REPORT

Kendall Bay Remediation Project

Hydrological Assessment

Client: JBS&G Australia Pty Ltd

Reference: M&APA1848R002F1.0

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1 Introduction

Royal HaskoningDHV has been engaged by JBS&G to provide expert advice regarding the estuarine processes within Kendall Bay and the Parramatta River (where applicable), and the interaction between the project proposal and these processes. The project proposal comprises the remediation of contaminated sediments within specific areas of Kendall Bay. A general description of the project is provided in **Section 2** and a detailed remediation methodology is provided in **Section 3**.

A description of the following aspects is provided within **Section 4** of this report (comprising this hydrological assessment):

- bathymetry and shoreline morphology;
- wave climate;
- water level;
- currents; and,
- sediment transport.

Concluding remarks and references are provided in **Section 5** and **Section 6** respectively.

This specialist report forms an input into the overarching Environmental Assessment prepared by JBS&G, and addresses the Secretary's Environmental Assessment Requirements (SEARS) (application number SSD 6701) relating to the key issue of 'water quality and sediments' including:

- impacts on surface water and groundwater, including potential impacts on bed and bank stability of Kendall Bay and the Parramatta River

2 Project Description

2.1 Project Background

Kendall Bay, located approximately 10 km west of the Sydney Central Business District (CBD) on the Parramatta River, was historically used for loading and unloading coal and other materials at the adjacent former Australian Gas Light Company (AGL) Mortlake gasworks.

Investigations carried out by AGL established that areas of sediments within the Bay had been contaminated and they entered into a voluntary remediation agreement (VRA) with the NSW Environment Protection Authority (EPA) in September 2005. The VRA committed AGL to further investigations and to remediate the sediment areas that required remediation.

Jemena inherited AGL's VRA obligations in late 2006 when the AGL Group was split up.

Two areas of contaminated sediments that require remediation have been identified by a number of phases of investigation followed by the application of human health and environmental risk assessments that were commissioned by Jemena. NSW Environmental Protection Authority, NSW Department of Health, NSW Department of Primary Industries (Fisheries), and NSW Roads and Maritime Services have been consulted throughout the investigation and risk assessment programs.

Approval for the Project is being sought under the State Significant Development (SSD) provisions (Division 4.1) of Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

2.2 Site Description

2.2.1 Site Locality

Kendall Bay is located on the southern side of the Parramatta River, approximately 10 km west of the Sydney central business district (CBD) and is located within the Canada Bay local government area (LGA) 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.

The proposed staging site located at 140 Tennyson Road, Mortlake (herein referred to as the 'proposed staging site') was formerly a marina, however is currently vacant and has been acquired by Jemena to facilitate the treatment and transport of the excavated sediment. The proposed staging site is located on the southern shoreline of Fairmile Cove within the Parramatta River and situated approximately 1 km north west of the remediation area in Kendall Bay.

2.2.2 Surrounding Context and Land Uses

The land 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 canoes, 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 which are predominately attached medium density dwellings and residential apartment buildings.

Kendall Bay is predominately used for recreational purposes by small private motorised boats, canoes and row boats. Kendall Bay can be accessed by pedestrians utilising the shared pathway that leads from Cabarita Point to Kendall Bay, and there is a public boat ramp adjoining the public wharf towards the north western corner of Cabarita Park.

The proposed 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.

2.3 Project Area

Collectively, the Project Area includes the:

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

The application of the three key areas outlined above is described below.

2.3.1 Remediation Areas

The project will involve the remediation of contaminated sediments within two defined areas within Kendall Bay. The extent of the defined remediation areas at the head of the Bay, referred to herein as the ‘Southern Remediation Area’, are shown on **Figure 1**. The remediation areas located on the western side of the Bay in the vicinity of the former loading wharf, referred to herein as the ‘Northern Remediation Area’, are shown on **Figure 2**.

2.3.2 Staging Site

Treatment of contaminated sediment, if required, will occur at the Staging Site located at 140 Tennyson Road, Mortlake (refer **Figure 3**). The Staging Site provides direct access to 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 proposed 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 provided access to floating pontoons.

2.3.3 Declared Area

The EPA Declared Area (refer **Figure 3**) will encompass 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.

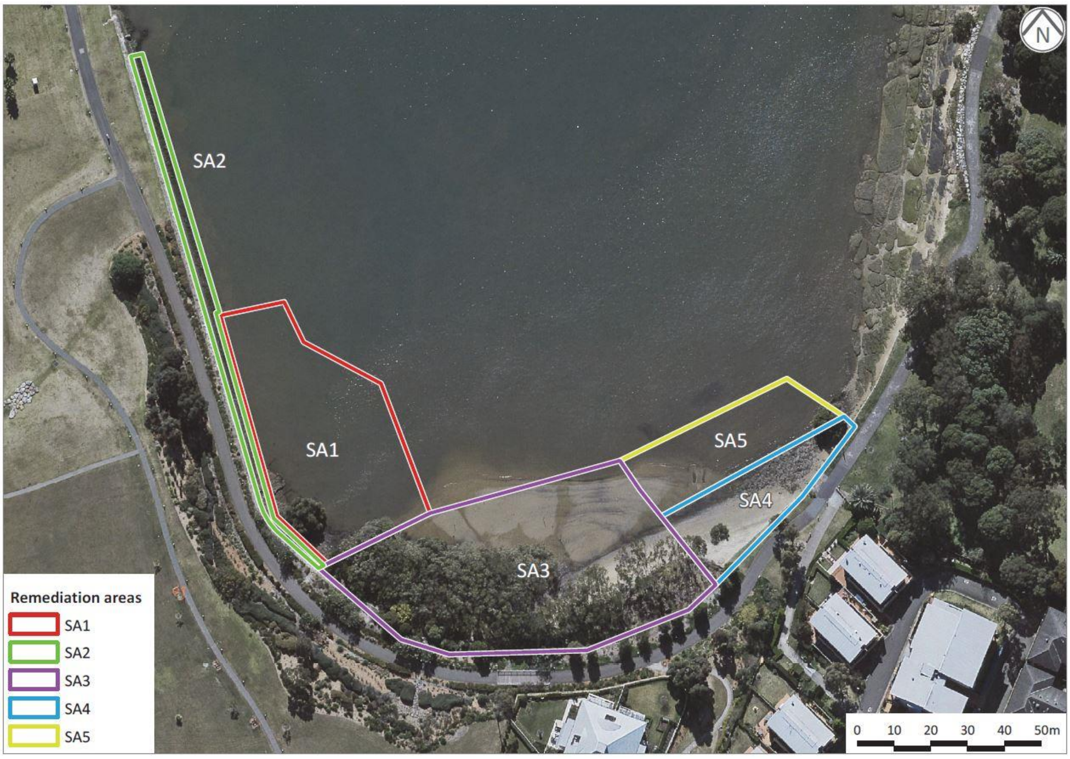

Figure 1: Southern Remediation Area (S&W, 2018)

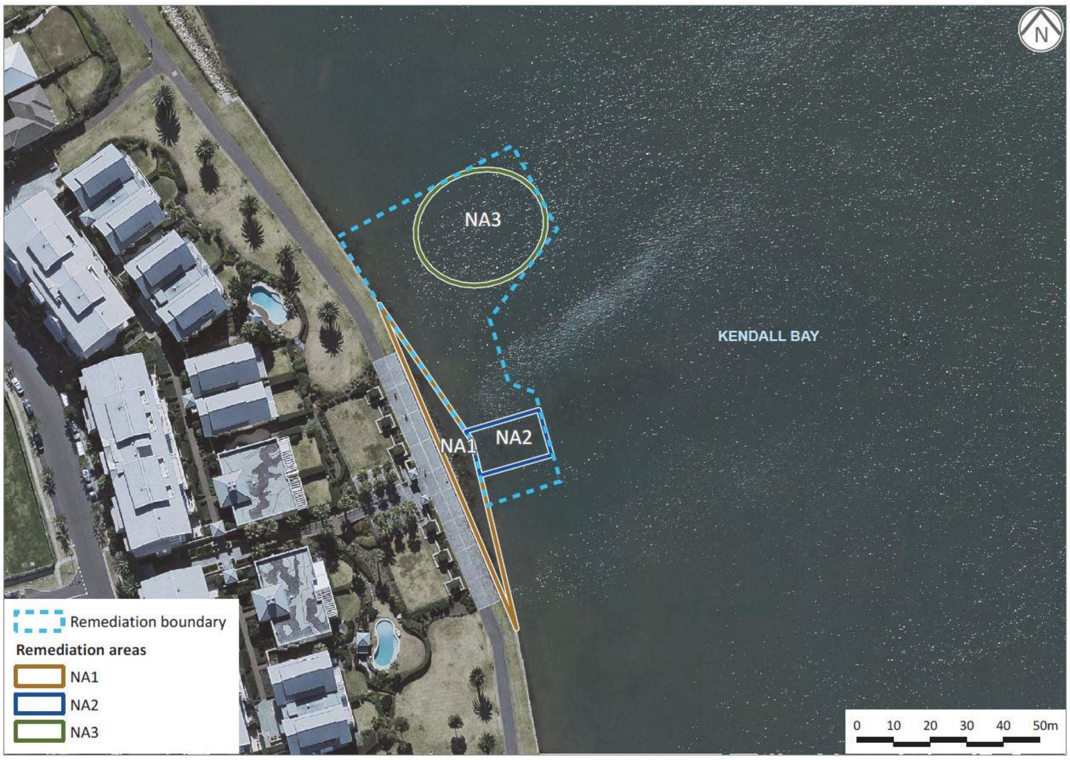

Figure 2: Northern Remediation Area (S&W, 2018)

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Figure 3: Staging Site and Declared Area (URS, 2007)

2.4 Remediation Approach

The remediation objectives and approach for each remediation area is summarised below from the more detailed description provided in the Remediation Action Plan (S&W, 2018).

