TRANSMISSION GULLY PROJECT

TECHNICAL REPORT #10

Marine Habitat & Species

Description & Values

August 2011

Front Cover Photo: Low tide on a calm day at Pauatahanui Inlet at the mouth of Duck Creek. High value tidal habitat visible. Hardening of the coastal margin for State Highway 58 is visible through railway irons in foreground and rip-rap in top left. Currently road run-off discharges directly into the Inlet. Reduction of traffic on this road will potentially have some long term benefits in terms of reduction in stormwater contaminants into the Inlet.	
Bibliographic reference: Boffa Miskell, 2011: Transmission Gully Project Technical Report 10 - Marine Habitat & Species: Values & Description. Prepared by Boffa Miskell Ltd for NZ Transport Agency and Porirua City Council. Report No: W09034E. 73 pp + App.	
Prepared by: Dr Sharon De Luca, Principal Ecologist Boffa Miskell Limited **Released by:** Stephen Fuller, Associate Director Boffa Miskell Limited **Document Status:** FINAL **Version:** **V.3** **Issue Date:** August 2011	**Internal Peer Review:** Dr Leigh Bull, Associate Principal Ecologist Boffa Miskell Limited

EXECUTIVE SUMMARY

INTRODUCTION

The proposed Transmission Gully (TG) road is 27 km long. It runs through a wide range of habitats from improved pasture, plantation forestry, shrubland, and scrub to forest remnants. It ranges from sea level to 280 m in altitude and crosses eight catchments, most of which discharge to Pauatahanui Inlet, which is a nationally significant estuary and wildlife refuge.

This report encompasses both a description of the existing marine/estuarine ecological values in the Porirua Harbour, Wainui Stream mouth and Whareroa Stream mouth (based on the existing literature and targeted field investigations in 2009 to 2011).

DESKTOP REVIEW

Data and information on the ecological values (invertebrates, fish, sediment grain size, sediment quality and water quality) was collated from a large number of sources. The concentration of key contaminants in surficial sediment was mapped and indicated significant heavy metal and hydrocarbon contamination in the Onepoto Inlet and elevated concentrations of agri-chemicals in both Inlets. Gaps in our current understanding of the ecological values that have the potential to be adversely affected by the proposed TG road were identified and used to inform the field surveys.

FIELD SURVEY METHODOLOGY

Intertidal surveys of infaunal and epifaunal invertebrates, sediment grain size, sediment quality, depth of oxygenation of sediment and macroalgal cover were undertaken at the mouths of streams that are likely to receive both construction and operational phase stormwater from TG. These streams included Pautahanui, Horokiri, Rations, Kakaho, Porirua and Wainui Streams, and Duck Creek. Similarly subtidal surveys were undertaken adjacent to the stream mouths that currently receive and retain the most terrestrial sediment during storm events. In addition, central subtidal basin sites were also sampled.

FIELD SURVEY RESULTS

The proportion of very fine sand plus silt and clay in surficial sediment samples varied significantly among sites within each of the Inlets. Central subtidal basins had a high proportion of fine sediment, as did the mouths of Horokiri, Rations and Porirua Streams.

Biological effects threshold concentrations were exceeded within the Onepoto Inlet but not within the Pauatahanui Inlet. This pattern is consistent with the current and historic land-uses within the catchments that feed into these estuaries, with the Onepoto Inlet being primarily industrial and residential and the Pauatahanui Inlet being primarily residential and rural.

Based on the existing literature and samples collected specifically for this project in 2009 to 2011, the near shore habitat (intertidal and shallow subtidal) within the Pauatahanui Inlet has a high diversity and abundance of epifaunal and infaunal benthic invertebrates, with many sensitive taxa present. However, the central subtidal basin areas comprise silt and clay sediment and have a low abundance and diversity of invertebrates. The assemblage in the Onepoto Inlet is slightly less diverse than the near shore areas of the Pauatahanui Inlet and has a higher proportion of tolerant species (see Appendix 10E). However,

species that are sensitive to organic enrichment were detected in both Inlets. The number of species that have a strong sand preference was only slightly higher in samples collected in the Pauatahanui Inlet compared to the Onepoto Inlet (see Appendix 10E).

Wainui Stream discharges to a high energy, open sandy beach, which is characterised by coarse grain size sediment, negligible contaminant concentrations in intertidal surface sediment, and a naturally depauperate benthic epifaunal and infaunal community. Whilst not quantitatively surveyed as part of this Project, the marine receiving environment at the Whareroa Stream mouth is considered to be similar to that of Wainui Stream based on existing data.

ASSESSMENT OF ECOLOGICAL VALUE

The ecological values of the intertidal marine habitat in Porirua Harbour are considered to be moderate in the Onepoto Inlet, high in the near shore intertidal and subtidal habitat within Pauatahanui Inlet, but moderate to low in the central subtidal basins of the Pauatahanui Inlet. The Wainui and Whareroa Stream mouths intertidal habitat is high energy and is considered to have high ecological values.

For the Onepoto Inlet this is based on moderate to high species richness and diversity of invertebrates, a dominance of tolerant taxa but the presence of sensitive taxa, presence of seagrass beds, a predominance of finer sediment grain sizes, a high degree of coastal edge habitat modification, and contaminants present above effects thresholds.

In comparison, the near shore habitat within the Pauatahanui Inlet is characterised as having a high diversity and abundance of invertebrates, a diversity of sensitive taxa and the presence of tolerant taxa, presence of seagrass beds, presence of keystone species (cockle beds), variable grain size characteristics, low concentrations of heavy metals, significant areas of unmodified coastal fringe habitat (containing native coastal vegetation), significant habitat and feedings areas for fish and birds, but elevated concentrations of agrichemicals and PAHs detected in some sediment samples. The central subtidal basins within the Pautahanui Inlet are characterised by silt and clay anoxic sediment and a low abundance and diversity of invertebrates (predominantly tolerant polychaete worms).

CONCLUSION

Throughout the literature investigated for this assessment, the common dominant threats to the harbour are recognised as sedimentation of the intertidal and subtidal benthic habitat and the discharge of contaminants. In order to maintain the moderate to high ecological values ascribed to Porirua Harbour, a key aim for large scale projects in the catchments should be to minimise sediment discharges (and associated contaminants) to the harbour.

CONTENTS

FIGURES

TABLES

APPENDICES

1. INTRODUCTION

This technical report is one of a series that report on ecological investigations being undertaken as part of NZTA 345PN Phase II Investigations, E&EA; work package WS-08 Ecological Assessment, Survey, Modelling, and Management (BML, 2009). The purpose of Work Package 08 is to comprehensively map and describe the values of ecological systems, and to describe the distribution and abundance of native flora and fauna that occur along this route. From this work the potential environmental effects of both the construction and ongoing operation of the proposed Transmission Gully Project can be assessed and measures required to mitigate adverse effects can be developed.

The proposed Transmission Gully (TG) road is 27 km long. It runs through a wide range of habitats from improved pasture, plantation forestry, shrubland, and scrub to forest remnants. It ranges from sea level to 280m in altitude and crosses 10 catchments, six of which discharge to Pauatahanui Inlet, a nationally significant estuary.

The Transmission Gully Project consists of three components:

- The "Transmission Gully Main Alignment" (the Main Alignment) involves construction and operation of a State Highway formed to expressway standard from Linden to McKays;
- The "Kenepuru Link Road" involves the construction and operation of a State Highway (limited access road) from the Kenepuru Interchange to Kenepuru Drive; and
- The "Porirua Link Roads" involves the construction and operation of two local roads connecting the Main Alignment to the existing eastern Porirua road network.

This report presents the results of the estuarine ecological values investigations (based on the existing literature and targeted field investigations in 2009-2011) undertaken within the Porirua Harbour and the Wainui Stream mouth.

The report begins by briefly outlining the site context (Section 2), followed by a review of existing literature (Section 3) on the estuarine ecological values (water quality, sediment quality, estuarine invertebrate and fish assemblages) and hydrodynamic environment associated with the Porirua Harbour. Because of the differing nature of the two Inlets of the harbour (Onepoto and Pauahatanui), the results of the literature review for each of these is summarised separately. Gaps in the existing information were identified (Section 4) and taken into consideration when establishing the methodology (Section 5) that would be adopted during the 2009 field investigation. The results of these field investigations are presented in Section 6, and then discussed (Section 7.0) in the context of the previous investigations that were summarised in the literature review. Assessment of the ecological values of the marine/estuarine habitats is presented in Section 8.0 and conclusions drawn in Section 9.0.

2. HABITAT CONTEXT

Porirua Harbour contains two shallow tidal inlets: the Onepoto Inlet and the Pauatahanui Inlet (Gibb & Cox, 2009). Transmission Gully alignment crosses eight catchments, five (Te Puka, Horokiri, Ration, Pauatahanui, Duck) of which the streams discharge into the Pauatahanui Inlet, and the remaining three (Cannons Creek, Kenepuru and Porirua) into the Onepoto Inlet of the harbour (see Figure 10.1). Consequently, the earthworks required for the construction of this road, as well as its ongoing operation, will result in discharges of stormwater to the streams and ultimately to the estuarine environment. In addition, construction and operational phase stormwater will also be discharged into the Wainui and

Whareroa Streams, of which the ultimate receiving environment is the Tasman Sea (see Figure 10.1). An increase in discharged sediment and contaminants has the potential to adversely affect the receiving environment, both in scale and time.

3. DESKTOP/LITERATURE REVIEW

A significant number of studies have been carried out on the Porirua Harbour since the 1970's. Particular research effort has focussed on the Pauatahanui Inlet. A three year long DSIR Project was conducted in the 1970's following a significant deposition of sediment from Whitby Stream within Browns Bay (Healy, 1976). Many of the studies carried out as part of the DSIR project, plus a large number of more recent relevant research projects have been summarised in the following sections. However, only research that is relevant to the current TG project has been reviewed. Thus, the literature review contained in this report is not an exhaustive list of all material available on the Porirua Harbour marine environment.

A map of the location of the sediment quality and marine ecology field studies reviewed and referred to in the following sections, plus the location of field investigations carried out as part of this project are provided in Figures 10.2a to 10.2f below.

3.1.1 Porirua Harbour

Catchment

Porirua Harbour (867 ha) contains two shallow tidal inlets: the Onepoto Inlet (283 ha) and the Pauatahanui Inlet (524 ha) (SKM, 2010). The catchment area for Porirua Harbour is approximately 600 km^2 (Glasby *et al.,* 1990).

Hydrological Characteristics

The Onepoto Inlet and the Pauatahanui Inlet have a common access to the sea via a narrow 0.1 km wide entrance (Glasby *et al.,* 1990). Maximum water depth in both inlets is approximately 3.0 m. Approximately 80% of the Onepoto Inlet is subtidal, whereas 60% of the Pauatahanui Inlet is subtidal (SKM, 2010). The ratio of subtidal to intertidal habitat is relatively high compared to other estuaries and tidal inlets. This latter characteristic has important implications for sedimentation and eutrophication patterns (Robertson & Stevens, 2009).

Both tidal inlets have dynamic features, modified by tides, waves and littoral sediment transport. Typically, tidal inlets are characterised by narrow deep throats through which strong currents flow, flood tidal deltas (sand bodies within the estuary bay) and ebb tidal deltas (immediately seaward of the throat) (Goff *et al*., 2003). The larger streams that enter into Porirua Harbour have complex flood tide deltas, with dynamic and often multiple channels at the stream mouths (SKM, 2010).

Circulation eddies occur in both Inlets, and these are likely to contribute to accumulation of fine sediment in the central basins. Within the Pauatahanui Inlet, most deposition occurs in the western and eastern parts of the central basin, where currents and circulation eddies are weakest (SKM, 2010).

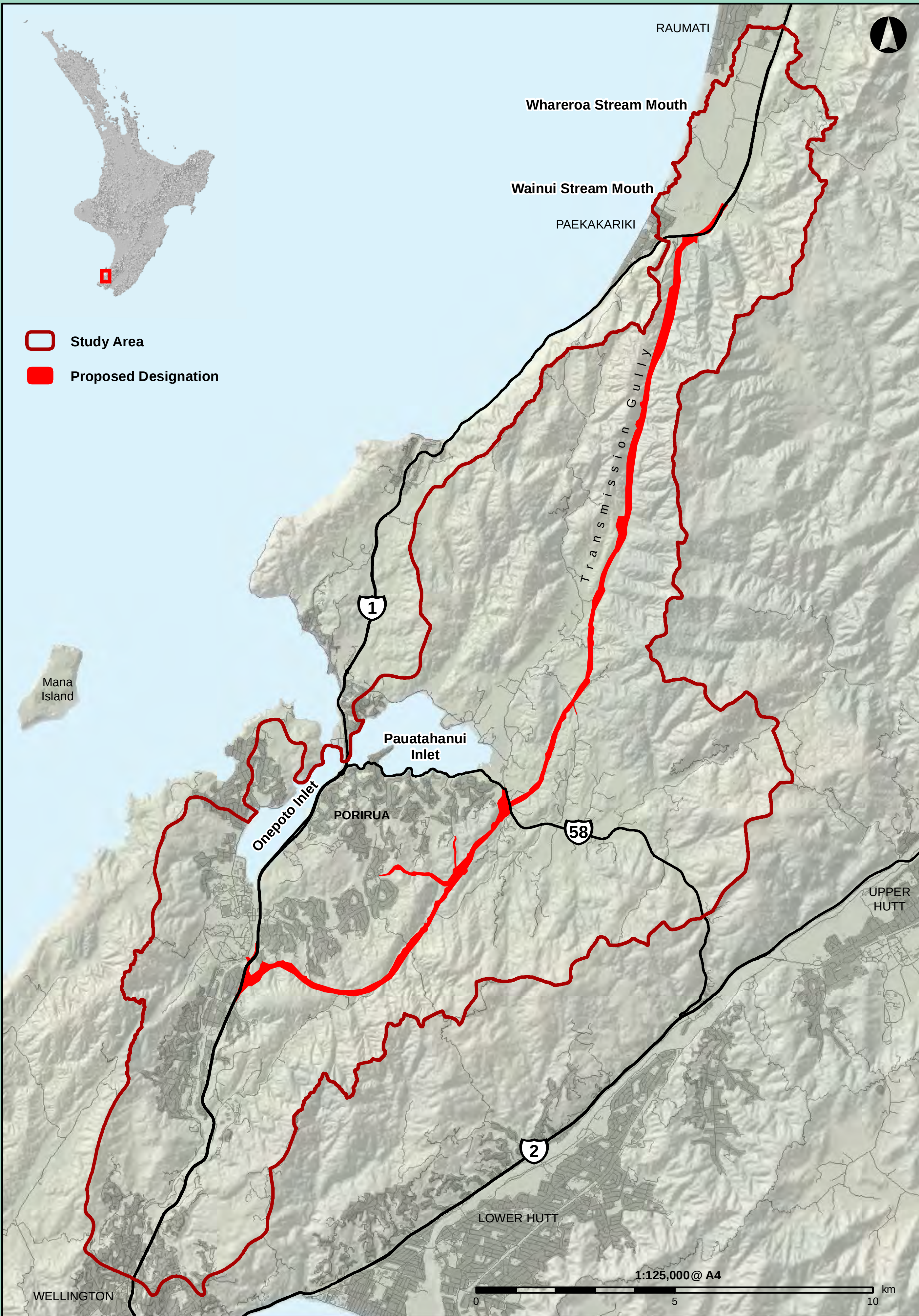
The primary driver for the movement of water into and out of Porirua Harbour is tidal exchange. Approximately 60% of the incoming tide flows to the Pauatahanui Inlet, with 40% to the Onepoto Inlet. Winds, waves and freshwater inflows also influence the movement of water.

Between 1974 and 2009 a net average deposition rate of 27.1 mm/year of fine sand has occurred within the harbour throat. Since 1980, much of this fine sand has been trapped against the breakwaters and Mana Marina entrance. The predominant source of sediment entering the Porirua Harbour is from both bed load and suspended load from the Porirua, Kakaho, Ration, Pauatahanui, Duck and Brown Streams (Gibb & Cox, 2009).

Recent broad-scale habitat mapping shows that the intertidal areas within the harbour is dominated by poorly sorted firm muddy sands, with a low proportion of soft muds (approximately 1.6% and 4.5% of the total intertidal habitat in the Pauatahanui Inlet and Onepoto Inlet respectively) (Stevens & Robertson, 2008) (see Figure 10.3 below).

Ecological Characteristics

Broad scale ecological features in the Porirua Harbour have been described and mapped by Stevens and Robertson (2008), and are shown in Appendix 10F and are discussed below for each Inlet separately.



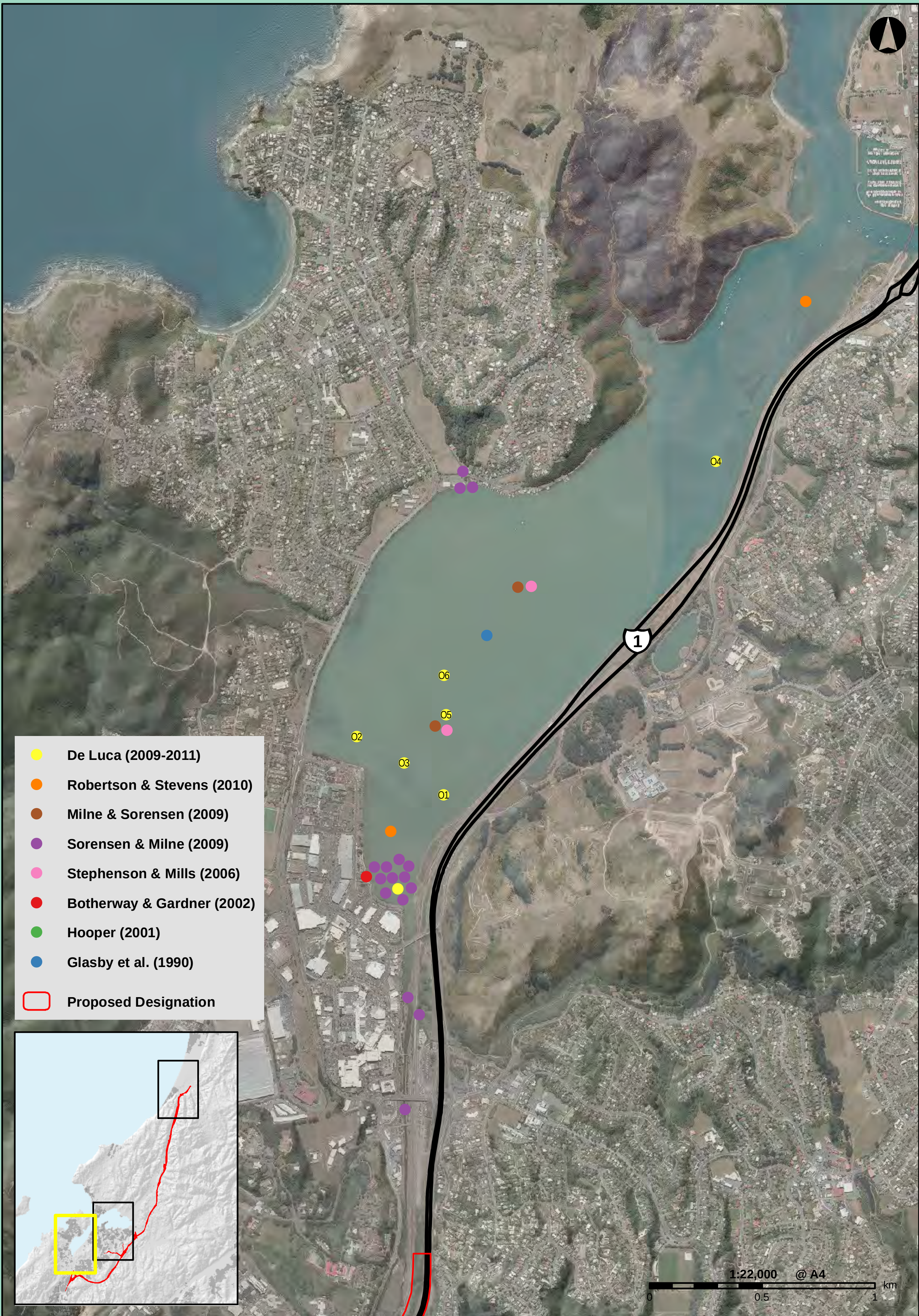
Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

