Warkworth to Wellsford

Marine Ecology and Coastal Avifauna Assessment

July 2019

QUALITY ASSURANCE

Prepared by

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GLOSSARY OF ABBREVIATIONS

The table below sets out the technical abbreviations.

Abbreviation	Meaning
AEE	Assessment of Effects on the Environment
ANZECC	Australian and New Zealand Environment Conservation Council
ARC	Auckland Regional Council (preceded the Auckland Council)
ASCV	Area of Significant Conservation Value
ARI	Average Return Interval
AUP (OP)	Auckland Unitary Plan Operative in Part
CEMP	Construction Environmental Management Plan
CESCP/s	Construction Erosion and Sediment Control Plan/s
Council	Auckland Council
Cu	Copper
DOC	Department of Conservation
dw	Dry weight
ESCP	Erosion and Sediment Control Plan
ERC	Environmental Response Criteria
GIS	Geographic Information System
GPS	Global Positioning System
Ha	Hectare
HMW	High Molecular Weight
ISQG	Interim Sediment Quality Guideline
km	Kilometres
km^2	Square kilometres
km/h	Kilometres per hour
m	Metres

Abbreviation	Meaning
m^2	Square metres
m^3	Cubic metres
MHWS	Mean High Water Springs
MSD	Multi-dimensional scaling
NIWA	National Institute of Water and Atmospheric Research
OSNZ	Ornithological Society of New Zealand
PAHs	Polycyclic Aromatic Hydrocarbons
TP10	Technical Publication 010 of Auckland Regional Council (1992)
P-Wk	Pūhoi to Warkworth project
RMA	Resource Management Act 1991
s.e.	Standard error
SEA	Significant Ecological Area as defined in the AUP(OP)
SH(x)	State highway (number)
t	Metric tonne
TOC	Total Organic Carbon
Transport Agency	NZ Transport Agency
TSS	Total Suspended Solids
USLE	Universal Soil Loss Equation
Zn	Zinc

GLOSSARY OF DEFINED TERMS

The table below sets out the defined terms (and some acronyms above apply)

Term	Meaning
Average Recurrence Interval (ARI)	The average time period between rainfall or flow events that exceed a given magnitude.
Best practicable option	Defined in section 2(1) of the RMA, as "in relation to a discharge of a contaminant or an emission of noise, means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to – (a) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects; and (b) the financial implications, and the effects on the environment, of that option when compared with other options; and (c) the current state of technical knowledge and the likelihood that the option can be successfully applied."
Benthic	Of, relating to, or occurring at the bottom of a body of water.
Conditions	Conditions placed on a resource consent (pursuant to section 108 of the RMA) or conditions of a designation (pursuant to subsection 171(2)(c) of the RMA).
Construction Runoff	Any runoff, sediment laden or otherwise, that flows as a result of the construction related activities. Typically results from rain events.
Construction works	Activities undertaken to construct the Project.
Contaminant	Defined in section 2(1) of the RMA, as "any substance (including gases, odorous compounds, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat – (a) when discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or (b) when discharged onto or into land or into air, changes or is likely to change the physical, chemical or biological condition of the land or air onto or into which it is discharged."
Designation	Defined in section 166 of the RMA, as "a provision made in a district plan to give effect to a requirement made by a requiring authority under section 168 or section 168A or clause 4 of Schedule 1 of the RMA."

Term	Meaning
Discharge	Defined in section 2(1) of the RMA, as including emitting, depositing, and allowing to escape.
Earthworks	Defined in section J1 of the AUP, as disturbance of soil, earth or substrate land surfaces. Includes: blading, boring (greater than 250mm diameter); contouring; cutting; drilling (greater than 250mm diameter); excavation; filling; ripping; moving; placing; removing; replacing; trenching; and thrusting (greater than 250mm diameter). Excludes: ancillary forest earthworks; and ancillary farming earthworks.
Epifauna	Any organism living on the surface of the ocean floor (both subtidal and intertidal).
Erosion control	Methods to prevent or minimise the erosion of soil, in order to minimise the adverse effects that land disturbing activities may have on a receiving environment.
Flocculation	The process whereby fine particles suspended in the water column clump together and settle. In some instances, this can occur naturally, such as when fresh clay-laden flows mix with saline water, as occurs in estuaries. Flocculation can be used to promote rapid settling in sediment retention ponds by the addition of flocculating chemicals (flocculants).
Indicative Alignment	An indicative road design alignment assessed by the technical experts that may be refined on detailed design within the designation boundary. The Indicative Alignment is a preliminary alignment of a state highway that could be constructed within the proposed designation boundary. The Indicative Alignment has been prepared for assessment purposes, and to indicate what the final design of the Project may look like. The final alignment for the Project will be refined and confirmed at the detailed design stage.
Infauna	Any organism living within intertidal or subtidal benthic sediment.
Intertidal	Marine habitat that occurs between high tide and low tide that is not permanently submerged.
Kaitiakitanga	Guardianship
Macroalgae	Macroscopic (visible to the naked eye) red, green and brown algae.
Pier	Vertical support structure for a bridge.

Term	Meaning
Primary habitat	The habitat type in which a species spends most of its time, though is not necessarily limited to (ie the species may use other habitat types less frequently).
Erosion and Sediment Control	Methods to prevent or minimise the erosion of soil, in order to minimise the adverse effects that land disturbing activities may have on a receiving environment.
Project	The Ara Tūhono Pūhoi to Wellsford Project: Warkworth to Wellsford section, which extends from Warkworth in the south, to the north of Te Hana.
Project area	The area within the proposed designation boundary, and immediate surrounds to the extent Project works extend beyond this boundary.
Project works	All proposed activities associated with the Project, including enabling, construction, operation and maintenance works.
Proposed designation boundary	The boundary of the land to which the notice of requirement applies.
Sediment control	Defined in section J1 of the AUP, as measures to prevent or minimise the discharge of sediment that has been eroded.
Sediment yield	That sediment which leaves the sediment retention devices and enters the receiving environment.
State highway	A road, whether or not constructed or vested in the Crown, that is declared to be a state highway under section 11 of the National Roads Act 1953, section 60 of the Government Roading Powers Act 1989 (formerly known as the Transit New Zealand Act 1989), or under section 103 of the LTMA.
Stormwater	Water that flows from impervious areas and completed areas of the State Highway after the construction period.
Subtidal	Marine habitat that occurs below low tide and is always submerged.
Taxa	Types / groups of animals. The singular is taxon. For example, gastropod is a taxon that includes snails and slugs.
Terrigenous	Sediment derived from the erosion of rocks on land; that is, that are derived from terrestrial environments.
Terrestrial	Land-based.

Term	Meaning
Turbidity	Turbidity is a measure of water clarity or murkiness of a waterbody.
Treatment Wetland	Vegetated stormwater treatment device designed to remove a range of contaminants, providing superior water quality treatment to ponds with increased filtering and biological treatment performance.

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1 INTRODUCTION

1.1 Overview of the Project

The NZ Transport Agency (Transport Agency) is lodging a Notice of Requirement (NoR) and applications for resource consent (collectively referred to as "the Application") for the Warkworth to Wellsford Project (the Project).

This report is part of a suite of technical assessments prepared to inform the Assessment of Effects on the Environment (AEE) and to support the Application. This assessment report addresses the actual and potential marine ecological effects arising from the Project. The assessment considers the effects of an Indicative Alignment and other potential effects that could occur if that alignment shifts within the proposed designation boundary when the design is finalised in the future.

1.2 Project description

The Project involves the construction, operation and maintenance of a new four lane state highway. The route is approximately 26 km long. The Project commences at the interface with the Pūhoi to Warkworth project (P-Wk) near Woodcocks Road. It passes to the west of the existing State Highway 1 (SH1) alignment near The Dome, before crossing SH1 just south of the Hōteo River. North of the Hōteo River the Project passes to the east of Wellsford and Te Hana, bypassing these centres. The Project ties into the existing SH1 to the north of Te Hana near Maeneene Road.

The key components of the Project, based on the Indicative Alignment, are as follows:

a) A new four lane dual carriageway state highway, offline from the existing State Highway 1, with the potential for crawler lanes on the steeper grades.

b) Three interchanges as follows:

   i. Warkworth Interchange, to tie-in with the Pūhoi to Warkworth section of SH1 and provide a connection to the northern outskirts of Warkworth.

   ii. Wellsford Interchange, located at Wayby Valley Road to provide access to Wellsford and eastern communities including Tomarata and Mangawhai.

   iii. Te Hana Interchange, located at Mangawhai Road to provide access to Te Hana, Wellsford and communities including Port Albert, Tomarata and Mangawhai.

c) Twin bore tunnels under Kraack Road, each serving one direction, which are approximately 850 metres long and approximately 180 metres below ground level at the deepest point.

d) A series of steep cut and fills through the forestry area to the west of the existing SH1 within the Dome Valley and other areas of cut and fill along the remainder of the Project.

e) A viaduct (or twin structures) approximately 485 metres long, to span over the existing SH1 and the Hōteo River.

f) A tie in to existing SH1 in the vicinity of Maeneene Road, including a bridge over Maeneene Stream.

g) Changes to local roads:

   i. Maintaining local road connections through grade separation (where one road is over or under the other). The Indicative Alignment passes over Woodcocks Road, Wayby Valley Road, Whangaripo Valley Road, Mangawhai Road and Maeneene Road. The Indicative Alignment passes under Kaipara Flats Road, Rustybrook Road, Farmers Lime Road and Silver Hill Road.

   ii. Realignment of sections of Wyllie Road, Carran Road, Kaipara Flats Road, Phillips Road, Wayby Valley Road, Mangawhai Road, Vipond Road, Maeneene Road and Waimanu Road.

   iii. Closing sections of Phillips Road, Robertson Road, Vipond Road and unformed roads affected by the Project.

h) Associated works including bridges, culverts, stormwater management systems, soil disposal sites, signage, lighting at interchanges, landscaping, realignment of access points to local roads, and maintenance facilities.

i) Construction activities, including construction yards, lay down areas and establishment of construction access and haul roads.

For description and assessment purposes in this report, the Project has been divided into the following areas (as shown in Figure 1 below):

a) Hōteo South: From the southern extent of the Project at Warkworth to the Hōteo River.

b) Hōteo North: Hōteo River to the northern tie in with existing SH1 near Maeneene Road.

For construction purposes, the Hōteo South section is divided into two subsections being:

- South – from the southern tie in with P-Wk to the northern tunnel portals; and
- Central – from the northern tunnel portals to the Hōteo River.

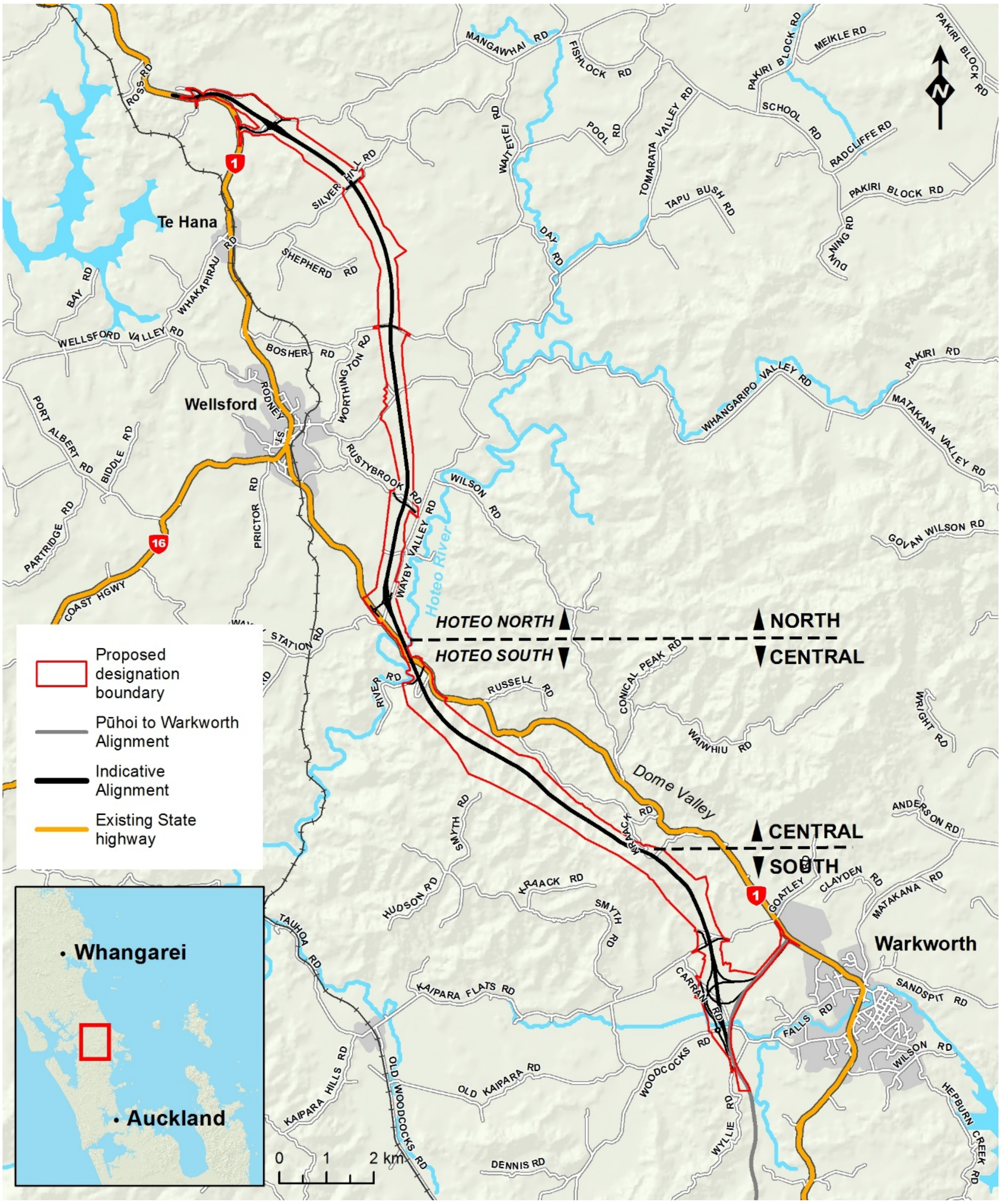

Figure 1 - Project Area

The Indicative Alignment shown on the Project drawings is a preliminary alignment for a state highway that could be constructed within the proposed designation boundary. The Indicative Alignment has been prepared for assessment purposes, and to indicate what the final design of the Project may look like. The final alignment for the Project (including the design and location of associated works including bridges, culverts, stormwater management systems, soil disposal sites, signage, lighting at interchanges, landscaping, realignment of access points to local roads, and maintenance facilities), will be refined and confirmed at the detailed design stage.

A full description of the Project including its design, construction and operation is provided in Section 4: Description of the Project and Section 5: Construction and Operation of the AEE contained in Volume 1 and shown on the Drawings in Volume 3.

2 METHODOLOGY

Methdology Summary

There are no identified direct effects of the Project on marine ecological values. Our marine ecology assessment therefore focused on those parts of the coastal marine area (CMA) within the Mahurangi Harbour and Kaipara Harbour where there is the potential for adverse ecological effects due to indirect Project water discharges.

We assessed the Indicative Alignment, but also considered potential changes to the alignment (and design and location of ancillary components) within the proposed designation boundary.

We collated information on the marine and coastal avifauna ecological values within the Mahurangi Harbour and Kaipara Harbour from existing literature. We supplemented this information with focused field surveys where we considered that sufficient information did not already exist to assess the effects of the Project.

Our investigation of marine ecological values in the Mahurangi and Kaipara Harbours included:

- a literature review of the existing marine ecological values;
- benthic invertebrate infaunal and epifaunal surveys;
- sediment grain size surveys and analysis; and
- analysis of common stormwater contaminants in sediment.

Our assessment draws together:

- the existing marine and coastal avifauna ecological values;
- the potential construction-related effects of the Project (sediment discharge and habitat disturbance);
- the potential operational-phase effects of the Project (primarily the discharge of treated stormwater); and
- potential cumulative effects on marine ecological values and the lifespan of the upper harbour areas.

We assessed the potential effects from construction sediment using the output of the Assessment of Coastal Sediment that estimated concentration of suspended sediments and depth and extent of sediment deposition under a range of construction scenarios.

Our assessment of operational phase stormwater discharges was informed by contaminant load modelling.

We assessed the level of the Project's potential adverse effects on marine and coastal avifauna ecological values using an assessment matrix that incorporates ecological value and effect magnitude.

2.1 Literature Review

We conducted a thorough search of relevant literature via Council websites, government websites, library catalogues, scientific journal websites and internet search engines. We reviewed and summarised the literature (both published and unpublished) in relation to the marine and coastal avifauna ecological values of Mahurangi Harbour and Kaipara Harbour.

A full list of the literature sources we have relied on to inform our assessment is set out in Section 7.

2.1.1 Coastal Avifauna

Field surveys of avifauna utilising the Mahurangi Harbour and Kaipara Harbour were not carried out as part of this Project; rather desktop data was obtained to characterise the coastal avifauna assemblages associated with the harbours. This level of information is considered sufficient for this Project given that there are no direct effects on marine ecological values or coastal avifauna.

A list of species was derived from the 1999-2004 Ornithological Society of New Zealand's (OSNZ) atlas survey (Robertson et al., 2007). Data for the Mahurangi Harbour was obtained for two 10km x 10km grid squares (266, 652; 266, 653) which encompass the harbour downstream of the alignment and surrounding area. Data for the Kaipara Harbour was obtained for four 10km x 10km grid squares (263, 653; 264, 655; 264, 654; 264, 653) which encompass the eastern section of the Kaipara Harbour including the Hōteo Inlet and Oruawharo Inlet and surrounding area (Figure 2).

The primary and secondary habitats for each of the species recorded within these grid squares was obtained from Heather & Robertson (2005), along with each species' New Zealand threat status according to Robertson et al., (2017). The species list obtained from the OSNZ atlas data served as a base list of avifauna species recorded in the wider landscape and therefore potentially present at, or near, the Project area.

2.2 Marine Ecology Field Surveys

Field surveys were carried out to identify existing benthic ecological values and assess sensitivity of habitats and organisms to potential effects of the Project.

The methodologies applied to the surveys are consistent with the methodology used in the Auckland Council surveys (by Halliday & Cummings, 2012, Lundquist et al., 2003, Gibbs, 2004 and Hailes & Carter, 2015) and the Further North (2013) surveys. These methodologies are described in more detail below.

Figure 2: OSNZ Squares Relevant to the Project

2.2.1 Mahurangi Harbour

We used a range of data, including data from infauna and epifauna benthic invertebrate surveys, sediment contaminant surveys and sediment grain size surveys most recently collected within the receiving environment of the Mahurangi Harbour. This included data collected for the Pūhoi to Warkworth resource consent application by Further North (2013) shown in green (Appendix A) and data collected for Auckland Council (Halliday & Cummings, 2012 shown in pink, Lundquist et al., 2003 shown in grey and Gibbs, 2004) (see Map ME-013)[1].

Data collected as part of the Pūhoi to Warkworth (P-Wk) resource consent application (Further North, 2013) was considered highly relevant to this study due to the fact that the survey sites incorporated areas within the upper reaches of the Mahurangi Harbour that may be potentially affected by discharges from the Project. The sites surveyed for the P-Wk resource consent application and on behalf of Auckland Council, provide appropriate spatial coverage to describe the existing marine ecological values of the upper, middle and lower reaches of the Mahurangi Harbour in order to assess the sensitivity of this harbour to potential effects of the Project.

Harbour modelling carried out as part of the P-Wk resource consent application identified areas potentially affected by discharges into the Mahurangi as a result of the P-Wk project. The outputs of this model were considered appropriate for use in estimating areas potentially affected by the Warkworth to Wellsford Project, due to the fact that both projects have the same discharge point locations, and a similar area of open earthworks. In addition, the earthworks for the two projects will be carried out consecutively, rather than at the same time, avoiding any compounding effects of multiple earthworks projects being carried out simultaneously within the same catchment, increasing the potential amount of sediment discharged to the harbour.

We considered that the sites surveyed for P-Wk on behalf of Further North (2013) and Auckland Council provided an appropriate spatial coverage of the potential receiving environment of the Mahurangi Harbour and we therefore did not consider it necessary to duplicate survey effort where this recent data existed.

A summary of the existing surveys we relied on is provided in Appendix A. The table summarises our benthic invertebrate community and sediment quality survey effort.

2.2.2 Kaipara Harbour

We used a range of data provided by Auckland Council collected in April 2017 as part of field surveys carried out within the middle to lower reaches of the Kaipara Harbour (Hailes & Carter, 2015). This data included intertidal benthic infauna community composition, intertidal and subtidal sediment grain size and sediment contaminant concentrations. We considered that the sites surveyed on behalf of Auckland Council in 2017 provided an appropriate general spatial coverage of the middle to lower reaches of the Kaipara Harbour and as such we did not duplicate survey effort.

Within the upper reaches of the Kaipara (the Oruawharo and Hōteo Inlets) are areas potentially affected by sediment discharges from the Project, but there was no existing information on marine ecological values for those areas. We therefore supplemented the

[1] See summary of survey data relied upon in Appendix A.

existing survey data for the Kaipara provided by Auckland Council (Hailes & Carter, 2015) with additional field surveys within these two inlets.

The survey sites we selected are generally representative of the areas potentially affected by earthworks within the proposed designation boundary. Our surveys were confined to intertidal areas within the potential receiving environment (see Maps ME-011 and ME-012)[2]. We carried out infauna and epifauna benthic invertebrate surveys, along with sediment grain size and sediment contaminant surveys, at two sites within the Hōteo Inlet (Hōteo 1 and Hōteo 2), and two sites within the Oruawharo Inlet (Oruawharo 1 and 2) (see Maps ME-011 and ME-012).

Harbour modelling carried out by NIWA (Allis, 2018) identified, at a finer scale, areas potentially affected by discharges into the Kaipara Harbours by the Project. The harbour modelling outputs (such as where sediment discharge from the Project is likely to settle after a large rainfall event) was used to refine survey site locations in order to confirm a robust basis for the assessment of potential effects from construction and operation of the Project. Survey sites positioned within the Oruawharo and Hōteo Inlets were assessed as having appropriate spatial coverage to robustly describe the existing environment and sensitivity of all areas identified, by the harbour model, as a potential receiving environment for sediment discharge from the Project. No additional survey sites within the Kaipara Harbour were therefore considered necessary.

2.2.3 Benthic Invertebrates

Infauna

The sampling methodology for infaunal benthic invertebrates was based on Lundquist et al., (2003) and Swales et al., (2002). At each intertidal sampling location, between six randomly placed replicate cores were collected within a circular area (10 m radius). A stainless steel tube (13 cm diameter and 15 cm deep) was used to collect sediment cores.

Each sample was subsequently sieved in seawater through a 0.5 mm mesh sieve, and the retained material placed into a jar and preserved with 70% ethanol in seawater. Samples were then sent to an independent taxonomist for extraction and identification of invertebrates.

Statistical Analysis

We calculated the average total abundance of benthic infauna individuals, average number of taxa (species richness) and average Shannon-Wiener Diversity Index[3] as well as the average proportion of each main taxa group for each intertidal site surveyed.

We have used multi-dimension scaling plots (MDS)[4] to plot the community composition of intertidal and subtidal benthic infauna. Samples that are located closely together on the two dimensional map have greater similarities in their invertebrate assemblage than those that are more distant from each. MDS plots of infaunal invertebrate assemblages were created using the multivariate statistical software package, PRIMER-6. Data were transformed using fourth root transformation (in order to weight the contributions of

[2] See summary of survey data relied upon in Appendix A.

[3] Shannon-Wiener Diversity takes into account both number of taxa and evenness (i.e. the spread of individuals across individual taxa). Communities with a large number of species that are evenly distributed are the most diverse and communities with few species that are dominated by one species are the least diverse.

[4] MDS plots are used to place samples on a map in two dimensions in such a way that the rank order of the distances between samples on the map exactly agrees with the rank order of the matching similarities.

common and rare species in the multivariate representation) and a Bray-Curtis similarity matrix was created prior to each MDS analysis (see Clarke & Warwick, 2001 for a detailed explanation of MDS, transformations and similarity matrices).

Epifauna

Epifaunal communities were surveyed at each intertidal sampling site carried out by Boffa Miskell in the Kaipara Harbour in June 2017 (Hōteo 1, Hōteo 2, Oruawharo 1, Oruawharo 2). At each site, six 0.25m^2 quadrats were randomly positioned in previously undisturbed areas. Epifaunal invertebrates and macroalgae on the sediment surface were identified and recorded, and crab burrows were counted as a relative indicator of mud crab populations. Raw epifaunal data is presented in Appendix C. Epifaunal invertebrate data are described qualitatively due to the very small number of species present.

2.2.4 Sediment Grain Size

At each survey site, six surface sediment samples (top 1-2 cm) were collected to measure sediment grain size. Replicate sediment samples collected within each survey site was combined and homogenised to form a single composite sample for each site. Clean sample collection procedures were followed (i.e. gloves were worn and clean instruments used to collect samples at each site).

Sediment samples were analysed by the University of Waikato for typical environmental grain size fractions. The <63 μm sediment fraction was further analysed into silt and mud size classes by way of laser particle analysis.

2.2.5 Sediment Contaminants

At each intertidal survey site, six surface sediment samples (top 1-2 cm) were collected for analysis of the suite of contaminants associated with stormwater. Replicate sediment samples were combined and homogenised to form a single composite sample for each site. Clean sample collection procedures were followed (i.e. gloves were worn and clean instruments used to collect samples at each site).

Sediment samples were sent on ice to Hill Laboratories where they were analysed for the concentration of contaminants commonly detected in urban stormwater and road runoff: copper (Cu), lead (Pb), zinc (Zn) and high molecular weight polycyclic aromatic hydrocarbons (HMW-PAHs) The concentrations of HMW-PAHs were normalised to 1% total organic carbon (TOC).

Assessment Criteria

Contaminant concentrations were compared against relevant biological threshold guidelines (i.e. ANZECC Interim Sediment Quality Guidelines (ISQG) and Auckland Council's Environmental Response Criteria (ERC)).

Table 1 below presents the Auckland Council's Environmental Response Criteria (ERC) thresholds and the ANZECC (2000) ISQG low value for various contaminants. These values enable the assessment of the environmental quality of coastal marine areas in relation to common contaminants (Cu, Pb, Zn and HMW PAHs) found in stormwater discharges (Auckland Regional Council, 2004). Green indicates low concentrations of contaminants that are unlikely to cause adverse effects on biology, amber indicates that there is the potential for adverse effects on biology, and red indicates likely effects on biology.

Table 1 - Auckland Council's Environmental Response Criteria (ERC) thresholds and the ANZECC (2000) ISQG low and high values

Stormwater Contaminants (mg/kg)	AC ERC Green	AC ERC Amber	AC ERC Red	ISQG – Low	ISQG - High
Copper	<19	19	34	65	270
Lead	<30	30	50	50	220
Zinc	<124	124	150	200	410
HMW PAHS	<0.66	0.66	1.7	1.7	9.6

The ANZECC ISQG are adopted from Long et al., (1995) sediment quality values, which are based on laboratory toxicity tests and field data. These data suggest that if a sediment contaminant is detected between the ISQG-low threshold and the ISQG-high threshold, it is possible that adverse effects could occur. Concentrations above the ISQG-high threshold suggest probable adverse effects[5].

The Auckland Council ERC thresholds are based on the ANZECC ISQG, plus additional currently available guidelines, which are consistent with development of trigger values associated with local conditions (Auckland Regional Council, 2004). The ERC amber thresholds are set relatively low in order to enable time for a response and further investigation before ecological effects are likely to occur (ERC Red and ISQG-low threshold concentrations).

2.2.6 Oxidation Reduction Potential / Anoxic Sediment Depth

The oxidation reduction potential (ORP) reflects the level of oxygenation in marine sediments, which influences the ability of the sediment to support marine life.

The ORP was measured in previously undisturbed surface sediment at intertidal survey sites in the Mahurangi Harbour using a YSI handheld multiparameter meter.

In the Kaipara Harbour, anoxic sediment depth was measured by collecting sediments cores. The depth of the surface oxygenated sediment above anoxic sediment was measured.

2.2.7 Water Quality

Auckland Council monitors water quality and assigns a class and rank of between 0 and 100, based on a Water Quality Index (WQI), developed by the commonly accepted Canadian Council of Ministers for the Environment (CCME) (2001). The water quality classes assigned include:

- Greater than 90 = excellent water quality;
- Between 75 and 90 = good water quality;
- Between 60 and 75 = fair water quality; and

[5] Even if a sediment quality threshold is not exceeded there is no surety that adverse ecological effects will not occur as not all organisms have been tested in order to develop the guideline values (Long et al., 1995).

- Lower than 60 = poor water quality.

2.2.8 Harbour sediment modelling – construction phase

The rainfall events modelled that were used in our assessment of effects on the marine ecological values included a 10-year (10-year ARI event) and 50-year (50-year ARI event). A 10-year ARI rainfall event has a 39% chance of occurring at least once during the 5-year (short-term) construction period, and a 63% chance of occurring during a 10-year (long-term) construction period. A 50-year ARI rainfall event has a 10% chance of occurring at least once during the short construction period and an 18% chance of occurring during the long construction period.

Mahurangi Harbour

The Mahurangi Harbour was previously modelled as part of the P-Wk project using a GLEAMS model. Both The P-Wk and the Warkworth to Wellsford projects have the same discharge points from the project footprint in to the Mahurangi Harbour. The construction phase of each project will not occur at overlapping timeframes, therefore minimising any potential cumulative effects arising from simultaneous earthworks projects within the catchment. The modelling carried out for the P-Wk project was based on the maximum area of open earthworks for each catchment within the Project footprint. The indicative area of open earthworks that will drain in to the Mahurangi Harbour is greater for the P-Wk project than the Warkworth to Wellsford project (27 ha for P-Wk and 15.9ha for the Project), meaning that the P-Wk model will provide a highly conservative estimate on potential effects of sediment discharges to the harbour for the Project. These modelling results are therefore appropriate to use in assessing the effects of the Project on the Mahurangi catchment and therefore remodelling was not carried out for the Project.

The following section describes the modelling methodology used for the Mahurangi harbour and is taken from the Further North (2013) Pūhoi to Warkworth Marine Ecology Assessment Report:

> *"Baseline sediment movement into Mahurangi Harbour, and the potential increase in sediment discharged to this waterway as a result of open earthworks during a short-term (5 year) and long-term (10-year) construction period, was modelled. The model predicts the sediment loads within the Mahurangi River catchment and sediment loads delivered to the coast, and predicts suspended sediment concentration and sediment loads. The previous model is summarised in the Catchment Sediment Model (Technical Report 4) and includes an assessment of the predicted changes to sediment load within the Mahurangi River catchment and Mahurangi Harbour associated with the Project.*
>
> *A brief summary of the scenarios modelled and the model construction is as follows:*
>
> *The models of the Mahurangi was used to explore all permutations of the following conditions:*
>
> - *Sediment loads and flows predicted in the 10-year and 50-year return period rain events;*
> - *Calm and ENE winds; and*
> - *Existing situation, events under the 'long' construction and 'short' construction.*
>
> *In total, this amounted to 24 scenario model runs.*

The following modelling parameters were developed based on the analysis of rainfall events in the affected catchments and the requirements for similar projects:

- *Mean tidal range was modelled for the sediment input events;*
- *Peak flows during the rain events have a 5-6 hour duration – mid-tide up to full and back to mid-tide;*
- *One particle size was modelled (combined silt/clay), with the size fraction being provided by the GLEAMS modelling team at NIWA. NIWA undertook analysis of the sediment along the indicative PP-Wk alignment and compared it with data they have collected previously. Based on this analysis, NIWA's suggested particle size distribution (NIWA, April 2013) for catchment sediment loads was:*
    - *Clay (<3.9 μm) 26%;*
    - *Silt (3.9 – 63.0 μm) 56%;*
    - *Sand (63.0 μm – 2mm) 18%*
- *Wind speed of 9m/s was used with ENE wind event modelling; and*
- *The seabed deposition threshold was 10mm."*

Kaipara Harbour

Oruawharo Inlet

A literature review, site visit and interpretative assessment of the likely depth and extent of additional sediment input associated with the Project was undertaken by NIWA for the Oruawharo Inlet (NIWA, 2018 Kaipara Harbour Coastal Modelling and Effects Assessment). The methodology was based on existing information (Swales et al., 2011, Gibbs et al., 2012, Green et al., 2017) and expert opinion. An assessment of previous studies was made with an understanding of estuarine geomorphic processes and accompanied by a site visit of the upper Oruawharo River.

Hōteo Inlet

Coastal modelling to simulate the effect of increased sediment load in to the Hōteo Inlet was undertaken by NIWA. The following section is taken from the Assessment of Coastal Sediment.

"Tides, tidal currents, wind-driven currents, waves and sediment transport were modelled using the Delft3D / SWAN model suites. The Kaipara Harbour model was first established in 2012 as a two-dimensional model for an investigation commissioned by Auckland Council to inform sediment related management decisions and environmental management of the harbour. The model was developed into a calibrated three-dimensional cohesive sediment transport model with funding from Auckland Council and the NIWA Cumulative Effects research programme in 2013. The Kaipara Harbour has been used by Pritchard et al. (2012) and Pritchard et al. (2013), and recently by Reeve and Green (2016) and Green et al., (2017). A full description of the model suite including resolution, implementation and calibration in Kaipara Harbour is described by Pritchard et al. (2012) and Pritchard et al. (2013), consequently we do not comment on model correctness here.

The model comprises three model grids (Figure 3-1), which cover:

- *the northern harbour (Wairoa estuary) (shown in black in the Figure 3-1);*
- *the central harbour (Tasman Sea offshore, Kaipara Harbour entrance, Oruawharo River and Arapaoa River estuaries) (shown in blue in the Figure 3-1);*
- *the southern harbour (includes Hōteo and Kaipara estuaries) (shown in red in the Figure 3-1).*

The model grid resolution varies between sub-grids and topography. In the southern harbour near the mouth of the Hōteo River, grid resolution is typically 60 m x 120 m. This relatively coarse resolution is necessary for efficient computing the model domain encompassing the entire Kaipara Harbour."

For a more detailed description of the coastal modelling methodology for the Kaipara Harbour refer to the Assesment of Coastal Sediment Report.

2.2.9 Contaminant Load Model – operational phase

The Operational Water Design technical report (Jacobs, GHD 2019) contains details of the model used to assess the water quality during the operational phase, accounting for changes due to the State Highway runoff. The Water Assessment Report discusses modelling of contaminant loads and contaminant concentrations associated with the Project.

The contaminant load model (CLM) Version 2 is a spreadsheet-based model that has been developed by Council to enable estimations of stormwater contaminant loads on an annual basis. The CLM was developed and calibrated to estimate the annual loads, i.e. kilograms per year (kg/yr), for certain contaminants in stormwater from large, heterogeneous urban areas of the Auckland region. The CLM estimates contaminant loads for four water quality parameters:

- Total suspended solids (TSS);
- Total zinc;
- Total copper; and
- Total petroleum hydrocarbons (TPH).

The CLM is used for catchments that are predominately urban (i.e. greater than approximately 80% urban). The CLM user manual (Auckland Regional Council 2010) recommends that for rural catchments only the urban parts of the catchment be included in the model. Therefore, the loads calculated are relative rather than absolute; the CLM only models contaminant loads from the urban parts of the catchment (including roads) and ignores all the rural parts of the catchments and associated contaminants. The model uses traffic assumptions and measures of impervious areas including roads, derived from a geographic information system (GIS), as inputs to a spreadsheet-based model.