2.4.1 Southern Remediation Area 1 – SA1

The objective in remediation 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.

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 0.5m below Lowest Astronomical Tide (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 in situ solidification (ISS) materials at an EPA licensed offsite waste facility may be considered before the waste materials are transported to landfill. A 0.3m 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.

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 settlement.

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. 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 area SA1 in a continuous sheet pile wall to provide environmental control during remediation. Contamination containment within the Remediation Area post remediation will be determined following remediation trial works.

2.4.2 Southern Remediation Area 2 – SA2

The objective in remediation 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.

The remediation strategy in this area is to remove stained rock/rubble and sediments to a depth of 0.3m between the seawall and to a nominal distance of 5m 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 0.3m 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.

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 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.

2.4.3 Southern Remediation Area 3 – SA3

The objectives in remediation 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 Remediation Area.

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 0.2m. 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 in amongst the mangroves to a nominal depth of 0.2m using small excavators. 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 stormwater flow from the large 1650mm diameter outlet discharging behind the mangroves at the head of the bay will be carried out. 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 landward 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 would train stormwater discharge away from the wall extension whilst allowing the flow to spread over the sand shoals without scouring a deep channel.

2.4.4 Southern Remediation Area 4 – SA4

The objective in remediation of 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 and to a nominal depth of 0.2 m (screened sand would be returned to the beach profile). The natural rocks over the beach 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 (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 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 +0.4 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 m^3.

The quantity of sand on the existing beach fluctuates 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. 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) 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 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 or not be approved by Council and RMS, other measures could include installation of a gross pollutant trap(s) (GPT) upstream in the system and construction of an energy dissipation structure at the outlet.

2.4.5 Southern Remediation Area 5 – SA5

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

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 mangrove area and would extend to the limit of SA5. The offshore boundary of SA5 is located around the 0.2m to 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 (VENM) would be compatible with the existing beach sand further inshore. 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).

2.4.6 Northern Remediation Area 1 – NA1

The primary objective of remediation in NA1 is to protect human health by preventing people using the area being exposed to contaminated sediments. Remediation works in NA1 will also 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.

The remediation strategy in this area is to remove stained rock/rubble and any contaminated sediment to 0.3 m depth 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 Lowest Astronomical Tide (LAT) and to provide a 0.3m 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.

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.

2.4.7 Northern Remediation Area 2 – NA2+NA3

The objective in remediation area 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 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 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 depth 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.

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. Contamination containment within the Remediation Area post remediation will be determined following remediation trial works.

3 Proposed Remediation Methodology

3.1 General

The proposed remediation construction method has been derived from the information contained within the Remediation Action Plan (S&W, 2018). It should be noted that the details of the remediation method are subject to the future design phase and refinement by the preferred remediation contractor.

The construction steps and methods proposed within the various remediation areas are briefly described in the following sections.

3.2 Remediation Area SA1 and NA2+NA3

- Installation of sheet pile walls around the perimeter of the remediation areas with barge-mounted equipment.
- Construction of supportive deep sediment mixed columns in SA1, 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.
- In-situ cement solidification of the upper sediment layer in SA1 using an amphibious excavator with a mixing attachment linked via a supply hose to a cement supply silo/tank mounted on a floating barge and positioned using GPS control.
- In-situ cement solidification of the upper sediment layer in area NA2+NA3 would be achieved by using barge-mounted equipment (as described above for column construction) to create a series of overlapping columns over the area down to the Unit 2B interface.
- Excavation of cement solidified material 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 impregnated geotextile 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.
- Placement of sand over the cobble layer in a similar manner to rock.

3.3 Remediation Area SA2 and NA1

- 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 0.9m overlap between adjacent panels, use of polyester non-woven geotextile fabric would facilitate underwater deployment (polypropylene geotextile fabric is buoyant).
- 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.

3.4 Remediation Area SA3

- 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).
- 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 (if required) and disposal by truck to a licensed waste facility.
- Sand placement will be achieved hydraulically 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 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 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.

3.5 Remediation Area SA4

- 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.
- 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.

3.6 Remediation Area SA5

- 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.
- Blending of excavated material with sand using earthmoving equipment for beneficial re-use in capping of other remediation areas.

4 Hydrological Assessment

4.1 General

The following reports on an assessment of the interaction of the proposed remediation works with existing natural processes and features, including:

- bathymetry and shoreline morphology;
- wave climate;
- water level;
- currents; and,
- sediment transport.

Where required to minimise impacts of the works on the above, mitigation measures will be incorporated into future detailed project design and the construction environmental management plan as appropriate.

4.2 Bathymetry and Shoreline Morphology

4.2.1 Existing Environment

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 (refer **Figure 4**).

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 6.0m and 8.4m below CD[1]. The Parramatta River channel has several deeper areas with depths between -16.1m CD and -15.6m CD between Breakfast Point and Raven Point, and down to -21.1m CD opposite Cabarita Point.

Within Kendall Bay the bathymetric levels are typically less than -2m 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 (shown on the historical aerial photograph on **Figure 5**) to the main channel of the Parramatta River.

The detailed bathymetry within Kendall Bay is provided on a plan prepared from a hydrographic survey undertaken by Hydrographic & Cadastral Survey Pty Ltd on 5 June 2014 (refer **Figure 6**), which shows surveyed depths relative to Chart Datum. The survey indicates that bed levels within the Southern Remediation Area at the head of the bay range between -0.2m CD and +2m CD. Bed levels within the Northern Remediation Area on the western side of the bay range between -1m CD and 0m CD.

Hydrographic survey data at the proposed staging site (refer **Figure 7**) indicates that the bed levels in the vicinity of the existing wharf structures at the site range between -3m CD to -3.5m CD.

[1] *Chart Datum (**CD**) is approximately the level of Lowest Astronomical Tide (**LAT**) and is approximately 0.9 m below Australian Height Datum (**AHD**).*