SAMPLING LOCATION CONTEXT

10.1



Boffa Miskell

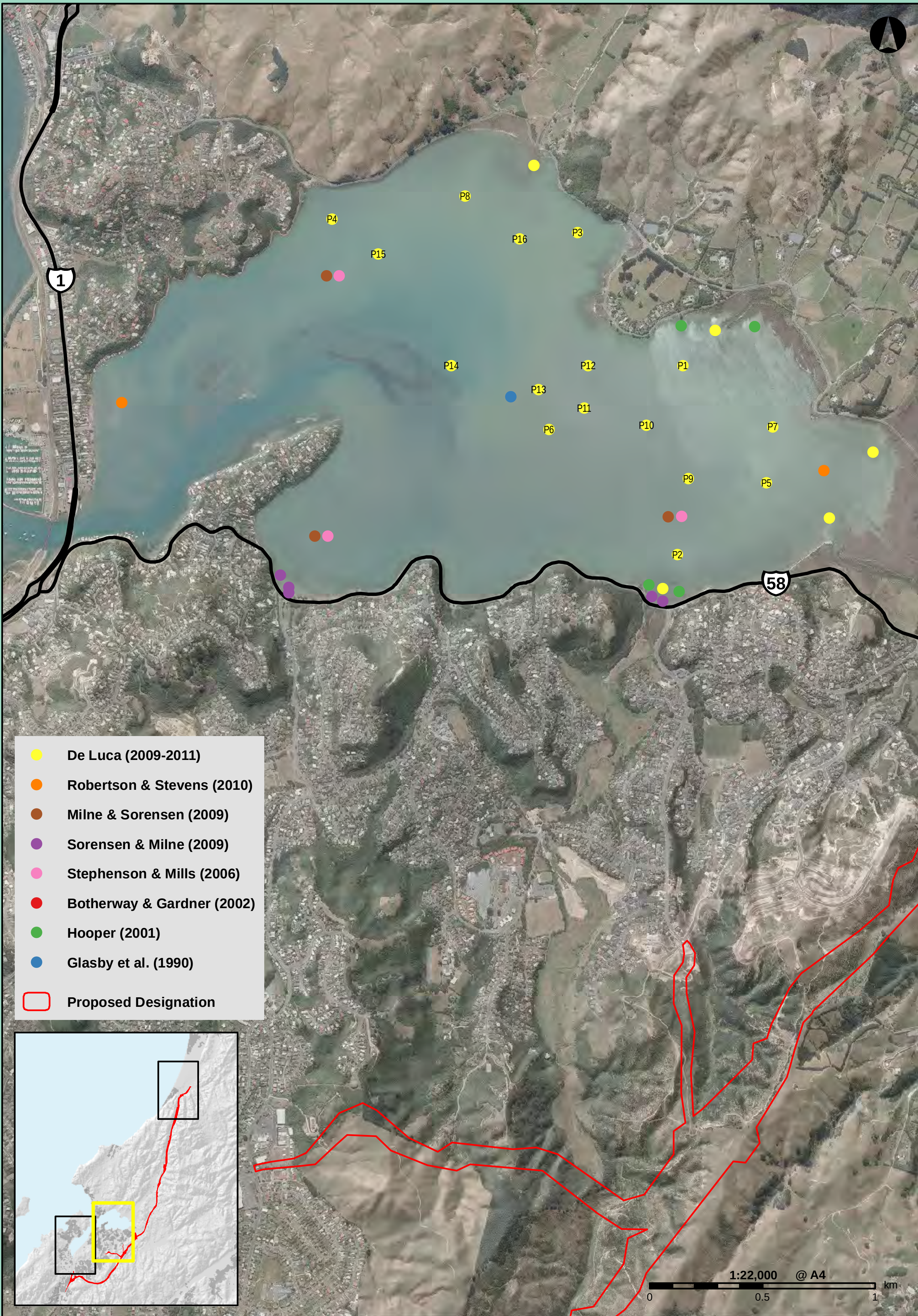
NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

SEDIMENT SAMPLING SITES

ONEPOTO INLET

10.2a



Boffa Miskell

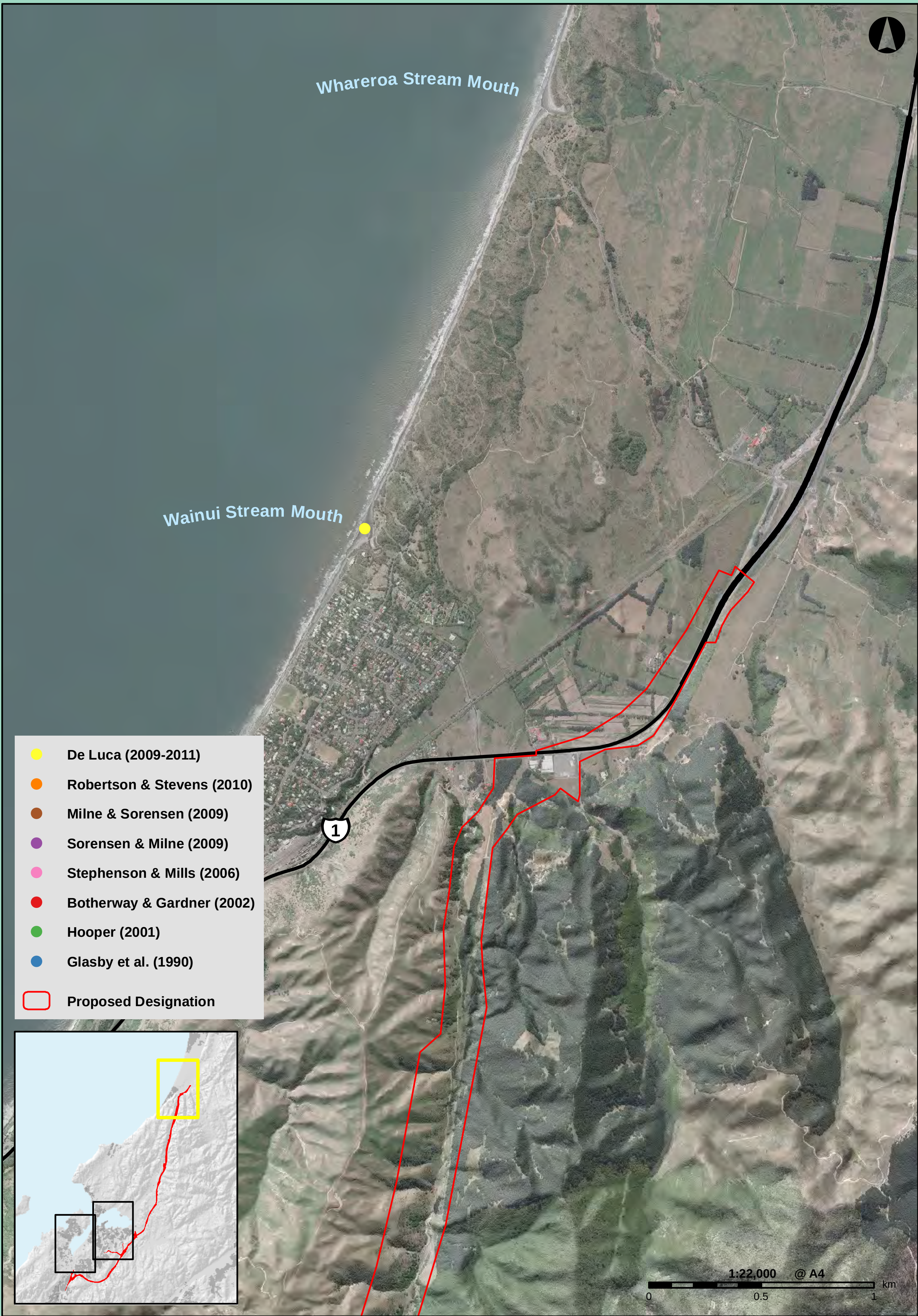
NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

SEDIMENT SAMPLING SITES

PAUATAHANUI INLET

10.2b



Boffa Miskell

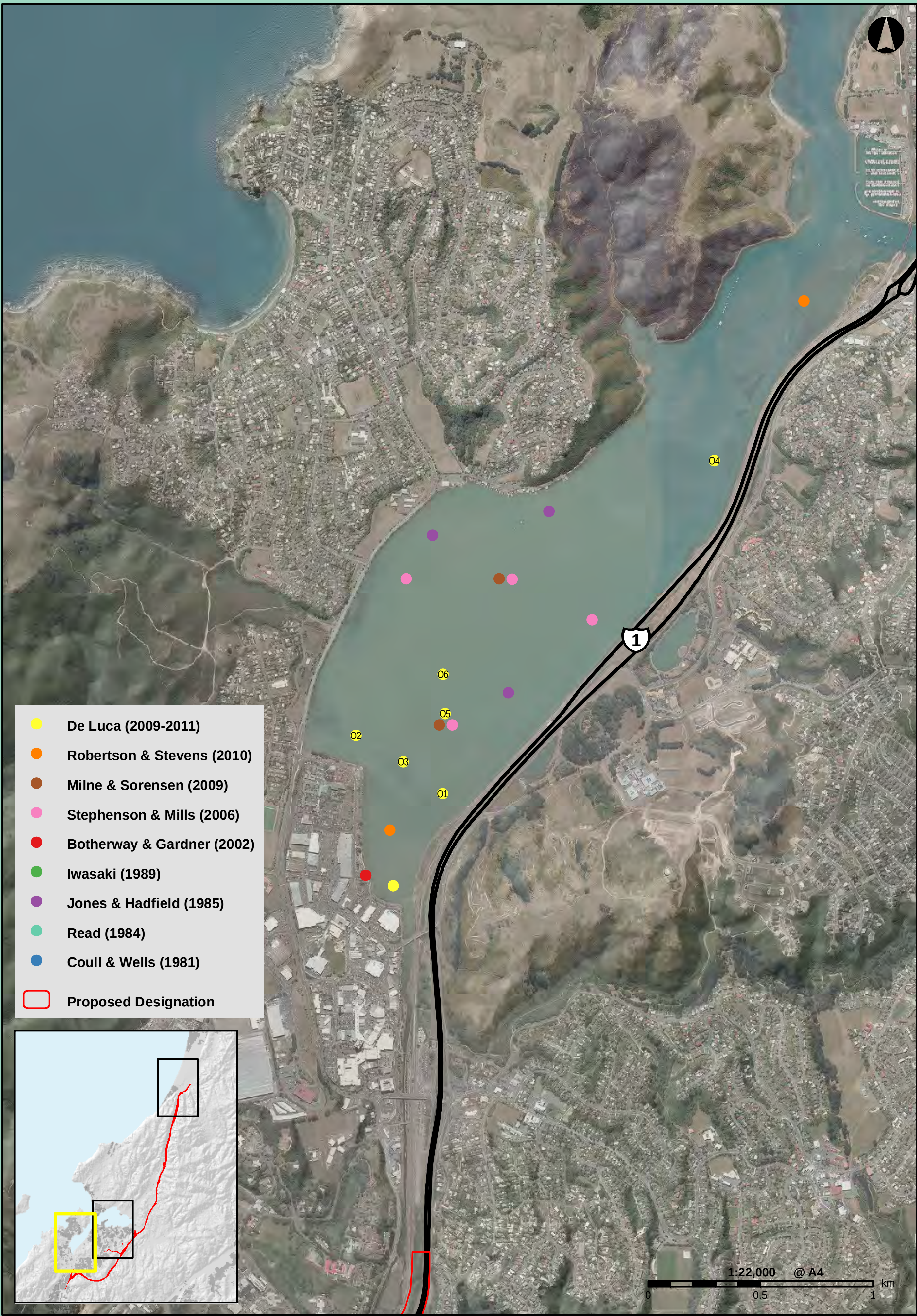
NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

SEDIMENT SAMPLING SITES

WAINUI/WHAREROA STREAM MOUTHS

10.2c

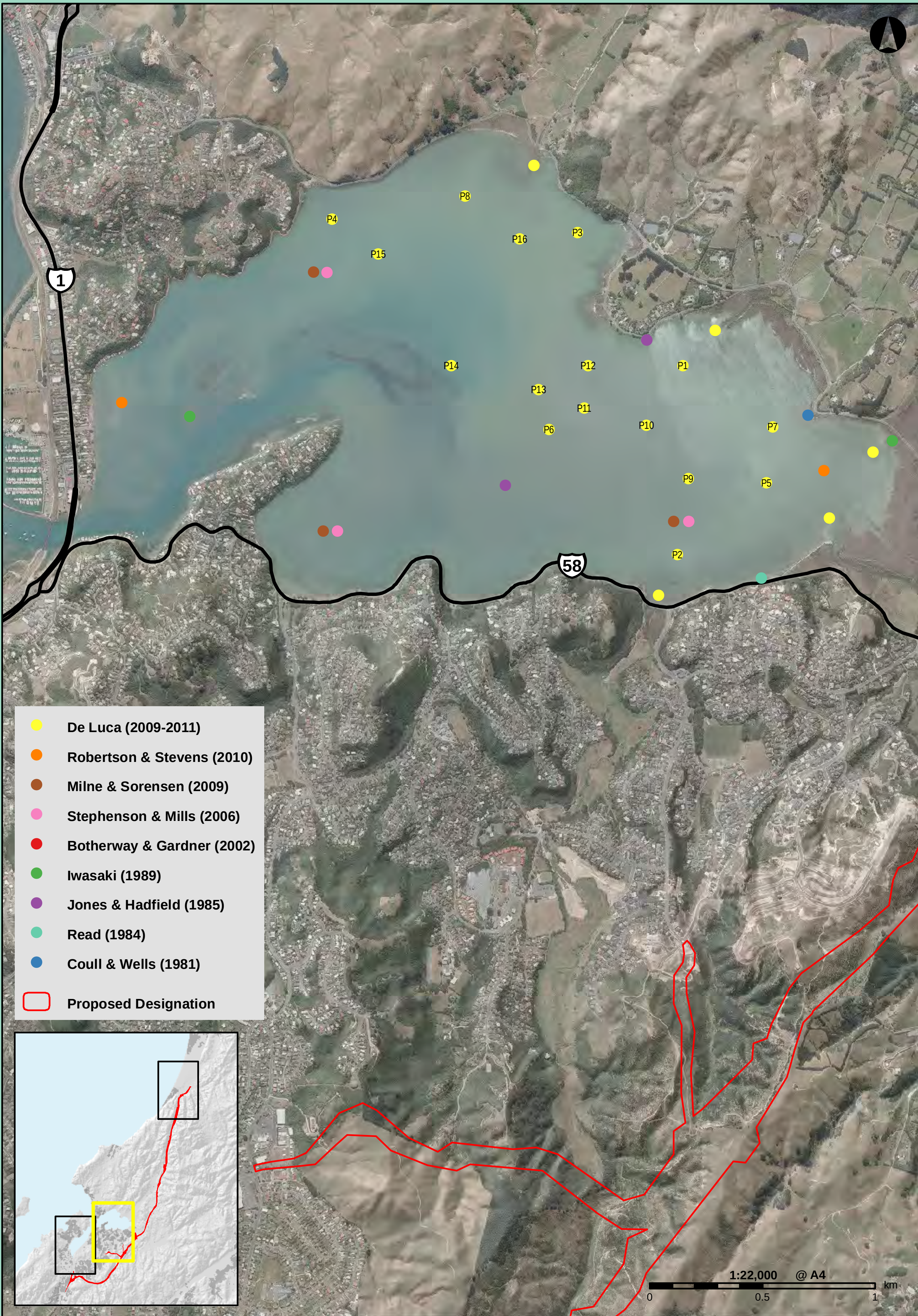


July 25, 2011 W09034A_MAR_SamplingInvFish_A4mb.mxd

Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

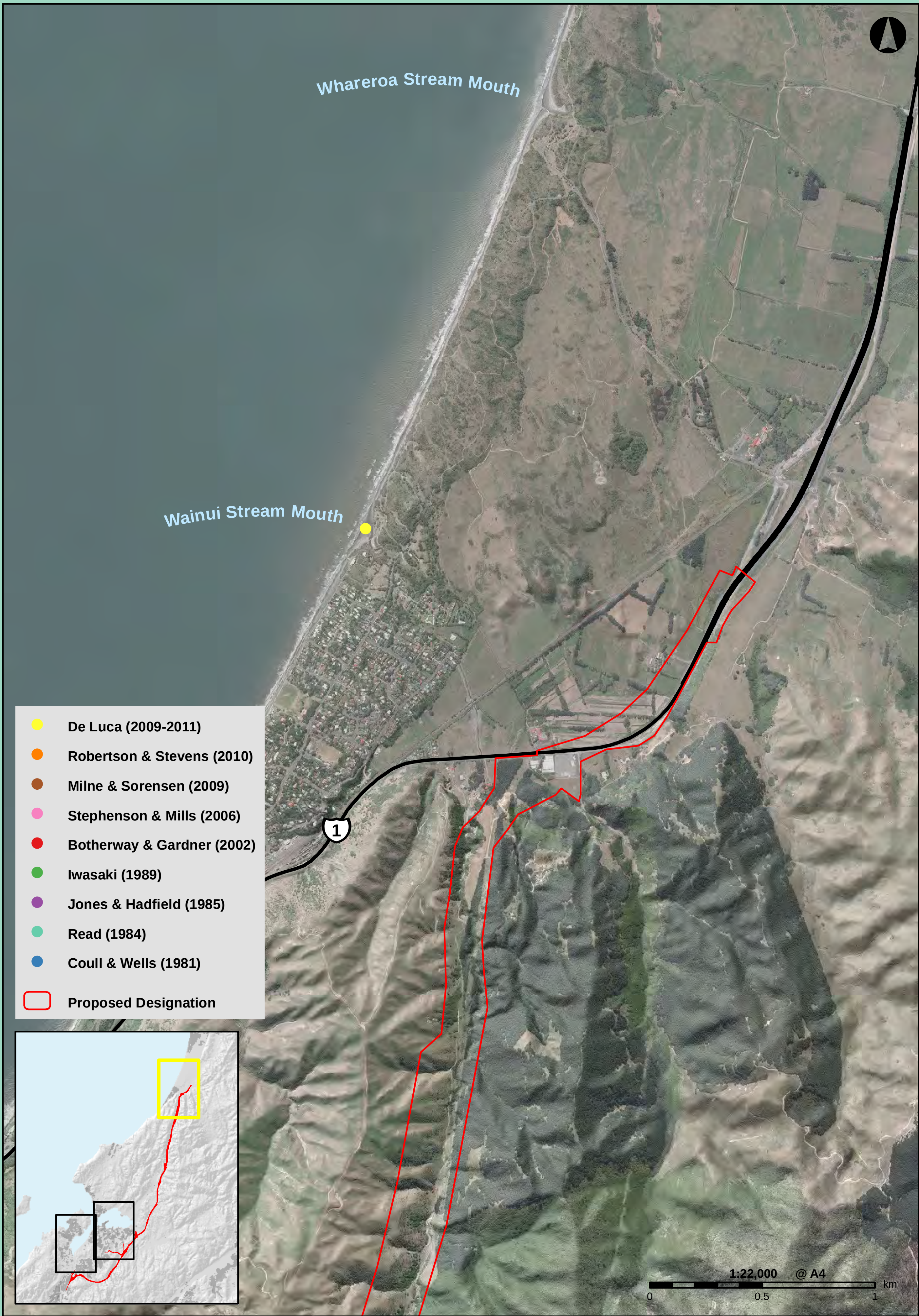
TRANSMISSION GULLY
INVERTEBRATES/FISH SAMPLING SITES 10.2d
ONEPOTO INLET



Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY
INVERTEBRATES/FISH SAMPLING SITES 10.2e
PAUATAHANUI INLET

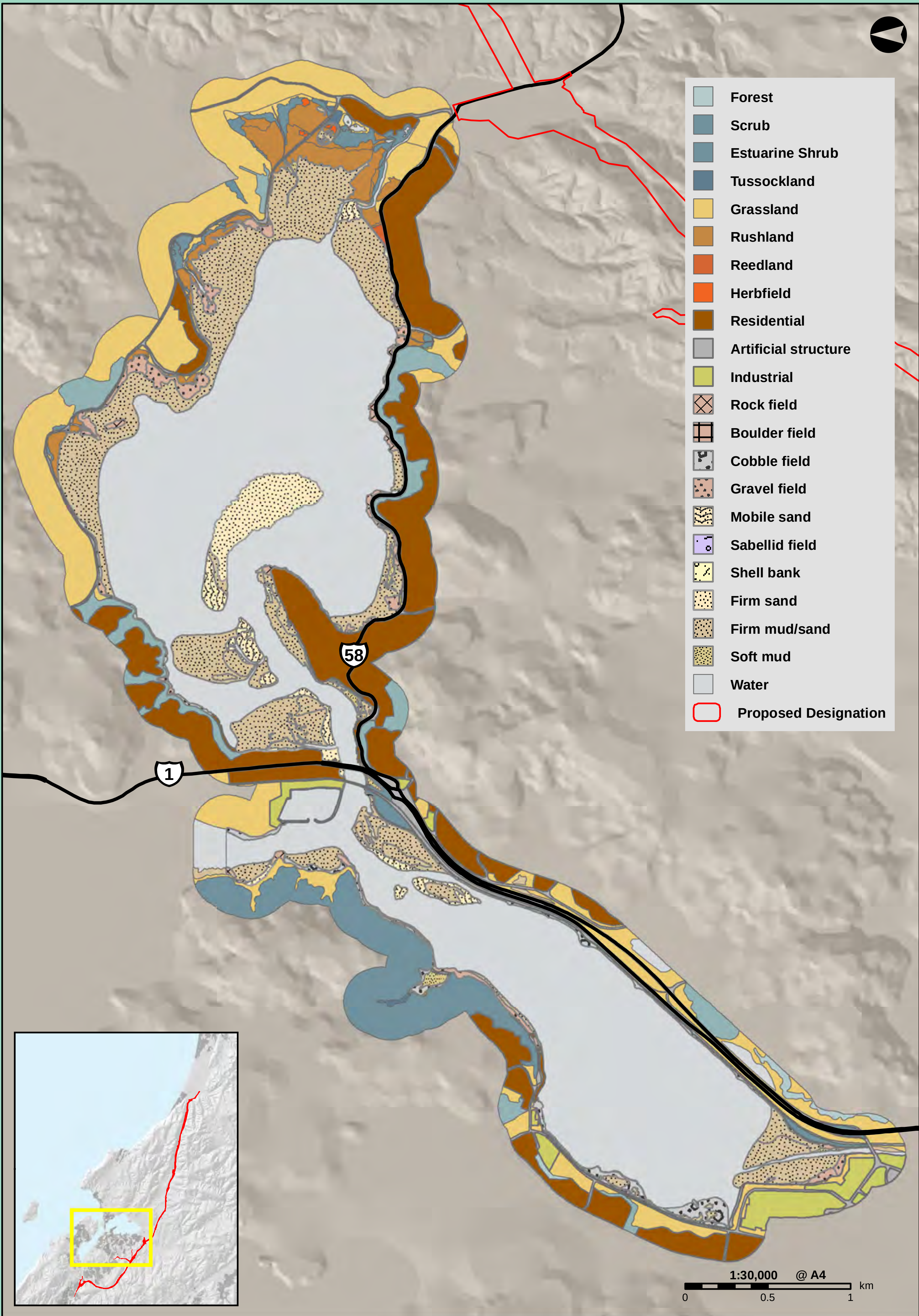


July 25, 2011 W09034A_MAR_SamplingInvFish_A4mb.mxd

Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY
INVERTEBRATES/FISH SAMPLING SITES
WAINUI/WHAREROA STREAM MOUTHS
10.2f



Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

BROAD SCALE FEATURES OF PORIRUA HARBOUR 10.3

(Stevens & Robertson, 2008)

3.1.2 Pauatahanui Inlet

Catchment

The Pauatahanui Inlet is approximately 3.5 km long by 2 km wide and is fed by six major streams (Pauatahanui, Horokiri, Browns, Rations and Kakaho Streams and Duck Creek) covering a catchment of approximately 100 km^2. The shoreline length is approximately 13.24 km (Bellingham, 1998; Gibb & Cox, 2009). The inlet is a dynamic sedimentary system and is largely subtidal, a feature which is not common for North Island estuaries (Swales *et al.,* 2005). Furthermore, the inlet is small compared to its catchment and is therefore sensitive to the effects of land-use practices, which are primarily rural and residential.

The inlet is a low energy estuarine system with a catchment that has been significantly modified over the past 150 years. The inlet is considered to be a sensitive receiving environment as it is already showing signs of ecosystem change, potentially due to sedimentation and accumulation of contaminants (Page *et al.*, 2004). Development of the Whitby area during the 1970's saw significant volumes of sediment discharged to the Whitby Stream which deposited on the beach at Browns Bay. Bulldozers were used to remove the 5 cm deep terrigenous sediment and a large scale research programme of the Pauatahanui Inlet was established (Healy, 1980; Kennedy, 1980). However, urbanisation and ongoing fragmentation of coastal ecological features continue to threaten the inlet ecosystem (Anstey & Blaschke, 2003).

The inlet has intertidal flats that fringe the central mud basin, and deltas have formed where streams discharge. The largest intertidal mud/sand flats are associated with the Pauatahanui, Horokiri, Rations and Kakaho Streams. Horokiri Stream enters the Pauatahanui Inlet on the northern side, with the land use in this catchment (33 km^2) being predominantly pastoral farming. The catchment for Pauatahanui Stream is largely rural, but residential land use dominates in the lower reaches of the stream. Saltmarsh vegetation is present adjacent to the Pauatahanui Stream mouth (Hooper, 2002).

The catchment for Kakaho Stream is small (11.3 km^2) and is also agricultural, with the upper stream areas surrounded by native bush. Rations Stream has a small low lying catchment (6.1 km^2), including pastoral land and a golf course. The lower part of Rations Stream is surrounded by saltmarsh contained within a Department of Conservation (DOC) reserve. Duck Creek drains a small catchment (11 km^2) and comprises an eastern and a western branch above the Duck Creek Golf Course. The land-use surrounding the eastern branch is predominantly pastoral and pine forest land, whereas the western branch has a mainly urban catchment. Browns Stream has a small (1.23 km^2), urban catchment. Much of the marsh area around the inlet has been drained for other land-uses such as grazing and roading (BML, 2000).

Hydrology and Water Quality

The estuary is characterised by strong tidal flushing, deep low water channels and active sediment transport. Water residence time is estimated at three days (Healy, 1980). The bottom sediments range from firm sand and rocks in the northern and middle areas, to soft muddy beds and seagrass on the eastern side (Healy, 1980). There is a range of salinities in the estuary as fresh and marine water mix.

Due to the shallow nature of the Pauatahanui Estuary, there is reasonably good mixing of the water column through the action of tides and waves and as a result the salinity throughout the estuary is similar to seawater (Healy, 1980; Swales *et al.,* 2005). Stratification of water may occur during storm flow conditions, where the fine catchment sediments are transported in the surface freshwater layer overlying the saline water. These fine particles aggregate as they settle through the water column and deposit on the estuary bed (McDougall 1976; Swales *et al*., 2005). Sediments and associated contaminants are reworked through resuspension and mixing, and the through the actions of burrowing and feeding of organisms.

The western and eastern ends of the central basins in the Pauatahanui Inlet accumulate most of the fine sediment, due to the weak tidal currents and circulation eddies. Estimates indicate that between 1974 and 2009 the net average deposition rates within the Pauatahanui Inlet were 9.1 mm/yr, which has reduced the tidal prism by 8.7%. At current sedimentation rates, the Pauatahanui Inlet is likely to infill in the next 145-195 years (SKM, 2010).

Sediment Characteristics

Healy (1980) estimated a sediment input to the inlet from these streams of 13,000 tonnes per annum, and calculated that the inlet will infill with sediment in approximately 1,000 years. The soils of the wider catchment are predominantly colluviums with loess on the moderately steep hills and the rolling parts of lowland hills and upland ridge crests and plateaux, loess with tephra on the high terraces, and gently undulating ridge crests and plateaux, and silty alluvium with some peaty beds on the low terraces and present stream flood plains. Bedrock with colluviums occurs in the steep hills and there are small areas of stony alluvium on the intermediate height terraces (Healy, 1980). Sediment within the inlet is heterogeneous, but is dominated by sands and gravels, with areas of silt and clay present mainly around certain stream mouths.

Whilst infilling is a natural process in estuaries, it is likely that the land-use changes, in particular the rapid urbanisation of the southern side of the inlet such as Whitby in the 1970's which has spread to the catchments of Brown's Bay and Duck Creek in recent decades, has exacerbated the natural infilling rate.

Based on radioisotope analysis and pollen dating, Swales *et al*. (2005) estimated the sediment accumulation rates over three time periods in the past 150 years. Subtidal sediments are rapidly mixed to a depth of approximately 5 cm over a period of days to months by the physical and biological processes. Swales *et al.,* (2005) were unable to reconstruct annual sedimentation patterns in the inlet due to the deeper mixing of sediments (up to 14 cm deep) that occurs over years and decades as a result of the burrowing and feeding activities of infaunal invertebrates. However, they estimated that the sediment accumulation rate (SAR) in the inlet since 1980 has averaged 4.6 mm per year, and predict that a SAR of >4.0 mm per year in the next 50 years is likely. The infilling of the Pauatahanui Inlet is moderated by the processes of wave resuspension and the flushing of fine sediment from the system primarily during flood flows.

Gibb & Cox (2009) estimated the average SAR since 1974 to be 9.1mm/year in the Pauatahanui Inlet, with a forecasted infilling between 2155 and 2205 (i.e. 145 to 195 years), changing the environment from a tidal estuary to a brackish swamp.

Sediment Contaminants

Sediment contaminant maps individually for the Onepoto Inlet and Pautahanui Inlet for copper, lead, zinc, high molecular weight polycyclic aromatic hydrocarbons (HMW PAHs), DDT, dieldrin and mercury are presented in Figures 10.4a to 10.4n below. Figures 10.4a to 10.4n should be referred to in conjunction with Figures 10.2a to 10.2f which indicate the source of each data point in Figures 10.4a to 10.4n.

Milne & Watts' (2008) survey of streambed sediment quality in the Wellington region in 2005 and 2006 revealed above ANZECC ISQG-low concentrations for total DDT (at 1% TOC) in Duck Creek, Browns, Horokiri, Pauatahanui, Kakaho and Ration Streams (Figures 10.2b and 10.4j). Browns Stream sediment also contained zinc above ISQG-low threshold concentration (Figures 10.2b and 10.4f).

Subtidal sediment quality analyses (Cu, Pb, Zn, Cr, Co, Ni, Fe, Mn) were carried out by Glasby et al. (1990) (<20 µm fraction) at 30 sites within the Pauatahanui Inlet. Pauatahanui Inlet sediment was considered to be uncontaminated to moderately contaminated with respect to lead (Glasby et al., 1990). The

Pauatahanui Inlet sediment was largely considered to be uncontaminated by zinc, but small areas adjacent to Rations Stream, Pauatahanui Stream, Duck Creek and north of Golden Gate Peninsula were considered to have sediment zinc concentrations that put these areas in the uncontaminated to moderately contaminated class (Glasby et al., 1990).

The mean contaminant concentration for each Inlet[1] indicated copper, lead and zinc to be in above the ARC ERC amber concentration in the Pauatahanui Inlet, but above the ARC ERC red concentration in the Onepoto Inlet. However, whilst average metal concentrations were below ARC ERC red concentrations in the Pauatahanui Inlet, at least one sediment sample collected exceeded this threshold as the maximum concentrations in the range reported are above ARC ERC red threshold concentrations for copper, lead and zinc. No samples collected from the Onepoto Inlet were below ARC ERC red thresholds (Glasby et al., 1990).

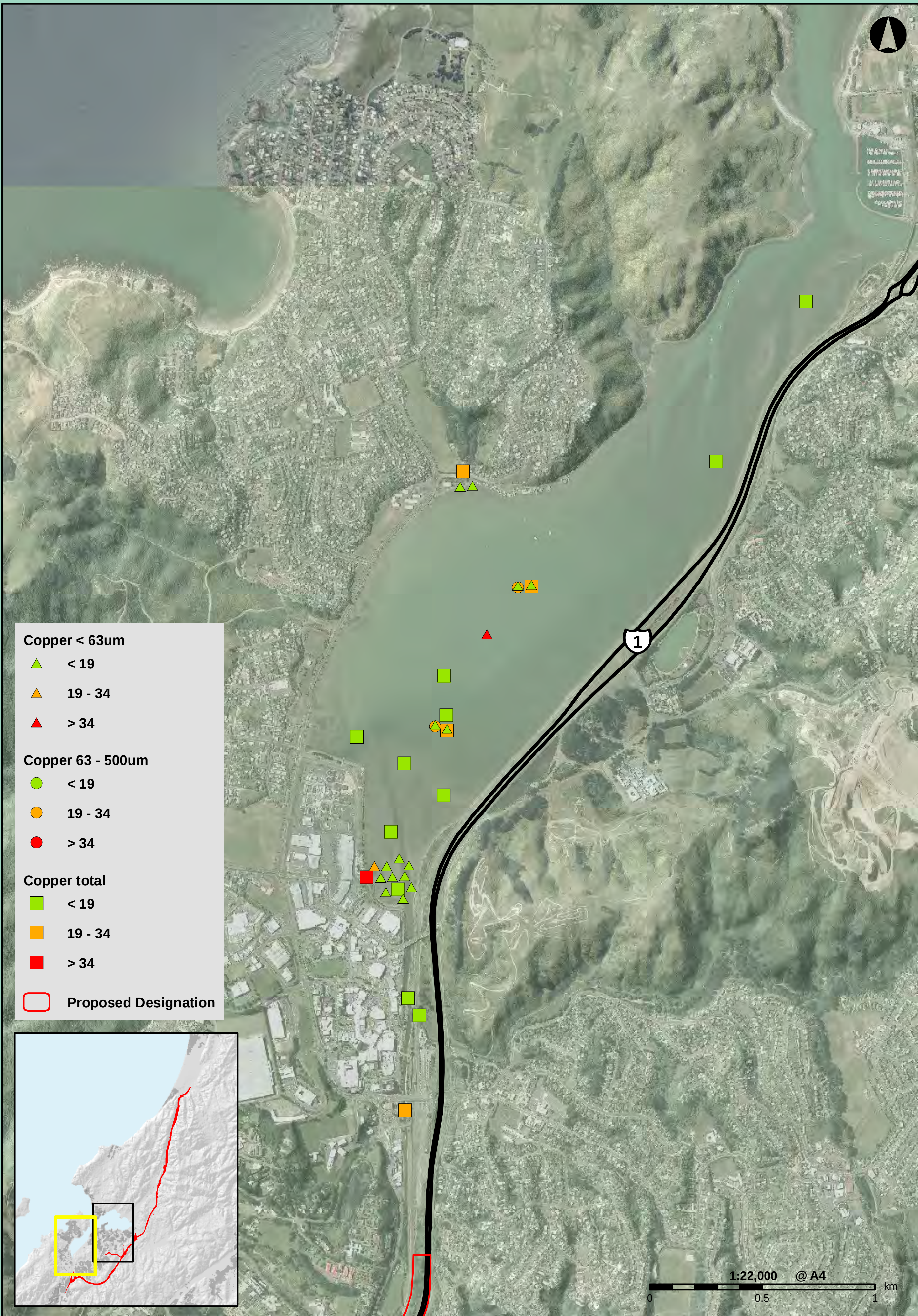
Sorensen & Milne (2009) and Milne & Sorensen (2009) analysed metal concentrations in subtidal sediments in the Porirua Harbour and their results indicated concentrations of copper, lead and zinc below effects threshold concentrations in both coarse (<500 µm fraction) and fine (<63 µm fraction) sediment fractions collected from the Pauatahanui Inlet (Figures 10.2b,10.4b,10.4d and 10.4f).

Subtidal sediment quality analyses undertaken by Stephenson & Mills (2006) in 2004 and 2005 revealed a significant decrease (between 10 and 25% decrease) in the proportion of <63 µm fraction sediment (silt and clay) at all three sites studied within the Pauatahanui Inlet, with corresponding increases in the proportion of sand grain sizes. The concentration of copper, lead, zinc and high molecular weight polycyclic aromatic hydrocarbons (HMW-PAHs) was below effects thresholds (Figures 10.2b, 10.4b, 10.4d, 10.4f, and 10.4h). 4,4'-Total DDT was detected above effects thresholds (ANZECC ISQG-Low) at all three sites in both 2004 and 2005 when normalised for 1% total organic carbon (TOC) (Figures 10.2b and 10.4j. Two sites within the Inlet had concentrations of 4,4'-Total DDT above the ARC ERC red threshold, most likely arising from rural soils from historical land-use practices.

Intertidal sediment quality sampling Porirua Harbour carried out by Robertson & Stevens (2009 and 2010) at two sites in the Pauatahanui Inlet indicated that metals (cadmium, chromium, copper, nickel, lead, zinc) were detected at low to very low concentrations, significantly below ISQG-low trigger values (Figures 10.2b, 10.4b, 10.4d, and 10.4f). In addition, the proportion of mud in the sediment samples was less than 10% but noted to be increasing in 2010. Robertson & Stevens (2009) noted redox potential discontinuity (RPD) depth (an indicator of sediment oxygenation) was an average of 2 cm (fair) at the lower Pauatahanui Inlet sampling site and 4 cm (good) at the upper site. In 2010 however, Robertson & Stevens (2010) identified the RPD depth at both sites to be 1 cm (fair-poor), suggesting poor oxygenation of the sediment. The researchers interpreted the "fair" RPD depth as likely to have reduced abundance and diversity of invertebrates, "good" represented a stable-normal invertebrate community composition and "fair-poor" suggests the benthic invertebrate community was likely to be in a transitional state (Robertson & Stevens, 2010).

Investigations of nutrients in intertidal sediments in the 1970's revealed low concentrations in subtidal sediment, and higher nutrients intertidally on the northern and eastern sides of the Pauatahanui lnlet compared to the southern shores. Healy (1980) and Kennedy (1980) considered the higher nutrients in sediment to the north and east was due to runoff from rural landuse. However, good tidal flushing prevents significant accumulation of nutrients in marine sediments (Kennedy, 1980).

[1] Note that the average concentration for copper, lead and zinc is presented in Figures 10.4.a-c at a site in the centre of each Inlet. In reality the sites sampled by Glasby et al. (1990) were spread throughout the Inlets. However, contaminant data for each site is not reported by the authors in their publication.



