Appendix A attached.

For our analysis and interpretation of these boreholes we have ignored the surface grab samples and boreholes with penetration of less than 0.5m as these boreholes are also effectively 'surface samples'. A total of 95 locations with penetration of more than 0.5m depth within the Kendall Bay area have been used from the S&W investigations. Further comment on interpretation of the materials encountered is given in Section 3.1 below.

We have adopted the borehole locations as shown on a supplied CAD plan. We have adopted the sonar derived sea bed levels at those locations (refer to Section 3.2.1 below).

We understand there has been no further geotechnical testing of any of the samples obtained.

2.3 JKG 2016 Limited Scope Investigation

A day of limited scope investigations were carried out by JKG in company with a Ventia Environmental Engineer along the existing sea wall revetment on the western side of Kendall Bay



in remediation Area SA2. The purpose of the investigation was to carry out some hand probing and testing to obtain initial data on existing conditions along the foot of the existing sea wall revetment. Observations have also been made in relation to conditions for Area NA1 where the existing vertical sea wall is present.

Refer to Appendix A for further details and results obtained including photos of existing conditions.

3 UPDATED GEOTECHNICAL MODEL

3.1 Geotechnical Units

The JKG 2012 Geotechnical Model Report included a Geotechnical Model of the subsurface conditions similar to that presented below. The 2012 Geotechnical Model was slightly different to the previous SKM 2011 model in terms of the subdivision of Unit 2.

The additional data in the SKM 2013 Factual Geotechnical Report and the S&W 2015 - 2016 Sediment Sampling boreholes have been interpreted to assign the Geotechnical Units to the descriptions of the materials encountered at each investigation location.

We note that Unit 1 and Unit 2A very soft clays are very similar in character and interpretation as either unit is subjective almost on a borehole by borehole basis. The main difference adopted for identification is that Unit 1 is usually more jelly like near the surface, of dark grey/black to green in colour, and has obvious presence of contaminants, either visually and/or by odour.

However, Unit 2A can also have some of these features, except that Unit 2A may vary more than Unit 1 in particle sizes present, there often being a noticeable sand content in Unit 2A. Contaminants still appear to be present in Unit 2A though in some cases as discrete layers / pockets such as of oily substances. As these materials in both Unit 1 and Unit 2A are all of similar geotechnical characteristics of very soft shear strength, of a clayey and compressible nature to imposed loads, it is appropriate to treat them as a combined material, Unit 1 and Unit 2A, for geotechnical analysis.

Identification of Unit 2B has usually been possible based on the lighter grey and mottled colour and strength description of firm or better.

A minor modification to the Geotechnical Model has been to subdivide Unit 2 such that Unit 2A Sands is allocated to the sandy beach deposits on the surface and near surface at the head (southern end) of Kendall Bay. The materials vary from relatively clean sands at the surface with



finer (silt and possibly clay) content increasing with depth. Unit 2A Sands have accumulated along the shoreline and intertidal areas in response to the sorting and cleaning action arising from waves and washes on the beach area at varying tidal levels. Some of the sediments may be relatively recent in terms of geological time, being deposits contemporaneous with Unit 1. In some locations, Unit 1 materials can be interpreted to be present below the Unit 2A Sands.

UPDATED GEOTECHNICAL MODEL

Geotechnical Unit	Material Type / Summary description	Strength / density	URS Contamination Unit
1	MARINE MUDS - includes recent surface sediment of jelly like hydrous brown to green sediment to about 0.2m depth. Usually dark grey/black to green.	Very Soft ($S_u = 0$ to 10kPa)	1 Contaminated sediments
2A	Silty sands, clayey sands to sandy clays and silty clays; assessed to be fluvial in terms of deposition; grading to lighter greys with depth	Variable; very loose or loose, or very soft to soft	1 Contaminated sediments And 2 Estuarine sediments
2A Sands	Sands to silty Sands, yellow brown grading to light grey and dark gray with increasing fines content with depth. Formed on the beach areas in the intertidal zone at the head of Kendall Bay.	Very loose to loose	1 Contaminated sediments And 2 Estuarine sediments
2B	Clay, sandy clay and clayey sand; residual or overconsolidated under glacial sediments; light grey with mottles orange and red brown.	Stiff grading to very stiff or hard, but often with a firm surface zone, or loose to medium dense	Not penetrated
3	SANDSTONE, slightly weathered with shale / laminite interbeds; a significant shale seam was encountered in JK8 at relatively high elevation.	Low to Medium rock strength, some weaker zones and/or core loss zones.	3 Sandstone (but not penetrated)

Refer to Section 3 of the JKG 2012 Geotechnical Model Report for further discussion of the characteristics of each Unit.

3.2 SURFER Contour plots

Our interpretation of the depths for each Unit for each borehole location has been tabulated in a spreadsheet for plotting and contouring purposes using the commercially available SURFER



program. The position of investigation locations of more than 0.5m depth, as used for the plots discussed below, are shown on the attached Figure 1 and Figure 2 together with the outline and coordinates of the designated Remediation Areas.

3.2.1 Sea bed surface levels

Ventia provided a CAD File plot of existing seabed levels which we understand has been based on sonar survey. From the CAD surface of sea bed levels, the RL(mAHD) has been determined at each of the plotted borehole locations. These data were then used in conjunction with the interpreted depths to each stratum surface to enable computer drawn contour plots to be drawn. We understand the sonar sea bed levels have formed the basis for Ventia models and volume calculations.

Comparison of the sonar sea bed surface levels with those previously adopted at the borehole locations for the plots in JKG 2012 Geotechnical Model Report showed the following:

- Difference in levels ranged from sonar levels up to 0.259m higher, to sonar levels to 0.130m lower, than the borehole levels
- Mean difference over 34 borehole was for sonar levels 0.033m higher than the boreholes
- Standard deviation over 34 boreholes was 0.103m.

Determination of sea bed level at a borehole location can be difficult when the sea bed surface sediments are very soft, since any soundings taken from the investigation platform such as a jack-up or floating barge, using a weighted sounding tape may be subject to error. The error arises as the weighted sounding tape can penetrate into the sea bed surface rather than stop at the sea bed surface. Such errors can be minimised by using a flat plate on the bottom of the sounding tape. However it is not known if such a plate was used or simply a weight which would penetrate further into the sea bed than a plate. Nonetheless, measurement of depths for sampling and strata observations are made from the same platform and are therefore consistent with the sea bed level sounding.

We understand that sonar is more sensitive to the surface of the soft sediments, and therefore gives a more accurate reading of the sediment surface level. Existing Sea Bed levels, as determined from the sonar results, are shown on the attached Figure 3 for Area A, the southern remediation areas. We note that the sonar levels present contours of sea bed levels which indicate large areas of similar levels and may be confusing. To simplify the contour plot we have taken the sonar levels at each of the Douglas Partners 2010 DCP test locations which form a reasonably regular grid



across the area. The resulting plot on Figure 3 presents smoothed sea bed level contours which are similar to the original sonar plot.

On Figure 3, we have shaded the sea bed levels below RL-0.6mAHD which corresponds with about Mean Low Water Springs (MLWS). The darker blue area below RL-0.8mAHD corresponds to levels below close to Indian Springs Low Water (ISLW, at RL-0.88mAHD) which are the low water levels for rising tides as occur in December and June each year. The Lowest Astronomical Tide (LAT) is about RL-1.0mAHD.

The unshaded area on Figure 3 represents the intertidal area that will be exposed at low water during usual twice monthly spring tide cycles.

3.2.2 Top of Unit 2B

As noted in Section 3.2.1 above, the existing sea bed level as determined by the sonar survey has been adopted for plotting of levels of each stratum, not the sea bed level determined during the borehole investigation.

However, we consider it would not be appropriate to use the logged depths for samples and strata observations in the boreholes relative to the sonar surface level since such logged depths would not be consistent with the original method of determination of sea bed level. Instead, we have applied a correction to the logged depths equal to the difference in sea bed levels between the two methods of measurement. In effect the discrepancy in sea bed levels has been applied to the combined thickness of the upper compressible strata, which for this site is the combined Unit 1 and Unit 2A very soft clayey sediments. As a result the levels of the top of the underlying Unit 2B stratum is the same as determined from the original investigation data as presented in the 2012 Geotechnical Model Report.

For the additional data (SKM 2013 and S&W 2015-2016) comparative sea bed levels are not available. Therefore we have adopted the sonar sea bed levels for determination of the top of Unit 2B levels. As a consequence there is potential for a minor discrepancy in levels of Unit 2B from different investigations arising from the different methods of sea bed and strata measurement. Based on the comparison outlined above it would be reasonable to conclude that the discrepancy should be mostly less than about 0.2m which is not significant in relation to variation between the borehole locations.



The results for analysis of Area A are shown on the attached Figure 4 for Depth (m) to Top of Unit 2B and Figure 5 for RL (mAHD) of Top of Unit 2B. We note that Figure 4 is the same as a plot of the combined thickness of Unit 1 and Unit 2A. The borehole locations used for Figures 4 and 5 are shown in Figure 6.

The results for analysis of Area B are shown on the attached Figure 7 for Depth (m) to Top of Unit 2B and Figure 8 for RL (mAHD) of Top of Unit 2B. As above, we note that Figure 7 is the same as a plot of the combined thickness of Unit 1 and Unit 2A.

3.3 Review of Geotechnical Design Values

3.3.1 Undrained Shear Strength

Section 3.1 of the JKG 2015 Report discusses the additional undrained shear strength data obtained from the SKM 2013 Factual Geotechnical Report. Reference should be made to the JKG 2015 Report in relation to the correction applied to determine the design shear strength profiles. The SKM data are presented in the attached Figure 9.

Also shown on Figure 9 are the hand shear vane test results obtained from the JKG 2016 Limited Scope Investigation. These data are consistent with the previous data.

As discussed in Section 3.1.2 of JKG 2015 Report an appropriate design shear strength profile shown on Figure 9 is the black line 'CASE C' Corrected Lower Bound Design which is defined as:

$$s_u = (0.8 + 2z) \text{ kPa}$$

where s_u is the design undrained shear strength at a depth z (m) below existing sea bed level.

Whilst this design profile is conservative in some areas, such as the mangrove area (part of Area SA3) at the head of Kendall Bay, due to sand content in the clays, we consider the profile is realistic especially for the Unit 1 sediments.

We note the vane shear testing has shown remoulded strengths significantly less than the initial strength, and mostly not measurable. That is, once a shear failure occurs, the materials lose strength, known as 'sensitivity'.



3.3.2 Compressibility and Rate of Consolidation

Section 3.2 of the JKG 2015 Report discusses the Compressibility and Rate of Consolidation characteristics of the sediments as determined by the test results in SKM 2013 Factual Geotechnical Report. No further laboratory testing has been carried out.

Therefore we consider the previous design values may be reasonably adopted as follows:

CR = 0.25 for Unit 1 and Unit 2A clayey materials

CR = 0.1 for Unit 1 and Unit 2A for materials with more than about 50% sand

where

CR is the Compressive Ratio = $C_c/(1+e_o)$ and

C_c the compression index for the corrected normally consolidated compression (on the e-log p plot from an oedometer test); and

e_o is the initial or existing void ratio of the clays

The rate of consolidation for the Unit 1 and Unit 2A materials may be estimated based on a design average Coefficient of Consolidation (c_v) of 0.5m²/year.

The presence of layers/lenses of sandy materials in the sediments may result in much quicker consolidation than derived from this Coefficient of Consolidation. However, most boreholes do not show such sandy layers/lenses to be present, though some are noted in the S&W boreholes. Such layers/lenses may be localised such that their effect is limited.

The above design values are only approximate. The actual field values may vary from the design values due to inherent variability of the materials and limitations of laboratory testing methods.

No testing has been carried out on the Unit 2B materials. However Unit 2B materials are typically of firm to stiff, or better, strength. Hence in soil mechanics terms, Unit 2B is over-consolidated and consequently settlement under additional surcharge loads will be minor and may be ignored.

3.3.3 Bulk Density

Section 3.3 of the JKG 2015 Report discusses the Bulk Density results of the sediments as determined by the test results in SKM 2013 Factual Geotechnical Report. No further laboratory testing has been carried out.



For Unit 1 and Unit 2A clayey materials, adopt an average bulk density of 1.43t/m^3 (14.0kN/m^3) to about 2.5m depth. Below 2.5m depth, slightly higher bulk density would be expected but has not been measured.

Higher bulk density of the sandy materials could be taken as 1.85t/m^3 (say 18kN/m^3) based on the one test result for sandy material with 40% fines (hence 60% sands).

4 COMMENTS AND RECOMMENDATIONS

4.1 Geotechnical Design Constraints

4.1.1 Bearing Capacity and Edge “Slip Circle” Failure

Bearing capacity on the very soft clays of Unit 1 and Unit 2A was discussed in Section 3.3 of JKG 2012 Construction Methodology Report. Section 4.2 of JKG 2015 Report updated that consideration based on the additional shear strength data from SKM 2013 Factual Report. As the design shear strength profile has not been updated, reference can be made to our discussion in JKG 2015 Report for further details of our assessment of bearing capacity. We provide further explanation of the design issue below which is particularly relevant for remediation area SA1.

4.1.1.1 Overload causes a “slip circle” failure

Placement of the capping layer is assumed to be from a barge to form the capping layer below tidal levels as shown in Part A of Figure 10.

The bearing capacity of the very soft clays (unit 1 and Unit 2A) is very limited. If the loading applied is too much for the undrained shear strength, then the bearing capacity is exceeded and a “slip circle” failure would occur. Part B, Figure 10 shows such a failure that might arise if an overfill surcharge near the edge of the capping layer placement occurs, or if the layer placed is too thick. If the capping layer thickness is more than the bearing capacity of the very soft clays, then such a “slip circle” failure would occur at the edge of the capping during placement of the capping.

Therefore the design requirement is to evaluate the allowable capping layer thickness with a reasonable factor of safety for construction purposes.



4.1.1.2 Bearing capacity design

Although the design capping layer thickness is 0.5m, we have based our analysis on a 0.6m capping layer to take into account possible overdredge or construction tolerance of 0.1m in addition to the design thickness.