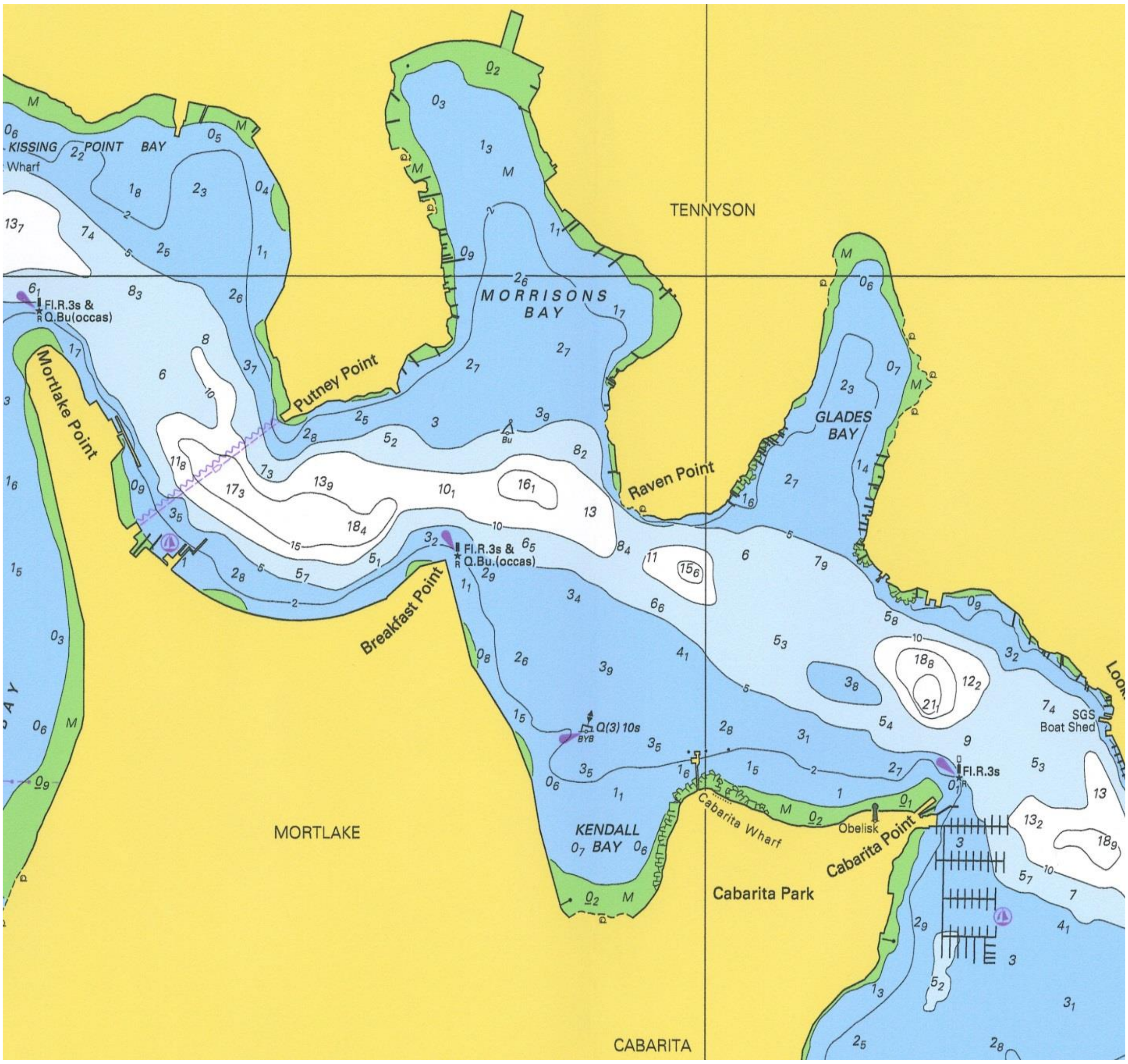

Figure 4: Admiralty Chart for Project Area (Aus 203)

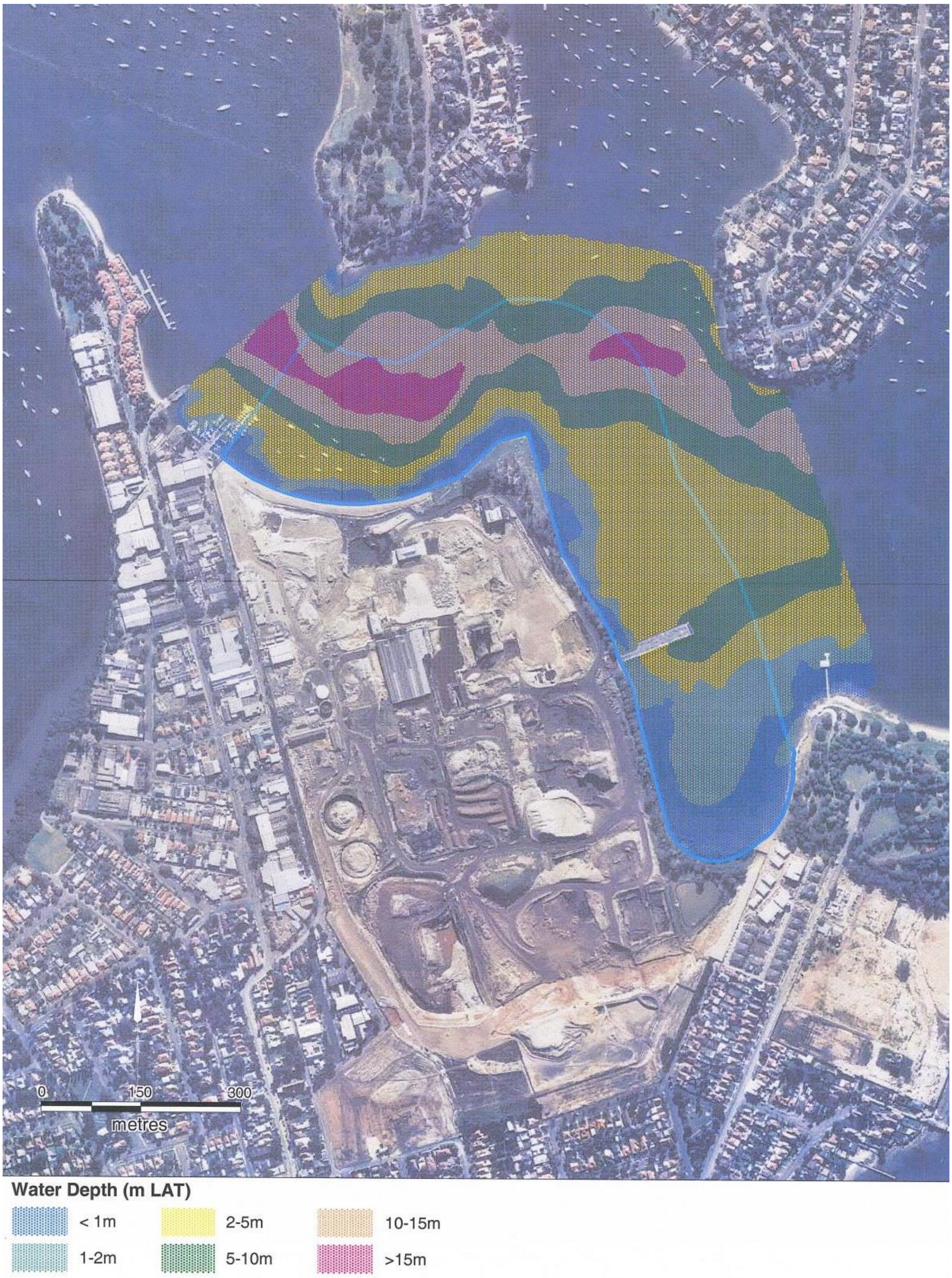

Figure 5: Historical aerial photograph and coarse bathymetry (URS, 2006)

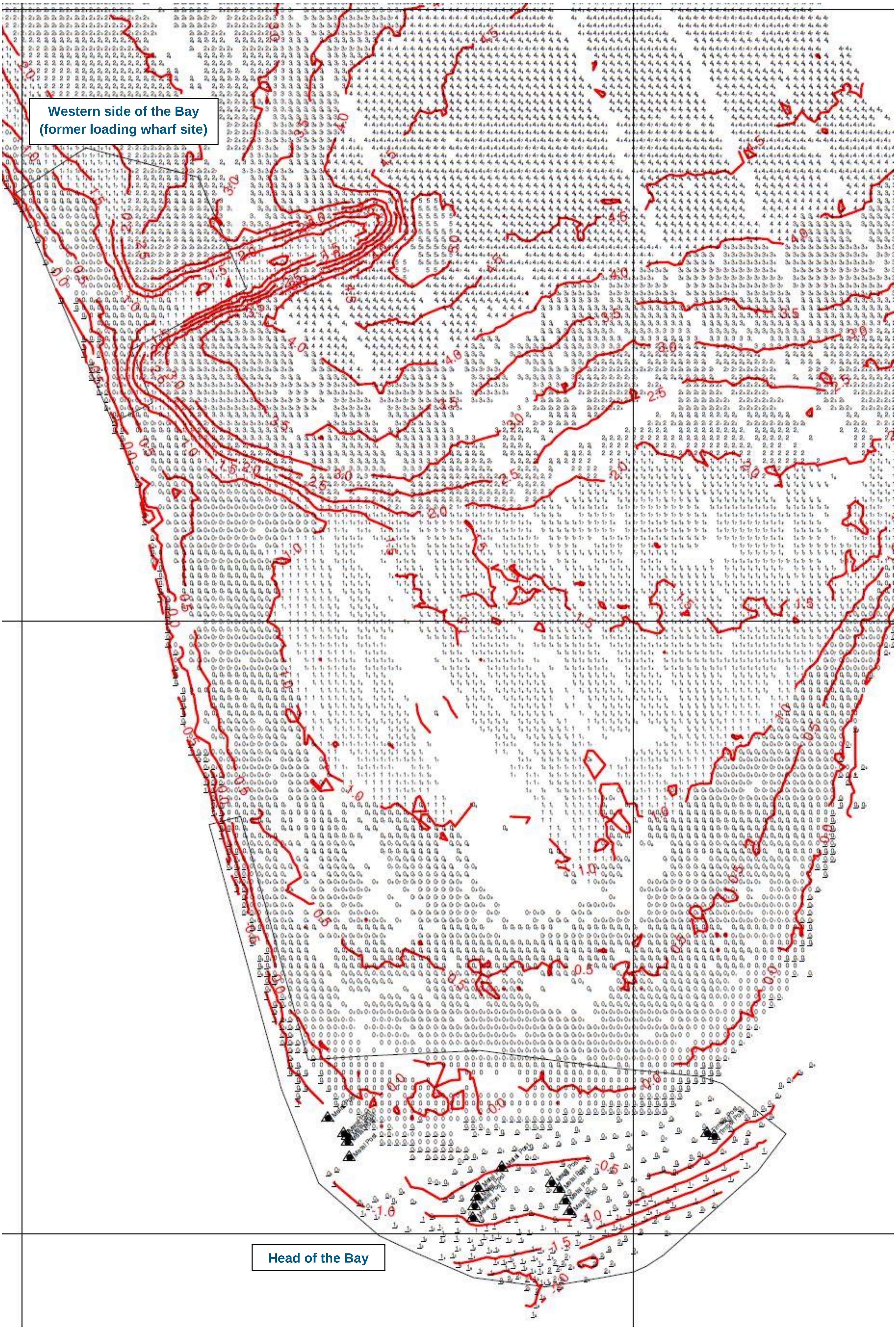

Figure 6: Detailed bathymetry within Kendall Bay (Hydrographic & Cadastral Survey Pty Ltd, 2014)

