NZ TRANSPORT AGENCY
WAKA KOTAHI

Roads of national significance

16 20 Western Ring Route – Waterview Connection

Assessment of Marine Ecological Effects

Boffa Miskell

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Quality Assurance Statement

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1. Summary Statement

The Waterview Connection project (Project) occurs adjacent to and within parts of the Waitemata Harbour, within the Coastal Marine Area (CMA), between Oakley Inlet in the east to a tidal tributary of Henderson Creek (Pixie Inlet) in the west (Figure 1). The Project area abuts the Motu Manawa (Pollen Island) Marine Reserve (MMMR), other Coastal Protection Areas (CPA1 and CPA2) (see Figures 2 and 2a) and General Management marine environment areas.

Within these marine habitats, the ecological values of the marine environments range from low-moderate to moderate-high, based primarily on the benthic invertebrate community composition and ambient sediment quality.

The intertidal mudflats of the Waterview Estuary and Oakley Inlet comprise deep soft mud and are dominated by mangroves. The subtidal channels are similarly characterised by fine muddy sediment. Within the intertidal habitat, small shellbank areas occur, where sediment grain size is coarser, and saltmarsh vegetation is supported. The two island features surrounded by the MMMR (Pollen and Traherne islands) comprise sandflats, mudflats, saltmarsh and terrestrial vegetation.

Sediment throughout the Waterview Estuary and Oakley Inlet contains elevated concentrations of common stormwater contaminants (predominantly above biological effects thresholds), whereas sediment in the Waitemata Harbour in areas immediately north of the Waterview Causeway typically have below effects thresholds contaminant concentrations.

Construction associated with the Project will have adverse effects on marine ecological values including permanent habitat loss, temporary habitat loss and disturbance from discharge of sediment and contaminants, and noise and vibration. Mitigation of the adverse effects of permanent marine habitat loss arising from construction of the Project can be off-set through remediation of intertidal mudflat habitat adjacent to the Causeway Embankment, a higher level of treatment efficiency of operational phase stormwater from Sectors 1-5, treatment of stormwater arising from the existing alignment, restoration of coastal fringe habitat (revegetation and weed control), and removal of gross litter and debris from the coastal edge.

Operation of the motorway, given the stormwater runoff treatment proposed, is not expected to have adverse effects on the marine ecological values, other than contributing to the long-term accumulation of contaminants in the marine sediment, which will occur at a lower rate than that which would occur without the Project.

2. Purpose of this Report

The purpose of this report is to provide an assessment of the Project on the existing environment as it pertains to marine ecology and an assessment of the significance of potential adverse effects. This document consolidates information from ecological assessments undertaken by Boffa Miskell Ltd and Bioresearches Group Ltd and presents a final report describing the ecological values present and the potential effects of this Project. Where this assessment identifies significant potential adverse effects on the environment, the report provides a scope of works to avoid, remedy or mitigate these effects where possible. Where there is uncertainty regarding the likely effects or the significance of effects, the report identifies an approach for monitoring and (where necessary) response.

The means by which marine ecological values will be managed and monitored over the course of the construction, and post-construction, of this Project is specified in the marine ecological sections of the Ecological Monitoring Plan (ECOMP). The ECOMP, in its entirety is included as Appendix H to the Construction Environmental Management Plan (CEMP). The sections relevant to marine ecology are attached as Appendix G of this report.

3. Description of Project

In 2009 the NZTA confirmed its intention that the 'Waterview Connection Project" would be lodged with the Environmental Protection Authority as a Proposal of National Signficance. The Project includes works previously investigated and developed as two separate projects: being the SH16 Causeway Project and the SH20 Waterview Connection. The key elements of the Waterview Connection Project are:

- Completing the Western Ring Route (which extends from Manukau to Albany via Waitakere);
- Improving resilience of the SH16 causeway between Great North Road and Rosebank Interchanges to correct historic subsidence and "future proof" it against sea level rise;
- Providing increased capacity on the SH16 corridor (between St Lukes and Te Atatu Interchanges);
- Providing a new section of SH20 (through a combination of surface and tunnelled road) between the Great North Road and Maioro Street Interchanges; and
- Providing a cycleway throughout the surface road elements of the Waterview Connection Project corridor.

Sectors 1-5 of the Project are relevant to the assessment of effects on marine ecological values and these are briefly summarised in the following sections (see Figure 3.1).

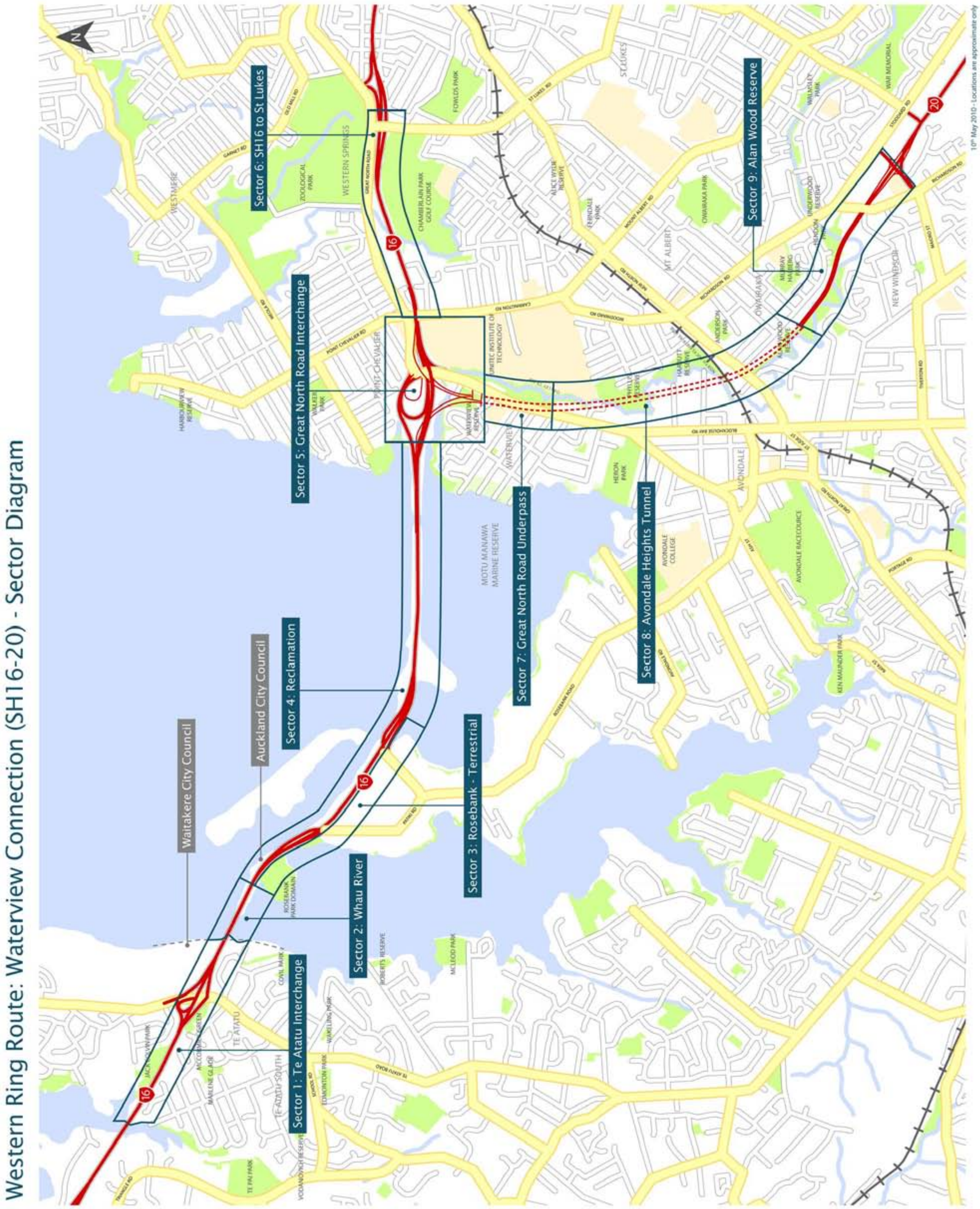


Figure 3.1: Project Sector Diagram

3.1 Sectors 1-5 of the Project

3.1.1 Sector 1- Te Atatu Interchange

Sector 1 includes significant improvements to the Te Atatu Interchange. These include enlargement and re-configuring of off- and on-ramps to accommodate additional lanes and to provide for bus shoulder and priority for buses and other high occupation vehicles.

Modifications to the configuration of the interchange, including provision for vehicle stacking resulting from ramp signalling and improved facilities for pedestrian and cycles using the interchange.

Within this Sector, adjacent to Jack Colvin Park, a permanent stormwater treatment wetland is to be constructed, which will receive stormwater from the newly constructed and existing SH16 roadway within this Sector.

3.1.2 Sector 2 – Whau River

Sector 2 includes the enlargement of the existing Whau River Bridges to accommodate additional lanes. A separate dedicated cycle/pedestrian bridge is also to be constructed alongside the enlarged Whau River Bridges.

3.1.3 Sector 3- Rosebank - Terrestrial

Sector 3 of the Project involves the re-configuration of the existing Rosebank Road on- and off-ramps to improve traffic merging on and off these ramps. The outside westbound lane will be “dropped” at the Rosebank Road exit ramp.

Between the Rosebank Road and Te Atatu Interchanges, additional lanes will be added to provide four lanes eastbound and westbound. A bus shoulder will also be provided in both directions.

3.1.4 Sector 4 - Reclamation

Sector 4 involves the provision of two additional westbound lanes from the Great North Road Interchange to the Rosebank Road Interchange to create a total of five westbound lanes plus a dedicated bus shoulder. An additional lane will be added from the Rosebank Road Interchange to the Great North Road Interchange to create a total of four eastbound lanes in this section. Works include widening of the Causeway Bridges and provision of a new cycle/pedestrian bridge.

Widening of the motorway through Sector 4 involves reclamation of intertidal estuarine and saltmarsh/coastal fringe habitat adjacent to both the eastbound and westbound lanes.

3.1.5 Sector 5 – Great North Road Interchange

Sector 5 of the Project extends from the Waterview Park area and incorporates the ramps and alignment associated with the connection of SH20 to SH16 (the Great North Road Interchange).

Works through this Sector are in close proximity to the CMA and some works in and over the CMA are required. Key elements include structures in the CMA (piers), structures over the CMA (ramps) and outlet structures to the CMA

3.2 Marine/Estuarine Environment Context

The Project occurs within the Waitemata Harbour, with the eastern boundary being Oakley Inlet and the western boundary being a tidal tributary of Henderson Creek (Pixie Inlet) (see Figure 1). The Project area occurs within the Motu Manawa (Pollen Island) Marine Reserve (MMMR), other Coastal Protection Areas (CPA1 and CPA2) and general management marine environment areas identified in the Auckland Regional Coastal Plan (ARC, 2004a) (see Figures 2 and 2a).

3.2.1 Waitemata Harbour

The Waitemata Harbour lies within the northeast coastal area of New Zealand, within the Hauraki Gulf. The wider Hauraki Gulf area is characterised by inlets, harbours, bays and offshore islands, with habitats ranging from oceanic to estuarine. The Waitemata Harbour extends westwards from the harbour entrance between North Head to the north and Bastion Point to the south.

The Waitemata Harbour is a drowned river valley that extends from Riverhead in the north-west to the Tamaki River in the east. It has tidal flats and mangroves in the upper reaches to the west, and deep navigable channels and sheltered bays.

Many streams discharge into the Waitemata Harbour. Streams of relevance to the Project include Oakley Creek, Meola Creek, Whau River and Pixie Stream (see Figure 1).

3.2.2 Waterview Estuary

The Waterview Estuary is a relatively modified marine environment, as a result of the original construction of SH16 in 1952-53 (Hume, 1991) and other landuse practices. The original construction of the SH16 Causeway had a significant effect on flow dynamics and restricted tidal flushing considerably (see Technical Report No. G4 Coastal Processes). This is evident in the build-up of soft sediments throughout the estuary. In addition, industrial activity and a long history of poor environmental practices (including the disposal of waste into the estuary both directly and through improper drain connections), has likely caused long-term impacts here (see Technical Report No. G4 Coastal Processes).

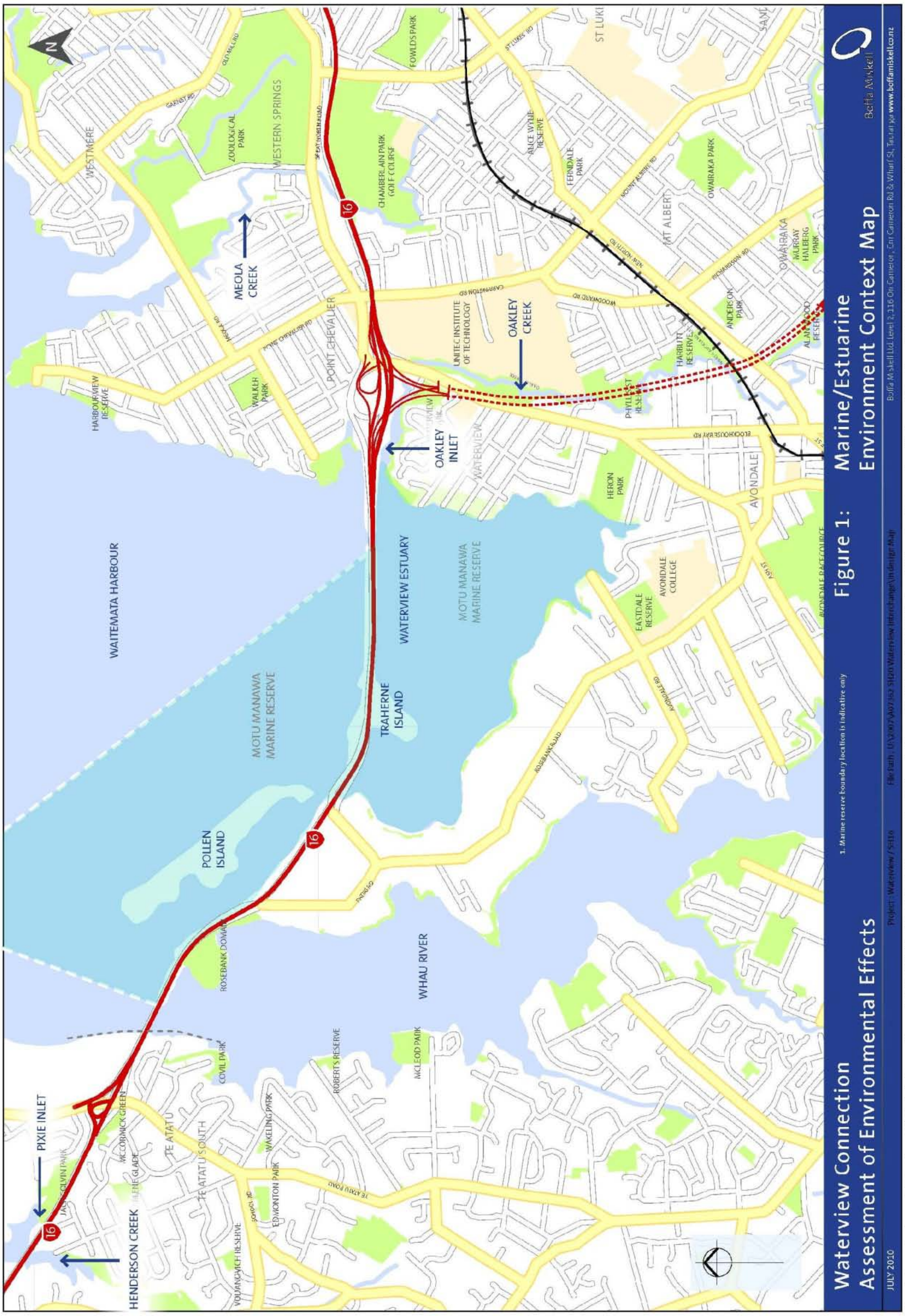
The intertidal mudflats of this inner harbour estuary comprise deep soft mud and are dominated by mangroves (*Avicennia marina* var. *australasica*). The subtidal channels are similarly characterised by fine muddy sediment. Within the intertidal habitat, there are some small shellbank areas where sediment grain size is coarser and some saltmarsh vegetation is supported.

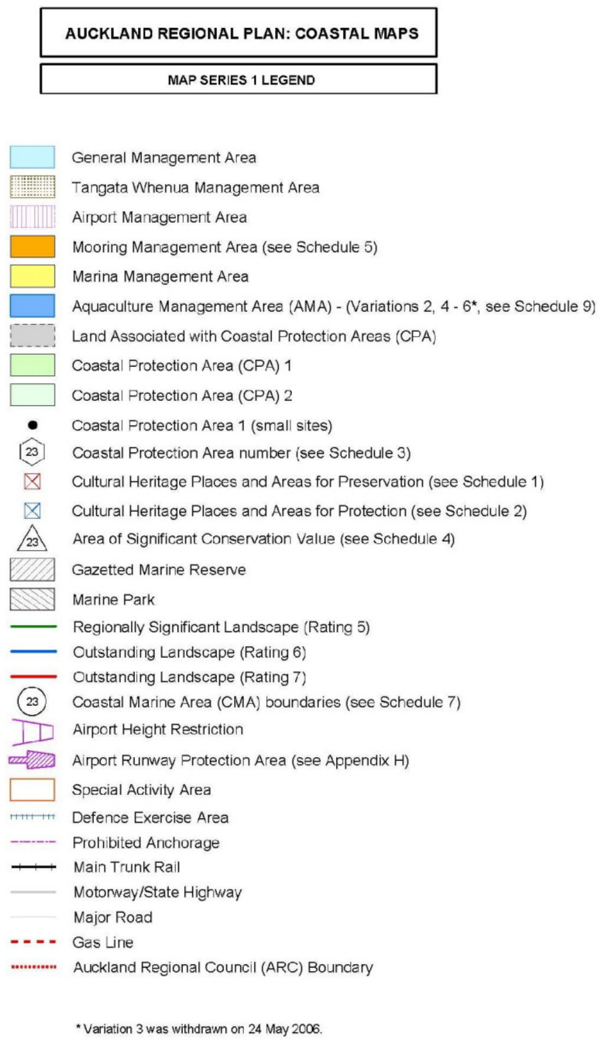
The Waterview Estuary and areas surrounding Pollen Island are classified as a CPA1 in the Auckland Regional Plan: Coastal (ARC, 2004a). The Department of Conservation (DOC) has classified the area as an Area of Significant Conservation Value (ASCV) and the estuary is contained within the MMMR (ARC, 2004a).

The MMMR, created in 1995, encompasses some 500 hectares of the inner reaches of the Waitemata Harbour. The MMMR surrounds Pollen Island and Traherne Island, and incorporates the Waterview Estuary and an extensive area of intertidal and subtidal flats on the northern side of the SH16 Causeway (see Figures 1, 2, 2a and 4). The eastern boundary extends upstream of the mouth of Oakley Inlet, whereas the western boundary extends into the Waitemata Harbour.

The MMMR has been described as a representative example of a low energy inner harbour ecosystem, within a large city, with historical and current surrounding landuse including industrial, residential and infrastructural (Sivaguru & Grace, 2002). The gazette notice for the MMMR recognises that there were ongoing contaminants (from road runoff, residential stormwater etc.) entering the Reserve at the time of creating the Marine Reserve Order, and that provided the discharges were meeting all the legal requirements, the discharges were able to continue.

The MMMR is dominated by intertidal mudflats, tidal channels, and extensive areas of mangrove stands. Smaller areas of saltmarsh and shellbanks are predominantly present adjacent to Pollen and Traherne Islands. The mudflats and shell banks support a typical diversity of coastal invertebrates and fish. In addition, these mudflats and sandflats are important feeding areas for a wide variety of shore bird species, both resident and non-resident, with the latter including both national and international migratory species (such as South Island pied oystercatcher (*Haematopus ostralegus finschi*) and eastern bar-tailed godwit (*Limosa lapponica baueri*), respectively) (see Technical Report No. G.3 Assessment of Avian Ecological Effects).


Waterview Connection
Assessment of Environmental Effects
Figure 1:
Marine/Estuarine
Environment Context Map
JULY 2010
Boffa Miskell
WAITEMATA HARBOUR
WATERVIEW ESTUARY
WHAU RIVER
MOTU MANAWA MARINE RESERVE
POLLEN ISLAND
TRAHERNE ISLAND
OAKLEY INLET
OAKLEY CREEK
MEOLA CREEK
PIXIE INLET
HENDERSON CREEK
POINT CHEVALIER
WESTERN SPRINGS
WESTMERE
AVONDALE
MT ALBERT
OWAIRAKA
WATERVIEW
TE ATATU SOUTH
UNITEC INSTITUTE OF TECHNOLOGY
1. Marine reserve boundary location is indicative only



Waterview Connection
Assessment of Environmental Effects

Figure 2a: Auckland Regional Plan: Coastal Maps Legend

JULY 2010 Project : Waterview / SH16 File Path : U:\2007\A07362 SH20 Waterview Interchange\Indesign Map

Boffa Miskell Ltd. Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf St, Tauranga www.boffamiskell.co.nz

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Pollen Island is considered a nationally important landform, as it contains the best remaining largely unmodified area of its type in the Waitemata Harbour (with this type being saltmarsh, mangroves, shellbanks (cheniers) and estuarine/harbour mud flats) (ARC, 2004a). Pollen Island supports a diverse range of plant and animal communities. In particular, the shellbanks support a range of migratory, native and endemic coastal birds, including some threatened species.

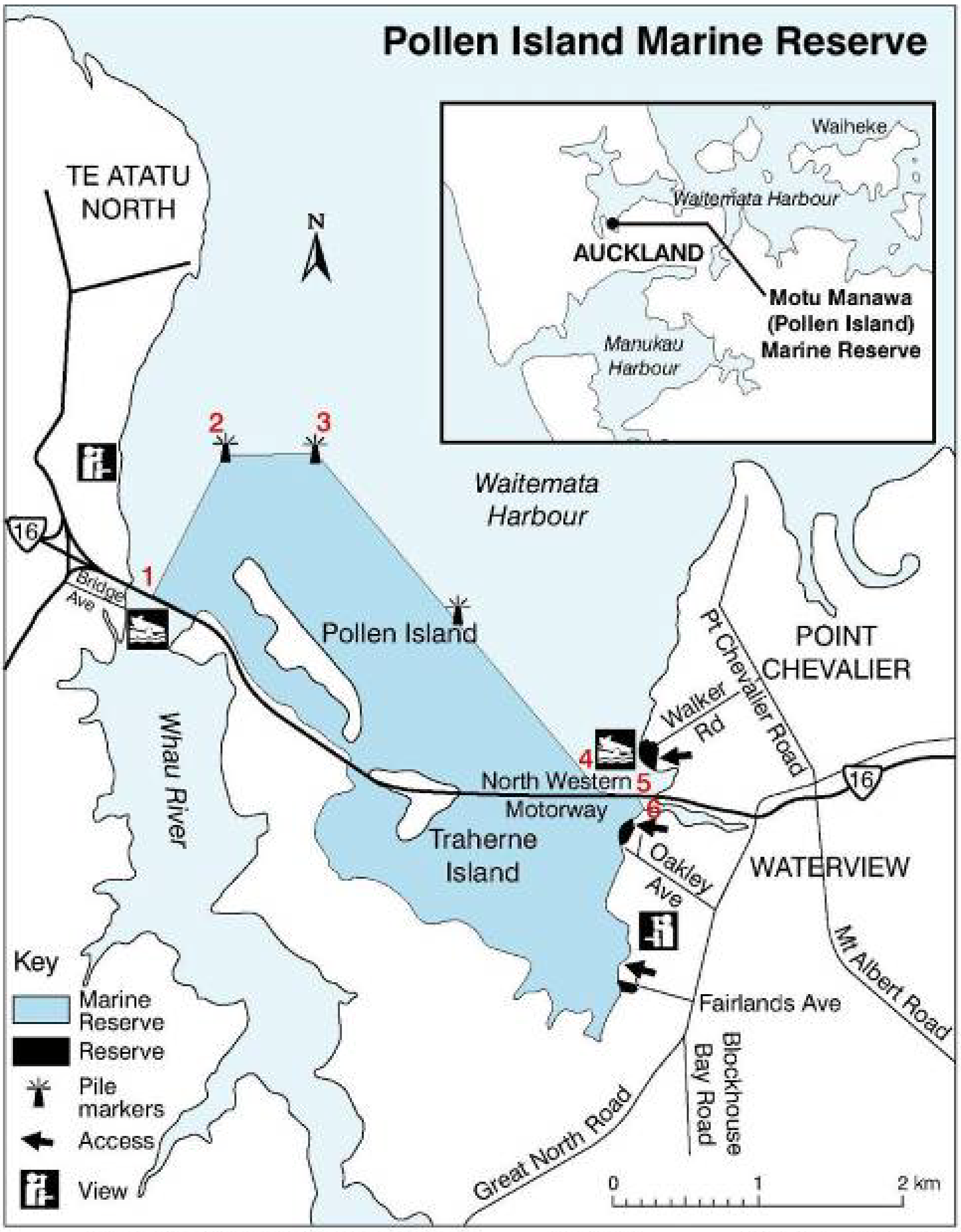
The MMMR contains a chenier island and active accretionary shell spits, which form part of the geological heritage of the region. Cheniers are long, narrow, often sinuous ridges of shell or sand formed approximately parallel to the shoreline, typically seaward of marsh or mudflat deposits. The cheniers located within the MMMR are almost entirely composed of the shells of dead cockles that have been transported across the tidal flats by small waves and tidal currents. In the 19^{th} century, shell from the cheniers at Pollen Island was quarried as feed stock for the production of lime (Hayward, 2007).

3.2.3 Oakley Creek

Oakley Creek is approximately 12 km long originating in Mt Roskill near Keith Hay Park. The creek catchment is approximately 84% urbanised and runs through largely residential and light industrial areas, under roads, through reserve areas and ultimately empties into the MMMR south of the Waterview Causeway via the Oakley Inlet. Oakley Creek has a long history of receiving contaminant inputs from a variety of sources and contains barriers to fish passage. In the upper reaches, the creek supports a limited diversity of pollution tolerant macroinvertebrates and two native fish species (short finned eel (*Anguilla australis* – Not Threatened) and long finned eel (*Anguilla dieffenbachii* – Threatened, Human Induced Gradual Decline) (see Technical Report No. G.6 Assessment of Freshwater Ecological Effects) (Hitchmough et al., 2007). Downstream of Great North Road, where the Oakley Creek becomes the Oakley Inlet and where there is tidal influence, contaminant concentrations in surface sediment are elevated and sediment grain size composition is dominated by fine silts and clays.