July 26, 2011 W09034A_MAR_SamplingSediment_Cu_A4mb.mxd

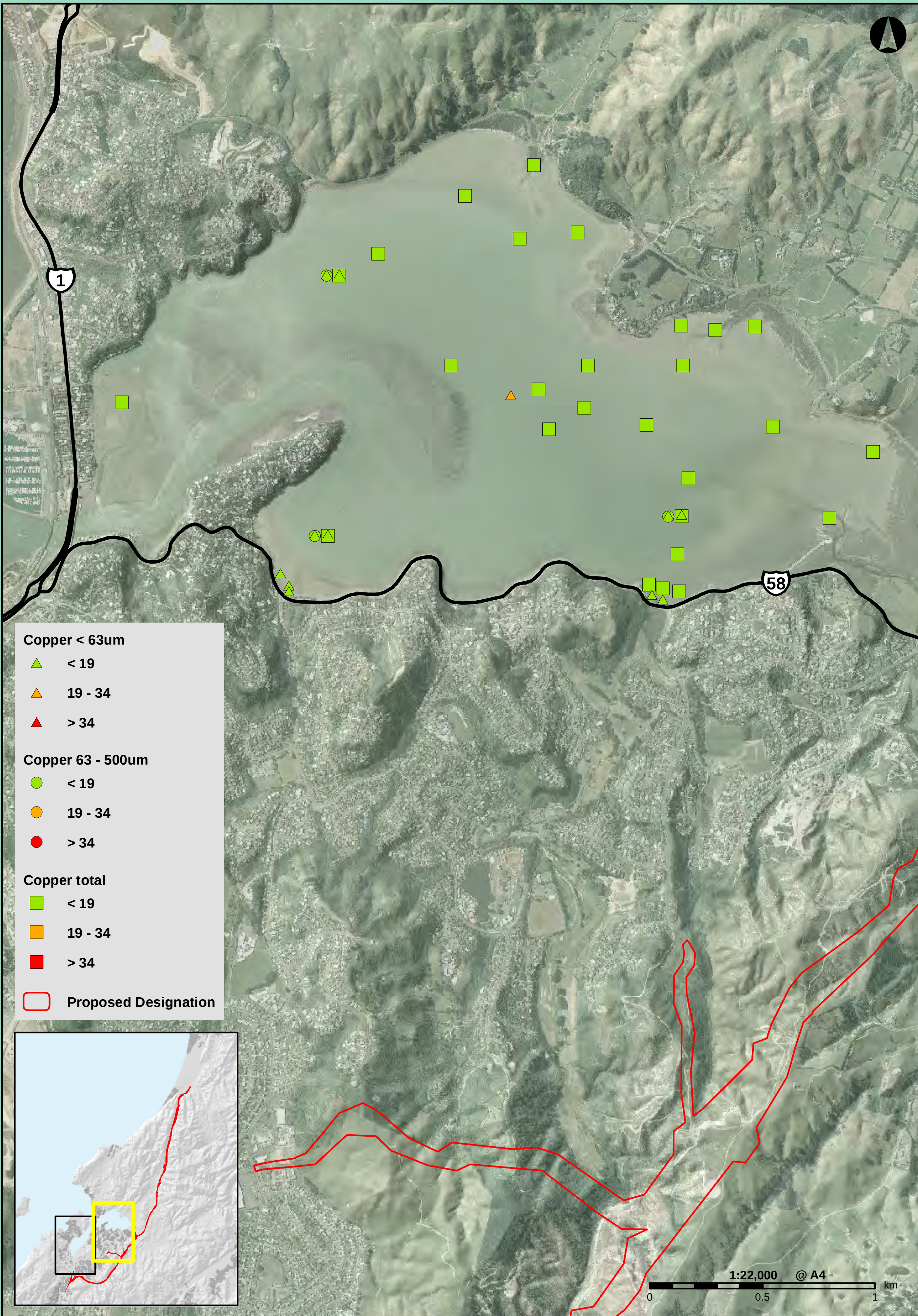
Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF COPPER IN SEDIMENT 10.4a

ONEPOTO INLET



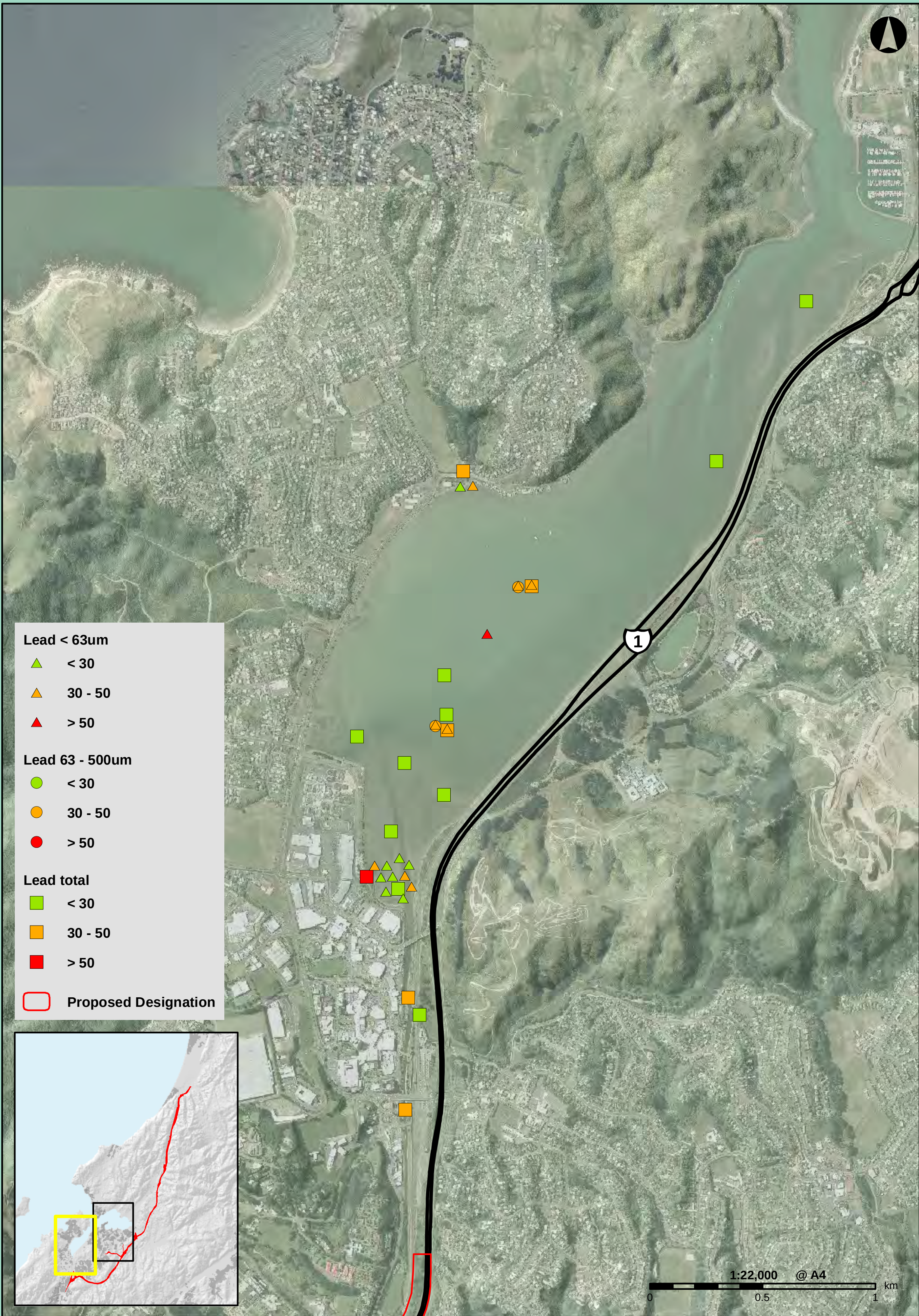
July 26, 2011 W09034A_MAR_SamplingSediment_Cu_A4mb.mxd © Boffa Miskell Ltd 2011

Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY
CONCENTRATION OF COPPER IN SEDIMENT
PAUATAHANUI INLET

10.4b



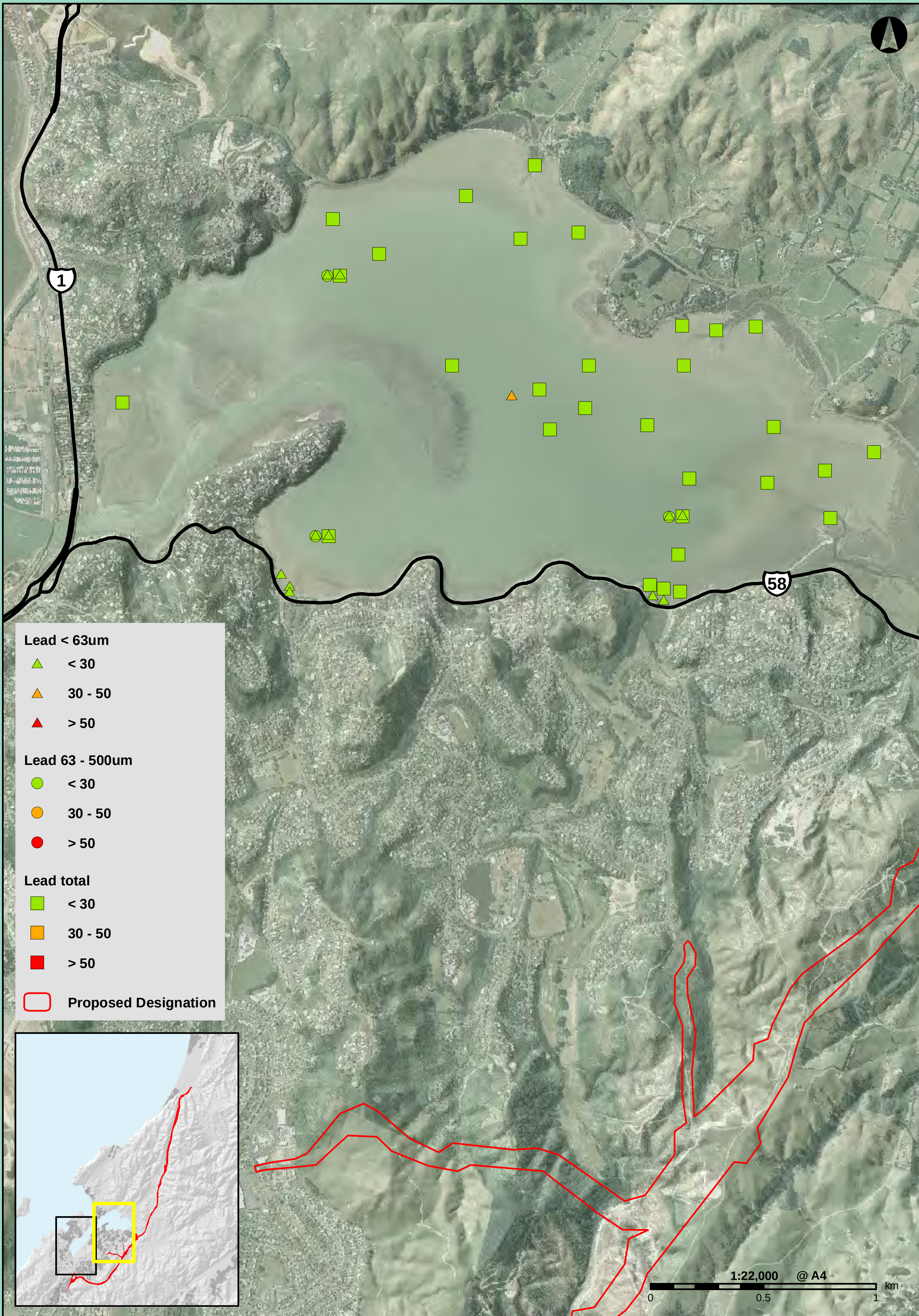
July 26, 2011 W09034A_MAR_SamplingSediment_Pb_A4mb.mxd © Boffa Miskell Ltd 2011

Boffa Miskell
NZ TRANSPORT AGENCY WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF LEAD IN SEDIMENT 10.4c

ONEPOTO INLET



July 26, 2011 W09034A_MAR_SamplingSediment_Pb_A4mb.mxd © Boffa Miskell Ltd 2011

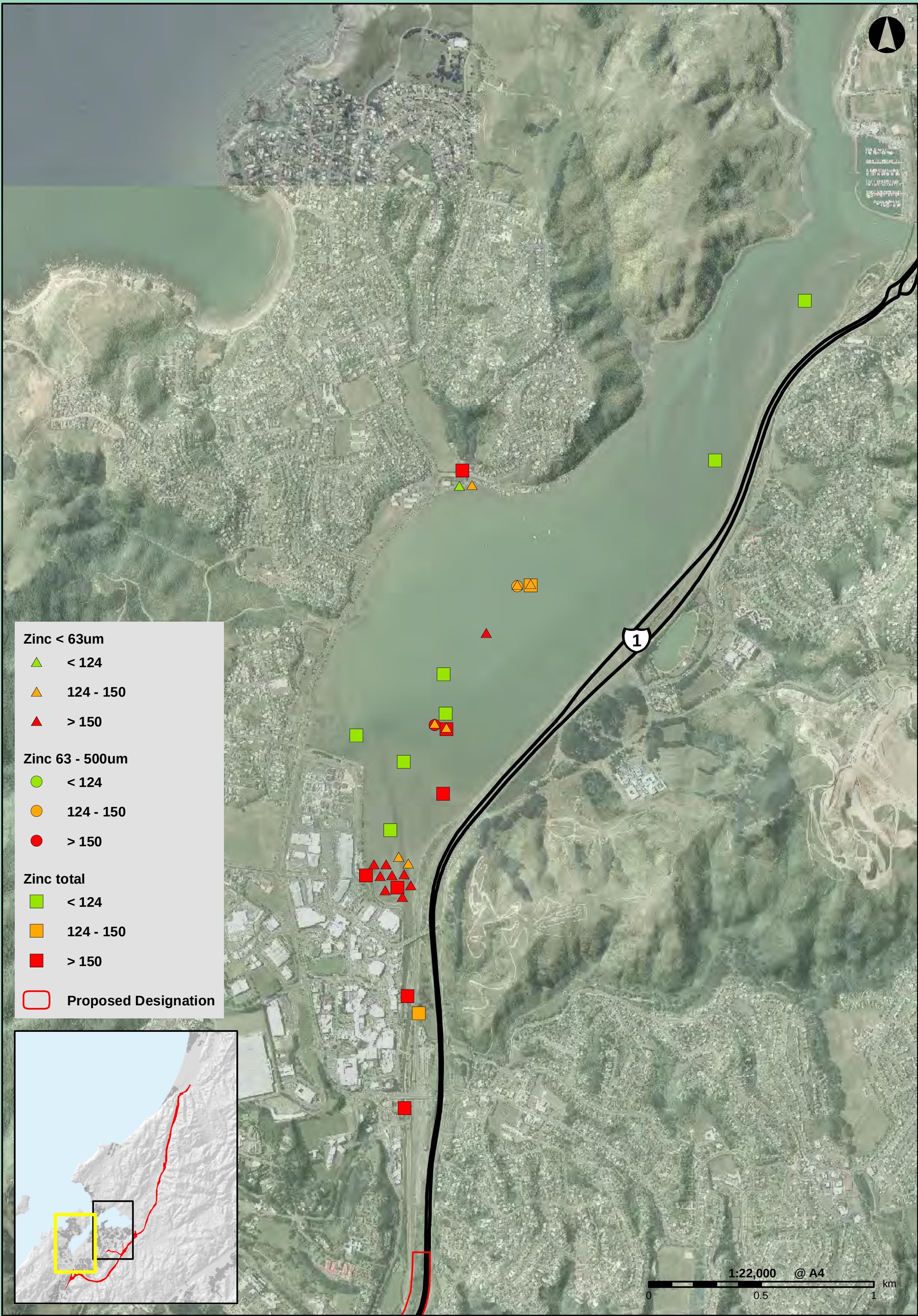
Boffa Miskell

NZ TRANSPORT AGENCY WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF LEAD IN SEDIMENT 10.4d