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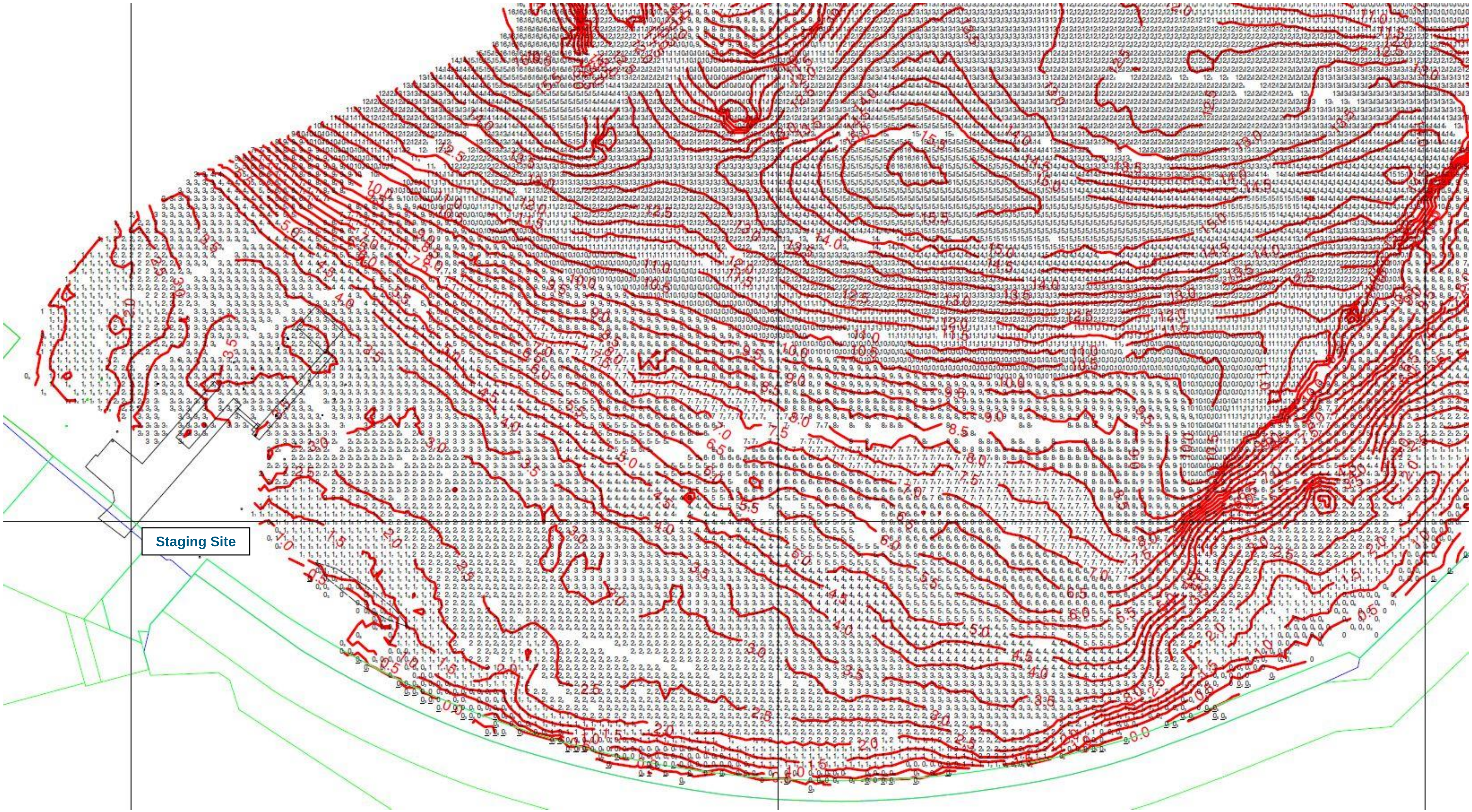

Figure 7: Bathymetric survey at the Staging Site (Hydrographic & Cadastral Survey Pty Ltd, 2014)

The foreshore areas of Kendall Bay are relatively shallow and intertidal with seabed levels above 0m CD. 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.

A rock platform exists along the eastern side of Kendall Bay and is gradually covered with sandy sediments to the south, forming a shallow beach area 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 8** provides a view along the eastern foreshore towards the head of Kendall Bay.

Figure 8: View from the eastern foreshore to the head of Kendall Bay looking west

Several foreshore protection structures exist behind the shallow intertidal area of Kendall Bay. A low-level sandstone block wall exists in the south-eastern corner of the bay (refer **Figure 8**) and 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 sandstone blocks (refer **Figure 9**). This revetment structure has been incorporated into the landscaped terracing up to the level of the adjacent foreshore promenade. The toe of the sandstone revetment appears to be protected by rip-rap generally less than 100mm in diameter, while bricks have been deposited along its base in the south-western corner of the bay.

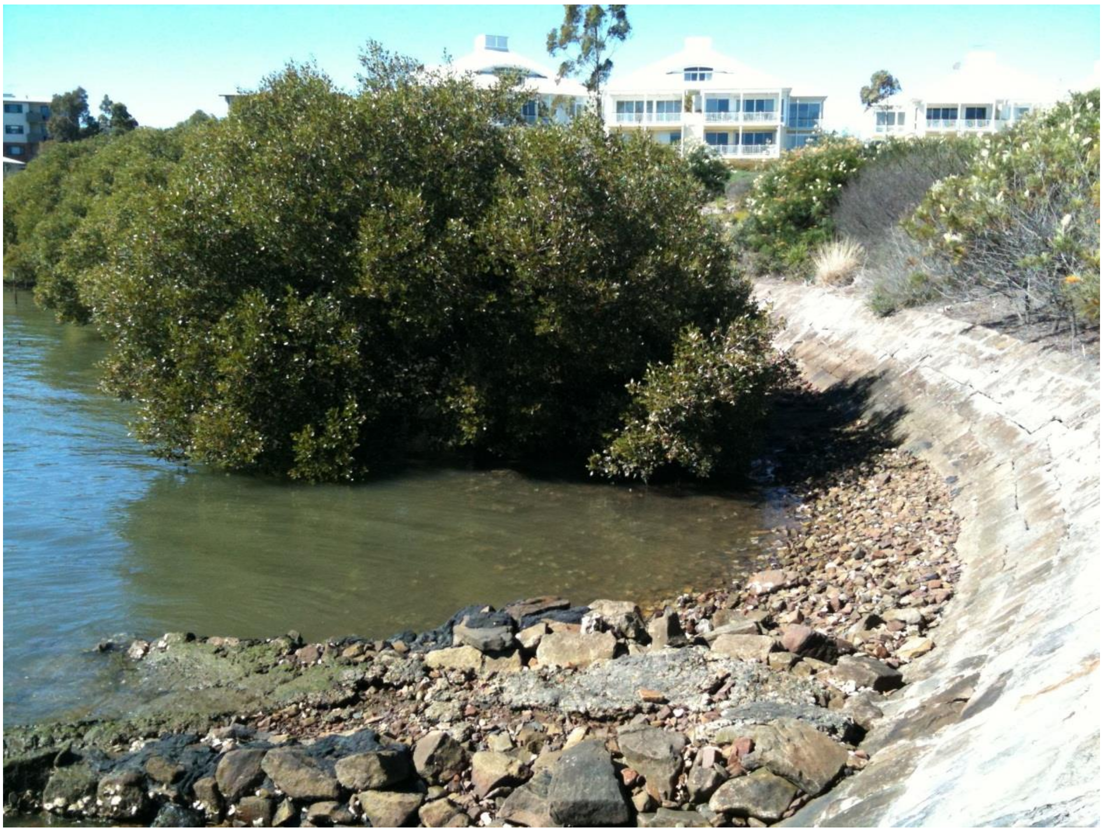

Figure 9: View of sloped revetment behind the mangrove stand

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 (refer **Figure 10**). 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 50mm to 200mm diameter. At the site of the former coal loading wharf (refer **Figure 11**) the rip-rap mound appears to comprise larger rock of between 200mm and 400mm diameter. Remnants of the demolished coal wharf structure (rubble and cut off concrete piles) are visible below the water surface.