2.3 Assessment of Effects

2.3.1 Ecological Value

As part of our Assessment of Effects, we have assessed the Indicative Alignment, but also considered potential changes to the alignment (and design and location of ancillary components) within the proposed designation boundary.

Marine Ecology

In New Zealand, no regional or national guidelines or criteria for the assessment of marine ecological values have been developed to date. In the absence of such guidelines, we have adopted the approach described below to assess soft sediment marine ecological value (including species richness and diversity), as it was developed for and used and accepted in previous Board of Inquiry consenting processes for major roads.[6]

We have described marine ecological values in this report as ranging from very low to very high. Table 2 lists the characteristics we have used to guide our assessment of the ecological values of parts of the marine environment within the Project area. Due to the lack of assessment criteria and guidelines, our assessment of low, moderate and high benthic invertebrate species richness and diversity is based on our expert judgment and experience.

Table 2 - Characteristics of estuarine sites with very low to very high ecological values

Ecological value	Characteristics
VERY LOW	• Benthic invertebrate community degraded with very low species richness, diversity and abundance. • Benthic invertebrate community dominated by organic enrichment tolerant and mud tolerant organisms with no sensitive taxa present. • Marine sediments dominated by silt and clay grain sizes (>85%). • Surface sediment anoxic (lacking oxygen). • Elevated contaminant concentrations in surface sediment, above ISQG-high effects threshold concentrations[7]. • Invasive, opportunistic and disturbance tolerant species highly dominant. • Estuarine vegetation absent. • Habitat extremely modified.
LOW	• Benthic invertebrate community degraded with low species richness, diversity and abundance. • Benthic invertebrate community dominated by organic enrichment tolerant and mud tolerant organisms with few/no sensitive taxa present. • Marine sediments dominated by silt and clay grain sizes (>75%). • Surface sediment predominantly anoxic (lacking oxygen). • Elevated contaminant concentrations in surface sediment, above ISQG-high or AC-red effects threshold concentrations[8]. • Invasive, opportunistic and disturbance tolerant species dominant. • Estuarine vegetation provides minimal/limited habitat for native fauna. • Habitat highly modified.
MEDIUM	• Benthic invertebrate community typically has moderate species richness, diversity and abundance. • Benthic invertebrate community has both (organic enrichment and mud) tolerant and sensitive taxa present. • Marine sediments typically comprise less than 75% silt and clay grain sizes. • Shallow depth of oxygenated surface sediment. • Contaminant concentrations in surface sediment generally below ISQG-high or AC-red effects threshold concentrations. • Few invasive opportunistic and disturbance tolerant species present. • Estuarine vegetation provides moderate habitat for native fauna. • Habitat modification limited.
HIGH	• Benthic invertebrate community typically has high diversity, species richness and abundance. • Benthic invertebrate community contains many taxa that are sensitive to organic enrichment and mud. • Marine sediments typically comprise <50% smaller grain sizes.

[6] See evidence of Dr De Luca in Board of Inquiry Hearings for NZTA Projects: Pūhoi to Warkworth, Waterview Connection, Transmission Gully, and Mackays to Peka Peka, East West Link.

[7] ANZECC (2000) Interim Sediment Quality Guideline (ISQG) High contaminant threshold concentrations or Auckland Regional Council's Environmental Response Criteria Red contaminant threshold concentrations (Auckland Regional Council, 2004).

[8] ANZECC (2000) Interim Sediment Quality Guideline (ISQG) High contaminant threshold concentrations or Auckland Regional Council's Environmental Response Criteria Red contaminant threshold concentrations (Auckland Regional Council, 2004).

Ecological value	Characteristics
	• Surface sediment oxygenated. • Contaminant concentrations in surface sediment rarely exceed ISQG and AC ERC low effects threshold concentrations. • Invasive opportunistic and disturbance tolerant species largely absent. • Estuarine vegetation provides significant habitat for native fauna. • Habitat largely unmodified.
VERY HIGH	• Benthic invertebrate community typically has very high diversity, species richness and abundance. • Benthic invertebrate community contains dominated taxa that are sensitive to organic enrichment and mud. • Marine sediments typically comprise <25% smaller grain sizes. • Surface sediment oxygenated with no anoxic sediment present. • Contaminant concentrations in surface sediment significantly below ISQG and AC ERC low effects threshold concentrations. • Invasive opportunistic and disturbance tolerant species absent. • Estuarine vegetation sequences intact and provides significant habitat for native fauna. • Habitat unmodified.

Avifauna Ecology

For the purpose of the assessment of effects on the avifauna associated with the Project, ecological values have been assigned to the avifauna assemblages associated with the Mahurangi and Kaipara harbours. With regard to species, all New Zealand biota have been assessed by DOC against a standard set of criteria (described in Townsend *et al.,* 2008) and lists published for each taxonomic group (Robertson et al., (2017) for avifauna). This provides a consistent basis on which to assign ecological value for individual species (see Table 3).

Table 3 - Criteria for assigning ecological value to species (based on Table 5 in EIANZ (2018))

Ecological value	Characteristics
Negligible	• Exotic species, including pests, species having recreational value.
Low	• Nationally and locally common indigenous species.
Moderate	• Locally (ED) uncommon or distinctive species; or • Species listed as any other category of At Risk, found in the ZOI[9] either permanently or seasonally.
High	• Species listed as At Risk – Declining, found in the ZOI, either permanently or seasonally.
Very High	• Nationally Threatened species, found in the ZOI either permanently or seasonally.

[9] The 'zone of influence' (ZOI) refers to all land, water bodies and receiving environments that could be potentially impacted by the project. It includes the Project Site and any environments beyond the Project Area where 'indirect effects' such as discharges may extend (sometimes called the Study Area).

2.3.2 Magnitude of Effect

We have assessed the magnitude of ecological effects using the criteria from the EIANZ Impact Assessment guidelines (2018)[10]. The EIANZ guidelines describe the magnitude of effects on a scale of 'Very High' to 'Negligible', as set out in Table 4.

Table 4 - Criteria for describing effect magnitude

Magnitude	Description
Very High	• Total loss or very major alteration to key elements/ features of the baseline conditions such that the post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether; and/or • Loss of a very high proportion of the known population or range of the element/feature.
High	• Major loss or major alteration to key elements/ features of the baseline (pre-development) conditions such that post development character/ composition/ attributes will be fundamentally changed; and/or • Loss of a high proportion of the known population or range of the element/feature.
Moderate	• Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/composition/ attributes of baseline will be partially changed; and/or • Loss of a moderate proportion of the known population or range of the element/feature.
Low	• Minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible but underlying character/composition/attributes of baseline condition will be similar to pre-development circumstances/patterns; and/or • Having a minor effect on the known population or range of the element/feature.
Negligible	• Very slight change from baseline condition. Change barely distinguishable, approximating to the "no change" situation; and/or • Having negligible effect on the known population or range of the element/feature.

2.3.3 Level of Ecological Effects

We then assessed the level of ecological effects using ecological value (determined in Table 2 for marine ecology and Table 3 for coastal avifauna) and effect magnitude (Table 4) using the matrix in Table 5 as a guide. Where the resultant effect level is shown in bold (i.e.

[10] Noting that the EIANZ Guidelines primarily relate to terrestrial and freshwater ecosystems, as those ecosystems are well covered by ecological literature and have less complex legislative contexts than the coastal environment (Page 3 of the EIANZ Guidelines).

moderate, high or very high), effects are typically considered significant and mitigation is therefore required.

Table 5 - Matrix combining magnitude and value for determining the level of ecological impacts

Effect Level		Ecological and/or Conservation Value				
		Very High	**High**	**Moderate**	**Low**	**Negligible**
Magnitude	**Very High**	**Very High**	**Very High**	**High**	**Moderate**	Low
	High	**Very High**	**Very High**	**Moderate**	Low	Very Low
	Moderate	**High**	**High**	**Moderate**	Low	Very Low
	Low	**Moderate**	Low	Low	Very Low	Very Low
	Negligible	Low	Very Low	Very Low	Very Low	Very Low
	Positive	Net Gain	Net Gain	Net Gain	Net Gain	Net Gain

3 EXISTING ENVIRONMENT

Exisiting environment Summary

Mahurangi Harbour

The Mahurangi Harbour is a drowned river valley with an area of approximately 24 km^2, with vast intertidal flats (1,610 ha) and subtidal areas present in its middle to lower reaches. The harbour contains areas classified as SEA M1 and M2 in the AUP(OP), in addition to the entire harbour being recognised as an ASCV by DOC. Dense mangrove stands fringe the tidal flats of the upper estuary and side embayments. Estuarine vegetation including seagrass meadows provides significant habitat for native fish, birds and invertebrates. The water quality of the harbour has been ranked as excellent by Auckland Council. The concentration of common stormwater contaminants in surface sediment is typically below effects thresholds, the proportion of silt and clay is rarely greater than 50% and surface sediment is oxygenated.

Benthic invertebrate community species diversity and richness is high in middle and lower reaches of the harbour. Benthic invertebrate diversity is low in the upper harbour (upstream of Hamiltons Landing). A large range of fish and birds use the harbour, including several *Threatened* or *At Risk* bird taxa.

Various embayments within the harbour have been modified through the establishment of intertidal oyster farms and terrigenous sediment input.

We consider the Mahurangi Harbour to have high marine ecological values in the middle and lower reaches, and moderate marine ecological values in the upper reaches.

The Mahurangi Harbour is part of network of regionally important, moderate size, east coast estuaries that provide important habitat for international migratory bird species, New Zealand endemic wading birds and several species of cryptic marshbirds. The large majority of the species associated with the coastal environments of the Mahurangi Harbour are classified as Threatened or At Risk, and this area is considered to have very high coastal avifauna values.

Kaipara Harbour

Kaipara Harbour is the largest enclosed harbour/estuary in New Zealand. It is divided into three main peninsulas and has a total surface area of 947 km^2. The harbour is recognised as a Significant Ecological Area. The Indicative Alignment and associated earthworks runs through four major catchments (Kourawhero, Hōteo , Oruawharo and Maeneene) that drain in to the southern part of the Kaipara Harbour. The Kourawhero and Hōteo catchment then drain in to the Hōteo Estuarine Inlet, whilst the Oruawharo and Maeneene catchments drain in to the Oruawharo Estuarine Inlet. These inlets contain areas classified as SEA M1 and M2 in the AUP (OP).

The upper intertidal zone contains vegetation sequences consisting of mangrove forest and shrubland, various indigenous saltmarsh and exotic grassland and rushland species. Vast areas of shallow intertidal mud and sandflats exist, which, along with mangrove and saltmarsh, provide important habitat for a number of avifauna species. Some of these avifauna species are *Threatened* or *At Risk*.

Kaipara Harbour has vast seagrass meadows that support a wide variety of fish, invertebrates and birds. These meadows provide important ecosystem functions such as stabilising sediment, nutrient cycling, provision of primary productivity as well as habitat.

The Kaipara Harbour has significant channel environments with healthy shellfish communities, which provide significant nursery areas for range of fish species including snapper, rig, and great white shark (protected under the Wildlife Act 1953 and an IUCN red listed species). The harbour is also recognised as an important area for the protected maui dolphin.

The water quality of the harbour has been ranked as excellent by Auckland Council. The concentration of common stormwater contaminants in surface sediment is typically below effects thresholds. The proportion of silt and clay is rarely greater than 50%, whereas surface sediment has a low oxygenation depth.

We collected samples from sites located within the upper reaches of the harbour in areas where sediment discharged from the Project may deposit after large rainfall events. Auckland Council recently surveyed the lower reaches of the harbour and we have incorporated that data into our assessment.

Benthic invertebrate community species diversity and richness is low in the middle and lower reaches of the harbour, and moderate in the upper harbour (Oruawharo River and Hōteo River), mainly due to the abundance of a number of mud tolerant species.

The harbour has been modified through the establishment of intertidal oyster farms, dredging, mangrove removal and the invasion of *Spartina anglica* within various embayments.

We consider the Kaipara Harbour to have high marine ecological values in the middle and lower reaches, and moderate marine ecological values in the upper reaches.

The Kaipara Harbour provides extensive high value habitat for thousands of international migratory bird species, New Zealand wading birds and several species of cryptic marshbirds. The large majority of the species associated with the coastal environments of both the Kaipara Harbours are classified as Threatened or At Risk, and as such the areas is considered to have very high coastal avifauna values.

3.1 Overview of Catchments

The Indicative Alignment passes through three major catchments; Mahurangi River, Hōteo River and Oruawharo River (Drawing No. ME-011-013 and ME-001).

1. The alignment starts within the Mahurangi River catchment in the south. This is the main tributary of the Mahurangi Estuary, a long estuary flowing southwards from Warkworth on the Hauraki Gulf. There are many small bays and estuaries along the sides of the estuary with two larger arms to the south. Many of the small bays and upper estuaries dry during the tidal cycle and are comprised of soft muddy sediment.

2. The alignment then passes through the Hōteo River catchment, the largest of the three main catchments. The Hōteo River Catchment drains in a south westerly

direction to the southern part of the Kaipara Harbour, a large enclosed harbour estuary located on the west coast. The Kaipara Harbour is a complex drowned-valley enclosed estuary on the west coast of the Northland peninsula (Gibbs et al., 2012). The harbour is composed of intertidal flat and shallow sub-tidal habitats with deep channels following historic rivers. Sand barriers form north and south heads as well as tidal deltas, beach and dune systems.

3. The Indicative Alignment continues north through Te Hana Creek and Maeneene Creek, tributaries of the Oruawharo River, an estuarine river which flows in to the Kaipara Harbour.

3.2 Mahurangi Harbour

Mahurangi Harbour is a drowned river valley, has an area of approximately 24 km^2, with intertidal mudflats and sandflats occurring over approximately 1,610 ha (Further North 2013).

3.2.1 Marine/Estuary Statutory Planning and Context

The Auckland Unitary Plan (operative in part) (AUP (OP)) has identified Significant Ecological Areas (SEA) within the marine environment of both the Mahurangi and Kaipara Harbours. The two levels of marine SEAs, SEA-M1 and SEA-M2 are described in Schedule 4 (Significant Ecological Areas – Marine Schedule) of the AUP (OP), as follows:

> *"SEA-M1 include those areas which, due to their physical form, scale or inherent values, are considered to be the most vulnerable to the adverse effects of inappropriate subdivision, use and development."*
>
> *"SEA-M2 are areas are of regional, national or international significance which do not warrant an SEA-M1identification as they are generally more* robust."

Marine SEAs that are identified as significant wading bird areas are denoted SEA-M1w or SEA-M2w accordingly.

The Mahurangi Harbour contains SEA-M1 and SEA-M2 areas. The main body of the harbour is SEA-M2 (76a) and the mouth of the Mahurangi River, Hamiltons Landing and Te Kapa River, (76 b-j, p), Dryers Creek (76f) plus adjacent to the headland at Cudlip Point (76k) and Big Bay (76l) and Saddle Island (76l) are recognised as SEA-M1. The upper reaches of the Mahurangi Harbour are depositional muddy flats.

Chapter L Schedule 4 of the AUP (OP) contains a description of the ecological values of the SEA-M1 and SEA-M2 areas identified in the Mahurangi Harbour. The relevant sections of Schedule 4 have been extracted from the Plan and are contained in sections below.

> ***SEA-M2-76a Mahurangi Harbour Intertidal flats:*** *"The Mahurangi Harbour is a classic example of a ria or drowned coastline. Within the harbour there are large areas of intertidal mud and sand. Outside of the mouth of the harbour there are a variety of more exposed shores ranging from broad rock platforms to small sandy beaches. This physical variety provides a similarly varied range of habitats for an assortment of animal and plant communities. The large sheltered harbour is one of the best wading bird habitats in the Rodney ecological district, with banded rail and godwit recorded. The northern and upper reaches of the harbour contain intact sequences from mangroves to terrestrial forest. There are also*

significant areas of fringing pohutukawa forest on Mahurangi East peninsula and Mahurangi Regional Park. The Department of Conservation has selected the inner harbour area as an Area of Significant Conservation Value (ASCV). The former Auckland Regional Council (now Auckland Council) has undertaken a long-term environmental and water quality monitoring of the harbours intertidal and subtidal benthic communities since 1984. The Mahurangi Action Plan was set up in 2004 in response to indications that the water quality of the harbour was in decline, due to increased sedimentation."

SEA-M1-76b-j, p Mangroves: *"In the shelter of the harbour grow extensive areas of mangroves. Some of these areas are judged to be amongst the best in the district (76b-j, 76p). The saline vegetation provides high quality habitat for threatened secretive coastal fringe birds particularly where it abuts terrestrial vegetation which provides roosts for the birds and potential nesting sites. There are significant ecological sequences from mangroves into terrestrial forest in the upper Mahurangi River areas. Mangroves at the river margin grade through puriri, kowhai and taraire forest to stands of young kauri and totara."*

SEA-M1-76f Dyers Creek: *"At Dyers Creek, a large expanse of mangroves adjoins a highly diverse and large area of regenerating coastal kauri – tanekaha forest on lowland hills."*

SEA-M1-76k Cudlip Point: *"At Cudlip Point, the moderately exposed rock platforms grade into an important area of regenerating totara forest on a headland or peninsula."*

SEA-M1-76l Big Bay: *"At Big Bay, the representative open rocky Hormosira[11] flats, boulders, and rock pools and the open fine sandy shores grade into a coastal complex forest of pohutukawa, taraire, kohekohe, mahoe, puriri and kowhai on cliffs and hillslopes. This type of forest is now relatively uncommon on the mainland."*

SEA-M1-76m, n Saddle Island: *"The marine area around Te Haupa (or Saddle) Island (76m, n) supports a particularly rich and diverse biota. Here too there are gradations between the marine and terrestrial ecosystems."*

SEA-M2w-76w1, 3 Wading Bird Habitat: *"See 76a Extensive intertidal feeding habitat for waders in this harbour."*

SEA-M1w-76w2, 4, 5, 6 Wading Bird Habitat: *"See 76g, i, j Extensive intertidal feeding habitat for waders along this coastline."*

Other regional ecological values

Other regional ecological values within Mahurangi Harbour have been described in the Further North (2013) Marine Ecology Assessment and detailed below.

"DOC has recognised almost the entire Mahurangi Harbour as an Area of Significant Conservation Value (DOC, 1994). The harbour contains a diversity of coastal habitat zones including rocky shorelines, sandy beaches, extensive mudflats, mangroves, saltmarsh and adjacent coastal forest. The area is regionally important for the collection of oyster spat."

[11] Neptune's necklace

Non-statutory documents
The Mahurangi Action Plan (2011) describes the values and vision for the harbour and identifies sediment as the key priority in the catchment. The plan contains a number of actions to be taken to reducing sediment generation including riparian management (retiring, fencing and replanting), planting shoreline margins, planting stream margins and steep hills.

3.2.2 Benthic Marine Invertebrates

The benthic marine invertebrates[12] within Mahurangi Harbour have been described in the Further North (2013) Marine Ecology Assessment and detailed below.

Literature Review
Auckland Council has been conducting surveys of the benthic macrofaunal communities at six intertidal sites (Cowan Bay (CB), Dyers Creek (DC), Hamiltons Landing (HL), Jamieson Bay (JB), Mid Harbour (MH), and Te Kapa (TK)) in Mahurangi Harbour since 1994 (see map within Appendix A). The survey strategy has developed over time and a range of intertidal taxa have been identified as being the most important to monitor for presence, abundance and community structure (Halliday & Cummings, 2012). We have analysed the most recent data (collected by Auckland Council in April 2017 and Further North, 2013), and present this data in Figure 3 to Figure 7 below.

Our literature review identified that the following five species, detected by Halliday & Cummings (2012) in Mahurangi Harbour, are sensitive to increased suspended sediment concentration: the bivalve species wedge shell, cockle, and nut shell, the gastropod *Notoacmea scapha* and the polychaete *Scoloplos cylindrifer* (Auckland Council, 2012).

Swales et al., (1997) reported increasing sedimentation at Hamiltons Landing, and Halliday & Cummings (2012) noted large changes in the abundance of taxa at that site. Halliday & Cummings (2012) attributed the decrease in abundance of the more sensitive species to the sediment at the site being largely muddy and the faunal communities potentially being at their ‘threshold’ for survival. The authors also noted increases in stress-tolerant or sediment tolerant species such as the polychaete worms *Cossura consimilis* and *Aricidea sp.* at Hamiltons Landing.

Overall, Halliday & Cummings (2012) concluded that the long-term trends in macrofaunal populations and communities at both intertidal and subtidal sites remained relatively similar in the period 1994 to 2011, apart from Hamiltons Landing.

Abundance – individuals
The average abundance of benthic infauna was highest at one of the upper harbour sites (IMO) (approximately 117), and HL (approximately 103) (Figure 3). Lowest abundances were detected at the upper harbour site IM1 (a little over 20 individuals per sample) (Figure 3). The high abundance at site IM0 located downstream of Warkworth township was primarily due to high numbers of oligochaete worms (80-90% of organisms detected in each replicate core were oligochaetes).

[12] Appendix C provides a description of the tolerance and sensitivity of benthic invertebrate species detected (where research data exists).

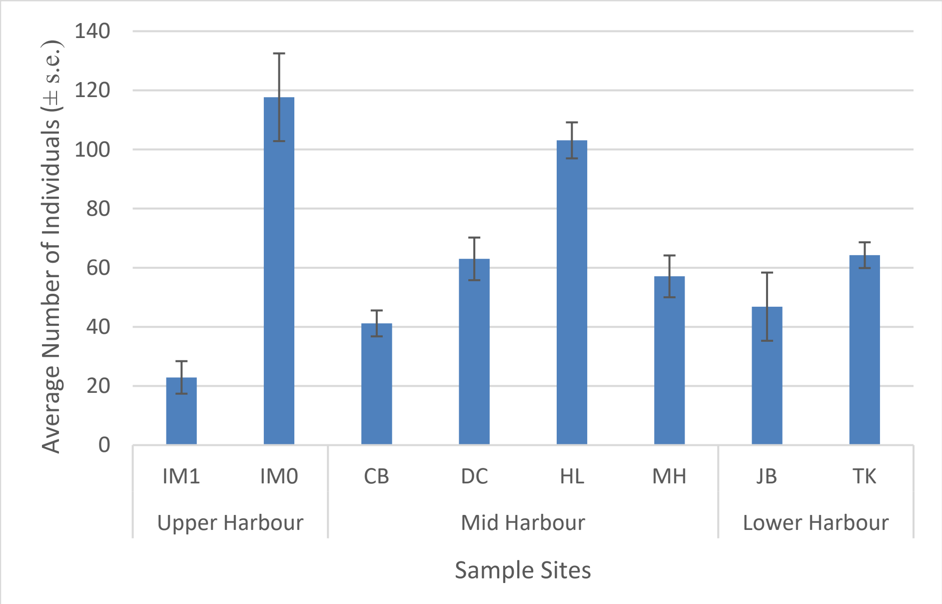

Figure 3 - Average number of benthic infauna (± s.e.) per core sample at each survey site

Diversity of taxa

We analysed the abundance of main taxa groupings. As shown in Figure 4, oligochaetes and polychaete worms (many species of which are tolerant of disturbance and high proportions of silt and clay) dominate in the upper harbour areas and side arms of the Mahurangi Harbour (HL, IM0, IM1). There is a lower abundance of bivalves (many species of which are sensitive to disturbance and cannot tolerate high proportions of silt and clay) in these areas of the harbour (Figure 4).

The upper harbour site (IM1) adjacent to Vialls Landing has a low abundance of organisms and different composition to most of the other sites (oligochaete and polychaete worms, and bivalves are the dominant benthic invertebrate groups), which is typical of highly depositional upper estuary habitats. Site IM0, located downstream of Warkworth township, had the highest abundance of oligochaete worms, in addition to numerous other tolerant taxa including amphipods, mud crab, and several species of tolerant polychaete worms.

Of the common kai moana species, adult cockles were abundant at some sites e.g. Dyers Creek, Te Kapa and Jamieson Bay (Halliday & Cumming, 2012).

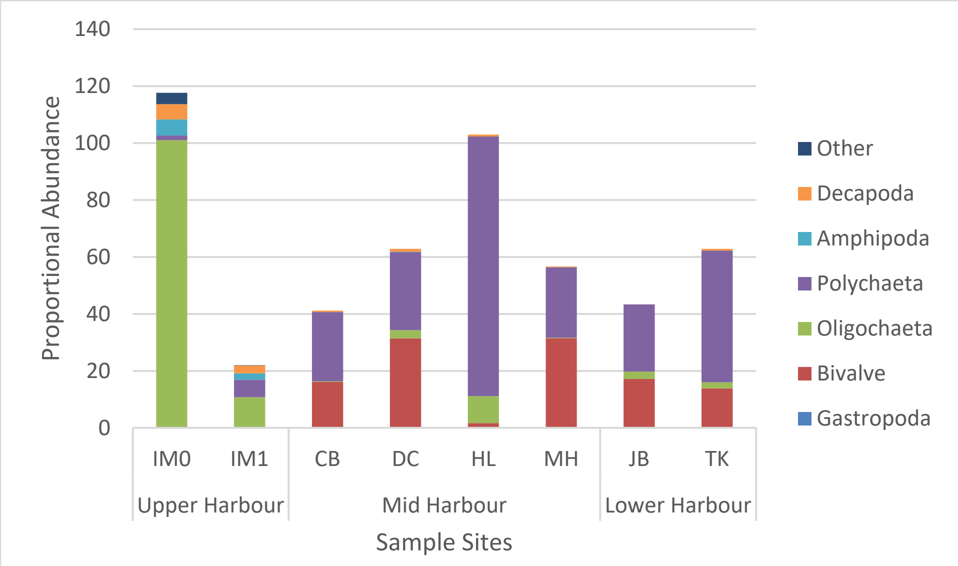

Figure 4 - Average proportion of main benthic infaunal taxa groups per core sample at each survey site

The average number of taxa per sample was highest at Dyers Creek (DC) (located intertidally within the central part the harbour, with approximately 9.5 taxa per sample). The lowest average number of taxa per sample was at sites IM1 and IM0 (approximately 4-5 taxa per sample), located in the upper reaches of the harbour **(**Figure 5). The number of taxa in samples from intertidal sites in the mid to lower parts of the harbour (sites CB, DC, HL, MH, JB and TK) was approximately between 6 and 8 (Figure 5**).**

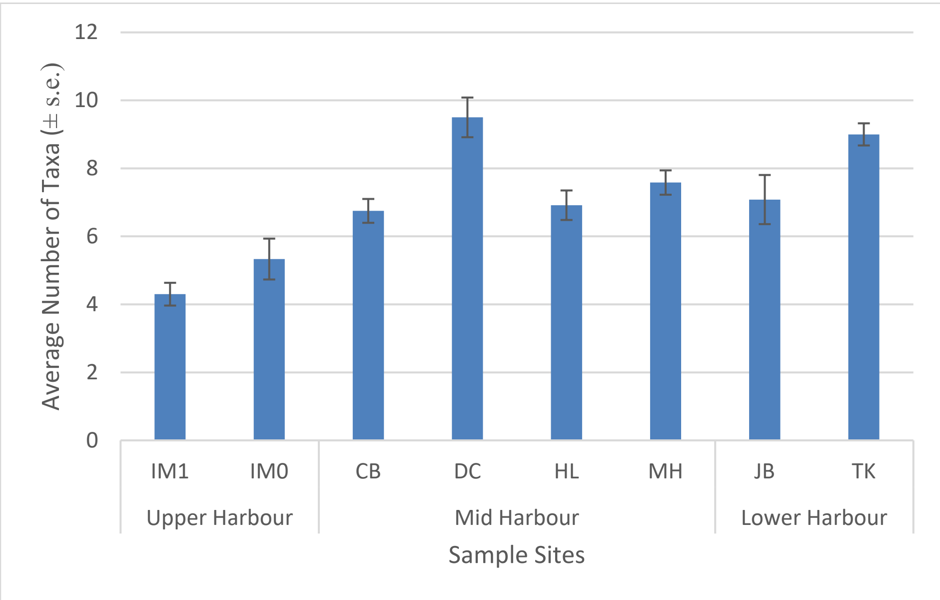

Figure 5 - Average number of taxa (± s.e.) per core sample at each survey site

The Shannon-Wiener diversity index was lowest at the three sites located in the upper harbour depositional area, with all three sites below 1.5: site IM0 (approximately 0.6), site IM1 (approximately 1.1) and Hamiltons Landing (approximately 1.2). The diversity index at the remaining intertidal sites ranged between approximately 1.4 and 1.7, indicating moderate species diversity (Figure 6).

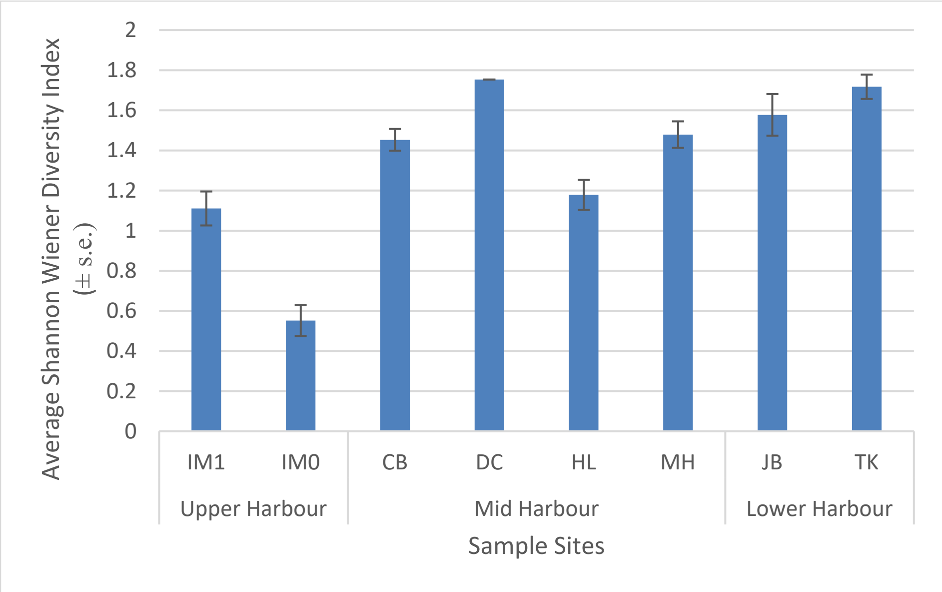

Figure 6 - Average Shannon Weiner diversity index (± s.e.) per core sample at each survey site

The MDS plot of intertidal benthic invertebrate community composition data shows a clear difference in assemblage between the upper harbour sites (IM0 and IM1) and the remaining intertidal sites (Figure 7).

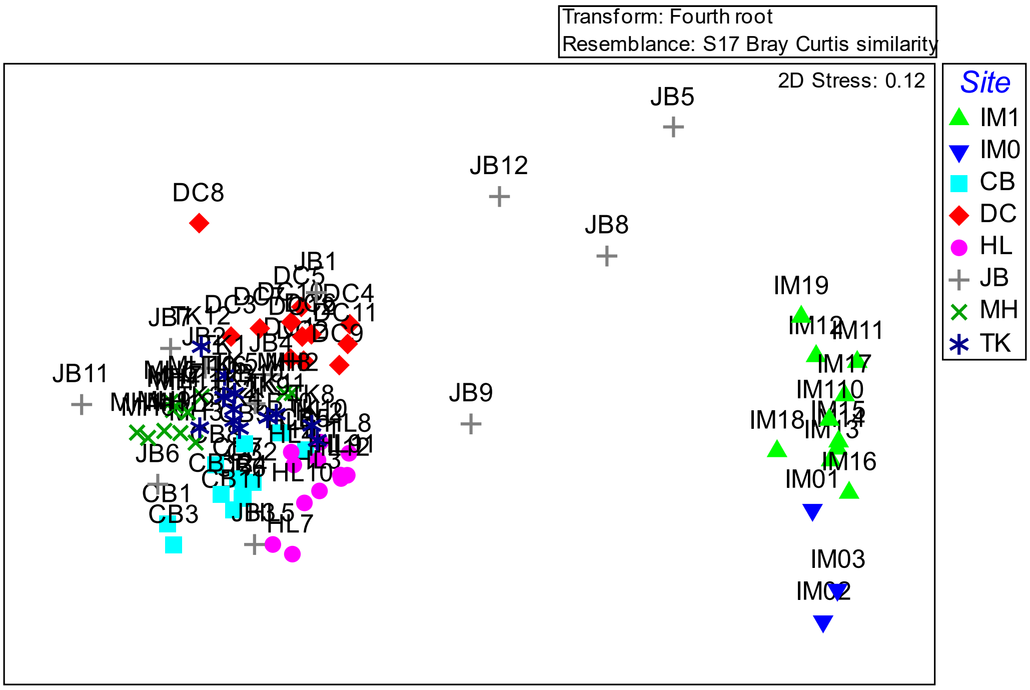

Figure 7 - nMDS plot of intertidal benthic infaunal community composition

3.2.3 Epifauna

Very few epifaunal species were observed within Mahurangi Harbour (refer to Appendix B for quadrat photographs). The most abundant epifaunal taxa present was mud crab, as evidenced by the presence of crab burrows. The average number of crab burrows per $0.25m^2$ quadrat was 44.3. Mud whelk was also observed at site IM8 (Dyers Creek). A low diversity in epifaunal species is typical of muddy intertidal habitat such as that observed within the Mahurangi Harbour.

3.2.4 Fish

The most up to date description of fish within Mahurangi Harbour has been described in the Further North (2013) Marine Ecology Assessment and detailed below.

> *"Morrison and Carbines (2006) report the diversity of fish in Mahurangi Harbour as modest, with a small number of common estuarine species accounting for over 90% of total fish numbers. The most common species detected include exquisite gobies (Favonigobius exquisitus), snapper (Pagrus auratus), yellow-eyed mullet (Aldrichetta forsteri), anchovy (Engraulis australis), jack mackerel (Trachurus novaezelandiae), red mullet (Upeneichthys lineatus) and mottled triple-fin (Grahamina capito). Parore (Girella tricuspidata), spotted dogfish (Mustelus lenticulatus), eagle ray (Myliobatus tenuicaudatus) and hammerhead shark (Sphyrna zygaena) were also detected (Morrison and Carbines, 2006).*
>
> *Other species that may be periodically present in Mahurangi Harbour include flounder (Rhombosolea plebeia), sole (Peltorhamphus latus), kahawai (Arripis trutta), trevally (Pseudocaranx dentex), red cod (Pseudophycis bachus), short-tailed stingray (Dasyastis brevicaudatus), long-tailed stingray (D. thetid), shortfin eel (Anguilla australis), longfin eel (A. dieffenbachii), and inanga (Galaxias maculatus) (NIWA, 2013; Francis et al., 2011; Morrisey et al., 2007; Thrush et al., 1991). Longfin eel, shortfin eel and inanga were detected in streams and rivers that discharge into the Mahurangi and are also likely to use parts of the harbour at various times of the year during migration and spawning periods.*
>
> *During benthic invertebrate and sediment quality field surveys for the Pūhoi to Warkworth resource consent application (Further North, 2013), fish species observed (but not surveyed) in the lower reaches of the harbour near Scott's Landing and the mouth of Pukapuka Inlet included snapper, mullet and kahawai.*
>
> *The Mahurangi Harbour has a large population (166,000 ± 28,000 s.e.) of snapper in a common size range (Morrison and Carbines, 2006). Juvenile snapper were frequently found adjacent to horse mussel beds, which have been previously identified predominantly in the middle to lower subtidal regions of the harbour. Juvenile snapper feed mainly on copepods, shrimp and polychaete worms, while adults consume brachyuran crabs, shrimps, bivalves, polychaete worms and hermit crabs, and occasionally harder shelled molluscs and bivalves (Usmar, 2009). During the benthic invertebrate and sediment quality field surveys carried out for the Pūhoi to Warkworth resource consent application (Further North, 2013) a stingray and an eagle ray were observed. Though no targeted survey has been undertaken, it is expected that stingrays may use the extensive intertidal flats within the Mahurangi Harbour as a feeding ground during high tide (Thrush et al., 1994)."*

3.2.5 Coastal Avifauna

Over 70 avifauna species were recorded within the 200 km^2 area of the two grid squares (Appendix D). Of those species, coastal and/or estuarine habitat provides primary or secondary habitat for approximately 30 species (refer to Appendix D for habitats), most of which (70%) are classified as At Risk or Threatened (Table 6).