3.2.4 Meola Creek

Meola Creek has typically poor water quality and sediments contain relatively high concentrations of stormwater contaminants. However, the marine environment, including the Te Tokaroa Reef, adjacent to the mouth of the Meola Creek is considered to have high biodiversity (Ford et al., 2006; Halliday et al., 2006). The Te Tokaroa Reef is a regionally important geological feature, arising from a lava flow from the Three Kings volcano, extending more than 2000 m offshore. It is classified as a CPA1, and supports a diversity of marine organisms, including sponges and bryozoans.



	Mt Eden49mN	Mt Eden49mE	WSG84 S	WSG84 E	NZMG49y	NZMG49x
Point 1	702030	290550	36 51 34.9972 S	174 39 30.7791 E	6481122	2658280
Point 2	702940	291020	36 51 05.4908 S	174 39 49.7934 E	6482022	2658769
Point 3	702940	291720	36 51 05.5138 S	174 40 18.0521 E	6482008	2659469
Point 4	700710	293550	36 52 17.9121 S	174 41 31.8604 E	6479740	2661253
Point 5	700665	293999	36 52 19.3827 S	174 41 49.9898 E	6479686	2661701
Point 6	700605	294013	36 52 21.3295 S	174 41 50.5534 E	6479626	2661713

Figure 4: Location and extent of Motu Manawa (Pollen Island) Marine Reserve (source: Department of Conservation).

3.2.5 Whau River

The Whau River has a long history of boating use, as well as discharges from industrial landuse. Concentrations of contaminants in sediment within the Whau Estuary (particularly the upper reaches) are among some of the highest in the Auckland region, and the ecological health of the estuary has been assessed as being low (Kelly, 2007; McHugh & Reed, 2006). Monitoring of sediment and contaminants as part of the Central Waitemata Monitoring Programme, indicates that the invertebrate community is dominated by pollution tolerant species of bivalves and polychaete worms (Halliday et al., 2006).

3.2.6 Pixie Inlet

Pixie Inlet, a tributary of Henderson Creek, lies to the west of Whau Creek. Henderson Creek runs through residential and industrial landuse, discharging into the Waitemata Harbour to the north-west of the Te Atatu Peninsula. Sediment quality in Henderson Creek has elevated concentrations of stormwater contaminants (McHugh & Reed, 2006), while ecological monitoring revealed that invertebrate assemblages were dominated by bivalves and polychaetes, and included some sensitive species (Halliday et al., 2006).

4. Methodology

4.1 Source of Data and Information

Data and information on the existing environment for this Project has been gathered from a number of sources, including published literature, ARC technical reports, unpublished reports and datasets and previous ecological assessments and fieldwork carried out by marine ecologists specifically for this Project in its historic different forms between 2001 and 2010.

4.2 Marine Sediment Quality

Assessment of intertidal and subtidal sediment aims to characterise the grain size and contaminant composition in order to establish baseline information. The following assessment is based on a combination of data sets sourced from NIWA, ARC, Bioresearches and field data collected by Boffa Miskell Ltd (BML), collected from different locations within the Project area and, other than the BML and Bioresearches data sets, for purposes not specifically related to the Project. As the methodology used differs, to a small extent, among researchers, all methodologies are presented below.

4.2.1 NIWA

Subtidal sediment samples were collected by NIWA in March 2003 mostly within the Waterview Estuary, with a few samples collected north of the Causeway Embankment and towards the Whau River Bridges (NIWA, unpublished data) (see Figures 5a and 5b). Sediment samples were separated into two grain size fractions (<63μm and 63-500μm), with each fraction being analysed by Hill Laboratories for concentration of copper (Cu), lead (Pb) and zinc (Zn) (reported as dry weight).

4.2.2 ARC

During 2004 and 2005, surficial sediment samples (top 2 cm) comprising ten subsamples from sites 7, 63 and 64 were analysed for concentration of copper, lead and zinc in the total sediment (<500μm fraction) and the fine sediment fraction (<63μm) by either NIWA or Hill Laboratories (depending on the monitoring programme) (Kelly, 2007).

4.2.3 Bioresearches

Sediment samples were collected from a boat at the Whau (sites 65-68) and Causeway Bridges (sites 27-30) using a stainless steel box dredge sampler (see Figures 5a and 5b). Samples were held on ice, and delivered to Hill Laboratories for analysis of total recoverable contaminants (heavy metals and polycyclic aromatic hydrocarbons (PAHs)). The sediment samples were collected adjacent to the Causeway Bridges and the Whau Bridges in April 2007, while the samples adjacent to Henderson Creek were collected in November 2009.

For grain size analyses, 100 g of sediment was mixed with water and dispersant (6.6% sodium polymetaphosphate and 1.4% sodium carbonate) and left for 24 hours. The mixed samples were then dried and passed a series of Wentworth sieves using a Rotap sieving machine. Mesh sizes were 3.35 mm, 2.00 mm, 1.18 mm, 0.60 mm, 0.15 mm, 0.063 mm and 0.0442 mm. The <0.0442 mm size fraction was further differentiated using pipette analyses. Fractions were then weighed and expressed as a percentage composition by weight, using the following size classes in Table 1.

Table 1: Sediment grain size classes (Bioresearches)

Sediment Fraction	Size Class
>3.35 mm	Gravel
2.0-3.35 mm	Granules
1.18-2.0 mm	Very coarse sand
0.6-1.18 mm	Coarse sand
0.3-0.6 mm	Medium sand
0.15-0.3 mm	Fine sand
0.063-0.15 mm	Very fine sand
<0.063 mm	Silt and clay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0 110 220 330 440 550 660 m
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Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
Concentration sampling sites sources
Auckland Regional Council
Bioresearches
Boffa Miskell
NIWA unpublished data
Figure 5a: Sediment Sampling Sites
Waterview Estuary
23 July 2010

69
70
64
32
31
18
65
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68
71
Waterview Connection
Assessment of Environmental Effects
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Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
Concentration sampling sites sources
Auckland Regional Council
Bioresearches
Boffa Miskell
NIWA unpublished data
Figure 5b: Sediment Sampling Sites
Whau River
23 July 2010

4.2.4 BML

Sampling was carried out between April 2008 and February 2010. At each of the BML intertidal sampling sites a composite surficial sediment sample (top 2 cm) was collected and divided in half. One half of the sample was sent on ice to Cawthron Institute for grain size analyses and the other half was sent on ice to Hill Laboratories for analysis of total copper, lead, zinc and PAHs.

In addition to the intertidal sediment samples, a portion of the sediment contained in each of the BML subtidal grab samples was held on ice and sent to the same laboratories as above for grain size and contaminant analyses.

Cawthron Institute use wet sieving with an automated sieve shaker and certified standard size mesh screens to separate grain size fractions. Fractions are dried and the results reported on a dry weight basis as per Table 2.

Table 2: Sediment grain size classes (Cawthron Institute)

Sediment Fraction	Size Class
>2.0 mm	Gravel
2.0-1.0 mm	Very coarse sand
1 mm – 500 µm	Coarse sand
500-250 µm	Medium sand
250-125 µm	Fine sand
125-63 µm	Very fine sand
<63 µm	Silt and clay

Hill Laboratories use nitric/hydrochloric acid digestion, followed by ICP-MS for analysis of heavy metals and sonication extraction, dilution or SPE cleanup (if required) with GC-MS SIM analysis for analysis of PAHs.

4.3 Saline/Coastal Fringe Vegetation

In 2001, the mangrove community structure within the Waterview Estuary was assessed by BML along four transects (see Figure 6), with the density of mangrove stems (per m^2) and average height of the thickets recorded. Transect locations were selected in areas considered representative of mangrove habitat within Waterview Estuary, following an initial field reconnoitre earlier in 2001.

During subsequent saline vegetation surveys undertaken by BML in 2003, representative mangrove habitats along the eastern and southern shoreline of the Waterview Estuary were also investigated. Five transects were run for 125 m from the landward margin, with a 0.25 m^2 quadrat placed at 5 m intervals (see Figure 6). For each quadrat, details of plant number, average height, pneumatophore numbers, seedlings, general appearance of health and abundance of associated species was recorded.

Building upon these earlier surveys (2001–03), the saline vegetation adjacent to the Oakley Inlet and the immediate coastal fringe around the Waterview Estuary and adjacent to SH16 between the existing Waterview and Te Atatu Interchanges was qualitatively investigated and described, as part of the 2008-2010 BML studies.

Full coastal vegetation descriptions are included in Technical Report No. G.17 Assessment of Terrestrial Vegetation Effects.

4.4 Marine Invertebrates

Information and data have been gathered from past ecological assessments relating to the Project BML 2001, BML 2003, BML 2008), ecological assessments relating to the SH16 widening project (Bioresearches, 2009), a subtidal soft sediment invertebrate survey carried out by Sivaguru & Grace (2002) and current (2009/2010) investigations carried out by BML based on the National Estuarine Monitoring Protocol (Cawthron, 2002).

4.4.1 Data/information collected between 2001-2008

The early investigations by BML utilised counts of three typical mangrove/mudflat species along four transects (see Figure 6) in order to assess the general health of the intertidal benthic community. These three species were mud crabs (using the density of burrows), mud snails and oysters.

In 2002, DOC published a report detailing the results of baseline quantitative sampling of the subtidal benthos and sediments of the MMMR (Sivaguru & Grace, 2002). Samples were collected from a boat, using a hand-hauled dredge and the contents sieved using a 1 mm mesh and preserved in 5% formalin. Organisms were subsequently extracted, identified and counted. Sediment type was subjectively described from hand specimens in the field.

This study included the mapping of several important parameters including sediment type, species diversity, benthic faunal associations and distributions of various species (including cockle, nut shell, spionid worms and mud snails).

In 2003, the intertidal areas of the Waterview Estuary and parts of Pollen Island and Traherne Island were investigated by BML along five transects (see Figure 6). Observations of benthic invertebrate species encountered, substrate types and habitat characteristics were made.

In 2009, benthic invertebrate samples were collected by Bioresearches from a boat immediately adjacent to the Whau River and Causeway Bridges using a stainless steel box dredge sampler. A single marine invertebrate sample was collected from each sampling location (numbered 27-30 and 65-68). Samples were sieved through a 0.5mm mesh, fixed in a 10% formalin solution, preserved in 70% isopropanol alcohol and the retained organisms extracted and identified.

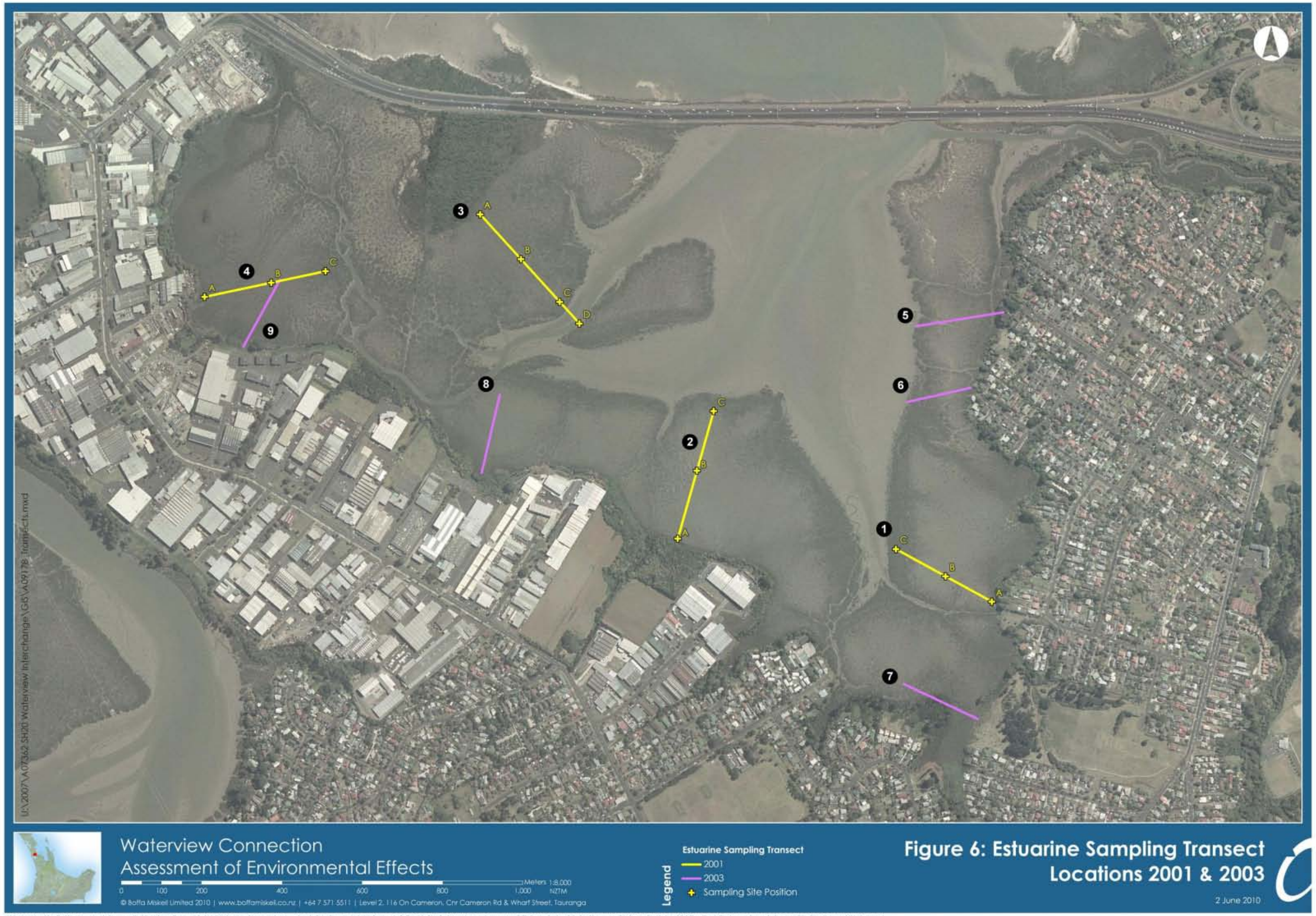

Figure 6: Estuarine Sampling Transect Locations 2001 & 2003

4.4.2 Current BML Surveys (2008-2010)

In 2008, three replicate core samples (13cm diameter x 15cm length) were collected from intertidal sampling sites (numbered 1-6, 8, 14, 16, 17) (see Figure 5a and Plates 1-12, 25, 29 in Appendix A). Core samples were sieved through a 0.5mm mesh and the retained material preserved with 50% ETOH. Samples were then transported to Cawthron Institute for extraction of organisms and their identification (BML, 2008).

A further more detailed assessment of intertidal invertebrate assemblages in areas close to potential operational and construction phase stormwater discharge points, in addition to current depositional areas, was carried out in 2009/2010. The methodology used was based on the National Estuarine Monitoring Protocol, Fine Scale Environmental Monitoring, developed by Cawthron Institute (2002).

Seven intertidal sites (sampling locations 9-13, 15, 18, see Figures 5a and 5b and Plates 13-24, 26-28, 30-32) and eight subtidal sites (sampling locations 21-26, 61, 62, see Figure 5a) were sampled. For each of the intertidal locations a 50m x 30m grid was mapped and subdivided into ten 15 m x 10 m smaller grid squares. Each of these smaller 15m x 10m grids was further subdivided into six 5 m x 5 m squares. Samples were collected from one randomly selected 5 m x 5 m square, resulting in 10 sampling sites within each intertidal location (Figure 7).

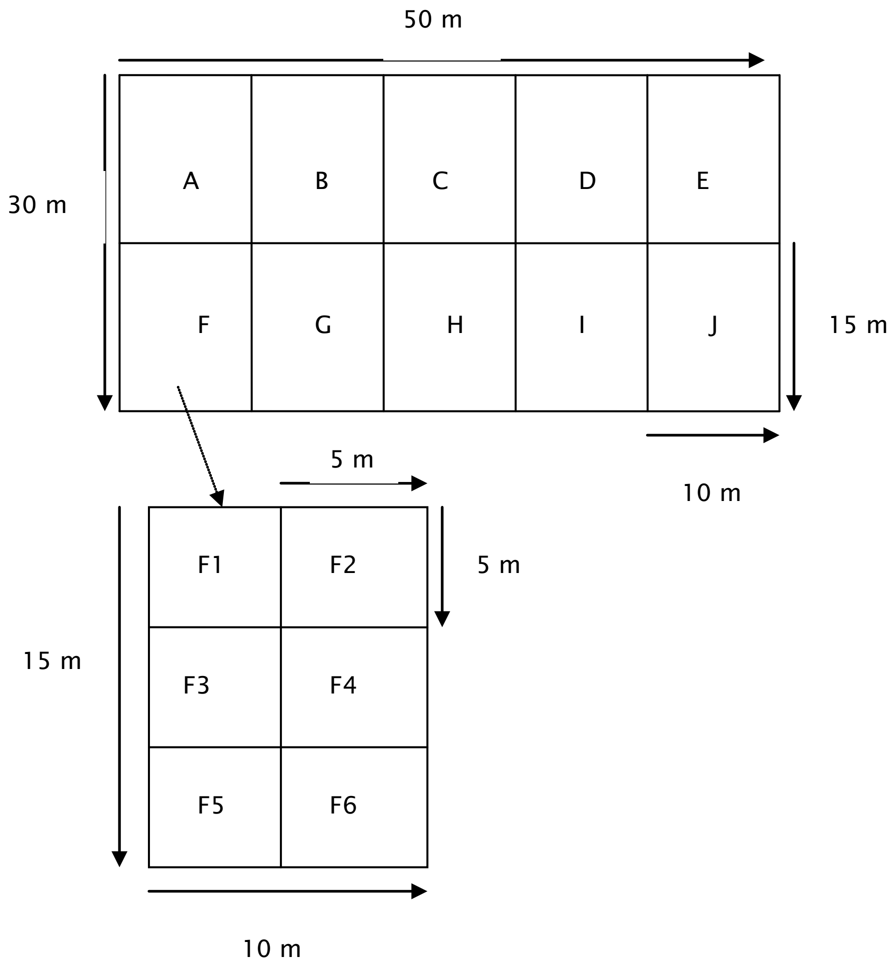

Figure 7: Schematic of intertidal sampling design

Within each of the ten randomly selected smallest grids (numbered 1-6), a core sediment sample (15 cm deep x 13 cm diameter) was collected for infaunal invertebrate analysis, a 0.5 m x 0.5 m quadrat was used to sample epifauna and surface algae (quadrats were also photographed), a redox discontinuity layer (RDL) sample was collected (where possible) using a 60mm diameter cylinder (to a depth of 8-10 cm), and a surficial sediment sample (top 2 cm) was collected for contaminant analyses and sediment grain size analyses.

The infaunal invertebrate core of sediment was sieved through a 0.5mm mesh, and the retained material preserved using 60% ETOH. Cawthron Institute invertebrate experts processed these samples, extracting and identifying the macrofauna present.

In the field, epifaunal invertebrates present within each quadrat were identified and counted and surface alga was identified and percentage cover of algae within each quadrat was estimated. RDL, the depth of the oxygenated layer of surface sediment (typically anoxic sediment is black coloured), was estimated in the field using a ruler.

Sediment samples from grids A-E were combined to form a composite sample, as were those from grids F-J. The two composite samples were divided in half, with one half being sent to Hill Laboratories for analysis of copper, lead, zinc and PAHs and the other half being sent to Cawthron Institute for grain size analyses.

In addition, two replicate intertidal sediment cores and composite sediment samples were collected from five locations along SH16 between Henderson Creek and the Waterview Causeway in February 2010 (Intertidal sampling sites 70-74 (see Figures 5a and 5b), Plates 33-44 in Appendix A) to close off gaps in the data once the Project design was further finalised. Samples were collected at approximately 2-5 m below mean high water spring (MHWS). Processing and analysis of these intertidal samples was as per above.

Subtidal samples were collected from a boat using a stainless steel grab sampler. Samples were processed in the same manner as the intertidal core samples. Due to the volume of sediment in each grab not being uniform among samples, because of differences in the benthic sediment composition (i.e. shell material can interfere with closure of the grab sampler), the invertebrate information collected is used for qualitative/descriptive purposes only.

4.5 Assessment of Ecological Value

Marine ecological values are described in this report as low, moderate and high.

The characteristics below have been used to assess the predominant ecological values of parts of the marine environment within the Project area, based on a weight of evidence approach. Not all of the characteristics within each ecological value category need to be present in order to ascribe a ecological value. Consideration of low, moderate and high benthic invertebrate species richness and diversity is based on expert judgement and experience.

Low Ecological Value

- benthic invertebrate community is degraded and has low species richness and diversity
- benthic invertebrate community is dominated by tolerant organisms with few/no sensitive taxa present
- marine sediments dominated by silt and clay grain sizes
- shallow depth of oxygenated surface sediment
- elevated contaminant concentrations in surface sediment
- invasive opportunistic and disturbance tolerant species present
- habitat highly modified

Moderate Ecological Value

- benthic invertebrate community has moderate species richness and diversity
- benthic invertebrate community has both tolerant and sensitive taxa present
- marine sediments typically comprise approximately 50-70% silt and clay grain sizes
- depth of oxygenated surface sediment typically greater than 0.5 cm
- contaminant concentrations in surface sediment generally below effects threshold concentrations
- few invasive opportunistic and disturbance tolerant species present
- habitat modification limited

<u>High Ecological Value</u>

- benthic invertebrate community is highly diverse and has high species richness
- benthic invertebrate community contains many sensitive taxa
- marine sediments typically comprise <50% silt and clay grain sizes
- depth of oxygenated surface sediment typically greater than 1.0 cm
- contaminant concentrations in surface sediment below low effects threshold concentrations
- habitat largely unmodified

4.6 Assessment of Effects

The project was considered in relation to the plans and policies that exist for the area, previous biological descriptions and current data collected in the field specifically for this project. The significance of impacts has been considered based upon the following:

- Type of impact (adverse/beneficial);
- Extent and magnitude of the impact;
- Duration of the impact (permanent, long-term, short-term);
- Sensitivity of the receptor / receiving environment;
- Comparison with legal requirements, policies and standards and guidelines.

Table 3 : Criteria for describing ecological impact magnitude

Magnitude	Criteria
High	• There is a large-scale permanent change in the ecological receptor and changes in its overall integrity
Medium	• There is a permanent change in the ecological receptor but no permanent change in its overall integrity
Low	• There is a small-scale permanent change or medium-term temporary change in the ecological receptor but its overall integrity is not permanently affected
Neutral	• There is no measurable change in the ecological receptor

Table 4 : Scales of temporal magnitude

Magnitude	Scale
Permanent	• Impacts continuing indefinitely beyond the span of one human generation (taken as approximately 25 years)
Temporary	• Long term (15-25 years) • Medium term (5-15 years) • Short term (up to 5 years)

The significance of the impacts arising from the Project has been categorised as Major, Moderate, Minor, or Negligible. Major or moderate impacts are considered to be 'significant' and are explored in greater depth.

In the assessment of construction and operational phase effects (Sections 6 and 7), the following combinations of ecological impact magnitude (Table 3) and temporal magnitude (Table 4) have been used to determine the significance of an effect:

Major High ecological impact of a temporary or permanent nature

Moderate Low ecological impact of a permanent nature or medium ecological impact of a permanent or temporary nature

Minor Low ecological impact of a temporary nature

Negligible Neutral ecological impact of a temporary or permanent nature

5. Description of the Existing Environment

5.1 Status under Statutory Plans

The Auckland Regional Plan: Coastal (ARC, 2004a) recognises CPA No. 53 (including the MMMR and extending to the true right bank of the Whau River north of the Whau River Bridge) as a CPA1 primarily due to the saline vegetation and wading bird habitat present. CPA No. 54 incorporates the full extent of the Whau River upstream of the Whau River Bridges and is recognised as a CPA2, also due to the saline vegetation and wading bird habitat provided (see ARC Coastal maps, Map Series 1, Sheet 2; Technical Report No. G.3 Assessment of Avian Ecological Effects, and Technical Report No. G.17 Assessment of Terrestrial Vegetation Effects).

Auckland City Council planning map D04 (No. 2) identifies the area of coastal vegetation to the north of SH16 as a Significant Ecological Area, primarily due to the saline vegetation sequence and the importance of the shellbanks as roosting sites for coastal bird species.

A native maritime herb (Maori musk – *Mimulus repens* (nationally at risk, naturally uncommon; regionally endangered) has also been observed along the margins of SH16 within Traherne Island (see Technical Report No. G.17 Assessment of Terrestrial Vegetation Effects).

5.2 Sediment Quality

5.2.1 Sediment Grain Size

Surface sediment grain size analyses carried out between 2008 and 2010 by BML indicate that the intertidal areas within Waterview Estuary predominantly comprise silt and clay grain size fraction, typically greater than 80% (e.g. see sites 3-6 and 9-13 in Figure 8).

The proportion of silt and clay grain size increases in a downstream direction within the Oakley Inlet; sites 1 and 2 had approximately 60% silt and clay, sites 3 and 4 had approximately 80% and sites 5 and 6 had approximately 90% silt and clay (see Figure 8).

North of the Causeway, intertidal sediment samples had a greater proportion of sand grain sizes (e.g. see sites 8, 14, 15, 17, 18, 71 and 73 in Figure 8). These results are consistent with the general pattern of sediment type described by Sivaguru & Grace (2002).