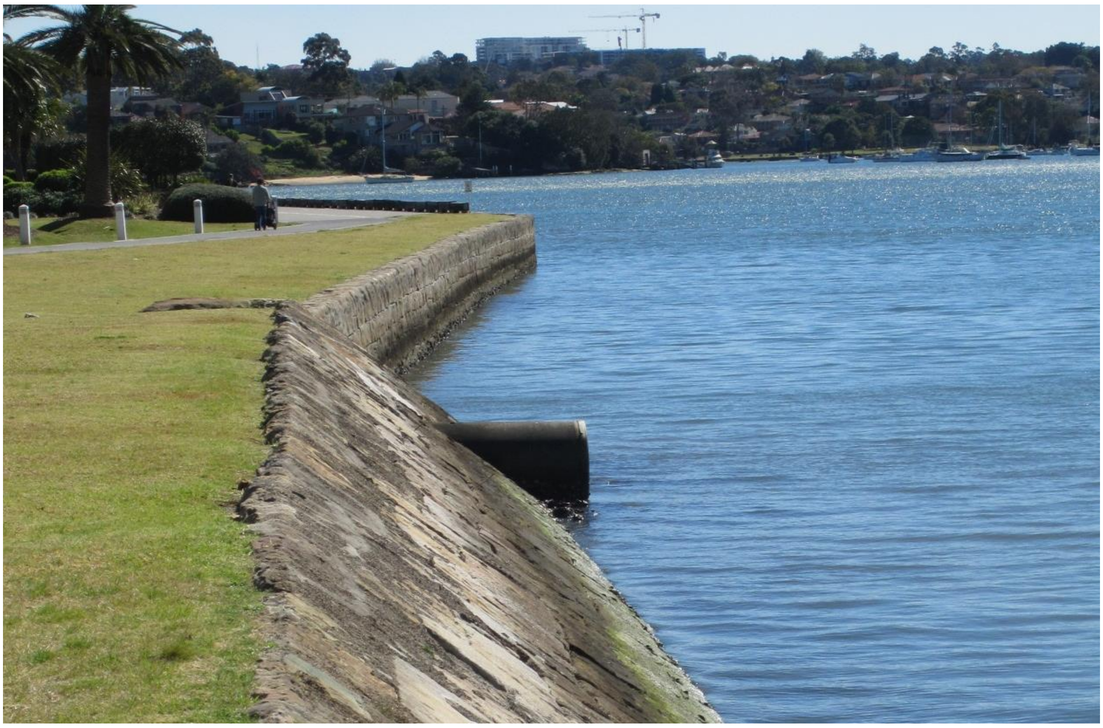

Figure 10: Transition between sloped revetment and vertical seawall structure

Figure 11: Rip rap and rubble at location of demolished wharf structure

The vertical seawall transitions into a sloped rock revetment of relatively recent construction approximately 250m south of the tip of Breakfast Point (refer **Figure 12**). At the tip of Breakfast Point a vertical blockwork seawall has been constructed to retain a terraced pedestrian walkway (refer **Figure 13**). 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 the same sloped rock revetment found on the western side of Kendall Bay.

Figure 12: Transition between sandstone block seawall and sloping rock revetment (looking towards Breakfast Point)

Figure 13: Vertical block seawall at Breakfast Point

The sloped rock revetment extends around 100m along the foreshore of Fairmile Cove before a sloped revetment commences (refer **Figure 14**). This comprises a facing of mortared sandstone blocks with rock toe protection, which appears to be of similar construction to the older seawall structure found at the head of Kendall Bay. This sloped seawall structure continues to the waterfront of the proposed staging site (refer **Figure 15**).

Figure 14: Sloped revetment within Fairmile Cove (looking towards Breakfast Point)

Figure 15: Sloped revetment within Fairmile Cove (looking towards the Staging Site)

4.2.2 Interaction with Proposal and Mitigation Measures

During the remediation works the bed levels in the Southern and Northern Remediation Areas would be temporarily modified in places as part of the excavation of contaminated materials. The temporary depression formed on the sea bed at each work area would generally then be filled with capping material to a target finished level at or below pre remediation bed levels. An exception to this exists at remediation area NA2+NA3 where penetration of hard surfaces over the footprint of the former coal wharf may not be possible. In this case, a capping layer of cobbles/sand would be placed over the top of the existing mounded area to provide substrate for re-establishment of viable benthic communities. This could locally raise bed levels by 200-300mm. However, the existing hazard to navigation posed by the mounded seabed in the former wharf area is already identified by a cardinal mark. This navigation aid would continue to alert boaters of the shallow inshore depths in the area following completion of the remediation works.

There are a number of measures that would be implemented to ensure that the target bed levels in each remediation area are able to be achieved and the thickness of the cap is maintained:

- plant and equipment would be selected that is fit for purpose;
- provision of GPS and other depth survey equipment on work barges to measure bed levels throughout excavation and capping placement activities;
- agreement on the allowable tolerances for the backfilled profile with NSW Roads and Maritime Services;
- hydrographic survey (supplemented by land-based survey in shallow areas) to determine pre and post excavation levels, and finished capping levels;
- verification of capping layer thickness by comparison of pre and post capping surveys;
- underwater photography using a drop camera and diver inspections at high tide;
- photographic records of foreshore and shallow areas taken at low tide;
- sizing of the granular capping material as a graded rip-rap blanket that is stable under the action of currents from wind waves and regular boat wake waves from passing ferries;
- specification of rock capping material properties to provide required durability for use in the marine environment, and sampling and testing of rock supply to confirm that these specifications are satisfied; and,
- implementation of a Site Management Plan (SMP) for ongoing monitoring and management of remediation areas, as outlined in the Remediation Action Plan (S&W, 2018).

The works in remediation area SA4 involve the raising of beach levels in the south-eastern area of Kendall Bay by around 0.5m. This would improve beach amenity as increasing sand reserves on the beach would improve accessibility from the adjacent promenade and increase the beach width available for use by the public. The beach sand would be retained by the proposed extension of the existing sandstone wall located on the western side of the beach.

Removal of stained rock/rubble and sediments at remediation areas SA2 and NA1 would need to be undertaken adjacent to existing seawall structures. Careful excavation is required in these areas to avoid removal or damage to seawall foundations. The following measures would be implemented to manage the risk of seawall damage:

- geotechnical stability assessment to identify any existing seawall instability and possible repair works to be completed prior to commencement of remediation activities;
- toe apron slabs or rock fill which forms a layer to support the toe of seawalls should not be removed;
- excavation along the toe of seawalls in limited lengths of maximum 10m followed by placement of capping material before the adjacent excavation is started;

- visual monitoring (conducted daily) of seawall for signs of instability during the works; and,
- completion of pre remediation and post remediation dilapidation surveys.

Piling associated with the installation of silt curtain enclosures would interact with the seabed and some localised scour may occur around the piles due to tidal currents and wave action. This would occur on the seabed outside of the remediation areas and scoured material would be deposited in close proximity to the alignment of piling. However, following pile removal it is expected that natural sediment movement processes would infill any localised depressions avoiding any longer term significant changes in seabed levels.

The available water depth adjacent to the existing wharf facilities at the Staging Site is such that dredging would not be required to accommodate construction vessels provided they have a draught less than around 2m. It is not expected that the selection of floating plant and equipment will be significantly limited by existing depths at the Staging Site given the shallow draught requirements of the intertidal areas of Kendall Bay.

4.3 Wave Climate

4.3.1 Existing Environment

The wave climate within Kendall Bay is influenced by wind waves and boat generated waves. A discussion of the nature of these contributions is provided below.

4.3.1.1 Wind Waves

Kendall Bay is exposed to overwater wind directions (i.e. wind fetches) in the sector between the NNW and E directions. A selection of worst case wind fetches within this sector have been defined to develop design wind wave conditions for 1 year Average Recurrence Interval (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 1** 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) with input wind data from AS 1170.2 – 2011 Structural Design Actions – Part 2: Wind Action.

Table 1: Wind Wave Climate

Wind Direction	Fetch Description	Fetch (m)	Average Depth (m)	1 year ARI		20 year ARI	
				H_{m0}[2] (m)	T_m[3] (s)	H_{m0} (m)	T_m (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

Note: Refer to **Figure 4** for geographic locations referred to above.

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 0.56m and peak wave period (T_m) of around 2.15 seconds in the case of a 1 year ARI design event.

4.3.1.2 Boat Generated Waves

Waves generated by boat traffic provide a significant contribution to the daily wave climate experienced within Kendall Bay. This statement is particularly relevant to 'Rivercat' and 'Harbourcat' vessels 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 part of an environmental assessment submitted for a marina proposal at Breakfast Point. A compilation of wave conditions was presented in this report and are reproduced in **Table 2**. Review of the 2016 ferry timetable determined Cabarita Ferry Wharf receives 25,608 ferries annually, which is similar to the annual number of passings reported in **Table 2**. Recreational boat ownership in Sydney Harbour has been reported to have increased by 1.3% annually between 1999 and 2009 (NSW Maritime, 2010) 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.

[2] *H_{m0} is the spectrally based significant wave height and is four times the square root of the variance of the sea surface variation. H_{m0} is approximately equal to the significant wave height (H_s) in deep water.*
[3] *T_m is the period of the peak of the wave energy spectrum.*

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Table 2: Design Near-Field Boat Wave Climate (GBAC, 2009)

Boat Type	No. Passings per Year[4]	Typical Maximum Wave Conditions[5]		Root-Mean-Square Typical Maximum Wave Conditions[6]	
		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

Table 2 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 reported in **Table 2** 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.