Table 6 - At Risk or Threatened bird species associated with the coastal / estuarine environment recorded by OSNZ squares for the Mahurangi and Kaipara harbours

Species	NZ Threat Classification (Robertson et al., 2017)	Mahurangi squares	Kaipara squares
Australasian bittern	Threatened - Nationally Critical	✓	✓
Black stilt	Threatened - Nationally Critical		✓
Black-billed gull	Threatened - Nationally Critical	✓	✓
NZ fairy tern	Threatened - Nationally Critical		✓
White heron	Threatened - Nationally Critical	✓	✓
Reef heron	Threatened - National Endangered	✓	✓
Banded dotterel	Threatened - Nationally Vulnerable	✓	✓
Caspian tern	Threatened - Nationally Vulnerable	✓	✓
Lesser knot	Threatened - Nationally Vulnerable	✓	✓
Wrybill	Threatened - Nationally Vulnerable	✓	✓
Banded rail	At Risk - Declining	✓	✓
Eastern bar-tailed godwit	At Risk - Declining	✓	✓
North Island fernbird	At Risk - Declining	✓	✓
Northern blue penguin	At Risk - Declining	✓	
NZ pied oystercatcher	At Risk - Declining	✓	✓
Red-billed gull	At Risk - Declining	✓	✓
White-fronted tern	At Risk - Declining	✓	✓
Northern NZ dotterel	At Risk - Recovering	✓	✓
Pied shag	At Risk - Recovering	✓	✓
Variable oystercatcher	At Risk - Recovering	✓	✓
Black shag	At Risk - Naturally Uncommon	✓	✓
Little black shag	At Risk - Naturally Uncommon	✓	✓
Royal spoonbill	At Risk - Naturally Uncommon	✓	✓
Spotless crake	At Risk – Relict	✓	✓
Australasian gannet	Not Threatened	✓	
Black swan	Not Threatened	✓	✓
Black-backed gull	Not Threatened	✓	✓
Grey teal	Not Threatened		✓
Little shag	Not Threatened	✓	✓
NZ scaup	Not Threatened		✓
NZ shoveler	Not Threatened	✓	✓
Pied stilt	Not Threatened	✓	✓
White-faced heron	Not Threatened	✓	✓
Australasian little grebe	Coloniser		✓

Species	NZ Threat Classification (Robertson et al., 2017)	Mahurangi squares	Kaipara squares
Eastern curlew	Migrant		✓
Turnstone	Migrant		✓
Whimbrel	Migrant		✓

Of the avifauna species which utilise coastal and/or estuarine environment a number of these species feed on marine/estuarine invertebrates and this include banded dotterel, banded rail, Eastern bar-tailed godwit, lesser knot, Northern NZ dotterel, red-billed gull, reef heron, royal spoonbill, variable oystercatcher and wrybill (Heather & Robertson, 2000). For the majority of the species listed in Table 6, the Mahurangi Harbour is likely to form a part of a wider network of coastal and estuarine habitats that they use depending on the time of year and tidal sequence.

As noted in Section 3.2.1, there are several areas identified within the Mahurangi Harbour as SEAs due to their wading bird habitats, namely the extensive intertidal feeding habitat for waders in the harbour (SEA-M2w-76w1, 3) and along the coastline (SEA-M1w-76w2, 4, 5, 6). The estuary is part of network of regionally important, moderate size, east coast estuaries that provide important habitat for wildlife, such as banded rail, Caspian tern, Australasian bittern, NZ dabchick, variable oystercatcher, and North Island fernbird (Green, 1990; Bell, 1986; cited within DoC, 1994).

3.2.6 Sediment Grain Size

Sediment grain size within Mahurangi Harbour has been described in the Further North (2013) Marine Ecology Assessment and detailed below.

Sediment grain size distribution is related to both the benthic invertebrate community composition and the concentration of contaminants in sediment. Harbours/estuaries with a high proportion of silt and clay typically have corresponding high concentrations of contaminants in the <63μm fraction. This is due to contaminants bind ing to small organic particles. Sediment with a high proportion of silt and clay is usually characterised by a tolerant and less diverse suite of organisms.

Sediment grain size data was collected Auckland Council at intertidal sites in the Mahurangi Harbour. The locations of their survey sites are shown in Appendix A and the percent sediment composition for each site surveyed is presented below in Figure 8 (Hailes & Carter, 2015). Figure 9 (Further North, 2013) shows that fine sand dominates the sediment grain size distribution at intertidal sites, with Dawsons Creek having the highest average percent composition of fine sediments (87%) and Hamiltons Landing the lowest (52%) (Figure 9). Within the intertidal sites surveyed, silt and clay comprise between 9% (at Jamieson Bay) and 66% (at Hamilton's Landing) of the total sediment composition. Medium sand comprised between 30% and 40% across all sites. Coarser sediments, including coarse sand and gravel/shell hash form a small component of the sediment composition at intertidal sites.

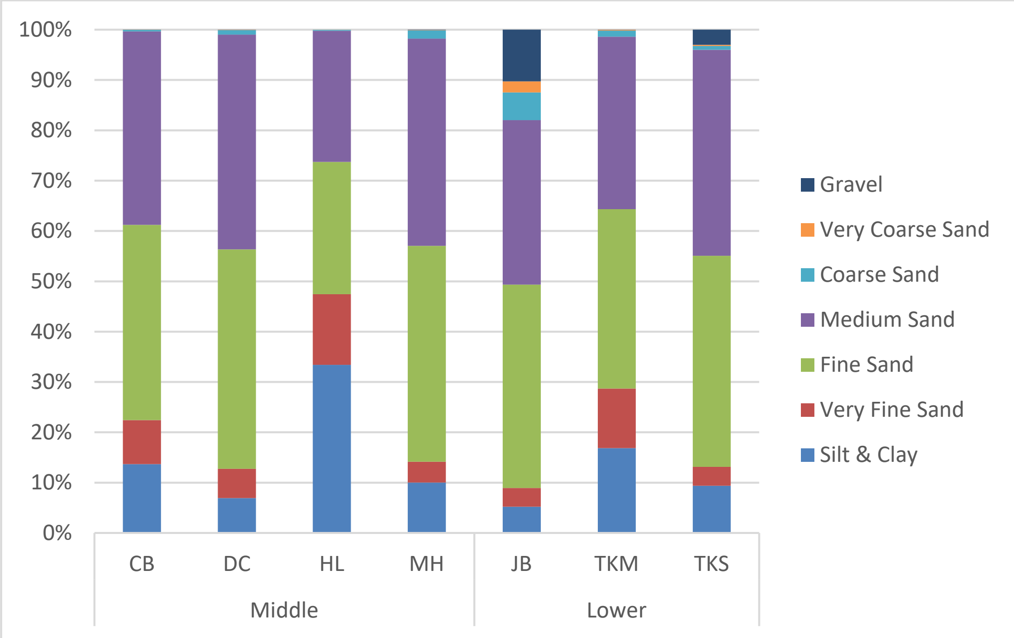

Figure 8 - Proportion of sediment grain size composition in surface sediment from survey sites within Mahurangi Harbour (Hailes & Carter, 2015)

Where freshwater meets denser saltwater, vertical circulation patterns are created, which churn up sediments and lead to higher sedimentation in upper reaches of the harbour compared to middle and lower reaches of the harbour where freshwater inflow has less influence. This higher sedimentation is clearly seen at Hamilton's Landing, which Swales et al., (2002) state is an area of high turbidity and has been an area of rapid sedimentation over 150-years. In the upper harbour the dense mangrove stands also influence the deposition of sediment (Swales et al., 1997).

Swales et al., (1997) calculated historic accretion rates for the Harbour between 1905 and 1975. In the lower harbour the accretion rate was estimated at 10 mm/year, while in the middle reaches, near Hamiltons Landing, the sediment accretion rate was much higher at 40 mm/year. Near the harbour mouth there has been relatively little accretion, most likely due to flushing and tidal exchange.

Intertidal sediment grain size distribution obtained from the 2015 survey (Hailes & Carter, 2015) was similar to that reported in Halliday & Cummings (2012), with silt and clay ranging between approximately 20-55%. However, in the Further North (2013) study, sites IM0, IM1a and IM1b located in the upper harbour had greater than 50% silt and clay, as did site IM6, which is located within a sheltered Inlet. Site IM0 located immediately downstream of Warkworth township had greater than 80% silt and clay. There is a clear trend of upper harbour depositional sites being characterised by a higher proportion of silt and clay sediment grain size (Figure 9).

The 2017 proportion of silt and clay at subtidal sites was similar to those detected by Halliday & Cummings (2012), with the highest proportion (approximately 48%) at site SM3 (Figure 9).

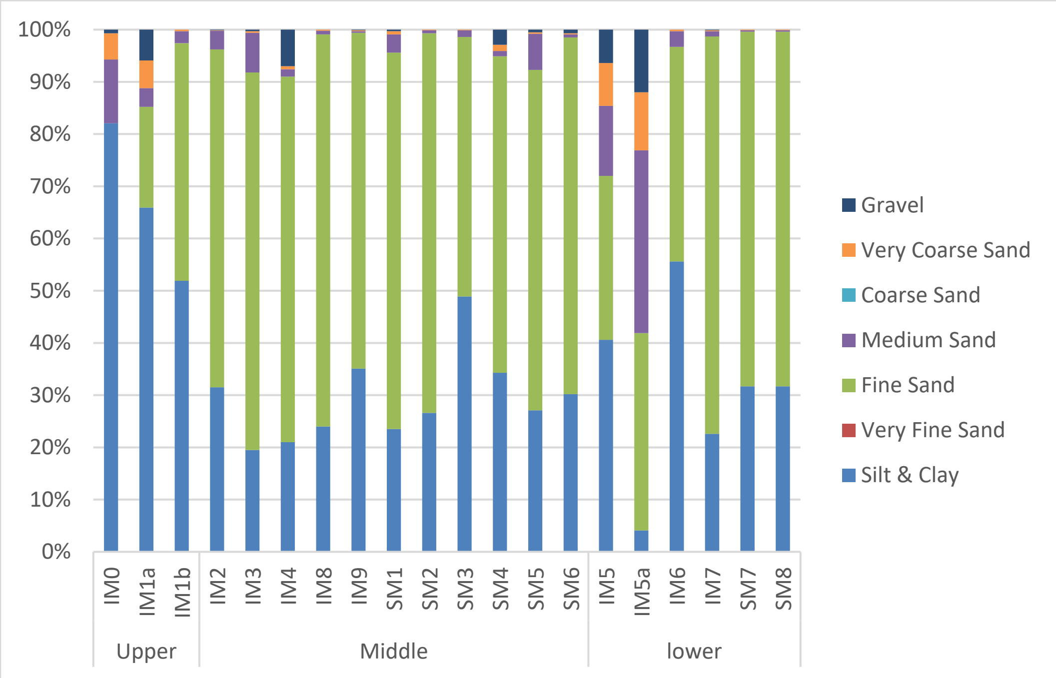

Figure 9 - Proportion of sediment grain size composition in surface sediment from survey sites IM and SM within Mahurangi Harbour (Further North, 2013)

3.2.7 Sediment Contaminants

A description of sediment contaminants within Mahurangi Harbour has been described in the Further North (2013) Marine Ecology Assessment and detailed below.

> *"...Intertidal sediment quality monitoring data from the Mahurangi (Halliday & Cummings, 2012) and that of a previous study by Gibbs (2004) indicated that copper, lead, zinc and HMW-PAHs were below effects thresholds at all sites within the Mahurangi. Contaminants are known to bind to finer particles and often a higher concentration is found within the <63µm fraction of sediment (mud) sampled or in samples with a high mud content. The concentration of metals in the fine sediment (<63µ m) fraction was higher than in the coarser sediment (>500µ m) fraction at almost all sites and for all contaminants where data is available. Sediment analysed from Jamieson Bay in 2013 indicated a concentration of HMW-PAHs approaching the ERC amber threshold..."* (refer to Table 7).

> *"...The concentration of metals and HMW-PAHs detected in the 2013 Further North survey in intertidal surface sediment was low at most sites, both in the total sediment[13] and the <63µ m fraction[14].*

> *Copper was detected in the >63µ m fraction in the amber ERC range at Vialls Landing (IM1a) (25.5 mg/kg) and Jamiesons Bay (IM6) (24.0 mg/kg), and above both the ERC red and the ISQG-Low thresholds in total sediment at Vialls Landing*

[13] Sediment sample as received by laboratory. Metals: total recoverable digestion nitric/hydrochloric acid digestion. ICP-MS, trace level. US EPA 200.2; PAHs: Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C.

[14] Sediment sample wet sieved through <63µm sieve. Metals: nitric/hydrochloric acid digestion. ICP-MS, trace, US EPA 200.2; PAHs: Sonication extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C.

(IM1a) (108 mg/kg) (refer to *Table 8). There is a large boat mooring area adjacent to Jamiesons Bay, and at Vialls Landing boats are currently (and were historically) stored and hauled out. It is likely that there is widespread copper contamination in estuarine sediment, particularly in the upper reaches, of the Mahurangi Harbour from anti-fouling of boat hulls arising from the historic and current boating activities.*

The concentration of copper was close to the AC ERC amber threshold (19 mg/kg) within both the <63µm and total fraction of sediment at IM1b located in the upper harbour and, to a lesser extent, site IM5a (15.8 mg/kg in total and 14.1 in <63µm fraction) located within mangrove habitat in the Te Kapa Inlet. At most of the other intertidal sites, the concentration was less than half the amber threshold. These results (excluding data from site IM1a) are similar to those of Halliday & Cummings (2012), whilst we recognise that different grain size fractions were analysed.

*The concentration of metals and HMW-PAHs at the subtidal sites that were surveyed was below the ERC amber threshold at all sites, in both total sediment and <63*µ*m fraction (Table 8). These results are consistent with Halliday & Cummings (2012).*"

Table 7 - Intertidal sediment contaminant concentrations in the Mahurangi Harbour

		Halliday & Cummings, 2012 and 2017 (bold)						Gibbs, 2004		Further North, 2013											
	Sediment Fraction	CB	DC	JB	HL	MH	TK	H3	M3	IMO	IM1a	IM1b	IM2	IM3	IM4	IM5	IM5a	IM6	IM7	IM8	IM9
Cu (mg/kg)	Total	3.0	**2.7**	**6.88**	**66.3**	**4.2**	5.55	13.5	14.6	25	108	18.5	8.8	6.3	5.0	5.9	15.8	6.0	6.2	3.6	4.0
	<63 µm	6.7	8.0	15.9	8.3	7.8	6.6	No data	No data	18.4	25.5	18.6	13.3	13.7	11.2	13.3	14.1	24.0	9.3	12.1	11.7
Pb (mg/kg)	Total	3.5	**22.1**	**5.55**	**5.88**	**3.66**	**33.9**	8.03	8.98	9.9	10.8	8.5	5.8	5.6	3.5	4.1	7.5	5.9	5.0	3.2	3.2
	<63 µm	6.2	6.2	11.1	7.5	7.3	5.5	No data	No data	72	10.2	10.0	9.1	8.3	8.1	9.7	8.5	18.7	7.5	7.8	9.6
Zn (mg/kg)	Total	30.0	**17.99**	**37.272**	**333.3**	**31.77**	**32.44**	51.8	57.1	84	93	59	38	31	34	35	52	32	32	21	24
	<63 µm	37	39.3	51.7	42.3	40.0	37.7	No data	No data	72	63.5	66	56	56	54	61	56	47	47	51	52
HMW PAHs (mg/kg)	Total	No data	No data	0.53	0.08	No data	No data	No data	No data	0.006	0.015	0.012	0.019	0.021	0.016	0.006	0.006	0.538	0.029	0.014	0.013
	<63 µm									0.003	0.017	0.013	0.012	0.014	0.015	0.012	0.012	0.015	0.011	0.016	0.012

Table 8 - Subtidal sediment contaminant concentrations in the Mahurangi Harbour (Further North, 2013)

	Sediment Fraction	SM1	SM2	SM3	SM4	SM5	SM6	SM7	SM8
Cu (mg/kg)	Total	5.1	5.8	3.5	7.4	6.1	5.3	5.6	4.8
	<63µm	10.7	12.0	9.4	10.7	11.4	11.4	11.3	10.7
Pb (mg/kg)	Total	5.1	4.1	3.3	6.5	5.1	3.4	4.6	3.2
	<63µm	8.3	7.3	7.1	8.6	7.4	7.8	8.9	7.6
Zn (mg/kg)	Total	42	28	27	42	44	33	36	31
	<63µm	49	46	40	47	45	48	53	45
HMW PAHs (mg/kg)	Total	0.030	0.017	0.035	0.043	0.008	0.012	0.009	0.015
	<63µm	0.015	0.015	0.020	0.015	0.012	0.013	0.025	0.031

3.2.8 Water Quality

Water quality monitoring undertaken by Auckland Council in the Mahurangi Harbour indicates that the estuary has good to excellent water quality with most parameters being below guidelines (Vaughan & Walker, 2015). Mahurangi Heads had excellent water quality, having the highest possible water quality index of 100 (Vaughan & Walker, 2015). Dawson's Creek had good water quality with a water quality index of 78.3. Little change has been observed at these sites over time and they have remained good to excellent. Auckland Council (2012) rated the estuary as having excellent water quality overall.

3.3 Kaipara Harbour

The Kaipara Harbour covers and area of 947 km^2, of which 407 km^2 (40,721 ha) is intertidal.

3.3.1 Marine/Estuary Statutory Planning and Context

Hōteo Inlet

The Hōteo inlet comprises depositional muddy upper harbour flats that are currently subject to high sediment deposition. The Inlet contains SEA-M1 and SEA-M2 areas. The edges of the inlet, adjacent to the main channel are classified as SEA-M2 (5b) and the mouth of the Hō teo River (3a) is recognised as SEA-M1.

Schedule 4 of the AUP (OP) contains a description of the ecological values of the SEA-M1 and SEA-M2 areas identified in the Hōteo inlet. The relevant sections of Schedule 4 have been extracted from the Plan and are set out below.

> ***SEA-M1-3a – Intertidal banks of Tauhoa River:*** *"Extensive area of intertidal banks associated with Tauhoa River, fringed with mangroves and supporting excellent saltmarsh and rich intertidal fauna."*
>
> ***SEA-M1-3b-d – Tauhoa Scientific Reserve:*** *"The Tauhoa Scientific Reserve (3b) is one of only two significant mangrove reserves in the country. The Department of Conservation has selected the Tauhoa Scientific Reserve and areas to the north*

(3b, 3c, 3d) as an Area of Significant Conservation Value (ASCV). The reserve comprises 291 hectares, 75-80% of which is dense mangrove forest. It was vested in the University of Auckland in 1949 and classified as a flora and fauna reserve. The reserve is considered to be of national importance."

***SEA-M1-3c, e, g – Tauhoa River**: "An extensive area of intertidal banks fringed with mangroves and supporting excellent saltmarsh and rich intertidal fauna. Here the banks have built up to form low islands and the saline vegetation in the intertidal area grades into the terrestrial vegetation. The saline vegetation provides high quality habitat for threatened secretive coastal fringe birds. The areas of adjacent terrestrial vegetation also provide shelter for the birds and potential nesting sites. This is one of the two most extensive areas of saline vegetation in the Kaipara Harbour and is relatively unmodified by reclamation."*

***SEA – M1-3w2 – Wading Bird Habitat:** "High quality habitat for threatened secretive coastal fringe birds"*

***SEA-M1-4 – Moturemu island:** "Moturemu Island is a regionally important wildlife habitat as it supports a breeding colony of grey-faced petrel which is unusual for the west coast of the region. Supports nationally and regionally threatened plant species."*

***SEA-M1-174 – Kaipara Harbour seagrass meadows:** "Seagrass meadows provide a number of important roles, including trapping and stabilising bottom sediments, nutrient recycling, the creation of high primary productivity, and the provision of habitat to a wide variety of plant and animal species, including invertebrates, fish and birds. Seagrass meadows tend to have greater numbers of fish and species diversity than adjacent non-vegetated habitats. Kaipara Harbour's vast seagrass meadows support a wide variety of fish and the harbour is the main source of juvenile snapper for the west coast of the North Island."*

***SEA-M1-5a – Mataia: "**Along the coast in the southern part of this area, developing mangroves below Mean High Water Springs grade into regenerating coastal kanuka forest. This type of connection is now rare in the main body of the Kaipara Harbour due to vegetation clearance and Reclamation around the harbour. Most other such gradations between natural saline and terrestrial vegetation in the Kaipara are found in the estuaries or rivers that flow into the harbour. Provides habitat for wading birds and secretive wetland birds."*

***SEA-M2-5b - Hōteo River:** "Mangroves and saltmarsh at mouth of Hōteo River, provides habitat for banded rail."*

***SEA-M2-5c – Mataia Creek:** "Mangroves and saltmarsh in estuarine creek grading into coastal forest on northern side. Provides habitat for banded rail."*

***SEA-M1w-5w1-2 – Wading bird habitat:** "Extensive areas of feeding habitat for waders along this coastline.*

Oruawharo Inlet

The Oruawharo Inlet is also a depositional muddy upper harbour area, which is subject to relatively high background sedimentation. The Inlet contains both SEA-M1 and SEA-M2 areas. The Oruawharo River feeds in to the Oruawharo Inlet, where the upstream edges of the estuary are classified as SEA-M2. Lower down the inlet towards the mouth of the River, there are a number of SEA-M1 areas.

Schedule 4 of the AUP (OP) contains a description of the ecological values of the SEA-M1 and SEA-M2 areas identified in the Oruawharo Inlet. The relevant sections of Schedule 4 have been extracted from the Plan and are set out below.

> ***SEA-M2w-1w1 – Wading bird habitat:*** *"Intertidal banks providing habitat and feeding ground for wading birds. Mangroves fringing inlet and wading bird habitat."*
>
> ***SEA-M1-1b – Port Albert – Atiu Creek****: "Coastal regional park with intact sequences from native forest to mangroves and estuarine ecosystems in Mullet Creek, Atiu Creek and Takahe Creek. The native forest on the park includes stands of regenerating kanuka forest and scrubland, mature pohutukawa coastal forest, kauri forest on the ridges, and totara forest with broadleaved forest in the gullies. On the prominent Kauri Point there are sequences of totara forest on ridges to coastal pohutukawa- puriri forest and to mangroves in the estuary. Large old growth mangroves occur in Takahe Creek. The park has intact areas of coastal forest which are now rare nationally."*
>
> ***SEA-M2-1c – Port Albert – Oruawharo River – Port Albert****: "Shallow intertidal habitats dominated by mangrove communities with fringing saltmarsh providing habitat for banded rail. Contiguous coastal forest present in upper reaches, including Topuni River. Mangrove communities in Oruawharo arm are different from other mangrove areas in Kaipara Harbour with small deposit-feeding bivalve and polychaete predators present."*
>
> ***SEA-M1-2a – Tapora Islands and Estuary - Intertidal Areas including Gum Store Creek****: "Area of sand banks, bars and dunes opposite the mouth of the Kaipara Harbour forming a complex habitat for a variety of animal and plant communities. The intertidal sand banks are a feeding ground and important mid tide roost for thousands of international migratory and New Zealand endemic wading birds including a number of threatened species. There is an area of mangrove and saltmarsh within inlet at the mouth of Oruawharo River which is contiguous with surrounding coastal forest."*
>
> ***SEA-M1-2b, c, d, e, f, g, h, i – Tapora Islands and Estuary:*** *"The associated sand bars and islands (2b, 2g, 2j) provide a high tide roost for thousands of international migratory and New Zealand endemic wading birds including a number of threatened species and a variety of other coastal bird species. In the shelter of the sand islands and inlet mouths grow important areas of mangroves and saltmarsh (2c, 2d, 2e, 2f, 2h, 2i, 2j). The vegetation adjoining the islands grades from the mangroves and saltmarsh into coastal shrublands and dune vegetation above Mean High Water Springs. Similarly, in the inlet mouths, the saline vegetation grades into freshwater vegetation beyond the coastal marine area. The saline vegetation provides high quality habitat for threatened secretive coastal fringe birds particularly where it abuts terrestrial vegetation which provides shelter for the birds and potential nesting sites. The saltmarshes and dune vegetation include a number of threatened plant species, including pingao ('gradual decline')."*
>
> ***SEA-M1-2j – Okahukura Peninsula Wetland: "****Estuarine wetland that is only inundated at extreme high tide, that provides habitat for threatened secretive wetland bird species. High plant species diversity, including good amounts of salt*

marsh ribbonwood with reeds and rushes grading into saltmarsh. Forms part of an ecological sequence from marine to freshwater backdune wetland."

***SEA-M1-2k – Tapora Islands and Estuary – Intertidal banks on north side of Big Sand Island**: "The Kaipara Harbour has been identified as an Important Bird Area (IBA) for its global significance for NZ fairy tern ('nationally critical'), black-billed gull ('nationally critical'), NZ dotterel ('nationally vulnerable'), and for its congregations of wading birds which migrate from their South Island breeding sites, and for species migrating from the northern hemisphere. These areas are classified as SEA-M1. The banks on the north side of Big Sand Island provide wading bird foraging habitat for wrybill ('nationally Vulnerable'), South Island pied oystercatcher ("at risk – declining"), Eastern bar-tailed godwit ("at risk – declining") and red knot[15] ('nationally vulnerable')."*

***SEA-M1w-2w1 - Wading bird habitat:** "Feeding ground and mid tide roost for thousands of international migratory and New Zealand endemic wading birds including a number of threatened species. High tide roost for thousands of international migratory and New Zealand endemic wading birds including a number of threatened species and a variety of other coastal bird species."*

Other Regional Ecological Values

North Kaipara Harbour has been identified as a significant ecological area for marine ecology under the notified Northland Regional Plan (notified 6 September 2017), with an ecological value ranking of high. The area is described as having a great diversity of habitats ranging from clean sandy areas at the entrance of the harbour to mudflats, mangroves and saltmarsh sequences in the upper reaches. Channel environments throughout the entire harbour have healthy shellfish communities, which provide important habitat for juvenile fish such as snapper (*Pargus auratus*) and rig (*Mustelus lenticulatus*), and shark species, including the great white shark (*Carcharodon carcharias*) (protected under the Wildlife Act 1953 and listed as an IUCN red species). The harbour is also gazetted as part of a Marine Mammal Sanctuary under the Marine Mammals Protection Act 1978, for protection of the critically endangered maui dolphin (*Cephalorhynchus hectori maui*).

A number of DOC Natural Areas and NRC Marine Management Areas have been defined within the upper reaches of the northern part of the harbour, including the Otamatea River, where indigenous mangrove communities with fringing saltmarsh habitat (including oioi and searush), mud and sand flat habitat, colonies of Pacific oyster including natural beds and farms (DOC Natural Area Report - Q08/062; NRC Marine Management Area 2 (conservation)) (Lux & Beadel, 2006). In addition, Araparoa River includes mangrove forest, shrubland and rushland, intertidal mud and sand flats and colonies of natural and farmed Pacific oysters (DOC Natural Area Report – Q08/084; NRC Marine Management Area 2 (conservation)) (Lux & Beadel, 2006).

Other non-statutory documents

The Integrated Kaipara Harbour Management Group was established in 2005 with the key purpose being to promote integrated management and inter-agency coordination and kaitiakitanga of the Kaipara Harbour and its catchment. The group have long term objectives covering biodiversity, fisheries, Matauranga Māori , climate change and socio-

[15] Also known as lesser knot

economic. Issues of concern include declining fish stocks, adverse effects of fishing, sedimentation, water quality, loss of biodiversity and unhealthy mauri.

3.3.2 Benthic Marine Invertebrates

Literature review

Auckland Council has been conducting surveys of the benthic macrofaunal communities at four intertidal sites in Kaipara Harbour since 2009. The Auckland Council survey strategy has developed over time and a range of intertidal taxa have been identified as being the most important to monitor for presence, abundance and community structure (Hailes & Carter, 2015). The most recent data for each site have been analysed and are presented along with data collected for the Project within the upper reaches of the Hōteo and Oruawharo Inlets. The graphs in Figure 10 and Figure 11 show the mean and standard error (s.e.) abundance and number of taxa for each of the measured sites. The locations of the sampling sites are mapped in Appendix A.

Abundance – individuals

In June 2017, our surveys of four upper harbour intertidal sites within the Kaipara Harbour (Oruawharo and Hōteo) indicated a moderate abundance of benthic infauna (Figure 10).

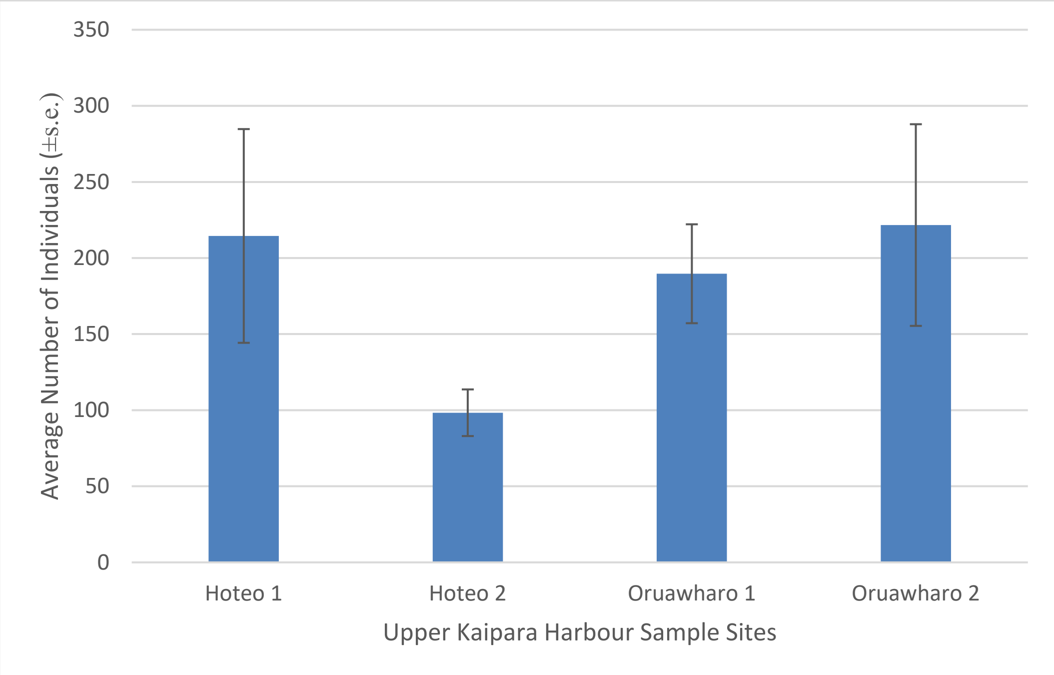

Figure 10 - Average number of benthic infauna (± s.e.) per core sample at each survey site, upper harbour sites (Kaipara Harbour) (Boffa Miskell, 2018)

Lower harbour sites (KaiB, KKF, NPC and TNP), surveyed in April 2017 by Auckland Council, had low abundance of benthic infauna (Figure 11).

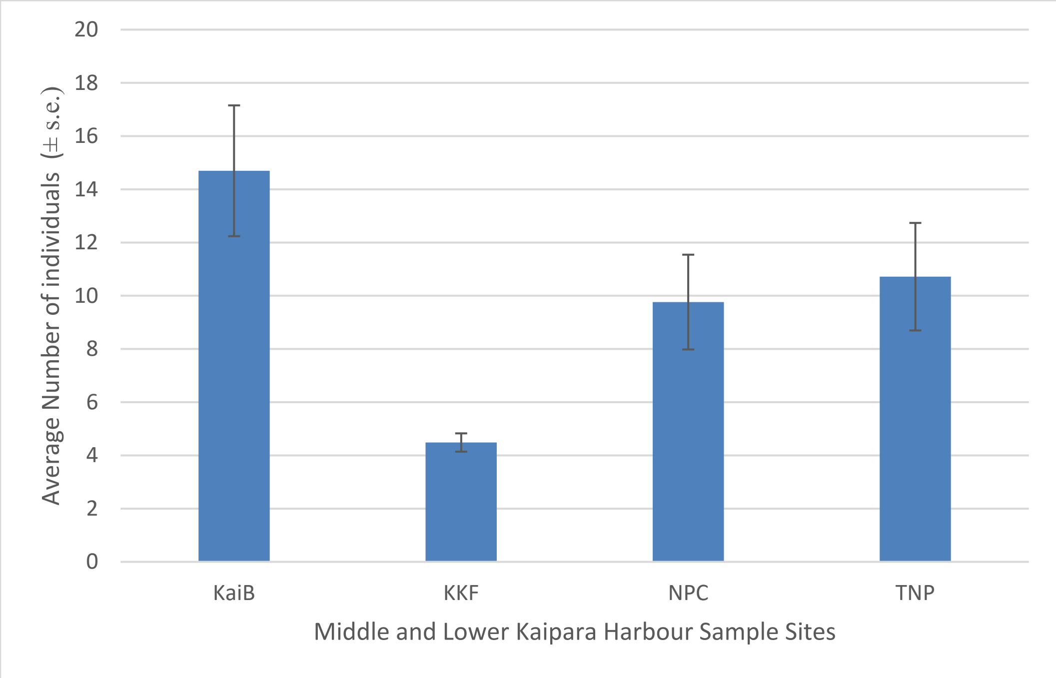

Figure 11 - Average number of benthic infauna (± s.e.) per core sample at each survey site, lower harbour sites (Kaipara harbour) (Auckland Council, 2017)

Diversity of taxa

Less than ten taxa were detected at sites located within the upper and middle reaches of the harbour (TNP, KaiB, KKF, NPC, Hōteo 1, Hōteo 2, Oruawharo 1, Oruawharo 2) (Figure 12 and Figure 13). The average number of taxa detected varied between 5 and 10 at intertidal sites within the lower estuary (Figure 13).