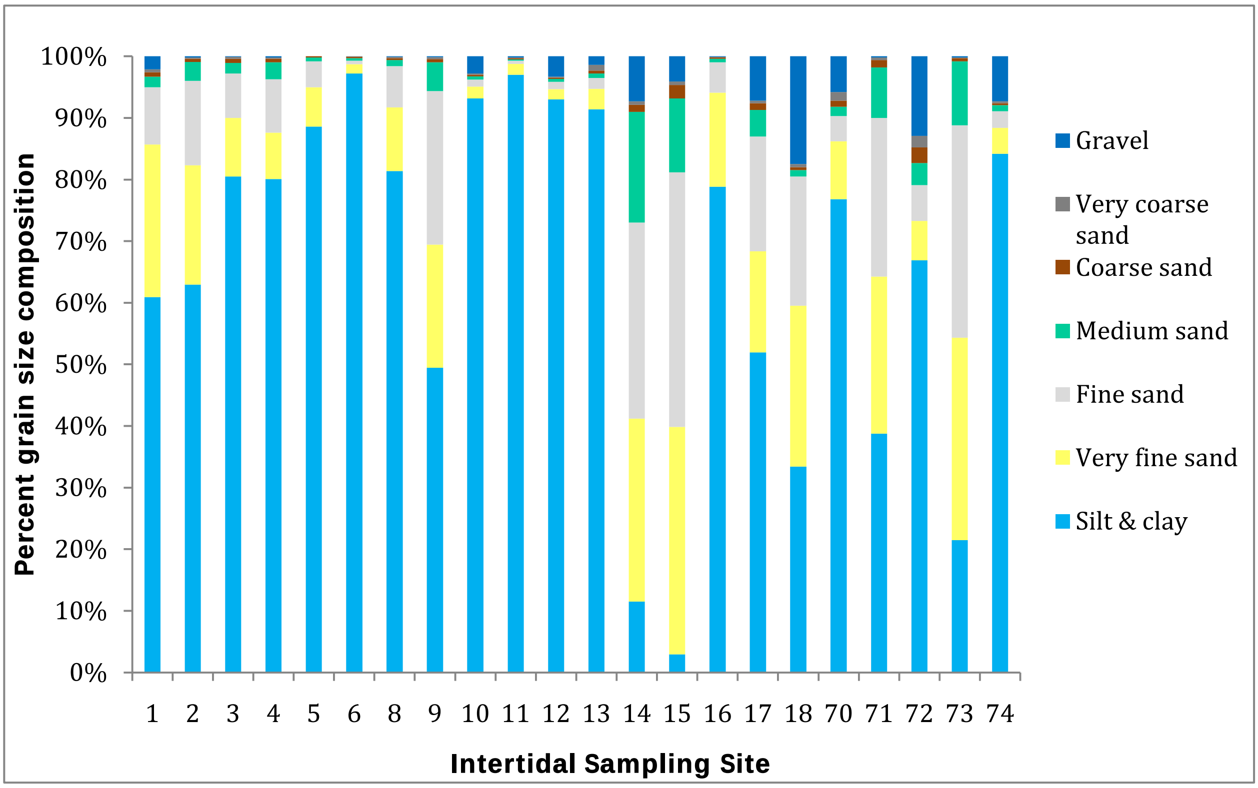

Figure 8: Intertidal sediment grain size

Within the Waterview Estuary, subtidal sediment grain size had the highest proportion of silt and clay (>80%) at sites 20 and 22-24 (see Figure 9), whereas sites 21, 25 and 26 had between 50% and 70% silt and clay. Sediment grain size composition was more coarsely grained at site 19 at the mouth of the Oakley Inlet.

The outer harbour areas (sites 60-62) comprise a combination of fine grain sediment and shell material (captured in the gravel category) (see Figure 9). Subtidal sediment patterns are consistent with that described by Sivaguru & Grace (2002).

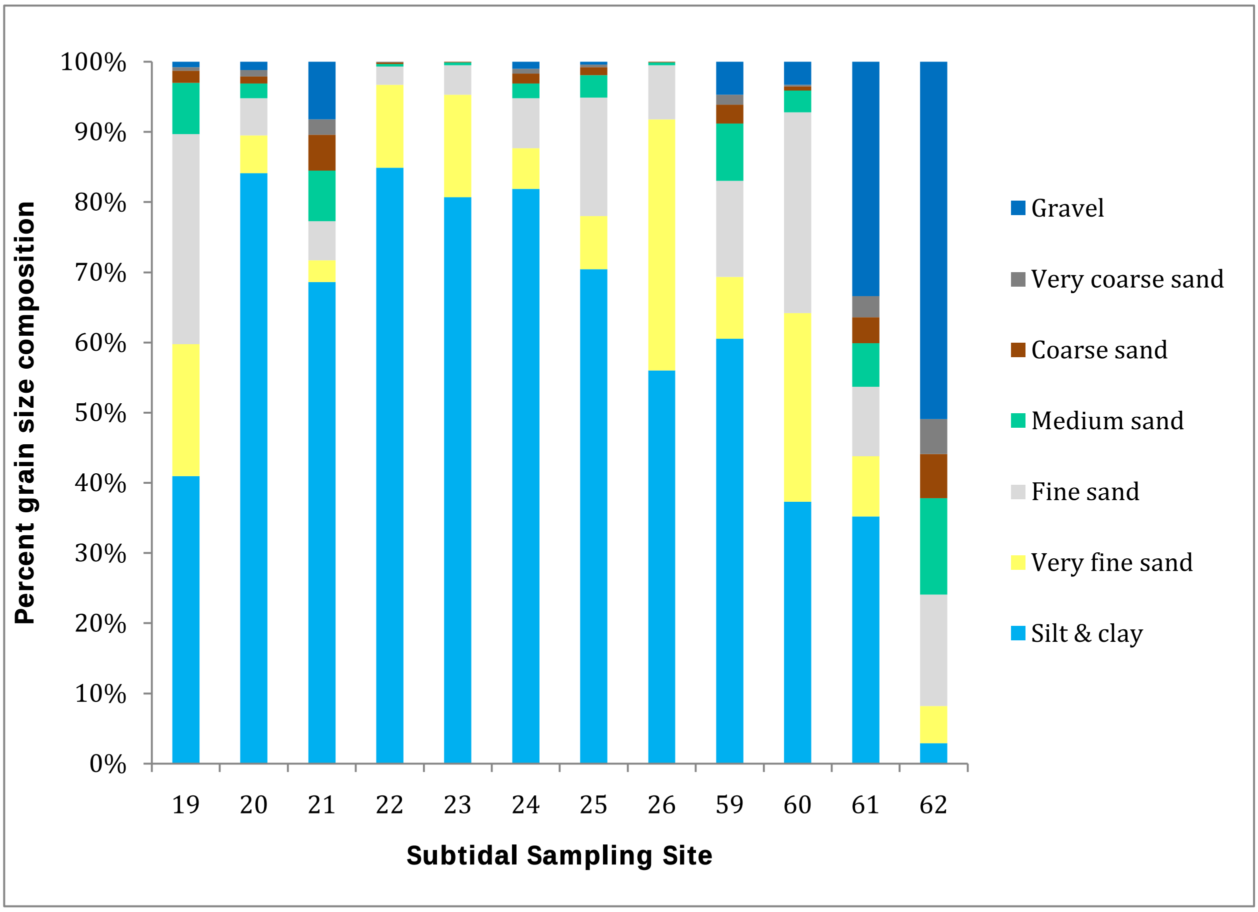

Figure 9: Subtidal sediment grain size

5.2.2 Sediment Contaminants

As previously stated, sediment contaminant data have been compiled from a number of recent studies, including those carried out by Bioresearches and BML as part of this Project (see Appendix B for raw data). The sediment fraction analysed differs between the data sourced from NIWA and that of the other data sets. NIWA analysed the <63 μm fraction and the 63-500μm fraction separately, whereas all other analyses were carried out on the total sediment. These different analysis types have been incorporated within Figures 10-13, using different shaped symbols to reflect the size fraction analysed. In addition, the ARC Ecological Response Criteria (ERC) thresholds (Table 6) for each sample (i.e. green, amber or red, reflecting different concentrations of contaminants) have been overlaid in these figures.

Table 6: Environmental Response Criteria for Sediment Contaminants (mg/kg) (ARC, 2004)

Parameter	Red	Amber	Green
Copper	>34	19-34	<19
Lead	>50	30-50	<30
Zinc	>150	124-150	<124
HMW PAH	>1.7	0.66-1.7	<0.66

ARC developed the ERC to assess whether measured contaminant concentrations are likely to be having adverse effects on marine ecological values. The ERC are based on ANZECC (2000) Interim Sediment Quality

Guidelines (ISQG) and other international sediment quality guidelines. The ERC are intentionally conservative, but generally concentrations in the green range indicate a low risk to organisms, concentrations in the amber range indicate possible effects on organisms, and concentrations in the red range indicate probable impact on organisms and potentially ecological functioning (ARC, 2004).

5.2.2.1 Copper

The distribution of copper in sediment in the wider Project area is shown in Figures 10a and 10b. The overall concentration pattern suggests high concentrations (exceeding the ERC red threshold of 34 mg/kg dry weight (dw)) upstream of the Oakley Inlet (upstream of the MMMR boundary) and high concentrations in the fine sediment proportion around the Causeway Bridges and Oakley Inlet mouth. Waterview Estuary contains a mix of amber (19-34 mg/kg dw) and green ERC concentrations (<19 mg/kg dw). However, where green ERC concentrations are present, they are typically detected in the 63-500 µm grain size range, and the corresponding <63µm grain size sample is consistently within the amber or red ERC thresholds (see Figure 10a). It is likely that total sediment throughout the Waterview Estuary is for the most part within the amber concentration range for copper.

In the outer harbour area (north of SH16) there is generally is less copper in surface sediments, with most sites falling within ERC green (see Figures 10a and 10b).

Sediment collected from sites 74 and 75, adjacent to the cycleway on the southern side of SH16, had copper in excess of the ERC red threshold (see Figure 10a). The concentration at site 75, located near an existing culvert beneath the SH16 west-bound Rosebank Road off-ramp, was the second highest recorded in this study (54 mg/kg), with the highest (60 mg/kg) being at site 1 within Oakley Inlet.

Samples collected near the Whau River Bridges indicate both amber and green ERC concentrations present, with amber on the downstream side of the bridges and green on the upstream side (see Figure 10b).

The concentration of copper in sediment collected from Henderson Creek (site 69) was detected in the green range, whereas the sample collected from Pixie Creek (site 70) had higher concentrations (in the amber range).

5.2.2.2 Lead

The concentration of lead in sediment shows a very similar pattern to that recorded for copper, with red ERC concentrations (>50 mg/kg dw) upstream of the CMA within Oakley Inlet, a mix of amber (30-50 mg/kg dw) and green (<30 mg/kg dw) within Waterview Estuary, and higher concentrations around the mouth of Oakley Inlet and the Causeway Bridges (see Figure 11a and 11b). Sites north of the Causeway typically have lead at concentrations less than 30 mg/kg dw.

Site 75, beneath the west-bound SH16 Rosebank Road offramp, had a high concentration of lead above the red threshold, whereas site 74 to the west of Traherne Island, had lead within the amber range (see Figure 11a).

The pattern for lead in the vicinity of the Whau River Bridges is similar to that for copper, with both amber and green concentrations present. Sediment collected from Henderson Creek had lead concentration within the green range, whereas that from Pixie Creek was within the amber range (see Figure 11b).

Predominantly ERC green concentrations were detected in sediment in outer harbour areas (see Figures 11a and 11b).

5.2.2.3 Zinc

The concentration of zinc in sediment shows a different pattern to copper and lead. ERC red concentrations (>150 mg/kg dw) extend from above the CMA in Oakley Inlet, to the mouth and out into the central area of Waterview Estuary (see Figure 12a). Very few sites have ERC amber zinc concentrations (124-150 mg/kg dw), with most other areas within the Waterview Estuary and the outer harbour areas revealing concentrations less than <124 mg/kg dw (ERC green).

Sediment collected from site 74 had a zinc concentration above the red threshold. Site 75 had the highest concentration of zinc reported, with a total sediment concentration of 820 mg/kg (see Figure 12a). The source of the zinc is unknown, but may be related to the surrounding landuse, as there is a car wreckers yard and other industry located close by.

Around the Whau River Bridges and the nearby outer harbour areas, the concentration of zinc is typically <124 mg/kg (Figure 12b).

5.2.2.4 High Molecular Weight (HMW) PAHs

HMW PAHs comprise the sum concentrations of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene and pyrene. One site above the CMA boundary within Oakley Inlet had HMW PAHs at ERC amber concentrations (0.66-1.7 μg/kg dw), and one site south of the Causeway Bridges had HMW PAHs above red ERC threshold (>1.7μg/kg dw). All other sites within the Waterview Estuary and outer harbour areas north of SH16 had concentrations of HMW PAHs within the ERC green threshold (<0.66 μg /kg dw) (see Figure 13a).

Samples collected adjacent to the Whau River bridge and Pixie Creek were within ERC green for PAHs, apart from the north western sample, which reached the amber threshold (see Figure 13b). The one sample collected near the northern end of Pollen Island was similarly detected to have PAHs at ERC green threshold (see Figure 13b).

Waterview Connection
Assessment of Environmental Effects
0 100 200 300 400 500 600 m
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Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
ARC ERC thresholds (mg/kg)
Copper < 63um
Copper 63 - 500um
Copper total
< 19
19 - 34
> 34
Motu Manawa Marine Reserve
Figure 10a
Concentration of Copper in Sediment
Waterview Estuary
2 June 2010

32
31
64
69
70
18
65
67
66
68
71
Waterview Connection
Assessment of Environmental Effects
0 100 200 300 400 500 600 m
© Boffa Miskell Limited 2009 | www.boffamiskell.co.nz | +64 7 571 5511
Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
ARC ERC thresholds (mg/kg)
Copper < 63um
Copper 63 - 500um
Copper total
< 19
19 - 34
> 34
Motu Manawa Marine Reserve
Figure 10b
Concentration of Copper in Sediment
Whau River
2 June 2010


Waterview Connection
Assessment of Environmental Effects
0 100 200 300 400 500 600 m
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Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
ARC ERC thresholds (mg/kg)
Lead < 63um
Lead 63 - 500um
Lead total
< 30
30 - 50
> 50
Motu Manawa Marine Reserve
Figure 11a
Concentration of Lead in Sediment
Waterview Estuary
02 June 2010

Figure 11 b
Concentration of Lead in Sediment
Whau River

75
74
33
63
62
61
34
72
73
14
15
36
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59
17
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8
48
45
46
23
57
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Waterview Connection
Assessment of Environmental Effects
0 110 220 330 440 550 660 m
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Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
ARC ERC thresholds (mg/kg)
Zinc < 63um
Zinc 63 - 500um
Zinc total
< 124
124 - 150
> 150
Motu Manawa Marine Reserve
Figure 12a
Concentration of Zinc in Sediment
Waterview Estuary
02 June 2010

32
31
64
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18
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66
68
71
Waterview Connection
Assessment of Environmental Effects
0 110 220 330 440 550 660 m
© Boffa Miskell Limited 2009 | www.boffamiskell.co.nz | +64 7 571 5511
Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
ARC ERC thresholds (mg/kg)
Zinc < 63um
Zinc 63 - 500um
Zinc total
< 124
124 - 150
> 150
Motu Manawa Marine Reserve
Figure 12b
Concentration of Zinc in Sediment
Whau River
02 June 2010


Waterview Connection
Assessment of Environmental Effects
0 100 200 300 400 500 600 m
© Boffa Miskell Limited 2009 | www.boffamiskell.co.nz | +64 7 571 5511
Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
HMW PAHs
< 0.66
0.66 - 1.7
> 1.7
Motu Manawa Marine Reserve
Figure 13a
Concentration of High molecular Weight PAHs in Sediment
Waterview Estuary
02 June 2010


32
31
64
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18
65
67
66
68
71
Waterview Connection
Assessment of Environmental Effects
0 100 200 300 400 500 600 m
© Boffa Miskell Limited 2009 | www.boffamiskell.co.nz | +64 7 571 5511
Level 2, 116 On Cameron, Cnr Cameron Rd & Wharf Street, Tauranga
Legend
HMW PAHs
< 0.66
0.66 - 1.7
> 1.7
Motu Manawa Marine Reserve
Figure 13b
Concentration of High molecular Weight PAHs in Sediment
Whau River
02 June 2010

5.2.2.5 Sediment Contaminant Summary

The sediment contaminant data indicates a higher concentration of contaminants in the lower reaches of Oakley Inlet, around the Oakley Inlet mouth, and the southern side of the Causeway Bridges. Within the Waterview Estuary, the concentration of contaminants varies, but typically higher concentrations were detected within Waterview Estuary compared to sites located north of the Causeway.

ARC's monitoring of stormwater contaminants at sites 7 (Oakley Creek mouth) and 64 (downstream of Whau River mouth) revealed that over the past 10 years there have been slow but steady increases in the concentration of copper and zinc in sediment. In comparison, lead has declined in concentration, most likely linked to the reduction of lead in petrol. The concentration of stormwater heavy metals at these two sites, plus at Pollen Island (site 63), measured by ARC in 2005, are presented in Table 7 (sourced from Kelly, 2007).

Table 7: Stormwater Heavy Metal Concentration in Sediment (<63µm fraction) with ERC (Kelly, 2007)

Contaminant	Oakley Creek	Pollen Island	Lower Whau
Site Number	7	63	64
Copper (mg/kg)	30.0	10.5	24.8
Lead (mg/kg)	57.4	21.3	42.9
Zinc (mg/kg)	193.8	76.2	179.7

The concentrations of stormwater contaminants in surface sediment in the upper Waitemata Harbour (Hewitt et al., 2006) and adjacent to Oakley Creek (Diffuse Sources, 2004) detected in routine monitoring by ARC are similar to the levels detected in this present study.

It is estimated that runoff from roads and motorways comprise approximately only one-third of the stormwater contaminants and sediment received by the marine environment associated with this Project (Technical Report No. G.30 Associated Sediment and Contaminant Loads).

5.3 Saline/Coastal Fringe Vegetation

The coastal fringe vegetation around Oakley Inlet, the coastal margins of the MMMR and the coastal margins adjacent to the Whau River bridge comprise a mixture of native shrubs, herbs, coastal/saltmarsh species, mangroves, exotic and weed species (Table 8 and Table 9). The ecological values of the terrestrial and coastal vegetation are described in detail in Technical Report No. G.17 Assessment of Terrestrial Vegetation Effects.

Table 8: Native coastal and saltmarsh species

Common Name	**Latin Name**
Arrow grass	***Triglochin striata***
Bachelor's button	***Cotula coronopifolia***

Blue Coastal Sedge	***Baumea juncea***
Coastal tree daisy	***Olearia solandri***
Drooping shore sedge	***Isolepis cernua***
Flax	***Phormium tenax***
Glasswort	***Sarcocornia quinqueflora* var. *quinqueflora***
Karamu	***Coprosma repens***
Knobby club rush/wiwi	***Ficinia nodosa***
Mangrove	***Avicennia marina* var. *australisica***
Maori musk	***Mimulus repens***
Needle tussock	***Austrostipa stipoides***
New Zealand celery	***Apium prostratum***
Oioi	***Apodasmia similis***
Pohuehue	***Muehlenbeckia complexa***
Raupo	***Typha orientalis***
Remuremu	***Selliera radicans***
Salt marsh ribbonwood	***Plagianthus divaricatus***
Sea blight	***Suaeda novae- zelandiae***
Sea celery	***Apium prostratum***
Sea primrose	***Samolus repens***
Sea radish	***Raphinus raphinistrum***
Sea rush	***Juncus krausii***
Shore groundsel	***Senecio lautus***

Many weed and exotic species are also present around the coastal margin (Table 9). Species noted during the marine surveys are listed below.

Table 9: Exotic and weed species

Common Name	Latin Name
-	*Cyperus sanguiolentus*
Bindweed/convulvulus	*Calystegia* sp.
Blackberry	*Rubus fruticosus agg.*
Boneseed	*Chryanthemoides monilifera*
Brush wattle	*Paraserianthes lophantha*
Buck's horn plantain	*Plantago coronopus*
Cape Ivy	*Senecio angulatus*
Chilean needle grass	*Nassella neesiana*
Climbing asparagus	*Asparagus scandens*
Climbing dock	*Rumex sagittatus*
Dimorphotheca	*Osteospermum fruticosum*
Ginger	*Hedychium garnerianum*
Gladioli	*Gladiolus* sp.
Gorse	*Ulex europaeus*
Gum tree	*Eucalyptus* sp.
Hawksbeard	*Crepis capillaries*
Japanese honeysuckle	*Lonicera japonica*
Jersey cudweed	*Pseudognaphalium luteoalbum*
Kikuyu	*Pennisetum clandestinum*
Mercer grass	*Paspalum distichum*
Moth plant	*Arujia sericifera*
Nasturtium	*Tropaeolum majus*
Pampas	*Cortaderia selloana*
Pasture grasses	-
Pine tree	*Pinus radiata*
Privet	*Ligustrum lucidum*
Redroot	*Amaranthus powellii*
Shore orache	*Atriplex prostrata*
Smilax	*Asparagus asparagoides*
Sow thistle	*Sonchus oleraceus*
Sydney golden wattle	*Acacia longifolia*
Tall fescue	*Schedonorus phoenix*
Tree privet	*Ligustrum lucidum*
Wandering Jew	*Tradescantia fluminensis*
Wattle	*Paraserianthes lophantha*
Woolly nightshade	*Solanum mauitianum*

Mangroves are the dominant saline vegetation species within the wider Waitemata Harbour and within the Waterview Estuary, Traherne Island and Pollen Island, and adjacent to the existing Causeway. Typically, mangroves are taller (up to 3-4 m in height) adjacent to the coastal fringe (landward extreme) and adjacent to the subtidal channels (seaward extreme). Shorter stature mangroves (approximately 0.3-0.5 m in height), sometimes referred to as having a prostrate growth form, are present within the central areas where the sediment grain size is often dominated by fine sand, less water retained on the sediment surface at low tide and potentially less nutrients are available for uptake.

Previous surveys of the mangroves present in these habitats (BML 2001 and 2003) have quantified density and height and estimated mangrove health based on visual assessment. However, these parameters have high natural variability, and cannot readily be used to assess health of the vegetation community. Typically mangrove height and density are driven by processes such as period of inundation, sediment qualities (including grain size), the hydrodynamic energy of the environment, salinity, shading and ambient temperature (Morrisey et al., 2007). No evidence of unthrifty mangrove stands was detected in the recent BML qualitative vegetation surveys (2009/2010).

5.4 Marine Invertebrates

5.4.1 Early Investigations

Brief summaries of the results from the earlier marine ecological investigations are provided below.

5.4.1.1 BML 2001 Survey

In order to assess the general condition of intertidal epifaunal invertebrate communities, BML (2001) utilised counts of mud crabs (estimated from burrow holes) and mud snails collected along transects 1-4 (see Figure 6). These two species are considered to be typical mangrove/mudflat epifauna species. High abundance of mud crab burrows and mud snails was detected, but abundance varied greatly within and among transects (see Figure 14).

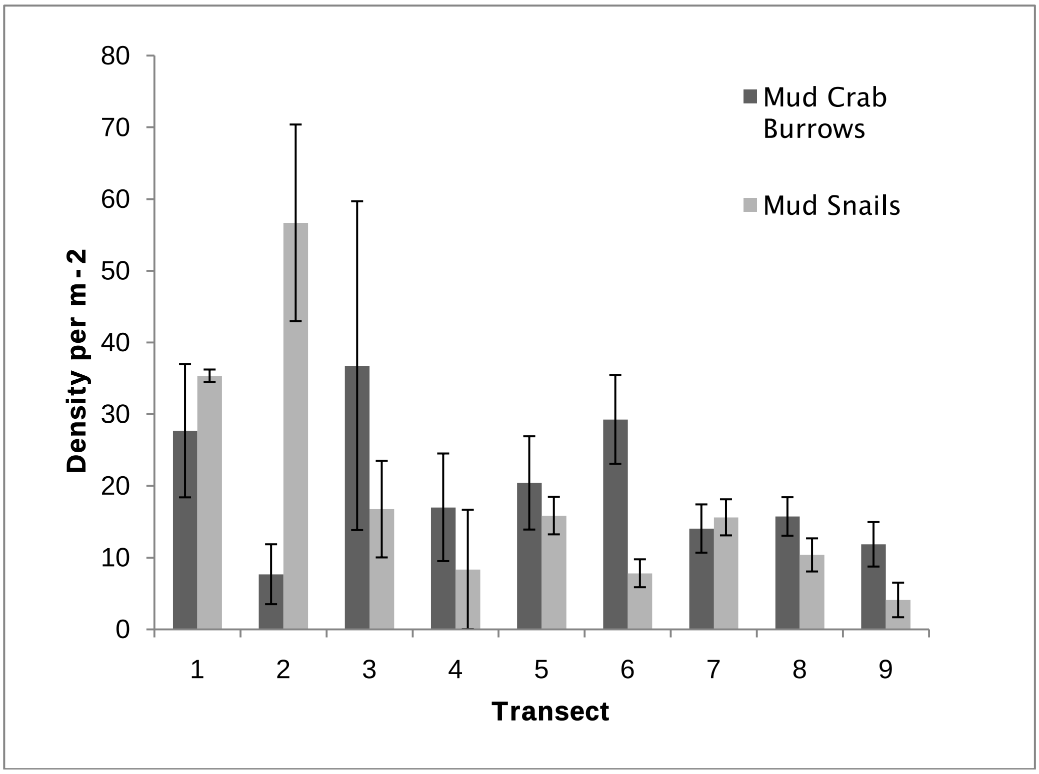
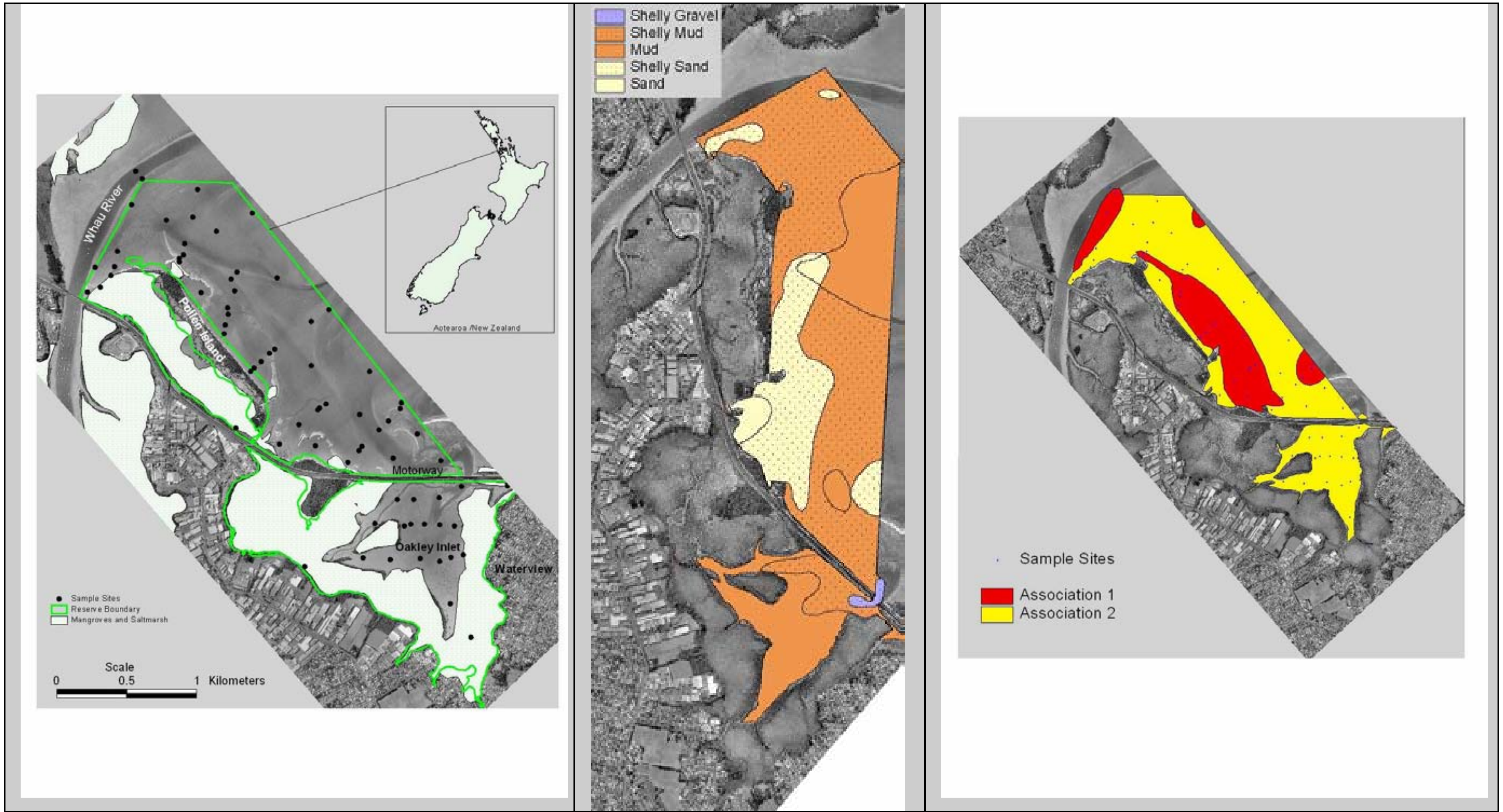


Figure 14: Density of mud crab burrows and mud snails detected in 2001 (transects 1-4) and 2003 (transects 5-9).