4.3.2 Interaction with Proposal and Mitigation Measures

The wave climate within Kendall Bay is relatively benign in maritime construction terms. Plant and construction methods should be readily available to operate efficiently under the ambient wave conditions.

Kendall Bay is regularly subjected to boat wake waves from passing Rivercats and periodically exposed to wind waves from the north-west to east sector. As such, any temporary structures should be designed to accommodate wave action. Such structures may (subject to detailed design) include piling used for installation of silt curtain enclosures, sheet pile walls around remediation areas SA1 and NA2+NA3, and anchoring/mooring of floating equipment. In accordance with AS 4997-2005, temporary structures presenting a low degree of hazard to life or property should be designed to withstand wave loads associated with a 20 year ARI wave condition. This wave height should be the average of the highest 1% of all waves in the design event and, in the case of wind waves, is determined by multiplying the significant wave height by a factor of 1.5 (for short narrow fetch).

It is also expected that waves would interact with the outer face of the sheet pile wall enclosures around remediation areas SA1 and NA2+NA3. Interaction of reflected waves with incoming waves may occur under certain conditions. This has the potential to disturb bed sediments along the toe of the sheet pile

[4] 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.
[5] Typical maximum wave conditions interpreted from GBAC database including WA (2001) and Blumberg et al (2003). Typical operating speeds are assumed.
[6] 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.

walls, particularly during low tide conditions. It is recommended that the full depth silt curtains enclosing the Northern Remediation Area and Southern Remediation Area are maintained for the duration of the remediation works. These will act to contain any turbidity resulting from disturbances caused by interaction of boat wake and wind waves with the face of the sheet pile walls. Localised scour may occur along the toe of the sheetpiles and should be allowed for in the design of these temporary structures. However, following cutting off of the sheet piles at the seabed level it is expected that natural sediment movement processes would infill any localised depressions avoiding any longer term significant changes in seabed levels.

The lowering of the bed levels within the remediation areas would be expected to cause waves to penetrate further into Kendall Bay before breaking. However, this would have minimal impact on the foreshore as it is protected with existing seawall structures and in some areas this situation would only occur temporarily before capping material is placed and pre-existing seabed levels are restored.

In remediation area SA1 the bed levels would be permanently lowered to LAT which would result in greater wave penetration into the south-western corner of the bay. Shoreline impacts would be mitigated by the existing seawall along the western side of the bay. However, the sand shoal forming substrate for mangroves growing at the head of the bay would be subject to increased wave action. Monitoring of the western area of mangroves should be undertaken to identify loss of sand from the shoal and/or undermining of mangroves. Protection of the batter slope from the mangrove area (SA3) to the depressed area of SA1 may be required to mitigate against erosion. It is noted that rip-rap already exists in the vicinity of this area at the toe of the seawall immediately adjacent to the mangroves (refer **Figure 9**).

The boating traffic associated with the construction activities would temporarily increase the frequency of boat wake wave generation adjacent to the foreshore areas between Kendall Bay and the Staging Site. However, this entire length of shoreline is protected by existing seawall structures that would mitigate the impact of increased exposure to wave energy.

The silt curtain enclosures installed around work areas would be expected to attenuate wind waves and boat wake from smaller vessels having short wave periods (i.e. excluding Ferries, Rivercats and Harbourcats) to some degree.

The capping material has been selected as a cobble sized rip-rap blanket so as to be stable in the local wind wave and boat wake climate, thereby ensuring its longevity. The performance requirements and basis for the capping design to achieve the required durability and robustness over an extended period of time are documented within the Remediation Action Plan (S&W, 2018). The capping design is also subject to the future detailed design phase and refinement by the preferred remediation contractor.

4.4 Water Level

4.4.1 Existing Environment

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.

4.4.1.1 Astronomical Tide

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 3** below.

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.

Table 3: Predicted Tidal Planes for Cabarita (MSB, 1995)

Tidal Plane	Water Level (m CD)
Highest Astronomical Tide (HAT)	2.1 (Fort Denison)
Mean High Water Springs (MHWS)	1.64
Mean High Water (MHW)	1.51
Mean High Water Neaps (MHWN)	1.38
Mean Tide Level (MTL)	0.98
Mean Low Water (MLW)	0.39
Mean Low Water Springs (MLWS)	0.27
Lowest Astronomical Tide (LAT)	-0.003 (Fort Denison)

4.4.1.2 Storm Surge and Sea Level Rise

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 ARI events, refer **Table 4**). These water levels include allowances for astronomical tide, design barometric setup and wind setup, and future sea level rise[7]. 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.

Table 4: Design still water levels at Fort Denison (DECCW, 2010)

Average Recurrence Interval	2010		2050		2100	
Years	m AHD	m CD	m AHD	m CD	m AHD	m CD
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

[7] *The values adopted for sea level rise between 2010 and 2050, and 2010 and 2100, were 0.34m and 0.84m respectively and remain suitable for adoption for current planning purposes.*

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.

4.4.1.3 Wave Setup

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 (refer **Table 1**) the wave setup is estimated to be between 0.09m and 0.13m. For the worst case 1 year ARI wind wave conditions (refer **Table 1**) the wave setup is estimated to be between 0.07m and 0.10m.

4.4.1.4 Freshwater Flooding

The Lower Parramatta River Flood Study (PWD, 1986) 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).

4.4.2 Interaction with Proposal and Mitigation Measures

Water level is an important consideration in the design of the temporary structures required to undertake the remediation works. The performance of silt curtains around the perimeter of the works would be potentially affected by tidal variation. The shallow intertidal environment within Kendall Bay relative to tidal range means that there would be a tendency for the silt curtain to ‘bunch up’ at low tide. The collapsed curtain at low tide may become partially buried by nearshore sediment movement as the tide rises and this can weigh the curtain down, preventing it from floating and performing its function as a continuous barrier. Difficulties with the rise and fall of floating silt curtains within the intertidal zone can be mitigated by fixing (draping) the curtains to a series of poles or piles leading out from the foreshore until deeper water is reached and a floating barrier can be better accommodated.

Given that a large portion of the remediation area is intertidal and the primary silt curtain is the first line of defence to contain turbidity, the preliminary design undertaken for the purpose of this assessment comprised a full depth silt curtain barrier fixed to piles along the entire length of the primary silt curtains around the Northern and Southern Remediation Areas. This incorporates a tidal compensating system that allows the boom at the top of the silt curtain to float up and down with the tide due the sliding action of floating rings fitted around each pile (refer **Figure 16**). This concept is considered to be a suitable example of a method to accommodate tidal water level variation, although other options may be considered in the detailed design phase.

A similar piled system should be employed for the portion of the secondary silt curtains running through intertidal areas. In deeper areas, secondary silt curtains could comprise a geotextile skirt with a floating boom held in position by a typical system of anchor blocks and restraint lines.

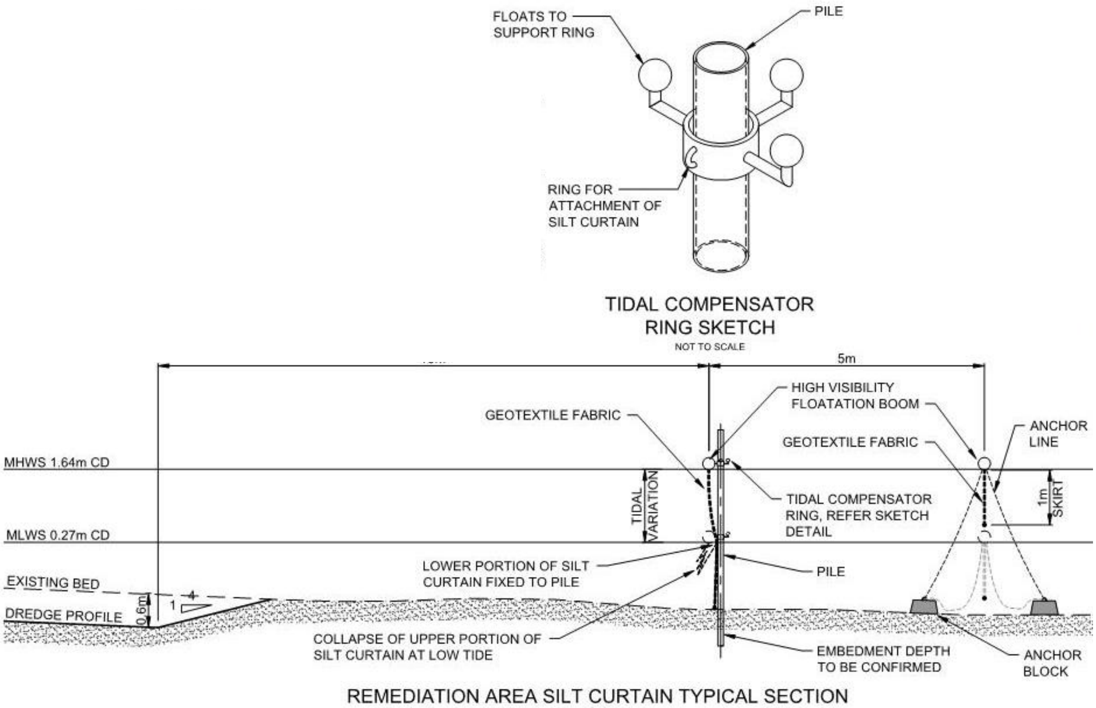

Figure 16 Tidal compensator ring system for silt curtains

The variation of water level with tides is also an important consideration for the remediation works. Given the shallow and intertidal nature of the bathymetry in Kendall Bay, access to areas of the site with floating plant is likely to be restricted by tidal movement. This is likely to require particular activities to be scheduled at high tides (e.g. silt curtain pile installation) and any reduction in productivity of in situ cement solidification, excavation, filling and capping activities would need to be accommodated within the construction schedule.