The critical design case is where the capping layer will be above low water tidal level, since then the full bulk density will be applicable for the surcharge load. Therefore where existing sea bed levels are at or above RL0.0m AHD the capping layer will cause the full surcharge load during MLWS tides (RL-0.6m AHD).

For analysis, a simple bearing capacity equation of $Q_{ult} = 6s_u$ where s_u is the design undrained shear strength may be adopted. However this simple analysis does not allow for the beneficial effect of increasing undrained strength with depth, but does make some allowance for the beneficial effect of a batter at the edge of the capping layer. The results of our analysis are summarised in the attached Table A adopting a Factor of Safety of 1.5.

The Table A results show that placement of the capping layer of up to 0.6m thickness is more than would be usually adopted with a Factor of Safety of 1.5; the allowable capping thickness is 0.4m for the capping being unreinforced. Although the capping layer thickness at the ultimate load for bearing capacity failure would be in at or in excess of the design thickness of 0.6m, the stability against a 'slip circle' failure would be on a 'knife edge'. If there is non-uniformity of strength or of loading from the capping then excessive deformations and a failure could readily occur. Therefore we consider that either

- The 0.5m capping layer would have to be placed in two layers, with an offset and/or batter between the edge of each layer; or
- A geogrid reinforcement would have to be provided below the capping.

We note that we have assumed a geotextile layer would be placed over the dredged surface before the capping materials are placed; the geotextile would act as a separator. The geotextile will have some limited tensile capacity which will assist with stabilising the capping against a 'slip circle' failure. However, the tensile capacity of a geotextile is limited and special joints would be required to achieve full tensile capacity of a geotextile. Provision of a geogrid would be required to have sufficient beneficial effect against a 'slip circle' failure.



4.1.1.3 Geogrid reinforcement

We have evaluated the beneficial effect of providing a geogrid reinforcement layer below the capping using the design principles in BR470 *Working platforms for tracked plant* BRE (2004). We note that the design method cautions that applying the method on weak subgrades with undrained shear strength of less than 20kPa may be of limited use (due to the usual loads applicable to tracked plant). Nonetheless, this method does provide a guide as to the beneficial effect gained from the geogrid in a case of relatively low loading over a significant area as applies for the capping layer.

The geogrid provides a tension force at the base of the capping to hold up the load from the capping and an overfill surcharge, if present, as deformations occur due to the load. The tension force is gained by friction of the geogrid embedded below the capping layer. For the scenario shown on Figure 10 Part C, the portion of geogrid below the edge of the capping layer (left hand side) will have limited load on the geogrid. Hence the tension generated on the edge side (left hand side) will be much less than the tension generated below the area of capping (right hand side). This means that it would be possible for the geogrid to slip or pull through under the capping on the edge (left hand side).

The results of the calculations are shown on Table A adopting an allowable tension in the geogrid of 10kN/m such as would be achieved using Tensar SS20 geogrid and a Factor of Safety of 2.0. The calculations have assumed a loose to medium dense sand capping layer with a design friction angle of 30°. The results in Table A show that a reasonable allowable thickness of capping layer that can be achieved within a large capping area to be 0.95m. For a design capping thickness of 0.6m (allowing 0.1m for overdredge) this means that an allowable overfill surcharge of 0.35m can be achieved within a large area.

However, at the edge of the capping (such as during placement of the capping layer), the amount of tension generated in the geogrid will be controlled by the friction generated below the edge batter of the capping layer as shown in Figure 10 Part C. Then the allowable additional surcharge above the design capping thickness of 0.5m will be limited to about 0.1m for an edge batter of 1V:2H or about 0.25m for an edge batter of 1V:4H.

At locations away from the edge of the capping layer, the allowable amount of additional surcharge on the reinforced capping will be dependent on the size (plan area) of the surcharge. An offset of at least 3.5m from the edge of the geogrid is required to generate the allowable tension in the geogrid.



The results of the analysis show that use of a geogrid will provide a better margin of safety against a 'flip circle' failure at the edge of the capping layer. However, as the margin is still limited, construction methods will require careful control.

Slightly higher allowable additional surcharges could be achieved by use of a gravel bedding layer immediately over the geogrid rather than the assumed capping sands. However placement of such a layer would require more complicated capping layer placement and consideration of whether additional dredging might be required to compensate for the thickness of gravel placed.

We recommend that the above approximate analysis be confirmed by more detailed analysis using specialist programs such as SLOPE-W as part of the final detailed design.

4.1.1.4 Capping below tidal levels

For capping placement below tidal levels, the capping and overfill surcharge would be a buoyant load on the underlying clays. Consequently the surcharge loads will be about half those for placement above tidal levels. The design capping layer thickness can be readily achieved as shown in Table A, especially if a geogrid is provided to reinforce the base of the capping layer.

4.1.1.5 Geogrid construction and detailing requirements

The geogrid would be laid on the geotextile after dredging has been completed, including verification of dredge depths/levels such as by sonar survey or spot survey soundings. We envisage the geotextile would be laid out in a similar manner to the geogrid, but with less emphasis on achieving the lap join on the longitudinal geotextile strips.

We envisage the geogrid would be rolled out from a barge mounted rig working away from the perimeter sheet piles as shown on Figure 11. The geogrid would need to be fixed to the top of the sheet piles, at least temporarily, to enable roll out without pulling the geogrid away from the sheet piles. In particular, it will be necessary to have the geogrid adjacent to the sheet piles at dredge level so as to avoid the formation of a catenary in the geogrid and so that full capping thickness is achieved adjacent to the sheet piles. Use of temporary or permanent weighting would be needed adjacent to the sheet piles to keep the geogrid close to the sheet piles. This arrangement is shown on the attached Figure 11. Suitable weighting could be a temporary pipe or beam lowered down on ropes/chains which is recovered as capping layer placement commences. Alternatively some gravel filled geofabric bags could be lowered into place and left in situ as capping is placed.



Due to tidal levels and draught of likely barges to be used, we anticipate that longitudinal roll out of geogrid strips (of the supplied geogrid width, usually 6m) would occur away from both shore line and the outer sheet piles with an overlap in the centre. A nominal 5m to 6m overlap would suffice to enable full geogrid tensile capacity to be achieved plus a margin for local pull in and construction tolerances.

The longitudinal strips would have a target transverse overlap of say 0.5m given the constraints of a marine laying operation. A suitable control for achieving confirming that an overlap has been achieved would be by diver verification.

However full tensile capacity would not be achieved by the strip transverse overlap. Therefore it will be necessary to lay a second layer of geogrid at right angle to the first strips to give the design tensile capacity in both directions. The same target overlap would also be required.

4.1.1.6 Bearing capacity for plant

The results in Table A show that use of plant for placement and screeding of the capping will have quite severe loading constraints if slip circle failures under the plant are to be avoided.

With the geogrid reinforcement, allowable surcharge loads from plant will be limited to 19kPa. This is significantly lower than most swamp dozer tracked plant which we would expect to have track bearing pressures of about 30kPa to 40kPa. Specialist buoyant swamp equipment may be available but would require further consideration of track loads, track dimensions and anticipated work methods.

4.1.2 Capping Layer Materials Design

Design of the capping layer material requirements is primarily within the expertise of a coastal / marine engineer, rather than geotechnical. Therefore the comments given below should be confirmed by a coastal / marine engineer to be reasonable and appropriate for detailed design. We have also assumed there are no other constraints in relation to contaminant / environmental factors that might affect selection of the capping materials.

We consider it is appropriate to consider both design studies and the evidence of existing conditions within Kendall Bay to enable selection of an appropriate capping layer material.



4.1.2.1 Design Study by SKM

Sinclair Knight Merz (SKM) prepared a Draft RAP dated 12/10/2012 which, when considering the requirements of a capping layer, included the following in Section 8.3.1 *“Protection from physical disturbance”*: in summary:

SKM referred to investigation of flow velocities in Kendall Bay by URS (2006c) and BGA Coastal (October 2009). SKM summarised the results of those studies and concluded *“An erosion threshold velocity of 0.3m/s is considered reasonable for assessing sediment scour potential in Kendall Bay.”*

We note this design velocity of 0.3m/s is greater than quoted tidal velocities for the Parramatta River channel (0.7m/s) or wind generated currents in Kendall Bay of up to 0.15m/s.

SKM conclude that for tidal and river flood flows, adoption of an average flow velocity for design of 0.3m/s leads to minimum particle size 4mm to prevent erosion and transportation. SKM also advise that there could be infill of finer particles within pore spaces of the 4mm material. No other grading requirements were given by SKM.

We note that 4mm gravel aggregate is unlikely to be readily available, but understand that 5mm aggregate is a commonly available size (as confirmed by enquiry of Hanson Quarries). Such 5mm aggregate could be blended with some finer sands to fill the voids, but further work would be needed to confirm the percentage of finer sands possible.

The 5mm aggregate is usually obtained from igneous rock quarries so as to provide a durable, strong crushed aggregate, such as needed for use in sub-surface drainage applications. Material from Hanson Kulnurra quarry would be an angular, “dark grey to black” basalt. We have not been able to confirm with Hanson as to whether a single sized 5mm crushed sandstone can be provided, but doubt it unless the quantity needed is sufficiently large. Durability of a sandstone aggregate would be substantially less than a basalt aggregate.)

We note that SKM did not consider the storm water outflow from the existing drainage culvert at the southern end of Kendall Bay, as that would be a detailed design issue. However, recent observation of stormwater discharge showed that a scour channel can develop through the mangrove and tidal flats exposed at the south end of Kendall Bay, particularly at low tide. We suggest that such scour could be addressed by provision of a reno mattress lined channel through the mangroves, then a swale in the surface levels of the tidal flats with a rockfill lining to get discharge to LW level. The requirements should be confirmed by a coastal engineer during detailed



design. An alternative would be to take the approach that any scour channel within the intertidal flats will be subject to re-deposition after scour occurs.

4.1.2.2 Design Study by URS / WRL

During previous design studies, URS also obtained advice from Water Research Laboratory (WRL) as included in Appendix E of URS report dated 21 December 2007. WRL letter dated 12 December 2007 presents their advice in relation to appropriate sizes of material to provide sea bed protection against the effects of tidal currents, wind-waves, Rivercat Ferry generated waves, wind induced currents and catchment run-off. In summary WRL concluded that the energy of Rivercat waves and wind waves would be similar and would dictate design.

WRL evaluated the required size of protection material on the basis of breaking waves using design approaches for stability of breakwaters. Depending on the method of analysis, the following summarises results for stability of a protection layer of rockfill assuming a sandstone rock is adopted for aesthetic/environmental reasons:

For 100year ARI wind waves	median size (D50) 0.244m to 0.538m or Median mass (M50) 31.9kg to 342.5kg
For Rivercat waves	median size (D50) 0.099m to 0.243m or Median mass (M50) 2.1kg to 31.6kg

These results indicate significantly sized rockfill say in the range of about 250mm to 500mm median particle size. These sizes were based on an assumed density of 2.2t/m^3 for sandstone which would be low for a good quality, durable sandstone which would be more like 2.4t/m^3 .

Similar but slightly smaller sizes would be required if a basalt rockfill is adopted (due to the higher density of basalt compared to sandstone).

We note that for a design life of 20 years, a good quality sandstone will be required for durability. Allowance should be made for laboratory testing of potential sources to confirm durability for use in the marine environment.

4.1.2.3 Evidence of Existing Conditions in Kendall Bay

We consider there are four sea bed regimes within Kendall Bay, as follows:



- i. **Exposed bedrock**, as found on the Cabarita Park headland. The exposed bedrock above intertidal levels is essentially clean of any sediment deposits. Such areas are not present within the designated remediation areas.
- ii. **Exposed sandy beaches within the intertidal zone.** These beaches are primarily located at the southern end of Kendall Bay and are within remediation Areas SA1, SA3, SA4 and SA5. The depth of sand varies. The sand is typically a fine to medium grained sand (there may be some particle size distribution curves in the SKM 2013 investigation report). With depth, the fines (silt and clay) content tends to increase and transition into the underlying very soft clays of Unit 1 and Unit2A. From observation, it would appear that the sandy beaches result from a combination of wind waves and river craft generated waves (wash), and are in effect limited to the intertidal zone. Some movement of the sands may occur, but the deposits appear to be in an equilibrium condition between the natural supply of sand (from the river sediments and storm water run-off) and the wave / current conditions in Kendall Bay. Studies might show that accretion is occurring in the sandy beaches, not erosion.
- iii. **Rock fill along the toe of the revetment and sea wall** on the western side in Areas SA2 and NA1. These materials have likely been placed during construction of the revetment and sea wall or later as maintenance to protect the toe of the revetment or sea wall from erosion by wind induced waves or river craft induced waves. Refer also to Appendix A for further observation of these areas.
- iv. **Bay sediments below intertidal levels.** These sediments comprise the Unit 1 and Unit 2A very soft clays. There can be varying content of sand sized particles present within the sediments, particularly near the intertidal beaches. Although the sediments appear to be in an equilibrium between sediment supply and the wave / current conditions, we understand that studies by others suggest that deposition is occurring within Kendall Bay over time.

Based on the above, a reasonable observation would be that the beach areas could reasonably be reinstated with sands similar to those currently present. That is, the capping could comprise a typical Sydney Sand, such as obtained from Kurnell sand quarries, or similar. Provision of a capping layer of 0.5m thickness would be similar to if not more than the sand layer currently present. (The borehole data could be analysed to confirm this, but has not been completed at this stage.) Whilst the sand capping layer surface may be exposed to some movement from waves and currents it would seem reasonable to conclude that it would not be any greater than currently experienced.

Similarly provision of a rockfill along the toe of the existing revetment and sea wall would provide protection against wave attack from wind waves and Rivercat waves.



4.1.2.4 Other Considerations

Other reinstatement objectives may also influence choice of the capping material. For example, visual aesthetics and possible recreation use of the beach area such as by children, or suitability for benthic organisms

Such considerations may favour adoption of a sand capping material over in imported fine gravel (5mm single size), especially if such material is say angular basalt as available from commercial quarry suppliers.