5.4.1.2 Sivaguru & Grace (2002) Survey

Intertidal and subtidal benthic associations present within the non-vegetated intertidal flats and subtidal areas within the MMMR were studied by Sivaguru & Grace (2002) in order to provide a baseline dataset for the previously unsurveyed soft sediment invertebrate assemblage. Sivaguru & Grace (2002) noted that whilst the Marine Reserve was created in 1995, in 2002 there was little information available on the marine life contained within the reserve. Their sampling locations are shown below in Figure 14. No samples were collected from Traherne Island and no intertidal samples were collected within Waterview Estuary.

Two main subtidal invertebrate assemblages were detected: Association 1 characterised by a low diversity of polychaete worms and the introduced bivalve *Theora lubrica* (window shell); and Association 2 characterised by a higher diversity of invertebrates including *Austrovenus stutchburyi* (cockles), *Nucula hartvigiana* (nut shells) and polychaete worms. These faunal associations closely reflect the sediment composition, with Association 1 most comprising soft muds and Association 2 comprising more coarse, shelly and sandy sediments (See figure 15, from Sivaguru & Grace (2002)).



Intertidal and Subtidal Sampling Sites	Sediment Type	Faunal Association

Figure 15: Sampling sites, sediment types and faunal associations (from Sivaguru & Grace, 2002)

5.4.1.3 BML 2003 Surveys

BML surveys of epifaunal assemblages in 2003, undertaken along five transects (5-9, Figure 6) revealed a high but variable abundance of *Helice crassa* (mud crab) burrows and mud snail abundance throughout the Waterview Estuary (see Figure 14). Oyster beds were located on the eastern shoreline of the inlet and on a drier mud bank, built on historic shell deposits, adjacent to the mouth of Oakley Inlet. Within the oyster beds, typical mudflat invertebrates were present, including *Diloma aethiops* (mudflat top shell), *Lunella smaragdus* (cat's eye), *Austrominius modestus* (modest barnacle), *Onichidella nigricans* (pulmonate slug) and *Anthopleura aureoradiata* (mud flat anemone). The remainder of the open intertidal habitat within the inlet was characterised as soft deep mud with a high abundance of mud crabs.

Epifaunal community composition was related to sediment grain size composition. Mud snails were detected within the low lying mangroves of Traherne Island, where the sediment had a higher proportion of gravel and sand. To the north of Traherne Island, where sediment is coarser, the dominant species changes to *A. stutchburyi* (cockle), *Cominella glandiformis* (mud flat whelk) and *Zeacumantus lutulentus* (horn shell). Mud crabs dominated areas of open mudflats where the sediment comprised soft deep mud.

Mangroves measured in 2003 varied in height between less than 0.5 m (transect 8 and 9) and greater than 2.0 m (transect 7) (see Figure 6), which is in accordance with observations in 2009 and 2010.

5.4.2 Recent Surveys – BML 2008/2010

5.4.2.1 Epifaunal Invertebrates

The abundance of surface invertebrates (epifauna) at intertidal sampling sites investigated in 2009-2010 is presented in Figures 16 and 17 (separated into two graphs for ease of interpretation). The data clearly shows two different invertebrate communities, one dominated by *Zeacumantus lutulentus*, *Diloma subrostrata* (gastropods) and the estuarine limpet *Notoacmea helmsi* (sites 15, 18, 72 and 73), the other dominated by mud crabs (estimated by counting mud crab holes) and mud snails (sites 9-13).

The sites dominated by the *Zeacumantus/Diloma/Notoacmea* association typically have a sediment grain size composition containing less than 50% silt and mud, whereas sites dominated by the mud crab/*Amphibola* association have a surface sediment composition of >80% silt and mud. These patterns are consistent with that described by Sivaguru & Grace (2002) and Morrisey et al. (2007).

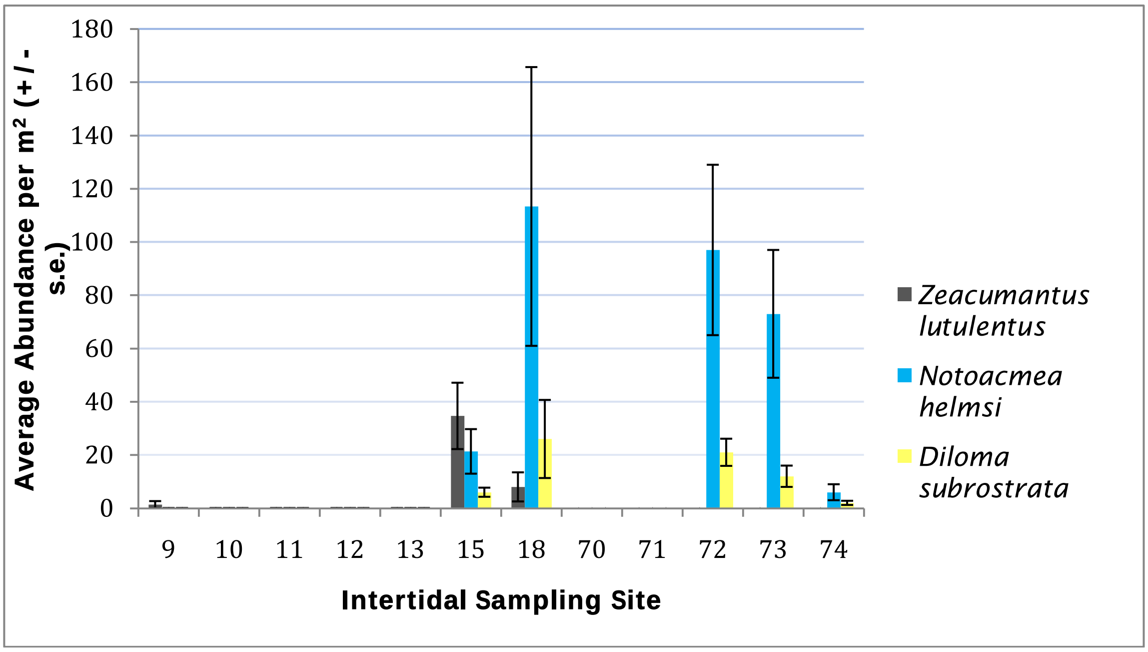


Figure 16: Average abundance of selected epifauna at intertidal sampling sites

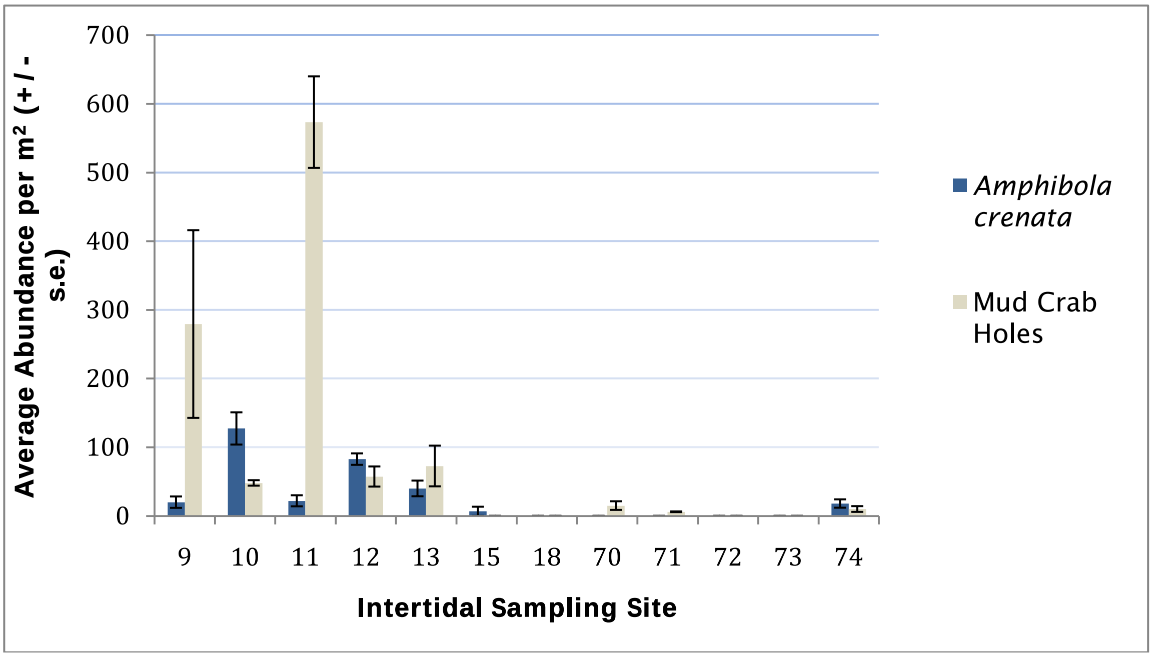


Figure 17: Average abundance of mud snails and mud crabs at intertidal sampling sites

5.4.2.2 Infaunal Benthic Invertebrates

Intertidal soft sediment surveys carried out by BML in 2008, focussed around tidal areas within and immediately adjacent to Oakley Inlet; surveys undertaken in 2009 and 2010 included the wider Project area within Waterview Estuary, north of the Causeway, and along the SH16 alignment (see Figures 5a and 5b). Subtidal samples collected by Bioresearches adjacent to the Whau River Bridges and the Causeway Bridges are included in the invertebrate data set. The occurrence of individual benthic invertebrate species at each site is presented in Appendix C.

Intertidal infauna abundance was variable, but overall was dominated by oligochaete and polychaete worms, amphipods, crabs and gastropods. The data indicates that for intertidal sampling sites the highest number of individuals (approximately 160 per core) was detected at site 8 (south of the mouth of Oakley Inlet), predominantly comprising of the scavenging amphipod *Paracorphium excavaum* (average total abundance of 110 per core sample) and oligochaete worms (average total abundance of 51 per core sample) (see Figure 18). Sites 2 and 4 (upstream of the CMA boundary at Oakley Inlet) had the next highest abundance of individuals (an average of c. 80-100 individuals per core), with the same two taxa having the highest average abundance at each of these sites. Sites 1 and 3 (upstream of the Oakley Inlet CMA boundary), site 17 (located to the north of the Causeway Bridges) and site 70 (Pixie Creek) had the next highest abundance of individuals (approximately 40-50 individuals). All remaining intertidal sampling sites had <30 individuals per core (see Figure 18).

The large standard error calculated for site 70 (see Figure 18) reflects a high abundance of *Potamopyrgus estuarinus (*a gastropod common in estuaries adjacent to freshwater inputs) in one replicate core sample, which was located closer to the stormwater discharge point.

No infaunal invertebrates were detected in sediment core samples collected from site 74.

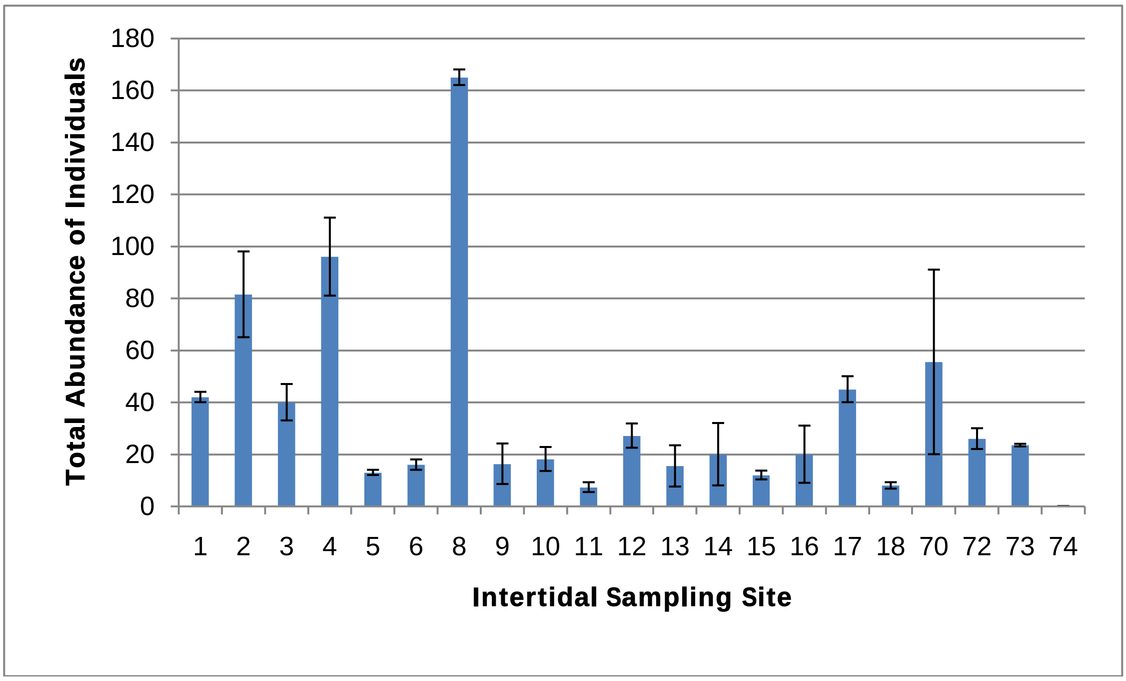


Figure 18: Total number of intertidal benthic invertebrate individuals per core

Subtidal sites were dominated by polychaete worms (in particular Capitellid worms) and amphipods. Due to the subtidal grab samples not being of uniform volume, comparisons of total abundance among sites is not possible. However, the number of taxa and relatively diversity (Shannon-Weiner) for subtidal invertebrates are described below.

Whilst the number of individuals per intertidal core varied among sites (see Figure 18), the average number of taxa was relatively uniform among sites, with approximately 4-6 taxa per sample (see Figure 19). Sites 16, 17, 72 had a higher average number of taxa (approximately 9-10) (see Figure 19). All three of these sites were located on the northern edge of the existing SH16 alignment.

More taxa were detected in the subtidal samples (6-9) compared to those from the intertidal (4-6) (see Figure 20). The highest numbers of taxa (13-19) were found north of the Causeway in the open harbour (sites 61 and 62), and adjacent to the Whau River Bridges (65-68) and Causeway Bridges (27-30). Between 10 and 12 taxa per grab were detected in the more open subtidal body of water within the Waterview Estuary (sites 21, 25, 26), with the lowest number of taxa detected in samples collected from the subtidal channel adjacent to the south-eastern edge of Traherne Island (sites 22-24) (see Figure 20).

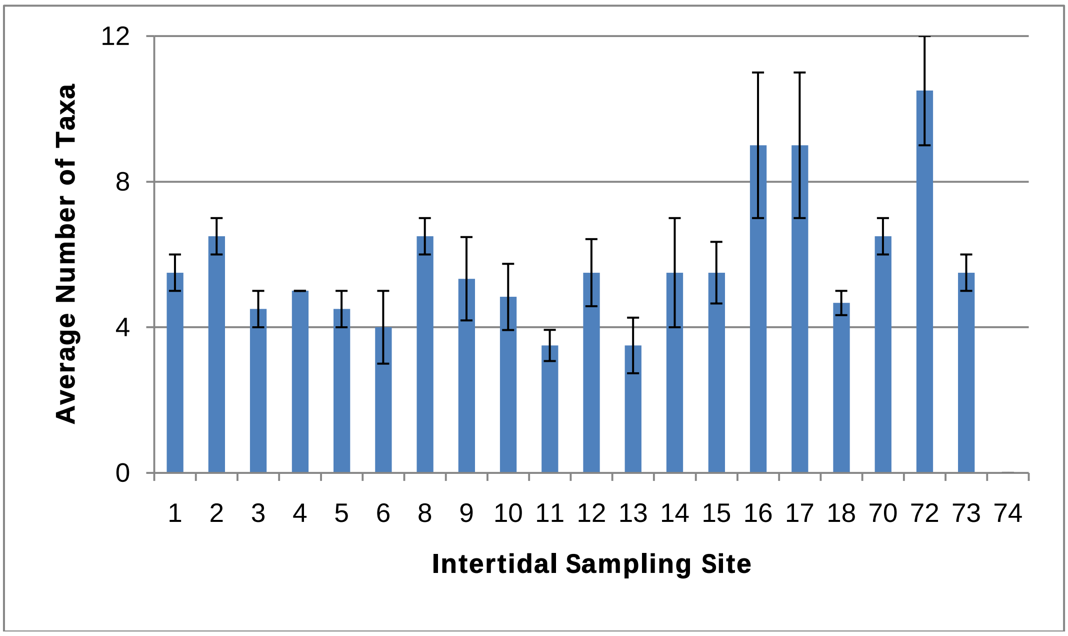


Figure 19: Average number of intertidal benthic taxa per core

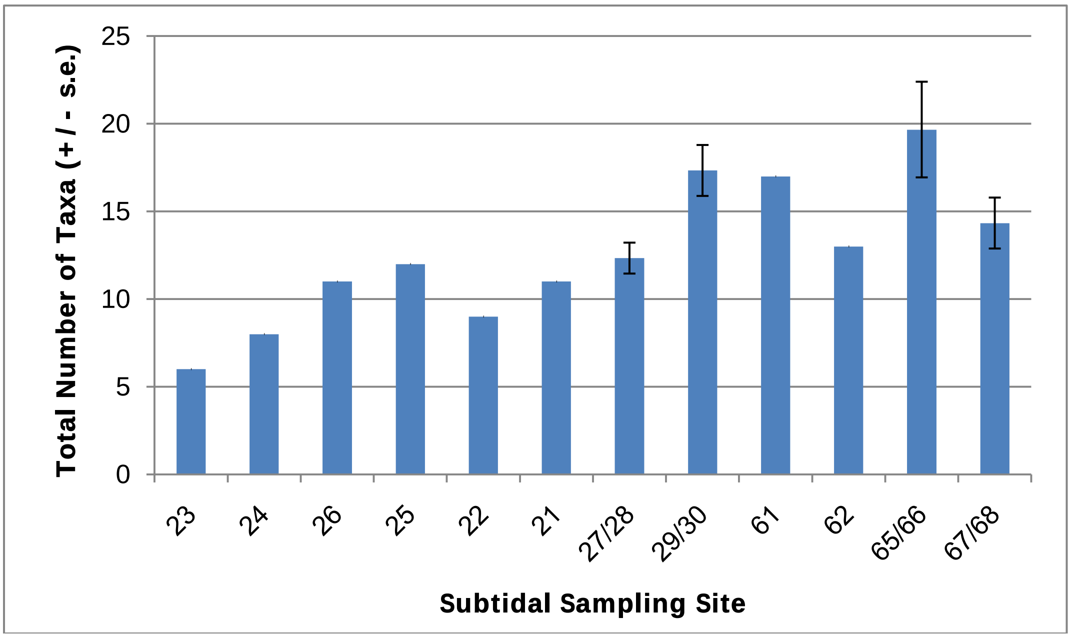


Figure 20: Total number of subtidal benthic taxa per grab

The Shannon-Wiener (SW) Diversity Index incorporates the concept of species richness (number of species/taxa) and evenness (a measure of the spread of abundance across species/taxa). This calculation takes into account relative abundance and removes the dominance of one or two species within a sample. For example, site 8 had the highest abundance of individuals across all sites and a reasonably high number of taxa, but the SW Diversity Index for this site is the second lowest across both intertidal and subtidal sites (approximately 0.75) due to the dominance of a small number of species (see Figure 21).

SW diversity is highest at intertidal sampling sites located north of the Causeway (approximately between 1.5 and 2.0), which is related to a lower proportion of silt and clay and the presence of shell material in sediment at these sites (see Figure 21). Sites 16 and 72 had the highest SW index, followed by sites 15, 17 and 18. Site 1 also had a moderately high SW diversity, most likely reflecting the presence of both freshwater and estuarine organisms at this upstream site within Oakley Inlet. Interestingly site 2, a short distance downstream of site 1 within Oakley Inlet, had the lowest diversity of all the intertidal sampling sites. This result is due to a higher abundance of the scavenging amphipod *Paracorphium excavatum* compared to the abundance of other taxa in the samples (see Figure 21).

Excluding site 2, there is a weak trend of decreasing diversity with increased distance downstream within Oakley Inlet to the mouth, from approximately 1.5 at site 1 to approximately 0.8-1.0 at sites 5, 6 and 8 (see Figure 21). Average diversity is similar amongst sites 9-14 (although the variability within sites is relatively high), with an average SW Diversity index of approximately 1.

Overall, the pattern of invertebrate diversity is moderate within tidal areas of Oakley Inlet upstream of the CMA. Diversity is lower towards the mouth of Oakley Inlet and throughout Waterview Estuary. Invertebrate diversity is higher north of the Causeway in the adjacent outer harbour.

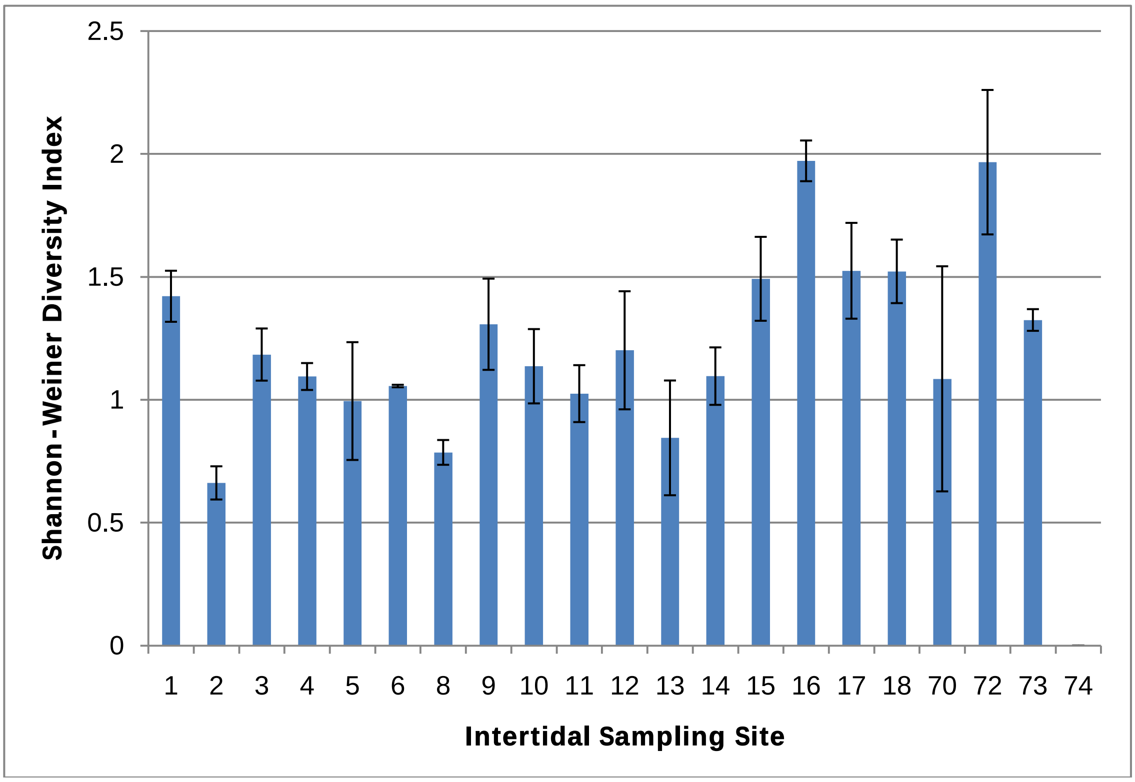


Figure 21: Average intertidal benthic invertebrate community diversity per core sample

Subtidal invertebrate diversity is higher north of the Waterview Causeway (sites 61 and 62), adjacent to the Whau River Bridges (sites 65-68), a small distance south of the Causeway (sites 21 and 22) and to a lesser extent adjacent to the Causeway Bridges (27-30). Diversity decreases with increasing distance south of the Causeway, with sites 23-26 having an index between 1.0 and 1.45 (see Figure 22). However, the subtidal invertebrate data need to be compared and interpreted cautiously, as they do not reflect the same volume of sediment sampled and for the most part, only one grab sample was collected.