In general, although the works would need to accommodate water level variation, the construction activities associated with the remediation project would not have any measurable impact on local water level variations elsewhere within Kendall Bay and the Parramatta River due to the very small size of the remediation areas relative to the scale of the Parramatta River and Sydney Harbour.

4.5 Currents

4.5.1 Existing Environment

Currents within Kendall Bay and surrounding areas can be generated by several processes that include:

- Tides;
- Freshwater flows;
- Wind;
- Boat wash; and,
- Stormwater inflows.

4.5.1.1 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 (ADCP) 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 0.7m/s were measured in an ESE 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 0.2-0.3m/s on the ebb tide. Ebb tide currents within Fairmile Cove were around 0.15m/s.

4.5.1.2 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.

4.5.1.3 Wind-induced Currents

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

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

Oscillatory currents from wind wave action vary according to the water depths within the bay. **Table 5** summarises the calculated near bed (50mm above the bed) horizontal velocities generated by the worst case NNW wind wave conditions for water depths of 3m, 2m and 1m.

Table 5: Maximum Horizontal Wind Wave Induced Currents at the Bed

Design Event	Wave Height (m)	Wave Period (s)	Maximum Near-bed Current Speed (m/s)		
			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
100 year ARI (NNW)	0.82	2.44	0.25	0.46	0.92

4.5.1.4 Boat Wash

Oscillatory currents generated by boat waves have been determined using the wake typically produced by Rivercat vessels passing the site on a daily basis. If a wave height of 0.3m and wave period of 7 seconds is adopted (refer **Table 2**), then at water depths within the bay of 3m, 2m and 1m the corresponding near bed (50mm above the bed) currents would be 0.27m/s, 0.37m/s and 0.63m/s respectively.

4.5.1.5 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 1650mm diameter pipeline exists (refer **Figure 17**). However, this pipeline flows into a large basin constructed from gabion baskets which would act to dissipate the energy of stormwater flow. During the site inspection a shallow incised channel was observed leading from the outlet through the sandy substrate within the mangrove stand under low flow conditions (refer **Figure 18**).

Figure 17: 1650mm stormwater outlet at the head of Kendall Bay

Figure 18: Shallow channel leading from 1650mm stormwater outlet

There are two stormwater outlets discharging through the existing seawall and on to the beach area in the south-eastern area of Kendall Bay (i.e. Remediation Area SA4). These comprise a 450mm diameter outlet located towards the eastern end of the beach (refer **Figure 19**) and a 670mm diameter outlet located in the middle of the beach (refer **Figure 20**).

The 450mm outlet is Council owned and receives runoff captured from road drainage at the northern end of Cabarita Road (gutter inlet at entry to park) and other surface inlet pits located in adjacent parkland areas. The 670mm outlet is a private drain that received runoff from the adjacent residential development known as Kendall Inlet.

Figure 19: 450mm diameter stormwater outlet within Remediation Area SA4

Figure 20: 670mm diameter stormwater outlet within Remediation Area SA4

4.5.2 Interaction with Proposal and Mitigation Measures

The construction of the sheet pile wall enclosures around remediation areas SA1 and NA2+NA3 is expected to cause temporary changes to the flow of tidal waters. As the sheet pile walls are being progressively constructed, tides will still be moving in and out of the bay around the barriers formed by the partially constructed sheet pile walls. A critical phase in the construction will be the installation of the final sections of the sheet pile wall enclosures. The creation of an increasingly narrowing entrance for exchange of tidal flows within the sheet pile wall enclosures will result in a concentration of tidal flows and an associated increase in the speed of tidal currents through the narrow entrances to the enclosures. This has the potential to cause scouring and thus mobilisation of contaminated bed sediments to areas outside the remediation areas during the ebb tide. Potential measures to mitigate bed scour from concentration of tidal flows during installation of the sheet pile walls include:

- completion of the final sections of sheet piling as quickly as practicable;
- scheduling the final stages of sheet pile wall construction during a neap tide period (lower tidal range and lower tidal currents);
- provision of ports or slots through the sheet pile walls to limit the concentration of tidal flows during installation, and which can be sealed at a later stage to facilitate containment of turbid water during solidification and excavation activities;
- ensure that the full depth silt curtains enclosing the Northern Remediation Area and Southern Remediation Area are in place to limit the offshore migration of any mobilised sediments; and,
- installation of a silt curtain barrier across the narrowing entrance to the sheet piling enclosures during the final stages of construction to contain turbidity generated from any localised scour.

Currents within Kendall Bay and Fairmile Cove are not expected to cause any inconvenience to floating plant and equipment or adversely affect their efficiency in execution of the proposed construction methods due to their low magnitude. The higher magnitude tidal currents off the end of Breakfast Point that may be experienced by floating plant in transit are relatively benign in maritime construction terms. Towed barges and other work boats regularly ply the Parramatta River without difficulty.

Near bed currents induced by wind waves and Rivercat wake are capable of disturbing the bed of Kendall Bay, as was concluded in a previous assessment undertaken by URS (2006). Although the primary and secondary silt curtains will provide attenuation of wave energy from wind waves, wake from Rivercats would still penetrate to the shoreline at each remediation area. Any potential disturbance of bed sediments within the remediation areas would be contained within the silt curtain enclosures. Disturbance of bed sediments outside of the remediation areas will occur during the construction period and this will be considered in the design of a water quality monitoring program for the remediation works.

Floating vessels operating during the construction period will increase boating traffic within the shallow waters of Kendall Bay. This would result in the bed sediments being more frequently subjected to currents generated by boat wake waves and wash from propellers. As noted above, any disturbance of bed sediments within the remediation areas will be contained within the silt curtain enclosures. However, bed sediment disturbed by the movement of vessel outside the silt curtains (it should be noted that this will be outside of the remediation areas) could be transported by prevailing tidal or wind-induced currents. To minimise unnecessary disturbance of the bed by construction traffic both inside and outside silt curtain enclosures the following additional mitigation measures are proposed:

- enforcement of speed restrictions on construction vessels (note that an existing 4 knot zone is already enforced west of Breakfast Point and the RMS Boating Map for the project area states that a speed limit of 4 knots must be observed within 100 metres of any dredge, floating plant, ferry or punt working with chains and wires); and,
- 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.

There are several stormwater outlets within Kendall Bay that have the potential to generate localised currents from their discharge, which could cause scour of sandy bed materials in remediation area SA3 and SA4.

In remediation area SA3, the large 1650mm diameter outlet at the head of the bay has the potential to create a scour channel extending into the proposed beach nourishment area created within SA4. This potential impact on beach amenity would be mitigated by the proposed extension of the existing sandstone wall. Eastward-migrating stormwater flows running alongside the extended wall may cause localised scour and undermining of the structure. To address this issue, stormwater flows are proposed to be redirected away from the wall by the installation of a series of spur walls along an alignment through the mangrove area as part of remediation works completed in SA3. These low-level rock mound structures would train stormwater discharge away from the wall extension whilst allowing the flow to spread over the sand shoals without scouring a deep channel.

The existing 450mm outlet within remediation area SA4 is located immediately behind a mangrove tree (refer **Figure 19**), which has a root mass that would provide resistance against stormwater flows. The existing mangroves have proven to be resilient to stormwater flows, particularly in remediation area SA3 where the large 1650mm diameter outlet discharges through a stand of mangroves. It is considered that as the mangrove tree is not proposed to be removed as part of the remediation works, the outlet would not significantly impact on beach amenity if it was left in its current configuration at the eastern end of the beach area.

It is expected that in high rainfall events, in the absence of any controls, the 670mm diameter stormwater outlet would discharge across the SA4 beach area creating a scour channel and deposition of debris and rubbish from the catchment. The associated impacts on beach amenity would be mitigated by the proposed stormwater management options in the remediation strategy, which include one or a combination of:

- diversion of the outlet to a location further to the east, where stormwater could discharge out on to the existing rock platform;
- installation of a gross pollutant trap(s) (GPT) upstream in the system; and,
- construction of an energy dissipation structure at the outlet (e.g. rock blanket).