4.1.3 Capping Layer Construction and Stability

We consider possible capping layer construction methods would comprise the following:

4.1.3.1 Spread from pontoon/barge as tidal levels allow

To do this, then either the capping sands would be pushed off the barge, or delivered by excavator bucket. Consideration could also be given to use hydraulic or conveyor based systems. These methods will allow capping layer thickness to be built up to required thickness (in one or two layers) but will require tight construction control to avoid overfilling and creating a mud wave or edge slip circle failure as discussed in Section 4.1.1 above.

Detailed scheduling consideration will be required for construction over the intertidal area (unshaded area on Figure 3) and will be dependent on the combination of the existing sea bed level, draught of pontoon/barge used, and actual tides on the day.

4.1.3.2 Spread from land based area using swamp dozers/excavators

This will not be possible on the existing sediments after dredging to required level due to the unacceptable surcharge load from the swamp dozer/excavator as discussed in Section 4.1.1.6.

The additional surcharge load from the swamp dozer/excavator tracks will result in a slip circle bearing failure of the capping either at the edge (when close) or under the tracks (due to a punching type bearing capacity shear failure). In addition, additional surcharge load would be required from stockpiled capping to be pushed forward by the dozer/excavator.

To be able to use a swamp dozer/excavator,



either it will be necessary to provide heavy reinforcement of the base of the capping layer, such as by a heavy geogrid plus either a coarser granular bedding layer over or by provision of anchorage of the ends of the geogrid (which we would not expect to be feasible);

or by working at a distance back from the filling edge (refer Part C of Figure O in JKG 2012 Construction Methodology Report). This will likely not be feasible even for a long reach excavator, due to the distances involved, and the requirement for an increased capping layer thickness below the excavator tracks to avoid a local punching shear bearing capacity failure.

Provision of heavy reinforcement to the base of the capping will require additional excavation (to compensate for the base layer thickness) resulting in additional material for removal offsite and treatment. There will then be additional cost of heavy geogrid and granular bedding layer. Further analysis would be required taking into account specific plant size and surcharge loads to determine geogrid tensile capacity required and additional thickness of the base layer.

4.1.3.3 Possible Generation of a Mud Wave

Section 4.1.1 has evaluated the bearing capacity constraint arising from a slip circle type bearing capacity failure of the capping layer.

Once an edge failure occurs due to overloading, it will generate a mud wave which will tend to be pushed ahead of subsequent placement due to loss of strength once the sediments are remoulded by the mud wave. This arises from the sensitivity of the very soft clays to remoulding (refer Section 3.3.1). The mud wave would continue to grow and move forward of capping placement unless construction can firstly remove the mud wave to design excavation levels and then carefully fill to required level over a sufficiently large area to prevent additional edge failure. The presence of the geogrid and geotextile will make removal of the mud wave difficult and expensive. If capping is placed over the mud wave without removal, then the resulting capping layer thickness would be less than required. Some consolidation settlements of the mud wave would allow some correction of capping layer thickness, but is unlikely to be sufficient to rectify any shortfall.

Formation of a mud wave will be a contingency condition which will require careful management and construction techniques to be avoided.

Existing sea bed slopes, as determined from the sonar survey (Figures 1 and 2) are typically about 2° to 3° and locally steeper to about 5° close to the revetment intertidal zone. The exception is the side slopes to the previous dredged channel adjacent to the original wharf in remediation Area NA2.



Sliding stability of the capping for Area NA2 is discussed in Section 4.9.3 below. Based on the calculations for Area NA2, sliding stability of the capping layer will not be an issue for the other areas, there being a factor of safety of well in excess of 1.5.

4.1.4 Settlement

The capping layer will increase the load on the underlying very soft clays. Dredging to the design 0.5m for the capping layer will remove some load at a design bulk density of 14kN/m^3 . However the capping could conservatively have a design bulk density of 20kN/m^3 . Therefore the 0.5m thick capping will cause a net increase in load of 3kPa (or slightly more where overdredge has occurred, being 3.6kPa for design purposes) on the very soft clays. The net increase will be the same for capping above and below tidal levels.

The very soft clays are normally consolidated such that the increased load will cause settlement to occur. We have used the design Compressive Ratio (CR) (Section 3.3.2) to estimate settlements. The results are shown on the attached Figure 12.

Calculated settlement for the areas with 0.5m capping layer can be estimated from Figure 12 by using Figure 4 for the southern remediation areas or Figure 7 for the northern remediation areas to determine the existing thickness of compressible very soft clays (combined thickness of Unit 1 and Unit 2A, which is equal to the depth to Unit 2B) at any particular location. Then subtract 0.5m for the capping and use the resulting thickness of compressible sediment on Figure 12 to determine the amount of consolidation settlement. Examples are given in Section 4.2.3 below.

Where the additional fill (capping sands) are placed over the existing sea bed, the net surcharge will be increased and consequently settlements will be increased.

The time rate of settlement will be dependent on the thickness of compressible very soft sediment remaining below the capping layer. For design purposes we have assumed that the underlying Unit 2B materials below the compressible very soft sediments are relatively impermeable such that consolidation drainage of excess pore water pressures (due to the surcharge load of the capping layer) will be only in one direction, to the base of the capping layer. Therefore the drainage path length will be the thickness of remaining Unit 1 and Unit 2A compressible very soft sediments. The attached Figure 13 presents results for the percentage consolidation against time for different thicknesses of remaining compressible sediments. Examples of this Figure are given in Section 4.2.3 below.



If there are continuous sandy layers of higher permeability within the compressible sediments or if there is drainage to the underlying Unit 2B, then the rate of settlement will be significantly quicker than that given by Figure 13.

4.1.5 Hydrostatic uplift

Hydrostatic uplift was considered in the JKG 2015 Report since the proposed capping layer at that time included an impermeable organoclay layer at the base of the capping. Such a layer would impede existing subsurface drainage paths for ground water flow from the areas upslope to the south and west.

We have been advised that the impermeable organoclay layer would no longer form part of the proposed capping layer. The capping layer materials will be relatively permeable such that seepage water pressure will not build up below the capping layer. Therefore hydrostatic uplift is no longer a design constraint, and need not be taken into account.

4.1.6 Temporary Batters and Shoring

Excavated temporary batters were addressed in Section 4.1 of the JKG 2015 Report. As the same design undrained shear strength is being adopted, the results are the same. In summary allow to form temporary excavated batters through the Unit 1 and Unit 2A sediments at 1V:6H with adjustment based on experience with the Unit 1 jelly like materials at this site as work proceeds. We anticipate that any temporary batters would likely be excavated in bites of about 0.3m maximum to achieve the overall design batter slope.

Where sheet piles are provided around the excavated remediation areas to limit the extent of excavation and stability, temporary batters will not be formed around the remediation area. However temporary batters will be required within the excavation area and should be formed as above.

The requirements for perimeter sheet piles are discussed in the relevant sections below addressing each remediation area.

Shoring will be required adjacent to the existing revetment and sea wall for stability reasons. Refer to Section 4.2.5 below.



4.2 Area SA1 (Red Line)

4.2.1 Proposed Scope of Remedial Work

Area SA1 is about 70m long (almost north to south) by up to about 38m wide, reducing to about 10m wide at the northern end as shown on Figure 1.

We understand the following scope of work is proposed, in summary:

- a) Provide sheet piles to assist with edge stability and limit extent of excavation;
- b) Alternative to sheet piles is to batter the excavation within stability limitations, though this alternative lacks the benefits of having a containment barrier around the site;
- c) Excavate for 0.5m depth using a wet dredge with moon pool and silt curtain arrangement. Dredging would use a grab and/or hydraulic excavator with bucket.
- d) Place geotextile fabric and then two layers of geogrids and then the capping layer to about existing sea bed levels;
- e) A contingency consideration might be for removal of soft sediments to top of Unit 2B, but this significantly alters many aspect of the design, and is not considered further in this report.

4.2.2 Geotechnical Conditions

Area SA1 (Figure 1) lies immediately adjacent to Area SA2 South which comprises the existing revetment and toe. The plotted boundary between SA2 South and western side of SA1 is about 2m to 4m (scaling from Figure 1) from the toe of the existing revetment.

The Additional Investigations by crow bar probing along the toe of the revetment (Section 2.3 and Appendix A) have shown that the rockfill toe will mostly be of limited thickness, since crow bar probes readily penetrated the rockfill at offsets of about 2m to 3m, except at the southern end (Ch150, Figure A1) where the rockfill extended out to an offset of nearly 8m (Table AA). Where penetration was achieved by DCP at Ch100 and Ch132, the results suggested a rockfill thickness of more than 0.6m and about 0.4m respectively over the underlying very soft Unit 1 and/or Unit 2A sediments.

The boreholes have shown the typical profile of Unit 1 and Unit 2A very soft clay sediments overlying the firm/stiff Unit 2B clays. The undrained strength from the hand vane shear tests during the Additional Investigations are consistent with the previous data, Figure B rev A (Appendix A).

The thickness of the very soft clay sediments overlying Unit 2B are summarised on Figure 4 for the investigation locations being shown as, and is equal to, the depth to top of Unit 2B. The data



interpreted from the S&W sediment sampling is broadly consistent with the previous investigations and provide data closer to the western boundary than previously available.

The data on Figure 4 show thicknesses of very soft clay sediments of about 2m to 3m at the southern end, increasing to about 9m (BH SW503A) or even 10m (BH SW510) at the north eastern boundary. Along most of the western boundary with Area SA2 South, the thickness of very soft sediment is suggested to be about 6m to 8m except for the decreased thickness towards the southern end. Although the investigation locations are offset east of the western boundary of Area SA1 by about 2m to 5m, say about 3m on average, it would be reasonable to assume the thickness of very soft sediment is similar at the western boundary of Area SA1.

The contours on Figure 4 suggest there will be a localised channel of thicker very soft sediments running through the area to the north east and north, being mostly about 8m to 10m thick. Such a channel has probably been formed in response to the original natural drainage pattern during lower sea levels of the last glacial period (of geological time), before the very soft clay sediments were deposited.

The elevation of the Top of Unit 2B is shown as RL contours (mAHD) on Figure 5. The channel feature is suggested by the contours, but is partially masked to the western side (near BH SW503A) by the computer drawn contouring.

Thickness of Unit 2B underlying the soft sediments has not been well defined due to the limited depth of most investigations. No further analysis has been completed at this stage. If required, reference can be made to Figure J1 for depth to rock or refusal, or Figure J3 for RL values for top of rock or refusal in the JKG 2012 Geotechnical Model Report.

4.2.3 Bearing and Settlement Estimates

There is no shear strength data from SKM 2013 within Area SA1. We consider it reasonable and appropriate to adopt the Case C Design Shear Strength line, as shown on Figure 9, for area SA1.

Bearing capacity for the capping layer, as applicable for Area SA1, is addressed in Section 4.1.1 and construction in Section 4.1.3 above.

Design settlement estimates from Figures 12 and 13 may be summarised as:



Location	Typical thickness of compressible sediment	Thickness of compressible sediment remaining after 0.5m dredge	Calculated design settlement (mm) of 0.5m capping (Figure 12)	Expected settlement at 1 year from capping placement (Figure 13)		Expected additional settlement (mm) after 1 year from capping placement
				Percentage	Amount (mm)	
South end	2m to 3m	1.5m to 2.5m	150 to 180	55% to 36%	82 to 65	68 to 115
West side	6m to 8m	5.5m to 7.5m	240 to 270	15% to 10%	36 to 27	204 to 243
Deepest channel	10m	9.5m	280	8%	22	258

The above estimates should only be regarded as approximate due to inherent variations in compressibility and coefficient of consolidation and hence should be rounded off. Some ongoing settlement due to creep (or secondary compression) would also occur in addition to the above. Sedimentation and adjustments to the sea bed levels over time may also alter the perceived settlements.

4.2.4 Edge Batters

Refer to Section 4.1.6 for discussion. We note that the Unit 1 material can resemble a jelly like deposit which may have less stability than the very soft clays.

Provision of perimeter sheet piles will obviate the need for edge batters around the remediation area.

4.2.5 Sheet Pile Retention

Consideration is being given to using cantilever steel sheet piles around the perimeter of Area SA1 to improve edge stability and contain the area of excavation and capping layer placement. We note that sheet piles might only be required where edge batters cannot be accommodated or where the benefits of the presence of sheet piles is required for risk management reasons.

The sheet piles would be leaky such that differential water levels across the sheet piles would be minimal, except due to temporary wave action. If necessary, holes should be cut through selected sheet piles after installation such that differential water levels during the tide cycle are negligible. Evaluation of required sheet pile penetration has assumed zero differential tidal water level. However, it is noted that wave action would likely result in some flexing movement of the sheet piles.



4.2.5.1 Sheet Piles Adjacent to Existing Revetment

For retention of the western side boundary of Area SA1, there will be, to some extent, a possible surcharge effect from the nearby revetment and rockfill toe. The surcharge could be reduced by preparatory removal of rockfill required for adjacent Area SA2 South (Section 4.3.1) but at this stage we have assumed that remediation in Area SA2 would not occur until after the capping is placed in Area SA1 as this would enable existing stability to be maintained.

We have assumed the sheet piles would act in a cantilever mode. Whilst provision of tie back anchors would assist with stability of the sheet piles, installation of such tie backs would be difficult due to the depth of drilling required to achieve any anchorage capacity and the due to access constraints. Tie back anchors have not been considered further.

The critical design case for cantilever sheet piles is in the vicinity of the south western corner of Area SA1 since:

- a) Existing sea bed levels are highest, and have been assumed to be at about RL+0.4m AHD (based on the sea bed levels on Figure 3);
- b) The boundary for Area SA1 is closest to the revetment toe, being a minimum of about 2m (based on scaling from Figure 1).

We have assumed that the sheet piles would be driven on this boundary line.