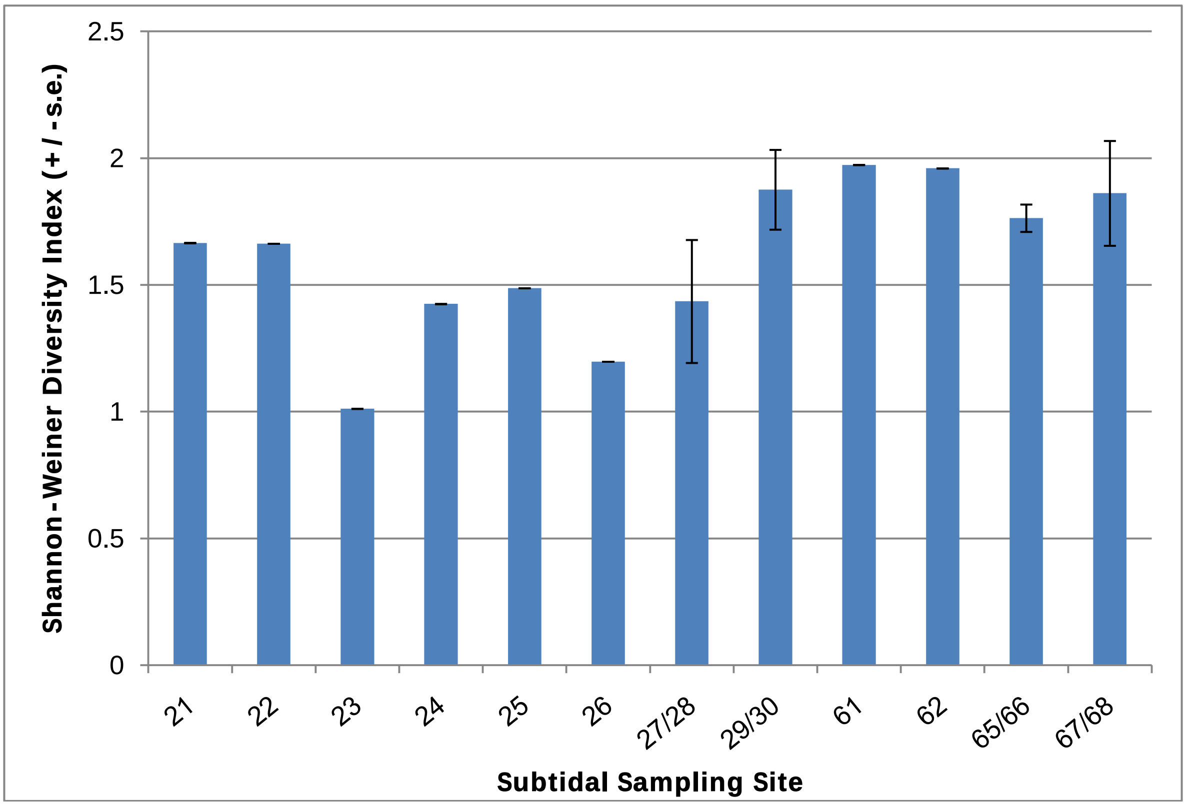


Figure 22: Subtidal benthic invertebrate community diversity per grab sample

The intertidal benthic invertebrate diversity detected in these studies is typical of urban estuaries in the Auckland region (De Luca, unpublished data).

There appear to be two intertidal community assemblages, one dominated by mud crabs, mud snails and worms (in the fine clays and muds) and the other having a greater diversity of taxa present, particularly epifauna (where sediment is more sandy/shelly). In general, the benthic invertebrate species and community composition detected were typical of urban, low energy, upper estuarine habitats. No special or rare species were identified.

5.5 Fish

Fish were not sampled as part of this assessment because recent data was available, fish are highly mobile and this gives them the ability to avoid areas of disturbance, and difficulties associated with sampling marine fish in a comprehensive but non-destructive manner.

The literature suggests that a variety of fish use tidal flats and subtidal channels that are surrounded by mangrove forest (Morrison et al., 2002). In their study of the importance of mangrove forests as juvenile fish nurseries, Morrison et al. (in prep.) measured relative abundance of fish using intertidal flats and mangrove forests. For Auckland east coast sites (including the Waitemata Harbour) the following species were common; short-finned eel (*Anguilla australis)*, estuarine triplefin (*Grahamina nigripenne)*, asian goby (*Favonigobius lentiginosus)*, exquisite goby (*Favonigobius exquisitus)*, sole (*Peltorhamphus latus)*, common smelt (*Retropinna retropinna)*, sand flounder (*Rhombosolea plebeian)*, parore (*Girella tricuspidata)*, yellowbelly flounder (*Rhombosolea leporina)*, anchovy (*Engraulis australis)*, snapper (*Pagrus auratus)*, grey mullet (*Mugil cephalus)*, spotty (*Notolabrus celidotus)*, yellow-eyed mullet (*Aldrichetta forsteri)*, and mottled triplefin (*Grahamina capito)*. It is likely that most of these species are also at least periodically present in the Oakley Inlet, the MMMR and adjacent to the Whau River.

Fish (and other fauna) may experience sublethal effects related to the quality of their environment. Research undertaken on the health of yellowbelly flounder from two harbour sites (the mouth of Henderson Creek and the mouth of the Whau River) and a reference site at Whangaparoa Peninsula, indicated significantly higher prevalence of pathological changes in fish sampled from the harbour sites (Nenadic, 1998). While cause and effect was not proven, Nenadic (1998) noted a strong correlation between the presence of contaminants and pathological abnormalities in fish. In addition, Nenadic (1998) noted that the harbour sites had lower pH, higher water temperature and lower dissolved oxygen concentration compared to the reference site, and concluded that hypoxia could also be a factor.

5.6 Summary of existing marine ecological values by Project Sector

5.6.1 Sector 1: Te Atatu Interchange

The upper reaches of Pixie Inlet are dominated by mangroves and common estuarine epifauna, including mud crabs and the small gastropod *Potamopyrgus estuarinus*. Stormwater from the adjacent residential catchment discharges into the estuarine habitat. Whilst the ecology of this area is not unique, with common organisms present, it appears to be in relatively good health given the surrounding landuse (see Technical Report No. G.6 Assessment of Freshwater Ecological Effects). Metals (copper, lead and zinc) in the sediment were within the ARC amber range, whereas PAHs were below the amber threshold.

5.6.2 Sector 2: Whau River

The location within the Whau River potentially affected by the Project is primarily the area adjacent to the existing Whau River Bridges. This area contains a typical subtidal invertebrate assemblage, with low sediment contaminant concentrations due to the flushing of fine sediment from the immediate area. Flora and fauna on the intertidal banks adjacent to the existing bridge abutments are also typical for this type of habitat, predominantly comprising mangroves, some saltmarsh species, exotic weed species above MHWS and mud crabs and worms dominating the invertebrate assemblage. Upstream of the Whau River Bridges sediment quality declines significantly in depositional areas and the ecological values are likely to be low. Downstream of the Whau River Bridges contaminant concentrations are low and the ecological values are likely to moderate to high.

5.6.3 Sector 3: Rosebank – Terrestrial

Sector 3 extends eastward from the Rosebank Domain to approximately the Rosebank Road/Patiki Road westbound off-ramp and contains primarily terrestrial habitat (see Technical Report No. G.17 Assessment of Terrestrial Vegetation Effects).

5.6.4 Sector 4: Reclamation

The largest coastal Sector (Sector 4) includes SH16 from the Whau River Bridges to the Great North Road Interchange (terminating near the mouth of Oakley Inlet), encompassing the marine/estuarine habitat on both the southern and northern side of the existing motorway.

The marine ecological features contained within this Sector include mangrove forest, saltmarsh, shellbanks, intertidal mudflats and sandflats, subtidal soft muds and man-made rocky shore (existing rock revetment).

Along the northern side of SH16 within this Sector, ecological values are high to moderate. The interface between the mown grass edge seaward of the existing Causeway and the saline habitat comprises a mixture of native and exotic vegetation and an accumulation of rubbish and debris. Seaward of this interface area, depending on the hydrology of the immediate area and the sediment characteristics, the vegetation often grades into coastal saltmarsh species and then into mangroves. On the western side of Pollen Island there are ecologically important drainage channels present that strongly influence the surrounding resident ecology.

Chenier shellbanks are present on and around Traherne Island and sandflats. There is a higher diversity of marine invertebrates in the immediate estuarine environment on the northern side of the motorway due to the presence of more heterogeneous habitats, to which a higher ecological value is ascribed. Where the habitat comprises mudflats with mangroves present, the invertebrate assemblage generally has relatively low diversity and is indistinguishable from that of the southern side discussed in subsequent paragraphs. Where the sediment contains more sand, cobbles or shell material a somewhat different invertebrate assemblage is present. The rock revetment provides further habitat diversity.

The southern side of the SH16 Causeway, seaward of the cycleway path between Rosebank Road and the eastern end of Traherne Island, has high to moderate ecological values. Vegetation grades from grass containing a mix of native saltmarsh and shrub species and exotic/weed species within and adjacent to the rock armouring, to saltmarsh species at the base of the slope/rock armouring, through to low stature mangroves. Estuarine invertebrates present within approximately 10 m from MHWS are ubiquitous, predominantly comprising mud crabs, mud snails, polychaete and oligochaete worms.

Eastward of Traherne Island extending to the mouth of Oakley Inlet, the benthic sediment largely comprises soft deep mud flats and the intertidal invertebrate assemblage is less diverse, as the range of species that can tolerate such habitat conditions is less extensive. Historical habitat modification of the environment is extensive, including the historic severing of the mudflat adjacent to the eastern abutment of the Causeway Bridges and realignment of the discharge from Oakley Inlet. Ecological values in this area are moderate to low.

Subtidal grab samples revealed typical invertebrate species are present adjacent to the Causeway Bridges. Organisms that tend to inhabit soft mud habitats within inner harbour sites are generally relatively tolerant of disturbance and other stressors.

The concentration of common stormwater contaminants in surface sediment is low on the northern side of the Causeway, and elevated around the Causeway Bridges and within the Waterview Estuary close to the Causeway and the mouth of Oakley Inlet. A higher concentration of contaminants was detected in the fine grain size component of sediment samples, and zinc was commonly detected in concentrations above the ARC ERC red threshold. Sediment samples collected from the mouth of Oakley Inlet revealed zinc typically above ARC ERC red, whereas lead and copper were generally detected within the ERC amber concentration range.

The ecological values within this sector are variable, with a generalised trend of decreasing ecological value with increasing proximity to the Causeway and mouth of the Oakley Inlet. One hot spot beneath the west-bound SH16 Rosebank Road off-ramp was detected, with the concentration of zinc in particular being very high.

5.6.5 Sector 5: Great North Road Interchange

Sector 5 encompasses a number of on- and off-ramps, some which traverse Oakley Inlet west of Great North Road. Mangroves inhabit the intertidal mudflats and generally the coastal edge vegetation comprises a narrow bank of native shrub, saltmarsh and exotic weed species. Some areas of native revegetation are present, predominately on the northern side of Oakley Inlet adjacent to the existing motorway. The estuarine ecological values are assessed as moderate to low in this area due to the high concentration of contaminants in sediment and limited diversity of benthic invertebrates.

5.6.6 Sectors 6 to 9

While sectors 6 to 9 are not adjacent to the CMA, the existing landuse and discharges from the Meola and Oakley catchments influence the freshwater sediment and water quality, which in turn has some influence on the downstream marine receiving environments. Stormwater discharges from these sectors are to freshwater environments (Meola Creek and Oakley Creek), some distance from the CMA, and as such, are discussed in Technical Report No. G.6 Assessment of Freshwater Ecological Effects.

6. Effects Assessment – Construction Activities

6.1 Sector 1: Te Atatu Interchange

The works in Sector 1 involve enlargement and reconfiguration of the on- and off-ramps at the Te Atatu Interchange in order to accommodate additional lanes and to provide for bus shoulders and priority lanes for buses and other High Occupancy Vehicles. Three lanes are proposed on the mainline carriageway westbound through the Te Atatu Interchange and four lanes are proposed eastbound.

Activities affecting the ecological values of the marine environment include the construction of a permanent stormwater treatment wetland located partially within both the CMA and Jack Colvin Park, the discharge of treated construction phase runoff from sediment retention ponds and decanting earth bunds, and the extension of an existing stormwater culvert within Pixie Inlet. These activities have the potential to affect marine ecological values by way of permanent intertidal habitat loss, temporary intertidal habitat disturbance and the discharge of construction phase runoff. The area of habitat loss has been calculated by Aurecon and these areas are included in Appendix D.

6.1.1 Permanent Intertidal Habitat Loss

The construction of the permanent stormwater treatment wetland within Jack Colvin Park requires the reclamation of approximately 1,100 m^2 of intertidal CMA within Pixie Inlet, involving the removal of approximately 1,000 m^2 of coastal vegetation (including mangroves) (see Plan set F.12 20.1.11-1-D-N-941-101). The ecological values of the area of permanent habitat loss are moderate, with primarily common, tolerant estuarine organisms present beneath a canopy of mangroves. In particular at this site, there is a high abundance of the common estuarine gastropod, *Potamopyrgus estuarinus*. Sediment quality at this site is affected by common stormwater contaminants (primarily copper, lead and zinc), with concentrations within the amber range of ARC's ERC, indicating the potential for ecotoxicological effects to occur if sediment-bound contaminants become bioavailable through construction disturbance.

Whilst common stormwater heavy metal contaminant concentrations in surface sediment were found to be only moderately elevated at this site, elevated concentrations of DDT and its breakdown compounds (DDD and DDE) were detected (Technical Report No. G.9 Assessment of Land and Groundwater Effects). Recommendations for further analysis of sediment quality prior to the construction of the stormwater treatment wetland are contained within Technical Report No. G.9 Assessment of Land and Groundwater Effects and Technical Report No. G.23 Coastal Works. If contaminated soil or sediment is detected it will be important that the excavated material is removed from the site and disposed of at an appropriate licensed landfill site to ensure contaminants are not released into the aquatic environment.

The effects of permanent intertidal habitat loss in this Sector are moderate.

6.1.1.1 Summary of Effects

Table 10: Sector 1 Permanent Habitat Loss - Summary of Effects

Activity	Ecological Values	Magnitude of	Permanent or	Significance of

		Impact	Temporary Scale	Effect
Reclamation of CMA for wetland	Moderate	Medium	Permanent	Moderate

6.1.2 Temporary Habitat Loss/Disturbance

6.1.2.1 Construction of Treatment Wetland

An area of approximately 550 m^2 of intertidal marine habitat is estimated to be temporarily disturbed during construction of the treatment wetland. This area of disturbance primarily relates to the establishment of erosion and sediment control treatment (rock toe silt fence) in order to protect the downstream environment. At the toe of the wetland embankment, immediately downstream of the reclamation, a rock toe with embedded geotextile fabric will be installed to act as a silt fence. This rock toe silt fence will ensure that suspended sediment arising from construction of the treatment wetland will be retained within the works area and not released to the downstream environment. The rock toe silt fence structure will extend to a distance of no more than 5.0 m from the edge of the wetland embankment. Upon completion of construction of the treatment wetland the rock toe will be removed. Seepage of water from between the wetland embankment and the rock toe silt fence will be pumped either to sediment retention ponds or to tankers for removal from the site (see Technical Report No. G.23 Coastal Works and Technical Report No. G.15 Assessment of Stormwater and Streamworks Effects).

Adverse effects of construction of the rock toe silt fence will be temporary habitat loss, mortality of benthic invertebrates through smothering, reduced oxygenation of benthic sediment, mangrove removal, trampling of sediment and temporary increase in suspended sediment during rock toe silt fence construction and removal. The potential adverse effects from not providing this protection of downstream intertidal habitat from the discharge of sediment during construction of the treatment wetland outweigh the temporary effects of installing the protection measures. Following removal of the structure, mangroves and benthic organisms will recolonise the area over time, with negligible effects anticipated in the long term.

During construction of the treatment wetland there will be some temporary low level noise (see Technical Report No. G.12 Assessment of Construction Noise Effects) and vibration disturbance to the surrounding marine habitat. Adverse effects on marine organisms may include reduced movement and foraging of mobile invertebrates (e.g. mud crabs and gastropods) and possibly temporary avoidance of the surrounding subtidal channels by fish.

Minor effects on flows are anticipated as a result of temporary occupation and disturbance of the CMA (Technical Report No. G.4 Assessment of Coastal Processes). The adverse effects on marine ecological values, from the minor flow alterations, given their temporary nature, are considered to be negligible.

On balance, the potential effects of temporary loss in Sector 1 are considered to be minor.

6.1.2.2 Discharge of Construction Phase Stormwater

Treatment of construction phase (incorporating both Erosion and Sediment Control treatments and temporary stormwater treatment) stormwater in Sector 1 is provided by sediment retention ponds and decanting earth bunds (DEBs), with both the ponds and the DEBs receiving additional chemical treatment. The locations of these treatment devices and their discharge points are provided in Technical Report No. G.22 Erosion and Sediment Control Plan 20.1.11-3-EN-740-101 to 103.

Removal of sediment (and associated contaminants) within sediment retention ponds is estimated at an average of 94% (Technical Report No. G.30 Assessment of Associated Sediment and Contaminant Loads Report). Therefore, the concentration of contaminants in the discharges is likely to be below biological effects threshold levels. Discharge of treated runoff will occur into Pixie Inlet, Henderson Creek and the Whau River; scour and erosion protection will be provided at each discharge point. In addition, super silt fences are to be installed at strategic locations in order to provide a "back up" in the unexpected event of a sediment control failure (Technical Report No. G.22 Erosion and Sediment Control Plan).

Given the high percentage of sediment removal estimated to be provided by the treatment devices and the dilution provided by the receiving environment, the adverse effects on marine ecological values from the discharge of treated runoff in Sector 1 are considered to be negligible.

6.1.2.3 Summary of Effects

Table 11: Sector 1 Temporary Habitat Loss/Disturbance - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Temporary occupation of CMA for erosion and sediment controls	Moderate	Low	Temporary	Minor
Discharge of construction phase stormwater	Moderate	Neutral	Temporary	Negligible

6.2 Sector 2: Whau River

The works in Sector 2 primarily focus on widening the Whau River Bridges to accommodate additional lanes and enlarging SH16 between the Patiki Road Interchange and the Whau River Bridges. The existing bridges will be widened by 7.25 m on the eastbound carriageway and 8.0 m on the westbound carriageway. In addition, a separate 3.0 m wide bridge will be provided as pedestrian/cycleway, adjacent to the westbound carriageway. Areas of habitat loss have been calculated (Technical Report No. G.23 Coastal Works) and are included in Appendix D.

Ecological values of the marine environment within Sector 2 are moderate, with a typical assemblage of subtidal benthic species with moderate diversity (dominated by bivalves, polychaete worms, and amphipods) and low concentrations of contaminants in the subtidal sediment. Intertidal marine flora and fauna adjacent to the existing bridge abutments comprise a similarly ubiquitous assemblage, dominated by mangroves, mud crabs, molluscs, polychaete and oligochaete worms.

6.2.1 Permanent Loss/Disturbance of Intertidal and Subtidal Habitat

Total permanent habitat loss in this Sector will be approximately 4,250 m^2 in the intertidal area and 60 m^2 in the subtidal habitat. Of the total permanent habitat loss approximately 3,150 m^2 is located with a CPA1. There will be permanent loss of coastal vegetation (primarily mangroves) from an area of approximately 2,350 m^2.

6.2.1.1 Whau River Bridge Abutments

In order to widen the abutments for the widened Whau River Bridges, approximately 1,260 m^2 of intertidal CMA will be reclaimed on the western side and approximately 1,280 m^2 on the eastern side. Due to deep marine muds within the site identified for reclamation to construct the eastern abutment widening, ground improvement works are required. Following the installation of Super Silt Fences removal of mangroves within the area to be reclaimed and within the construction area, during low tide, ground improvement using Marine Deposit Displacement (MDD) will be undertaken. MDD involves the placement of durable rock onto a geotextile separator on top of the marine muds (at any tide) and light tamping using an excavator (at low tide) until a 1.0 m deep foundation has been created (Technical Report No. G.23 Coastal Works).

Rock will be placed on the marine sediment during all phases of the tide. Some marine sediment will be disturbed and resuspended during this process, especially when undertaken at high tide. However, the concentration of suspended sediment generated is likely to be low. Constraining the tamping of the rock to low tide will minimise the further generation of suspended sediment (Technical Report No. G.23 Coastal Works). Contaminant concentrations in sediment immediately around the Whau River Bridges are low, suggesting that resuspended sediment is unlikely to pose an ecotoxicological risk to marine organisms.

Lightweight fill material will be placed on top of the rock base and, once design level has been achieved, a silt fence will be positioned at the top of the abutment embankment adjacent to minimise the runoff of sediment laden water into the CMA (Technical Report No. G.23 Coastal Works).

Mangrove material removed from the intertidal working area will be disposed of at an appropriate off-site facility.

Widening the Whau River Bridges abutments involves permanent habitat loss, with consequent mortality of marine invertebrates and mangroves, which is considered to be a moderate adverse effect. Other potential adverse effects arising from the permanent reclamation works, such as increased suspended sediment concentration and runoff from the reclaimed construction, will be avoided or adequately mitigated through best practice erosion and sediment control measures.

6.2.1.2 Whau River Bridges and Cycleway Bridge Piles

Forty-two new 1.5 m diameter piles will be installed in order to support the widened bridges. The pedestrian/cycleway bridge will be supported by seven 1.5 m diameter piles. The combined loss of marine habitat resulting from installation of the piles is 58 m^2 of subtidal habitat and 22 m^2 of intertidal habitat (Technical Report No. G.23 Coastal Works).

The widened Whau River Bridges will be supported by cast in-situ bridge piles, which will be concreted into metal casings. The metal casings will be driven into the benthic sediment and the marine mud contained within them will be removed using an auger piling rig. The marine mud excavated from the casings will be removed and disposed of at an appropriate facility if the mud is determined to be contaminated. The casings will remain in place permanently below water level only (see Technical Report No. G.23 Coastal Works).

Whilst only a relatively small area is involved, the permanent loss of subtidal and intertidal habitat and mortality of marine invertebrates and mangroves which is required for the establishment of permanent bridge piers presents a moderate adverse effect.

6.2.1.3 Causeway Embankments

Between Ch4400 and Ch4659, the present SH16 alignment has been constructed on a man-made embankment, due to the presence of intertidal mudflats and sandflats. This embankment will be widened in order to accommodate additional traffic lanes, bus shoulders and the pedestrian/cycleway path and will involve permanent and temporary intertidal habitat loss (see Plan set F.12 20.1.11-1-D-C-941-103 and F.13 20.1.11-1-D-N-942-103). Biofilter strips for stormwater treatment will be installed within the bus shoulders (see Technical Report No. G.15 Assessment of Stormwater and Streamworks).

In-situ mudcrete, constructed within a coffer dam, is the ground improvement/reclamation method proposed to construct a base for the widened embankment. This method has been proposed because the contamination analyses in sediment revealed high concentrations of nickel (250 mg/kg at Bore Hole 469) on the southern side of the existing Causeway at 0.75m depth, between CH4550 and CH4500, and to reduce the disturbance footprint (Technical Report No. G.23 Coastal Works). The coffer dams will seal off the work area, not allowing any disturbed sediment to be discharged outside of the area of reclamation. Application of in-situ mudcrete to the sediment will permanently bind the nickel and other contaminants, thus removing the risk of discharge to the wider marine environment. Furthermore, the coffer dam will contain any cement that may settle on the sediment surface, therefore removing the risk of pH alteration to the adjacent marine environment. If sediment-laden water or contaminated water is contained within the construction works area contained by the coffer dam, the water will be removed using a suction truck prior to removal of the coffer dam. Subsequently, once the required design level and compaction has been achieved, a silt fence will be installed on top of the embankment in order to prevent sediment laden water arising from construction discharging into the CMA (Technical Report No. G.23 Coastal Works).

As part of the process of identifying opportunities for mitigating the adverse effects of permanent marine habitat loss in Sectors 2 and 4, a design was developed to remediate a 3.0 m wide area on each side of the Causeway Embankment where mudcrete is proposed to be used as the ground improvement technique. An opportunity was identified to reduce the permanent habitat loss footprint, instead resulting in an additional area of temporary habitat disturbance. This area is referred to as the “mudflat remediation zone”. Instead of forming the mudcrete to the existing sediment surface as was originally proposed, sediment will be excavated to a depth of 0.5m from the 3.0 m wide outer edge of the ground improvement works on each side of the embankment (in sections as the work progresses), prior to mudcreting. The excavated sediment will be stored within the works footprint and then the mudcreting process applied to the ground improvement area. Subsequently, the stored sediment will be replaced on top of the mudcrete (Technical Report No. G.23 Coastal Works).

Any large protruding mangrove material will be removed from the replaced marine sediment the surface will be smoothed out and then allowed to settle naturally. Marine organisms will recolonise this area over time, as the replaced sediment depth of 500 mm is more than sufficient to support infaunal and burrowing invertebrates, as well as mangroves.

The permanent loss of intertidal habitat, mortality of marine organisms and removal of mangroves involved in widening the Causeway Embankment in this Sector is considered to be a moderate adverse effect.

6.2.1.4 Access to Rosebank Domain

In order to widen the motorway between the Patiki Road on-ramp and the Rosebank Domain Raceway, and construct the cycleway/footpath parallel to the westbound carriageway, the existing access road to the Rosebank Domain Raceway will be realigned, involving permanent reclamation of mangrove covered tidal mudflats. Foundation undercut is the method proposed for reclamation in this area, and involves the removal of in-situ material (when not inundated) to a depth of approximately 1.0 m. The excavated material will be removed from the site and disposed of at an appropriate facility if it is determined to be contaminated.

The permanent loss of intertidal habitat and mortality of marine invertebrates and mangroves as a result of the realigned road is a moderate adverse effect.

6.2.1.5 Summary of Effects

Table 12: Sector 2 Permanent Habitat Loss - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Permanent habitat loss – Whau Bridge abutments	Moderate	Medium	Permanent	Moderate
Permanent habitat loss – bridge piers	Moderate	Medium	Permanent	Moderate
Permanent habitat loss – Causeway Embankment	Moderate	Medium	Permanent	Moderate
Permanent habitat loss – access to Rosebank domain	Moderate	Medium	Permanent	Moderate

6.2.2 Temporary Loss/Disturbance of Intertidal and Subtidal Habitat

Total temporary habitat loss in this sector will be approximately 4,800 m^2 in the intertidal habitat and 10 m^2 in the subtidal habitat.

6.2.2.1 Temporary Staging Platforms

Two 7.0 m wide temporary staging platforms (i.e. temporary bridges) will be constructed adjacent to the existing Whau River Bridges. Eighty-eight supporting steel piles (anticipated to be 600 mm diameter) will be driven into the underlying mud until sufficient bearing capacity is achieved. Upon completion of the construction of the permanent bridges, the temporary platform and piles will be removed. Vibration equipment attached to cranes will be used to remove the piles. Disturbance to marine organisms from noise, vibration and increased suspended sediment during removal of the piles will be temporary. The benthic habitat occupied by the temporary piles, following removal of the piles and the dissipation of the suspended sediment generated during removal of piles, will be recolonised in the longer term by marine organisms. The adverse effects arising from this temporary habitat loss is considered to be minor, given that marine organisms will recolonise the area in the longer term.

6.2.2.2 Causeway Embankment Construction – Erosion and Sediment Control

In a similar manner to that described for downstream protection in Sector 1, a rock toe silt fence will be constructed seaward of the area identified for permanent intertidal occupation by the widened Causeway embankment. The rock toe silt fence will extend no more than 5.0 m from the seaward edge of the widened embankment and will provide protection from sediment-laden water generated during the construction discharging into the CMA. Once the widened embankment has achieved design level and compaction and a silt fence has been positioned along the top of the newly formed embankment, the rock toe silt fence will then be removed, by incorporation of the material into the cladding of the embankment outer edge. The mudflats temporarily occupied by the rock toe silt fence will then, over time, be recolonised by marine invertebrates and mangroves. The adverse effects of the temporary habitat loss is considered to be minor and acceptable given the relatively small area involved and the recolonisation by marine organisms over time.