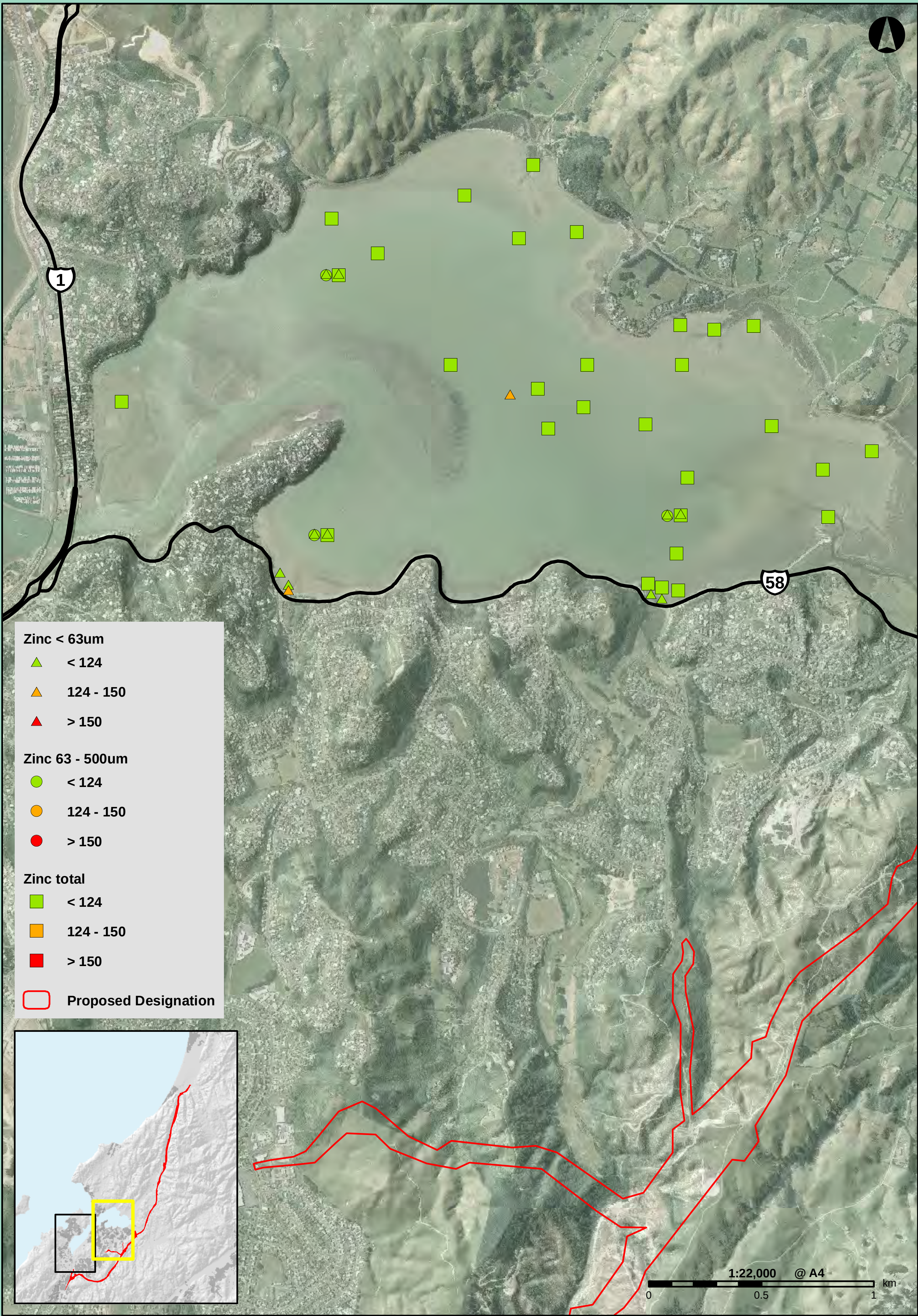
PAUATAHANUI INLET



July 26, 2011 W09034A_MAR_SamplingSediment_Zn_A4mb.mxd © Boffa Miskell Ltd 2011

Boffa Miskell NZ TRANSPORT AGENCY WAKA KOTAHI

TRANSMISSION GULLY
CONCENTRATION OF ZINC IN SEDIMENT 10.4e
ONEPOTO INLET



July 26, 2011 W09034A_MAR_SamplingSediment_Zn_A4mb.mxd

Boffa Miskell

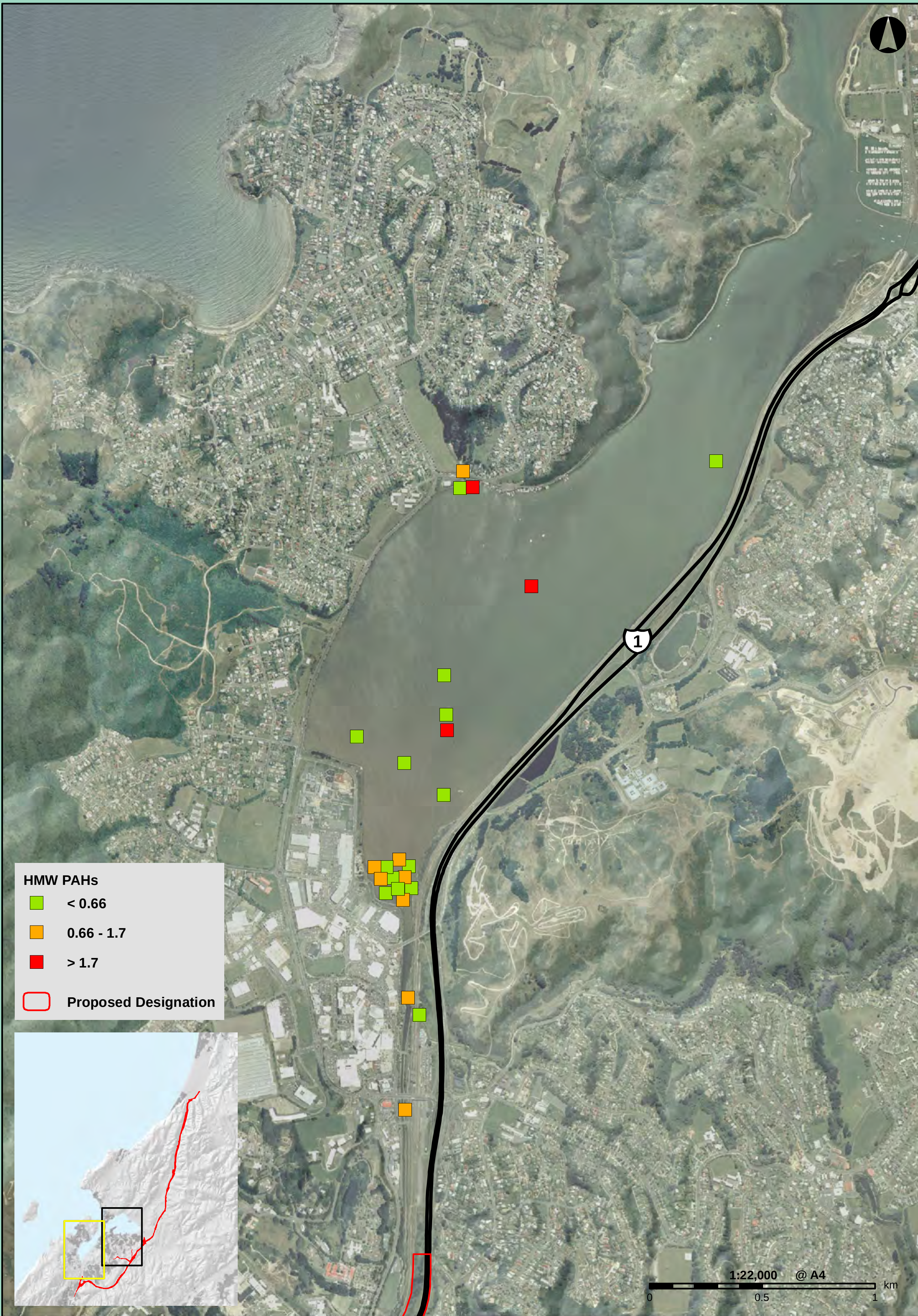
NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF ZINC IN SEDIMENT

PAUATAHANUI INLET

10.4f



May 3, 2011 W09034A_MAR_SamplingSediment_PAH_A4mb.mxd © Boffa Miskell Ltd 2011

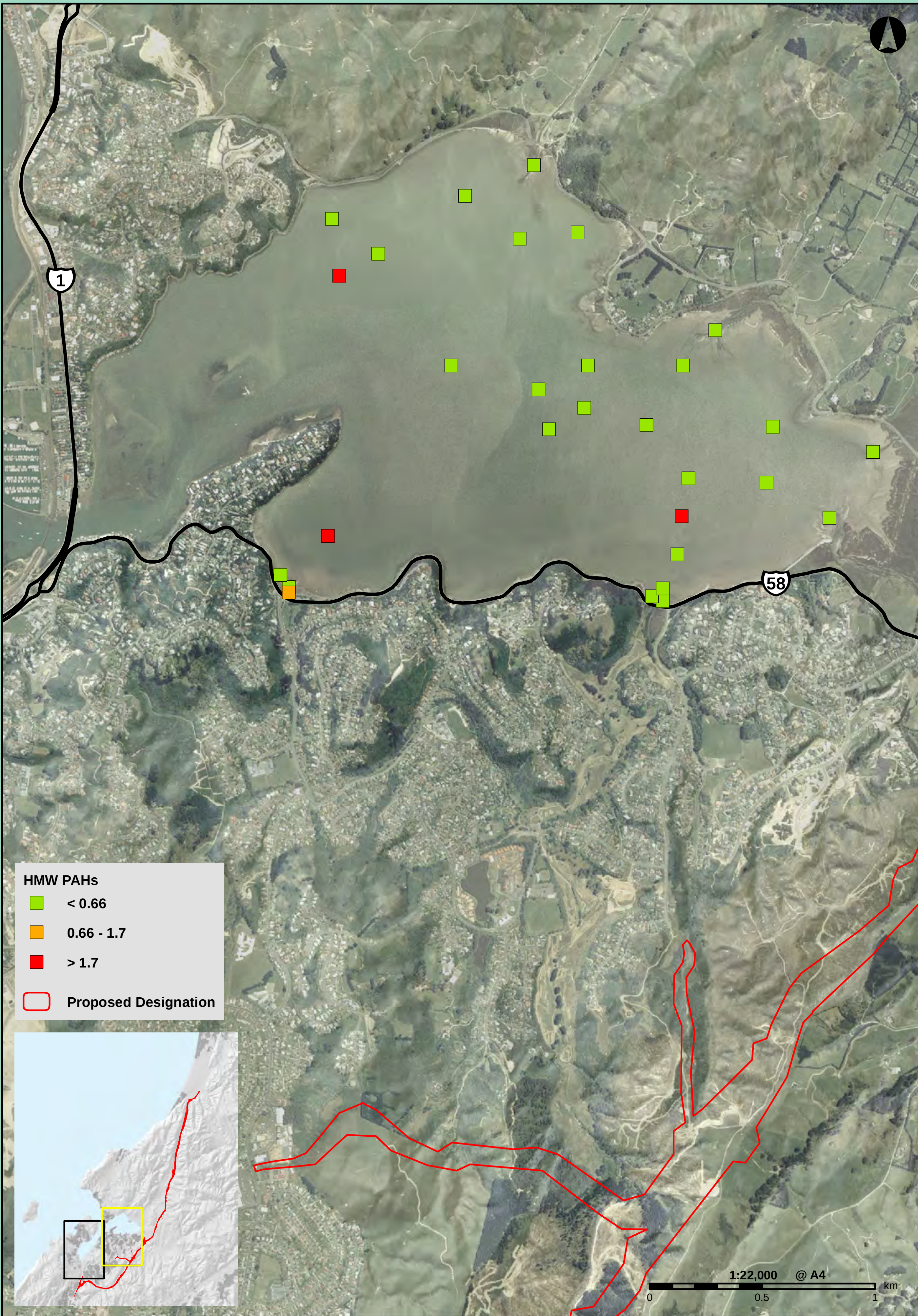
Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF HMW-PAHs IN SEDIMENT 10.4g

ONEPOTO INLET



May 3, 2011 W09034A_MAR_SamplingSediment_PAH_A4mb.mxd © Boffa Miskell Ltd 2011

Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF HMW-PAHs IN SEDIMENT **10.4h**

PAUATAHANUI INLET

Boffa Miskell

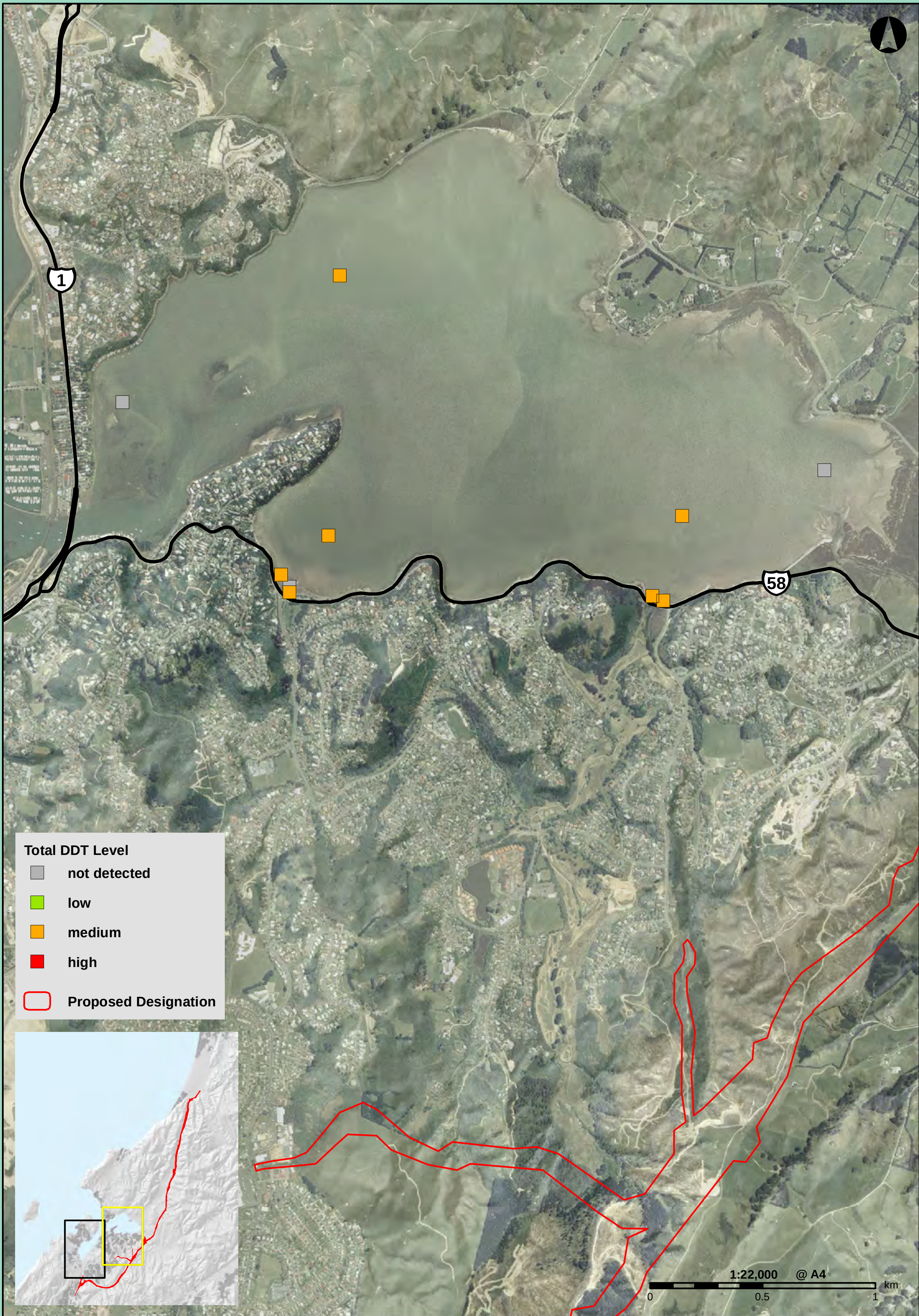
NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF DDT IN SEDIMENT

ONEPOTO INLET

10.4i



May 3, 2011 W09034A_MAR_SamplingSediment_DDT_A4mb.mxd

Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF DDT IN SEDIMENT

PAUATAHANUI INLET

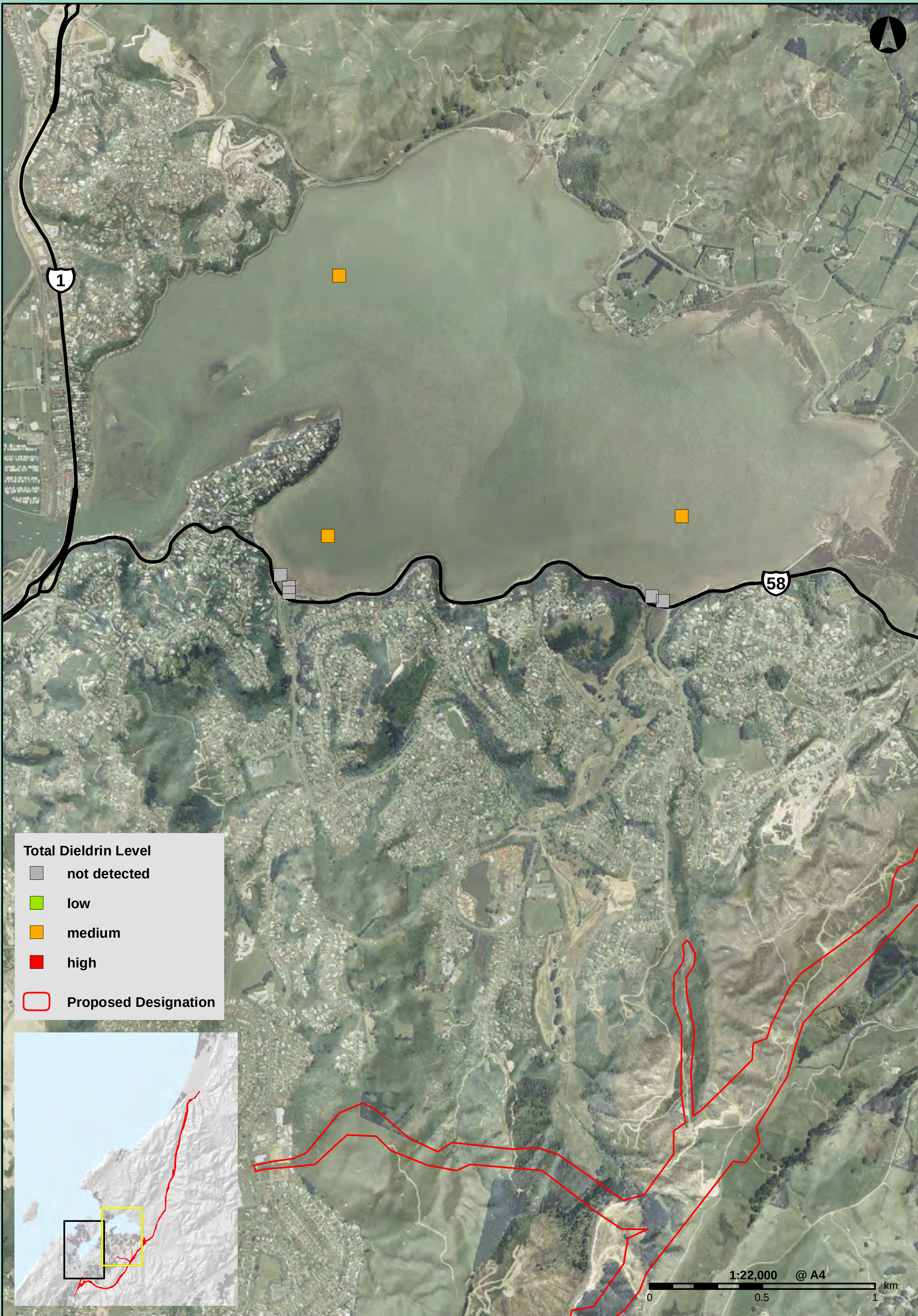
10.4j

Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY
CONCENTRATION OF DIELDRIN IN SEDIMENT
ONEPOTO INLET

10.4k



Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF DIELDRIN IN SEDIMENT 10.4l

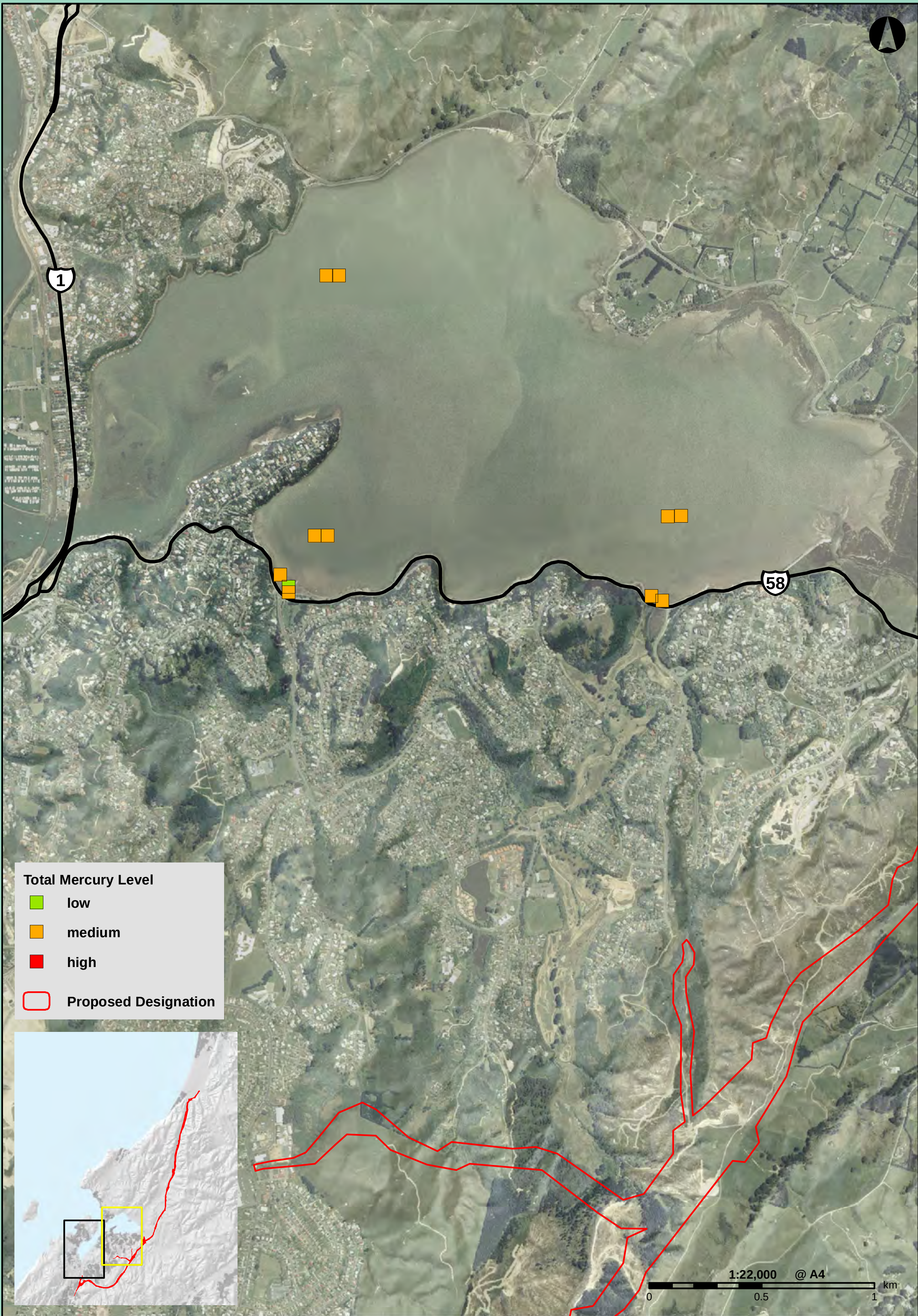
PAUATAHANUI INLET

Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY
CONCENTRATION OF MERCURY IN SEDIMENT
ONEPOTO INLET

10.4m



Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CONCENTRATION OF MERCURY IN SEDIMENT 10.4n

PAUATAHANUI INLET

Ecological Values

The Pauatahanui Inlet is the largest relatively unmodified estuarine area in the southern part of the North Island and has the status of a site of national significance in DOC's Sites of Special Wildlife Interest (SSWI) database. The inlet is listed in the Regional Policy Statement (RPS) as a site of national significance for indigenous vegetation (saltmarsh and seagrass) and significant habitats for indigenous fauna, as well as a landscape and seascape of regional significance (GWRC, 1995). The inlet is further recognised as an Area of Significant Conservation Value (ASCV) in the Wellington Regional Coastal Plan based on the natural, conservation, geological and scientific values (GRWC, 2000). The Coastal Plan further states that the wildlife reserve contains diverse waterfowl and wading bird habitat (for both local and migratory species), threatened fish species (including *Galaxias* spp.), significant saltmarsh vegetation and endangered vegetation (GWRC, 2000).