Since the seabed will generally be restored to at or below its pre remediation level, the proposed works would not have any adverse long term impact on currents within the bay. Deepened remediation areas (e.g. SA1, SA2, NA1) may experience a minor reduction in current velocities, however natural infilling of these areas over time (refer **Section 4.6.2**) will act to smooth out bed contours and restore existing hydraulic conditions. As noted above in **Section 4.3.2**, the lowering of bed levels in remediation area SA1 would result in greater wave penetration into the south-western corner of the bay and increased exposure of sand shoals around the western perimeter of the mangrove area to currents from wave action. This should be monitored and could be mitigated if required by provision of rock rip-rap protection over affected areas, which already exists in the south-western corner of the bay.

4.6 Sediment Transport

4.6.1 Existing Environment

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 directions 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 where 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 and are not considered to have any significant influence on sediment transport within Kendall Bay.

Review of historical aerial photographs 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 (refer **Figure 9** and **Figure 21**). 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 21: Aerial photographs of Kendall Bay in 1943 (left) and 2015 (right)

Comparison of historical hydrographic surveys undertaken in '1956' and 2014 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 (refer **Figure 22**), 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

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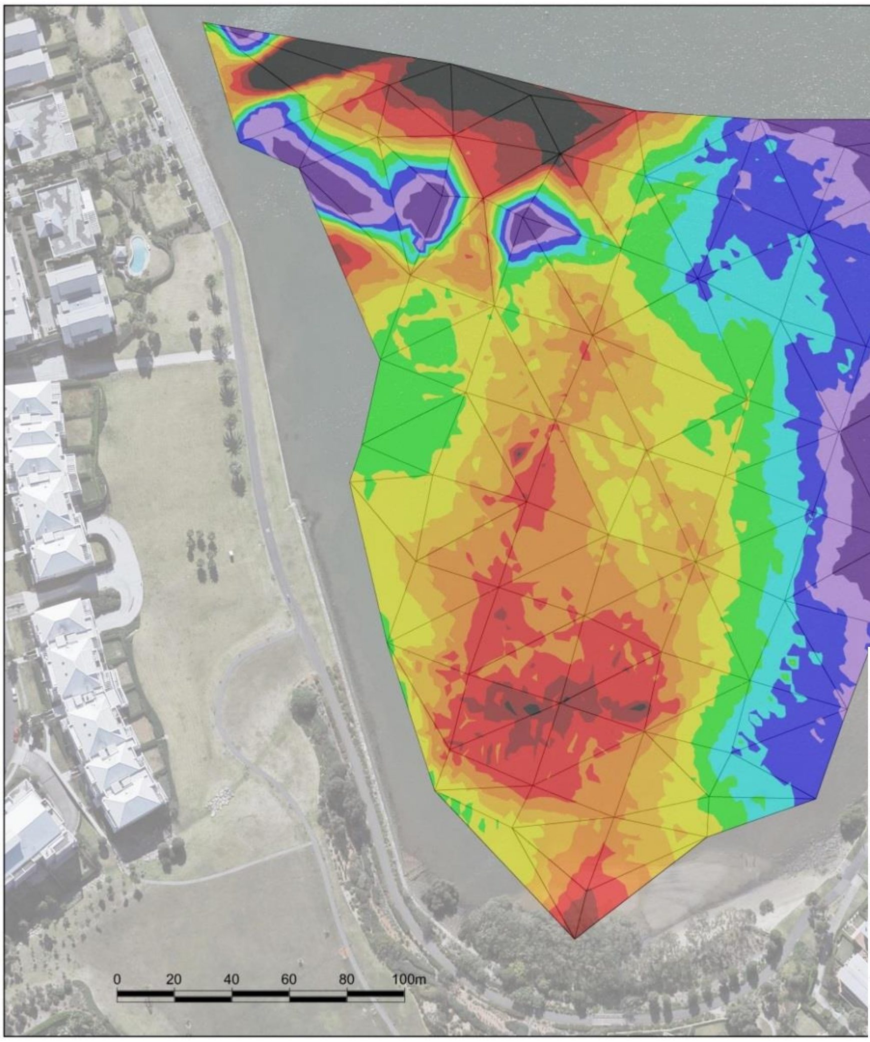
hydrographic survey data does not have sufficient time resolution to capture this variability. Furthermore, the ‘1956’ survey data provided by RMS was reported to comprise a compilation of several surveys completed pre-1995 (details of these surveys were not available).



Depth Difference Table

Number	Colour	Min Difference	Max Difference
1		−1.39	−0.80
2		−0.80	−0.60
3		−0.60	−0.40
4		−0.40	−0.20
5		−0.20	0.00
6		0.00	0.20
7		0.20	0.40
8		0.40	0.60
9		0.60	0.80
10		0.80	1.00
11		1.00	2.93

Figure 22: Depth difference between 1956 and 2014 hydrographic surveys

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:

- Irvine (1980)
  This study 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)
  This study 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.

4.6.2 Interaction with Proposal and Mitigation Measures

The proposed remediation works would have a temporary impact on sediment transport processes associated with potential cross-shore and a longshore movement of sediments by wind or boat wake wave action. This would be localised to the remediation areas where removal of bed material is proposed and would be limited to the period before the capping layer is placed. During this time some minor infilling within the deepened remediation area by sediment mobilised from adjacent areas may occur, however this is not expected to adversely impact on the achievement of the required excavation profile (i.e. it will not create a significant amount of additional excavation). In remediation areas SA1 and NA2+NA3 the installation of sheet pile wall enclosures would temporarily disrupt sediment transport processes. However, these structures would provide environmental control during remediation activities and mitigate infilling of excavated areas and cutting off of the sheet pile walls at seabed level at the completion of the works would restore natural sediment transport processes post-remediation.

The physical action of in situ cement solidification and excavation within the remediation area by hydraulic and mechanical means will mobilise bed sediments into suspension within the water column. However, the transport of these sediments outside of the remediation area will be prevented by the primary silt curtain enclosures, and by the sheet pile wall enclosures in the case of remediation areas SA1 and NA2+NA3. The effectiveness of silt curtain enclosures to contain turbidity generated inside remediation areas will be maintained with the implementation of a water quality monitoring program and an inspection and maintenance program for the silt curtain structures.

Some temporary reduction in sediment transport may occur in the lee of the floating (secondary) silt curtains due to the attenuation of wind waves and shorter period boat wake.

Following the completion of the sediment removal works, the bed levels within the remediation areas would generally be restored to at or below their pre remediation (natural) bathymetry by the placement of the capping layer. Remediation areas where the bed levels are finished below natural depths (e.g. SA1, SA2, NA1) are expected to be subject to natural infilling, particularly in shallow nearshore areas where surrounding sediments can progressively encroach into depressed areas under the action of wind waves and boat wake waves resulting in smoothing of the bed contours over time. The imported capping material would be more stable than the pre-existing muddy bed sediments, particularly in the deeper water offshore of the shallow intertidal beach areas. In deeper water it is expected that the muddy sediments brought down the Parramatta River during freshes/floods, would accumulate and form a thin veneer of sediment above the capping material over the longer term, as side bays such as Kendall Bay are generally depositional environments.

In remediation area SA4, readjustment of the beach profile and/or loss of sand offshore under wave action would be minimised by ensuring that the grading of the imported sand material is compatible with the existing beach sand and placed at the same slope and planform alignment. The beach sand would be retained by the proposed extension of the existing sandstone wall located on the western side of the beach. As discussed in **Section 4.5.2**, scour of beach sand by the existing 670mm diameter stormwater outlet and associated impacts on beach amenity would be resolved by either diversion of the outlet to a location further to the east, where stormwater could discharge out on to the existing rock platform, or by construction of an energy dissipation structure at the outlet (e.g. rock blanket).

5 Conclusion

The Kendall Bay Remediation Project will have a minor and temporary impact on hydrological processes as a result of:

- modification (lowering) of the bed levels within the remediation areas;
- additional boat wake and wind wave penetration into the Bay;
- potential disturbance of bed sediments by construction traffic; and,
- disturbance of bed sediments by cement-based solidification and excavation activities.

However, the above impacts would be mitigated by:

- foreshore protection offered by existing seawall structures;
- enforcement of existing boat speed restrictions;
- minimising the use of engine propulsion within Kendall Bay;
- installation of sheet pile wall enclosures around remediation areas SA1 and NA2+NA3;
- installation of silt curtain enclosures and implementation of an inspection and maintenance program; and,
- implementation of a water quality monitoring program.

The design of the proposed works will need to accommodate hydrological processes, including:

- survey measures to verify the accuracy of restored seabed levels;
- appropriate sizing of granular capping material to ensure its longevity under the action of the local wind and boat wake wave climate;
- extension of the existing sandstone wall to retain beach sand placed in remediation area SA4;
- installation of spur walls to train stormwater discharge flowing through remediation area SA3;
- stormwater discharge from beach outlets in remediation area SA4;
- design of temporary structures to accommodate wave action and tidal water level variation;
- selection of plant and equipment that is able to operate efficiently in the shallow, intertidal areas of Kendall Bay; and,
- scheduling of selected work activities at high tides.

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