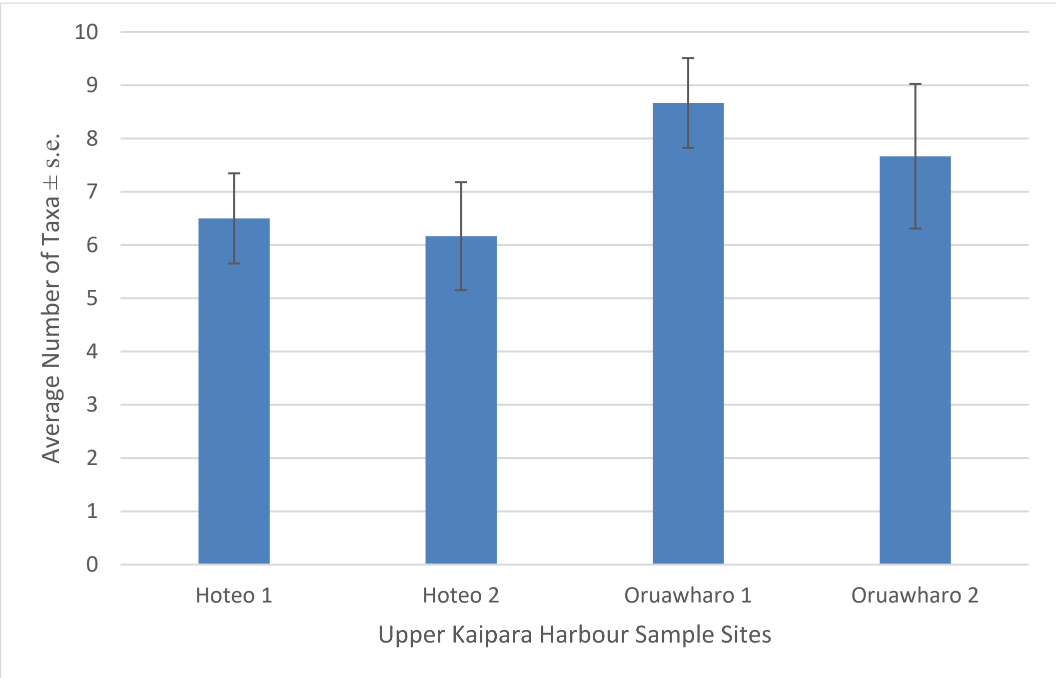

Figure 12 - Average number of taxa (± s.e.) per core sample at each survey site, upper harbour sites (Kaipara Harbour) (Boffa Miskell, 2018)

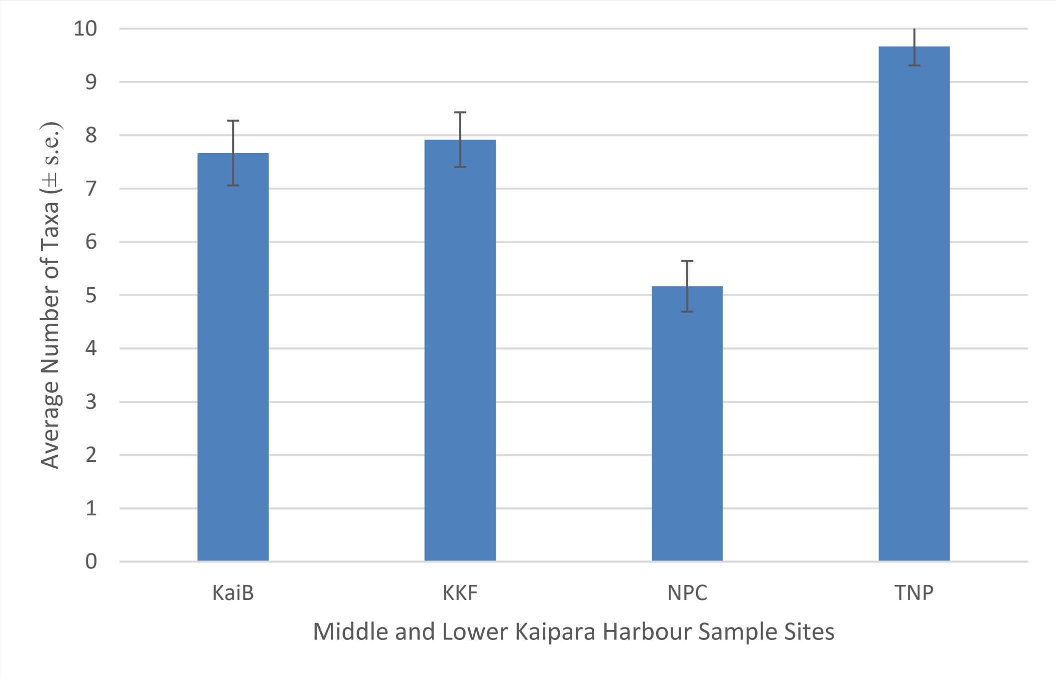

Figure 13 - Average number of taxa (± s.e.) per core sample at each survey site, lower harbour sites (Kaipara Harbour) (Auckland Council, 2017)

Upper harbour sites (Hōteo 1 and 2, Oruawharo 1 and 2) are characterised by tolerant and/or opportunistic species, with oligochaete worms dominating Hōteo 1 and 2 and Oruawharo 2. The estuarine snail *Potamopyrgus estuarinus* dominated the assemblage at Oruawharo 1 (Figure 14).

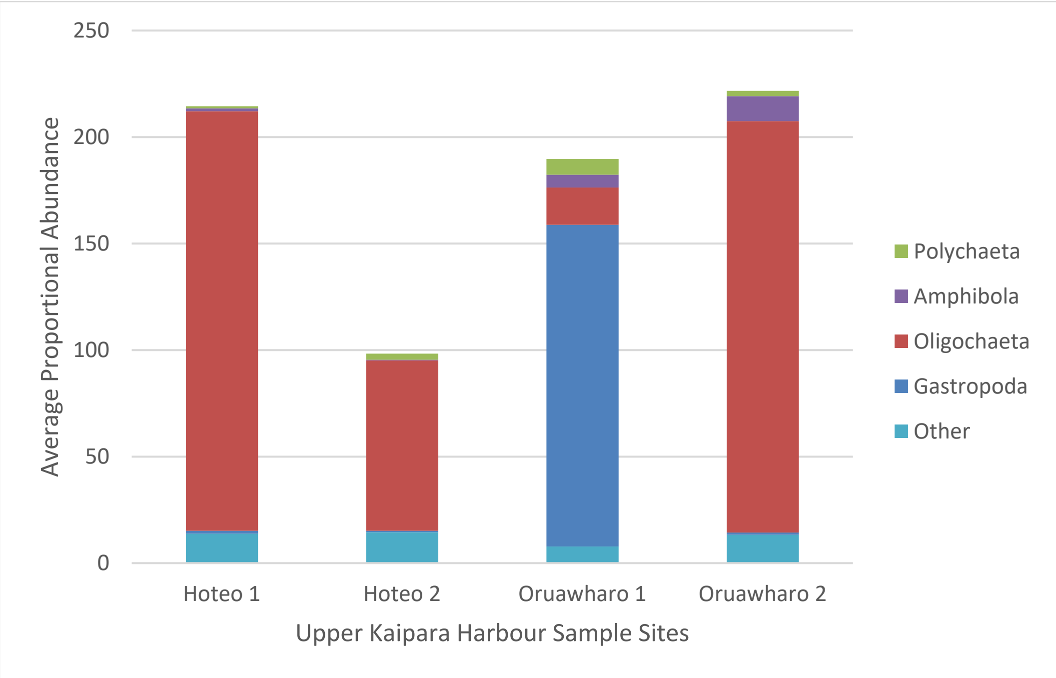

Figure 14 - Average proportion of main benthic infaunal taxa groups per core sample at each survey site, upper harbour sites (Kaipara Harbour) (Boffa Miskell, 2018).

At lower harbour sites, there was a greater diversity of taxa, with the most abundant organisms being polychaete worms and bivalves (Figure 15). These sites have different habitat characteristics compared to the upper harbour sites, being on mostly sandflats compared to the mudflat environment of the upper harbour.

Of the common kai moana species, cockles were the most common and were present at harvestable size at all lower harbour sites (KaiB, KKF, NPC and TNP). The average density of cockles (all size classes) per core was 1-2 individuals. Cockles were not detected at upper harbour sites. However, the mud snail *Amphibola crenata* (another kai moana species) was observed at upper harbour locations adjacent to those sampled.

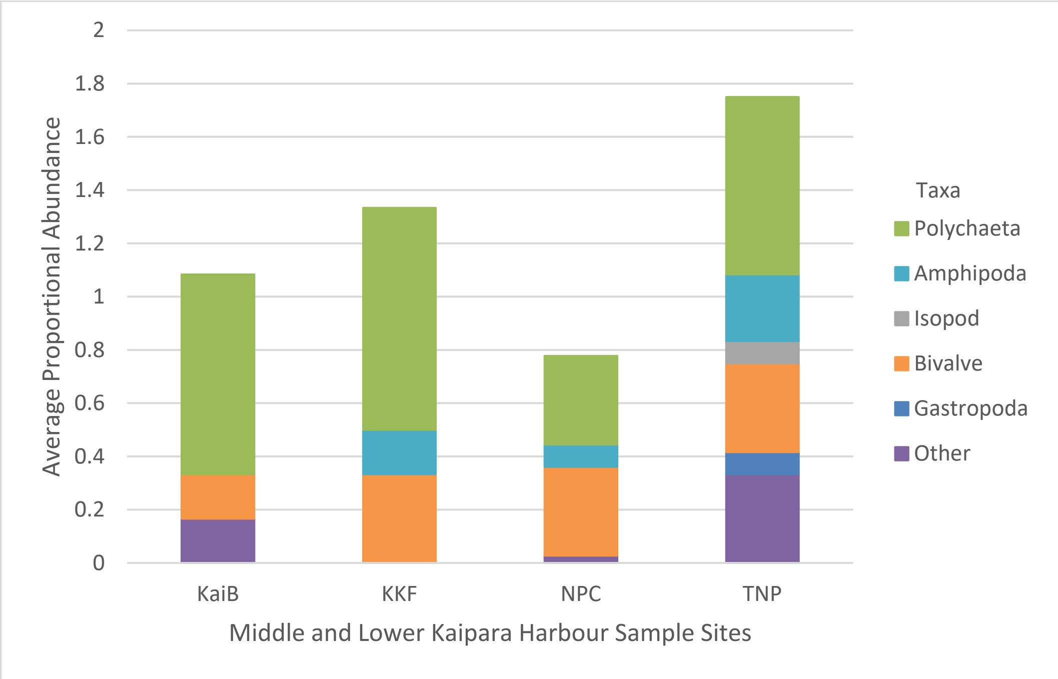

Figure 15 - Average proportion of main benthic infaunal taxa groups per core sample at each survey site, lower harbour sites (Kaipara Harbour) (Auckland Council, 2017)

We detected a moderate benthic invertebrate diversity at sites on the mudflats of the upper harbour (Oruawharo 1 and Hōteo 2) (Figure 16), whereas a low diversity was detected at all sites located within the middle to lower reaches of the harbour (KaiB, KKF, NPC and TNP) (Figure 17).

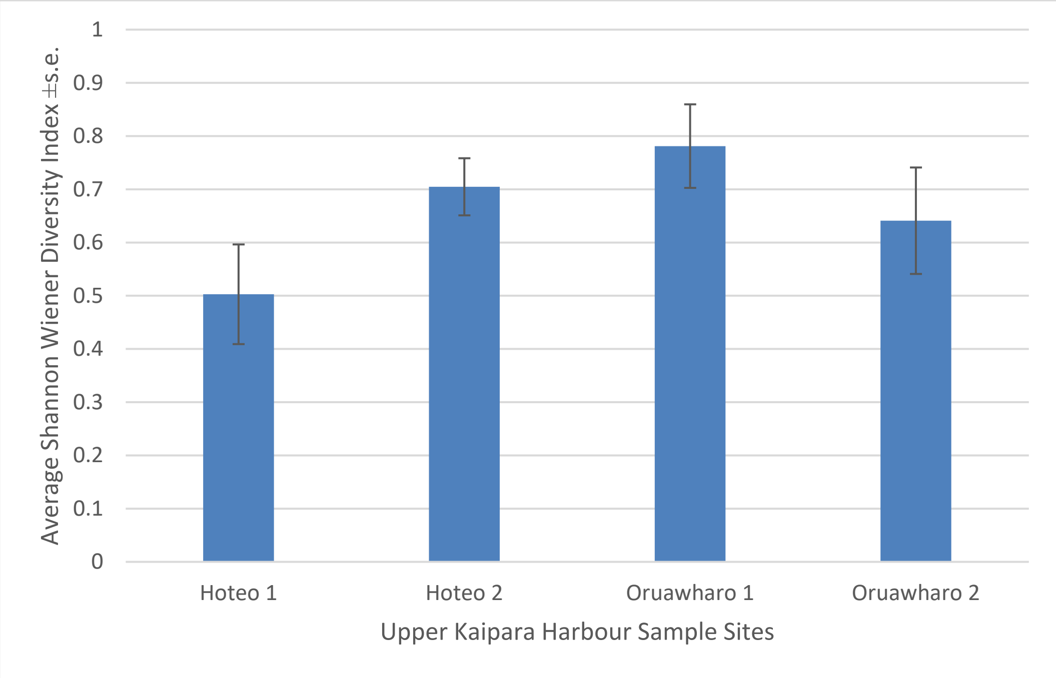

Figure 16 - Average Shannon Wiener Diversity Index (± s.e.) per core sample at each survey site, upper harbour sites (Kaipara Harbour)

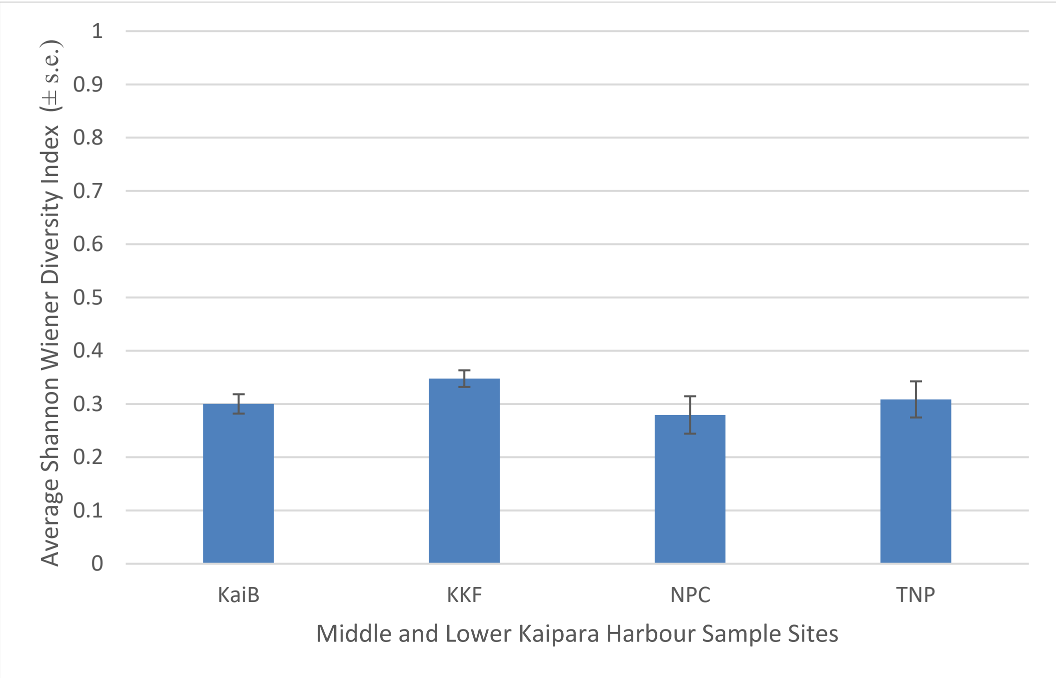

Figure 17 - Average Shannon Wiener Diversity Index (± s.e.) per core sample at each survey site, lower harbour sites (Kaipara Harbour).

The MDS plot of the intertidal invertebrate assemblages in the Kaipara Harbour shows some grouping of sites within the upper harbour sites (Hōteo and Oruawharo sites), with Oruawharo 1 being more dissimilar to the other three sites (Figure 18)[16]. More similarity in

[16] Relatively high stress of 0.2 indicates that the two-dimensional plot does not convey the 3-dimensional patterns particularly well.

the community composition was apparent among the middle and lower harbour sites compared to the upper harbour sites (i.e. the middle and lower harbour sites had a larger number of species in common compared to the upper harbour sites) (Figure 19).

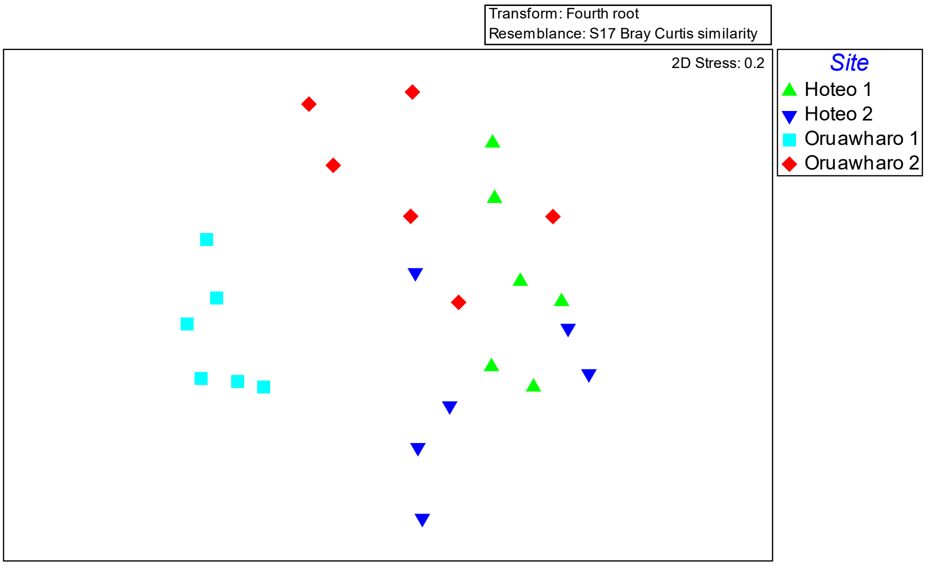

Figure 18 - nMDS plot of intertidal and subtidal benthic infaunal community composition, upper harbour sites (Kaipara Harbour)

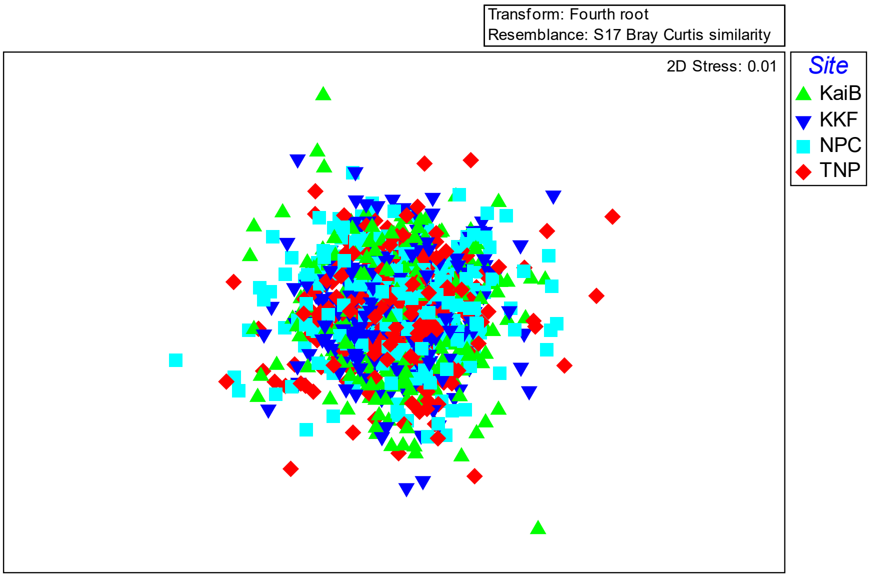

Figure 19 - nMDS plot of intertidal and subtidal benthic infaunal community composition, lower harbour sites (Kaipara Harbour).

3.3.3 Epifauna

Very few epifaunal taxa were present at intertidal survey sites. Mud crabs were the most abundant, as evidenced by the presence of crab burrows. The average number of mud crab burrows per 0.25m^2 quadrat was 93. Polychaetes were also present as well as the Pacific oyster (*Crassostrea gigas)*. This lack of diversity in epifauna is representative of muddy intertidal habitat.

3.3.4 Fish

The Kaipara Harbour contains habitats that are recognised as important nursery areas for a range of commercial and non-commercial fishes (Morrison et al., 2014). For snapper and rig, Kaipara Harbour is believed to be the largest and most important nursery area in New Zealand (Northland Regional Council, 2013). The harbour is also recognised as an important breeding area for great white shark, which is a protected species under the Wildlife Act 1953 and an IUCN red listed species (pers.comm. C. Duffy, DOC).

3.3.5 Coastal Avifauna

Over 75 avifauna species were recorded within the 400 km^2 area of the four grid squares (Appendix D). Of those species, coastal and/or estuarine habitat provides primary or secondary habitat for approximately 50% of species (refer to Appendix D for habitats), most of which are classified as At Risk or Threatened (Table 6). For the majority of these species, the Kaipara Harbour is likely to form a part of a wider network of coastal and estuarine habitats that they use depending on the time of year and tidal sequence (Dowding & Moore, 2006).

Of the avifauna species that utilise the coastal/estuarine environment, a number of these species feed on marine/estuarine invertebrates and this includes banded dotterel, black stilt, banded rail, Eastern bar-tailed godwit, lesser knot, northern NZ dotterel, red-billed gull, black-billed gull, reef heron, royal spoonbill, turnstone, whimbrel, curlew, variable and NZ pied oystercatchers (Heather & Robertson, 2000).

As noted in Section 3.3.1, there are several areas identified within the Kaipara Harbour (including the Oruawharo and Hōteo inlets) as SEAs due to their wading bird habitats, namely the extensive intertidal feeding habitat for waders in the harbour and along the coastline.

Haggitt et al., (2008) describe the Kaipara Harbour as one of the five most important areas in New Zealand for wading birds, with most of the 150,000 migrant waders that visit New Zealand annually passing through the Kaipara on their way to feeding grounds throughout New Zealand. New Zealand species for which the Kaipara provides critical habitat include black stilt (*Himantopus novaezelandiae*; Threatened – Nationally Critical), northern New Zealand dotterel, wrybill and NZ fairy tern (*Sterna nereis davisae;* Threatened - Nationally Critical) (Haggitt et al., 2008).

The Kaipara Harbour has been recognised by the Important Bird Area (IBA) programme as meeting the criteria for being globally important for the conservation of bird populations (Gaskin 2013). Chapter L Schedule 4 of the AUP (OP) outlines its global significance for NZ fairy tern and black-billed gull (Threatened - Nationally Critical), northern NZ dotterel (At Risk - Recovering), and for its congregations of wading birds which migrate from their South Island breeding sites, and for species migrating from the northern hemisphere.

The Kaipara Harbour provides extensive wading bird foraging habitat for wrybill and lesser knot (both Threatened - Nationally Vulnerable) as well as NZ pied oystercatcher and Eastern bar-tailed godwit (both At Risk – Declining). The numerous sand bars and islands provide high tide roost habitat for thousands of international migratory bird species and high tide roost and nesting habitat for New Zealand endemic wading birds and coastal bird species, including Caspian tern (Threatened – Nationally Vulnerable).

The Kaipara Harbour provides breeding, foraging and roosting habitat for the *Threatened* NZ fairy tern. Small numbers of NZ fairy tern nest within the Kaipara Harbour, including at Papakanui Spit; new shell patches are being created in the Kaipara Harbout to increase the number of potential breeding sites. Most east coast NZ fairy tern move to the Kaipara Harbour during the non-breeding season, where autumn and winter flocks can number 20-30 birds (Parrish & Pulham 1995; Baird et al., 2013; Preddey & Pulham 2017). Birds feed in adjacent estuaries or a short distance out to sea, where they forage by hovering 5-15 m above the water surface, before diving for prey. A number of high tide roost sites are located around the Kaipara Harbour, including Tuhoa shellbank. Fairy terns' high tide roost sites are open areas of mud, sand, shell or sparsely vegetated salt marsh, which are also used by other roosting shorebirds. Tidal heights determine site usage. Roosts are abandoned or adopted in response to natural or human-induced changes, including vegetation encroachment and disturbance.[17]

The Kaipara Harbour is one of the most important estuaries in Northland due to its large size and diversity of interconnected habitat sequences which attract large numbers and a wide variety of estuarine birds (Northland Regional Council, 2016). As discussed in Chapter L Schedule 4 of the AUP(OP), the margins of the Kaipara Harbour have large areas of intertidal banks fringed with mangroves which support high quality saltmarsh habitat utilised by threatened secretive coastal fringe birds. Most relevant to this project are the mangroves and saltmarsh habitat at the mouth of the Hōteo River, along the margins of the Oruawharo inlet and the Tauhoa Scientific Reserve (an Area of Significant Conservation Value) which provide habitat for numerous species of cryptic marshbirds including Australasian bittern (Threatened – Nationally Critical), banded rail, fern bird, spotless crake and marsh crake (all At Risk – Declining). Haggitt et al., (2008) identify lower Oruawharo River and Hōteo River as significant sites as they contain threatened species or complete ecological sequences from marine to terrestrial enviornments.

3.3.6 Sediment Grain Size

The proportion of silt and clay in surface sediment is highest at the upper harbour intertidal sites compared to lower to middle harbour sites (Figure 20 and Figure 21). Sites located within the Hōteo and Oruawharo inlets contained between 78% and 93% silt and clay (Figure 20). Sites located in the middle and lower reaches of the harbour were dominated by fine sand (approximately 78-97%), with between 3% and 28% silt and clay (Figure 21).

[17] Pulham, G.; Wilson, D. 2013 [updated 2017]. Fairy tern. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online* www.nzbirdsonline.org.nz

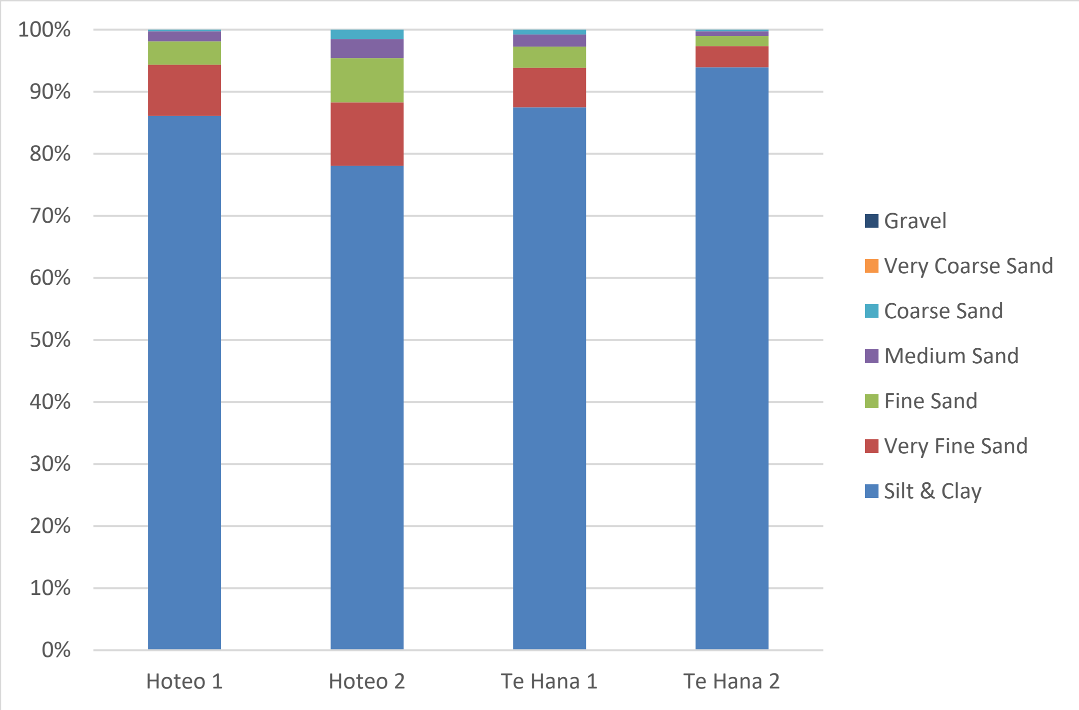

Figure 20 - Proportion of sediment grain size composition in surface sediment from survey sites within the upper Kaipara Harbour (Boffa Miskell, 2018)

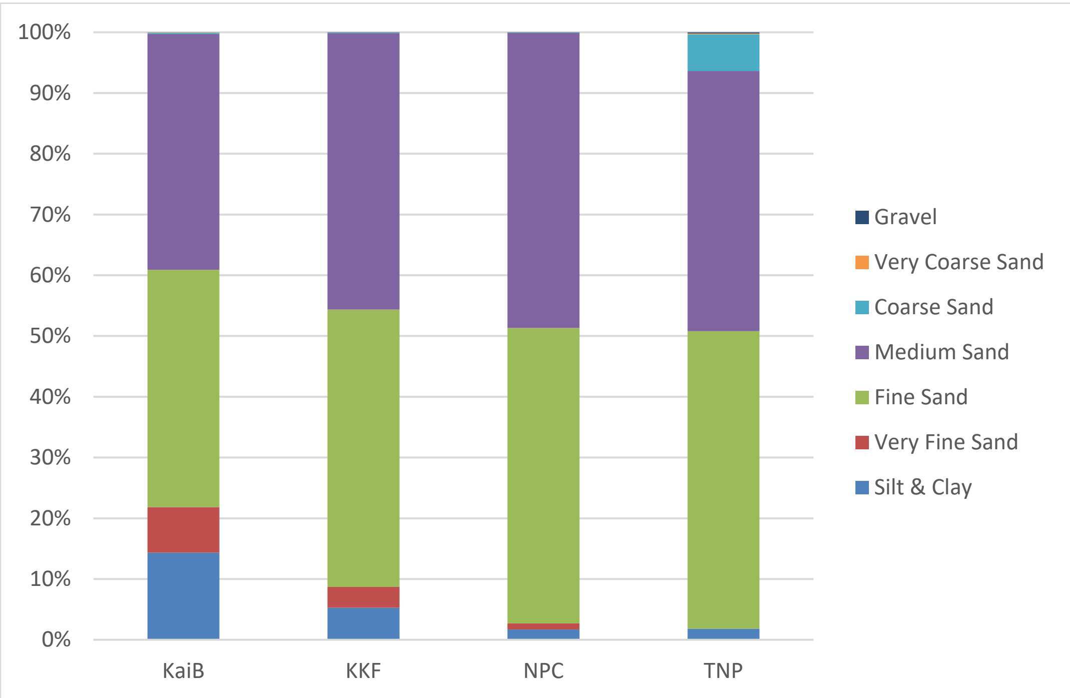

Figure 21 - Proportion of sediment grain size composition in surface sediment from within the lower Kaipara Harbour (Auckland Council, 2017)

3.3.7 Sediment Contaminants

Sediment quality surveys at intertidal sites within Oruawharo and Hōteo Inlets were carried out for the Project (see sample sites mapped within Appendix A).

The concentration of common stormwater contaminants in intertidal surface sediment was below the ARC ERC and ANZECC ISQG effects thresholds in both Oruawharo and Hōteo Inlets, with the exception of copper at Oruawharo 1 (refer Table 1). Copper concentrations were elevated at Oruawharo 1 (20 mg/kg) and just above ARC ERC amber guideline value (19 mg/kg), but below the red guideline value (34 mg/kg) (Table 9). Elevated copper indicates that this site may have slightly lower ecological value compared to other sites surveyed within the Kaipara Harbour.

Table 9 - Intertidal contaminant concentrations in Kaipara Harbour

Contaminant mg/kg	Oruawharo 1	Oruawharo 2	Hōteo 1	Hōteo 2
As	8	10	11	11
Cd	0.1	0.1	0.1	0.1
Cr	20	24	29	25
Cu	20	16	14	12
Pb	9.1	9.4	7.4	6.7
Hg	0.056	0.044	0.05	0.032
Ni	12	14	12	11
Zn	64	71	64	58
HMW PAHS	0.01	0.01	0.01	0.01

3.3.8 Depth of Anoxic Sediment

The average redox depth detected in June 2017 in surface sediment at intertidal sites in the Oruawharo and Hōteo Inlet was <1 cm, indicating anoxic surface sediment. Anoxic sediment is common within low energy environments such as mangrove forests and often results in a low abundance and distribution of marine species, due to sensitivity to an oxygen depleted environment.

3.3.9 Water Quality

Varying levels of water quality were recorded throughout the harbour in the most recent sampling carried out in 2014 (Vaughan & Walker, 2015).

Kaipara Heads was assessed as having the best water quality in the Auckland region with excellent water quality and a WQI of 100 (Vaughan & Walker, 2015). Tauhoa Channel, Hōteo River and Omokoiti Beacon all have fair water quality (WQI 85.4, 63.4 and 85.2 respectively) (see maps within Vaughan & Walker, 2015). Makarau Estuary and Kaipara River both have poor water quality (WQI 52.2 and 45.8 respectively) (see maps within Vaughan & Walker, 2015).

3.4 Assessment of Existing Ecological Values

Marine Ecology

Our assessment of ecological value for the Mahurangi and Kaipara marine environments is based on the criteria we have set out in Table 2, which details some of the common characteristics of these environments under different ecological value categories. Whilst recognising that invertebrate communities and sediment quality within estuaries are often variable, both spatially and temporally, we have assessed the values using all of the data we describe above, guided by the characteristics set out in Table 2. This process involves condensing a large volume of data into single descriptors. It should be noted that there is a great deal more existing information available regarding the Mahurangi Harbour compared to the Kaipara Harbour; this may have some influence on the data, for example, greater sampling effort typically results in the detection of more species.

The overall ecological values of the mid to lower reaches of both the Mahurangi and Kaipara Harbours are similar, based on the criteria in Table 2. Both have generally low contaminant concentrations in sediment, oxygenated surface sediment, generally less than 50% silt and clay in surface sediment, some estuarine vegetation providing habitat for native fauna, and some habitat modification where oyster farms exist.

Ecological values are lower in the upper reaches of both the Mahurangi and Kaipara Harbours compared to the middle and lower reaches, primarily due to a low diversity of benthic invertebrate assemblages in these areas, higher levels of silt and clay, less oxygenated surface sediment, and less estuarine buffer vegetation providing filtration and habitat for fauna.

Due to the large differences in benthic invertebrate community composition between the upper reaches and that of the middle and lower reaches of both waterways, we have divided the assessment of ecological value into these two areas.

In our assessment:

- overall marine ecological values of the Mahurangi Harbour are **high** in the middle to lower reaches, and **moderate** in the upper reaches; and
- the overall marine ecological values of the Kaipara Harbour are **high** in the middle to lower reaches, and **moderate** in the upper reaches.

Coastal Avifauna Ecology

The Mahurangi Harbour is part of network of regionally important, moderate size, east coast estuaries that provide important habitat for international migratory bird species, New Zealand endemic wading birds and several species of cryptic marshbirds. The Kaipara Harbour provides extensive high value habitat for thousands of international migratory bird species, New Zealand endemic wading birds and several species of cryptic marshbirds. The large majority of the species associated with the coastal environments of both the Mahurangi and Kaipara harbours are classified as Threatened or At Risk, and as such both areas are considered to have very high coastal avifauna values.

4 ASSESSMENT OF EFFECTS

Assessment of effects summary

Potential adverse effects on the marine environment of the Project are all indirect, arising from the discharge of treated runoff from open earthworks during construction and treated stormwater runoff from the road during the operational phase. Discharge of treated runoff to the Mahurangi Harbour (via the Mahurangi River) on the east coast and the Kaipara Harbour (via the Hōteo River and Oruawharo River) on the west coast may occur throughout the construction and operation phases. The receiving environments in both harbours are Significant Ecological Areas.

Construction Phase

Sediment runoff from open earthworks areas during large rainfall events discharging to the Mahurangi and Kaipara Harbours during construction of the Project has the potential to adversely affect marine ecological values. Potential effects relate to large rainfall events which have the potential to result in acute effects and cumulative sedimentation in the harbours throughout the entire construction period. Erosion and Sediment Controls (ESC) are an inherent part of the construction methodology of this Project and accordingly we have assumed that best practice ESC will be put in place. Both the Project Water Assessment Report and the Construction Water Management Design technical report assess the effectiveness of these control measures. Further, section 6.1 of the Water Assessment Report sets out the relatively conservative basis for the catchment sediment modelling undertaken and the probabilities of large rainfall events occurring through the earthworks activities.

The concentration of total suspended sediment (TSS) and the area and depth of deposited sediment under a 10-year and 50-year rainfall event (under various wind conditions) have been modelled and mapped under the P-Wk 5 year construction programme scenario in the Mahurangi Harbour catchment and a 7 year construction programme scenario in the Kaipara Harbour catchment.