DOC manages four areas within the inlet being: Pauatahanui Wildlife Refuge, Pauatahanui Inlet Wildlife Management Reserve, Horokiri Wildlife Management Reserve and Duck Creek Scenic Reserve (DOC, 1996). The largest of these areas is the Pauatahanui Wildlife Refuge (169 ha), located in the eastern half of the Inlet, and was intended to protect wildlife from disturbance, especially hunting. Adjacent to the wildlife refuge is the Pauatahanui Wildlife Management Reserve (42.91 ha), situated at the head of the Pauatahanui Inlet. Both Pauatahanui Stream and Ration Creek flow through this reserve which encompasses a coastal wetland containing tidal flats consisting of predominantly indigenous salt marsh vegetation (DOC, 1996). The reserve also contains sluice gates that artificially hold back tidal water in the marshland area in order to provide bird feeding habitat to areas previously modified (BML, 2000). The Horokiri Wildlife Management Reserve (5.04 ha) abuts the wildlife refuge and is situated to the west and south of Grays Road near Horokiri Stream. The area is characterised by an estuarine wetland (DOC, 1996). Duck Creek Scenic Reserve (1.04 ha) consists of a flat swampy basin mainly covered in rushes. The reserve is surrounded on three sides by roads, being located on State Highway 58 where Duck Creek flows into Pauatahanui Inlet (DOC, 1996).

Saline Flora

The inlet and its immediate surrounds contain a variety of habitats including intertidal sandflats, saltmarsh, rushlands and manuka shrubland (Fuller, 1995). Relatively natural estuarine vegetation profiles are present in the eastern part of the Inlet. Three species of threatened/rare plants are present within marginal vegetation (Fuller, 1995; Rosier, 1994) and are discussed further in Technical Report 6 (Vegetation).

The Horokiri Wildlife Management Reserve, Pauatahanui Inlet Wildlife Refuge, Pauatahanui Wildlife Management Reserve and Duck Creek Scenic Reserve contain regionally rare saltmarsh, rushland and saline herbfield communities. Approximately 9.7% of the inlet margins (primarily in the east) are vegetated with saltmarsh, of which 5.6% is rushland (*Juncus krausii* and *Apodasmia similis*) (Stevens and Robertson, 2008). Glasswort (*Sarcocornia quinqueflora*) is common on upper intertidal shellbanks in the north and east of the Inlet, and salt marsh ribbonwood (*Plagianthus divaricatus*) is present where the vegetation transitions from estuarine to terrestrial.

Saltmarsh distribution in the harbour was mapped in 2007 (Stevens & Robertson, 2008) and is shown in Appendix 10F.

Salt marsh plants, such as *J. krausii*, accumulate heavy metals in their tissues, which when dropped as leaf litter, leaches into the seawater in the dissolved phase (Kennedy, 1980). Given the good tidal flushing in the harbour, it is expected that dissolved contaminants are removed from the harbour to the open sea.

Seagrass (*Zostera muelleri*) enhances estuarine biodiversity by providing an important habitat for invertebrate organisms that fish and birds feed on. Fish known to feed within seagrass include yellow-eyed mullet, stargazer, juvenile flatfish, snapper, trevally, garfish, and spotty. Oystercatcher, pied stilt and spoonbill also feed within seagrass. Approximately 41ha of seagrass is present intertidally within the Pauatahanui Inlet (Stevens & Robertson, 2008), with the plants appearing lush and healthy.

Seagrass is vulnerable to suspended sediment and reduced sediment quality (Stevens & Robertson), and anecdotal evidence reported by The Guardians of the Pauatahanui Inlet suggests a decline in the area of seagrass beds over the past 30-40 years. Intertidal seagrass distribution within the Porirua Harbour was mapped in 2007 and is shown Appendix 10F (Stevens & Robertson, 2008). However, no broad scale information on subtidal distribution of seagrass was found during the literature search.

Macroalgal cover on intertidal sediments within the Porirua Harbour was investigated by Stevens & Robertson (2008, 2009) and revealed some nuisance macroalgae in both the Pauatahanui Inlet (around the Pauatahanui Stream). Macroalgae cover increases with increased nutrients and, when the sediment below is smothered, can cause localised areas of rotting algae, poorly oxygenated and sulphide rich sediments. Overall, Porirua Harbour was given a rating of "fair" for macroalgae cover condition by Stevens & Robertson, which was of sufficient concern for the authors to recommend annual monitoring. Macroalgae distribution intertidally has been mapped by Stevens & Robertson (2008) and is shown in Appendix 10F. No broad scale information was found during the literature review on the distribution of macroalgae subtidally.

Invertebrates

The main features of the intertidal estuarine macrofaunal community that are commonly reported in the literature as ascribing higher ecological value to the estuary are the high density of *Austrovenus stutchburyi* (cockles), polychaete worms and copepods.

The first systematic sampling of the cockles in the Pauatahanui Inlet was undertaken in 1976, as part of the wider Pauatahanui Environmental Programme (Healy 1980) and published by Richardson et al (1979). Many population studies have been undertaken subsequently. Total cockle populations declined in density between 1976 and 1992, from approximately 400-600 million to 200 million. Causes of the decline in cockle density have been purported to be sedimentation, exploitation and natural temporal variation (Grange, 1993; Nilsen *et al.,* 1988; Grange & Tovey, 2002) (see sampling locations in Figures 10.2d and 10.2e). Since 1992, surveys have been carried out every three years with the most recent survey in November 2010. Results indicate that the intertidal cockle population size has been relatively stable since 1992. The 2010 results show that the total population detected in 2010 is the highest since 1992 at 277 million cockles, increasing from 233 million in 2007 (Michael, 2011). Cockles are a known keystone species within estuaries and harbours and have been used as an indicator of ecosystem health (Michael, 2011). It is concluded that given the relatively stable population sizes of cockles between 1992 and 2010, and the high proportion of juvenile cockles detected in recent surveys, that the intertidal habitat within the Pauatahanui Inlet has not significantly changed during this period (Michael, 2011).

Copepods have been found in especially high abundance in the estuary and are predated upon by juvenile flatfish. Other dominant macrofauna include wedge shell (*Macomona liliana*), nut shell (*Nucula hartivigiana*), mud snails (*Amphibola crenata*), mud crab (*Helice crassa*) and numerous species of polychaete worms (Swales *et al.,* 2005) (see sampling locations in Figures 10.2d and 10.2e).

At a site between Pauatahanui Stream mouth and Duck Creek mouth, Read (1984) reported the macroinvertebrate community composition to be dominated by polychaete worms and cockles (*Microspio* *maori, Capitella* sp., *Heteromastus filiformis, Axiothella serrata, Boccardia acus, Austrovenus stutchburyi, Scoleocolepides benhami*). Other intertidal invertebrate studies have focussed on meiofauna and reported high abundances of copepods and nematodes (Coull & Wells, 1981; Iwasaki, 1989). The estuary supports the locally highly abundant marine copepod *Parastenhelia megarostrum* (Fuller, 1995; Rosier, 1994) (see sampling locations in Figures 10.2d and 10.2e).

Robertson & Stevens (2009) noted that the intertidal benthic invertebrate community within the two sites studied in Pauatahanui Inlet had a biotic coefficient within the "good" range, but that there was an increasing abundance of organic enrichment tolerant species present, typical for the catchment land-use. The mean species richness was high (15-21 per core) and the taxa were dominated by polychaetes (50%), followed by bivalves, crustacea and gastropods. Robertson & Stevens (2010) confirmed from their most recent studies that the intertidal infaunal invertebrate community composition remains dominated by a broad range of sensitive species. Further, these researchers state that the epifaunal invertebrate community at the two Pauatahanui Inlet sites comprised typical shellfish and other organisms, whereas the epifauna was less diverse in the Onepoto Inlet (Robertson & Stevens, 2010). The typical highly variable nature of epifauna communities was noted, a feature which makes it difficult to identify trends in temporal data sets (see sampling locations in Figures 10.2d and 10.2e).

Subtidal invertebrate assemblages were reported as diverse and stable by Stephenson & Mills (2006), with an average of 32 species detected at each site sampled in 2005. The dominant taxa included oligochaete worms, *Heteromastus filiformis* (polychaete), *Nucula hartvigiana* (bivalve), *Asychis* sp. (polychaete), *Arthritica crassiformis* (bivalve), *Cossura* sp. (polychaete) and *Boccardia* sp. (polychaete). A subsequent study by Milne & Sorensen (2009) revealed 62 species of invertebrates found subtidally, in near shore habitats, within the Pauatahanui Inlet, with the most abundant organisms (across all samples collected within the wider Porirua Harbour) being crustaceans (64%), polychaete worms (25.1%) and bivalve molluscs (24.9%) (see sampling locations in Figures 10.2d and 10.2e).

Fish

A survey in 1983/1984 recorded 43 species of fish in both Inlets of the Porirua Harbour (Jones & Hadfield, 1985), some of which would be tidally or seasonally transient. More than 43 species of marine fish were found in the inlet by Stevenson *et al.* (1987) and 12 indigenous freshwater fish species were detected in the streams that discharge into the estuary (see sampling locations in Figures 10.2d and 10.2e). Of the fish species that use the Harbour at some stage, four at At Risk species (inanga, long-finned eel and lamprey (all declining) and pipefish (sparse, but secure overseas) (Allibone et al., 2010).

In a 2001 survey, limited inanga spawning habitat was detected within Duck Creek (downstream of the golf course), upstream of the SH58 bridge within Pauatahanui Stream, and downstream of the bridge within Horokiwi Stream (Taylor & Kelly, 2001). While Browns and Rations Streams were not sampled, no inanga spawning habitat was detected within Kakaho Stream at the time of the survey (see sampling locations in Figures 10.2d and 10.2e).

Avifauna

A wide variety of birds utilise the inlet, including waterfowl, waders, wetland birds, international and national migratory waders (DOC 1996). Owen (1984) recorded 43 avifauna species in the Pauatahanui Wildlife Management Reserve, including spur-winged plover, grey teal, grey duck, New Zealand shoveler, paradise shelduck and herons.

According to the local community group Guardians of Pauatahanui Inlet (GOPI), 50 bird species are known to occur in the Pauatahanui Inlet and its immediate terrestrial margin (http://www.gopi.org.nz/birds/).

Twenty-nine of these are associated directly with the inlet waters, fringing marshes and streams; of which 14 are regarded as 'resident' species. The remaining 21 of the 50 species are associated with the inlet's terrestrial margin, and 12 of these species are considered to be 'resident'. The following species are listed by GOPI as the most commonly seen birds in the inlet and its marshes: black-backed gull, red-billed gull, mallard, paradise shelduck, black swan, royal spoonbill, pied stilt, spur-winged plover, oystercatcher, little shag, black shag, white-faced heron and pukeko.

Summary of Ecological Values

The extensive literature on the Pauatahanui Inlet indicates that a range of estuarine habitats are present, supporting diverse communities of saline vegetation, invertebrate, fish and birds. Sediment quality is largely characterised by low concentrations of contaminants. There are significant concerns raised in many of the reports reviewed regarding sedimentation rates within the estuary and stability of the cockle populations.

3.1.3 Onepoto Inlet

Catchment

The approximately 4 km long Onepoto Inlet is fed by the Porirua Stream and other small tributaries, draining a total catchment of approximately 70 km^2 (Hooper 2002). Gibb & Cox (2009) estimated the shoreline length to be 9.03 km. This Inlet is smaller and shallower than the Pauatahanui Inlet, with approximately half of the inlet being exposed at low tide (Healy 1980). The benthic sediment is predominantly muddy, with surrounding land-use predominantly being residential and industrial.

Hydrology and Water Quality

Water quality is frequently compromised, with high concentrations of nutrients, faecal indicator bacteria, and contaminants commonly recorded (BML, 2000).
Sediment deposits in the central basin within the Onepoto Inlet. Erosion along much of the Onepoto shorelines occurs most likely as a result of wave reflections from the modified harbour edges. Estimates suggest that between 1974 and 2009 deposition within the Onepoto Inlet has been around 5.7 mm/yr, and the tidal prism has reduced by 1.7%. At current sedimentation rates, the Onepoto Inlet may infill within the next 290-390 years (SKM, 2010).

Sediment Characteristics

Gibb & Cox (2009) estimated that since 1974 the SAR has been on average 5.7 mm/year, with sediment derived from the Porirua Stream accumulating in the central mud basin at approximately 5.0 mm/year. Forecasted infilling of the Onepoto Inlet is within the next 290 to 390 years (2300 to 2400).

Sediment Contaminants

A higher proportion of residential and industrial land-use in the catchment compared to the Pauatahanui catchment has resulted in lower sediment quality in the Onepoto Inlet (Botherway, 1999 in BML, 2000). Glasby *et al*. (1990) determined that there were two primary sources of heavy metal contaminants entering the Onepoto Inlet: one being Porirua Stream and the other Porirua City. The average concentration of copper, lead and zinc within the Inlet exceeded the ARC ERC Red threshold (Figures 10.2a, 10.4a, 10.4c, and 10.4e). More recently (2005-2006), Milne & Watts (2008) survey of streambed sediment quality in the Wellington region revealed above ANZECC ISQG-low concentrations of zinc (Figures 10.2a and 10.4e) and total DDT (at 1% TOC) in Porirua (Figures 10.2a and 10.4i) and Browns Streams (Figures 10.2b and 10.4j).

Botherway & Gardner (2002) studied intertidal invertebrate assemblages and stormwater derived heavy metal concentrations in sediment at various distances from a stormwater drain (adjacent to Semple Street) located in the southernmost end of the Onepoto Inlet. They determined that concentrations of zinc throughout the Inlet were likely to be above biological effects thresholds (Figures 10.2a and 10.2e) and that in the vicinity of the stormwater drain the concentration of copper (Figures 10.2a and 10.4a), lead (Figures 10.2a and 10.4c) and zinc (Figures 10.2a and 10.4e) in sediment was high. Within 5.0 m of the drain outlet copper was detected at approximately 50 mg/kg (Figure 10.4a), lead at approximately 100 mg/g (Figure 10.4c) and zinc was detected between 280-500 mg/kg (Figure 10.4e). These concentrations are approximately double the ARC ERC red threshold concentrations. At 1.5 km distance from the stormwater drain the heavy metal concentrations in sediment, whilst somewhat lower, were still significantly greater than the ARC ERC red concentrations (Figures 10.2a, 10.4a, 10.4c and 10.4e).

Stephenson & Mills (2006) reported the <63 µm fraction of sediment to be between 70-90% at the two Porirua Harbour sites monitored in 2005. Contaminant concentrations in sediment were overall higher than those from the Pauatahanui Inlet, with total copper, lead and zinc all exceeding the ARC ERC amber threshold for biological effects and comprising approximately double the concentration of that detected in the Pauatahanui Inlet (Figures 10.2a, 10.4a, 10.4c and 10.4e). At one Porirua Harbour site, zinc was detected in sediment in excess of the ARC ERC red threshold (Figure 10.4e). Whilst HMW PAHs were detected at double the concentration of the samples collected from the Pauatahanui Inlet, all results were below effects threshold concentrations (Figure 10.4g). Total DDT was lower in Porirua Harbour (Figure 10.4i) compared to Pauatahanui Inlet (Figure 10.4j). Total DDT exceeded effects thresholds at one Porirua Harbour site (Figure 10.4i).

Sorensen & Milne (2009) in their survey of intertidal sediment quality in the Porirua Harbour determined that the Semple Street stormwater outfall and Porirua Stream were the primary sources of contaminants in the southern end of Porirua Harbour. Zinc (Figures 10.2a and 10.4e) and total DDT (Figures 10.2a and 10.4i) were detected in concentrations above effects threshold concentrations at all sites and comprised the contaminants of greatest concern in this area. Copper, lead and mercury were also detected above lower effects threshold guidelines at several sites (Figures 10.2a, 10.4a, 10.4c and 10.4m).

Intertidal sediment quality sampling carried out by Robertson & Stevens (2009 and 2010) at two sites in the Onepoto Inlet indicated that metals (cadmium, chromium, copper, nickel, lead and zinc) were detected at low to very low concentrations, significantly below ISQG-low trigger values (Figures 10.2a, 10.4a, 10.4c and 10.4e). In addition, the proportion of mud in the sediment samples was less than 10%, but noted to be increasing. The depth of oxygenated sediment (RPD) at the two Onepoto Inlet sites was in the “fair” category in 2009, which is likely to be reflected by a reduced abundance and diversity of benthic invertebrates (Robertson & Stevens, 2009). However, studies carried out in 2010 (Robertson & Stevens, 2010) indicated a reduction in the RPD to 1.0-2.0 cm which reflects a “fair-poor” oxygenation rating and may indicate that the invertebrate community may be in a transition state.

Subtidal sediment quality analyses (Cu, Pb, Zn, Cr, Co, Ni, Fe, Mn) were carried out by Glasby et al. (1990) (<20 µm fraction) at 42 sites within the Onepoto Inlet. The authors concluded that for lead the southern-most portion of the Onepoto Inlet was moderately to strongly contaminated, the central portion was moderately contaminated and the northern portion of the Onepoto Inlet was classed as uncontaminated to moderately contaminated.

A similar pattern was evident for zinc, with the sediment from the southern-most portion of the Onepoto Inlet moderately contaminated and the central and northern portion uncontaminated to moderately contaminated.