Consideration has been given to the possible surcharge effect of the revetment on the sheet piles. The assumed design section is shown on Figure 14. There is no easy analytical solution for the effect of the distributed load arising from the revetment on the horizontal earth pressures on the sheet pile wall. A simple approximation can be made by subdividing the revetment into vertical strips and replacing each strip with a line load surcharge, as shown on Figure 14. The point of action of the resultant horizontal pressure from the line load is on the influence line at 40° below the horizontal. It can be seen from Figure 14 that the horizontal resultants from the line loads all fall below the depth of excavation. Before the sheet piles are installed, the surcharge effect from the revetment would be in equilibrium throughout the soil mass. Hence, once the sheet piles are installed, there would be equal and opposite horizontal resultant forces acting on the sheet piles. Therefore, we consider it is appropriate that the horizontal resultants below dredge level be ignored for design evaluation of the sheet pile wall requirement.

Notwithstanding the above, there would be some lateral pressure from the revetment above the level of the horizontal resultant. As a design approximation, the surface and layer thickness of the rockfill at the toe of the revetment has been assumed to be horizontal, not sloping down towards



the bay as occurs in reality. The additional load from the horizontal rockfill provides a surcharge effect in the sheet pile analyses to compensate for effect of the revetment.

The rockfill has been assumed to be 0.4m thick, above the existing sea bed level. For analysis, the rockfill has been assumed to have a bulk density of 20kN/m^3 , active earth pressure coefficient, K_a , of 0.3, and to remain fully saturated; that is there is no drainage of ground water from within the rockfill during the period of lower tidal levels.

Below the rock fill and on the excavation side of the sheet piles, very soft clays of Unit 1 and Unit 2A have been assumed below RL0.0mAHD. We have adopted the Case C ĩ Corrected Lower Bound Design undrained shear strength profile shown on Figure 9 for the full depth of the sheet pile.

A design Bulk Density of 14kN/m^3 has been adopted for the very soft clays (Section 3.3.3). However, for a sensitivity analysis we have also considered a higher bulk density of 16kN/m^3 , which might be applicable where the Unit 1 and Unit 2A sediments have a higher sand content, on the retained side only.

A dredging depth of 0.6m has been adopted based on the required 0.5m plus an allowance of 0.1m for construction tolerance, and possible over dredge.

Ground water level on the dredge side has been taken as a worst case at the dredged surface (RL-0.6mAHD), which is equivalent to MLWS. When tidal levels are above this level, the sheet pile requirements are reduced as the water pressures on each side of the sheet pile are closer to being in balance.

A cantilever sheet pile analysis has been carried out based on the above to determine the required toe level for moment stability and resulting design bending moment in the piles. The results are summarised in the table below:

Bulk Density of Very Soft Clays	Required Total Sheet Pile Length below RL+0.4mAHD	Design Highest Toe Level	Design Maximum Bending Moment
Either 14kN/m^3 or 16kN/m^3 on both sides	6.1m	RL-5.7mAHD	24kNm/m



16kN/m ³ on Revetment side 14kN/m ³ on Dredged side	7.75m	RL- 7.35mAHD	38kNm/m
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Computations for the assumed bulk density of 14kN/m³ were not fully completed; the nett pressure diagram indicates the results would be slightly less than for 16kN/m³.

These design bending moments are not large and BHP 75kg/m steel sheet pile would be more than adequate for bending. A lighter sheet pile could be used, depending on availability and other factors such as handling and corrosion over the design life. For budgeting purposes, allow for say 6.5m long sheet piles along entire western side.

It is likely that for sheet piles of 6.5m to 7.75m length, some locations will encounter the underlying Unit 2B clays before full penetration is achieved. In these circumstances, a nominal toe into Unit 2B of 0.5m would be sufficient to compensate for lack of penetration due to the significantly strong Unit 2B for lateral resistance.

Consideration will have to be given to likely effects of wave action causing the sheet piles to bury themselves due to the effect of pile self-weight relative to limited adhesion on the pile by the very soft clays. If this is judged to be of concern, then the sheet piles should be driven to encounter the Unit 2B clays at toe level.

Detailed design should check overall stability by completion of suitable slip circle analyses. Given the limited depth of dredging required (0.6m maximum) we would not expect overall stability to be an issue.

However, a cantilever sheet pile is a relatively flexible form of retention, particularly given the strength and associated low modulus of the very soft clays. Some lateral movement of the sheet pile wall due to the dredging operation must be anticipated. The revetment should be monitored for movement arising from the dredging process. If such monitoring shows lateral movements are of concern, then a staged approach of excavation in strips perpendicular to the wall, and backfilling with capping layer before excavating the next strip may be required.

4.2.5.2 Sheet Piles on Other Boundaries

On the other boundaries to Area SA1, there will not be any external surcharge load, assuming there is no construction loads applied to the sediment surface outside but adjacent to the sheet piles.



Two cases can be considered for these boundaries:

Where existing sea bed levels are below tidal levels

Where existing sea bed levels are above tidal levels

Where **existing sea bed levels are below tidal levels**, there will be no out of balance water pressures across the cantilever sheet piles. The sheet piles will only have to retain earth pressures arising from the proposed design 0.5m dredging.

In theory, the earth pressures acting on the retained side would be negligible due to the combined effect of low submerged bulk density and very low, but finite, undrained shear strength of the sediments. For such cases, it is more usual to design for retention of a dense fluid as a minimum, which has been adopted below. Completion of cantilever sheet pile analyses have given the following results:

Dredge Depth below existing sea bed level	Bulk Density of Very Soft Clays	Required Total Sheet Pile Length below existing sea bed level for stability	Design Maximum Bending Moment
0.5m	14kN/m ³ on both sides	1.2m	0.2kNm/m

This result shows that minimal sheet pile penetrations would be required and a very light pile section would suffice. Allowance for over dredge to 0.6m below existing sea bed level would not significantly increase the above.

However the sheet piles will likely extend to above MHWS with a top level of, say, RL+1.0mAH, and will be subject to wave action. Therefore we would anticipate that the sheet piles would be provided with somewhat longer penetrations to cater for self-weight and wave action effects. A penetration to at least 4m below the sea bed would result in the sheet pile toe being in very soft clays with a design undrained strength of about 10kPa. A check of self-weight versus likely adhesion would be required once a sheet pile section has been chosen. Handling, long term corrosion and other factors may dictate selection of the sheet pile section / type, rather than structural design for bending.

Where **existing sea bed levels are above tidal levels** then the critical design case will be for the excavated surface being above low water and the retained side remaining saturated. As a result



there will be an out of balance water pressure at low water and longer sheet pile penetrations will be required.

Analysis has been based on retention of a dense fluid as a minimum. Completion of cantilever sheet pile analyses have given the following results:

Dredge Depth below existing sea bed level	Bulk Density of Very Soft Clays	Required Total Sheet Pile Length below existing sea bed level	Design Maximum Bending Moment
0.6m	14kN/m ³ on both sides	2.4m	2kNm/m

Sheet Pile Lengths

We have assumed the top of sheet pile would be at RL+1.0m AHD (ISHW) such that the top would only be submerged during unusual high tides.

Then the required sheet pile length for the north eastern side where sea bed level is about RL-0.8m AHD (Figure 3) would be 5.8m. Sea bed levels are lowest at the north east corner at about RL-1.2m AHD. Then the maximum sheet pile length required would be 6.2m. Allow for an average sheet pile length of, say, 6.0m for other than the western side adjacent to the revetment.

For the top of sheet piles at RL+1.0m AHD there will be only a small upstand visible during the Springs High Tides. If it is required that the sheet piles extend further above high tide levels for visibility or other operational considerations, then long sheet piles should be provided accordingly.

An alternative conservative allowance would be for driving the sheet piles until toe resistance is derived from the underlying Unit 2B materials. Resulting toe levels can be estimated from the plot of RL Top of Unit 2B (Figure 5). Relatively long sheet piles would be required where the boundary crossed the deeper channel (Section 4.2.2).

4.2.5.3 Possible Corrosion over Design Life

It is understood that if the steel sheet piles are to remain Insitu, then a design life of 20 years is required.



Although we are not coastal / marine structural design consultants, we understand that long term corrosion of steel sheet piles is often addressed using the principles in section 6.5.3 of AS2159 'Piling - Design and Installation' AS2159 states *"Where no protection systems are to be applied to steel piles, allowance shall be made for uniform corrosion and loss of section. In the absence of other information, corrosion allowance shall be as tabulated in Table 6.5.3."*

Where steel sheet piles are exposed above existing sea bed levels at site the following exposure classification would be appropriate based on Table 6.5.2(A):

For piles in sea water - submerged	severe exposure classification
For piles in the tidal/splash zone	severe exposure classification

No guidance is given for piles buried within the sediments. We consider it would be conservative to treat them as exposed to sea water as corrosion rates are usually lower for buried elements in the absence of specific corrosion causes such as galvanic action.

The resulting corrosion allowance given in Table 6.5.3 is *"0.04 to 0.1mm/year uniform corrosion allowance"*. Adopting the higher figure, a uniform corrosion allowance of 2mm all round would be required for the 20 year design life. Therefore where there is minimal structural design requirements for the long term, a minimum pile section of 4mm thickness would be required. A BHP 75kg/m steel sheet pile has a minimum design thickness of 9mm at the clutches and 16mm at the web. Therefore such a pile would have more than adequate long term corrosion durability for the design life.

The above allowance should be confirmed to be reasonable by a marine design consultant.

4.2.6 Construction Considerations and Recommendations

A number of aspects are discussed in the sections above and are not repeated here.

4.2.6.1 For the Western Side of Area SA1:

We recommend that a moderate pile section be adopted to enable handling and driving through existing rockfill without excessive damage.

We recommend an allowance be made for some pre-clearing of rock fill and obstructions along pile line before pitching and driving. Due to the very limited surcharge load capacity on the underlying very soft clays, we anticipate that relative shallow draught pontoons / barges would be used for this,



together with a small tracked excavator for digging out the rockfill and placing the sand backfill. Stability of the barge with a tracked excavator will need evaluation. The work would have to be completed during high tides to enable barge access. At the southern end where existing sea bed levels are higher, it may be necessary to use hand excavation methods.

Any temporary excavation should be backfilled with sand before piling.

The old outfall pipe at about Ch128 (Appendix A) and the south western corner are specific locations where pre-clearing will be required. Towards the northern end, the increased offset from the toe of the revetment suggests less pre-clearing will be required.

No waler beam is anticipated unless some sheets do not achieve significant penetration; that is a waler beam would be a contingency measure only.

We consider that provision of sheet piles is a prudent risk management measure along this side. We note that theory says it should be possible to batter back for a 0.5m dredge depth (0.6m with over dredge allowance) and capping layer there remains some uncertainties in relation to shear strengths and existing stability of the revetment. Provision of the sheet pile support would help maintain stability plus offers advantages for construction of the capping layer.

4.2.6.2 For the Other Sides of Area SA1

Pre-clearing would not be anticipated to be required as only isolated obstructions are likely.

Care will be required when pitching piles to keep a positive connection so as to restrain the sheet piles from penetrating to greater depths than required due to dynamic effects whilst pitching. (That is, the piles might disappear into the sediment if ~~dropped~~ into position whilst pitching.)

The design corrosion allowance would be as above. We assume sheet piles would remain for the long term but would be cut off at sea bed level on completion of remediation.

The alternative of excavated batters could be adopted rather than sheet piles but this would lose the advantage of perimeter piles to contain the area of work and to provide an initial temporary anchorage point for geotextile and geogrid laying. For temporary batters, further consideration would be required for other controls for excavation and capping placement.



4.3 Area SA2 South (Green Striped)

4.3.1 Proposed Scope of Remedial Works

Area SA2 South is located between the toe of the existing revetment and Area SA1, Figure 1. The area is about 75m long and varies in width from about 2m at the southern end to about 4m at the northern end (based on scaling from Figure 1).

The proposed scope of work is understood to be, in summary:

- a) Remove existing rubbish, including demolition spoil, and surface stained materials to a nominal depth of about 0.2m;
- b) Replace to about existing sea bed levels with clean sandstone rockfill.

4.3.2 Geotechnical Conditions

Existing geotechnical conditions are discussed in Appendix A attached (Section A3.1).

In summary, a rock fill toe/apron is present along the length of the revetment. Existing levels are highest at the southern end at about RL+0.4mAHD, but drop northwards to a nominal level of about RL-0.5mAHD (about low tide level) beyond the old outfall pipe structure at about Ch128 (Figure A1).

The thickness of rock fill has not been proven. However, the crow bar probing shows that the lateral extent of the rockfill of more than about 0.4m thickness is about 2m to 4m from the base of the revetment towards the northern end and up to about 8m from the base of the base of the revetment at the southern end.

The very soft clays of Unit 1 and Unit 2A are underlying the outer edge of the rockfill, as encountered by crow bar probing. The nearby depths in boreholes to Top of Unit 2B (Figure 4) suggest the very soft clays will extend to depths of about 6m to 8m below existing sea bed level but reducing towards the southern end of Area SA2 to about 2m to 3m depth. A localised deeper channel of about 9m thickness appears to be present as discussed in Section 4.2.2 above. The extent to which the revetment rockfill may have penetrated into the very soft clays has not been proven, but would be expected to be substantial in view of the limited bearing capacity of the Unit1 and Unit 2A very soft clays.

4.3.3 Construction Considerations and Recommendations

We anticipate that Area SA2 South would be remediated after Area SA1 since installation of the sheet piles would be required for Area SA1. In addition, possible spillage of materials during



excavation in Area SA1 would possibly result in the need for reworking Area SA2 South if that work is completed first.

Due to the very limited surcharge load capacity on the underlying very soft clays, we anticipate that relatively shallow draught pontoons / barges would be used for the work in Area SA2 South. A small tracked excavator would be located on the barge for digging out the rockfill and placing the replacement rockfill. Stability of the barge with a tracked excavator will need evaluation. The work would have to be completed during high tides to enable barge access. At the southern end where existing sea bed levels are higher, it may be necessary to use hand excavation methods.

Suitable rockfill is discussed in Section 4.1.2.2 above based on the Design Study by URS / WRL.

4.4 Area SA2 North (Green striped)

4.4.1 Proposed Scope of Remedial Works

Area SA2 North is located adjacent to the toe of the existing revetment over a length of about 85m. The remediation area is understood to be defined as extending laterally from the toe of the existing revetment to about the line of the 2012 Area A panhandle, a width scaled from Figure 1 as about 10m to 12m.