The modelling predicts a reduction in the suspended sediment concentration in marine receiving water (TSS) to concentrations significantly below effects thresholds within approximately three days in all scenarios within both the Mahurangi and Kaipara Harbours. An exception to this was observed in a small area on the Kakaraia Flats (within the Kaipara Harbour), where suspended sediment concentration was modelled to exceed $80 g/m^3$ for more than 72 hours under a 50-year ARI event. Overall, however, we conclude that the level of effect of suspended sediments from construction of the Project on benthic invertebrates, and marine/estuarine habitat values is low to very low and temporary.

The model predicts that three days following the rainfall event the deposition of sediment in the Mahurangi Harbour in a 10-year average return interval (ARI) rainfall event will result in relatively small increases in the area of each harbour predicted to receive sediment (at the biological thresholds relevant to muddy benthic habitats of 5-10 mm and >10 mm). The 10-year ARI event in the Mahurangi Harbour is considered to have a low level of effect.

In the Kaipara Harbour, adjacent to the Hōteo River mouth, modelling indicates that a 10-year ARI event during construction of the Project is likely to result in significant additional areas of sedimentation at depths 5-10mm and >10mm in some wind scenarios. Calm wind conditions are predicted to result in an additional 5.4ha of benthic habitat receiving 5-10mm of sediment and an additional 2.3ha receiving >10mm of sediment. In NE wind conditions, 6.6ha of additional habitat receives 5-10mm of sediment, and 1.7 ha receives more than 10mm of sediment. In SW winds, smaller areas are affected (1 ha 5-10mm and 0.9ha >10mm). Overall, the 10-year ARI event is assessed as potentially having a moderate magnitude of effect and moderate level of effect (based on the EIANZ criteria and given the ecological values present). However, we consider that effects are at the lower end of the moderate scale in the 10-year ARI in the Hōteo Inlet due to the temporary nature of the effect and the large area of mudflat habitat in the Inlet.

In the 50-year ARI rainfall event in Mahurangi Harbour, adverse effects on marine ecological values of a moderate level of effect may occur in the 5-year construction scenario. In this event, using the P-Wk maximum earthworks open area, the area of marine environment receiving >5-10mm increases from an existing baseline of approximately 90ha to 110ha; and the area receiving >10mm increases from an existing baseline of approximately 40ha to around 44ha. In the current Project, the area of open earthworks is likely to be approximately 58% of that for P-Wk, which will result in a smaller deposition footprint. Modelling indicates that sediment is primarily deposited in the upper reaches of the harbour (ie upstream of Hamiltons Landing). Given that we have not modelled rainfall events between a 10-year and 50-year ARI, the threshold rainfall event size where moderate level of adverse effects may begin to occur could be less than the 50-year event.

In 50-year ARI event in the Hōteo River catchment, the area of marine environment receiving >5-10mm and >10mm increases by 13-27 ha over the baseline deposition area. Whilst a much larger area is affected in the 50-year event, it is likely that benthic organisms would recolonise these areas, with community composition likely to be similar to baseline within approximately 3-5 years. We consider the 50-year ARI rainfall event in the Hōteo Inlet could have a moderate magnitude of effect and moderate level of effect.

In order to assess the effects of the Project on sedimentation within the harbours over the entire construction period, we have estimated the construction sediment loads within both harbours. Within the Mahurangi Harbour, over the P-Wk 5-year construction period, the sediment load is predicted to increase by 793 tonnes (0.9% increase above baseline). Within the Kaipara Harbour, over the 7-year construction period, sediment load delivered to the Hōteo Inlet is predicted to increase by 1,916 tonnes (1% increase above baseline) and sediment load delivered to the Oruawharo Inlet is predicated to increase by 139 tonnes (0.2% increase above baseline). The discharge of sediment over the construction period adds to the accumulation of sediment in the upper reaches of both harbours, which adds in a very small way to the reduction in lifespan of the harbours and is unlikely to have greater than negligible to low level of effect on marine ecological values.

We consider that the following scenarios are likely to result in significant adverse effects on marine ecological values should they occur during maximum open earthworks;

- An acute rainfall event that results in greater than or equal to the load of sediment calculated in a 30 year ARI event in the Mahurangi catchment (600 t).

- An acute rainfall event that results in greater than or equal to the load of sediment modelled in a 10 year ARI event in the Hoteo catchment (512 t).

- Greater than or equal to 5% of the baseline sediment load occurring over the construction period in any of the Project related catchments draining to the Hōteo Inlet, Oruawharo inlet or the Mahurangi Harbour.

Given there will be no direct effect on the coastal environment, coastal avifauna is discussed in this report in the context of the marine environment providing foraging and roosting habitat, not as breeding habitat.

The only potential adverse effects will be associated with indirect effects on food supply and / or foraging ability. During construction, if sediment laden water is discharged to the receiving environment, there is the potential for adverse effects on marine water quality through increased suspended sediment, which in turn can have potential impacts on the ability of visual foragers to locate prey items. In addition, deposition of terrigenous sediment on benthic habitats could smother benthic invertebrates and reduce the foraging prey available for avifauna that feed on intertidal flats.

Any potential effects on avifauna are dependent on the level and duration of potential effects on marine ecological values. Given the low to very low level of effect determined for the marine ecology assessment (during construction), the relatively low level of predicted additional deposition of Project related sediment and the short-term nature of the elevated TSS levels, the mobile nature of the avifauna species and the extensive foraging network available, we consider that the magnitude of effect on visual foragers to locate prey will be negligible. The overall level of effect from both suspended sediment and the predicted additional deposition of Project related sediment is likely to have a Low effect on the coastal avifauna assemblages associated with the Mahurangi and Kaipara Harbours.

Operational Phase

During the operational phase of the Project, stormwater from the road will be discharged to the Mahurangi Harbour and the Kaipara Harbour (via the Hōteo and Oruawharo Rivers). Constructed wetlands will primarily be used to treat operational phase stormwater from the Project prior to discharge to aquatic environments. Wetlands will be designed to remove an average of 75% of suspended solids and associated contaminants from stormwater. We anticipate that any residual sediment and associated contaminants will largely be distributed within the upper estuary and upper harbour areas due to these areas being low energy depositional habitats.

The contaminant load model calculations indicate that there are no significant increases in stormwater contaminants within operational phase discharges to the Mahurangi and Kaipara Harbour. Therefore, we consider potential adverse effects on marine ecological values to be negligible.

The operational phase discharge of treated stormwater is likely to have an overall Low level of effect on the coastal avifauna assemblages of the Kaipara and Mahurangi Harbours.

We do not consider that the results of the assessment of construction and operational phases of the Project would alter if the alignment were moved to a new position within the proposed designation boundary as the potential sediment discharges during construction are likely to be similar, and the operational phase effects will be unchanged.

4.1 Construction Phase

During construction of the Project, treated runoff will discharge to streams and rivers that ultimately discharge to Mahurangi Harbour and the Kaipara Harbour. The potential effects on the marine receiving environments, which are Significant Ecological Areas (Marine), from construction are related to sediment discharged from the earthworks.

This assessment assumes that erosion and sediment controls (ESC) are an inherent part of the construction methodology and that best practice ESC will be put in place. Both the Project Water Assessment Report and Construction Water Management Design technical report assesses the effectiveness of these control measures.

It is also cognisant of the fact that with best practice ESC in place, discharges may still occur in large rainfall events. Figure 19 of the Water Assessment Report indicates that there is an approximate 45 % chance of a 10 year ARI event occurring during bulk earthworks and an 11% chance of a 50 year ARI event. These probabilities reduce over the summer months when earthworks activities will be at their peak.

Discharges may cause elevated total suspended sediment (TSS) within the water column and deposition of sediment on the seabed. Deposited sediment and TSS may, in turn, adversely affect marine organisms through smothering and clogging of filter-feeding structures and gills. Effects on organisms are a factor of volume of sediment (concentration of suspended sediment and depth of deposited sediment) and duration of exposure. The level of these effects also depends on the nature and values of the existing receiving environment.

High loads of suspended sediments can have negative effects on the physiological condition of filter feeding taxa, such as some bivalves (which are sensitive to elevated suspended sediment), and areas of higher sediment deposition will most likely exclude colonisation of, or remove, these species. Marine taxa have differing sensitivities to suspended sediment concentration and duration of exposure. Thus, our approach to the assessment of effects of suspended sediment has been:

- to gain an understanding from the modelling outputs of the area affected by suspended sediment at minimum biological effects threshold concentrations and duration of exposure; and
- then determine whether the areas affected are likely to contain organisms that are sensitive to suspended sediment.

Based on events as discussed in section 6.1.1 of the WAR, the only potential adverse effects on coastal avifauna possible from the Project will be those associated with indirect effects on food supply and / or foraging ability. As such, any potential effects on avifauna are dependent on potential effects on marine ecological values. During construction, if sediment-laden water is discharged to the receiving environment, there is the potential for adverse effects on marine water quality through increased suspended sediment, which in turn can have potential impacts on the ability of visual foragers to locate prey items. In addition, deposition of terrigenous sediment on benthic habitats could smother benthic invertebrates and reduce the foraging prey available for avifauna that feed on intertidal flats.

The Project will not result in any loss of habitat (including breeding), mortalities of nesting birds (including eggs and chicks) or disturbance.

4.1.1 Marine Ecology Effects Thresholds

Literature Review

The following sections indented and in italics have been extracted verbatim from the Further North (2013) Pūhoi to Warkworth Marine Ecology Assessment Report[18].

> *"Research undertaken by Hewitt et al. (2001), Ellis et al. (2002) and Nicholls et al. (2003) on the tolerance of marine invertebrates to TSS has primarily been laboratory-based due to the difficulties in manipulating the concentration of TSS in the field. Laboratory trials have shown measurable adverse effects on marine organisms at a range of TSS concentrations and a range of extended periods".*
>
> *"Research indicates that sensitive organisms (eg horse mussel, pipi and a tubeworm) suffer sublethal effects (i.e. behavioural or physiological effect on individuals) after three or more days' exposure to TSS concentrations around 75-80 g/m³"*

Of the organisms upon which research has been carried out those that are known to be present within the Mahurangi and Kaipara Harbours are listed in Table 10 below.

Table 10 - Laboratory trial results of the effect of TSS on marine invertebrates that are present in Mahurangi and Kaipara Harbours

Species	Effect detected	TSS concentration and duration of exposure at which effects were measured	Reference	Mahurangi Harbour	Kaipara Harbour
Pipi - (*Paphies australis*)	Reduced condition	75 g/m³ (exposure >13 days)	Hewitt et al., 2001	Uncommon. Unlikely to be present in the muddy upper harbour.	Uncommon. Unlikely to be present in the muddy upper harbour.
Horse mussel - (*Atrina zealandica*)	Reduced condition	80 g/m³ (exposure >3 days)	Ellis et al., 2002	Uncommon. Unlikely to be present in the muddy upper harbour.	Uncommon. Unlikely to be present in the muddy upper harbour.
Tubeworm - (*Boccardia* sp.)	Reduced feeding rate	80 g/m³ (exposure >9 days)	Nicholls et al., 2003	Common	Common

[18] Drs Bell and De Luca agree with the text extracted verbatim from the Further North (2013) marine assessment authored by De Luca.

Wedge shell - (*Macomona liliana*)	Reduced survival	300 g/m³ (exposure >9 days)	Nicholls et al., 2003	Common	Common
Cockle - (*Austrovenus stutchburyi*)	Reduced condition	400 g/m³ (exposure >7 days)	Hewitt et al., 2001	Common	Common

> *"The current published scientific research indicates that the deposition of fine grain sediment derived from the land at a depth of greater than 5 mm on top of muddy benthic sediment has adverse effects on small, less mobile marine invertebrates (Nicholls et al., 2009). Deposition of terrigenous sediment (~5mm thick) to an estuarine environment, can resulte in lower invertebrate densities and a significant change in community structure (Reid et al., 2011; Pratt et al., 2014). A thin layer of terrigenous sediment is shown to reduce the supply of oxygen to underlying sediment leading to a reduction in burrowing behaviour of bivalves and decomposition within deeper layers (Cummings et al., 2009). Thicker deposits of fine grain sediment affect an increasing number of species, with most bivalves and gastropods affected at 5-10mm deposition. Layers greater than 30 mm significantly affect most organisms that inhabit muddy sediment which in turn affects food supply for fish and birds that utilise the marine habitat. Adverse effects are also experienced at shallower depths of fine sediment deposition when the receiving environment sediment is coarse grained. For instance, mud deposited on coarser grained sediment such as sand has effects at shallower depths of deposition compared to mud deposited on mud (Lohrer et al., 2006).*
>
> *With respect to the duration of sediment deposition remaining in place, the literature suggests that most marine invertebrates can tolerate the deposition of sediment for up to three days by isolating themselves from environmental stressors (e.g. bivalves close their valves, other invertebrate cease feeding and may burrow) (Nicholls et al., 2009). Many organisms are able to slow their metabolism and temporarily reduce their reliance on oxygen by changing their metabolic pathway from aerobic to anaerobic during this time. If the sediment deposition persists for longer than three days, sublethal and lethal effects begin to occur in the most sensitive taxa. Less sensitive organisms may tolerate sediment deposition for a longer period before adverse effects begin to occur (Lohrer et al., 2006). Our assessment has therefore evaluated the depth of sediment deposition at three days following the peak of the rainfall events modelled, in order to capture effects on the most sensitive species from a sedimentation event."*

Many marine invertebrates are susceptible to the discharge of sediment as most taxa have limited mobility, whereas fish, especially upper harbour species that are used to a muddy depositional environment, are highly mobile and will move to areas that are less affected for foraging. The marine invertebrate communities present in the Mahurangi and Kaipara Harbours include both sensitive and tolerant taxa. The upper reaches of both bodies of water are characterised by tolerant, opportunistic organisms that prefer high proportions of silt and clay in benthic sediment. The middle and lower reaches of both harbours are characterised by a more diverse community, containing sensitive organisms that are intolerant of high proportions of silt and clay.

We consider that sensitive benthic invertebrate taxa may be adversely affected at 5-10 mm deposition, and a larger number of species may be adversely affected at greater than 10 mm deposition (ie community level effects may occur). We note that typically benthic invertebrates inhabiting substrates dominated by silt and clay are more tolerant of sediment deposition than those which inhabit sandy substrates.

> *"The modification of estuarine habitats due to sedimentation above effects threshold levels can reduce ecological heterogeneity (variation). Benthic sandflat and mudflat taxa have differing sensitivities to the deposition of terrigenous (land derived) sediment. Different life stages of single taxa can also have differing sensitivity to deposited sediment. Thus, deposition of terrigenous sediment can result in a shift towards tolerant organisms dominating the invertebrate community composition. For example, oligochaete worms, mud crab (Helice crassa) and the amphipod Paracorophium excavatum are known to prefer mud habitats comprising 95-100% mud grain sizes, whereas cockles, and the gastropods Cominella glandiformis and Diloma subrostrata prefer 5-10% mud (Gibbs & Hewitt, 2004).").*

We assessed potential adverse effects of sedimentation by identifying the areas affected by sediment deposition at biological effects threshold depths (5-10 mm and >10 mm), exposed for more than 3 days. We then determined whether the areas predicted to receive sediment above these effects thresholds are likely to contain organisms that are sensitive to fine sediment deposition.

The tolerance of taxa detected in the Mahurangi and Kaipara Harbours (where data exists) are outlined in Appendix C which summarises the findings of numerous scientific papers on the relationships between organisms and mud.

4.1.2 Suspended Sediment within Mahurangi Harbour

Effects on Marine Ecology

<u>Baseline</u>

Baseline water clarity in the upper reaches of the Mahurangi Harbour is low, due to persistent suspended sediment (i.e. the water is turbid) and only organisms that can tolerate low light penetration and elevated sediment concentrations inhabit these upper harbour areas. The marine ecological assessment undertaken for P-Wk (Further North, 2013) determined that in the baseline situation, a 10-year ARI and 50-year ARI rainfall event results in high concentrations of suspended sediment (i.e. up to approximately 500 g/m^3) in the upper reaches of the harbour for several days. Higher concentrations of TSS were found to occur when the rainfall events are modelled with ENE wind, as opposed to calm wind, due to wave-induced re-suspension of sediment.

<u>Construction Phase</u>

Modelling of the 5-year construction period undertaken for P-Wk indicated that TSS is markedly reduced at one day post the peak of a 50-year ARI event with ENE wind. In addition, after three days, modelling indicated that there are only very small areas in the upper reaches of the harbour of low concentration TSS (i.e. <100 g/m^3). The current Project involves significantly less indicative earthwork area (58% of the P-Wk maximum open earthworks area) and therefore, we conclude that the magnitude of effect is likely to be significantly lower than those for P-Wk (which was considered to be negligible) (Table 4).

P-Wk modelling of 10-year ARI events indicated that TSS was significantly less than the 50-year ARI and at three days post the peak of the rainfall event (which was considered to be a negligible level of effect) (Table 4).

The middle and lower reaches of the Mahurangi Harbour are not expected to be affected by Project related TSS discharged to the upper reaches.

Based on moderate ecological value in the upper reaches of the Mahurangi Harbour and a negligible magnitude of effect, the level of effects is assessed as very low (Table 5).

Effects on avifauna

During construction, if sediment laden water is discharged to the receiving environment, there is the potential for adverse effects on marine water quality through turbidity, which in turn can have potential impacts on the ability of visual foragers to locate prey items. Visual foraging species recorded in the Mahurangi Harbour include several species of shags, terns and herons classified as Threatened and At Risk (Table 6).

Given the low to very low level of construction effects determined for the marine ecology assessment (above), the availability of extensive similar foraging habitat elsewhere in the Mahurangi Harbour and wider estuarine network, the short term and confined nature of the elevated TSS levels, we consider that the magnitude of effect on visual foragers to locate prey will be negligible (Table 4).

Therefore, we have assessed the overall level of effect from suspended sediment to be low (Table 5) for coastal avifauna in the Mahurangi Harbour.

4.1.3 Suspended Sediment within Kaipara Harbour

Effects on Marine Ecology

The following section describes the predicted sediment discharge under a 7-year construction scenario for earthworks associated with the Project within catchments within the Kaipara Harbour based on the Assessment of Coastal Sediment Report (Allis, 2018).

The Kaipara Harbour is a typically described as a muddy, turbid environment due to historic and ongoing land-use change. The annual load of sediment discharged to the Kaipara Harbour via freshwater sources is estimated to be 690,000 t/year, with 85% of that load coming down the Wairoa River (which is not affected by the Project). The Project occurs within the catchments of the Hōteo River and the Oruawharo River, which contribute 4.3% and 2.3% of the total harbour annual sediment load (Section 2.4, Assessment of Coastal Sediment Report).

Hōteo

The Hōteo River estuary is almost entirely dominated by baseline sediment from the Hōteo River (88%). Sediment discharged from the Hōteo River is dispersed to both the north and south once entering the estuary (Section 2.5 Assessment of Coastal Sediment Report). Sediment grain size composition within the Hōteo River Estuary is dominated by mud (Sections 2.6 and 2.7, Assessment of Coastal Sediment Assessment).

Baseline

The Assessment of Coastal Sediment report states[19] that in the baseline situation, elevated TSS (>500 g/m^3) (Table 11, Assessment of Coastal Sediment) occurs near the mouth of the Hōteo River and extends in a plume to Moturemu Island (directly west of the Hōteo River mouth). Lower TSS concentration (*c.* 50 g/m^3) spreads throughout the Tauhoa River arm of

[19] Section 3.4.1

the Harbour for most rainfall events modelled (Assessment of Coastal Sediment report, NIWA 2018).

Modelling indicated that for the 10-year ARI rainfall events, TSS does not exceed 80 g/m^3 for three days (Figures 46-48, Assessment of Coastal Sediment report) and the sediment plume is quickly dispersed.

TSS footprint is largest for the 50-year ARI event with NE wind (Figures 41, 50, 53, 59 in the Assessment of Coastal Sediment report). Sediment plumes are quickly dispersed down the tidal channels and across the intertidal flats where they settle on the sea bed. One and three days post-peak rainfall event, TSS is elevated adjacent to the Hōteo River mouth (Figures 49-51 and Figures 52-54 in the Assessment of Coastal Sediment report). For the 50-year ARI rainfall events with NE wind, TSS exceeds 80 g/m^3 for three days within one model cell (2.1 ha) (Figure 53, Assessment of Coastal Sediment report). We know that exceedance of 75-80 g/m^3 for more than three days (Table 8) is a trigger concentration and duration that the most sensitive species (e.g. pipi) may start to show some measurable sublethal effects.

Construction Phase

There are minor differences in TSS patterns between the baseline and the construction phase for 10-year and 50-year ARI events, for all wind conditions (Section 3.3.2, Assessment of Coastal Sediment report). None of the modelled 10-year events exceed the TSS threshold of >80 mg/kg for a period of more than three days. Of the 50-year events, the calm wind scenario also does not cause the TSS concentration/time threshold to be breached.

In the 50-year ARI rainfall event with NE winds, a 1.4ha area on the Kakaraia Flats (Appendix E) exceeds the TSS concentration/time threshold, whereas in the 50-year event with SW winds a 3.5ha area southwest of Breach Point exceeds the threshold (Section 3.3.2 and Figures 20 and 27, Assessment of Coastal Sediment report). Middle and lower reaches of the Kaipara Harbour are not affected by elevated TSS from the Project discharged from the Hōteo and Oruawharo Rivers (Assessment of Coastal Sediment report).

The concentration/time TSS threshold originates from scientific literature relating to pipi and horse mussels. However, neither pipi nor horse mussels are likely to be present in the muddy upper harbour area where the TSS threshold is predicted to be exceeded in both the baseline and the construction phase modelling of the 50-year ARI rainfall event under some wind scenarios. The tube worm, *Boccardia*, may be present in the upper harbour habitat, but literature indicates that this species can tolerate 80 g/m^3 for a period of nine days before measurable sublethal effects may begin to occur. TSS from the 50-year ARI rainfall event is not expected to remain above 80 mg/m^3 for nine days or more (Section 3.3.2, Assessment of Coastal Sediment report).

We consider that that magnitude of effect of TSS arising from the modelled rainfall events is likely to be negligible.

<u>Oruawharo Inlet</u>

Baseline and Construction Phase

Sediment from the Wairoa River is widely dispersed within the Kaipara Harbour and reaches the smaller arms of the northern parts of the harbour (including the Oruawharo River estuary) (section 2.5 Assessment of Coastal Sediment report). Sediment-laden freshwater discharged to the Maeneene and Te Hana Creeks is conveyed to Oruawharo River estuary, where it is subject to a range of coastal processes that dilute and disperse sediment to the wider estuary. The Oruawharo River estuary is a depositional environment that has been subject to rapid infilling and is dominated by mud (Section 2.6, Assessment of Coastal Sediment report).

There are no available baseline measurements of sediment load or suspended sediment concentration in the Oruawharo River estuary. However, the increase in sediment load from the Project is small. For example, in a 50-year ARI event, sediment load increases by 3.7% from a baseline of 4425 tonnes. The Assessment of Coastal Sediment report states that the increase in sediment load is not expected to result in TSS concentrations substantially higher than the baseline situation or for a longer duration than the baseline situation.

The magnitude of effect of exceeding the TSS concentration/time threshold in the 50-year event during construction is assessed as negligible (Table 4). Based on moderate ecological values in the Oruawharo and Hōteo River estuaries, the level of effect of elevated TSS on marine ecological values is assessed as very low (Table 5).

Effects on Avifauna

During construction, if sediment laden water is discharged to the receiving environment, there is the potential for adverse effects on marine water quality through increased suspended sediment, which in turn can have potential impacts on the ability of visual foragers to locate prey items. Visual foraging species recorded in the Kaipara include several species of shags, terns (including the NZ fairy tern; Baird et al., 2013, Ismar et al., 2014) and herons classified as Threatened and At Risk (Table 6).

Given the low to very low level of construction effects determined for the marine ecology assessment (above), the availability of extensive similar foraging habitat elsewhere in the Kaipara Harbour and wider estuarine network, the short term and confined nature of the elevated TSS levels, we consider that the magnitude of effect on visual foragers to locate prey will be negligible (Table 4).

Therefore, we have assessed the overall level of effect from suspended sediment to be low (Table 5) for coastal avifauna in the Kaipara Harbour.

4.1.4 Summary of effects of suspended sediment

Low suspended sediment concentration and the short duration of exposure primarily in the upper harbour habitats of the Mahurangi and Kaipara Harbours, as well as the organisms in the upper harbour being tolerant of turbidity and low light penetration, means that the magnitude of effect arising from the 50-year ARI rainfall event is negligible. We consider the level of potential adverse effects on marine ecological values arising from suspended sediments related to the Project in rainfall events 50-year ARI to be low to very low (Table 11).

Table 11 - Assessment of level of effect of TSS on marine ecological values during a 50-year ARI rainfall event during the construction phase

Marine Habitat	Ecological Value	Impact Magnitude	Level of Effect
Mahurangi Harbour			
Upper Harbour	Moderate	Negligible	Very Low
Middle and Lower Harbour	High	Negligible	Low
Kaipara Harbour			
Upper Harbour (Oruawharo Inlet)	Moderate	Negligible	Very Low

Marine Habitat	Ecological Value	Impact Magnitude	Level of Effect
Upper Harbour (Hōteo Inlet)	Moderate	Negligible	Very Low
Middle and Lower Harbour	High	Negligible	Low

We do not consider that the results of the assessment of construction-related suspended sediment would alter if the alignment were moved to a new position within the proposed designation boundary, as the potential sediment discharges during construction are likely to be the same and the operational phase effects will be unchanged.

Effects on avifauna

We have assessed the overall level of effect from suspended sediment to be low for the coastal bird assemblages within the Mahurangi and Kaipara harbour (Table 12).

Table 12 - Assessment of level of effect of TSS on coastal avifauna during a 50-year ARI rainfall event during the construction phase

Marine Habitat	Ecological Value	Magnitude of Effect	Level of Effect
Mahurangi Harbour	Very High	Negligible	Low
Kaipara Harbour	Very High	Negligible	Low

In conclusion, effects arising from Project-related suspended sediment (turbidity) on coastal avifauna is not significant, with low levels of effect.

4.1.5 Sediment Deposition within Mahurangi Harbour

Effects on Marine Ecology

Baseline Sediment Deposition

Sediment deposition in the Mahurangi Harbour was previously modelled for P-Wk, based on a maximum open earthworks area of 27 ha. The Mahurangi Harbour in the baseline situation receives large volumes of sediment in 10- and 50-year ARI rainfall events.

Modelling indicated that the baseline 10-year ARI rainfall events (with calm and ENE wind conditions) results in deposition on the mangrove fringes of the upper reaches of the harbour at high depths (mostly 10-50 mm) with lower depths of deposition (<10 mm) in the central areas of the upper harbour extending to the margins of the middle of the harbour (see Drawing No's. ME-14 and ME-15).

Modelling of the baseline 50-year events (calm and ENE) showed deeper deposition on the mangrove margins of the upper reaches of the harbour (>50 mm), with larger areas receiving 10-50 mm of sediment (including on the margins of the low tide channels) and sediment extending across the central part of the upper harbour down to the middle section of harbour (Drawing No's. ME-16 and ME-17).

Construction Phase Sediment Deposition

Construction related sediment deposition in the muddy upper reaches of the Mahurangi Harbour was previously conservatively assessed for P-Wk as having the potential for a moderate level of effect under a 50-year ARI event, and low level of effect under a 10-year ARI event, under the 5 year construction scenario that was used for P-Wk (Pūhoi to Warkworth Marine Ecology Assessment Report). The current Project has significantly lower indicative open area compared to P-Wk (27ha for P-Wk and 15.9ha for the current Project i.e. 58% of the P-Wk area), which means that the sediment load would also be lower, but a longer construction period of 7 years (1 year enabling work and 6 years bulk earthworks).

Drawing No's. ME-18 and ME-19 show the additional areas within the harbour that will receive 5-10mm of sediment and >10mm of sediment in the 10-year ARI rainfall events. These maps show diffuse, small additional areas of deposition in the upper reaches of the harbour. The effect of P-Wk construction related sediment was previously assessed as having a low level of effect, based on a 1.1% increase in area of benthic habitat receiving >5mm of sediment. We consider that the Project, with significantly less indicative open earthworks area, would have a negligible magnitude of effect on marine ecological values.

Drawing No's. ME-20 and ME-21show the additional areas of deposition within the harbour that will receive 3-5 mm, 5-10 mm and >10 mm of additional sediment in the 50-year ARI rainfall events. Sediment deposition areas are larger and more continuous in the 50-year events compared to the 10-year events. The ENE wind scenario results in larger areas of deep deposits compared to the calm scenario. Benthic invertebrate communities may be adversely affected at the sediment deposition >5 mm, and given the larger areas affected, there may be some effect on community composition through smothering. However, the organisms that inhabit the upper reaches of the Mahurangi Harbour are tolerant of sediment and muddy conditions and relatively resilient. We expect that there may be a short-term (a few years) adverse effect on community composition, but we expect in the longer term that organisms will recolonise deposition areas, resulting in a negligible effect. The increase in area of muddy upper harbour benthic habitat receiving 5-10 mm of sediment increases in the construction phase by 21-23 ha, and the area receiving >10 mm increases by 4-5 ha (Table 13) for the significantly larger area of earthworks for the P-Wk project. It is expected that the areas affected in a 50-year ARI rainfall event with ENE winds for the current Project would be significantly smaller.

Table 13 - Areas of deposition in the 50-year ARI rainfall event in the Mahurangi under baseline and construction phase (ha).

Modelled scenario	Area 5-10mm Baseline	Area 5-10mm Construction	Area >10mm Baseline	Area >10mm Construction
50-year calm	90.5	111 (20.5 ha, incr 22.7%)	40.2	43.8 (3.6 ha, incr 9%)
50-year ENE	90.7	113.3 (22.6 ha, incr 24.9%)	37.5	42.5 (5 ha, incr 13.3%)

Given the reduced area of open earthworks in the Project, we consider the magnitude of effect from sediment deposition arising from a 50-year ARI rainfall event occurring in the upper reaches of the Mahurangi Harbour to be a moderate magnitude of effect (Table 4). When combined with the moderate ecological values in the upper harbour, the overall level of effect is assessed as moderate using the EIANZ impact assessment criteria (Table 5), which is considered a significant effect for RMA purposes, which would require mitigation if such an event occurs.

Effects on avifauna

Runoff of sediment from open earthwork areas during rainfall events discharging to the Mahurangi Harbour (during construction of the Project) has the potential to adversely affect marine invertebrates and indirectly the wading and marsh bird species that feed on them. Modelling indicates that the areas of benthic habitat receiving sediment deposition above threshold concentrations (for 10-year ARI and 50-year ARI rainfall events) is likely to be predominantly within the upper harbour areas.

In terms of sediment deposition during a 10-year ARI event, the maps show diffuse, small additional areas of deposition in the upper reaches of the harbour, with a 1.1% increase in area of benthic habitat receiving >5mm of sediment.

The modelling for the 50-year ARI rainfall event results in an area of muddy upper harbour benthic habitat receiving 5-10 mm of sediment increases in the construction phase by c.20-23 ha, and the area receiving >10 mm increases by c.4-5 ha (combined effect on 1.7% of the intertidal habitat within the Mahurangi Habour). The above marine ecology assessment determined a moderate overall level of effect on the upper reaches of the Mahurangi Harbour. These upper reaches form only part of the wider foraging network that coastal species utilise within the Mahurangi area and the wider landscape.

The assessment of potential effects on the coastal avifauna has taken into consideration the mobile nature of the coastal species and wider foraging network available, the baseline levels of sediment discharge from other land uses and the predicted sediment likely to result from the Project in large rainfall events.

We conclude that the predicted additional deposition of Project related sediment associated with a 10-year ARI rainfall event is likely to have a negligible magnitude of effect on those species foraging on the intertidal mudflats in the Mahurangi Harbour. Based on a negligible magnitude of effect on a very high value, we consider the overall level of effect on the coastal avifauna assemblage associated with a 10-year ARI rainfall would be Low in the Mahurangi Harbour

Based on the context of the Mahurangi Harbour, a 50-year ARI rainfall event is likely to have a negigible magnitude of effect (impacting only 1.7% of the intertidal habitat within the Mahurangi Habour[20]) on those species foraging on the intertidal mudflats in the Harbour. Based on a negligible magnitude of effect on a very high value, we consider the overall level of effect on the coastal avifauna assemblage associated with a 50-year ARI rainfall would be low in the Mahurangi Harbour.

4.1.6 Sediment Deposition within the Kaipara Harbour

Effects on Marine Ecology

The following section describes the predicted sediment deposition footprint under the 7-year construction scenario for earthworks (1 year enabling works, 6 years bulk earthworks) associated with the Project within the Oruawharo and Hōteo Estuaries based on the modelling undertaken for the Project detailed in the Assessment of Coastal Sediment report. Assessment of the effect of sediment deposition is considered at the scale of the Hōteo Inlet and the Oruawharo Inlet, not the entire Kaipara Harbour, due to its' very large size and convoluted shape.

The sediment deposition patterns are similar between the baseline and construction scenarios, with the construction scenarios having slightly thicker deposits and sediment dispersed over a slightly larger area (Section 3.3.2, Assessment of Coastal Sediment report). The range of additional sediment deposition thickness in the modelled construction scenarios is between 0.02-1 mm at the end of three days.

Hōteo Inlet

Baseline Sediment Deposition

Modelling indicates that in the baseline conditions, sediment-laden water discharged into the harbour via the Hōteo River disperses down the tidal channels and across the intertidal flats. Most of the sediment deposits between the river mouth and an island 3 km to the west of the river mouth (Moturimu Island) (Appendix E). In baseline conditions, 50-year events can deposit up to 50 mm of sediment adjacent to the Hōteo River mouth, further into the Harbour and up the Tauhoa River estuary (including the Tauhoa Scientific Reserve) (Appendix E).

[20] EIANZ (2018) defines a neglible magnitude of effect as "Very slight change from baseline condition. Change barely distinguishable, approximating to the no change situation and/or having negligible effect on the known population or range of the element/feature".

Construction Sediment Deposition

Using the same sediment deposition thresholds as for the Mahurangi Harbour assessment (5-10 mm and >10 mm), at the end of the 7-day model period, under calm wind conditions in the 10-year ARI rainfall event, the area that receives 5-10 mm in the baseline is 43 ha, which increases to 49 ha during construction (14% increase) (Table 14 below and Table 17 Appendix D, Assessment of Coastal Sediment report). In the baseline situation 23 ha of estuary receives >10 mm of sediment, which increases to 25 ha during construction, increasing by 10% (Table 14 below and Table 17 Appendix D, Assessment of Coastal Sediment report).

Under SW wind, the 10-year ARI event deposits at a depth of 5-10 mm over 20 ha in the baseline, with an additional 1 ha in the construction scenario (5% increase). Similarly, 18 ha receives >10 mm in the baseline situation, which increases to 19 ha during construction (a 4.9% increase) (Table 14 below and Table 17, Appendix D, Assessment of Coastal Sediment report).

Under the NE wind, the 10-year ARI event deposits 50 ha in the baseline increases by 6 ha with construction (6.6% increase), whereas the >10 mm baseline of 36 ha increases to 38 ha with construction, with an additional 1.7 ha of habitat affected (4.7%) (Table 14 below and Table 17, Appendix D, Assessment of Coastal Sediment report).

Table 14 - Areas of deposition in the 10-year ARI rainfall event in the Hōteo Inlet under baseline and construction phase.