Milne *et al.* (2009) reported subtidal sediment copper (Figures 10.2a and 10.4a) and lead (Figures 10.2a and 10.4c) above ARC ERC amber concentration and zinc (Figures 10.2a and 10.4e) above ARC ERC red concentration for coarse sediment samples (<500µm fraction). However, only lead (Figure 10.4c) and zinc (Figure 10.4e) were above ARC ERC amber concentration for the fine sediment fraction (<63µm).

Ecological Values

Porirua Stream upstream of the mouth comprises of continuous channelized run of uniform depth with riparian margins clad with riprap and minimal riparian vegetation. Porirua Harbour estuary is already highly modified and has moderate estuarine values and provides limited habitat for invertebrates, fish and waterfowl. Inanga spawning habitat is negligible within the lower reaches of Porirua Stream (Taylor & Kelly, 2001). *Undaria pinnatifida*, the invasive seaweed, whilst a very minor feature of the macroalgal community overall, is present within and around the Mana Marina (Stevens and Robertson, 2008).

Saline Flora

Only 0.3% of the margins of the Onepoto Inlet contain saltmarsh (primarily *J. krausii* and *A similis*). This is due to limited suitable habitat due to historic reclamation and development along the coastal edge. Saltmarsh distribution in the harbour was mapped in 2007 (Stevens & Robertson, 2008) and is shown in Appendix 10F.

Seagrass (*Zostera muelleri*) enhances estuarine biodiversity by providing an important habitat for invertebrate organisms that fish and birds feed on, as stated above. Approximately 17.3ha of seagrass is present intertidally within the Onepoto Inlet (Stevens & Robertson, 2008), with the plants appearing lush and healthy. Intertidal seagrass distribution within the Porirua Harbour was mapped in 2007 and is shown Appendix 10F (Stevens & Robertson, 2008). Seagrass can grow in the subtidal fringes in New Zealand estuaries if sufficient light penetrates (Stevens & Robertson, 2008). However, no broad scale information on the distribution of seagrass subtidally was available.

Macroalgal cover on intertidal sediments within the Porirua Harbour was investigated by Stevens & Robertson (2008, 2009) and revealed some nuisance macroalgae in the Onepoto Inlet (around the Porirua Stream). Approximately 65% of the intertidal area within the Onepoto Inlet had macroalgae present at >5% cover. Macroalgae distribution intertidally has been mapped by Stevens & Robertson (2008) and is shown in Appendix 10F.

Invertebrates

The intertidal invertebrate assemblages around the stormwater outfall adjacent to Semple Street showed an increase in number of taxa with increasing distance from the outfall (Botherway & Gardner 2002). A significant difference in community structure was detected between samples collected at 5 m and 140 m from the outfall; the differences were with regards to species abundance rather than differences in the suite of species present. Of the 31 taxa and 7,527 individuals detected at both 5 m and 140 m from the outfall, polychaetes were the most abundant (71% of all individuals), followed by bivalves (16%), amphipods (5%) and oligochaetes (5%). The most dominant species within the polychaetes were *Scolecolepides benhami*, *Scolelepis* sp., *Capitella* sp., and *Arthritica bifurica* and *Austrovenus stutchburyi* within the bivalves. The number of taxa detected ranged approximately between six and 11, with the Shannon-Wiener Diversity Index predominantly between 1.2 and 1.7 (Botherway & Gardner, 2002) (see sampling locations in Figure 10.2d).

Robertson & Stevens (2009) noted that the intertidal benthic invertebrate community with the two sites studied in Onepoto Inlet had a biotic coefficient within the “good” range, but that there was an increasing abundance of organic enrichment tolerant species present compared to previous surveys, typical for the catchment land-use. Mean species richness per core was high at one site (22) and moderate at the other (13), and the taxa were dominated by polychaetes (50%) followed by bivalves, crustacea and gastropods. Similar results for species richness and diversity were detected by Robertson & Stevens in 2010. However, the authors note that the structure of the infaunal invertebrate community appeared to be different between 2008 and 2009 for one of the Onepoto Inlet sites and one of the Pauatahanui Inlet sites. The authors postulate that this difference in community structure was consistent with increases in mud content within the benthic sediment. However, they also note that the difference could equally be due to natural variation. Importantly, the invertebrate community at all four sites studied within the Porirua remains diverse containing species that are sensitive to elevated mud content (Robertson & Stevens, 2010) (see sampling locations in Figure 10.2d).

Stephenson & Mills (2006) reported the subtidal invertebrate community as being relatively stable based on diverse fauna, changes in faunal composition between 2004 and 2005 being restricted to uncommon species, and a trophic structure that is consistent with the nature of the sediments at the sites. Subtidal benthic invertebrates were dominated by polychaete worms (*Asychis* sp., *Heteromastus filiformis*), bivalves (*Arthritica crassiformis*, *Nucula hartvigiana*) and oligochaete worms. Species richness (13 to 15) and Shannon-Weiner Diversity Index (1.5 to 2.0) was relatively high, with an average of 24 taxa present at each site. An increase in the number of individuals per sample between 2004 and 2005 was recorded at all but one site (see sampling locations in Figure 10.2d).

Milne & Sorensen (2009) recorded 26 species of invertebrates subtidally within the Onepoto Inlet, with the most abundant organisms (across all samples collected within the wider Porirua Harbour) being crustaceans (64%), polychaete worms (25.1%) and bivalve molluscs (24.9%) (see sampling locations in Figure 10.2d).

Fish

As stated above, 43 species of fish have been detected in by Jones & Hadfield (1985) and Stevenson et al., (1987) (see sampling locations in Figures 10.2d and 10.2e). Of the fish species that use the Harbour at some stage, four at At Risk species (inanga, long-finned eel and lamprey (all declining) and pipefish (sparse, but secure overseas) (Allibone et al., 2010).

Avifauna

Due to the lack of suitable terrestrial edge habitat for shore bird species, the diversity of avifauna in the Onepoto Inlet is low. Black swans, gulls and other exotic species are common. More information is contained within Technical Report 8.

Summary of Ecological Values

The Onepoto Inlet has lower ecological values than the Pauatahanui Inlet, due to extensive coastal edge habitat modification and the surrounding industrial landuse activities. However, the Inlet supports moderate diversity invertebrates and fish communities.

3.1.4 Wainui Stream mouth

Very little information on the ecological values present at the Wainui stream mouth was found during the literature search. However, basic site and conservation value descriptions are summarised from Todd et al. (unpublished) below.

The catchment of the Wainui Stream is a mixture of pasture, scrub and exotic forest (MacDonald & Joy, 2009). Water quality is typically high, but may be compromised by runoff from the township of

Paekakariki, septic tank leachate from the motor camp located upstream of the estuary and agricultural runoff in the upper reaches of the stream (Todd et al., unpub).

The Wainui Stream forms a small tidal stream mouth estuary, which drains to Paekakariki Beach, which is a high energy, open sandy beach. A small lagoon is present behind the beach, which passes through coastal dunes. The stream mouth is occasionally blocked and there are large amounts of driftwood in the lower reaches of the estuary (Todd et al., unpub).

Saline Flora

A small area of saltmarsh wetland is present upstream, primarily comprising flax (*Phormium tenax*), tall fescue (*Schedonorus phoenix*), purua grass (*Bolboscheonus caldwellii*) three-square (*Schoenoplectus pungens*), kuawa (*Schoenoplectus tabernaemontani*), knobby clubrush (*Isolepis prolifera*) and giant umbrella sedge (*Cyperus ustulatus*). A number of terrestrial and aquatic weed species are present including kikuyu, gorse, tree lupid, boneseed, brush wattle, arum lily, water celery, monkey-musk, crack willow, marram and parrot's feather (Todd et al, unpub).

Fish

Migratory freshwater fish that use the estuary include longfin and shortfin eels, torrentfish, two species of bully, banded kokapu and giant kokapu (Greater Wellington, 2008; Todd et al., unpub).

Avifauna

Shore birds that have been observed at the stream mouth include black-backed gulls, variable oyster catchers, pied stilts, banded dotterels, spur wing plovers and other common species. It is likely that shore plovers, royal spoonbills, white-faced herons, black shags, mallards, pukeko and pipits also are occasionally present (Greater Wellington, 2008; Todd et al., unpub).

3.1.5 Whareroa Stream mouth

The beaches along the Kapiti Coast are long, wide and gently sloping (Stevens & Robertson, 2006). The tidal river mouth estuary of the Whareroa Stream is a modified ecosystem that discharges through a sandy beach to the high energy marine environment (see Plates 10.15-10.17 in Appendix 10C). The estuary is approximately 10-20 m wide and 1-2 m deep (Robertson & Stevens, 2007). The stream mouth is occasionally blocked and as such the mouth is artificially managed and there is a significant amount of drift wood present on the beach and within the lower reaches of the stream/estuary. A small saltmarsh wetland is present in the upper estuary and to the north there are relatively unmodified dunes. A retaining wall has been constructed adjacent to the south bank. Upstream of the dunes, the stream has been channelised and is considered highly modified (Todd et al., unpub).

Habitat diversity is considered to be moderate, given the significant saltmarsh vegetation, presence of weed species, channelised nature of the lower reaches of the stream and lack of tidal flats (Robertson & Stevens, 2007).

The catchment of the Whareroa Stream is primarily coastal farmland, comprising approximately 80% pasture and 20% scrub (MacDonald & Joy, 2009). Water quality is reported to be adversely affected by agricultural and road runoff (Todd et al., unpub). Robertson & Stevens (2007) note that the stream water is humic stained (see Plate 10.17 in Appendix 10C) with moderate concentrations of nutrients and *E. coli*. Water quality is considered to be significantly reduced when the mouth constricts or closes (Robertson & Stevens, 2007).

Saline Flora

The dunes on each side of the stream mouth contain vegetation that is representative of the original dune environment along this coast and as such are listed as a Priority One Recommended Area for Protection (Ravine, 1992). The saltmarsh wetland is dominated by tall fescue (*Schedonorus phoenix*), with knobby clubrush (*Isolepis nodosa*), clubrush (*Isolepis prolifera*), giant umbrella sedge (*Cyperus ustulatus*), wiwi (*Juncus edgariae*), purua grass (*Bolboschoenus caldwellii*), three-square (*Schoenoplectus pungens*), kuawa (*Schoenoplectus tabernaemontani*) and bachelors' button (*Cotua coronipifolia*) also present adjacent to the stream mouth. Weeds are prevalent in the wetland and lower reaches of the stream, including blackberry, brush wattle, gorse, kikuyu and water celery (Todd et al., unpub).

Invertebrates

Stevens & Robertson (2006) used the National Estuary Monitoring Protocol (Cawthron, 2002) approach to monitoring the ecological values at the Whareroa Stream mouth. They collected infaunal invertebrate samples at two locations; stream estuary and beach (see habitat map in Appendix 10G). Species richness was similar at the two locations (8 taxa detected at the upper shore site and 9 at the lower shore site). Estuarine/marine infaunal invertebrates detected were primarily amphipods and isopods, and some oligochaete and polychaete worms (Stevens & Robertson, 2006). These organisms are typically detected at exposed sandy beaches with mobile sediment. A number of freshwater and terrestrial organisms were also detected in the samples, and the authors state that this is likely due to the presence of standing water (Stevens & Robertson, 2006).

Fish

The migratory freshwater and estuarine fish that have been recorded in this habitat include longfin eel, giant kokapu, redfin bully, inanga, shortfin eel, banded kokapu, common bully, koaro, lamprey, yellow-eyed mullet, anchovy and smelt (Greater Wellington, 2008; Taylor & Kelly, 2001; Todd et al., unpub).

Avifauna

Birds known to use the Whareroa Stream mouth include banded dotterel, black-backed gull, mallard, pipit, pukeko, red-billed gull, royal spoonbill, shore plover, shovelers, spur wing plover, variable oystercatcher and white-faced heron.

Sediment Quality

Stevens & Robertson (2006) report that the sediment at the mouth of Whareroa Stream is dominated by sand (approximately 99%) and contains low concentrations of copper (2.7 mg/kg dw), lead (5.0 mg/kg dw) and zinc (22.0 mg/kg dw).

4. INFORMATION GAPS

The above literature review revealed a paucity of information on the intertidal invertebrate assemblages around the stream mouths entering into the Onepoto Inlet and the Pauatahanui Inlet. In addition, there was little sediment quality data at these specific sites. Beyond the stream mouths in the adjacent subtidal habitat and central subtidal basins, invertebrate assemblage and sediment quality data was also lacking. A lack of information on ecological values at the mouth of the Wainui Stream was also identified.

Consequently, the 2009/2010 intertidal and 2011 subtidal field investigations were designed to collect the necessary data to cover these aspects in relation to potential construction and operational phase stormwater discharges into Porirua Harbour (Onepoto and Pauatahanui Inlets) and the Tasman Sea (via Wainui Stream) from the proposed alignment. Benthic invertebrates (both infauna and epifauna) in particular were considered as an important component of both the intertidal and subtidal surveys as they are a group that could potentially be significantly affected by the discharge of sediment and associated contaminants.

5. METHODS

5.1 2009/2010 Intertidal Field Investigations

Intertidal estuarine sampling was carried out in accordance with the Estuarine Environmental Assessment and Monitoring National Protocol (Cawthron, 2002) within Porirua Harbour at the mouth of Duck Creek, Pauatahanui Stream, Rations Stream, Horokiri Stream, Kakaho Stream and Porirua Stream (see Figures 10.2d and 10.2e), and at the mouth of Wainui Stream (Figure 10.2f). Sampling and assessment of the sites within Porirua Harbour were undertaken between 9th and 12th November 2009, whereas Wainui Stream mouth was investigated on 8th December 2010.

Whareroa Stream discharges to a similar receiving environment as the Wainui Stream i.e. high energy open sandy beach. Whareroa Stream mouth is one of Greater Wellington Regional Council's ecological monitoring sites. As robust recent data was readily available, additional data was not required to be collected for this site.

Sampling focused on stream mouth within the intertidal habitat as the primary effect of construction and operation of the Project is the discharge of stormwater to streams which ultimately discharge into the marine environment. Initial discussions with SKM revealed that sediment laden water discharged via the streams may, in the estuarine habitats, result in deposition of sediment around stream mouths and subtidally.

Whareroa and Wainui Streams discharge to a high energy open coast environment, and are unlikely to retain sediment. However, if sediment was deposited at the mouths of these streams, it would most likely occur at/adjacent to the stream mouth.

Kakaho Stream mouth was sampled as a control site, as no construction or operational phase stormwater from the Project is discharged to this stream. An additional control site (Browns Stream mouth) has been included in the adaptive monitoring plan which will be sampled prior to construction.

5.1.1 Intertidal sampling design

At each location a 50 m x 30 m grid (subdivided into 10 15 m x 10 m smaller grids, identified as A to J) was established using GIS prior to entering the field. The 10 smaller grids (A to J) were then subdivided into six 5 m x 5 m grids (identified as 1 to 6). Sampling was undertaken at one of the randomly selected 5 m x 5 m grids (1 to 6) within each 15 m x 10 m grid (A to J) (see Figure 10.5). The following analyses were undertaken for each of these smallest grids:

- A core sediment sample (15 cm deep x 13 cm diameter) was collected for infaunal invertebrate analysis. The core of sediment was sieved through a 0.5 mm mesh and the retained material preserved using 60% ETOH. Cawthron Institute invertebrate experts processed the samples, extracting and identifying the macrofauna present.

- A 0.50 m x 0.50 m quadrat was used to sample epifauna and macroalgae (quadrats were photographed). All organisms occurring within the quadrats were identified to species level and enumerated. Macroalgal cover was estimated on the basis that a 5 x 5 cm area equates to 1 % cover. Crab/worm holes at the sediment surface were also counted.
- A redox discontinuity layer (RDL) sample was collected using a 60 mm diameter cylinder (to a depth of 8 cm to 10 cm)
- A surface sediment (top 2-3 cm) sample was collected for contaminant and nutrient analyses and sediment grain size analyses. Two composite sediment samples were collected. The sediment samples from grids A to E were combined to form a single composite sample, as were samples from F to J. These two composite samples were each divided in half, with one half of each composite sample being sent to Hill Laboratories for analysis of total copper, lead, zinc, polycyclic aromatic hydrocarbons, total nitrogen and total phosphorus (see Appendix 10A for analysis methodologies) in the <2 mm fraction and the other half being sent to Cawthron Institute for sediment grain size analyses (using wet sieve methodology).

NB: Around the mouth of Duck Creek, the intertidal habitat was found to be too narrow to accommodate the 50 m x 30 m sampling grid, therefore sampling at this site was limited to six 15 m x 10 m sub-grids, with only one composite sediment sample collected.

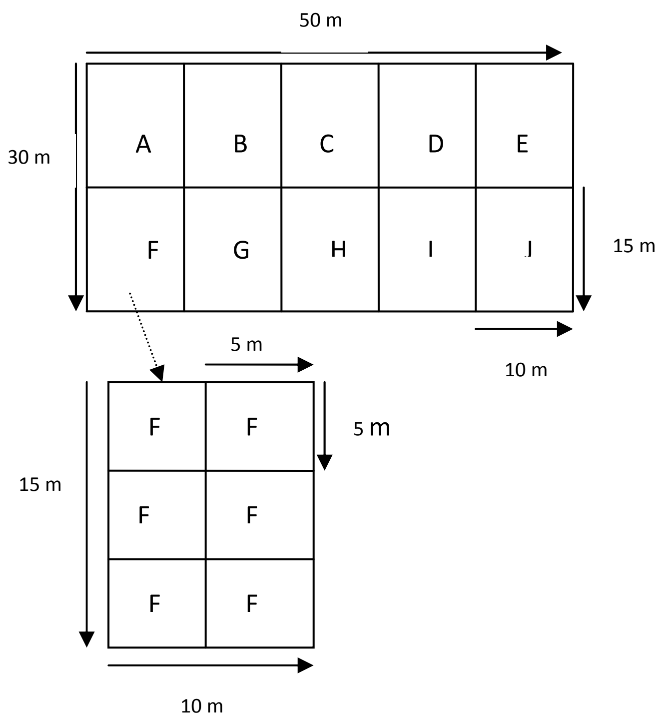


Figure 10.5: Schematic showing benthic experimental design.

5.1.2 Statistical Analyses

Data were plotted to determine the presence of outliers, and then initially analysed using basic descriptive statistics such as averages and proportions. Invertebrate community composition data was further analysed using multivariate analyses (Primer-v6 software). Individual invertebrate core samples that contained zero organisms were removed from the data set and the remaining samples were analysed using an ordination technique called non-metric multidimensional scaling (MDS). Data were transformed using fourth root transformation and similarity analysed using Bray Curtis similarity co-efficients. The resultant MDS was plotted in two-dimension (with robust 2D stress values i.e. less than 0.2) overlaid with similarity groupings (20%, 30%, 40%) based on a cluster analysis.

5.2 2011 Subtidal Field Investigations

A total of 12 sites within Porirua Harbour were sampled on 16th December 2010 (Figure 10.3) comprising eight sites within the Pauatahanui Inlet (sites P1 to P8, Figures 10.2a and 10.2b) and four sites within the Onepoto Inlet (sites O1 to O4, Figures 10.2a and 10.2b). Sampling was undertaken ± two hours of low tide (low tide (LT) was approximately 12:21 pm) using a SeaDoo Jet Ski in order to move efficiently among shallow-water subtidal sites. At each site replicate quadrats were sampled to assess epifaunal abundance and diversity and replicate core samples were obtained to assess infaunal abundance and diversity. Samples were also obtained for sediment grain size and sediment contaminant analysis. Sample acquisition generally followed that described in Robertson *et al*. (2002) for surveying estuarine environments within New Zealand. All sampling was done via SCUBA or snorkelling.