The proposed scope of work is understood to be, in summary:

- a) Remove existing rubbish, including demolition spoil, and surface stained materials to a nominal depth of about 0.2m where the existing rockfill toe is present
- b) Replace to about existing sea bed levels with clean sandstone rockfill.

4.4.2 Geotechnical Conditions

Existing geotechnical conditions are discussed in Appendix A attached (Section A3.1).

Conditions are similar to the northern end of Area SA2 South as discussed in Section 4.3.2. That is, there is an existing rock fill apron and toe extending laterally to about 2m to locally about 4m from the revetment, over the underlying very soft clays of Unit 1 and Unit 2A.

4.4.3 Construction Considerations and Recommendations

We understand the remedial works are limited to the existing rockfill apron/toe and that no work is required for the adjoining Unit 1 and Unit 2A very soft clays.



Due to the very limited surcharge load capacity on the underlying very soft clays, we anticipate that relatively shallow draught pontoons / barges would be used for the work in Area SA2 North. A small tracked excavator would be located on the barge for digging out the rockfill and placing the replacement rockfill. Stability of the barge with a tracked excavator will need evaluation. The work would have to be completed during high tides to enable barge access.

Suitable rockfill is discussed in Section 4.1.2.2 above based on the Design Study by URS / WRL.

Special consideration may have to be given to work methods and rockfill placement in the vicinity of the existing storm water outfall pipe at Ch0 (Figure A1).

4.5 Area SA3 (Magenta Line)

4.5.1 Proposed Scope of Remedial Works

Area SA3 is located at the southern end, or head of Kendall Bay (Figure 1) and is roughly trapezoidal in shape with an average width (east – west) of about 80m by an average of about 40m (north – south). The southern half, approximately, is covered by mangroves and is at elevations above mean sea level (RL0mAHD) (Figure 3), reaching about RL+1.7mAHD according to contours on Figure 1. The northern half comprises the intertidal beach below mean sea level extending to about RL-0.4mAHD.

We understand the proposed scope of work is, in summary:

- a) Clean and remove surface staining and rubbish from within the mangrove area
- b) Clean and remove surface rubbish including coke and coal fragments from the sand surface to a nominal depth of 100mm below existing;
- c) Reinstate existing levels by spreading a layer of sand compatible with the existing sand (ie of similar grading);
- d) Construct spur wall structures or similar at several points along a desired alignment through the mangrove area to train stormwater flows from the existing culvert and to limit possible easterly migration of the discharge channel so that it remains clear of Areas SA4 and SA5.

4.5.2 Geotechnical Conditions

In summary, the sandy beach deposits are present within the intertidal zone and grade into the underlying Unit 1 and Unit 2A very soft clays. From Figure 4, the thickness of combined Unit 1 and Unit 2A sediments will increase from about 1m to 1.5m along the northern margin of the mangroves to about 4m at the northern boundary of Area SA3.



The thickness of the Unit 1 and Unit 2A sediments has not been proven within the mangroves. We note that the extensive root mat associated with the mangroves is present near the existing surface. Sandy beach deposits appear to be present at the higher elevations within the mangroves.

4.5.3 Construction Considerations and Recommendations

We anticipate that the cleaning and rubbish removal work within the mangroves will be carried out by hand. Access on foot within this area is possible, in part due to the beneficial effect of the mangrove roots.

We anticipate that work within the intertidal zone of the sandy beach area will be carried out using relatively shallow draught pontoons / barges. A small tracked excavator would be located on the barge for removing the top 100mm of sand and placing the replacement sand. Stability of the barge with a tracked excavator will need evaluation. The work would have to be completed during high tides to enable barge access.

We would not expect use of land based equipment will be feasible in the intertidal zone due to the limited bearing capacity of the underlying very soft clays relative to likely surcharge loads from small tracked plant (Section 4.1.1 above). If required, this aspect could be considered further based on specific load and track dimensions of specific plant. Allowance could be made for the presence of the surface Unit 2A sands on the beach area, but possible variation in thickness of the sands due to past scour erosion from stormwater may be a limitation dictating that uncertainty may arise as to continuity of the sand cover.

Access for use of hand methods may be problematic at lower elevations due to the limited bearing capacity and possible OH&S implications of personnel becoming bogged. Hand work from temporary access matting may be a suitable methodology, albeit slow, to overcome the access constraint.

We recommend that any training walls for the culvert outlet be designed and constructed using a flexible form of construction such as gabions and reno mattresses. This would enable the structures to accommodate settlements and differential settlements. Design bearing pressures should be limited to not more than 10kPa which will limit the height of gabion possible to about 0.5m above existing ground level. Care will be required during construction if the base of such a gabion wall is to be embedded below existing ground levels.



We would anticipate that long term durability of such gabions and reno mattresses in the marine environment may be limited, requiring possible long term maintenance. Specialist advice from suppliers should be sought in regard to long term durability.

4.6 Area SA4 (Blue Line)

4.6.1 Proposed Scope of Remedial Works

Area SA4 is located at the south eastern end of Kendall Bay and comprises the existing intertidal beach area, Figure 1. Area SA4 is roughly triangular in shape extending for about 60m along the foreshore and extending up to about 20m from the existing shoreline. Existing ground levels range from about RL-0.4mAHD on the outer, north side, to about RL+0.5mAHD at the northern end of the foreshore to about RL+1.7mAHD at the southern end of the foreshore adjacent to the mangroves in Area SA4 (Figures 1 and 3).

We understand the proposed scope of work is, in summary:

- a) Clean and remove surface rubbish including coke and coal fragments from the sand surface to a nominal depth of 100mm below existing;
- b) Add 0.5m layer of suitably graded clean sand compatible with the existing sand (ie of similar grading) extending out to the northern area boundary to transition to Area SA5;
- c) Extend the existing spur wall (at the southern corner of Area SA4) seaward to the extent of sand placement to compartmentalise the beach and intertidal area.

4.6.2 Geotechnical Conditions

Area SA4 comprises the existing intertidal sand beach and accumulated sand deposits above normal high water.

Subsurface data is limited to the intertidal areas, Figure 1. In summary:

- BH SS23 encountered sands to 1.2m depth.
- BH SW11, at a slightly higher elevation than SS23, encountered sands to end of borehole at 0.9m.
- BH SW4 and BH SW2 located towards the outer edge of the intertidal beach encountered sands to 0.47m and 0.74m depth respectively, over the Unit 2B firm sandy clay.
- Nearby DCP tests by Douglas Partners indicated loose and loose to medium dense conditions based on assuming similar sands to the nearby boreholes.
- However DCP 100 and DCP 100.1, located seaward of BH SW2, dropped to 0.6m (refusal) and 1.8m respectively under own weight.



Therefore we interpret the data to show the existing intertidal sandy beach, and sand accumulation area at higher elevation, comprises sand of loose to medium dense condition over the Unit 2B firm sandy clays. However, at the outer edge of the intertidal zone in the vicinity of the boundary of Area SA4, the sands are either not present or of limited thickness such that Unit 1 and Unit 2A very soft clays are present to depths of about 1m or more.

4.6.3 Construction Considerations and Recommendations

Based on the available data, access on the intertidal beach and the sand accumulation zone will be possible for small tracked plant down to about RL+0.4mAHD, say. Below this elevation, bearing capacity will be doubtful, and may change rapidly over short distances.

Therefore we recommend that any removal of existing sand and placement of new sand below RL+0.4mAHD be carried out using relatively shallow draught pontoons / barges. A small tracked excavator would be located on the barge for removing the top 100mm of sand and placing the replacement sand. Stability of the barge with a tracked excavator will need evaluation. The work would have to be completed during high tides to enable barge access. Care will be needed to spread the sand evenly and to limit the dump surcharge height to about 0.5m above existing sea bed level at the outer extent so as to avoid bearing slip circle failures and a mud wave. Work at the outer edge should be completed together with Area SA5.

We expect that construction of the spur wall to, say, not more than 0.5m above existing levels would be founded on sands over most of the wall length. If the spur wall is to extend beyond RL+0.4mAHD, then the founding conditions should be proven by further site investigations.

For a sand foundation, and assuming the wall base is not more than 0.3m below existing levels, an allowable bearing pressure of 50kPa would be feasible after the exposed founding level has been compacted by use of a vibrating sled compactor. We note that such compaction should be carried out during low tide periods so that ground water level is as low as possible. At least 5 passes of a vibrating sled compactor should be carried out. If ground water is encountered in the foundation trench, then further advice should be sought. If a more substantial wall or deeper founding level is required, then further advice should be sought. Wall design should include flexibility to accommodate likely settlements and differential settlements. Further advice in this regard can be provided once wall details are known.



4.7 Area SA5 (Yellow Line)

4.7.1 Proposed Scope of Remedial Works

Area SA5 is located directly seaward of Area SA4, and is roughly rectangular in shape of about 50m long by 18m wide. The area is mostly below the intertidal zone, Figure 3.

We understand the proposed scope of work is, in summary:

- a) Clean and remove surface rubbish including coke and coal fragments from the sand surface; excavation to a nominal depth is not required;
- b) Add 0.5m layer of suitably graded clean sand compatible with the existing sand in Area SA4 (ie of similar grading).

4.7.2 Geotechnical Conditions

The borehole data shows a profile of Unit 1 and Unit 2A sediments will underlie this area for thicknesses of about 1m in the vicinity adjoining Area SA4, increasing in thickness seaward to about 4m at the north western corner, Figure 4.

In summary the borehole data shows:

- BHs JK8, SS06 and SS24 suggest more sandy sediments (silty sands to sandy silts) for the upper 1m to 1.5m than the other locations (such as Area SA1).
- Borehole SW6 is similar, but more clayey with depth to about 1m depth.
- BH SHA17 did not achieve any core recovery to 1.6m depth, but from the moisture content of the grab sample (moisture content of 33%) is probably also sandy rather than a very soft clay.
- Vane shear strengths measured in BH SS06 are higher than the design line, possible due to the sand content.

Based on the above, the Unit 1 sediments are either more sandy and stronger than normal, or are absent such that the sediments encountered are sandy Unit 2A materials. Therefore we consider that adoption of the Case C design line for Undrained Shear strength (Figure 9) would be conservative.

4.7.3 Construction Considerations and Recommendations

In our assessment, the available data suggests that the more sandy and stronger sediments present below the existing sea bed in Area SA5 would not have the same design limitation for allowable surcharge loads as evaluated for the usual Unit 1 and Unit 2A very soft clay sediments



(Section 4.1.1). Therefore it should be possible to lay a 0.5m thick capping layer without a geogrid reinforcement under the capping PROVIDED the method of distributing the sand capping materials will be able to be controlled to avoid overfill surcharge loads. The geofabric layer should still be provided to act as a separator and provide a nominal reinforcement benefit. The thickness of capping should taper to form an edge batter around the outer perimeter. Capping placement in Area SA5 should be an extension of sand placement in Area SA4.

We note there is an element of risk in the above assessment of the materials due to the inherent limitations of the various investigations completed and consequent uncertainty. To minimise the risk of unexpected slip circle failure during capping placement, we recommend the capping be placed in two layers each of about 0.25m thickness.

The alternative method to minimise risks would be to provide a sheet pile perimeter and geogrid reinforcement as for Area SA1.

4.8 Area NA1 (Yellow Line)

4.8.1 Proposed Scope of Remedial Works

Area NA1 forms a triangular area adjacent to the existing vertical sea wall over a length of about 100m and extending laterally up to about 8m at the centreline of the old wharf, Figure 2.

The proposed scope of work is understood to be, in summary:

- a) Remove existing rubbish, including demolition spoil, and surface stained materials to a nominal depth of about 0.2m where the existing rockfill toe is present
- b) Replace to about existing sea bed levels with clean sandstone rockfill.

4.8.2 Geotechnical Conditions

There is an existing foreshore intertidal beach adjacent to existing sea wall which is exposed at low tides. The intertidal beach extends seawards for about 4m based on scaling from Figure 2.

Observations of the exposed rockfill in the intertidal beach are presented and summarised in the attached Appendix A. In summary, rock fill appears to be predominantly about 400mm size and smaller, with occasional pieces to about 500mm. Other fill materials such as brick, brick fragments, pipes and steel pieces are present. Old timber piles cut off at existing sea bed level are also present.



As noted and discussed in Appendix A, there is evidence of movement of the existing sea wall, particularly at the southern end. The movements suggest either translation or forward rotation of the sea wall, or both.

Douglas Partners completed some DCP tests close to the sea wall and also offset from the sea wall beyond Area NA1 as a longitudinal profile within Area B 2012. Adjacent to the sea wall DCP1 and DCP3 had shallow refusal at 0.45m or nil depths. Moving away from the sea wall, the DCP probes penetrated about 2m or more to firm sediments inferred from the DCP blow counts.

BH SS13 by SKM was close to the sea wall on the beach area. BH SS13 found 0.2m thickness of gravelly sand over the very soft Unit 1 clays extending to 1.2m depth, then clayey Sand probably of Unit 2A to end of hole at 1.6m depth. The encountered gravelly sand would likely be a crust of fill associated with beach and wall construction.

BH SW903 was also on intertidal beach near SS13. BH SW903 only had 40mm hand cores to max 0.73m depth and found silty sands, of varying colours: brown, pale to mid grey and dark grey to black. The sandy sediments appear to be part of the sandy beach sediments. Unit 1 clays are either absent or beneath sampled depth (i.e. not encountered).

The depth of rock fill has not been proven and neither has the founding level or founding stratum of the vertical seawall.

4.8.3 Construction Considerations and Recommendations

Although available data close to the existing near vertical sea wall is limited, in our assessment the limited depth of removal of rockfill (to about 0.2m depth) and replacement will be possible but will need to be carried out in limited lengths of maximum 10m, say, to minimise the possible impact on the existing sea wall. We envisage the removal and replacement would be carried out from floating plant during the daily tide cycle.