6.2.2.3 Access to Rosebank Domain – Erosion and Sediment Control

The realignment of the access road to the Rosebank Domain involves reclamation of intertidal mudflats (see Plan set F.18 drawing number 20.1.11-1-D-N-520-104). As above, in order to provide protection to the wider intertidal area from sediment-laden water arising from construction, a rock toe silt fence will be installed no more than 5.0 m from the seaward edge of the area of reclamation. The construction and removal methodology for the rock toe silt fence are as described in the paragraph above. Accordingly, the adverse effects of the temporary habitat loss are considered to be minor and acceptable given the relatively small area involved and the recolonisation by marine organisms over time.

6.2.2.4 Discharge of Treated Stormwater.

Treatment of construction phase stormwater in this Sector is by way of the Eroision and Sediment Control devices briefly described above, until the permanent stormwater treatment devices are in operation i.e. no separate temporary stormwater devices are required in this Sector.

With the TP90 compliant Erosion and Sediment controls and stormwater controls in place it is estimated that an average of 94% of the TSS generated will be removed prior to discharge into the CMA (Technical Report No. G.30 Associated Sediment and Contaminant Loads). The adverse effects arising from the discharge of treated stormwater are considered to be negligible.

6.2.3 Disturbance from Vibration and Noise

6.2.3.1 Noise

During construction works within Sector 2, there will be noise disturbance to marine organisms from a large range of machinery and activities, with the activities likely to generate the highest noise levels comprising rammed piling techniques and pad footing construction (Technical Report No. G.5 Assessment of Construction Noise Effects).

There may be some avoidance of the immediate area by fish and possibly transient cetaceans, and some more sensitive benthic invertebrates may cease feeding or foraging during the noisiest periods. Construction in this Sector is estimated to occur over a 40 month period, thus whilst the construction noise will not be occurring in the very long term, this temporary period is relatively long (3.3 years) in comparison to the life cycle of some smaller marine organisms (less than one year). It is possible that settlement of some invertebrate larval stages may be inhibited in the vicinity of the works due to the disturbance activities, favouring less disturbed areas in preference.

However, the effect of construction noise on marine organisms in this Sector is considered to be negligible, given the intermittent and temporary nature of the disturbance.

6.2.3.2 Vibration

Vibration during construction within Sector 2 will be generated primarily from vibratory rollers for the road construction and the bridge piling; the latter of these is more likely to affect the marine environment, due to the activity occurring within or adjacent to the marine habitat (Technical Report No. G.19 Assessment of Vibration Effects). It is considered that during piling, fish and other mobile organisms may avoid the area, and sessile (sedentary) or infaunal (sediment dwelling) marine invertebrates may remain inactive, not feeding or foraging etc. As with noise disturbance considered above, it is possible that settlement of some invertebrate larval stages may be inhibited in the immediate area of construction vibration disturbance.

Installation of piles is estimated to take approximately 2-3 days per permanent pile and 1-2 days per temporary pile. In addition, removal of the temporary piles will take approximately 2-4 days per pile (Technical Report No. G.23 Coastal Works). Given the temporary nature of the disturbance effect, it is considered that the effects on marine organisms will be negligible.

6.2.4 Potential Discharge of Cement

Widening of the existing bridges and the construction of the new cycleway bridge will require wet concrete work over the waterway at the mouth of the Whau River. In-situ concreting of piles poses a potential risk to the marine environment from discharged cement causing an alteration to ambient pH (Technical Report No. G.23 Coastal Works).

The use of steel casings and the Tremie Concrete method will minimise the risk of cement discharge to the marine environment (see Technical Report No. G.23 Erosion and Sediment Control Plan). The Tremie Concrete method controls the delivery of cement to the base of the structure and results in a smaller volume of cement-contaminated water being generated. The only cement-contaminated water will be the water displaced out of the top of the pile casing. Where the pH of this water is above 8.5, it will be collected via a suction truck and removed of site for treatment and disposal (Technical Report No. G.23 Coastal Works).

In addition, concrete placement will be carried out under stringent conditions to ensure negligible loss of cement to the environment. Concrete trucks will use designated truck wash areas, and wash water will be either treated appropriately within the Construction Yard(s) or removed off-site for treatment and disposal (see Technical Report No. G.22 Erosion and Sediment Control Plan).

The discharge of cement or cement laden water will be avoided through the protection and mitigation measures summarised above.

6.2.5 Temporary Alteration to Flow

Minor effects on flows are anticipated as a result of temporary occupation and disturbance of the CMA (Technical Report No. G.4 Assessment of Coastal Processes). The adverse effects on marine ecological values of the minor flow alterations, given their temporary nature, is considered to be negligible.

6.2.6 Summary of Effects

Table 13: Sector 2 Temporary Habitat Loss/Disturbance - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Temporary habitat loss - piles	Moderate	Low	Temporary	Minor
Temporary habitat loss – Causeway embankment rock toe silt fence	Moderate	Low	Temporary	Minor
Temporary habitat loss – Rosebank Domain rock toe silt fence	Moderate	Low	Temporary	Minor
Discharge of treated stormwater	Moderate	Neutral	Temporary	Negligible
Noise and vibration	Moderate	Neutral	Temporary	Negligible
Temporary alteration to flow	Moderate	Neutral	Temporary	Negligible

6.3 Sector 3: Rosebank – Terrestrial

Sector 3 comprises predominantly land, with little intertidal habitat. Adjacent to the southern side of the Causeway approximately between Ch3800 to Ch4100 and Ch2700 to Ch3000 are areas of intertidal mudflats occupied by coastal margin vegetation, mangroves and typical common benthic invertebrates.

All construction works and erosion and sediment control structures are outside the CMA in Sector 3. However, activities that have the potential to adversely affect marine ecological values include discharges into the CMA from construction phase sediment retention ponds and disturbance from noise and vibration (Technical Report No. G.15 Assessment of Stormwater and Streamworks).

6.3.1 Discharge of treated stormwater

Sediment retention ponds located on the southern side of the Causeway between Ch3800 and Ch3950, and cartridge vaults provide the erosion and sediment control and temporary stormwater treatment required in Sector 3. Treated stormwater discharges into the CMA. Given that the average suspended sediment removal efficiency from sediment retention ponds during the earthworks period is expected to be 94% (see Technical Report No. G.30 Associated Sediment and Contaminant Loads), the discharge of sediment and potentially contaminants to the intertidal habitat in this area is likely to be very low.

Consequently, it is considered that the adverse effects on marine ecological values from the discharges to the CMA from SRP 3A and 3B are considered to be negligible.

6.3.2 Disturbance from Noise and Vibration

In this Sector, the primary source of vibration disturbance will be from vibratory rollers used for road construction, but such disturbance is relatively low level in comparison to other Sectors. The vibratory rollers will not be located adjacent to the CMA for most the Sector, apart from the two segments identified in section 6.3.1 above (for SRP 3A and 3B) (see Technical Report No. G.5 Assessment of Vibration Effects). Disturbance from vibration on marine organisms in this Sector is considered to have negligible adverse effects.

Construction works and therefore noise disturbance in Sector 3 will occur during both day and night, due to residential housing being located a considerable distance from this area of works. A similar range of machinery and activities as that described for Sector 2 will be used in Sector 3, with drilling rigs, concrete vibrators, hydraulic jacks, excavators, grinders, jack hammers and asphalt spreaders comprising the noisiest machinery (Technical Report No. G.5 Assessment of Construction Noise Effects). Given the distance from the CMA that most of these machines and activities will be occurring in this Sector, it is considered that there will be negligible adverse effects on marine organisms.

6.3.3 Summary of Effects

Table 14: Sector 3 Temporary Habitat Loss - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Discharge of treated stormwater	Moderate	Neutral	Temporary	Negligible
Noise and vibration	Moderate	Neutral	Temporary	Negligible

6.4 Sector 4: Reclamation

The largest coastal Sector (Sector 4) includes most of the alignment on SH16 from the Whau River Bridges to the Great North Road Interchange, and encompasses marine/estuarine habitats on both the northern and southern sides of the existing Causeway and the mouth of Oakley Inlet.

The main construction activities in Sector 4 that affect the CMA are the realignment of three sections of low tide channel (two within Oakley Inlet and one within Waterview Estuary adjacent to the southern side of the existing Causeway) to accommodate widening of SH16, raising and widening the Causeway, widening of the Causeway Bridges and construction of a new pedestrian/cycleway bridge. The Causeway embankment between Great North Road Interchange and Rosebank Road is required to be upgraded to accommodate the additional general traffic lanes and bus shoulders. Five general traffic lanes and a bus shoulder are proposed in the westbound direction, while four general traffic lanes and a bus shoulder are proposed for the eastbound carriageway (Technical Report No. G.23 Coastal Works).

An important consideration in the engineering design solutions has been the ongoing settlement of the existing Causeway and the likely settlement of the proposed extensions to the Causeway, due to the nature of the sediment that construction must occur on top of (i.e. very deep soft intertidal mudflats). Thus, ground improvement options have been carefully considered to address the issue of settlement, whilst minimising the area of permanent reclamation within the marine/estuarine habitat and the area of temporary habitat disturbance (Technical Report No. G.23 Coastal Works). The area of habitat loss has been calculated by the Project engineers and is included in Appendix D (Technical Report No. G.23 Coastal Works).

The marine/estuarine ecological features contained within Sector 4 include mangrove forests and saltmarsh, intertidal mudflats and sandflats, subtidal soft muds and man-made rocky shore (rock revetment). The ecological values of these features vary throughout the Sector in relation (in part) to sediment grain size, sediment quality and hydrodynamic environment.

A broad generalisation of ecological values ascribes high to moderate values to habitat north of the Causeway (characterised by higher benthic invertebrate diversity, coarser sediment grain size and lower contaminant concentrations in surficial sediment), and moderate to low values for areas within the Waterview Estuary and Oakley Inlet (characterised by a low diversity of tolerant benthic invertebrates, fine grain size and elevated concentrations of contaminants in surficial sediment). However, there are smaller patches within the

Waterview Estuary that have greater ecological value, generally where the sediment grain size is coarser and a greater diversity of invertebrate species is supported.

6.4.1 Permanent Loss of Intertidal and Subtidal Habitat

Permanent loss of subtidal habitat from the construction works in this sector comprises approximately 1,400 m^2, whereas intertidal habitat loss is estimated to be 51,700 m^2 (incorporating mangrove removal from an area of 28,500 m^2). Plan set F.12 20.1.11-3-D-N-941-100 to 108 shows the extent of Permanent Reclamation in this Sector.

Permanent reclamation of the CMA is required on both sides of the existing SH16 carriageway in order to widen the Causeway embankment and bridges. Improvement of foundation soils will also be required, due to the sediment largely comprising deep soft mud.

6.4.1.1 Causeway Bridges – Permanent Piers

The eastbound Causeway bridge is required to be widened by approximately 5.6 m, and the westbound bridge by approximately 9.0 m. A separate bridge will be provided for the 3.0 m wide pedestrian/cycleway (Technical Report No. G.23 Coastal Works).

In order to support the widened bridges, 36 piles will be positioned within the CMA. The piles proposed are 0.5 m diameter octagonal concrete piles that will be driven into the marine sediment (Technical Report No. G.23 Coastal Works). Driving of the piles is likely to generate temporary noise and vibration disturbance in addition to elevated suspended sediment. Noise and vibration are considered in section 6.4.6 below. The suspended sediment generated will be moved with the tidal flows, given that the bridge piles are located in or adjacent to the main channel. Therefore, the effect of increased suspended sediment will be diluted in the wider marine system and is unlikely to have adverse effects on marine organisms.

The pedestrian/cycleway bridge, located on the southern side of the Causeway, is proposed to be supported by four 1.0 m diameter cast in-situ concrete piles within the CMA. The piles will be cast within metal casings. The metal casings will be driven into the sediment and the potentially sediment-laden water contained with casings will be removed using an auger, and taken off-site for treatment and disposal if it is determined to be contaminated (Technical Report No. G.23 Coastal Works).

The adverse effects on marine ecological values are largely around permanent habitat loss, but temporary increased suspended sediment may result from the installation of the piers. The adverse effects of permanent habitat loss and mortality of marine invertebrates as a result of installation of the Causeway Bridges piles are considered to be moderate, whereas the adverse effects of temporary increased suspended sediment are considered to be negligible.

6.4.1.2 Causeway Bridges – Abutments

The ground improvement works required in order to support the widened Causeway Bridge abutments involve Marine Deposit Displacement (MDD), which requires the placement of durable rock onto the marine mud (with a geotextile separator) and lightly tamping using an excavator until a 1.0 m deep foundation has been created. This method of ground improvement does not require occupation of the CMA beyond the toe of the newly formed embankment. The placement of rock can be undertaken during any tide, but the tamping will be carried out at low tide in order to minimise the generation of suspended sediment (Technical Report No. G.23 Coastal Works).

Adverse effects on marine ecological values from permanent habitat loss and mortality of marine organisms, as a result of widening the Causeway Bridge abutments are considered to be moderate.

6.4.1.3 Widening of the Causeway Embankment

In order to widen the Causeway embankment, significant ground improvement is required to be undertaken. These works can only be carried out while the work area is free of standing water. Therefore, the first step for each work area is the installation of a coffer dam in order to keep out seawater. The area beneath and contained within each coffer dam that is outside of the permanent reclamation area, is considered as a temporary loss of habitat and is discussed in section 7.4.2.2 below.

Removal of mangroves from within the permanent reclamation area will be required. Additional mangrove and coastal vegetation removal will be required in order to position the coffer dams, and this is discussed in section 7.4.2.2 below. The largely dry shellbanks (chenier ridges) that are located on the northern side of the existing Causeway embankment within the area of permanent reclamation will be removed from the intertidal area prior to the commencement of construction works and stored until completion of construction, when they can then be replaced at the toe of the new Causeway Embankment.

Several different ground improvement methods are proposed for the various parts of the widening of the embankment (see Coastal Works Report), all involving permanent loss of intertidal marine/estuarine habitat. The main ground improvement method to be used is in-situ mudcrete. This process involves the mixing of marine muds in-situ with a dry binder (cement) using a rotating mixing head to create a hardened foundation between 2-4 m deep. Following completion of the in-situ mudcrete process the new Causeway embankments will be constructed using geotexile layers and granular fill. Rock armour coastal protection will be provided to the seaward facing slopes (Technical Report No. G.23 Coastal Works).

In addition to permanent habitat loss, mortality of benthic invertebrates, removal of mangroves and habitat disturbance, potential adverse effects on marine organisms may arise from the in-situ mudcrete process due to generation of cement dust, discharge of cement-laden water, noise and vibration. Of these, the effect of cement dust and cement-laden water on the pH of saline water is the main concern, as adverse effects on marine organisms may occur when pH increases above approximately 8.5 (ANZECC, 2000), with normal seawater pH typically between 7.5 and 8.4.

Mudcrete binds contaminants that are present in the sediment, ensuring that they are not released to the wider environment and do not become bioavailable. This is particularly important in areas to the south of the existing Causeway embankment where copper, lead and zinc have been detected above effects threshold concentrations in surface sediment.

The use of coffer dams around the works areas, in addition to ensuring there is a damp cloth apron around the mixing head and the use of misting nozzles, will mitigate the potential adverse effects from air borne and water borne cement. Any water contained within the coffer dams that is considered to be contaminated will be removed by a suction truck, treated and disposed of off-site.

As discussed in the assessment of effects for Sector 2 above, the design incorporates remediation of a 3.0 m wide area of intertidal habitat by mudcreting to 500 mm below the present sediment surface and replacing the marine sediment excavated. Newly deposited marine sediment will be smoothed out following replacement in the intertidal area, large protruding mangrove material will be removed and the sediment will settle naturally. Marine organisms will recolonise the area of disturbed sediment over time as the replaced sediment depth of 500 mm is more than sufficient to support infaunal and burrowing organisms, as well as mangroves.

The adverse effects on marine organisms from the widening of the Causeway embankment are negligible or able to be mitigated, apart from permanent habitat loss which is a moderate adverse effect.

6.4.1.4 Summary of Effects

Table 15: Sector 4 Permanent Habitat Loss - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Permanent habitat loss – bridge piers	Moderate	Medium	Permanent	Moderate
Permanent habitat loss – bridge abutments	Moderate	Medium	Permanent	Moderate
Permanent habitat loss – Widening of the Causeway Embankment	Low/Moderate (southern side); Moderate/High (northern side); assumed average of moderate	Medium	Permanent	Moderate

6.4.2 Temporary Loss/Disturbance of Intertidal and Subtidal Habitat

Temporary loss of marine habitat in this Sector includes approximately 5,700 m^2 of subtidal habitat and approximately 50,000 m^2 of intertidal habitat.

6.4.2.1 Temporary Staging Platforms

Two 7.0 m wide temporary staging platforms (i.e. temporary bridges) will be constructed adjacent to the existing Causeway Bridges. A total of 52 supporting steel piles (anticipated to be 600 mm diameter) will be driven into the underlying mud until sufficient bearing capacity is achieved. Upon completion of the construction of the permanent bridges, the temporary platform and piles will be removed (Technical Report No. G.23 Coastal Works). Vibration equipment attached to cranes will be used to remove the piles. Disturbance to marine organisms from noise, vibration and increased suspended sediment during removal of the piles will be temporary and is considered to have negligible adverse effects. The benthic habitat occupied by the temporary piles will, following removal of the piles, be gradually recolonised by marine organisms. The adverse effects arising from this temporary habitat loss are considered to be minor given the temporary nature of the habitat loss and the ability of organisms to recolonise the area.

6.4.2.2 Widening of the Causeway Embankment

6.4.2.2.1 Channel Re-Alignments

Modifications to three sections of low tide channel are required in order to widen the Causeway embankment; two within Oakley Inlet (Ch650 to Ch700 and Ch800 to Ch870) and one adjacent to the southern side of the Causeway to the west of the Causeway Bridges (Ch1550 to Ch1720) (see Plan set F.13 20.1.11-3-D-C-942-108 and 20.1.11-3-D-C-942 107 respectively). These channel modifications involve the movement of the low tide channels away from the alignment, in order to accommodate the permanent reclamation that is necessary (Technical Report No. G.23 Coastal Works, Technical Report No. G.4 Assessment of Coastal Processes).

Preparation works at each of the three locations include the establishment of a temporary storage lagoon for excavated material. The storage lagoon will contain the excavated material so that there will be no loss of sediment or water from the area into the adjacent marine areas. The location of the storage lagoons will be either within an area that will be permanently reclaimed at a later stage of the Causeway Embankment widening (i.e. a sacrificial area) or within the Contractor's yard (Technical Report No. G.23 Coastal Works).

Excavation will be carried out from the middle of the proposed new channel working progressively towards each end of the new channel, using a long-reach excavator located on a barge at low tide (in order to minimise the generation of suspended sediment). The material excavated will be pumped from the barge via a large diameter pipe to the storage area. Scour protection will be provided to the newly excavated channel on the northern slope at the end of each work shift. The upstream plug of sediment followed by the downstream plug of sediment within the new channel will be removed when conditions are favourable (i.e. as the tide is falling, just before low tide). The newly formed and the existing low tide channels will both be functional at this point (Technical Report No. G.23 Coastal Works).

To fill in the existing channel, material will be placed at each end of the channel to prevent the flow of water through it and scour protection will be placed at this time. The sediment contained in the storage lagoon will be pumped directly into the existing channel during low tide in order to minimise the generation of suspended sediment. Upon completion of filling in the existing channel, the storage lagoon will be removed (Technical Report No. G.23 Coastal Works).

The newly filled in low tide channels (now representing intertidal mudflats) will subsequently receive ground improvement works in a similar manner to the existing intertidal mudflats adjacent to the Causeway that are to be permanently reclaimed (i.e. in-situ mudcrete to form a robust foundation) (Technical Report No. G.23 Coastal Works).

Potential adverse effects of the proposed channel re-alignments on marine ecological value will arise from increased concentration of suspended sediment, deposition of sediment, redistribution of sediment-bound contaminants and mortality of benthic invertebrates due to intertidal and subtidal habitat disturbance.

Hydrodynamic Modelling – Deposition of Sediment and Suspended Sediment

Hydrodynamic modelling of the suspended sediment and sediment deposition patterns has been carried out for each of the channel re-alignment areas under base flow and a water quality design storm (approximately a one month return period) (see Technical Report No. G.4 Assessment of Coastal Processes). Modelling of both medium silts (6-20 μm) and coarse silts (20-63 μm) was undertaken, in order to capture the "worst case" for suspended sediment (using medium silts) and the worst case for deposition depth (using coarse silts). Technical Report No. G.4 Assessment of Coastal Processes refers to the channel re-alignments as Excavation A (XA), B (XB) and C (XC) as shown in Figure 23 below.

Figure 23: Location of channel re-alignment works (image from Google Earth).

Graphs of the results of the hydrodynamic modelling from Technical Report No. G.4 Assessment of Coastal Processes are shown in Appendix E. The appendix contains graphs showing maximum total suspended sediment during the 10 day modelling period, and total deposition. In addition to these output graphs, benthic invertebrate sampling sites that had a higher diversity of organisms present (in particular, bivalves and gastropods) were identified and a time series (half hourly) plot was prepared for each site showing total suspended sediment concentration over the modelling period (10 days).

Sediment Deposition

The modelling results, using medium silt grain size, indicates that the largest area affected by sediment deposition occurs in excavation of the channel adjacent to the Causeway (C), during the water quality event modelled (Figure 24, Table 16). Sediment deposition arising from excavation A and B during base flow conditions (note there is no deposition following the water quality event modelled) results in a depth of deposition of only 1-3 mm, which is unlikely to have adverse effects on benthic invertebrate communities (Lohrer et al., 2006, Technical Report No. G.4 Assessment of Coastal Processes). It is considered that the adverse effects arising from sediment deposition, modelling medium silt grain size, for channel excavations A and B are less than minor.

For excavation C, the difference in area of deposition, for sediment depths 1-3mm, between the base flow and water quality event is not large (i.e. 1600 m^2 compared to 1675 m^2). A larger area receives 3-5mm deposition (750 m^2) for base flow conditions compared to the water quality event (250m^2), due to removal of sediment from the Waterview Estuary to north of the Causeway Bridges during higher flood flows, resulting in a thinner deposit of sediment over a larger area (Table 16) (Technical Report No. G.4 Assessment of Coastal Processes).

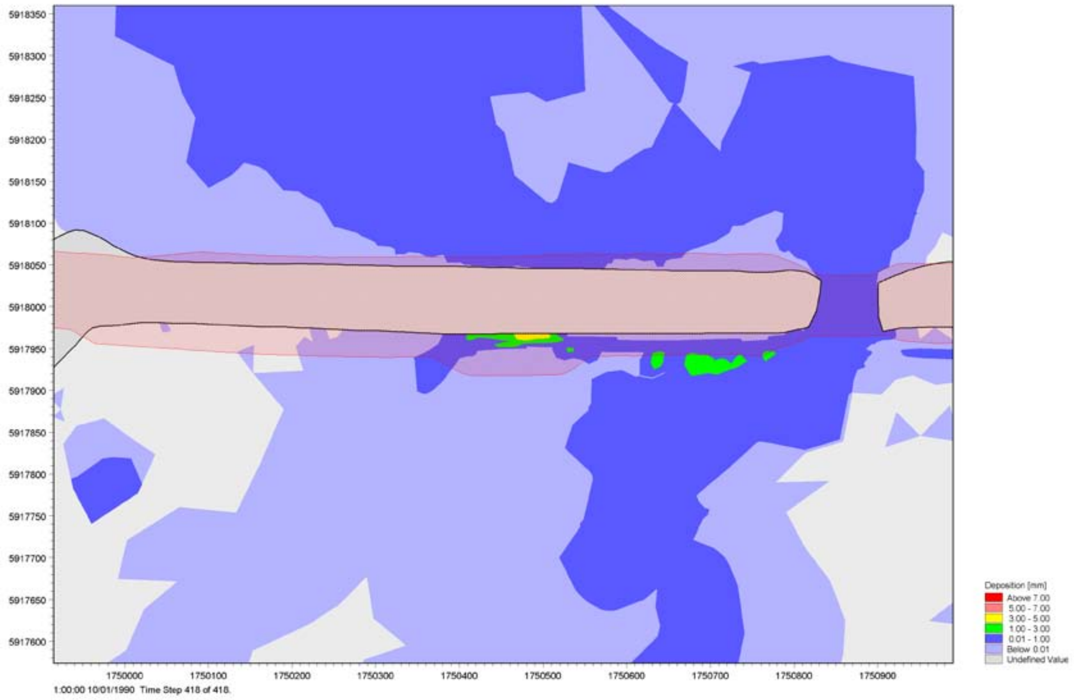


Figure 24: Sediment deposition pattern (from Assessment of Coastal Processes report) – Excavation C, medium silt grain size (NB: green shading indicates less than 1-3 mm depth, yellow shading indicates 3-5mm depth) and the pink hatching shows the construction footprint.

Table 16: Modelled sediment deposition from channel excavations – medium silt

Excavation	Medium Silt Base Flow	Medium Silt Water Quality Event
A	1-3 mm 1,150 m^2	1-3 mm 0 m^2
B	1-3 mm 320 m^2	1-3 mm 0 m^2
C	1-3 mm 1,600 m^2 3-5 mm 750 m^2	1-3 mm 1,675 m^2 3-5mm 250 m^2

The modelling indicates that 80% of the sediment released during excavation work at Excavation C is exported from the Waterview Estuary, with deposition at a depth of 3-5mm, primarily at the source of the excavation. This deposition of 3-5 mm at the excavation site is sediment that is dropped from the excavator bucket into the area being worked (Technical Report No. G.4 Assessment of Coastal Processes). Therefore, there are no additional adverse effects on marine benthic invertebrates arising from this deposition, above that of the excavation works themselves. Furthermore, this depth of deposition of marine sediment would be unlikely to have adverse effects on the benthic invertebrate community that inhabit the fine silt grain size within Waterview Estuary even if deposited on undisturbed areas (Lohrer et al., 2006). It is considered that the adverse effects arising from sediment deposition, modelling medium silt grain size, for channel Excavation C are negligible.