Modelled scenario	Area 5-10mm Baseline (ha)	Area 5-10mm Construction (ha)	Area >10mm Baseline (ha)	Area >10mm Construction (ha)
10-year calm	43	49 (5.4 ha, increase 14%)	23	25 (2.3 ha, increase 10%)
10-year SW	20	21 (1 ha, increase 5%)	18	19 (0.9 ha, increase 4.9%)
10-year NE	50	56 (6.6 ha, increase 12%)	36	38 (1.7 ha, increase 4.7%)

Deposition of sediment at 5-10 mm depth is likely to cause mortality to sensitive benthic invertebrate species through smothering, which in turn affects the community composition. Effects on community composition are likely to be significant in the shorter term (3-5 years), with recolonisation potentially occurring naturally over time. Deposition of sediment at depths greater than 10mm is likely to cause mortality to most, if not all, benthic invertebrates present. Areas that receive >10 mm of sediment will take longer to recover through natural recolonisation processes and the assemblages may not be similar to the original assemblages smothered, in the longer term.

The 10-year ARI rainfall event during construction has the potential to cause additional adverse effects on sensitive species above the baseline, where 1-6.6 ha of additional areas of estuary receive 5-10 mm deposition. In addition, the 10-year ARI event has the potential to cause additional adverse effects at a community level where 0.9-2.3 ha of additional parts of the estuary receive >10 mm of sediment. Overall, the area of intertidal habitat potentially affected (5-10 mm plus >10 mm) by a 10-year ARI is between 1.9 and 8.3 ha. An increase in deposition of 1.9 ha in SW wind conditions is relatively small in the context of the upper reaches of the Kaipara Harbour and unlikely to result in significant adverse effects above the effects of the baseline situation. However, the 10-year ARI event in calm and NE conditions is expected to result in 7.7 ha and 8.3 ha of additional benthic habitat receiving deposited sediment that will affect organisms and communities. In those wind conditions, the increase in area affected is considered to be a moderate magnitude of effect, but at the lower end of the scale given the temporary nature of the effect and the large area of mudflats in the Hōteo Inlet. In other words, our assessment of the 10-year ARI in the Hōteo Inlet is relatively conservative.

At the end of the 7-day model period, under calm wind conditions in the 50-year ARI rainfall event, the area that receives 5-10 mm in the baseline is 123 ha, which increases to 126 ha during construction (2.4% increase) (Table 15 below and Table 17, Appendix D, Assessment of Coastal Sediment report). In the baseline situation 30 ha of estuary receives >10mm of sediment, which increases to 51 ha during construction, increasing by 69.2% (Table 15 below and Table 17, Appendix D, Assessment of Coastal Sediment report).

Under SW wind, the 50-year ARI event deposits at a depth of 5-10 mm over 31 ha in the baseline, with an additional 21 ha in the construction scenario. Similarly, 13 ha receives >10mm in the baseline situation, which increases to 17 ha during construction (a 13% increase (Table 15 below and Table 17, Appendix D, Assessment of Coastal Sediment report).

Under the NE wind, the 50-year ARI event deposits 83 ha in the baseline increases by 2 ha to 84 ha with construction, whereas the >10mm baseline of 51 ha increases to 63 ha with construction, with an additional 11.7 ha of habitat affected (Table 15 below and Table 17, Appendix D, Assessment of Coastal Sediment report).

Table 15 - Areas of deposition in the 50-year ARI rainfall event in the Hōteo Inlet under baseline and construction phase.

Modelled scenario	Area 5-10mm Baseline (ha)	Area 5-10mm Construction (ha)	Area >10mm Baseline (ha)	Area >10mm Construction (ha)
50-year calm	123	126 (3 ha, increase 2.4%)	30	51 (21 ha, increase 69.2%)
50-year SW	31	52 (21 ha, increase 67.7%)	13	17 (4.3 ha, increase 13%)
50-year NE	83	84 (1 ha, increase 1.2%)	52	63 (11.7 ha, increase 22.8%)

The 50-year ARI rainfall event has a low probability of occurring (10% chance in a 5-year construction period). However, it has the potential to cause significant adverse effects on sensitive species during construction. 1-21 ha of additional areas of estuary will receive 5-10 mm deposition. The deposition has the potential to cause adverse effects at a community level where 4-21 ha of additional parts of the estuary receive >10 mm of sediment. Overall, the area of intertidal habitat potentially affected (5-10 mm plus >10 mm) by a 50-year ARI is between 13 and 27 ha, which is assessed as a moderate magnitude of effect (albeit temporary) at the scale of the Hōteo Inlet.

Oruawharo Inlet

Baseline and Construction Sediment Deposition

The Assessment of Coastal Sediment report states (section 4.2.2) that a sediment deposition baseline of 6 mm/yr is assumed, with 3.6 mm of that arising from the Oruawharo River sources. Only around 5% of sediment discharged to the Oruawharo River leaves the estuary, with the remainder distributed around the estuary by wind, waves and tidal currents, and depositing in sheltered areas around of the fringes of exposed reaches and within mangrove stands.

Table 13 within the Assessment of Coastal Sediment report summarises the potential sediment deposition within the Oruawharo Inlet and sub-estuaries, under three conservative deposition scenarios. The Project is not expected to add more than 0.26 mm (in the 50-year ARI rainfall event) of sediment to the baseline deposition in any of three scenarios (all sediment retained within the Oruawharo estuary mouth, the Maeneene Creek mouth or the Te Hana Creek mouth) in any of the rainfall events (2-, 10-, 50-year ARI) considered.

We conclude that the additional deposition of Project-related sediment is barely perceptible and has a negligible magnitude of effect (Table 4) on marine ecological values in the Oruawharo Inlet and sub-estuaries. Therefore, with moderate ecological values and a negligible magnitude of effect, the level of effect is assessed as very low (Table 5).

Effects on avifauna

The assessment of potential effects on wading and marsh bird species has taken into consideration the mobile nature of birds, the baseline levels of sediment discharge from other land uses and the low predicted sediment from the Project relative to background sediment in large rainfall events.

For the Hōteo Inlet, under SW wind conditions, the 10-year ARI event deposits an additional 1 ha (over baseline) at a depth of 5-10 mm and an additional 1 ha (over baseline) at a depth of >10 mm during construction (Table 14). Under calm and NE conditions, there is a c.5-6 ha additional habitat affected at 5-10 mm (c.13% increase on baseline), and c. 2 ha increase in >10 mm (5-10% increase above baseline).

The modelling for the 50-year ARI rainfall event in the Hōteo Inlet results in 13-27 ha of additional upper harbour habitat receiving sediment above effects thresholds (>5 mm and 5-10 mm) depending on the wind scenario. This increase in sediment is considered to represent a significant proportion of the baseline (i.e. 68-69%). However, at the scale of the entire intertidal habitat available to wading and marsh bird species within the Kaipara Harbour, this 27 ha represents 0.06% of the total intertidal area (40,721 ha).

At the Oruawharo estuary mouth, the Maeneene Creek mouth and the Te Hana Creek mouth, the modelling indicates that the Project is not expected to add more than 0.26 mm of sediment to the baseline deposition, which is considered negligible.

Given the mobile nature of coastal avifauna and their use of a network of foraging habitats, we conclude that the predicted additional deposition of Project related sediment associated with both the 10-year and 50-year ARI rainfall events are likely to have a negligible magnitude in the context of the wider Kaipara Harbour; combined with the very high avifauna values in this area, the overall effect on those will be low at the scale of the wider Kaipara Harbour.

4.1.7 Summary of effect of deposited sediment

We conclude that in all storm event and wind scenarios modelled within the Kaipara Harbour and within the middle and lower reaches of the Mahurangi Harbour, the level of effect of sediment deposition on benthic invertebrates, estuarine vegetation, marine/estuarine habitat values and coastal avifauna is moderate to very low (Table 16).

We do not consider that the results of the assessment of construction of the Project would alter if the alignment were moved to a new position within the proposed designation boundary, as the potential sediment discharges during construction would be similar and operational phase effects unchanged.

Table 16 - Assessment of level of effect of sediment deposition on marine ecological values and avifauna in 10 and 50 year ARI rainfall events during the construction phase

10 year ARI			
Marine Habitat	**Ecological Value**	**Impact Magnitude**	**Level of Effect**
Mahurangi Harbour			
Upper Harbour	Moderate	Negligible	Very Low
Kaipara Harbour			
Upper Harbour (Hōteo Inlet)	Moderate	Moderate	Moderate
Upper Harbour (Oruawharo Inlet)	Moderate	Negligible	Very Low
Avifauna	**Ecological Value**	**Impact Magnitude**	**Level of Effect**
Mahurangi Harbour	Very High	Negligible	Low
Kaipara Harbour	Very High	Negligible	Low
50 year ARI			
Marine Habitat	**Ecological Value**	**Impact Magnitude**	**Level of Effect**
Mahurangi Harbour			
Upper Harbour	Moderate	Moderate	Moderate
Kaipara Harbour			
Upper Harbour (Hōteo Inlet)	Moderate	Moderate	Moderate
Upper Harbour (Oruawharo Inlet)	Moderate	Negligible	Very Low
Avifauna	**Ecological Value**	**Impact Magnitude**	**Level of Effect**
Mahurangi Harbour	Very High	Low	Moderate
Wider Kaipara Harbour	Very High	Negligible	Low

Noting that effects of a moderate level, using the EIANZ criteria, would require mitigation, we conclude, marine ecological values could be significantly adversely affected by sediment deposition in the Mahurangi Harbour in a 50-year ARI event, whereas events >10-year ARI event may have significant adverse effects on marine ecological values in the Hōteo Inlet of the Kaipara Harbour. With respect to coastal avifauna, given their mobile nature and use of a network of foraging habitats, at the scale of the Mahurangi Harbour and the Kaipara Harbour, adverse effects are likely to be Low.

4.1.8 Cumulative Effects of Potential Sediment Deposition

Effect on Marine Ecology

After treatment by erosion and sediment control devices, residual sediment from runoff from open earthworks during the entire construction period will discharge to the Mahurangi and Kaipara Harbours and add to the baseline sediment and future discharges such as those due to forestry harvesting. The residual Project related sediment, whilst small in comparison to the background sediment discharged for rainfall events smaller than the 10-year ARI, and small in comparison to predicted forestry harvesting discharges[21], contributes to the long-term sedimentation of the harbours and is considered to be a cumulative effect.

Mahurangi Harbour

The Project's contribution to sediment loads over a 7-year construction period (1 year enabling works, and 6 years bulk earthworks) has been calculated using different models for each of the two harbours.

The Project's contribution to sedimentation in the Mahurangi Harbour has been calculated on an annual average basis, using the relevant 50-year hindcast rainfall record, and with earthworks occurring in the flats rather than the hills [22]. This is representative of the current earthworks and typical rainfall in the Project location. The total amount of earthworks in the Mahurangi Harbour catchment is estimated at 43.3 ha, with an indicative area of peak open earthworks of 43.3 ha.

Over the 7-year construction period, the Project is likely to contribute an additional 793 tonnes of sediment to the Mahurangi Harbour, which is a 0.92% increase above baseline.

Other activities that are likely to contribute to the cumulative effect of sedimentation within the Mahurangi Harbour between now and construction of the Project and/or during construction of the Project include construction of P-Wk and forestry harvesting.

The assessment of the Project's contribution to the cumulative effect of sediment can be divided into effects on:

- marine ecological values during construction; and
- the lifespan of the upper reaches of harbour in geological time.

With respect to marine ecological values, the Project's effect is assessed as negligible as the increased rate of sedimentation is small (compared to the baseline and likely future sources) and temporary (ie. over seven years).

On lifespan, while the Project contributes to the cumulative sedimentation of the harbour, the contribution is small and relatively insignificant compared to other sources of sediment in the contributing catchment (Table 17). The Project's contribution to the cumulative effect of reducing the lifespan of the Mahurangi Harbour through sedimentation is assessed as negligible in the context of other inputs and processes occurring in geological time.

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[21] Section 5.3, Catchment Sediment Modelling Technical Report.

[22] P-Wk earthworks assessment for the Mahurangi Harbour was divided into a flats focus area and a hills focus area.

Kaipara Harbour

Of the 310 ha of earthworks required for the Project, c.267 ha occur in the Kaipara Harbour catchment, mostly within the Hōteo River catchment but some within the Oruawharo River catchment (c.63 ha).

Project related sediment that could be discharged to the Hōteo River mouth and the Oruawharo River mouth has been estimated based on an annual average sediment load modelled on hindcast rainfall data between 1983-1989 (the wettest 7-year period in the previous 40 years of rainfall data). Over the 7-year construction period, there is likely to be an increase of sediment into the Kaipara Harbour via the Hōteo River of 1,459 tonnes, which is a 0.8% increase above existing baseline. Sediment from the Oruawharo River (and tributaries) is likely to increase over the 7-year construction period by 98 tonnes, which forms a 0.2% increase above baseline.

Similar to the assessment for the Mahurangi Harbour, with respect to marine ecological values, the Project's cumulative effect is assessed as negligible as the increased rate of sedimentation is small (compared to the baseline and likely future sources) and temporary (i.e. seven years). While the Project contributes to the cumulative sedimentation of the harbour, the contribution is small and relatively insignificant compared to other sources of sediment in the contributing catchment (Table 17).

Effect on Avifauna

The ongoing process of sedimentation of the Mahurangi and Kaipara Harbours reduces the foraging habitat coastal avifauna. The Project's contribution to sedimentation is small when compared to the baseline and is unlikely to have more than a negligible magnitude of effect on the foraging and food supply available for the coastal avifauna assemblages associated with the Mahurangi and Kaipara harbours (Table 17).

The Project's contribution to the cumulative effect of sedimentation in the Mahurangi and Kaipara Harbours is assessed as negligible in the context of other inputs and processes occurring in geological time.

Table 17 - Assessment of cumulative effect of sedimentation reducing the lifespan of the Harbours

Marine Habitat	Ecological Value	Impact Magnitude	Level of Effect
Mahurangi Harbour			
Upper Harbour	Moderate	Negligible	Very Low
Kaipara Harbour			
Upper Harbour (Oruawharo)	Moderate	Negligible	Very Low
Upper Harbour (Hōteo)	High	Negligible	Low
Avifauna	**Ecological Value**	**Impact Magnitude**	**Level of Effect**
Mahurangi Harbour	Very High	Negligible	Low
Kaipara Harbour	Very High	Negligible	Low

4.2 Operational Phase Discharge of Treated Stormwater

During the operational phase of the Project, treated stormwater runoff will ultimately be discharged to the Mahurangi Harbour and the Kaipara Harbour (via the two main subcatchments; the Hōteo and Oruawharo). The Project's stormwater treatment system will be designed to remove an annual average of 75% of TSS and associated contaminants (copper, lead, zinc and hydrocarbons, including polycyclic aromatic hydrocarbons), with the residual sediment and contaminants being discharged via streams and rivers to the marine environment (Water Assessment Report).

Constructed wetlands are the preferred stormwater treatment for the Project and will be designed in accordance with Auckland Council TP10 guidelines. Water quality treatment is proposed for all new impervious areas. Gross litter, floatables and 75% of total suspended solids (on a long-term average annual basis) and associated contaminants will be removed (Water Assessment Report).

As with any stormwater discharge, there may be cumulative effects in the long-term arising from the residual contaminants contained in the treated discharge accumulating in the marine sediments. The contaminant accumulation rate, in marine sediments, depends on the hydrodynamic environment (i.e. sheltered or high energy) and the ratio of sediment to contaminants discharged (i.e. the dilution of the contaminants within sediment).

Currently, stormwater contaminants in surface sediment are below biological effects thresholds in both the Mahurangi (apart from copper at upper harbour site IM1 - Vialls Landing – Mahurangi Harbour) and the Kaipara (apart from copper in the upper Kaipara Harbour site TH1 - Oruawharo 1) (see Sections 3.2.8 and 3.3.9 above).The upper reaches of the Mahurangi and Kaipara Harbours have high background sediment discharges which will dilute the residual contaminants in treated operational phase stormwater. It is unlikely that contaminants from the Project will influence the overall sediment contaminant concentrations given that high baseline of sediment and the low residual contaminant load in treated stormwater discharges.

Accordingly, we expect that any long-term change in sediment quality as a result of the Project will be negligible in the estuarine receiving environments and therefore will have a very low level of effect on marine ecological values (Table 18).

Effects on avifauna

Due to the location of the Project away from the coastal environment, it will not result in disturbance to coastal avifauna, or traffic-related mortalities. Some seabirds are attracted to artificial lighting and suffer mortalities from fallouts onto operating roads. As such, downward pointing lighting should be incorporated into detailed design in order to minimise the chances of fallout events occurring.

In terms of stormwater contaminants, the above marine assessment determined that the magnitude of the effect of operational phase discharge of treated stormwater on the organisms in the estuarine receiving environment is likely to be negligible.

Accordingly, for the coastal avifauna assemblages associated with the Mahurangi and Kaipara harbours, the magnitude of effect for the operational phase discharge of treated stormwater is likely to be negligible, and the overall level of effect low (Table 19).

Table 18 - Assessment of the discharge of operational phase treated stormwater

Marine Habitat	Ecological Value	Impact Magnitude	Level of Effect
Mahurangi Harbour			
Upper Harbour	Moderate	Negligible	Very Low
Kaipara Harbour			
Upper Harbour (Oruawharo)	Moderate	Negligible	Very Low
Upper Harbour (Hōteo)	High	Negligible	Low
Avifauna	**Ecological Value**	**Impact Magnitude**	**Level of Effect**
Mahurangi Harbour	Very High	Negligible	Low
Kaipara Harbour	Very High	Negligible	Low

4.3 Summary of Ecological Effects

Below are tables summarising the ecological values, potential adverse effects on marine (Table 19) and avifauna (Table 20) values, assessment of magniture and level of potential effects according to the EIANZ Guidelines, interpretation of those effect in terms of the RMA, and whether avoidance, remedy or mitigation is required.

Table 19 - Summary of Ecological Effects of Marine Ecological Values

Location	Potential Adverse Effect	Ecological Value	Magnitude of Effect (EIANZ)	Level of Effect (EIANZ)	Significance of Effect (RMA)	Avoid, Remedy or Mitigate
MAHURANGI HARBOUR						
Suspended Sediment						
Upper Harbour	Behavioural and physiological effects on organisms	Moderate	Negligible	Very Low	Negligible	NA
Significant Deposited Sediment in a 10-year ARI						
Upper Harbour	Smothering of benthic individuals and communities	Moderate	Negligible	Very Low	Negligible	NA
Significant Deposited Sediment in a 50-year ARI						
Upper Harbour	Smothering of benthic individuals and communities	Moderate	Moderate	Moderate	Significant	Mitigate sediment load if >30 year ARI events occur.[23]
Deposited Sediment Cumulative Effect						

[23] And if the load of sediment discharged due to the Project is greater than that interpolated from modelling for the 50 year event in the Mahurangi Harbour.

Location	Potential Adverse Effect	Ecological Value	Magnitude of Effect (EIANZ)	Level of Effect (EIANZ)	Significance of Effect (RMA)	Avoid, Remedy or Mitigate
Whole Harbour	Reduced lifespan of harbour	Moderate	Negligible	Very Low	Negligible	Mitigate if sediment load from construction is >5% of the baseline
Discharge of Operational Phase Treated Stormwater						
Upper Harbour	Ecotoxicological effects	Moderate	Negligible	Very Low	Negligible	NA
KAIPARA HARBOUR						
Suspended Sediment						
Oruawharo Inlet	Behavioural and physiological effects on organisms	Moderate	Negligible	Very Low	Negligible	NA
Hōteo Inlet	Behavioural and physiological effects on organisms	Moderate	Negligible	Very Low	Negligible	NA
Significant Deposited Sediment in a 10-year ARI						
Oruawharo Inlet	Smothering of benthic individuals and communities	Moderate	Negligible	Very Low	Negligible	NA
Hōteo Inlet	Smothering of benthic individuals and communities	Moderate	Moderate	Moderate	Significant	Mitigate sediment load if >10 year ARI events occur.[24]
Significant Deposited Sediment in a 50-year ARI						
Oruawharo Inlet	Smothering of benthic individuals and communities	Moderate	Negligible	Very Low	Negligible	NA
Hōteo Inlet	Smothering of benthic individuals and communities	Moderate	Moderate	Moderate	Significant	Mitigate sediment load if events >10 year ARI occur
Deposited Sediment Cumulative Effect						
Oruawharo Inlet	Reduced lifespan of harbour	Moderate	Negligible	Very Low	Negligible	NA
Hōteo Inlet	Reduced lifespan of harbour	Moderate	Negligible	Very Low	Negligible	Mitigate if sediment load from construction

[24] And the load of sediment discharged due to the Project is greater than that modelled for the 10 year event in the Hōteo Inlet.

Location	Potential Adverse Effect	Ecological Value	Magnitude of Effect (EIANZ)	Level of Effect (EIANZ)	Significance of Effect (RMA)	Avoid, Remedy or Mitigate
						is >5% of the baseline
Discharge of Operational Phase Treated Stormwater						
Oruawharo Inlet	Ecotoxic-ological effects	Moderate	Negligible	Very Low	Negligible	NA
Hōteo Inlet	Ecotoxic-ological effects	Moderate	Negligible	Very Low	Negligible	NA

In conclusion, modelling indicates significant adverse effects (of a moderate level, EIANZ) on marine ecological values may occur in the Mahurangi Harbour in the 50-year ARI event, and in 10-year and 50-year ARI events in the Hōteo Inlet during the open earthworks period.

Our assessment also states that the potential effects identified from modelling the 10-year ARI event in the Hōteo Inlet are at the lower end of moderate level of effects (with respect to EIANZ) and the lower end of significance (with respect to RMA) and therefore is conservative. However, we propose using the highest load of sediment modelled in the 10-year event as a mitigation trigger in the Hōteo Inlet (see outline of mitigation approach in Appendix F).

With respect to the 50-year ARI event in the Mahurangi Harbour, given that we have not modelled events between the 10-year and the 50-year event, we propose, in the mitigation section below, that the load of sediment associated with a rainfall event size threshold smaller than the 50-year event be used as a mitigation trigger i.e. >30-year ARI event (see mitigation approach in Appendix F).

Operational effects on marine ecological values are assessed as negligible.

Table 20 - Summary of Ecological Effects of Avifauna Ecological Values

Location	Potential Adverse Effect	Ecological Value	Magnitude of Effect (EIANZ)	Level of Effect (EIANZ)	Significance of Effect (RMA)	Avoid, Remedy or Mitigate
Suspended Sediment						
Mahurangi Harbour	Foraging ability	Very High	Negligible	Low	Less than minor	NA
Kaipara Harbour	Foraging ability	Very High	Negligible	Low	Less than minor	NA
Significant Deposited Sediment in a 10-year ARI						
Mahurangi Harbour	Food supply	Very High	Negligible	Low	Less than minor	NA
Kaipara Harbour	Food supply	Very High	Negligible	Low	Less than minor	NA
Significant Deposited Sediment in a 50-year ARI						
Mahurangi Harbour	Food supply	Very High	Negligible	Low	Less than minor	N/A
Kaipara Harbour	Food supply	Very High	Negligible	Low	Less than minor	NA

Location	Potential Adverse Effect	Ecological Value	Magnitude of Effect (EIANZ)	Level of Effect (EIANZ)	Significance of Effect (RMA)	Avoid, Remedy or Mitigate
Deposited Sediment Cumulative Effect on Lifespan of Harbour						
Mahurangi Harbour	Food supply	Very High	Negligible	Low	Less than minor	NA
Kaipara Harbour	Food supply	Very High	Negligible	Low	Less than minor	NA
Discharge of Operational Phase Treated Stormwater						
Mahurangi Harbour	Food supply	Very High	Negligible	Low	Less than minor	NA
Kaipara Harbour	Food supply	Very High	Negligible	Low	Less than minor	NA

No significant adverse effects on coastal avifauna are likely during either construction or operational phases of the Project.

5 RECOMMENDED MITIGATION

Recommended mitigation summary

Mitigation principles for the Project have been developed by the Project team. The mitigation approach refers to taking an integrated and connected approach to mitigation, linking in with mana whenua aspirations, potentially programmes run by other stakeholders, and practical, achievable mitigation into focussed and specifically selected areas to achieve greater ecological outcomes.

Modelling of 10- and 50-year ARI rainfall events indicates that a 50-year event in both the Mahurangi and Kaipara Harbours (Hōteo catchment) and a 10-year event in the Hōteo catchment may result in a moderate level of adverse effect on benthic invertebrate community composition and habitat quality that would require mitigation. Across the whole construction period, Project-related sediment discharges contribute to long-term sedimentation in both harbours and therefore contributes in a very small way to the cumulative effect of ecological decline.

We have taken a conservative approach to mitigation and propose that actual sediment discharged from the Project during construction be measured at representative erosion and sediment control devices to inform whether mitigation (to reduce sediment loads) is required for both cumulative sedimentation effects and larger acute rainfall events (interpolated sediment load for >30-year ARI in the Mahurangi Harbour and modelled sediment load for >10-year ARI in the Hōteo catchment). The period to mitigate the construction sediment, if required, should be within a generation (nominally 25 years), after which additional benefits accrue.

The ecology and landscape planting proposed (on the EM Series Plans in the Volume 3 Drawing set) to mitigate adverse effects of the Project on terrestrial and freshwater ecology and landscape matters has multiple benefits, and accordingly will result in less sediment runoff from those areas compared to the existing landuse. However, if large acute rainfall events occur during construction and if the total sediment contribution of the Project over the construction period exceeds 5% of the baseline, further measures to reduce sediment discharges to the harbours will be required to be developed and implemented. Mitigation measures that reduce the runoff of sediment from land to marine receiving environments that could be considered include planting of riparian margins (especially large streams) and retiring steep grazing or forestry land.

We recommend implementation of best practice erosion and sediment control, monitoring of ESC devices, identification of sediment deposition triggers (acute and chronic) and development and implementation of mitigation measures.

5.1 Mitigation Principles

Mitigation principles for the Project have been developed by the Project team and include the following concepts:

- Develop a cohesive and integrated approach to mitigation across disciplines;

- Consider the wider environmental context in line with ki uta ki tai concept (from mountain to sea);
- Acknowledge mana whenua aspirations for restoration and consider opportunities where these might coincide with mitigation requirements;
- Consider opportunities to integrate with other programmes e.g. Mahurangi Action Plan, Kaipara Integrated Catchment Strategy, Healthy Waters, Kaipara Landcare group, Te Araroa Walkway etc;
- Consider practical implementation and whole-of-life obligations for the Transport Agency and the likelihood of successful outcomes; and
- Aggregate mitigation into areas where the ecological outcomes can be maximised.

We support these principles and an overall integrated approach to mitigation from a marine ecology and coastal avifauna perspective. We recommend that these principles are incorporated, as far as practicable, when developing potential mitigation measures relating to sediment discharges, should mitigation be required.

5.2 Acute Rainfall Events

5.2.1 Overview of mitigation approaches

Mitigating sediment discharge effects from acute rainfall events is generally achieved by using best practice erosion and sediment control management practices to reduce the amount of sediment that leaves the earthworks site, and implementing adaptive management and continuous improvement principles.

However, the scale of the earthworks, the length of time that the construction works will take place over, and natural variability in climate and rainfall events mean that the predicted contributing events and levels of effect may not be the same as those which occur in reality. This is why the assessment undertaken for the Project and the erosion and sediment control measures recommended adopt a conservative approach (assumptions related to the frequency of acute events, the amount of sediment generated from the Project and resultant downstream marine ecology effects). This conservative approach suggests that the actual effects from the Project are no worse than predicted.

In order to determine the actual effects of sediment discharge during the construction of the Project itself, we typically recommend monitoring of the receiving environment after acute events be imbedded in the Project mitigation, to ensure any unexpected effects are properly assessed and managed. However, this is very challenging and is not considered appropriate for this Project, as set out below.

5.2.2 Project challenges

The Project presents challenges in terms of applying typical post event monitoring approaches due to the characteristics of the particular environment downstream of where the Project is proposed to take place.

The upper reaches of the Mahurangi and Kaipara Harbours are low energy, depositional, muddy habitats with high baseline sediment loads. These characteristics make it very difficult to distinguish freshly deposited fine grain terrigenous sediment from the existing muddy sediment that has built up over time.

Baseline sediment discharges comprise natural erosion from land and stream banks (exacerbated by various land use practices) and runoff from activities in the catchment that disturb the land e.g. open earthworks, vegetation removal, grazing of steep land, felling of forestry.

During construction of the Project, runoff from open earthworks will be treated via a range of erosion and sediment control devices which will be designed to best practice at the time. However, during large rainfall events, the effectiveness of the erosion and sediment control devices is diminished such that in those large rainfall events, sediment-laden water will be discharged to streams and ultimately to the upper estuarine receiving environments.

Project sediment will be mixed with natural runoff and other catchment sediment. It will not be possible to distinguish sediment from each of those sources in the muddy, depositional estuarine receiving environment.

Thus, attempting to monitor Project sediment deposition arising from acute rainfall events in the receiving environment is not effective. Such monitoring is highly unlikely to provide useful information to determine the actual effect (of the Project) on marine ecological values. Detection of freshly deposited fine/muddy terrigenous sediment is much less problematic where the receiving environment is sandy and baseline sediment loads are low.

The implication is that:

1. a large rainfall event could occur during the Project's open earthworks period;
2. sediment could be discharged to upper harbour muddy habitats from the Project and other sources;
3. an assessment of effect of deposited sediment on benthic invertebrate community composition could be triggered by a rainfall event and undertaken; and
4. even if a significant adverse effect on the benthic community is detected, it is very difficult, if not impossible, to distinguish natural and catchment-related effects from Project-related effects. It would be very difficult to determine whose sediment is whose and develop mitigation measures relating to the effects of the Project.

We consider that in the estuarine receiving environments for the Project, given their existing muddy nature and the high background load of sediment naturally discharged and from other catchment activities, carrying out triggered (by acute large rainfall events) assessments of effect on benthic ecological values would be relatively pointless. Similarly, carrying out routine 6-monthly assessments of the ecological values of the estuarine receiving environment is unlikely to be helpful in distinguishing baseline and catchment effects from Project effects.

Minimisation of the deposition of terrigenous sediment in the marine environment is of utmost importance. That is why on large earthworks projects such as this Project significant effort is put in to development and management of erosion and sediment control devices, site management, monitoring upcoming weather, training of contractors on site etc.

Deposition of terrigenous sediment in the marine environment is very difficult to remedy. Once sediment has deposited, attempts to remove that sediment would increase the level of effect on marine ecological values and increase the period over which natural recolonization of organisms would occur. Therefore, even if it was possible to distinguish Project sediment from catchment sediment and existing sediment, any ecological response to the deposition of Project-related sediment would need to be in the form of mitigation (or offset if mitigation was not possible), as attempts to remediate are not recommended.

5.2.3 Alternative recommended approach

For the reasons above, we have developed a different approach to monitoring and mitigating construction-related sediment discharges, suitable for this Project.

We propose measuring the load of Project-related sediment that is actually discharged including in particular acute large rainfall events over the entire construction period at source i.e. at a representative number of erosion and sediment control (ESC) devices[25]. The data gathered can then be used to extrapolate likely effects (using existing Project modelling, assessment and factual information) and assess if mitigation is necessary.

5.2.4 Thresholds for monitoring and assessment

The thresholds for when this monitoring and assessment should take place should align with our earlier assessment of when significant effects may occur. As noted, ecological assessment of the outputs from modelling sediment deposition following large rainfall events resulted in the 10-year ARI event and 50-year ARI event in the Hōteo catchment, and a 50-year event in the Mahurangi catchment being identified as having a moderate[26] level of effect which will require mitigation and would be considered significant under the RMA.

With respect to the moderate level of effect (EIANZ, 2018) identified in the 50-year ARI event in the Mahurangi Harbour, as we have not modelled rainfall events between a 10- and 50-year ARI, we cannot say with complete certainty that significant adverse effects begin at 50-year events or greater i.e. significant adverse effects may occur somewhere in between these two events. Accordingly, it is appropriate to take a more conservative approach. In this case, we have assumed any rainfall event bigger than a 30-year event in the Mahurangi catchment may result in significant adverse effects on marine ecological values. Events of this magnitude have appeared in the rainfall records of the 7 wettest years over the past 40 year period, so whilst infrequent would be possible during the indicative 7 year construction programme.

In summary, we propose measuring the volume of sediment discharged from the Project at representative ESC devices during:

- 10-year ARI or bigger events in the Hōteo catchment; and
- 30-year ARI or bigger events in the Mahurangi catchment.

5.2.5 Response to monitoring

If the actual sediment load during those events exceeds the predicted load of sediment that we have relied on for our assessment, then mitigation for that sediment would be required. We recommend that the sum of sediment loads from those events for each catchment during the open earthworks phase of construction will be calculated and will form an

[25] To be identified by an erosion and sediment control expert.

[26] Moderate, high and very high level of effect typically require mitigation (EIANZ Impact Assessment Guidelines).

indirect substitute for monitoring potential Project-related adverse effects in the estuarine receiving environments.

At the end of earthworks, we will be able to calculate the load of Project-related sediment discharged during large acute rainfall events for each harbour.

We propose that the load over and above the predicted thresholds for significant effects is mitigated through measures that will reduce the sediment released to the affected harbours e.g. through riparian planting, retiring steep farming or forestry land, and planting grazing land as native shrubland. More detail on the proposed approach to mitigation is provided in Section 5.4.

5.3 Cumulative Effect of Long-Term Sedimentation

During the entire construction period, Project-related sediment contained in treated ESC discharges contributes to the cumulative effect of sedimentation in the upper harbour habitats (most of which are SEA-M areas), which in turn contributes in a small way to ecological decline in the long-term.

The long-term simulation of construction sediment loads is based on 7 of the wettest consecutive years in the past 40-year rainfall record. Contained within those 7 years are two c. 30-year events, which while possible, are considered relatively unlikely to occur during construction of the Project.

If similar rainfall events to those modelled for the long-term simulation occur during the construction period, in the region of 793 tonnes of additional sediment could be discharged to the Mahurangi Harbour, 1,459 tonnes to the Hōteo Inlet and 98 tonnes to the Oruawharo Inlet.

The contribution of the Project to the modelled long-term sedimentation of the harbours is, however, relatively small in comparison to the background (0.9% increase in the Mahurangi Harbour and 0.8% in the Hōteo Inlet and 0.2% in the Oruawharo Inlet of the Kaipara Harbour). The contribution is also short-term (i.e. only during the 7-year construction period) and is considered negligible in terms of the life-span of the harbours in geological time.

We recommend calculating the total load of sediment discharged during construction in order to determine the Project's contribution to the long-term sedimentation of the harbours. The modelled increase in sedimentation due to open earthworks during 7 of the most rainy years is small (< 1% above baseline). This scenario would have negligible adverse chronic effects on the ecology of the harbours. However, should the Project's contribution in practice actually be greater than 5%[27] of the baseline due to a higher frequency of large rainfall events during the earthworks season, then the Project contribution to cumulative sedimentation may be considered significant. For each harbour, we recommend that if the Project-related contribution to sedimentation is greater than 5% of the baseline over the open-earthworks construction period, then it would be appropriate to mitigate or offset the sediment discharged to the harbours.

[27] There is no rule or precedent for mitigating sediment >5% of the baseline sediment, rather expert opinion has informed this quantum. However, we have previously assessed increases above baseline sedimentation that are greater than 5% of baseline sedimentation as ecologically significant, and these assessments have been accepted in Environment Court and Board of Inquiry hearings.

5.4 Proposed Mitigation of Sediment

Upon completion of the open earthworks within each catchment, if mitigation of sediment discharges from the Project is required, mitigation measures should be undertaken that directly reduce sediment runoff to the harbours. The mitigation shoud occur within a period less than that which is considered a permanent effect.