Reinstatement will require rock fill sized for hydrodynamic stability under wind wave and ferry wash waves which affect this area, as discussed in Section 4.1.2.2 above. We recommend the requirements be confirmed by specialist advice from coastal engineers. Based on the WRL 2007 advice, the rockfill is likely to be at least 250mm size sandstone rockfill. We recommend the rockfill should extend beyond the existing toe / apron to create a transition of reducing thickness of rock fill for edge stability reasons and to improve support to the toe of the existing wall.



If remediation has to extend beyond the toe of the intertidal beach then expected conditions are similar to Area NA2 such that the same approach as for Area NA2 would be adopted.

We recommend that a detailed dilapidation survey of the existing sea wall and adjacent paved area be carried out before any site work commences. The purpose of the survey is to document existing conditions as a basis for assessing possible claims from the adjoining land owner that damage has been caused to the wall.

In view of the apparent existing signs of movement of the wall, we recommend that no additional loading from surcharge loads or mooring loads be applied to the wall during the works.

4.9 Area NA2 (Red Line)

4.9.1 Proposed Scope of Remedial Works

Area NA2 is a rectangular area about 20m (east – west) by 13m wide (north – south) located immediately adjacent to Area NA1, Figure 2. The area is located on southern half of the old wharf alignment and consequent mound left by dredging for the unloading berths and subsequent sedimentation. Existing sea bed levels vary from about RL-1.5m AHD on the western side, down to about RL-3.8m AHD at the south east corner based on Figure 2, though we note there is an inconsistency in the contours such that this value should be checked by others. The existing sea bed slopes are discussed in Section 4.9.3 below.

We understand the following scope of work is proposed, in summary:

- a) Provide sheet piles to assist with edge stability and limit extent of excavation;
- b) An alternative to sheet piles may be to batter the excavation within stability limitations, though this alternative lacks the benefits of having a containment barrier around the site and would not address stability limitations of the capping layer on the existing sea bed slope;
- c) Excavate for 0.5m depth using a wet dredge with moon pool and silt curtain arrangement. Dredging would use a grab and/or hydraulic excavator with bucket.
- d) Place geotextile fabric and then two layers of geogrids and then the capping layer to about existing sea bed levels;
- e) A contingency consideration might be for removal of soft sediments to top of Unit 2B, but this significantly alters many aspects of the design, and is not considered further in this report.
- f) A further contingency option may be to extend the remediation area such that a toe berm can be created at the base of the existing sea bed slope.



4.9.2 Geotechnical Conditions

Investigations within Area NA2 have been limited in number as shown on Figure 2. However, many of the S & W sampling locations were only for near surface grab samples, all Unit 1 type materials.

Data from deeper sampling is available at the following locations within Area NA2 as shown on Figure 7; in summary:

- BH SW561 depth to Unit 2B of 2.25m
- BH SW812 depth to Unit 2B of >1.2m (not encountered)
- BH SS11 (SKM) depth to Unit 2B of 1.45m
- BH SHB23 depth to Unit 2B of 4.1m

The overlying sediments are the Unit 1 and Unit 2A very soft clays.

Data is also available from nearby locations, but outside of Area NA2.

The Depth to Top of Unit 2B is summarised on the attached Figure 7, together with computer interpreted contours using SURFER. We note that alternative contour interpretation is possible particularly if additional infill data are obtained by further investigations. The corresponding contours for RL at Top of Unit 2B are presented in Figure 8.

DCP probes by Douglas partners are consistent with depths of in excess of about 2m or more to firm sediments.

4.9.3 Construction Considerations and Recommendations

The available borehole data shows that the Unit 1 and Unit 2A very soft, compressible clays extend to below a dredge depth of 0.5m. As a result, bearing capacity and settlement will be dictated by remaining Unit 1 and 2A sediments similar to Area SA1. Therefore proposed dredge to 0.5m depth and replace with permeable sand capping of 0.5m thickness will be possible subject to addressing the very soft strength of the remaining sediments.

4.9.3.1 Sliding Stability in Area NA2

Area NA2 is located partially over the edge slope on the southern side of the original wharf alignment (Figure 2). Existing sea bed levels reflect past dredging around the original wharf and may also reflect the build-up of sediment beneath the wharf over time, since no maintenance dredging would have been completed below the wharf alignment. The original wharf alignment appears as a ridge in existing sea bed levels with a deeper channel adjacent to the north and south.



The most recent sea bed contours have been derived from a sea bed survey using sonar methods and have been adopted for analysis of capping layer stability (Figure 2). The contours show the ridge area at about RL-1.5mAHD. The adjacent channels are at about RL-4mAHD to RL-5mAHD to the south of the ridge line. As noted above (Section 4.9.1) the contour values have an inconsistency and need to be checked by others.

The sonar contours show that edge slopes at the south eastern corner of Area NA2 are between about 16° (1V:3.5H) to 20° (1V:2.75H) as determined by hand scaling off the contour plot on Figure 2. It is noted that the edge slopes on the south facing ridge further to the east are steeper (contours closer together) with slopes of about 28° (1V:1.9H) at about half way along the ridge to about 24° (1V:2.25H) near the eastern end of the ridge. Measured slopes on the northern side of the ridge are slightly flatter, being about 20° (1V:2.8H) or less.

There are no investigation locations through these side slopes. Therefore, at this stage it is not known whether the subsurface profile is similar to the ridge area or not. Past dredging may have removed some or all of Unit 2A originally present. However, sedimentation since dredging may have resulted in Unit 1 being present, though the above slopes would indicate that significant thicknesses of Unit 1 may not be present due to inherent stability limitations at those slopes. Although limited, available data suggests at least about 2m (BHS SW554, SW557, SW712) of Unit 1 and Unit 2A very soft clays to be present within the deeper dredged channel area (Figure 7).

As noted above, within Area NA2, the investigation locations show the very soft clays of Unit 1 and Unit 2A to be of between 1.45m (BH SS11) to 4.1m (BH SHB23) thickness below existing sea bed levels.

Therefore, after excavation by dredging of existing sediments, we assume that the capping layer will be placed on top of the very soft clays of Unit 1 and Unit 2B.

It is understood that the capping layer will be placed to about existing sea bed levels. Therefore the capping layer will represent a surcharge layer on the sloping dredged surface at slopes about equal to existing; that is slopes of about 16° to 20°.

We have considered stability of the sloping capping layer on the underlying very soft clays. A simple sliding block analysis (assuming the end forces on the block are equal and opposite, and can therefore be ignored) has been adopted.



Our analysis shows that for the existing undrained strength using Case C Corrected Lower Bound Design Shear strength profile, Figure 9, the Factor of Safety for sliding stability is marginally less than 1.0 at 20° and would be about 1.2 at 16°. Whilst the latter may be acceptable for the short term, the former value would not be considered to be acceptable. Therefore measures to improve stability on this edge slope will be required, as discussed below.

These analyses have adopted a bulk density for the capping layer of 20kN/m³ which is likely to be conservative with respect to stability. A lower bulk density (such as 18kN/m³) would result in slightly higher factors of safety.

The capping will act as a surcharge load on the underlying very soft clays. With time, as consolidation occurs in the very soft clays, there will be an increase in the undrained strength of the very soft clays. An estimate of the increased undrained strength shows that the same sliding block analysis would give Factors of Safety for the long term case of about 1.5 at 20° and about 1.9 at 16°. These values would be considered acceptable for the long term.

Based on the above results, we recommend that measures be taken to control / improve stability during placement of the capping layer in Area NA2 over the south to south east facing slopes.

One simple measure would be to install steel sheet piles on the south and east perimeters of Area NA2 as shown schematically on Figure 14. For initial budgeting purposes allow for sheet piles at least similar to those required for Area SA1 adjacent to the revetment toe (Section 4.2.5). The sheet piles would be driven into the underlying Unit 2B firm to stiff clays to provide ~~the fixity~~ Further detailed design stability analysis would be required to confirm depth of embedment and bending moment capacity required to improve the short stability during capping placement to a Factor of Safety of at least 1.5. For initial budgeting purposes, allow for pile penetrations to about 4m say below existing sea bed level, but to be confirmed during detailed design. The resulting maximum sheet pile length assuming the top of pile at RL+1.0mAHD would be about 8.3m.

Although the simple analyses show the sheet piles will not be required in the long term, it is difficult to estimate the time required for sufficient strength gain in the underlying very soft clays such that the sheet piles would no longer be required. Therefore we consider it would be appropriate to leave the sheet piles insitu, cut off at existing sea bed levels, and recommend this be allowed for.



To improve the surface stability of the capping layer in this area of sloping capping, allowance should be made for use of the 5mm single sized aggregate rather than a sand capping. Such aggregate will have improved shear strength over a sand and will also have better stability in response to currents. Capping layer placement would have to commence at the area of lowest elevation and work back upslope due to stability considerations during capping placement.

We recommend further geotechnical investigation be carried out to enable detailed design for the sheet piles to be completed. Such investigation would be aimed at better defining subsurface profile, and in particular strengths, along the sheet pile wall alignment and in the areas upslope and down slope from the wall.

4.9.3.2 Capping Layer Bearing Capacity and Construction

The strength of the subsurface profile is assumed to be similar to that encountered in Area SA1 based on available data (except possibly for the steeper side slope to the dredged channel as discussed above).

Hence consideration for bearing capacity and capping layer construction are similar to those for Area SA1 as discussed in Sections 4.1.1, 4.1.3, 4.2.5 above. Therefore we recommend that design for Area NA2 allow for, in summary:

- Installation of perimeter sheet piles (in addition to those need for slope stability)
- Dredging to design depth of 0.5m starting at the highest elevations and working down slope
- Placing geotextile separator
- Placing geogrid reinforcement in both directions with temporary fixing to the sheet piles; maintain fixing until capping layer placement has been completed.
- Placing of capping commencing at the lowest elevations and working back upslope, but with careful control of the thickness placed to avoid unacceptable overfill surcharge .
- Where existing sea bed slopes are more than about 1V:6H (about 10°), use 5mm gravel capping.
- Cutting off the sheet piles at finished sea bed level.

We have considered the need for sheet piles along the western side of Area NA2 due to proximity to the existing vertical sea wall. As the sea wall is offset at least about 7m from the edge of Area NA2, and the sonar sea bed levels indicate the rockfill toe/apron will likely have terminated before reaching Area NA2, we consider there will not be any significant surcharge loads on the sheet pile from the sea wall and/or rock fill toe. Therefore design for the sheet pile retention will only have to allow for the design 0.5m dredging, plus 0.1m overdredge. This has been addressed in Section



4.2.5 above and the results may be adopted for Area NA2. That is, nominal sheet pile sections are required with a penetration of 4m below existing sea bed level, subject to check on pile adhesion against pile self-weight.

Based on the above the following sheet pile lengths would be required for Area NA2 assuming top of sheet pile at RL+1.0mAHD and sea bed levels as shown on the Detail of Area NA2, Figure 2:

Side of Area NA2	Existing sea bed level (mAHD) (Figure 2, Detail: contour values to be checked by others)		Penetration below sea bed level (m)	Sheet pile length (m)
Western	Highest	RL-1.3	4	6.3
	Lowest	RL-1.6	4	6.6
	Approx. Average	RL-1.5	4	6.5
Northern	Highest	RL-1.6	4	6.6
	Lowest	RL-2.4	4	7.4
	Approx. Average	RL-2.1	4	7.1
Eastern	Highest	RL-2.4	4	7.4
	Lowest	RL-3.8	4	8.8
	Approx. Average	RL-3.0	4	8.0
Southern	Highest	RL-1.5	4	6.5
	Lowest	RL-3.8	4	8.8
	Approx. Average	RL-2.5	4	7.5

We recommend that further investigations be carried out along the western side of Area NA2 to confirm subsurface conditions and in particular that there is no significant rockfill present at the sheet pile alignment. These investigations could be combined with those recommended above in relation to sea bed stability.

4.10 Area NA3 (Red dashed line)

4.10.1 Proposed Scope of Remedial Works

Area NA3 is a roughly circular area of about 32m diameter positioned to the north of the old wharf alignment as shown on Figure 2. Sea bed levels from Figure 2 range from about RL-1.3mAHD to About RL-3.2mAHD, but this should be checked by others.

We understand the following scope of work is proposed, in summary:



- a) Provide sheet piles to assist with edge stability, provide a temporary anchorage for geogrid, and limit extent of excavation;
- b) Excavate for 0.5m depth using a wet dredge with moon pool and silt curtain arrangement. Dredging would use a grab and/or hydraulic excavator with bucket.
- c) Place geotextile fabric and then two layers of geogrids and then the capping layer to about existing sea bed levels;

4.10.2 Geotechnical Conditions

Investigations within Area NA3 are limited with only three locations extending deeper than 0.5m, Figure 7. Based on our interpretation of these sediments the depth of Unit 1 and Unit 2A very soft clays over top of Unit 2B varies from about 1.5m to 3m, Figure 7.

Conditions similar to Area SA1 and NA2 are assumed for design purposes.

4.10.3 Construction Considerations and Recommendations

We consider that it is appropriate to adopt same approach as for Areas SA1 and NA2 except that sheet piles are not required to take into account either a nearby revetment or sliding stability due to the seabed slope.

Therefore we recommend that design for Area NA3 allow for, in summary:

- Installation of perimeter sheet piles;
- Dredging to design depth of 0.5m starting at the highest elevations and working down slope
- Placing geotextile separator
- Placing geogrid reinforcement in both directions with temporary fixing to the sheet piles;
- Placing of capping commencing at the lowest elevations and working back upslope, but with careful control of the thickness placed to avoid unacceptable overfill surcharge .
- Cutting off the sheet piles at finished sea bed level.

Based on the above the following sheet pile lengths would be required for Area NA3 assuming top of sheet pile at RL+1.0mAHD and sea bed levels as shown on the Detail of Area NA2, Figure 2:

Side of Area NA3	Existing sea bed level (mAHD) (Figure 2, Detail: contour values to be checked by others)	Penetration below sea bed level (m)	Sheet pile length (m)
Western & South western	RL-1.3	4	6.3
North eastern	RL-3.2	4	8.3



Approx. Average	RL-2.6	4	7.6
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4.11 Further Investigations

As this is a complex project involving many disciplines/specialties, we recommend that there be a workshop of all parties involved to make sure that the final design is well integrated such that all parties have adequately considered all constraints and objectives for the proposed works.