Results from the modelling of sediment deposition, assuming coarse silt grain size, for the channel excavation works are shown in Table 17 and Figure 25. For Excavation A, under base flow conditions, sediment deposits both at the source of excavation and adjacent to the Causeway Bridges, whereas during the water quality event modelled, deposition occurs only at source. The sediment that is deposited at source, as discussed above, does not cause any additional adverse effects to that of the excavation works itself i.e. the disturbance of excavating sediment to a depth significantly below that in which benthic invertebrates can inhabit is the primary adverse effect. Even at depositional depths of >7mm, which may cause adverse effects where the deposition is occurring on undisturbed mudflats (Lohrer et al., 2006), there are no adverse effects likely at source, due to physical effects of excavation itself. At the Causeway Bridges, there is deposition of sediment to a maximum of 5 mm, which is unlikely to cause adverse effects on benthic invertebrate communities due to the benthic sediment comprising fine mud (Lohrer et al., 2006). Modelling of sediment deposition using medium silt grain size indicated that the pattern of deposition was almost identical for Excavation A and B. As such, sediment deposition for coarse silt grain size arising from the excavation of area B has not been modelled. Instead, it can be inferred from Excavation A, that the adverse effects would be negligible (see Technical Report No. G.4 Assessment of Coastal Processes). Therefore, the effects of sediment deposition arising from Excavation A or B, assuming coarse silt grain size are considered to be negligible.

Excavation adjacent to the Causeway embankment (C) was shown, using medium silt grain size, to have a similar pattern between base flow conditions and the water quality event modelled. Therefore, only base flow conditions have been modelled for coarse silt grain size. Figure 25 indicates that sediment is deposited at source and within the low tide channel on the southern side of the western Causeway Bridges abutment.

Deposition of sediment below probable effects thresholds i.e. <7 mm (Lohrer et al., 2006) occurs over an area of approximately 18,000 m^2 (Table 17). Deposition >7 mm is estimated to occur over an area of approximately 1,665 m^2 within the excavation footprint (therefore not causing additional adverse effects above the excavation works itself) and 250 m^2 outside of the area of excavation. Therefore, adverse effects on benthic marine invertebrate communities may occur due to sedimentation arising from Excavation C, over an area of 250 m^2. The benthic invertebrate sampling sites closest to the area where deposition outside of the excavation area is likely to occur (sites 21 and 29), were dominated by ubiquitous, tolerant organisms such as polychate worms, oligochaete worms and amphipods.

The literature suggests that repeated deposition of thin layers of terrigenous material (i.e. sediment originating from land, not marine sediment) is more damaging to benthic invertebrate communities than a larger one off event (Lohrer et al., 2006). In the channel excavation works described above, the modelling represents the worst case, with repeated depositions (daily for an excavation period of 5 days) being modelled, with no loss due to resuspension assumed. Therefore, it is likely that the depth of the deposition and area where deposition is greater than 7 mm is less than that stated above (see Assessment of Coastal Processes report).

However, it is considered that the adverse effects arising from Excavation C, assuming coarse silt grain size, are minor due to the likely smothering of benthic organisms (polychaete worms, oligochaete worms and amphipods). Figure 25 below shows that the area of deposition of sediment at a depth greater than 7 mm is predominantly within the works footprint. There are some small areas of deposition greater than 7 mm outside the Project footprint (covering approximately 250 m^2) to the south of the Causeway Embankment, towards the existing bridges and low tide channel (Technical Report No. G.4 Assessment of Coastal Processes).

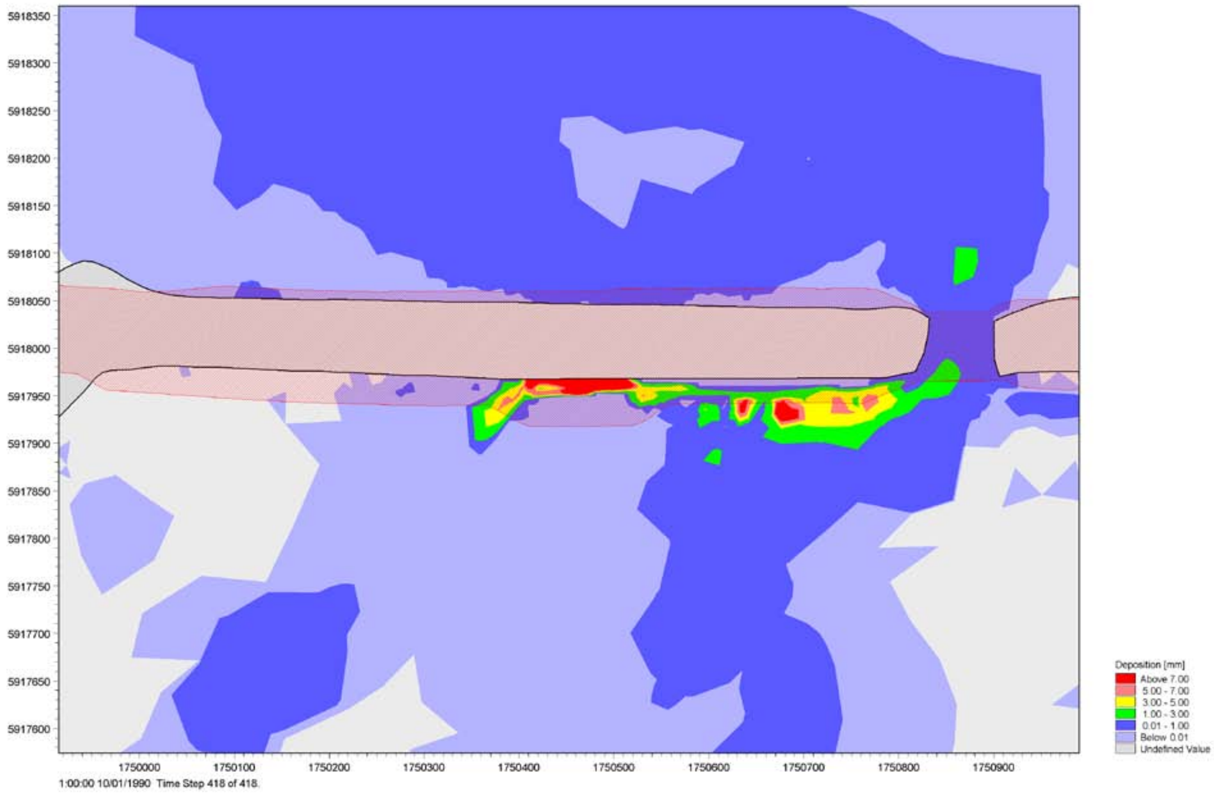


Figure 25: Sediment deposition pattern (from Assessment of Coastal Processes report) – Excavation C, coarse silt sediment grain size, base flow (NB: green shading indicates less than 1-3 mm depth, yellow shading indicates 3-5mm depth, light red shading indicates 5-7 mm depth and bright red indicates >7 mm depth). The pink hatching shows the construction footprint.

Table 17: Modelled sediment deposition from channel excavations – coarse silt

Excavation	Coarse Silt Base Flow	Coarse Silt Water Quality Event
A	At source 1-3 mm 1,400 m^2 3-5 mm 400 m^2 5-7 mm 600 m^2 >7 mm 800 m^2 At Causeway Bridges 1-3 mm 5,200 m^2 3-5 mm 200 m^2	1-3 mm 1,400 m^2 3-5 mm 0 m^2
B	Similar to A above	Similar to A above
C	At source 1-3 mm 1,320m^2 3-5 mm 4,020 m^2 5-7 mm 1,000 m^2 >7 mm 1,915 m^2	Similar to BF as per results for medium silt.

It is concluded that for all the scenarios modelled, except Excavation C with coarse silt grain size, the effects of sediment deposition on benthic marine invertebrates are negligible. The deposition of >7 mm of sediment over 250 m^2 of benthic habitat is considered to be a minor adverse effect, because although such a deposition event is likely to smother the epifaunal and infaunal invertebrate assemblages present, the area will be recolonised by marine organisms in the longer term. Analysis of silt grain size from the excavation areas indicates that medium silt grain sizes dominate (Technical Report No. G.4 Assessment of Coastal Processes). Therefore, the actual sediment deposition area is likely to be somewhere between that modelled for medium silt grain size and that modelled for coarse silt grain size. For Excavation C, this means that the actual deposition of sediment >7 mm (i.e. that which would cause smothering of benthic organisms), outside of the construction footprint, is likely to be between 0 and 250 m^2 (Technical Report No. G.4 Assessment of Coastal Processes). Furthermore, the modelling assumes no loss or movement of deposited sediment (referred to as "sticky bed") which would not occur in reality given tidal movement, wind and waves (Technical Report No. G.4 Assessment of Coastal Processes).

Suspended Sediment

The graphs of suspended sediment concentration presented in Appendix F, show for each cell modelled, the maximum concentration of suspended sediment during the 10 day modelling period. In order to assess effects on marine organisms, it is necessary to have an understanding of both concentration and duration of exposure.

Invertebrate sampling sites that contained the most sensitive benthic invertebrate assemblages (primarily those that contained the highest diversity of taxon e.g. bivalves, gastropods, or amphipods in addition to polychaete and oligochaete worms) were identified in the areas of elevated suspended sediment concentration. The sites considered to comprise more sensitive organisms were 15, 24, 26, 27, 28, 29, 30, 72 and 73 (see Figures 5a and 5b for site locations). Time series plots for these sites were created, with suspended sediment concentration plotted every 30 minutes throughout the 10 day period modelled, for each of the channel excavation scenarios modelled (see Technical Report No. G.4 Assessment of Coastal Processes). Graphs for all sites for the modelled scenarios are presented in Appendix F.

Suspended sediment concentration was below 100 mg/m^3 (or mg/L) for all sites except site 24. Site 24 is located in the south-west upper estuarine area within Waterview Estuary (see Figure 5a for location). For three of the nine scenarios modelled, suspended sediment exceeded 100 mg/m^3 at site 24 (see Figures 26-28 below) (Technical Report No. G.4 Assessment of Coastal Processes).

Figure 26 shows that during carrying out the works to excavate area C, assuming medium silt and base flow conditions, the concentration of suspended sediment in the water column increases to almost 200 mg/m^3 on the first work day and to a maximum of approximately 350 mg/m^3 on day 6. During evenings, when no excavation work is carried out, the concentration of suspended sediment generally reduces to between 100 and 220 mg/m^3. There is a two to three day period during the modelled works when suspended sediment concentration exceeds 300 mg/m^3 (days 5-7) during flood tide only (Technical Report No. G.4 Assessment of Coastal Processes).

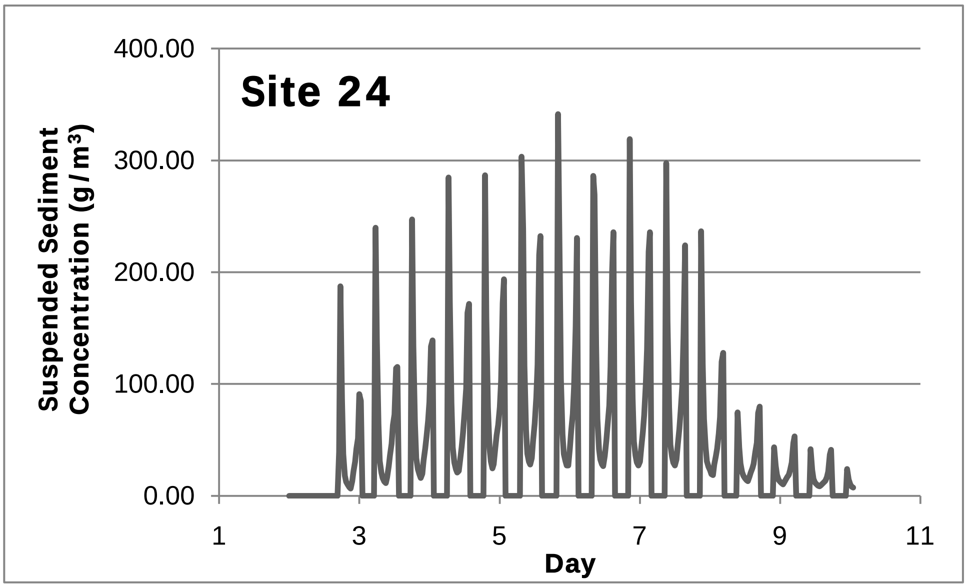


Figure 26: Time series of suspended sediment concentration for modelling of Excavation C, Medium Silt, Base Flow Conditions

Figure 27 shows that during a water quality event, but all other parameters remaining the same as modelled in Figure 26, the concentration of suspended sediment is less than during base flows at site 24 due to the increased flushing from storm flows. The maximum concentration approaches, but does not exceed, 300 mg/m^3 during the period modelled (Technical Report No. G.4 Assessment of Coastal Processes).

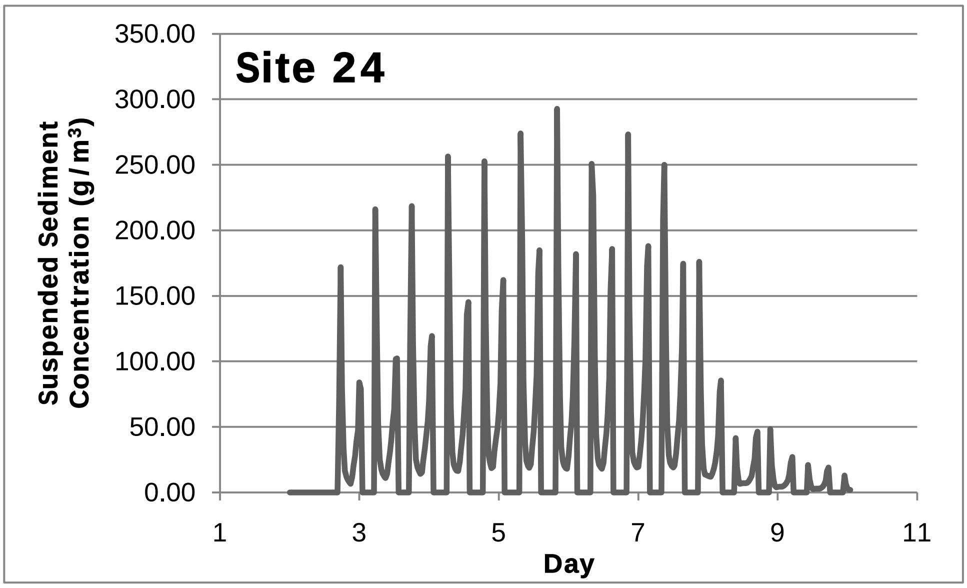


Figure 27: Time series of suspended sediment concentration for modelling of Excavation C, Medium Silt, Water Quality Event Conditions.

The pattern of suspended sediment concentration for base flows during Excavation C is similar when coarse silt (see Figure 28) is used as a modelling parameter to that of medium silt (Figure 26). The larger grain size tends to fall out of suspension more readily and does not reach the same maximum concentration during base flows as for medium silt grain size (Technical Report No. G.4 Assessment of Coastal Processes). Figure 28 indicates that suspended sediment concentration reaches a maximum of approximately 275 g/m^3.

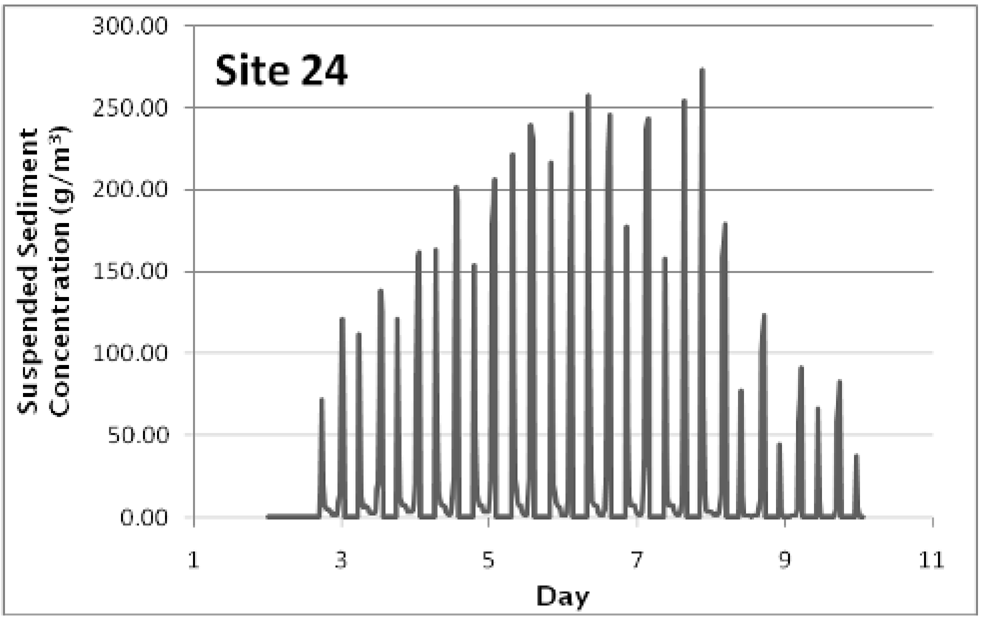


Figure 28: Time series of suspended sediment concentration for modelling of Excavation C, Coarse Silt, Base Flow Conditions.

Organisms present at site 24 included wedge shell (*Macomona liliana*), oligochaete worms, and polychaete worms (including *Boccardia* sp.).

Of all the organisms identified in the benthic invertebrate survey for this Project, based on the existing scientific literature, no organisms are known to be adversely affected by a suspended sediment concentration of <100 mg/m^3, apart from the polychaete worm *Boccardia* sp., which has been documented to halt feeding after nine days continuous exposure to 80 mg/L suspended sediment (Nicholls et al., 2003). Exposure to >80 mg/L suspended sediment for a continuous period of at least nine days is not predicted to occur at any of the modelled sites, including size 24. Nicholls et al. (2003) further detected in laboratory trials a decline in survival of wedge shells after nine days continuous exposure to 300 mg/L suspended sediment.

Based on the hydrodynamic modelling results and the literature, adverse effects on *Boccardia* sp. and wedge shell arising from suspended sediment generated from the channel excavations are not anticipated. The maximum suspended sediment concentration for all the channel excavations modelled occurs at site 24 for a period of 2-3 days and is estimated to be between 300 mg/L and 350 mg/L (see Figure 26). Adverse effects on benthic marine organisms are not likely due to the short exposure period.

Other marine organisms that may be adversely affected by increased suspended sediment are mobile (i.e. fish and cetaceans). Given their high mobility, these organisms can readily avoid areas of elevated suspended sediment and therefore adverse effects on them are highly unlikely.

Given the short duration of elevated suspended sediment and the low concentration of maximum suspended sediment, it is considered that adverse effects on marine organisms arising from suspended sediment as a result of channel re-alignments necessary to widen the Causeway are likely to be negligible.

6.4.2.2.2 Coffer Dams

Coffer dams will be constructed around any areas where mudcrete ground improvement works) are to be undertaken, in order to contain the works area and provide a relatively dry working environment. The coffer dams will contain water, sediment and contaminants and not permit their discharge to the wider marine environment. Coffer dams will also provide erosion protection to the existing Causeway embankment, as the existing rip rap protection will need to be removed to permit access to the CMA and to enable the coffer dams to be tied in (Technical Report No. G.22 Erosion and Sediment Control Plan).

Portable water-filled temporary dams (such as Aquadam®) are the preferred option along most of Sector 4, as the depth of soft sediments excludes the use of sheet piling. The widths of the two sizes of Aquadam® proposed to be used are approximately 5 m and 10 m. The area beneath and contained within the Aquadams® will be cleared of vegetation and rock material in order to provide a flat working surface and ensure full contact of the dam with the sediment surface. During construction works, and prior to removal of the Aquadam® at the completion of construction, sediment-laden or contaminated water will be removed from within the dam using a suction truck (Technical Report No. G.22 Erosion and Sediment Control Plan, Technical Report No. G.23 Coastal Works). Removal of the Aquadam® will result in a temporary increase in suspended sediment.

Interlocked steel sheet piles are also proposed to be used as watertight coffer dams where the sediment does not comprise deep soft mud (i.e. to the east of the Causeway Bridges). Use of sheet piling involves a smaller area of temporary disturbance and temporary habitat removal compared to the Aquadams®. The sheet piles will be vibro-driven through the marine sediments at low tide from a long reach tracked crane located on the Causeway Embankment to a depth of around 10 m below ground level. In addition, a silt fence and wave buffer will be installed to the seaward face of the sheet piles. Upon completion of the ground improvement works, and during construction works where necessary, any sediment-laden or contaminated water will be removed using a suction truck. Sheet piles will be removed using a crane located on the improved ground. Removal of the sheet piling will result in a temporary increase in suspended sediment (Technical Report No. G.23 Coastal Works).

Whilst providing protection to the wider marine environment from discharges of sediment and contaminants, the adverse effects of the coffer dams on marine ecological values are primarily temporary habitat loss and habitat disturbance. Marine invertebrates and mangroves will readily recolonise the areas smothered by the Aquadam® and areas disturbed, upon completion of the works and removal of the dam. On balance, it is considered that the adverse effects of the coffer dams are likely to be minor, given that they are to be used temporarily and will mitigate potential discharge of sediment and cement that may cause significant adverse effects on marine ecological values.

6.4.2.2.3 Mudflat Remediation Zone

As an outcome of the identification of mitigation opportunities to offset permanent marine benthic habitat loss proposed throughout Sectors 1-5, a mudflat remediation zone on each side of the Causeway embankment is proposed. This area will form part of the temporary habitat disturbance instead of permanent habitat loss.

The temporary disturbance involves excavation of intertidal sediment in a staged manner, to a depth of approximately 0.5 m, within the coffer dams or sheet piling used to contain sediment and provide a dry working environment. The sediment will be stored within the works footprint and replaced on top of the mudcrete, over an area of 3.0 m wide on each side of the Causeway embankment. During excavation and storage of the sediment, it can be assumed that the majority of the invertebrate organisms will perish. However, upon replacement of the sediment, organisms (including mangroves) will readily recolonise over time and recreate the previous habitat.

Whilst there is temporary habitat disturbance and associated minor adverse ecological effects, the net outcome from this proposed modification to the design is positive, with a reduction to the permanent habitat loss.

Native coastal fringe vegetation will be planted into sheltered parts of the Causeway embankment revetment primarily along the southern side of the alignment, but also in some parts of the northern side. This planting will assist with increasing biodiversity values and replacing some of the coastal margin habitat lost through the construction works (see F.16 Urban Design and Landscape Plans).

6.4.3 Discharge of Sediment-bound Contaminants from Excavations

Contaminants that are bound to fine sediment particles may be disturbed primarily by the channel excavation works and the installation and removal of the coffer dams.

The sediment that is released into the water column from the Excavations at A, B and C will have a concentration of bound contaminants. Sediment quality data relating to the surface layer of sediment indicates that the highest concentration of contaminants occurs in the upper reaches of Oakley Inlet, downstream of Great North Road.

Excavations A and B will, therefore, disturb sediment that has elevated concentrations, above effects thresholds, of common stormwater heavy metals such as copper, lead and zinc. The modelling of sediment deposition indicated that for medium and coarse silt grain size, deposition following Excavation A and B is primarily confined to the area immediately surrounding the excavation, with a small amount of coarse silt deposited within the main channel adjacent to the Causeway Bridges (Technical Report No. G.4 Assessment of Coastal Processes). As such, the result is the deposition of “like upon like”, which is unlikely to result in an increase in bioavailable contaminants. Therefore, it is considered unlikely that there will be additional adverse effects on marine organisms relating to the contaminants in deposited sediment over and above that of contaminants in ambient sediment.

Excavation C will result in the greatest sedimentation depth and area, but the surface sediments have a lower concentration of heavy metals. The areas where deposition occurs have similar concentrations of metals, and therefore there is unlikely to be additional adverse effects on marine organisms relating to the contaminants in the deposited sediment over and above that of the contaminants in the ambient sediment.

The low concentration of suspended sediment (containing a concentration of heavy metals) predicted to arise from the excavation works and the installation and removal of coffer dams is unlikely to have an adverse effect on marine ecological values due to the large dilution provided by the Waterview Estuary and wider harbour.

It is considered that the adverse effects of discharge of sediment-bound contaminants from marine sediment disturbance in Sector 4 are likely to be negligible.

6.4.4 Alteration to Flows and Erosion of Intertidal Mud Banks

Substantial effects on flow have been avoided through engineering design changes e.g. no encroachment of the drainage channel behind Pollen Island and the paring back of the Causeway Bridge abutments in order to minimise the impingement on the confluence between Waterview Estuary, Oakley Inlet and the Causeway channel (Technical Report No. G.4 Assessment of Coastal Processes). The widened bridge abutments are likely to result in some minor erosion of the adjacent intertidal banks as the environment settles back into equilibrium following the works (see Technical Report No. G.4 Assessment of Coastal Processes), which is considered to have negligible effects on marine ecological values.

Minor effects on flows are anticipated as a result of temporary occupation (e.g. for temporary piles) (Technical Report No. G.4 Assessment of Coastal Processes). The adverse effects on marine ecological values of the minor flow alterations, given their temporary nature, is considered to be negligible.

6.4.5 Discharge of Treated Stormwater

In order to protect the marine environment from the runoff of sediment-laden water, construction stormwater generated along the embankment will be treated through the use of TP90-compliant decanting earth bunds on the northern side of SH16 (between Ch3200 to Ch3850), which will discharge into the intertidal habitat within the MMMR, and super-silt fences along both sides of SH16 (see Technical Report No. G.22 Erosion and Sediment Control Plan).

As construction progresses and greater areas of impervious surface are completed, there is the potential for road runoff to be discharged into the marine environment, with adverse effects on marine organisms possibly arising from increased suspended sediment, deposition of sediment, and increased contaminant burden in surface sediment. Temporary stormwater treatment of runoff from the newly formed carriageway during the construction period will be provided by a combination of sand filter trenches and biofilter strips. The construction phase stormwater proposed has been estimated to achieve 94% removal of TSS (Technical Report No. G.30 Associated Sediment and Contaminant Loads).

It is considered that the adverse effects on marine ecological values arising from the discharge of treated stormwater during construction in this Sector are likely to be negligible.

6.4.6 Disturbance from Noise and Vibration

Bridge piling and vibratory rollers for road construction will be the primary source of vibration disturbance in Sector 4. Bridge piling comprises the main effect on marine organisms, but this activity will be temporary. Installation of piles is estimated to take approximately 2-3 days per permanent pile and 1-2 days per temporary pile. In addition, removal of the temporary piles will take approximately 2-4 days per pile. Mobile organisms will be able to avoid the area and less mobile invertebrates may potentially not feed or forage during the periods of high vibration disturbance. Given the temporary nature of the bridge piling works, disturbance from vibration on marine organisms is considered to be negligible.