EIANZ (2018) defines timescales for duration of effects, with permanent effects being those that occur beyond 25 years (span of one human generation) (Table 9, EIANZ (2018)). We consider it appropriate to mitigate significant adverse construction-related sediment effects within a nominal 25-year period, after which additional benefits will accrue if the mitigation remains..

The mitigation triggers are summarised below. Should these be exceeded then consideration of the marine mitigation should be undertaken as outlined by the process in Appendix F.

5.4.1 Mitigation Triggers:

Hōteo catchment

- Acute rainfall events: mitigate where the sum of sediment loads discharged due to the Project in large rainfall events exceeds the highest load modelled for the 10-year events (512 tonnes);

- Chronic discharges (cumulative effect): mitigate where the total sediment load discharged over the open earthworks period is greater than 5% of the baseline sediment (179,202 tonnes).

Oruawharo catchment

- Chronic discharges (cumulative effect): mitigate where total sediment load discharged over the open earthworks period is greater than 5% of the baseline sediment (64,990 tonnes);

No mitigation is required for acute events.

Mahurangi catchment

- Acute rainfall events: mitigate where the sum of sediment loads discharged due to the Project in large rainfall events where the load exceeds the 30-year event load interpolated from the modelling (i.e. 600 tonnes);

- Chronic discharges (cumulative effect): mitigate where the total sediment load discharged over the open earthworks period is greater than 5% of the baseline sediment (85,351 tonnes).

5.4.2 Mitigation Response

Smaller rainfall events are more likely to occur than large rainfall events. For example, the likelihood of a 10-year ARI event occurring during a 6-year bulk earthworks programme is

45%, and 11% for a 50-year ARI event. These ARIs express annual occurrence probabilities which will, in fact, be less in the summer months which is when peak earthworks activities will occur. We do not know the frequency or size of rainfall events that will actually occur during the open-earthworks period of construction, so we cannot propose a specific and quantified mitigation response to this upfront.

In order to determine if a mitigation response is required, it is first necessary to monitor a representative set of erosion and sediment control devices to be able to quantify the load of sediment discharged to the receiving environment in large rainfall events and across the entire earthworks period (in all size rainfall events) (Appendix F).

At the end of earthworks, we will then be able to determine the total load of sediment discharged to each harbour due to acute rainfall events (based on the event and sediment load triggers) and the cumulative load of sediment discharged (Appendix F).

The next step would be to be develop a range of mitigation options (taking the Project mitigation principles into account) that could be undertaken to mitigate Project sediment within a nominal 25 year period (after which net gains will begin to accrue if the mitigation action continues). Mitigation measures should be catchment specific i.e. sediment loads in the Hōteo Inlet are mitigated by actions to reduce sediment discharges in the Hōteo Inlet catchment.

Mitigation for Project-related sediment discharges should directly reduce sediment runoff to the receiving environments and be aligned with the Project's mitigation principles. Mitigation measures that reduce sediment runoff from land and ultimately reduce sediment discharges to the marine environment could include the following:

- planting of riparian margins of streams;
- other stream bank stabilisation measures;
- retiring steep farm grazing land and planting with shrubs/trees to stabilise soils (native planting would have additional ecological benefits beyond sediment retention);
- retiring of forestry land following harvesting and enabling vegetation to regenerate or planting (again native vegetation would have additional ecological benefits);
- retiring of unharvested forestry land[28].

The sediment runoff reduction from a range of mitigation options would need to be assessed (primarily using land cover and slope) for a range of site locations in order to determine the best combination of methods and sites (see method for calculation in Appendix F). This consideration of mitigation options can be undertaken once the quantum of sediment to be mitigated and the available sites for mitigation measures to be carried out on are known. Understanding the characteristics of potential mitigation sites is

[28] Retiring of forestry land with trees unfelled and gradually drilling and poisoning small areas of trees to enable light penetration to the native understory provides multiple ecological benefits through less soil disturbance and therefore less runoff, less habitat disturbance and therefore less impact on native organisms that inhabit the native understory and the exotic forestry trees. We note that this option may not be available, as trees are currently programmed to be felled prior to the Project commencing.

important because sediment runoff is strongly influenced by slope, soils and existing land use.

In summary, we recommend monitoring representative ESC devices during construction in order to derive the total Project-related sediment discharge during construction (cumulative effect) and the Project-related sediment during 30-year or greater events in the Mahurangi Harbour and 10-year or greater events in the Hōteo catchment (acute effects).

We recommend mitigating sediment discharges from acute events (if they occur) in each harbour within a 25-year period by reducing sediment release through measures such as retiring steep farm and forestry land and riparian planting/stream bank stabilisation. We also recommend that if the total sediment load discharged from the Project is greater than 5% of the baseline, then that load (less the sediment from those larger acute events if they occur) also be mitigated through reducing other sediment discharges (Figure 22). The sediment discharge reduction from the proposed landscape and ecology (terrestrial and freshwater) planting has been modelled and should be considered to contribute to mitigation of the project-related sediment load discharged.

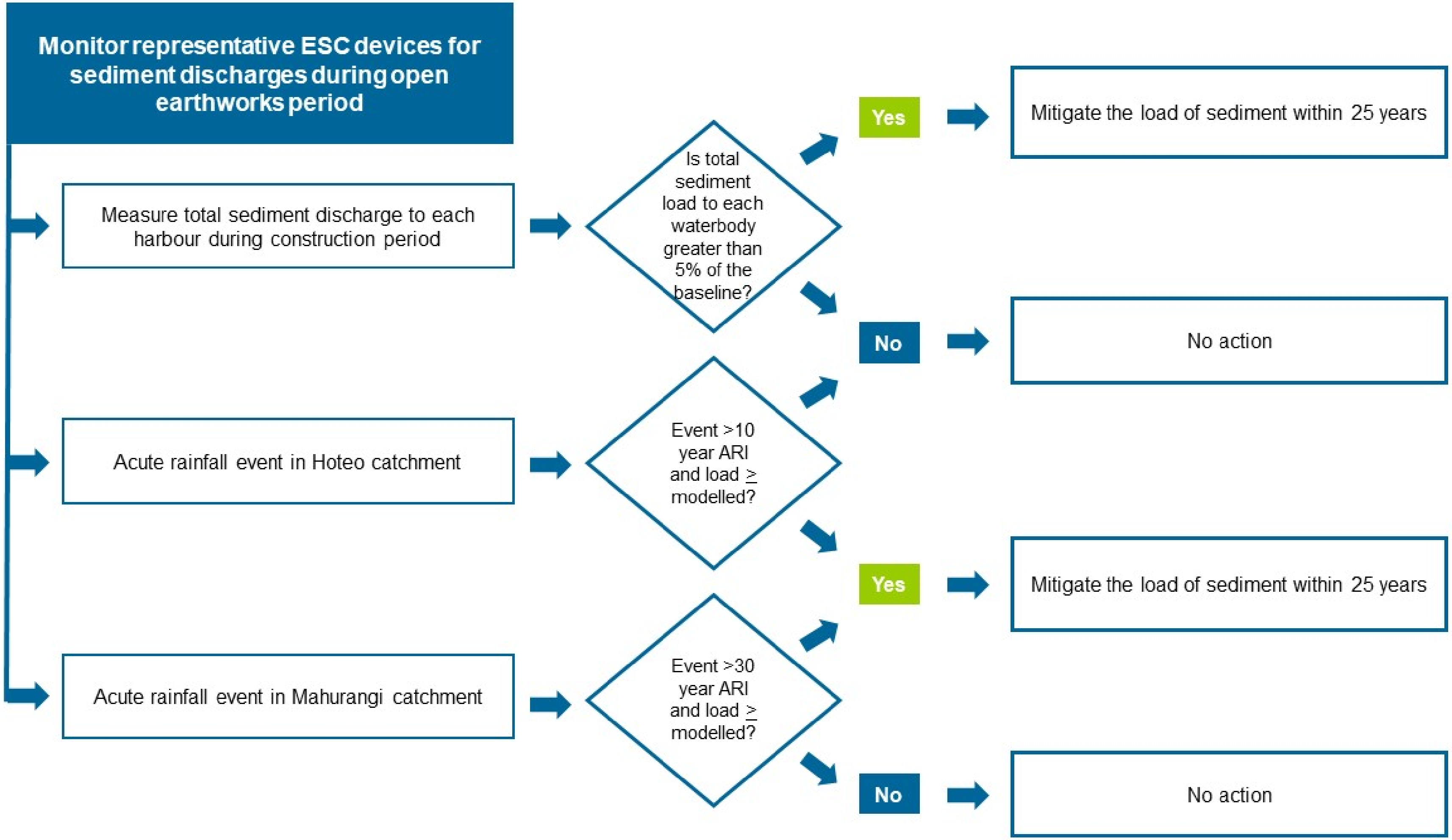

Figure 22 - Sediment discharge triggers and mitigation response flow chart (see sediment loads in section 5.5 below).

5.5 Recommendation

We recommend that a process be developed to determine if mitigation is required for acute and chronic sediment deposition, and to manage the development and implementation of a mitigation response (if required).

Determining if mitigation is required for acute and chronic sediment deposition

We propose that sediment load triggers are set for mitigation. The proposed triggers are:

a) The load of sediment exceeding that calculated from modelling data for a ≥30-year ARI event in the Mahurangi Harbour (600 tonnes);

b) The load of sediment exceeding that modelled for a ≥10-year ARI event in the Hōteo Inlet (512 tonnes);

c) Total sediment discharged from the project during open earthworks is greater than 5% of the baseline sedimentation for the earthworks period, for each of the marine receiving environments i.e. the Mahurangi Harbour, Hōteo Inlet and Oruawharo Inlet.

Calculating total sediment to be mitigated (acute and chronic)

A process should be set out to identify steps to be taken should one or more ≥30-year ARI rainfall event in the Mahurangi catchment occur during open earthworks and the load(s) of sediment exceeds that modelled. Such a condition should reflect that at the end of the open earthworks period, the total load of sediment discharged in events ≥30-year ARI (where the sediment load exceeds that modelled) should be calculated. That total load will form the basis of the development of mitigation measures for the Mahurangi harbour.

Similarly, in the Hōteo catchment, such a condition should identify steps to be taken should one or more ≥10-year ARI rainfall event occur during open earthworks and the load(s) of sediment exceeds that modelled. The condition should reflect that at the end of the open earthworks period, the total load of sediment discharged in events ≥10-year ARI (where the sediment load exceeds that modelled) should be calculated. That total load will form the basis of the development of mitigation measures for the Hōteo Inlet catchment.

A process relating to chronic sedimentation (i.e. contribution to cumulative effect) should be implemented that identifies that should the total load of sediment discharged from the Project during open earthworks in each harbour/inlet exceed 5% of the baseline sediment discharged over the same period, measures should be developed to mitigate that sediment load.

Development of mitigation options

If mitigation for acute and/or chronic sediment discharges are determined to be required at the end of earthworks in the Mahurangi, Hōteo or Oruawharo catchments, then a range of mitigation options and sites will need to be identified and sediment runoff reduction benefits calculated in order to determine the preferred combination of mitigation measures and sites (see Appendix E). Options for sites and mitigation measures should be developed by a suitably qualified ecologist, water resources scientist/hydrologist (or other suitable subject matter expert), the Transport Agency and in consultation with relevant stakeholders. The mitigation measures should balance the sediment load(s) identified within a nominal period of 25 years, after which additional benefits will begin to accrue if the mitigation action continues. We suggest that conditions would be an appropriate vehicle to set out the process for the development of mitigation options, in addition to the preparation of a mitigation plan by a suitably qualified and experienced ecologist (to be certified by AC).

6 CONCLUSIONS

The marine ecological values within both the Mahurangi and Kaipara Harbours are moderate in the upper reaches and high in the middle and lower reaches. The upper reaches of both harbours comprise deep fine mud and receive a high baseline load of sediment.

Potential effects of the Project on the marine ecological values may occur from the discharge of construction phase sediment and the discharge of operational phase stormwater. Recommended measures to minimise sediment runoff include erosion and sediment control designed to regional and Transport Agency guidelines and standards, staging of works and storm event weather forecasting in order to stabilise open areas prior to the storm event occurring.

Assessment of modelled rainfall events indicated that the 50-year event in the Mahurangi Harbour and 10-year and 50-year events in the Hōteo Inlet of the Kaipara Harbour may result in Project-related sediment having significant adverse effects in the upper harbour benthic habitats, with potential flow on effects to coastal avifauna that forage on the benthic intertidal flats.

Project-related sediment discharges from erosion and sediment control devices should be monitored throughout the duration of the construction period and should the Project's contribution to cumulative sedimentation of the harbour be significantly greater than predicted (5% or more of the baseline), the same quantum of sediment should be reduced through mitigation measures within a 25-year period. In addition, we recommend that sediment discharges during acute rainfall events that are greater than a 10-year event in the Hōteo catchment and greater than a 30-year event in the Mahurangi Harbour be mitigated in order to balance sediment discharged from those rainfall events also within a 25-year period. Options for reducing sediment discharges could include retiring steep farm or forestry land and additional riparian planting to stablilise stream banks.

We have assessed discharge of operational phase stormwater as having insignificant adverse effects on marine ecological values and avifauna.

We have proposed sediment deposition triggers (acute and chronic) for both the Mahurangi Harbour and Hōteo Inlet during open-earthworks, based on sediment discharge estimates from a representative suite of ESC devices. Should sediment triggers be breached, measures to mitigate the load of sediment should be developed and implemented.

Overall, with appropriate mitigation in place and benefits accruing within a generation (nominally 25 years), it is considered that adverse effects would be less than minor.

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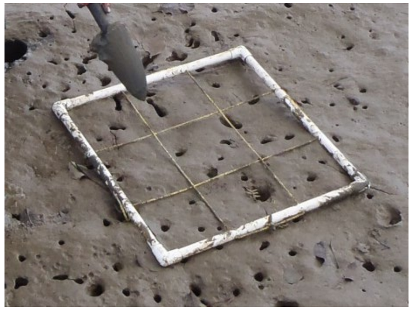
APPENDIX A: SAMPLE SITE SUMMARY

	Appendix A: Summary of prior marine surveys and project surveys relied on for effects assessment	
	Mahurangi Harbour	**Kaipara Harbour**
Intertidal infauna invertebrate survey	Seven sites: mid harbour - HL, CB, DC, MH and lower harbour - TK, JB – April 2017 (unpublished raw data provided by Auckland Council via NIWA, Halliday & Cummings, 2012); Three sites: upper harbour IM0, IM1a and IM1b – May-July 2013, (Further North, 2013)	Four sites: lower harbour - TNP, KKF, NPC, KaiB (unpublished raw data provided by Auckland Council via NIWA, Hailes & Carter, April 2017) Four sites: upper harbour – Hōteo 1, Hōteo 2, Oruawharo 1, Oruawharo 2 – June 2017 (Field surveys Boffa Miskell, 2017)
Intertidal epifaunal invertebrate survey	Twelve sites: lower harbour – IM5, IM6 and IM7; mid harbour - IM2, IM3, IM4, IM9 and IM8; and upper harbour - IM0, IM1a, b (Further North, April-July, 2013)	Four sites: upper harbour – Hōteo 1, Hōteo 2, Oruawharo 1, Oruawharo 2 – June 2017 (Field surveys Boffa Miskell, 2017)
Intertidal sediment grain size and contaminant	Twenty sites: upper harbour - IM0, IM1a, b (Further North, April – July, 2013); mid harbour - IM2, IM3, IM4, IM9 and IM8 (Further North, April – July, 2013) and CB, DC, HL, MH (Halliday and Cummings, 2012 and 2017), H3 and M3 (Gibbs, 2004); and lower harbour – IM5, IM6 and IM7 (Further North, April – July, 2013) and JB and TK (Halliday and Cummings, 2012 and 2017)	Four sites: lower harbour - TNP, KKF, NPC, KaiB, (sediment size only) (unpublished raw data provided by Auckland Council via NIWA, Hailes & Carter, April, 2015) Four sites: upper harbour – Hōteo 1, Hōteo 2, Oruawharo 1, Oruawharo 2 (Field surveys Boffa Miskell, June, 2017);
Subtidal sediment grain size and contaminant	Eight sites: lower harbour – SM5, SM6, SM7, SM8; and mid harbour – SM1, SM2, SM3, SM4 (Further North, April, 2013)	Four sites: lower harbour - TNP, KKF, NPC, KaiB (unpublished raw data provided by Auckland Council via NIWA, Hailes & Carter, April, 2015)

	Appendix A: Summary of prior marine surveys and project surveys relied on for effects assessment	
	Mahurangi Harbour	**Kaipara Harbour**
Intertidal oxidation reduction potential	Eight sites: lower harbour – IM5, IM6 and IM7; and mid harbour - IM2, IM3, IM4, IM9 and IM8 (Further North, April – July, 2013)	Four sites: upper harbour - Hōteo 1, Hōteo 2, Oruawharo 1, Oruawharo 2 (Field surveys Boffa Miskell, June, 2017)

APPENDIX B: EPIFAUNA AND REDOX - MAHURANGI AND KAIPARA HARBOURS

Site	Location	Quadrat	Redox Core
M1			

Crab burrows	113 (37.7)
Macroalgae	0
Macrofauna	0

Redox (ORP)	386.6
pH	1.52
Salinity (μs/cm)	66
DO %	94.3
TDS (g/L)	0.042
Temperature (°C)	18.24

M2

Crab burrows	218 (72.7)
Macroalgae	0
Macrofauna	0

No redox core sample.

Redox (ORP)	460
pH	1.53
Salinity (µs/cm)	80
DO %	92.9
TDS (g/L)	0.056
Temperature (°C)	18.74

M3

Crab burrows	124 (41.3)
Macroalgae	0
Macrofauna	0

Redox (ORP)	478.1
pH	1.51
Salinity (µs/cm)	60
DO %	96
TDS (g/L)	0.039
Temperature (°C)	17.6

M4

Crab burrows	134 (44.7)
Macroalgae	0
Macrofauna	0

Redox (ORP)	444.6
pH	1.41
Salinity (µs/cm)	66
DO %	92.4
TDS (g/L)	0.043
Temperature (°C)	18.9

M5

No quadrats taken (replaced with site M5a)

Redox (ORP)	470.1
pH	1.45
Salinity (µs/cm)	57
DO %	103.8
TDS (g/L)	0.037
Temperature (°C)	18.5

M5a

Crab burrows	237 (79)
Macroalgae	0
Macrofauna	7

- 5 x *Austrovenus stutchburyi*
- 1 x *Paphies australis*
- 1 x *Diloma subrostrata*

Redox (ORP)	469.3
pH	1.7
Salinity (µs/cm)	41
DO %	110.8
TDS (g/L)	0.029
Temperature (°C)	16.8

M6

Crab burrows	1 (0.3)
Macroalgae	0
Macrofauna	4

- 2 x *Austrovenus stutchburyi*
- 1 x *Paphies australis*
- 1 x *Diloma subrostrata*

edox (ORP)	475
pH	1.7
Salinity (µs/cm)	285
DO %	84
TDS (g/L)	0.054
Temperature (°C)	19.5

M7

Crab burrows	72 (24)
Macroalgae	0
Macrofauna	0

No redox core sample.

Redox (ORP)	464.6
pH	1.53
Salinity (µs/cm)	55
DO %	90.8
TDS (g/L)	0.035
Temperature (°C)	19

M8

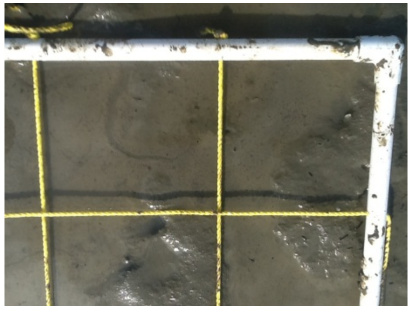
Crab burrows	94 (31.3)
Macroalgae	0
Macrofauna	3

- 2 x *Cominella glandiformis*
- 1 x *Elminius modestus*

No redox core sample.

Redox (ORP)	477.6
pH	1.64
Salinity (µs/cm)	54
DO %	95.2
TDS (g/L)	0.035
Temperature (°C)	19.9

M9



Crab burrows	203 (67.7)
Macroalgae	0
Macrofauna	0

Redox (ORP)	477.7
pH	1.7
Salinity (µs/cm)	64
DO %	93.2
TDS (g/L)	0.041
Temperature (°C)	21.2

<table>
<tr><th>Site</th><th>Quadrat</th><th>Site</th><th>Quadrat</th></tr>
<tr>
<td>Hōteo 1 a</td>
<td>

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<tr><td>Macroalgae</td><td>1</td></tr>
<tr><td>Macrofauna</td><td>2</td></tr>
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filamentous green algae
25 x Eliminus modestus (barnacle)
80 x polychaete holes
20 x pneumatophores
</td>
<td>Hōteo 1 b</td>
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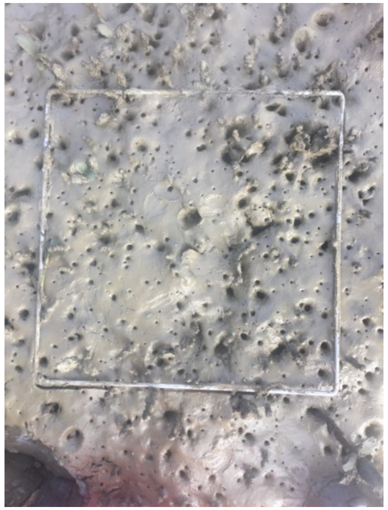
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25 Eliminus modestus (barnacle)
3 x Crassostria gigas (oyster)
100 x polychaete holes
5 x pneumatophores
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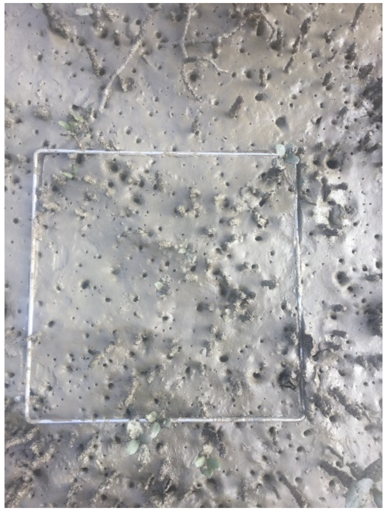
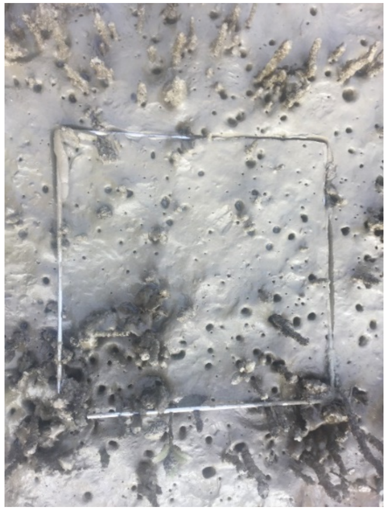
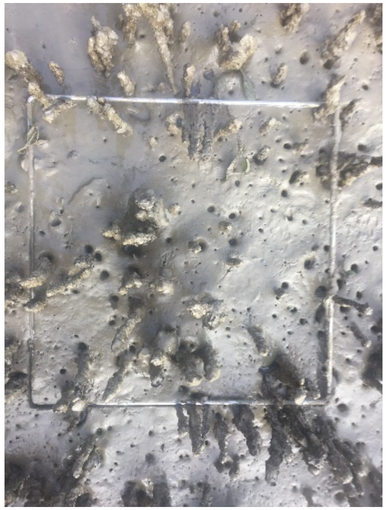
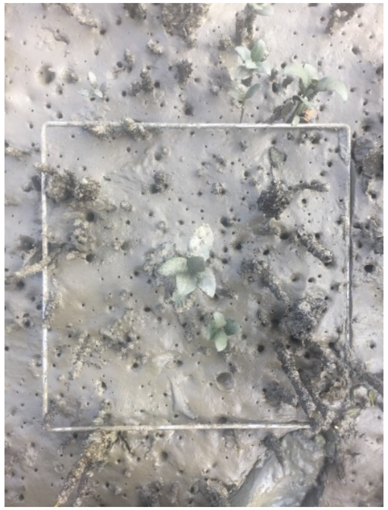
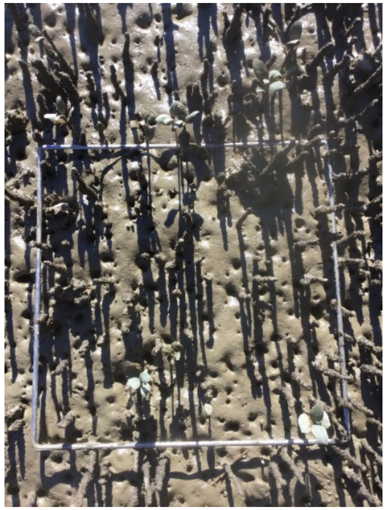
Hōteo 1 c	 Redox: <1cm Crab burrows: 119 Macroalgae: 0 Macrofauna: 3 1 x *Crassostrea gigas* (oyster) 80 x polychaete holes 10 x pneumatophores	**Hōteo 1 d**	 Redox: <1cm Crab burrows: 46 Macroalgae: 1 Macrofauna: 2 filamentous green algae 7 x *Crassostrea gigas* (oyster) 40 x polychaete holes 8 x pneumatophores

Redox	<1cm
Crab burrows	119
Macroalgae	0
Macrofauna	3

Redox	<1cm
Crab burrows	46
Macroalgae	1
Macrofauna	2

Hōteo 1 e	 Redox: <1cm Crab burrows: 61 Macroalgae: 1 Macrofauna: 1 filamentous green algae 90 x polychaete holes 37 x pneumatophores	**Hōteo 1 f**	 Redox: <1cm Crab burrows: 59 Macroalgae: 1 Macrofauna: 0 filamentous green algae 60 x polychaete holes >25 *Eliminus modestus* (barnacle) 6 *Crassostrea giga* (oyster)

Hōteo 2 a		**Hōteo 2 b**	

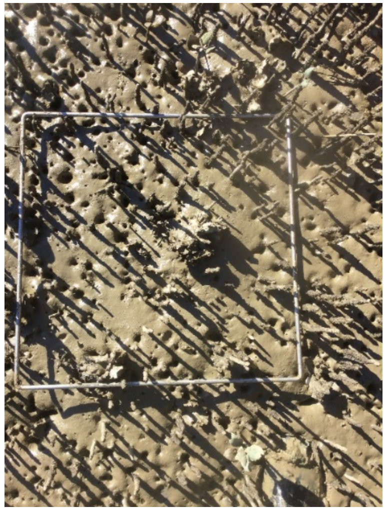
Redox	<1cm
Crab burrows	102
Macroalgae	1
Macrofauna	2

filamentous green algae
3 x *Crassostrea gigas* (oyster)
50 x polychaete holes
64 x pneumatophores

Redox	<1cm
Crab burrows	160
Macroalgae	1
Macrofauna	1

filamentous green algae
40 x polychaete holes
120 x pneumatophores

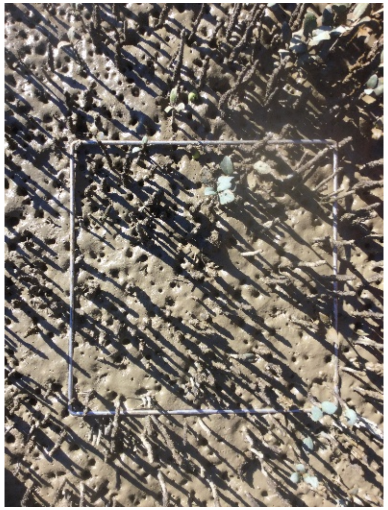
Hōteo 2 c



Redox	<1cm
Crab burrows	135
Macroalgae	1
Macrofauna	2

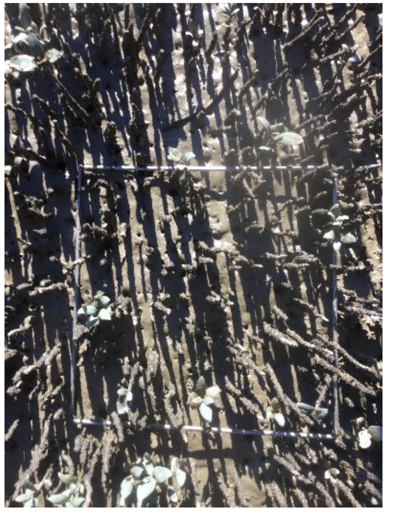
filamentous green algae
10 x *Crassostrea gigas* (oyster)
90 x polychaete holes
64 x pneumatophores

Hōteo 2 d

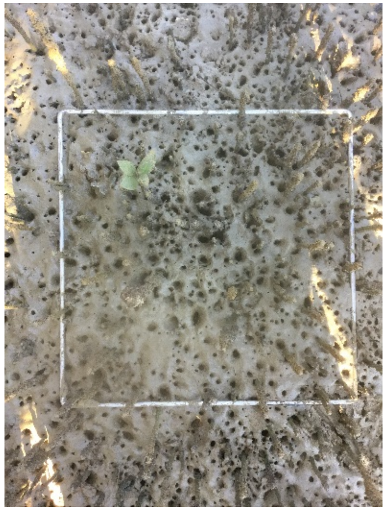


Redox	<1cm
Crab burrows	188
Macroalgae	1
Macrofauna	1

filamentous green algae
80 x polychaete holes
70 x pneumatophhores

Hōteo 2 e	 Redox: <1cm Crab burrows: 92 Macroalgae: 1 Macrofauna: 1 filamentous green algae 58 x polychaete holes	**Hōteo 2 f**	 Redox: <1cm Crab burrows: 57 Macroalgae: 1 Macrofauna: 2 filamentous green algae 21 x *Crassoctrea gigas* (oyster) 20 x polychaete holes 112 x pneumatophores

Oruawharo **1 a**



Redox	<1cm
Crab burrows	268
Macroalgae	1
Macrofauna	2

filamentous green algae
2 x *Crassostrea gigas* (oyster)
300 x polychaete holes
62 x pneumatophores

Oruawharo **1 b**

Redox	<1cm
Crab burrows	136
Macroalgae	1
Macrofauna	2

filamentous green algae
1 x *Crassostrea gigas* (oyster)
3 x pneumatophores
120 x polychaete holes

Oruawharo **1 c**

Redox	<1cm
Crab burrows	302
Macroalgae	1
Macrofauna	1

filamentous green algae
60 x pneumatophores
136 x polychaete holes

Oruawharo **1 d**

Redox	<1cm
Crab burrows	222
Macroalgae	1
Macrofauna	1

filamentous green algae
64 x polychaete holes
56 x pneumatophores

Oruawharo **1 e**	 Redox: <1cm Crab burrows: 42 Macroalgae: 0 Macrofauna: 1 20 x polychaete holes	Oruawharo **1 f**	 Redox: <1cm Crab burrows: 39 Macroalgae: 0 Macrofauna: 1 10 x polychaete holes

Redox	<1cm
Crab burrows	42
Macroalgae	0
Macrofauna	1

Redox	<1cm
Crab burrows	39
Macroalgae	0
Macrofauna	1

<table>
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<td>Oruawharo 2 a</td>
<td>
<table><tr><td>Redox</td><td><1cm</td></tr><tr><td>Crab burrows</td><td>3</td></tr><tr><td>Macroalgae</td><td>2</td></tr><tr><td>Macrofauna</td><td>0</td></tr></table>

filamentous green algae</td>
<td>Oruawharo 2 b</td>
<td>
<table><tr><td>Redox</td><td><1cm</td></tr><tr><td>Crab burrows</td><td>3</td></tr><tr><td>Macroalgae</td><td>1</td></tr><tr><td>Macrofauna</td><td>0</td></tr></table>

filamentous green algae
7 x pneumatophoes</td>
</tr>
</table>

Oruawharo **2 c**

Redox	<1cm
Crab burrows	3
Macroalgae	1
Macrofauna	0

filamentous green algae
11 x pneumatophores

Oruawharo **2 f**

Redox	<1cm
Crab burrows	0
Macroalgae	1
Macrofauna	1

filamentous green algae
16 x pneumatophores

Oruawharo **2 e**	 Redox: <1cm Crab burrows: 1 Macroalgae: 1 Macrofauna: 0 filamentous green algae 15 x pneumatophores	Oruawharo **2 f**	 Redox: <1cm Crab burrows: 2 Macroalgae: 1 Macrofauna: 1 filamentous green algae 8 x pneumatophores

APPENDIX C: INVERTEBRATE SENSITIVITY CHARACTERISTICS

Sources: Gibbs & Hewitt (2004), Robertson & Stephens (2009) and Nicholls et al., (2009)

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
Anemone	*Anthopleura aureoradiata*		**Sensitive to mud**	No	Yes	Mud flat anemone, attaches to cockle shells and helps to reduce the rate at which cockles accumulate parasites. It can also grow in small vertical shafts of its own an inch or more deep, fastened to small stones. Grows up to10mm, intolerant of low salinity, high-turbidity and increasing silt/clay sediment content (Norkko et al., 2001). It has green plant cells in its tissues that convert solar energy to food (Robertson and Stevens, 2016). Optimum range 5-10% mud, distribution range 0-15% mud.
	Edwardsia sp.	**Indifferent**	**Tolerant to mud**	Yes	No	A tiny elongate anemone adapted for burrowing; colour very variable, usually 16 tentacles but up to 24, pale buff or orange in colour. Fairly common throughout New Zealand. Prefers sandy sediments with low-moderate mud. Intolerant of anoxic conditions.
Ribbon worm	*Nemertea sp.*	**Tolerant**	**Prefers some mud**	Yes	Yes	Ribbon or Proboscis Worms, mostly solitary, predatory, free-living animals. Intolerant of anoxic conditions. Optimum mud range 55-60%, but distribution between 0-95%.
Polychaete worm	*Aglaophamus macroura*	**Sensitive**	NA	Yes	Yes	A large, long-lived (5 yrs or more) intertidal and subtidal nephtyid that prefers a sandier, rather than muddier substrate. Feeding type is carnivorous. Significant avoidance behaviour by other species. Feeds on *Heteromastus filiformis*, *Orbinia papillosa* and *Scoloplos cylindrifer* etc.
	Aonides trifida		**Sensitive to mud**	No	Yes	Small surface deposit-feeding spionid polychaete that lives throughout the sediment to a depth of 10cm. *Aonides* is free-living, not very mobile and strongly prefers to live in fine sands; also very sensitive to changes in the silt/clay content of the sediment. In general, polychaetes are important prey items for fish and birds. Optimum mud range 0-5% and distribution between 0-5%.
	Aricidea		**Tolerant to mud**	No	Yes	Slender burrowing worms that are probably selective feeders on grain-sized organisms such as diatoms and protozoans. *Aricidea sp.*, a common estuarine paranoid, is a small sub-surface, deposit-feeding worm found in muddy-sands. These occur throughout the sediment down to a depth of 15cm and appear to be sensitive to the changes in the mud content of the

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
						sediment. Some species of Aricidea are associated with sediments with high organic content. Optimum mud range 35-40%, but distribution between 0-70%.
	Armandia maculata	**Sensitive**	NA	Yes	No	Common subsurface deposit-feeding/herbivore. Belongs to Family Dpheliidae. Found intertidally as well as subtidal in bays and sheltered beaches. Prefers fine sand to sandy mud at low water. Does not live in a tube. Depth range: 0-1,000m. A good coloniser and explorer. Pollution and mud intolerant.
	Asychis		-	No	Yes	-
	Boccardia (Paraboccardia) syrtis and acus	**Sensitive**	**Sand preference**	Yes	Yes	Small surface deposit and suspension feeding spionids. Prefers low-moderate mud content but found in a wide range of sand/mud. It lives in flexible tubes constructed of fine sediment grains and can form dense mats on the sediment surface. Prefers sandy sediment to muddy. Very sensitive to organic enrichment and usually present under unenriched conditions. When in dense beds, the community tends to encourage build-up of muds. Intolerant of elevated TSS for more than six days. Sensitive to sediment deposition. Optimum range 10-15% mud, distribution 0-50% mud.
	Capitella capitata	**Opportunistic and Anoxia Tolerant**	**Prefers some mud but not high percentage**	Yes	Yes	A blood red capitellid polychaete which is very pollution tolerant. Common in sulphide rich anoxic sediments. Optimum range 10-15% or 20-40% mud, distribution range 0-95% mud, based on *Heteromastus filiformis*.
	Cirratulidae sp.	**Opportunistic**	**Sand preference**	Yes	No	Subsurface deposit feeder that prefers sands. Small sized, tolerant of slight unbalanced situations. Optimum range 10-15% mud, distribution range 5-70% mud.
	Cossura consimilis		**Prefers some mud but not high percentage**	No	Yes	*Cossura consimilis* is usually found in habitats which are sandier rather than muddy. *Cossura consimilis* also shows sensitivity to copper contamination. Where estuarine sediments become muddier (exceeding their optimum range) and/or polluted (particularly with copper), the abundance of Cossura consimilis is likely to decline. *Cossura consimilis* tolerates a sediment mud content of 5 to 65%, with an optimum range of 20-25%.
	Euchone sp.		**Tolerant to mud**	No	Yes	-
	Glyceridae	**Indifferent**	**Prefers some mud but not high percentage**	Yes	No	Glyceridae (blood worms) are predators and scavengers. They are typically large, and are highly mobile throughout the sediment down to depths of 15 cm. They are distinguished by having four jaws on a long eversible pharynx. Intolerant of anoxic conditions. Often present in muddy conditions. Intolerant of low salinity.