Confirmation of some comments given above is also required from other appropriate specialists.

Further geotechnical investigations have been recommended in relation to Area NA2 as discussed in Section 4.9.3.

Further design analyses are required to confirm the edge stability and overall stability of the capping layer taking into account the reinforcement of the geogrid. In addition overall stability of the sheet piles for Area SA1 adjacent to the revetment should be confirmed. Such analyses would be carried out using programs such as SLOPE-W which can specifically model the geogrid reinforcement.

5 GENERAL COMMENTS

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. As an example, careful placement of the capping materials to limit allowable overfill surcharge. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and JK Geotechnics accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

Occasionally, the subsurface conditions between the completed boreholes may be found to be different (or may be interpreted to be different) from those expected. Such variation can be expected in a marine depositional environment as found at Kendall Bay and may occur over relatively short distances, of the order of a few metres. Variation can also occur with groundwater conditions especially due to changes in sediment types. If such differences appear to exist, we recommend that you immediately contact this office.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be



prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

It is understood that all aspects in relation to contamination are being addressed by others and have not been addressed in this report unless we have been specifically briefed to take this into account.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the proposed development described in this report then all recommendations should be reviewed. Copyright in this report is the property of JK Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

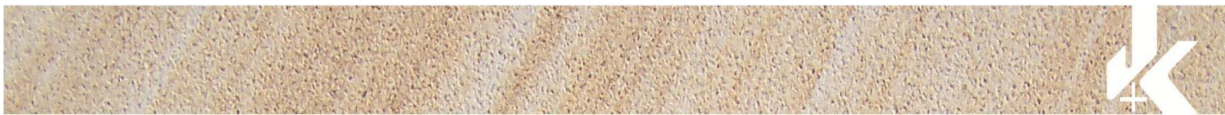


TABLE A SUMMARY OF CAPPING LAYER THICKNESS DESIGN CONSTRAINTS

Condition assumed	Capping layer thickness UNREINFORCED	Capping layer thickness REINFORCED (10kN/m Allowable Tension)
FOR (a) ABOVE TIDAL LEVELS (Existing sea bed above RL0.0mAHD)		
Allowable Thickness (FoS = 1.5) No surcharge	0.4m (single layer)	0.95m (large area, single layer)
Ultimate Thickness at edge of large area No surcharge	0.6m (single layer)	Not Evaluated
Allowable Overfill Surcharge at edge of 0.5m (nom) capping layer	Nil	0.26m for capping batter at 1V:4H
Allowable additional surcharge more than 3.5m from top edge of capping temporary batter	0.4m (single layer)	0.35m over large area 0.75m over 2m by 6m area
FOR (b) BELOW TIDAL LEVELS (Existing sea bed below RL-0.6mAHD)		
Allowable Thickness (FoS = 1.5) No surcharge	0.8m (single layer)	1.4m (large area, single layer)
Allowable Overfill Surcharge at edge of 0.5m (nom) capping layer	0.3m	0.52m for capping batter at 1V:4H

REFER TO TEXT OF REPORT

Design Thickness = 0.5m

Overdredge / Tolerance = 0.1m

Bulk Density for capping = 20kN/m³ for compacted sands or 5mm gravel

(Alternative case, not analysed, bulk density = 18kN/m³ for sands placed hydraulic compaction)

For Existing Sea Bed levels between RL0.0m and RL-0.6mAHD, results are prorated between (a) and (b).

Appendix 4

EXAMPLE ISS PROJECTS

EXAMPLE ISS PROJECTS

A large number of in situ solidification projects have been successfully completed around the world. This appendix provides details of a small number of these highlighting the application of in situ solidification and the various methods used. It is by no means an exhaustive list, but provided to demonstrate the range of methods and areas of application.

Details of the experience of some major Australian Contractors with in situ stabilisation/solidification are also included as well as some technical review papers concerning the methods.

UNITED STATES OF AMERICA

In-situ treatment at South 8th Street Landfill Superfund Site, West Memphis, AR

The South 8th Street Landfill was a 30-acre industrial and municipal waste landfill. Before becoming a landfill, the site was excavated for gravel, resulting in numerous borrow pits. After 1957, the pits were used for disposal of industrial and municipal wastes. Between 1960 and 1970, waste oil sludge from a nearby refinery was deposited on 2.6 acres of the landfill. USEPA conducted borings between 1981-1988 and found the oil sludge soil was contaminated with PAHs, PCBs and lead.

In situ mixing with auger reagents was utilized to remediate the soil. The following mixing proportions were used:

- Soil – 64.5 percent;
- AG limestone – 16.1 percent;
- Portland cement – 12.9 percent; and
- Fly ash – 6.5 percent.

Site remediation was completed over the course of two years between 1998 and 2000. Treatment costs were approximately \$106/cubic yard (cyd). Sampling during a five-year review of the contaminated site concluded that the site had achieved remediation goals and chemical and physical performance standards.

Maine US New Jersey Department of Transportation

The former Portland Gas Works (PGW) is located in the City's West End and is situated along the north shoreline of the Fore River. The project site was operated by the Portland Gas Light Company (Portland Gas) between 1852 and 1965 and provided the City and surrounding communities with manufactured gas. Once the interstate natural gas pipeline arrived in 1965, Portland Gas ceased operations and the plant was decommissioned. In 1966, Portland Gas merged with the Lewiston Gas Light Company to form the Northern Utilities, Inc. In 2008, the company was acquired by Unifil.

Kendall Square Redevelopment Project, Cambridge, Massachusetts

Kendall Square is a former 10-acre manufactured gas plant (MGP) site in East Cambridge, Massachusetts. By-products from MGP operations contaminated the soil with coal tar and petroleum residues. As a temporary clean up remedy, a previous owner of the property capped the subsurface contamination with a parking lot, which remained in place for about 30 years. Revitalization of the area surrounding the property has since made it attractive for redevelopment. The results of an environmental investigation found 4 acres of soil impacted with PAHs and VOCs, from 0 to 20 feet below grade, and a 3-acre NAPL plume that consisted of DNAPL at the groundwater/clay interface about 20 feet below grade and LNAPL on the groundwater surface about 10 feet below grade.

Excavation and disposal was chosen as the remediation strategy for the parcels of the property outside the NAPL plume. ISS was selected to treat the NAPL plume and contaminated soil. A mixture of Portland cement, bentonite and water was mixed and injected into the impacted soil, immobilizing free-phase NAPL in the subsurface. In-situ soil mixing was accomplished using a 10-foot, crane-mounted auger system. The mixed soil columns were overlapped by 35%, ensuring that all impacted soil was treated. ISS treatment resulted in the immobilization of the COCs within a 20-foot thick monolithic, solidified mass with a volume over 100,000 cubic yards.

In situ Treatment Using Shallow Soil Mixing Method at Former MGP Site



Ashley River Superfund Site, South Carolina

The Koppers Co., Inc. Charleston Plant is located on 102 acres north of downtown Charleston, South Carolina. The site includes a part of the Ashley River used as a barge canal. Koppers operated the site as a wood-treating facility from 1940 to 1977, primarily treating raw lumber and utility poles with creosote, as well as pentachlorophenol and copper-chrome-arsenate.

The majority of wood-treating operations were conducted in the eastern portion of the site, identified as the Former Treatment Area. Wastewater from these processes was discharged into a ditch, which flowed eastward to the intertidal Ashley River. From 1978 to the early 1980s, the site was used for storing wastes, including waste oil. Results of site investigations showed that the Ashley River sediments were contaminated with PAHs and DNAPL, such as creosote stringers, in several Areas of Potential Ecological Concern. The maximum Total PAH concentration was 500 mg/kg. ISS, using a slurry of cement-based grout augmented with proprietary chemicals, was used to solidify the upper two feet of sediment in a one-acre area to create a solid, cohesive layer that would be less susceptible to erosion than natural sediments. The solid surface layer separates the underlying sediment from erosion to decrease the impact of contaminants on the benthic community and upper trophic level receptors.

Gowanus Canal – New York

The Gowanus Canal Superfund site is located in Brooklyn, New York, in a densely populated urban environment. The canal is currently used for transport by a small number of local industries and has several turning basins, and many street surface level and elevated crossings. The canal has extensive NAPL-impacted sediments, as documented in the USEPA record of decision [ROD; USEPA (2013b)]. The NAPL impacts arose from over a century of industrial activity along the canal, including the operations of three MGPs. In the Gowanus Canal, there are two sediment layers of concern:

- the soft, unconsolidated overlying sediment layer, on average 3 m thick, which contains organic and inorganic contaminants as a result of historic and current discharges, including coal tar from the former MGP sites and contaminated solids from combined sewer overflows (this layer to be removed by dredging); and
- the deeper, underlying native sediments with significant impacts from MGP-derived residuals and NAPL, which cannot be removed for a variety of reasons, including the depth of contamination, potential geosstructural impacts to the ageing bulkheads, and other structures immediately abutting the canal.

In 2011, USEPA Region II completed a comprehensive remedial investigation in the

Gowanus Canal and a feasibility study of remedial alternatives to address the remedial action objectives of eliminating the migration of NAPL from underlying soils into the canal sediment and overlying water so as to minimize NAPL serving as a source of contaminants, primarily PAHs, to the canal. A proposed plan was issued in December 2012. ISS of the native sediment was included as the preferred alternative to address high NAPL impacts in the native sediment.

Hunters Point Shipyard Parcel F, San Francisco Bay, California

A field-scale test of in-situ activated carbon (AC) amendment for contaminated sediment remediation was conducted at this site. Using commercial equipment, AC was successfully incorporated into the test plots to a nominal 1 foot depth at a dose of 2-3%. In-situ bioassays showed the benefit of AC treatment, though at 18 months' post-treatment the in-situ assay results were confounded due to newly deposited sediment. Ex situ bioassays showed about 50% reduction in PCB bio-uptake with a 2% AC dose.

Field-exposed AC retained a strong stabilization capability to reduce aqueous equilibrium PCB concentrations by as much as 95%, which supports the long-term effectiveness of AC in the field at least up to 18 months. Neither PCB resuspension from the test plots nor adverse impacts to the benthic community were observed. Scaling-up the AC treatment method results in possible total cost savings of 70 to 75% less than

sediment dredging and disposal for the Hunters Point South Basin test site. If ongoing contaminant sources are eliminated and freshly deposited sediments are clean, in-situ AC amendment of contaminated sediments can provide a suitable method for reducing contaminant exposure to the water column and biota.

Columbus, Georgia MGP Plant

The former Columbus MGP site is located in the south-western section of the CBD of Columbus, Georgia, adjacent to the Chattahoochee River. Soil and groundwater contamination from plant operations was assessed from 1990 to 1991. The Georgia Power Company evaluated remedial alternatives in 1991 and selected ISS using Portland cement as a remedial alternative that immobilized contaminants and reduced the permeability and leachability of the soil matrix. Soil mixing at the site was accomplished by repeated upward and downward movements of a rotating auger with overlapping treated zones. Site remediation was completed in June of 1992.

After 10 years, the structural integrity and geochemical nature of the solidified mass continued to exceed the original performance standards established prior to implementation of ISS. The data revealed no evidence that the long-term future integrity of the site would be less stable than current site conditions. Therefore, the use of ISS at the site was an appropriate long-term treatment method for contaminated MGP soils.

Soil mixing at the former Columbus MGP plant



The results of the 10-year follow-up study are summarized below:

- groundwater has not penetrated the solidified mass;
- all samples surpassed geotechnical pre-remediation performance standards;
- the liner integrity has remained in place;
- solid phase geochemistry did not show physical or chemical deterioration;
- groundwater monitoring has shown that leaching has not occurred; and
- results from Remedial Options Assessment Modelling have shown there is low potential for leaching in future.

Manitowoc River, Manitowoc, Wisconsin

The Wisconsin Fuel & Light site is a former MGP facility located along the Manitowoc River in Manitowoc, Wisconsin. The site had been filled with uncontrolled material, including debris and other material typically used behind sea walls. Portions of the foundations from the previous coal gasification structures also remained. The underlying soils at this site were contaminated with coal tars, which were stabilized using a reagent mixture of activated carbon, cement, fly ash, and organophilic clays.

The ISS treatment of impacted soil was accomplished by simultaneous injection and mixing of cement-based grout using 4- and 7-foot-diameter tools. This created a series of overlapping, vertically oriented columns of stabilized soil. The rotary and vertical movement of the boring/mixing tool was designed to ensure effective mixing. Approximately 15,000 cubic yards of soil were treated during a 2-year period to an average depth of 32 feet.

CANADA

Sydney Tar Ponds Site, Nova Scotia

The Sydney Tar Ponds were a hazardous waste site on Cape Breton Island in Nova Scotia, Canada. Located on the eastern shore of Sydney Harbour in the former city of Sydney (now amalgamated into the Cape Breton Regional Municipality), the Tar Ponds formed in a tidal estuary at the mouth of Muggah Creek, a freshwater stream that runs into the harbour. Throughout the 19th century, runoff from coke ovens associated with Sydney Steel Corporation's (SYSCO) now-decommissioned steel mill filled the estuary with a variety of coal-based contaminants and sludge. On 12 May 2004, the Governments of Canada and Nova Scotia announced a 10-year, \$CAD 400 million plan to clean up the Sydney Tar

Ponds and Coke Ovens. The plan called for PCB-contaminated sediments to be destroyed in an approved PCB incinerator to be set up temporarily at a decommissioned industrial facility 5 km east of the coke ovens. Remaining materials would be treated in place then contained within an engineered containment system.

At the Tar Ponds, treatment consisted of ISS with cement, a process by which contaminated sediments are mixed with Portland cement powder or similar hardening agents.

UNITED KINGDOM

Remediation of Former Gas Works, Dalmarnock, Glasgow

The in-situ treatment (1,340 m³) was carried out utilising an Allu soil cutter/mixer to achieve effective in-place mixing of the treatment reagents with the gas holder materials. The treatment process involved mixing the wastes with the designated E-Clay in slurry form and cementitious/bentonitic materials in dry form. The wastes were mixed with the treatment materials to produce a homogeneous mass.