Construction works, and therefore noise disturbance, in Sector 4 will occur during both day and night, due to residential housing being located at some distance from this area of works. A similar range of machinery and activities as that described for Sector 2 will be used in Sector 4, with drilling rigs, concrete vibrators, hydraulic jacks, excavators, grinders, jack hammers and asphalt spreaders comprising the noisiest machinery. Given that the marine organisms adjacent to the exiting Causeway currently tolerate a noisy motorway, it is considered that effects of noise disturbance on marine organisms will be negligible.

6.4.7 Summary of Effects

Table 18: Sector 4 Temporary Habitat Loss/Disturbance - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Temporary habitat loss – staging platform piers	Moderate	Low	Temporary	Minor
Sediment deposition from Channel re-alignment A	Low/Moderate	Neutral	Temporary	Negligible
Sediment deposition from Channel re-alignment B	Low/Moderate	Neutral	Temporary	Negligible
Sediment deposition from Channel re-alignment C	Low/Moderate	Moderate	Temporary	Minor
TSS from Channel re-alignment A	Low/Moderate	Neutral	Temporary	Negligible
TSS from Channel re-alignment B	Low/Moderate	Neutral	Temporary	Negligible
TSS from Channel re-alignment C	Low/Moderate	Neutral	Temporary	Negligible
Temporary habitat loss from coffer dams	Low/Moderate (southern side); Moderate/High (northern side); assumed average of moderate	Low	Temporary	Minor
Discharge of sediment-bound contaminants arising from channel re-alignments	Low/Moderate	Low	Temporary	Negligible
Alteration to flows and erosion of intertidal mud banks	Low/Moderate	Low	Temporary	Negligible
Discharge of	Average of	Neutral	Temporary	Negligible

treated stormwater	moderate assumed			
Disturbance from noise and vibration	Average of moderate assumed	Neutral	Temporary	Negligible

6.5 Sector 5: Great North Road Interchange

The works within Sector 5 that impinge on the marine environment are the construction of new ramps to connect SH20 to SH16 west- and east-bound, and the upgrading of the cycleway/footpath between Great North Road and the Causeway. Some of the ramps bridge over the Oakley Inlet downstream of Great North Road, and piers will be positioned within the CMA. In addition, temporary staging platforms will be required to be constructed. Area of habitat loss has been calculated (Technical Report No. G.23 Coastal Works) and these are also included in Appendix D.

The marine ecological values within Sector 5 are moderate to low due to the presence of elevated concentrations of heavy metals in intertidal surface sediment and the limited diversity of benthic invertebrates. The intertidal banks of Oakley Inlet are inhabited by mangrove stands and coastal fringe vegetation is present between the Inlet and the existing SH16 alignment.

Potential effects of construction on marine ecological values arise from permanent habitat loss, temporary habitat loss and disturbance, noise and vibration and the discharge of construction phase stormwater.

6.5.1 Permanent Intertidal and Subtidal Habitat Loss

The area of permanent habitat loss from the location of piles in Sector 5 is estimated to be 20 m^2 of intertidal habitat.

Ramps 2 and 3 have circular piles located within the CMA. Ramp 2 has four 2.1 m diameter concrete bored piles, all three piles are contained within metal casings and all will transition to 1.8 m at the top of the normal tidal range. Ramp 3 has a 2.1 m diameter concrete bored pile in steel casing, that transitions to 1.8 m at the top of the normal tidal range (see Drawing set F 20.1.11-3-D-S-917 430 and 431, and F.12 20.1.11-3-D-C-941-109).

The adverse effects of installation of the permanent piers include mortality of benthic invertebrates, removal of saline vegetation and permanent habitat loss. The adverse effects on marine ecological values are considered to be moderate.

6.5.1.1 Summary of Effect

Table 19: Sector 5 Permanent Habitat Loss - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Permanent habitat	Low/Moderate	Medium	Permanent	Moderate

loss – bridge piers				

6.5.2 Temporary Habitat Loss and Disturbance

The area of temporary subtidal habitat loss/disturbance is estimated to be approximately 15 m^2, whereas subtidal habitat loss/disturbance is estimated to be approximately 5 m^2.

Construction of the ramp viaduct structures requires temporary occupation and disturbance of the CMA, primarily from the temporary piling to support 12 staging platforms (see Drawings set F 20.1.11-3-D-S-610-500 and 501, F.12 20.1.11-3-D-C-942-109, and Technical Report No. G.23 Coastal Works). The staging platforms extend from the northern and southern sides of Oakley Inlet, thereby minimising disturbance of the low tide channel. The purpose of the platforms is to provide access for the pile boring equipment and also to protect the CMA from the deposition of spoil dropping from the auger. Given the elevated contaminant concentrations in the Oakley Inlet, spoil generated from the auger will be collected on the staging platforms, removed off-site and disposed of at an appropriate facility (Technical Report No. G.23 Coastal Works).

The 85 temporary steel piles are 0.6 m diameter and will be driven into the underlying material at low tide in order to minimise the generation of suspended sediment, until a sufficient bearing capacity is achieved. The platform supported by the piles comprises a steel superstructure and timber decking. It is envisaged that the temporary structures will be in place for approximately 18 months, and once construction is completed, they will be dismantled and removed in the reverse order of installation (including removal of piles during low tide) (Technical Report No. G.23 Coastal Works).

The adverse effects on marine ecological values associated with the temporary staging platforms include increased suspended sediment concentration, removal of vegetation (including mangroves), mortality of benthic invertebrates and temporary habitat loss. The areas of intertidal and subtidal habitat temporarily disturbed during construction will be readily recolonised following completion of construction and removal of the staging structures. It is considered that the adverse effects on the marine ecological values of temporary habitat loss/disturbance in Sector 5 will be minor, given that recolonisation of disturbed areas by benthic marine organisms will occur.

There will be some minor changes to flows in Sector 5 due to the temporary occupation of the CMA by the staging piers, but the effects of the small temporary flow changes on marine ecological values are considered to be negligible.

6.5.3 Shading of Saline Vegetation

Shading of saline vegetation beneath the new ramps (ramp heights are estimated to range between 9.0 m and 27.0 m within the CMA) may limit the recolonisation of disturbed intertidal mudflat areas by mangroves upon completion of construction. In addition, existing mangroves that will be shaded may be less thrifty.

Shading of saline vegetation beneath the temporary staging platforms may restrict growth during the estimated 18 months that they are in place. However, upon removal of the structures, the vegetation is expected to recover fully over time.

Given the ubiquitous distribution of mangrove forests in estuarine areas in Auckland, it is considered that the adverse effects arising from the shading of some mangrove areas in Sector 5 will have negligible adverse effects on marine ecological values.

6.5.4 Noise and Vibration Disturbance

During construction works within Sector 5, there will be noise disturbance to marine organisms from a large range of machinery and activities, with the activities likely to generate the highest noise levels comprising bored piling techniques, rock breaking and pad footing construction (Technical Report No. G.5 Construction Noise Assessment Report).

Installation of piles is estimated to take approximately 2-3 days per permanent pile and 0.5-1 day per temporary pile. In addition, pile removal will be undertaken at a rate of 2-4 piles per day. There may be some avoidance of the immediate area by fish and some more sensitive benthic invertebrates may cease feeding or foraging during the noisiest periods. Given the temporary nature of the bridge piling works, disturbance from vibration on marine organisms is considered to be negligible.

Vibration during construction within Sector 5 will be generated primarily from vibratory rollers for the road construction and the boring of piles. Of these, the piling is more likely to affect the marine environment, due to location within or adjacent to the intertidal habitat. It is considered that during piling, fish and other mobile organisms will avoid the area, and sessile (sedentary) or infaunal (sediment dwelling) marine invertebrates are likely to remain inactive, not feeding or foraging etc.

As the construction disturbance related to noise and vibration in Sector 5 is temporary, it is considered the effects on marine ecological values to be negligible.

6.5.5 Discharge of Treated Stormwater

Erosion and sediment control techniques in Sector 5 include super silt fences, decanting earth bunds and sediment retention ponds (see Technical Report No. G.22 Erosion and Sediment Control Plan).

A super silt fence will be used to contain sediment from works adjacent to the Oakley Inlet (see Drawings EN-740-108 Rev A and EN-740-109 Rev B). Sediment retention ponds will be used to treat dirty water in addition to chemical treatment. Of these ponds, 5A and 5C discharge treated water to Oakley Inlet, whereas 5B and 5D discharge to an existing wetland (adjacent to the Contractor's Yard) (Technical Report No. G.22 Erosion and Sediment Control Plan).

Three wet ponds will treat runoff from the three Contractor's Yards in this Sector, all discharging ultimately to the CMA. Given the risk of contaminants to enter stormwater collected from the Contractor's Yards it will be important to ensure that the ponds operate effectively (Technical Report No. G.22 Erosion and Sediment Control Plan).

Adverse effects arising from the discharge of construction phase stormwater in Sector 5, provided the stormwater treatment and control devices discussed in Technical Report No. G.22 Erosion and Sediment Control Plan and Technical Report No. G.15 Stormwater and Stream Works Report are in place and working efficiently to proposed treatment levels, are considered to be negligible.

6.5.6 Summary of Effects

Table 20: Sector 5 Temporary Habitat Loss/Disturbance - Summary of Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Temporary habitat loss – staging platform piers	Low/Moderate	Low	Temporary	Minor
Shading of saline vegetation	Low/Moderate	Neutral	Temporary	Negligible
Discharge of treated stormwater	Low/Moderate	Neutral	Temporary	Negligible
Disturbance from noise and vibration	Low/Moderate	Neutral	Temporary	Negligible

6.6 Sectors 6 to 9

Simulations of stormwater discharges down Oakley Creek and into the CMA during flood events during upstream construction have been carried out and indicate that the additional suspended sediment and deposited sediment is minimal provided the specified sediment control devices are in place (see Technical Report No. G.4 Assessment of Coastal Processes report).

Treated stormwater will also discharge into Meola Creek, and this is considered in the Technical Report No. G.6 Assessment of Freshwater Ecological Effects report.

The adverse effects arising from construction in Sectors 6-9 on marine ecological values are considered to be negligible.

7. Effects Assessment: Operational Phase

The potential adverse operational effects of the Project on marine ecological values primarily relate to the discharge of road runoff, shading of coastal vegetation from new structures, increased noise and disturbance and alterations to tidal flows.

7.1 Sector 1: Te Atatu Interchange

Treatment of road runoff in Sector 1 will be through a Stormwater Treatment Wetland, and two swales (see Technical Report No. G.15 Stormwater and Stream Works Technical Report and Drawings 20.1.11-3-D-D-300-101 and 20.1.11-3-D-D-300-102). Both the treatment wetland (located with Jack Colvin Park), discharging to Pixie Inlet, and the swales (located adjacent to the Te Atatu eastbound on-ramp and the westbound off-ramp), discharging to the Whau River, have been designed to remove an average of 80% of total suspended sediment and associated contaminants (as per ARC TP10). In addition two grassed swales, incorporating infiltration devices, will treat runoff from the on- and off-ramps in this Sector.

Given the level of treatment of the road runoff provided in this Sector (at least 80% TSS removal), which includes runoff from the existing untreated pavement, the adverse effects of the stormwater discharge on marine ecological values are considered to be negligible. However, stormwater contaminants will continue to accumulate in marine sediment and there is the potential for adverse effects on marine organisms in the long-term.

Minor changes to flows resulting from the reclamation of the CMA in Pixie Inlet are anticipated (Technical Report No. G.4 Coastal Processes). Small scale localised changes to the marine invertebrate assemblage present due to minor flow alterations may result in this Sector, but these changes are considered to be negligible in terms of marine ecological values.

Table 21: Sector 1 Permanent Habitat Loss - Summary of Operational Phase Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Discharge of treated stormwater	Moderate	Neutral	Permanent	Negligible
Alteration of flows	Moderate	Neutral	Permanent	Negligible

7.2 Sector 2: Whau River

Road runoff in Sector 2 will be treated using cartridge filters and biofilter strips (see Assessment of Stormwater and Streamworks Effect report and Drawing 20.1.11-3-D-D-300-103). Runoff from the widened Whau River Bridges and a short section of motorway west of the Whau Bridges, will be intercepted by catch pits and piped to the treatment devices on the eastern abutment of the Whau Bridge. Discharges will be into the Whau River. The discharge structure provides erosion and scour protection.

The grass swales (incorporating infiltration devices) treat runoff from the motorway between the Rosebank Park Domain Go-karting Track and the Whau River Bridges and adjacent existing pavement, and are designed to exceed the minimum width required by ARC's TP10. Runoff from the two small service areas within Sector 2 (TD2C and TD2D) is directly discharged to the adjacent coastal rock revetment.

Sediment and associated contaminants contained in the treated discharge into the Whau River will have been reduced by least 80%.

The effects of the discharge of stormwater on marine ecological values in this Sector are considered to be negligible. However, there will be ongoing accumulation of stormwater contaminants in marine sediment, which in long -term may have adverse effects on marine organisms.

Shading beneath the Whau River Bridges extension is unlikely to cause adverse effects on coastal plant growth and colonisation. It is considered that shading of vegetation in this Sector will have negligible effect on marine ecological values.

Minor changes to flows resulting from the reclamation of the CMA for the widened abutments and widening the SH16 carriageway are anticipated, with some small channels let to re-adjust their path naturally (Technical Report No. G.4 Coastal Processes). Small scale localised changes to the marine invertebrate assemblage present, due to minor flow alterations in this Sector, may result but these changes are considered to be negligible in terms of marine ecological values.

Table 22: Sector 2 Permanent Habitat Loss - Summary of Operational Phase Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Discharge of treated stormwater	Moderate	Neutral	Permanent	Negligible
Shading of vegetation	Moderate	Neutral	Permanent	Negligible
Alteration of flows	Moderate	Neutral	Permanent	Negligible

7.3 Sector 3: Rosebank – Terrestrial

Treatment of operational stormwater in this Sector is by cartridge filters, with discharges to intertidal mangrove mudflats within the CMA (Drawings 201.111-3-D-D-300-104 and 105). The level of treatment provided will exceed TP10 requirements (at least 80% removal of TSS) and therefore reduces the concentration of contaminants entering the marine environment. Discharge structures will be appropriately designed and constructed to avoid scour and erosion. The adverse effects of the discharge of treated stormwater in this Sector are considered to be negligible. However, there will be ongoing accumulation of stormwater contaminants in marine sediment, which in the long-term, may have adverse effects on marine organisms.

Table 23: Sector 3 Permanent Habitat Loss - Summary of Operational Phase Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Discharge of treated stormwater	Moderate	Neutral	Permanent	Negligible

7.4 Sector 4: Reclamation

A combination of cartridge filters and biofilter treatment devices are proposed for the treatment of operational phase stormwater within Sector 4 (Drawings 20.1.11-D-D-300-104 to 108). Biofilter treatment devices were proposed through the process of identifying opportunities to offset the adverse effects of permanent habitat loss arising from the construction design. Where cartridges are proposed, the runoff from the widened motorway section in Sector 4 will be intercepted by slot drains, dish channels and/or catch pits and piped to cartridge vault treatment devices located on the verge of the motorway. Treated runoff will be discharged to the CMA via similar structures to that in Sector 3.

The biofilter treatment devices comprise a 7.0 m wide filter strip vegetated densely with the native jointed wire rush (*Apodasmia similis*) above a granular filter layer of scoria and oyster shells. Treated runoff percolates through the vegetation to the granular filter layer and subsequently to the rock armouring discharging in a diffuse manner into the intertidal marine environment. These devices are designed to remove at least 80% TSS. Moores et al. (2009) determined that a similar stormwater treatment design achieved approximately 75% removal of suspended sediment and >90% removal of dissolved copper and zinc (Technical Report No. G.15 Assessment of Stormwater and Streamworks Effects).

Sediment and contaminant load calculations indicate that during the operational phase of the Project there will be between 20% and 40% less copper and zinc discharged to the marine environment compared to that currently discharged from the existing alignment which receives very little stormwater treatment (Technical Report No. G.30 Associated Sediment and Contaminant Loads).

The adverse effects of the discharge of treated road runoff to the marine environment in this Sector are considered to be negligible. However, there will be ongoing accumulation of stormwater contaminants in marine sediment, which, in the long-term, may adversely affect marine ecological values.

Following construction of the Project, road traffic may be closer to the marine environment in some sections of the alignment, with potential increased disturbance to marine organisms, primarily from noise and vibration. However, along much of the Causeway, where biofilter treatment devices are used, there will be >7.0 m of vegetation between the closest lane (bus shoulder) and the intertidal habitat. The additional adverse effects arising from noise and vibration in this Sector, above that of the existing busy and noisy existing motorway, are considered to be negligible.

Minor changes to flows and minor erosion on mud banks may result from the reclamation of the CMA for the widened abutments, piers and widening the SH16 carriageway (Technical Report No. G.4 Coastal Processes). Small scale localised changes to the marine invertebrate assemblage present may occur, due to minor flow alterations in this Sector, but these changes are considered to be negligible in terms of marine ecological values.

Table 24: Sector 4 Permanent Habitat Loss - Summary of Operational Phase Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Discharge of treated stormwater	Assumed average of moderate	Neutral	Permanent	Negligible
Traffic noise and vibration	Assumed average of moderate	Neutral	Permanent	Negligible
Alteration of flows	Assumed average of moderate	Neutral	Permanent	Negligible

7.5 Sector 5: Great North Road Interchange

The permanent stormwater treatment devices in Sector 5 that discharge directly to the CMA include biofilter strips, cartridge filters, wetlands and a swale (see Drawings 20.1.11-1-D-D-300-109 and 113). The biofilter strips, as those in the previous Sectors, are designed to exceed ARC's TP10 minimum width and therefore provide additional treatment, prior to discharge to the CMA. The treatment devices are designed to exceed ARC's TP10, reducing the concentration of contaminants entering the marine environment to at least 80%. It is considered that the adverse effects on marine ecological values in this Sector arising from the discharge of treated stormwater are negligible. However, the treated stormwater discharges will contain some residual contaminants, which will add to their accumulation in marine sediment in the long-term and potentially cause adverse effects on marine organisms in the future.

There will be some shading of coastal vegetation beneath the viaduct ramps over Oakley Inlet. This may limit the recolonisation of some areas disturbed during the construction phase of the Project, and may cause some plants to become unthrifty. However, given the relatively small areas involved, and the ubiquitous nature of mangrove forests in Auckland estuarine environments, the adverse effects of shading on marine ecological values in this Sector are considered to be negligible.

Following construction of the Project, road traffic may be closer to the marine environment in some sections of the alignment, with potential increased disturbance to marine organisms, primarily from noise and vibration. The additional adverse effects arising from noise and vibration in this Sector, above that of the existing busy and noisy existing motorway, are considered to be negligible.

Minor changes to flows may result from the reclamation of primarily intertidal CMA relating to the installation of new piers (Technical Report No. G.4 Coastal Processes). Small scale localised changes to the marine invertebrate assemblage present may occur, due to very minor flow alterations in this Sector, but these changes are considered to be negligible in terms of marine ecological values.

Table 25: Sector 5 Permanent Habitat Loss - Summary of Operational Phase Effects

Activity	Ecological Values	Magnitude of Impact	Permanent or Temporary Scale	Significance of Effect
Discharge of treated stormwater	Low/moderate	Neutral	Permanent	Negligible
Shading of vegetation	Low/moderate	Neutral	Permanent	Negligible
Traffic noise and vibration	Low/moderate	Neutral	Permanent	Negligible
Alteration of flows	Low/moderate	Neutral	Permanent	Negligible

7.6 Sectors 6 to 9

The discharge of operational phase stormwater to the freshwater habitats of Oakley and Meola Creeks in Sectors 6-9 is considered in the Technical Report No. G.6 Assessment of Freshwater Ecological Effects.

8. Cumulative Effects

The Project's primary potential cumulative effects on marine ecology would relate to the ongoing discharge of stormwater and the reclamation of the CMA within the wider Waitemata Harbour system.

Ongoing discharges of stormwater into the CMA (and MMMR) contribute to the accumulation of contaminants in marine sediment over time, along with wastewater discharges, industrial effluent discharges and runoff from agricultural land. The Waterview Estuary has received industrial discharges and untreated stormwater discharges over a long period historically. Baseline estimates of contaminant loads entering the Waterview Estuary indicate that 1,022 kg of zinc and 138 kg of copper is discharged into the estuary each year. Estimates of these loads during the operational phase of the Project indicate an 8% reduction in zinc and a 10% reduction in copper (due to the improved stormwater treatment provided for SH16) (Technical Report No. G.30 Associated Sediment and Contaminant Loads). There are also many other sources of contaminants entering the CMA. For example, it has been calculated that currently roads and motorways contribute approximated 26% of the zinc and 31% of the copper that is discharged annually into Oakley Creek and Waterview Estuary (Technical Report No. G.30 Associated Sediment and Contaminant Loads).

The higher the level of treatment provided to the stormwater prior to discharge to an aquatic environment, the longer the time period until adverse effects on ecological values are likely to occur. This Project seeks to treat all runoff from the additional impervious surfaces constructed, in addition to the treatment of most of the existing currently untreated alignment, which will reduce the rate of accumulation of contaminants in marine sediments. In addition, operational phase stormwater from Sectors 1-5 will be treated to a higher level than other parts of the Project given the direct discharge to the CMA, which will result in at least 80% removal of TSS (Technical Report No. G.15 Assessment of Stormwater and Streamworks Effects). However, the treated stormwater discharged will still contain a level of residual contaminants, which will contribute to the long-term accumulation of contaminants in marine sediments. As with any stormwater discharge, there will be cumulative effects in the long-term arising from the contaminants contained in the discharge accumulating in the environment.

The reclamation required for this Project needs to be considered within the context of the cumulative effects of historical and current works that permanently reduce marine benthic habitat in the Waitemata Harbour and the MMMR. It is difficult to quantify the area of historical marine benthic habitat loss in the Project area. However, the margins of the Waterview Estuary have been modified by industrial and residential landuse and the establishment of roading (e.g. the original construction of Causeway in the 1950s). It can be concluded that the marine habitat has been significantly modified with some benthic habitat loss and/or degradation.

Whilst permanent loss of marine benthic habitat is undesirable, the approximately 5.87 ha of permanent loss associated with this Project will not affect the functioning of the marine reserve habitat or the wider Waitemata Habour habitat. It is estimated that the permanent marine habitat loss arising from this Project, within the MMMR, comprises approximately 1% of the total reserve area. Within the wider Waitemata Harbour context, the permanent marine habitat loss comprises 0.0003% of the total harbour area (18,130 ha). Therefore, a small proportion of the MMMR and Waitemata Harbour will be permanently lost due to this Project. It is considered, given the historical modifications to the marine environment in this area, and the ecological values present, that the cumulative loss of marine benthic habitat is minor.

9. Potential Mitigation

Direct mitigation of some of the potential effects associated with this Project (i.e. sediment and contaminant discharges) will occur through the installation of erosion and sediment control devices, temporary stormwater devices, long-term permanent stormwater treatment devices, use of coffer dams, practices such as the use of suction trucks to remove contaminated water, removal and replacement of the shell banks, and the timing of works (e.g. carrying out disturbance works during low tide to minimise suspended sediment generation).

However, it is difficult to directly mitigate in a marine context for both temporary habitat loss (considered a minor adverse ecological effect) and permanent habitat loss (considered a moderate adverse ecological effect) and the cumulative effects associated with the ongoing discharge of stormwater contaminants.

These effects can be off-set by the following initiatives:

- improving the efficiency of contaminant removal from operational phase stormwater discharging into the CMA.
- remediation of a 3 m wide area of intertidal habitat on each side of the Causeway embankment by reducing the height of the mudcrete by 0.5 m.
- treating stormwater runoff from the existing alignment, in addition to the new alignment.
- restoration of coastal fringe habitat along the alignment (involving weed control and revegetation).
- removal of gross litter and debris from within and adjacent to the CMA along the alignment.
- planting into the rock revetment along sheltered parts of the Causeway embankment.

Improving the removal of stormwater contaminants prior to discharge into the CMA has direct benefit to marine ecological values through slowing down the accumulation of contaminants in marine sediment and therefore extending the time before biological effects thresholds are exceeded.

The development of the design innovation to lower the toe of the Causeway embankment in order to create the Ecological Remediation Zone resulted in approximately 1.32 ha of permanent habitat loss becoming temporary habitat loss. It is anticipated that these areas will, over time, be recolonised by marine organisms including mangroves and become a functioning part of the wider marine environment.

The treatment of road runoff from the existing alignment, which reduces the rate of accumulation of contaminants in the marine environment, has benefit to marine ecological values and also forms part of the mitigation of permanent marine habitat loss.

Restoration of the coastal fringe (weed control and revegetation with appropriate native species) along the alignment provides benefit to the marine ecological values through increasing biodiversity.

Immediately adjacent to and within the CMA, further proposed off-set mitigation includes the removal of gross litter, rubbish and debris that is currently abundant in these areas.

Vegetation of the faces of the ground improvement work areas along the Causeway embankment (within the rock revetment) with appropriate coastal fringe species provides an opportunity for some increases in biodiversity at the interface of the terrestrial and coastal habitats. However, planting can only be undertaken where the revetment is sheltered from wave action (primarily the southern side of the embankment) in order to ensure that the permeability of the structure is not reduced.

On balance, it is considered that implementation of the mitigation opportunities identified above sufficiently offsets the moderate adverse effects on marine ecological values arising from permanent marine benthic habitat loss and the minor effects arising from temporary habitat loss.

10. Monitoring

Pre-construction, during construction and post-construction monitoring of suspended sediment, pH, sediment quality and benthic invertebrate community composition is detailed in the Ecological Management Plan (ECOMP) (attached as Appendix G) which forms Appendix H of the Construction Environmental Management Plan (CEMP). These monitoring measures will ensure that the construction mitigation measures proposed work effectively to protect the marine ecological values.

11. Summary and Conclusions

Construction associated with the Project will have adverse effects on marine ecological values including permanent habitat loss (approximately 5.87 ha), temporary habitat loss and disturbance (approximately 7.24 ha), discharge of contaminants and sediment, and noise and vibration disturbance. All of these effects, other than permanent habitat loss are considered to be adequately mitigated and/or are considered minor or negligible.

It is difficult to mitigate the adverse effects of permanent habitat loss in a marine context. However, there are opportunities to off-set the adverse effects of the Project on the marine environment through remediation of the mudflat adjacent to the Causeway embankment, achieving better contaminant removal efficiency in operation phase stormwater (from both the existing and the new alignment), restoration of the coastal fringe habitat along the alignment, and removal of gross litter and debris from within and adjacent to the CMA.

It is concluded that the Project's construction phase adverse effects will be adequately mitigated provided the offset mitigation identified above is implemented.

Operation of the motorway, given the higher quality of road runoff treatment proposed, is not expected to have adverse effects on the marine ecological values, other than contributing to the long-term continued accumulation of contaminants in the marine sediment.

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