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
	Goniada sp.	**Indifferent**	**Prefers some mud but not high percentage**	Yes	No	Slender burrowing predators (of other smaller polychaetes) with proboscis tip with two ornamented fangs. The goniadids are often smaller, more slender worms than the glycerids. The small goniadid *Glycinde dorsalis* occurs low on the shore in fine sand in estuaries. Optimum mud range 50-55%, distribution range 0-60% mud.
	Hesionidae sp.	**Indifferent**	NA	Yes	No	Fragile active surface-dwelling predators somewhat intermediate in appearance between nereidids and syllids. The New Zealand species are little known.
	Heteromastus filiformis	**Opportunistic**	**Prefers some mud but not high percentage**	Yes	Yes	Small sized capitellid polychaete. A sub-surface, deposit-feeder that lives throughout the sediment to depths of 15cm and prefers a sandy-muddy substrate. Despite being a capitellid, *Heteromastus* is not opportunistic and does not show a preference for areas of high organic enrichment as other members of this polychaete group do. Relatively tolerant of sedimentation and not very mobile. Optimum range 10-15% or 20-40% mud, distribution range 0-95% mud.
	Macroclymenella stewartensis		**Prefers fine sand and some mud**	No	Yes	A sub-surface, deposit-feeder that is usually found in tubes of fine sand or mud. This species is found throughout the sediment to depths of 15cm and potentially has a key role in the reworking and turn-over of sediment. This worm may modify the sediment conditions, making it more suitable for other species (Thrush et al., 1988). Common at low water in estuaries. Intolerant of anoxic conditions.
	Magelona dakini		**Sensitive**	No	Yes	A small, thin and shovel-nosed (shield like head) burrower and subsurface deposit feeder. Adults grow up to 70mm long. Magelonids are most abundant in sandy habitats and are highly sensitive to lead contamination. Where estuarine sediments become polluted and/or very muddy, the abundance of magelonids is expected to decline.
	Nicon aestuariensis	**Tolerant**	**Prefers mud**	Yes	Yes	A nereid (ragworm) that is tolerant of freshwater and is a surface deposit-feeding omnivore. Prefers to live in moderate to high mud content sediments. Optimum range 55-60% or 35-55% mud, distribution range 0-100% mud.
	Orbinia papillosa	**Sensitive**	**Prefers sand**	Yes	Yes	Long, slender, sand-dwelling unselective deposit-feeders which are without head appendages. Found in fine and very fine sands (occasionally mud) and can be uncommon. Pollution and mud intolerant. Sensitive to time and depth of deposition. Optimum range 5-10% mud, distribution range 0-40% mud.
	Owenia petersenae	**Indifferent**	-	No	Yes	Members of the Oweniidae have characteristic tubes which are considerable longer than the animal and are composed of shell fragments and sand grains which are stacked on top of each other. Oweniids often remain intact within their tubes and must be carefully removed for proper examination. O. fusiformis is currently thought to include a variety of species. Normally a suspension feeder, but is capable of detrital feeding. Is a

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
						cosmopolitan species frequently abundant on sandflats. Are classified as intermediate type species along organic enrichment gradients (Pearson and Rosenberg 1978).
	Paraonidae sp.		-	No	Yes	Slender burrowing worms, which selectively feed on grain-sized organisms such as protozoans and diatoms.
	Pectinaria australis	**Sensitive**	**Tolerant to mud**	Yes	No	Subsurface deposit-feeding herbivore. Lives in a cemented sand grain cone-shaped tube. Feeds head down with tube tip near surface. Prefers fine sands to muddy sands. Mid tide to coastal shallows. Belongs to Family *Pectinariidae.* Often present in NZ estuaries. Density may increase around sources of organic pollution and eelgrass beds. Intolerant of anoxic conditions.
	Perinereis vallata		**Prefers sand**	No	Yes	An intertidal soft shore nereid (which are common and very active omnivorous worms). Prefers sandy, muddy sand, sediments. Sensitive to large increases in sedimentation.
	Phyllodocidae	**Indifferent**	NA	Yes	No	The phyllodocids are a colour family of long, slender, and very active carnivorous worms characteristically possessing enlarged dorsal and ventral cirri which are often flattened and leaf-like (paddleworms). They are common intertidally and in shallow waters.
	Prionospio aucklandica		**Prefers muddy sands**	No	Yes	Common at low water mark in harbours and estuaries. A surface deposit-feeding spionid that prefers living in muddy sands but is very sensitive to changes in the level of silt/clay in the sediment.
	Scolecolepides benhami	**Tolerant**	**Strong mud preference**	Yes	Yes	A surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. Prefers low-moderate mud content (<50% mud). A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions. Optimum range 25-30% mud, distribution range 0-60% mud.
	Scoloplos (Scoloplos) cylindrifer	**Sensitive**	**Prefers sand**	Yes	Yes	Belongs to Family *Orbiniidae* which are thread-like burrowers without head appendages. Common in intertidal sands of estuaries. Long, slender, sand dwelling unselective deposit feeders. Optimum range 0-5% mud, distribution range 0-60% mud.
	Sphaerosyllis sp.	**Indifferent**	**Prefers sand**	Yes	No	Belongs to Family *Orbiniidae* which are delicate and colourful predators. Very common, often hidden amongst epifauna. Small and delicate in appearance. Prefers sandy sediments. Optimum range 25-30% mud, distribution range 0-40% mud.
	Syllidae	**Indifferent**	**Prefers sand**	Yes	No	Belongs to Family *Syllidae.* Delicate and colourful predators. Very common, often hidden amongst epifauna. Small size and delicate in appearance.

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
						Prefers mud/sand sediment. Optimum range 25-30% mud, distribution range 0-40%.
	Terebellidae sp.	**Indifferent**	NA	Yes	No	Large tube or crevice dwellers with a confusion of constantly active head tentacles and a few pairs of anterior gills.
	Travisia olens novaezealandiae		**Sensitive to mud**	No	Yes	Belong to the Opheliids. Short-bodied, cigar-shaped, muscular sand burrowers. Opheliids are deposit feeders, but probably selective in their intake of particulate material. The large, fat, bad smelling, grey-white coloured scalibregmatid *Travisia olens* is found on open to semi-protected sand beaches. Optimum range 0-5% mud, distribution range 0-5%.
Oligochaete worm	*Oligochaete sp.*	NA	**Strong mud preference**	Yes	Yes	Segmented worms - deposit feeders. Classified as very pollution tolerant by AMBI (Borja et al., 2000) but a review of literature suggests that there are some less tolerant species. Many oligochaete species prefer sand and then mud. Tolerant of depth of sedimentation and time exposed. Optimum range 95-100% mud, distribution range 0-100% mud.
Gastropod	*Amphibola crenata*		**Tolerant to mud**	No	Yes	A pulmonate gastropod endemic to NZ. Common on a variety of intertidal muddy and sandy sediments. A detritus or deposit feeder, it extracts bacteria, diatoms and decomposing matter from the surface sand. It egests the sand and a slimy secretion that is a rich source of food for bacteria. Juveniles prefer finer sediment than adults.
	Chiton glaucus	**Indifferent**	NA	Yes	No	The green chiton, is a marine polyplacophoran mollusc in the Family *Chitonidae*, the typical chitons. It is the most common chiton species in NZ. The shell, consisting of eight valves surrounded by a girdle, is fairly large, up to 55mm in length.
	Cominella glandiformis	NA	**Strong sand preference**	Yes	No	Endemic to NZ. A carnivore living on surface of sand and mud tidal flats. Has an acute sense of smell, being able to detect food up to 30 metres away, even when the tide is out. Intolerant of anoxic surface muds. Optimum range 5-10% mud, distribution 0-10% mud.
	Notoacmaea helmsi	NA	**Strong sand preference**	Yes	No	Endemic to NZ. Small limpet attached to stones and shells in intertidal zone. Intolerant of anoxic surface muds. Optimum range 0-5% mud, distribution range 0-10% mud.
	Notoacmea scapha		**Strong sand preference**	No	Yes	Endemic to NZ, a small grazing limpet attached to stones and shells in intertidal zone. Intolerant of anoxic surface muds and sensitive to pollution.

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
	Potamopyrgus estuarinus			No	Yes	Endemic to NZ. Small estuarine snail, requiring brackish conditions for survival. Feeds on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds.
Bivalve	*Arcuatula (Musculista) senhousia*		**Tolerant**	No	Yes	*Musculista senhousia* is a small invasive mussel originating from Asia and growing up to 35mm. It can live on both hard and soft substrates in the intertidal and shallow subtidal zones to 20 m depth and often occurs in dense patches.
	Arthritica sp.	**Tolerant**	**Prefers mud but not high percentage**	Yes	Yes	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds. Optimum range 55-60% or 20-40% mud, distribution range 0-70% mud.
	Austrovenus stutchburyi	NA	**Prefers sand**	Yes	Yes	The cockle is a suspension feeding bivalve with a short siphon - lives a few centimetres from sediment surface at mid-low water situations. Can live in both mud and sand but is sensitive to increasing mud - prefers low mud content. Rarely found below the RPD layer. Has average mobility. Is sensitive to depth of sediment deposited. Can be considered to have average overall tolerance to sedimentation. Prefers sand with some mud (optimum range 5-10% mud or 0-10% mud), distribution range 0-85% mud.
	Hiatula (Soletellina) siliquens	**Sensitive**	**Prefers sand**	No	Yes	Soletellina is a genus of bivalve molluscs in the family Psammobiidae, known as sunset shells. Intolerant of eutrophic or muddy conditions (Robertson and Stevens, 2016).
	Macomona liliana	NA	**Prefers sand**	Yes	Yes	A surface deposit feeding wedge shell. This species lives at depths of 5-10cm in the sediment and uses a long inhalant siphon to feed on surface deposits and/or particles in the water column. Rarely found beneath the RPD layer. Prefers a sandy substrate. Has moderate mobility, and has average tolerance to depth and duration of sediment deposition. Prefers sand with some mud (optimum range 0-5% mud), distribution range 0-40% mud.
	Nucula hartvigiana	**Tolerant**	**Prefers sand**	Yes	Yes	The nut clam of the Family *Nuculidae*, is endemic to NZ. It is found intertidally and in shallow water, especially in *Zostera* sea grass flats. It is often found together with the New Zealand cockle, *Austrovenus stutchburyi*, but is not as abundant showing a preference for mud. Like *Arthritica* this species feeds on organic particles within the sediment. Not very mobile. Intolerant of depth and duration of sediment deposition. Optimum range 0-5% mud, distribution range 0-60% mud.
	Paphies australis	NA	**Strong sand preference as adult. Sand or mud as juvenile**	Yes	No	The pipi is endemic to NZ. Pipi are tolerant of moderate wave action, and commonly inhabit coarse shell sand substrata in bays and at the mouths of estuaries where silt has been removed by waves and currents. They have a broad tidal range, occurring intertidally and subtidally in high-current harbour channels to water depths of at least 7m. Prefer sandy substrates. Highly mobile suspension feeders. Intolerant of depth of sediment

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
						deposition. Adults optimum range 0-5% mud, distribution 0-5% mud. Juveniles often found in muddier sediment.
Cumacea	*Colurostylis lemurum*	NA	**Prefers sand**	Yes	Yes	A cumacean and semi-pelagic detritus feeder. Some species of cumacea can survival in brackish water. Most species live only one year or less, and reproduce twice in their lifetime. Cumaceans feed mainly on microorganisms and organic material from the sediment. Species that live in the mud filter their food, while species that live in sand browse individual grains of sand. Optimum range 0-5% mud, distribution range 0-60% mud.
Decapod	*Austrohelice crassa*	NA	**Strong mud preference**	Yes	Yes	Surface deposit feeder and predator/scavenger. Prefers a muddy substrate, is very mobile and tolerant of sedimentation. Overall considered relatively insensitive. Optimum range 95-100% mud, distribution range 5-100% mud.
Mysid shrimp	*Mysidacea sp.*	**Indifferent**	NA	Yes	No	Mysidacea is a group of small, shrimp-like creatures. They are sometimes referred to as opossum shrimps. Wherever mysids occur, whether in salt or fresh water, they are often very abundant and form an important part of the normal diet of many fishes.
	Corophiidae	**Tolerant**	**Tolerant**	No	Yes	*Corophiidae* is a family of amphipods. They tolerate a sediment mud content of 40-100%, with an optimum range of 95-100%. Therefore, they are usually found in very muddy habitats. Corophiid amphipods can also tolerate organic enrichment and pollution. Corophiids is likely to increase when the sediment mud content increases (exceeding 40-50%) and/or becomes polluted or organically enriched.
Amphipod	*Paracorophium sp.*	**Indifferent**	**Strong mud preference**	No	No	A tube-dwelling corophioid amphipod. Two species in NZ, *P. excavatum* and *P. lucasi*. Both are endemic to NZ. *P. lucasi* occurs on both sides of the North Island, but also in the Nelson area. *P. excavatum* has been found mainly in east coast habitats of both the South and North Islands. Sensitive to metals. Also very strong mud preference. Optimum range 95-100% mud, distribution range 40-100% mud. Often present in estuaries with regularly low salinity conditions.
	Phoxocephalidae sp.	**Sensitive**	**Tolerant to mud**	Yes	Yes	A family of amphipods.
	Talitridae		-	No	Yes	A family of Amphipods which includes all terrestrial amphipods as well as some marine and semi-terrestrial species.

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
	Torridoharpinia hurleyi		**Sensitive to mud**	No	Yes	-
	Waitangi brevirostris		**Sensitive to mud**	No	Yes	*Waitangi chelatus* is known to prefer a very low mud content of 0-5% and has been shown to be sensitive to lead contamination. If the sediment becomes muddier and/or polluted the abundance of *Waitangi chelatus* is likely to decline.
Isopod	*Exosphaeroma planulum*		-	No	Yes	Small seaweed dwelling isopod. Prey species for birds and fish. Little is known about the Exosphaeroma genera.
	Exosphaeroma waitemata		-	No	Yes	Small seaweed dwelling isopod. Prey species for birds and fish. Little is known about the Exosphaeroma genera.
Copepod	*Copepod*		-	No	Yes	Very small crustaceans usually having six pairs of limbs on the thorax. The benthic group of copepods (Harpactacoida) have worm-shaped bodies.
Hexapod	*Collembola*				Yes	Collembola are mostly of terrestrial origin and are one of the most abundant arthropods found in wetland communities. Some species live on water surfaces. Little is known of Collembola.
Cirriped	*Austrominius modestus*		-	No	Yes	Small acorn barnacle. Capable of rapid colonisation of any hard surface in intertidal areas and prefers sheltered shores. *Austrominius modestus* tolerates lower salinity and higher temperatures than most other native barnacles however, this species cannot survive in permanent low salinity. *A. modestus* accumulates zinc and other heavy metals yet its use as a biomonitor is not yet agreed.
Diptera	*Dolichopodidae larvae*			No	Yes	
	Muscidae			No	Yes	
	Orthocladiinae			No	Yes	
	Psychodidae (larvae)			No	Yes	
	Tanypodinae			No	Yes	

		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Mahurangi Harbour	Present in Kaipara Harbour	Details
Echinoderm	*Taeniogyrus dendyi*			No	Yes	A soft bodied sea cucumber that is worm-like in appearance and burrows up to 20cm into sand - a deposit feeder and sediment disturber.

APPENDIX D: THREAT STATUS OF AVIFAUNA RECORDED IN THE OSNZ ATLAS SQUARES WITHIN AND NEAR THE MAHURANGI AND KAIPARA HARBOURS

The following table lists species recorded within the OSNZ atlas from two 10 km x 10 km grid squares (266, 652; 266, 653) which encompass the Mahurangi Harbour and surrounding area ('Mahurangi squares), and four 10 km x 10 km grid squares (263, 653; 264, 655; 264, 654; 264, 654) which encompass the eastern section of the Kaipara Harbour including the Hōteo Inlet and Oruawharo Inlet ('Kaipara squares'). The primary (dark green) and secondary (light green) habitats for each of the species recorded was obtained from Heather & Robertson (2005), along with each species' New Zealand threat status according to Robertson et al., (2017).

SPECIES - Robertson et al., 2017		CONSERVATION STATUS - Robertson et al., 2017			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	Mahurangi squares	Kaipara squares
Kereru	*Hemiphaga novaeseelandiae*	Endemic	Not Threatened	Not Threatened[CD Inc]									✓	✓
Kingfisher	*Todiramphus sanctus vagans*	Native	Not Threatened	Not Threatened									✓	✓
Morepork	*Ninox n. novaeseelandiae*	Native	Not Threatened	Not Threatened									✓	✓
North Island fantail	*Rhipidura fuliginosa placabilis*	Native	Not Threatened	Not Threatened[EF]									✓	✓
North Island kaka	*Nestor meridionalis septentrionalis*	Endemic	Threatened	Nationally Vulnerable[CD PD RF]									✓	□
Pied tomtit	*Petroica macrocephala toitoi*	Endemic	Not Threatened	Not Threatened									✓	□
Shining cuckoo	*Chrysococcyx l. lucidus*	Native	Not Threatened	Not Threatened[DP]									✓	✓
Tui	*Prosthemadera n. novaeseelandiae*	Endemic	Not Threatened	Not Threatened[Inc]									✓	✓
Blackbird	*Turdus merula*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Brown quail	*Coturnix ypsilophora australis*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
California quail	*Callipepla californica*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Eastern rosella	*Platycercus eximius*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Grey warbler	*Gerygone igata*	Endemic	Not Threatened	Not Threatened									✓	✓
Pheasant	*Phasianus colchicus*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Silvereye	*Zosterops lateralis lateralis*	Native	Not Threatened	Not Threatened[SO]									✓	✓
Canada goose	*Branta canadensis*	Introduced	Introduced	Introduced & Naturalised[SO]										✓
Cattle egret	*Ardea ibis coromanda*	Migrant	Migrant	Migrant[SO]										✓
Chaffinch	*Fringilla coelebs*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Dunnock	*Prunella modularis*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	
Goldfinch	*Carduelis carduelis*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Greenfinch	*Carduelis chloris*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓

SPECIES - Robertson et al., 2017		CONSERVATION STATUS - Robertson et al., 2017			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	Mahurangi squares	Kaipara squares
House sparrow	*Passer domesticus*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Kookaburra	*Dacelo novaeguineae*	Introduced	Introduced	Introduced and Naturalised[SO RR]									✓	
Magpie	*Gymnorhina tibicen*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
NZ pipit	*Anthus n. novaeseelandiae*	Native	At Risk	Declining									✓	✓
Peafowl	*Pavo cristatus*	Introduced	Introduced	Introduced & Naturalised[SO]										✓
Redpoll	*Carduelis flammea*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Skylark	*Alauda arvensis*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Song thrush	*Turdus philomelos*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Spur-winged plover	*Vanellus miles novaehollandiae*	Native	Not Threatened	Not Threatened[SO]									✓	✓
Starling	*Sturnus vulgaris*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Tufted guineafowl	*Numida meleagris*	Introduced	Introduced	Introduced & Naturalised[SO]										✓
Swamp harrier	*Circus approximans*	Native	Not Threatened	Not Threatened[SO]									✓	✓
Welcome swallow	*Hirundo n. neoxena*	Native	Not Threatened	Not Threatened[SO ST]									✓	✓
Wild turkey	*Meleagris gallopavo*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Yellowhammer	*Emberiza citrinella*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Australasian bittern	*Botaurus poiciloptilus*	Native	Threatened	Nationally Critical[RF Sp TO]									✓	✓
Australasian little grebe	*Tachybaptus n. novaehollandiae*	Coloniser	Coloniser	Coloniser[SO]										✓
Black shag	*Phalacrocorax carbo novaehollandiae*	Native	At Risk	Naturally Uncommon[SO Sp]									✓	✓
Black stilt	*Himantopus novaezelandiae*	Endemic	Threatened	Nationally Critical[CD RR]										✓
Black swan	*Cygnus atratus*	Native	Not Threatened	Not Threatened[SO]									✓	✓

SPECIES - Robertson et al., 2017		CONSERVATION STATUS - Robertson et al., 2017			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	Mahurangi squares	Kaipara squares
Black-billed gull	*Larus bulleri*	Endemic	Threatened	Nationally Critical[RF DP]									✓	✓
Feral goose	*Anser anser*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Grey duck	*Anas s. superciliosa*	Native	Threatened	Nationally Critical[SO DP]									✓	✓
Grey teal	*Anas gracilis*	Native	Not Threatened	Not Threatened[Inc SO]										✓
Little black shag	*Phalacrocorax sulcirostris*	Native	At Risk	Naturally Uncommon[RR]									✓	✓
Little shag	*Phalacrocorax melanoleucos brevirostris*	Native	Not Threatened	Not Threatened[Inc]									✓	✓
Mallard	*Anas platyrhynchos*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
North Island fernbird	*Bowdleria punctata vealeae*	Endemic	At Risk	Declining[DP]									✓	✓
NZ dabchick	*Poliocephalus rufopectus*	Endemic	At Risk	Recovering[DP]										✓
NZ pied oystercatcher	*Haematopus finschi*	Endemic	At Risk	Declining									✓	✓
NZ scaup	*Aythya novaeseelandiae*	Endemic	Not Threatened	Not Threatened[Inc]										✓
NZ shoveler	*Anas rhynchotis variegata*	Native	Not Threatened	Not Threatened									✓	✓
Paradise shelduck	*Tadorna variegata*	Endemic	Not Threatened	Not Threatened									✓	✓
Pied shag	*Phalacrocorax varius varius*	Endemic	At Risk	Recovering									✓	✓
Pied stilt	*Himantopus h. leucocephalus*	Native	Not Threatened	Not Threatened[SO]									✓	✓
Pukeko	*Porphyrio m. melanotus*	Native	Not Threatened	Not Threatened[Inc SO]									✓	✓
Spotless crake	*Porzana t. tabuensis*	Native	At Risk	Relict[DP SO]									✓	✓
White heron	*Ardea modesta*	Native	Threatened	Nationally Critical[OL SO St]									✓	✓
Banded dotterel	*Charadrius bicinctus bicinctus*	Endemic	Threatened	Nationally Vulnerable[DP]									✓	✓
Banded rail	*Gallirallus philippensis assimilis*	Native	At Risk	Declining[DP RR]									✓	✓
Black-backed gull	*Larus d. dominicanus*	Native	Not Threatened	Not Threatened[SO]									✓	✓

SPECIES - Robertson et al., 2017		CONSERVATION STATUS - Robertson et al., 2017			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	Mahurangi squares	Kaipara squares
Caspian tern	*Hydroprogne caspia*	Native	Threatened	Nationally Vulnerable[SO Sp]									✓	✓
Eastern bar-tailed godwit	*Limosa lapponica baueri*	Native	At Risk	Declining[TO]									✓	✓
Eastern curlew	*Numenius madagascariensis*	Migrant	Migrant	Migrant[SO]										✓
Lesser knot	*Calidris canutus rogersi*	Native	Threatened	Nationally Vulnerable[TO]									✓	✓
Northern NZ dotterel	*Charadrius obscurus aquilonius*	Endemic	At Risk	Recovering[CD]									✓	✓
NZ fairy tern	*Sternula nereis davisae*	Endemic	Threatened	Nationally Critical[CD RR]										✓
Red-billed gull	*Larus novaehollandiae scopulinus*	Native	At Risk	Declining									✓	✓
Reef heron	*Egretta sacra sacra*	Native	Threatened	Nationally Endangered[DP SO Sp]									✓	✓
Royal spoonbill	*Platalea regia*	Native	At Risk	Naturally Uncommon[Inc RR SO Sp]									✓	✓
Turnstone	*Arenaria interpres*	Migrant	Migrant	Migrant[SO]										✓
Variable oystercatcher	*Haematopus unicolor*	Endemic	At Risk	Recovering									✓	✓
Whimbrel	*Numenius phaeopus*	Native	Migrant	Migrant[SO]										✓
White-faced heron	*Egretta novaehollandiae*	Native	Not Threatened	Not Threatened[SO]									✓	✓
White-fronted tern	*Sterna s. striata*	Native	At Risk	Declining[DP]									✓	✓
Wrybill	*Anarhynchus frontalis*	Endemic	Threatened	Nationally Vulnerable[RR DP]									✓	✓
Australasian gannet	*Morus serrator*	Native	Not Threatened	Not Threatened[De Inc SO]									✓	✓
Buller's shearwater	*Puffinus bulleri*	Endemic	At Risk	Naturally Uncommon[OL St]									✓	
Cook's petrel	*Pterodroma cookii*	Native	At Risk	Relict[RR Inc]									✓	
Flesh-footed shearwater	*Puffinus carneipes*	Native	Threatened	Nationally Vulnerable[RR TO]									✓	
Fluttering shearwater	*Puffinus gavia*	Endemic	At Risk	Relict[RR]									✓	
Northern blue penguin	*Eudyptula minor iredalei*	Native	At Risk	Declining[DP EF]									✓	

SPECIES - Robertson et al., 2017		CONSERVATION STATUS - Robertson et al., 2017			Native forest	Exotic Forest	Scrub / shrubland	Farmland / open country	Freshwater / wetlands	Coastal / Estuary	Oceanic	Urban/Residential	Mahurangi squares	Kaipara squares
Rock pigeon	*Columba livia*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓
Spotted dove	*Streptopelia chinensis tigrina*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	
Myna	*Acridotheres tristis*	Introduced	Introduced	Introduced & Naturalised[SO]									✓	✓

APPENDIX E: BATHYMETRY AND NAMED FEATURES NEAR HŌTEO RIVER MOUTH[29]

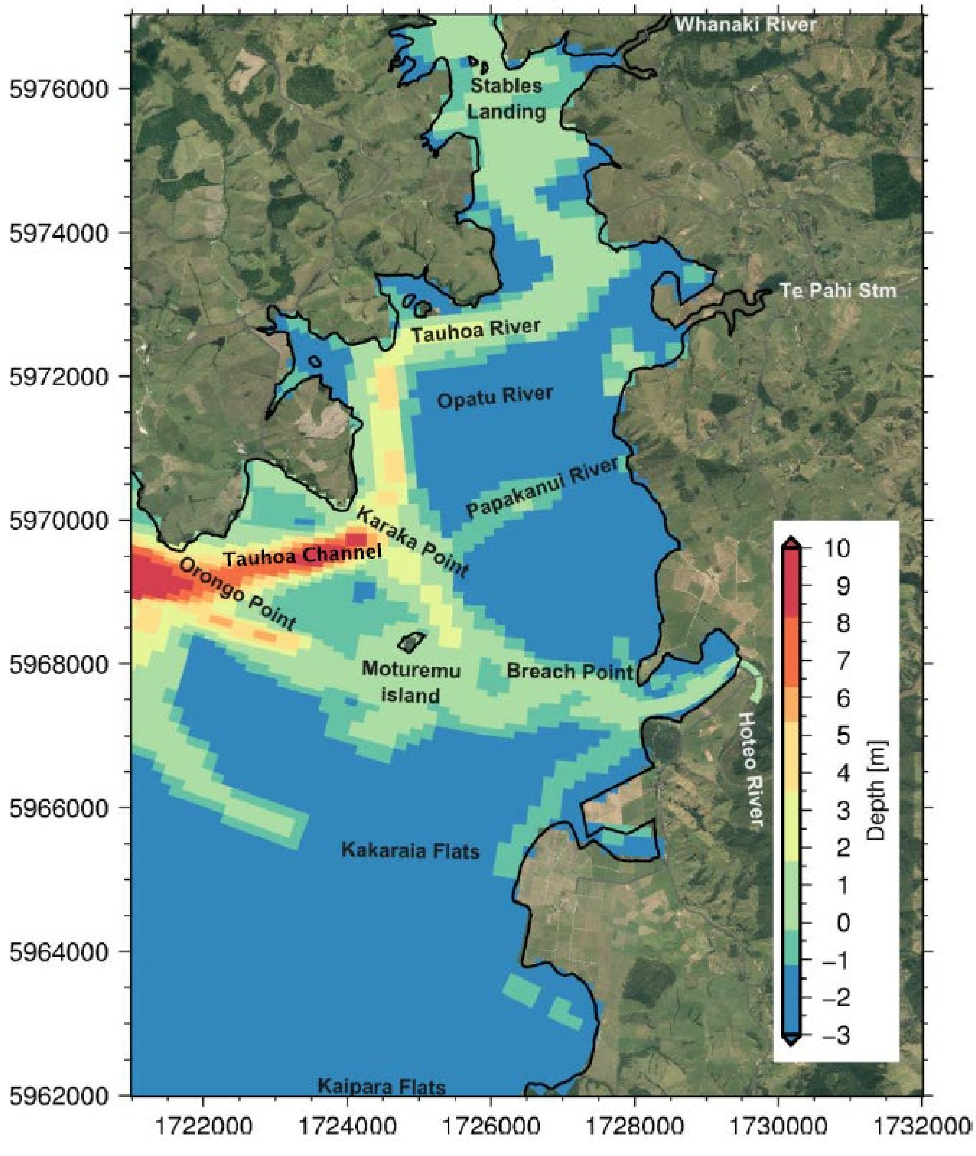

Figure 20: **Model bathymetry and named features near the discharge of the Hoteo River into the Kaipara Harbour.**

[29] From Assessment of Coastal Sediment Report

APPENDIX F: MARINE MITIGATION CALCULATION PROCESS

JACOBS

Memorandum

Subject	**Marine Mitigation Calculation Process**	**Project Name**	Warkworth to Wellsford
Attention	Justine Bennett	**Project No.**	IZ083000
From	Kate Clay, Lydia Cetin		
Date	May 2019		

1. Introduction

This note outlines a process to calculate the necessity and size of additional mitigation areas of land to be retired and planted to offset the quantum of sediment discharged during the project.

The quantum of sediment discharged from the Project during construction should be offset in one generation, which is nominally 25 years following the end of the Project, through land retirement and planting strategies. The types of land retirement and planting available for sediment mitigation are:

- Planting and stabilisation of riparian margins of streams;
- Retirement of pasture areas and planting with shrubs and trees;
- of plantation forest areas, which may remain as exotic forest or be replanted as native forest Retirement, and cease being harvested.

The Project already includes Landscape and Ecology (L&E) mitigation planting, which has the additional benefit of erosion reduction. If the L&E mitigation planting does not offset the full quantum of sediment discharged during construction, then additional sediment mitigation planting will be required.

2. Sediment Reduction Factors

The sediment offset of the indicative L&E planting has been estimated through modelling. This has enabled quantification of the average annual offset of different retirement and planting types within the Project Designation. These sediment reduction factors have been calculated for mitigation planting in different areas and are set out in Table 1.

Table 1 Estimated sediment reduction factors (average offset) associated with retirement and planting mitigation options over 25 years

Mitigation type	Options	Sediment reduction over 25 years
Planting and stabilisation of riparian margins of streams	Stream REC class 2-3	**0.35 Tonnes/metre**
	Stream REC 4+	*Not previously assessed
Retirement of pasture areas and planting with shrubs/trees	Flat slopes	**1.11 Tonnes/hectare**
	Flat to moderate slopes	**1.83 Tonnes/hectare**
	Moderate slopes	**2.91 Tonnes/hectare**
	Steep slopes	*Not previously assessed
Retirement of plantation forest	Retire after harvest in 2020	**1.82 Tonnes/hectare**
	Retire before harvest in 2020	**3.64 Tonnes/hectare**

Note: *the current proposed mitigation planting does not include these categories, should future planting be proposed for these typologies an appropriate Sediment Reduction factor will need to be derived.

It should be noted that the modelled indicative L&E mitigation planting, which is based on the indicative alignment and associated level of design, is subject to change as the Project progresses. Only areas within the proposed designation were modelled, therefore retirement and planting of steep areas of pasture and planting of higher order streams has not been modelled to date. The forest reduction factors are based on literature not modelling, so there is potential that retiring steeper areas of forestry could increase the sediment offset. Additionally, the modelling focussed on those catchments discharging to the Kaipara Harbour where the greatest sediment yields were predicted, and the Mahurangi was not modelled.

Therefore, these sediment reduction factors will need to be confirmed following detailed design as the quantum and location of the proposed landscape and ecological mitigation may change through that process.

3. Outline of Sediment Quantum Calculation Process

The steps and inputs to calculate the areas and types of planting and retirement necessary to mitigate the quantum of sediment discharged during construction are as follows:

1. Identify the quantum of sediment to be mitigated from the construction site in tonnes (to be provided by on site monitoring). This will include the sediment generated through large storm events and cumulative total of small rain fall events;
2. Calculate the quantum of sediment to be offset through the final Ecology and Landscape mitigation planting in a nominal 25-year timespan, as estimated with a modelling exercise;
3. Minus the L&E mitigation quantum (step 2) from the total sediment offset quantum (step 1), to calculate the net quantum of sediment to be offset through additional mitigation (e.g. land retirement and planting).
4. Based on the sediment reduction factor, calculate the area/length required of additional sediment mitigation planting.

Figure 1 below represents the process schematically:

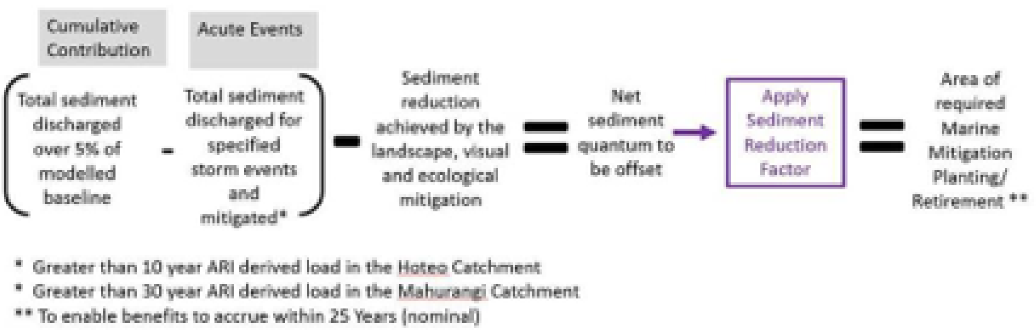

Figure 1 Process to estimate area required for additional marine mitigation planting