EUROPE

Finland

The EU Life Stable project focused on the sediments of the Aurajoki River and answered the needs of the Port of Turku. The harbour site is placed at the estuary of the Aurajoki River. The annual natural migration of the sediments caused by the river flow reaches about 100,000 m³. The river basin required dredging in order to sustain traffic in the harbour area. The estuary sediments were contaminated as a result of heavy vessel traffic and the city activities. The most critical contaminant was TBT which was mainly caused by industrial operations and ship building.

The confined disposal of roughly 80,000 m³ of contaminated dredged masses was not regarded as a feasible solution due to the need to construct a new disposal site on land, while underwater disposal would demand expensive sorting and cleansing of the material. The Life Stable project provided an alternative solution, solidification of the dredged sediments, which would enable immobilising the contaminants and allow for the utilisation of the stabilised masses as a construction material in the development process of the harbour storage and operational fields (Lahtinen et al. 2009).

ISS of Former Dalmarnock Gasworks, Glasgow



Appendix 5

**CSIRO TECHNOLOGY
BRIEF
ACTIVATED CARBON
AMENDMENT
MATERIALS**

Technology Brief - Activated carbon (carbonaceous materials) amendment technologies for sediment management (in situ remediation)

INTRODUCTION

Within sediment remediation projects, amendments may be applied into or onto the sediment surface layer, into a sand cap, or within a geotextile mat to reduce the bioavailability of contaminants of concern (COCs). When compared to sand or sediment caps, amended caps have the potential to reduce the thickness of traditional caps and also improve resistance to erosional events. Amended caps are usually designed to be permeable, thus allowing for groundwater flow and tidal fluctuations, and improved advective transport of COCs by ebullition and NAPLs.

Many sorptive treatment amendments that have been trialed for binding contaminants, including activated carbon (AC) and other various carbonaceous amendments (CM, e.g. biochar, coke) organoclays (e.g. bentonite with an organic molecule), apatite (phosphate mineral), zeolites, bauxite, and zero valent iron. The amendments AC, organoclay, and apatite have been found to be the most effective for in situ sediment remediation and AC particularly effective for control dissolved HOCs.

The high degree of sequestration of HOCs (such as PAHs and PCBs) by activated carbon (AC) has been recognized for decades. Applications of AC for remediation purposes have been used for soils since the 1960s. During the 1970-1990 period the science has developed strongly, and practical applications and guidance for sediments from 2000. Numerous demonstrations have been performed in laboratory and the field (freshwater and marine), and many larger scale demonstrations from year ~2004 to present.

Organoclays have been designed to capture NAPL while being permeable enough to permit groundwater advection (minimize swelling) and gas migration, and mixtures of binding phases (e.g. organoclays and AC) can be prepared.

Carbonaceous Materials (CM) and Activated Carbon (AC)

Carbonaceous materials (CM) such as soot and charcoal, often referred to as black carbon (BC) or hard carbon, may bind sediment-bound hydrophobic organic contaminants (HOCs) very strongly, up to one to two orders of magnitude higher than those for natural amorphous organic matter (OM)

Activated carbon (AC) is a porous, manufactured material with a high surface area and affinity for adsorbing contaminants. AC is produced from coal or biomass feedstock and treated at high temperature to produce a highly porous structure with great sorption capacity for HOCs.

The function of AC is to reduce porewater concentrations of HOCs by sequestration and binding to the AC surface. AC has slow kinetics of contaminant desorption.

AC amendment does not decrease total sediment concentrations of contaminants. Rather, it decreases contaminants available for biouptake and transport to surface- and groundwater.

Sustainability

In situ AC sediment treatment remedies may offer significant environmental benefits, while avoiding the environmental impacts often associated with more invasive sediment cleanup technologies (far less disruptive to communities and stakeholders than dredging or many conventional capping remedies).

Increasingly, a combination of sediment cleanup technologies applied specific zones within the sediment cleanup site will provide the best outcomes (long-term protection while minimizing short-term negative impacts and achieving greater cost effectiveness).

Project examples

The field site trials of AC treatments span range of contaminated aquatic environments: tidal creek and marsh and mudflat, freshwater river, marine harbor, deep-water fjord.

Pilot- or full-scale field sediment treatment have been completed or are underway at more than 25 field sites in the United States, Norway, and the Netherlands (see Figure in Patmont, 2015).

It is now quite evident that when applied correctly, in situ treatment of sediment HOCs using sorptive, AC-bearing materials has progressed from an innovative sediment remediation approach to a proven, reliable technology.

Types of AC Materials and Application

There exist multiple providers of AC materials that have been demonstrated as suitable for achieving remediation goals, for example:

- Aquablock (a dense aggregate core, clay agglomerate of clay-sized materials, polymers, and powdered AC additives): <http://www.aquablok.com/in-situ-treatment/>
- Bioblock: http://www.biologge.no/en/bioblok_old/bioblok_sediments_old/
- Sedimite (includes weighting and inert binder, pelletized form that breaks up over time): <http://sedimite.com>
- TOG (Calgon Carbon, water focus): <http://www.calgoncarbon.com/granular-activated-carbon/>
- Rembind: <http://www.ziltek.com.au/>

Green remediation: Life cycle analyses have demonstrated that AC produced from anthracite coal is less sustainable than AC produced from biomass feedstock (plants, e.g. coconut charcoal).

AC form, size, and dose

The AC type, particle size and dosage, sediment characteristics, and properties of contaminants affect the effectiveness of AC amendment to immobilize HOCs in aquatic sediments.

For most applications, a 2 to 4% AC dose (dry weight) provides 60 to >95% reduction in porewater concentrations of the major HOCs, PAHs and PCBs.

Greater surface area increases rate of binding, but more difficult to apply and control fate and effects.

- Powdered Activated Carbon (PAC) (varying definitions: <300 µm; <180 µm)

- High surface area facilitates fast sorption kinetics.

Granular Activated Carbon (GAC) (varying definitions: >300 μm ; 90% >180 μm)

- >400 μm size range not effective
- 75 to 300 μm size range very effective. Not as effective, being not as fast adsorption kinetics (month-years) as PAC in removing HOCs from dissolved phase, but similar effectiveness in long term.

Generally, a 1-cm-thick AC amendment layer and a 1-m-thick cap of sand have similar ability to isolate contaminated sediments. However, project-specific conditions, such as bioturbation, will require a thicker cap (than 1 cm) to guarantee isolation.

AC application methods

Amendments can be applied as direct amendment (onto or into sediment surface, with or without mixing in the sediment), as blended cover (within a sand cap as a layer or distributed), or contained in a mat (Figure 1). Placements methods include:

1. applying (spraying) an AC slurry as a thin layer to surface sediment (1-2 cm) (AC material may include weighting or binding materials). Mechanical spraying devices used include a pneumatic spreader, bark blower, or hydroseeders etc.
 - may include mixing the material in (e.g. with mechanical mixing equipment such as a tiller)
2. injecting/mechanical mixing an AC slurry into the sediment surface (to 15-30 cm depth) using a mechanical equipment such as a tine sled device.
3. hydraulic spreading from a barge of AC amendment premixed into clean sand or sediment to create a blended cover material (10-20 cm thick layer) over large areas.
4. laying of mats/geotextiles (e.g. 1-2 cm mat laid by crane and anchored in place to counter any mat buoyancy).

Care taken to ensure capping materials are homogenous

When applying to existing sediments, applications have generally sort to achieve %-AC similar to the %-TOC of the native sediments.

Initial mixing of CM with sediment and subsequent remixing can be advantageous because of the more homogenous distribution of CM between sediment particles, which facilitates HOC mass transfer.

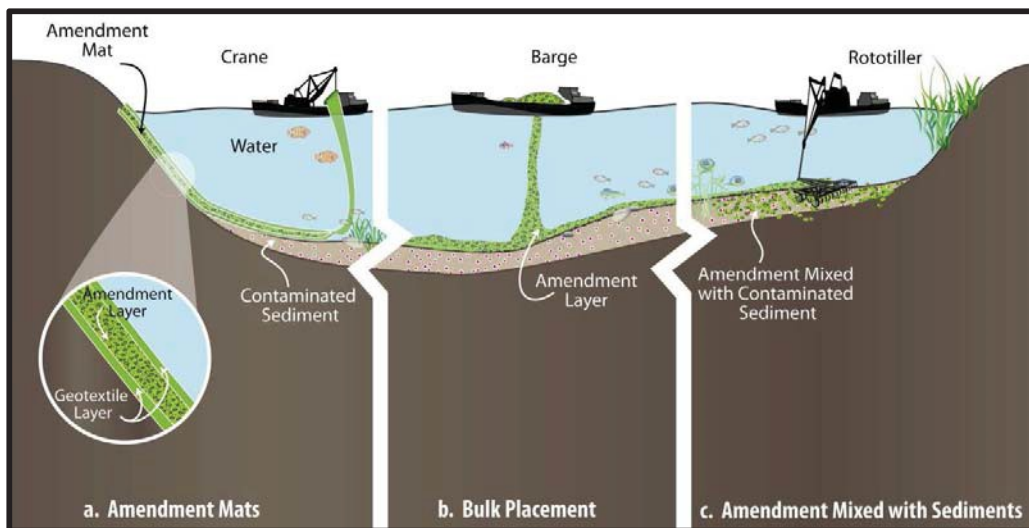


Figure 1: Placement Methods for Sediment Amendments (from USEPA, 2013)

Validation tests and monitoring

The effectiveness of AC treatments may be variable from site to site depending on the properties of the target contaminant, site conditions, and engineering options applied for the treatment. Specific-site and sediment characteristics can reduce the effectiveness of AC application compared to other potential sediment cleanup technologies. These characteristics include (but are not likely limited to) the presence of non-aqueous phase liquids (NAPLs), relatively high concentrations of black carbonaceous particles or tar-like materials that may interfere with HOC sorption to AC, or other factors that result in slow sediment-to-AC transfer rates for relatively large molecular volume HOCs (Choi et al. 2014; 2016).

A range of short- (days-weeks) to medium term screening tests (2-3 months) should be undertaken to optimize AC materials (e.g., grain size or porosity) and dosing based on site-specific conditions (sediment properties etc). Screening assessments will typically include (i) short-term slurry-phase tests being conducted using representative sediment samples collected in the field, with assessment of HOC physicochemical properties, partitioning- and desorption characteristics, AC sorption, and (ii) mid-term validation tests that assess final aqueous HOC concentrations (reduction >70% desired) and effects testing to validate (chronic toxicity of bioaccumulation tests).

Monitoring of amendments is required to evaluate whether reductions in chemical toxicity, bioavailability, or fluxes have been achieved and maintained. In the months to years after AC placement, appropriate field monitoring methods should be used to confirm the success of the in-situ AC amendment. The methodology and schedule should be appropriate to monitor AC placement stability, contaminant (bio) availability, ecosystem health. Typically such post-AC treatment studies would include analyses of porewater HOC concentrations or contaminant flux to water, together with chronic toxicity and bioaccumulation studies.

Effectiveness and Challenges

Up to 100-fold porewater concentration reductions in HOCs and a significantly increased survival of benthic invertebrates in contaminated sediments have been observed from AC-

treatments.

The long-term permanence of amendments and their ability to retain contaminants over time are not well understood.

The negative effects of AC itself on benthic species, if any, have been shown to be mild. For GAC amendments/treatments, few negative effects have been observed when GAC <4%. For PAC amendments/treatments, negative effects are more frequently observed. Higher AC dose and smaller AC particle size further reduce bioaccumulation of HOCs but may induce stress in some organisms.

Negative effects, sometimes observed at higher AC concentrations, have generally been quite mild. In a review of 'biological responses to activated carbon amendments in sediment remediation', Janssen and Beckingham (2013), observed effects in ~18% of studies, broken down as effects to organism survival (2%), growth (6%), behavior (5%), and lipid content (5%). Low dose AC amendments generally show no or only mild effects on the diversity and abundance of the benthic community.

Overall, the beneficial effects of reducing toxicity at low AC concentrations most probably outweigh the mild negative effects observed at higher AC concentrations. Numerous studies have also indicated benefits of AC amendments even in uncontaminated sediments.

Some influence on effectiveness of AC-treatments may be attributed to organism behaviour (e.g. dissolved/dietary exposure). AC may either directly sorb nutritive substances or sorb enzymes and other solubilizing agents in the gut, which would be dependent on AC particle size and an organism's feeding behavior. Thus sediment-dwelling organisms that ingest considerable amounts of sediments, such as worms, may be more susceptible to AC amendment because they are exposed to AC not only by direct contact but also by the ingestion of AC particles (effects feeding and lipid content).

Dilution of nutritional content of sediment or changes in bulk density by AC treatment may reduce plant growth and biomass.

Isolation of the AC-amended sediments (active capping layer) with clean sediment/sand (inactive capping layer) may have additional benefits. Additional capping layers may decrease the risk of contaminated AC dispersion and lower footprint of AC-amendment footprint.

AC application complexity and challenges

AC delivery via dosing can be problematic in surface sediments due to near neutral buoyancy of AC, and challenges with obtaining homogeneity (e.g. mixing in, even thickness). Therefore delivering AC-treatment materials as more dense materials (e.g. bound-AC forms – see providers above).

Sediments with high content naturally present black carbon (BC) or oil may sequester HOCs very effectively, thus limiting the effectiveness of CM/AC amendments.

Contaminants may move through the cap due to: dynamic hydrological and topographical conditions, permeability or erosion of capping materials (engineer material to prevent), organisms bioturbating deeper than the thickness of the cap (significant thickness)

Mixed binding layers may have advantages, e.g. organoclays (modified bentonite) for

control of non-aqueous phase liquids (NAPLs).

When applying mats or geotextiles (impregnated with AC), care must be taken to minimize potential damage to the mat and provide a more even surface for placement (rocks and debris removed from sediment surface).

If mats or geotextiles lose their permeability, in locations with significant groundwater flow or gas ebullition there is the potential for the mat/geotextile to be lifted.

Periodic maintenance of amended sediments/caps may be necessary to ensure long life.

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