- At each sampling site a general assessment of the area was made focusing on the nature of the surficial sediment type(s), with each site given a classification rank based on habitat complexity in accordance with Table 10.1.
- The primary biological habitat occurring at each site was evaluated and given a classification number in accordance with Table 10.2. Classification rankings were made at the time of sampling.
- To assess infaunal abundance and diversity three sediment cores (haphazardly placed) were collected from each site using 13 cm diameter × 10 cm deep PVC tubes. Each tube had a tapered leading edge to facilitate penetration, with the top end capped. The cap had a small hole (10 mm diameter) to allow water to escape as the tube was driven into the sediment. Sediment cores were processed and preserved as per that described above for the intertidal sampling.
- To provide information on epifaunal abundance and macroalgal percent cover, three haphazardly placed 0.25 m^2 quadrats were sampled at each site, approximately 0.5 m from where cores were taken. Data was collected as that described above for intertidal epifauna and macroalgae. Crab/worm holes at the sediment surface were counted where possible (visibility was limited to <0.25 m).
- Seagrass (*Zostera* sp.) cover was estimated using the cover classes presented in Schwarz *et al*. (2006).
- Using a modified garden trowel, three replicate samples were scraped from the top 2 cm to 3 cm of the sediment surface approximately 0.5 m to 1 m distance from the location of the infauna cores. Samples were processed and analysed for grain size and contaminants in an identical manner to the intertidal sediment samples.
- To assess the sediment anoxic layer at each site, one clear plastic graduated cylinder 5.8 cm diameter was driven into the sediment to a depth of 15 mm. The cylinder was then removed and the origin (depth) of the sediment anoxic layer (generally visible as a dark black (anoxic) zone, relative to lighter oxygenated sediment) measured.
- To obtain a depth measurement at each site, a fibreglass tape measure (15 m length) with a dive weight attached was deployed from a vessel to the substratum. Care was taken to ensure that the tape maintained a vertical alignment, with the distance between the substratum and sea surface measured. These measurements were then corrected to Lowest Astronomical Tide (LAT). The sea state during sampling was very calm on the day of sampling.

Table 10.1: Complexity ranks for physical subtidal habitats.

Complexity Scale Rank	Habitat Type
1	Fine mud
1.25	Fine mud with patches of silty sand, often with burrows or depressions
1.5	Silty sand, often with burrows or depressions
1.75	Sand, often with burrows or depressions
2	Sand and shell hash, often with burrows or depressions
2.25	Shell hash
2.5	Sand with small areas of pebbles, cobbles or rocks
2.75	Rocks or cobbles inundated with sand
3.0	Bare rock and cobble reef
3.25	Rock and cobble reef. Low-to-moderate turf, sessile invertebrate and macroalgal cover
3.5	Low lying platform reef. Low-to-moderate turf, sessile invertebrate and macroalgal cover
3.75	Low lying platform and cobble reef. Moderate-to-high turf sessile invertebrate and macroalgal cover
4.0	Small to moderate boulder reef. High turf, sessile invertebrate and macroalgal cover
4.25	Moderate to large boulder reef. High turf, sessile invertebrate and macroalgal cover
4.5	Large platform reef. High turf, sessile invertebrate and macroalgal cover
4.75	Mixed boulder and platform reef. High turf, sessile invertebrate and macroalgal cover
5.0	Complex boulder and platform reef complexes characterised by large walls, rocky overhangs and caves. High turf, sessile invertebrate and macroalgal cover

5.2.1 Statistical Analyses

Data were analysed in an identical manner to that described for intertidal invertebrate assemblages above.

Table 10.2: Classification scheme for intertidal and subtidal biological habitat types.

(Based on a synthesis of information from Morton and Miller (1968), Cummings et al. (2002), Gibbs and Hewitt (2004), Ford et al. (2004), Hewitt and Funnel (2005). NB: Intertidal biological habitats have been included as some of these may be sampled during the survey).

Habitat number	Biological habitat/community	Typical zonation / depth range (m)	Description
1	Adult tuatua beds (*Paphies subtriangulata*)	Mouth of estuary	Areas dominated by high abundances of the surf clam *Paphies subtriangulata*; common at the mouth of harbours and in areas of high tidal current.
2	Adult pipi beds (*Paphies australis*)	Mouth to mid-reaches of estuary	Areas dominated by high abundances of *Paphies australis*, common in areas of high current in sand and silty sand.
3	Adult cockle beds (*Austrovenus stutchburyi*)	Mid reaches of estuary	*Austrovenus stutchburyi* common in mud and sandflats forming high-density monospecific beds, but may also co-occur with *Macomona liliana* and *Nucula hartvigiana* at lower densities.
4	Adult wedge shell beds (*Macomona liliana*)	Mid reaches of estuary	Common in silty sand and mudflats at mid-tide forming high-density monospecific beds, but also co-occurs with *Austrovenus stutchburyi* and *Nucula hartvigiana*.
5	*Austrovenus stutchburyi* /*Macomona liliana* association	Mid- to upper- reaches of estuary	Association of adult *Austrovenus stutchburyi* and *Macomona liliana*; individuals generally smaller than those found in monospecific beds.
6	Adult nut shell beds (*Nucula hartvigiana*)	Mid- to upper- reaches of estuary	Common in mudflat areas of estuaries.
7	Mussel beds	Variable	*Perna canaliculus* beds are commonly found in estuaries on subtidal and intertidal rocky reef substratum in areas of high current (e.g., main channels).
8	Adult horse mussel beds (*Atrina zelandica*)	Mouth of estuary and areas of high current	*Atrina zelandica* occurs in beds with sponges and ascidians. *Atrina* are adults, often patchily distributed, beds are tens of meters in size.
9	*Zeacumantus* / *Amphibola* / *Helice / Alpheus* association	Mid- to upper- reaches of estuary	Common faunal association within mudflat and silty sand areas in upper reaches of estuaries and around mangrove habitat. Conspicuous taxa include gastropods *Zeacumantus lutulentus, Amphibola crenata* and crustaceans *Helice crassa* and *Alpheus* sp.
10	Polychaete dominated	Mouth to upper-reaches of estuary	Polychaete dominated communities, common across harbour from mouth to upper reaches. Taxa distribution and abundance change in accordance with increasing muddiness.
11	Intertidal rocky reef habitat	Variable	Intertidal rocky reef habitat, characterised by compressed zonation compared to that of open coasts. Main zones include Barnacle zone; Oyster/mussel zone; Coralline algae and *Hormosira* zone; and mixed algal zone (fucalean dominated).
12	Shallow macroalgal dominated subtidal rocky reef	Variable	Shallow subtidal macroalgal zone, often dominated by *Carpophyllum flexuosum*.
13	Seagrass intertidal	Variable	Patches and/or meadows of intertidal seagrass *Zostera capricorni*
14	Seagrass subtidal	1-8 m depth	Patches and/or meadows of *Zostera capricorni*; occurs in shallow subtidal.
15	Serpulid calcareous tube worms	Intertidal to shallow subtidal	Most commonly represented by *Spirobranchus cariniferus* found on the soft sediments of harbour flats on isolated stones and dead shell.

5.3 Assessment of Ecological Value

Marine ecological values are described in this report as being low, moderate or high. Table 10.3 lists the characteristics which have been used to assess the predominant ecological values of parts of the marine environment within the project area, based on a weight of evidence approach. Not all characteristics listed within each ecological value category need to be present in order to assess ecological value. Consideration of low, moderate and high benthic invertebrate species richness and diversity is based on expert judgment and experience.

Table 10.3: Characteristics of estuarine site with low, moderate and high ecological values.

ECOLOGICAL VALUE	CHARACTERISTICS
LOW	• Benthic invertebrate community degraded with low species richness and diversity. • Benthic invertebrate community dominated by organic enrichment tolerant and mud tolerant organisms with few/no sensitive taxa present. • Marine sediments dominated by smaller grain sizes. • Shallow depth of oxygenated surface sediment. • Elevated contaminant concentrations in surface sediment, above ISQG-high or ARC-red effects threshold concentrations[2]. • Invasive, opportunistic and disturbance tolerant species dominant. • Minimal habitat and feeding areas for fish and birds present. • Seagrass beds not present. • Saltmarsh habitat disconnected, absent or highly modified. • Habitat highly modified.
MODERATE	• Benthic invertebrate community typically has moderate species richness and diversity. • Benthic invertebrate community has both (organic enrichment and mud) tolerant and sensitive taxa present. • Marine sediments typically comprise approximately 50-70% smaller grain sizes. • Depth of oxygenated surface sediment typically >0.5 cm. • Contaminant concentrations in surface sediment generally below ISQG-high or ARC-red effects threshold concentrations. • Few invasive opportunistic and disturbance tolerant species present. • Habitats and feeding areas for birds and fish present but modified or small. • Seagrass areas patchy or small. • Connects to saltmarsh habitat limited or modified. • Habitat modification limited.
HIGH	• Benthic invertebrate community typically highly diverse with high species richness. • Benthic invertebrate community contains many taxa that are sensitive to organic enrichment and mud. • Marine sediments typically comprise <50% smaller grain sizes. • Depth of oxygenated surface sediment typically >1.0 cm. • Contaminant concentrations in surface sediment rarely exceed low effects threshold concentrations. • Habitats and feeding areas for birds and fish present and largely unmodified. • Keystone species present (e.g. significant cockle beds). • Seagrass beds present. • Natural connections to saltmarsh habitat present. • Habitat largely unmodified.

[2] 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).

6. RESULTS

Photos of each of the sites sampled and representative intertidal benthic sediment are provided in Appendix 10C.

6.1 Sediment Quality

6.1.1 Sediment Grain Size

Intertidal Sediment Grain Size

The proportion of silt and clay varied among the sites sampled (Figure 10.6, Table 10.4), with Horokiri sediment having the highest proportion (>30%) and Pauatahanui having the lowest (>5%) within Porirua Harbour. Silt was not detected at the Wainui Stream site. Overall sediment composition patterns at Porirua Harbour sites showed that Rations, Porirua and Horokiri sites were dominated by the finest three sediment grain fractions; Kakaho and Duck sediment comprised more than 50% gravel; and Pauatahanui sediment was dominated by fine and medium sand grain sizes. Wainui Stream mouth was dominated by fine sand (>85%).

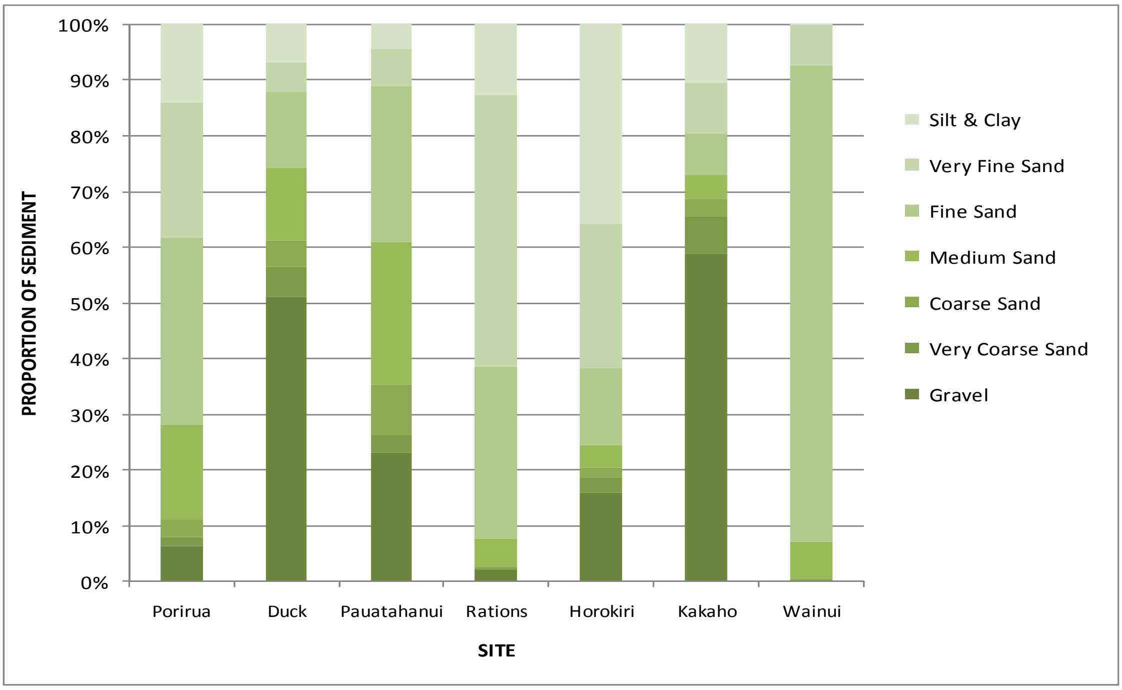


Figure 10.6: Intertidal surface sediment grain size composition.

Table 10.4: Mean intertidal surface sediment grain size.

	Gravel	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt & clay
	>2mm	<2mm & >1mm	<1mm & >500µm	<500µm & >250µm	<250µm & >125µm	<125µm & >63µm	<63µm
Porirua	6	2	3	17	34	24	14
Duck	51	5	5	13	14	6	7
Pauatahanui	23	3	9	25	28	7	4
Rations	2	0	0	5	31	49	13
Horokiri	16	3	2	4	14	26	36
Kakaho	59	7	3	4	8	9	11
Wainui	0	0	1	7	86	7	0

Subtidal Sediment Grain Size

The grain size characteristics varied significantly across all sites and within each inlet (Figure 10.7, Table 10.5). Sites that had the lowest proportion of silt and clay in surficial sediment included P1, P5, P7, O2, O3 and O4 (see Figures 10.2a and 10.2b for sampling site locations). Within the Pauatahanui Inlet, the least muddy sites were located adjacent to Horokiri and Pauatahanui Streams, and the muddiest site was detected in the centre of the Inlet (P6). Of the four sites studied in the Onepoto Inlet, O1 (located adjacent to the mouth of the Porirua Stream) had high mud content, where the two sites located to the west of O1 had a higher proportion of large grain sizes, which was similar to O4, located some distance to the north of O1 (Figure 10.7, Table 10.5).

Subtidal surficial sediment overall had a higher proportion of silt and clay, compared to intertidal sites studied.

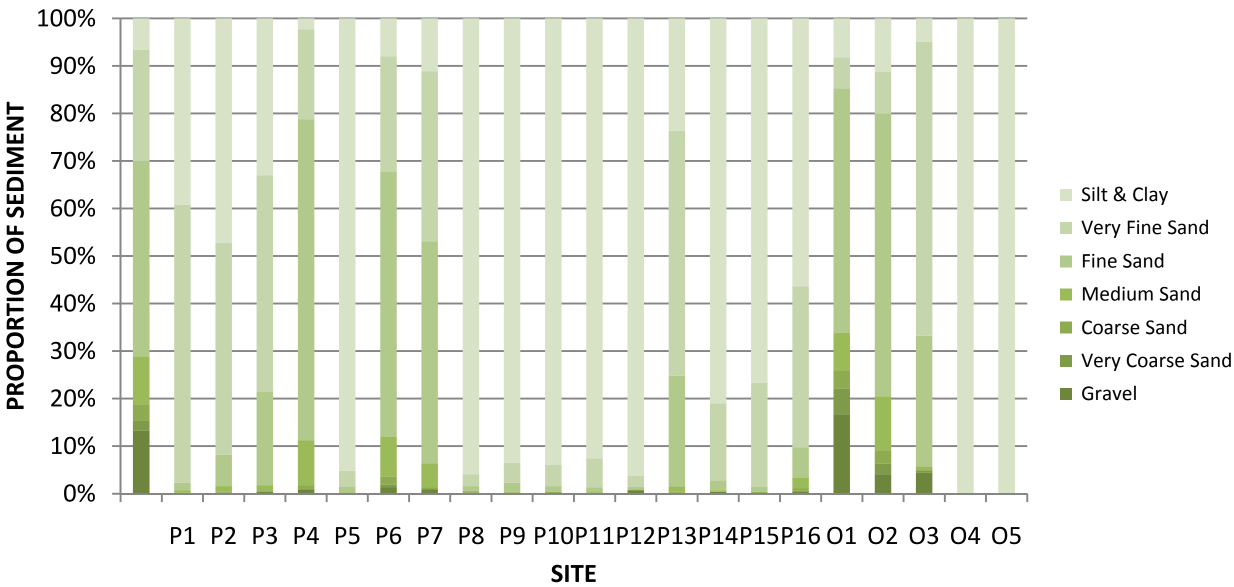


Figure 10.7: Subtidal surface sediment grain size composition.

Table 10.5: Mean subtidal surface sediment grain size.

	Gravel	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt & clay
	>2mm	<2mm & >1mm	<1mm & >500µm	<500µm & >250µm	<250µm & >125µm	<125µm & >63µm	<63µm
P1	13.2	2.1	3.5	10.1	41.1	23.4	6.6
P2	0	0.1	0.1	0.5	1.6	58.5	39.2
P3	0.20	0	0.2	1.2	6.6	44.6	47.2
P4	0.4	0.1	0.2	1.1	19.6	45.6	33
P5	0.8	0.2	0.8	9.4	67.6	18.9	2.3
P6	0	0	0.1	0.2	1.2	3.3	95.2
P7	1.3	0.6	1.7	8.4	55.7	24.3	8
P8	0.9	0	0.4	5.1	46.7	35.8	11.1
P9	0.2	0.1	0.2	0.1	1	2.5	95.9
P10	0	0.1	0.1	0.2	1.9	4.2	93.5
P11	0	0.3	0.1	0.1	1.1	4.5	93.9
P12	0.1	0.1	0.1	0.2	0.8	6.1	92.6
P13	0.7	0	0.1	0.1	0.5	2.4	96.2
P14	0.1	0.1	0.2	1.1	23.3	51.5	23.7
P15	0.4	0	0.1	0.2	2.1	16.2	81.0
P16	0.1	0.2	0.1	0.1	0.9	21.9	76.7
O1	0.4	0.2	0.5	2.3	6.3	33.9	56.4
O2	16.7	5.4	3.8	8	51.4	6.5	8.2
O3	4.1	2.2	2.8	11.4	59.4	8.9	11.2
O4	4.4	0.4	0.3	0.6	27.5	61.9	4.9
O5	11.9	0.5	1.5	19.3	5.1	7.5	8.3
O6	0.3	0.1	0.2	0.4	1.8	7.1	90.1

6.1.2 Sediment Contaminants

Intertidal Sediment Contaminants

In order to build a more comprehensive understanding of the quality of the primary marine receiving environment (i.e. Porirua Harbour), the contaminant data collected from this study (Table 6) has been mapped with data from the existing literature (Figures 10.4a to 10.4n). Data has been categorised based on the ARC's ERC or ANZECC's ISQG (see Appendix 10A).

Analysis of common stormwater metals (Figures 2a-c and 4a-4f) and HMW-PAHs (Table 6, Figures 10.2a to 10.2c and Figures 10.4g to 10.4h) indicated that concentrations at all intertidal sites sampled were significantly below low effects thresholds, except for zinc in sediment from Porirua (Table 10.6, Figure 10.4e) which exceeded the ARC ERC green threshold, but was below the ISQG-Low (Table 10.6).

The concentration of phosphorus in sediment ranged between 130–345 mg/kg, with the highest concentration detected at Kakaho Stream mouth and the lowest at Ration Stream mouth. Concentrations at Duck Creek, Horokiri and Porirua Streams were similar (Table 6). According to the phosphorus rating developed by Robertson & Stevens (2010), this places all sites in the "good to very good" range. The concentration of phosphorus at Pauatahanui and Rations was similar to that detected by Robertson & Stevens (2010), whereas the remaining sites had higher concentrations.

The highest nitrogen concentration was recorded at Horokiri Stream (though only slightly higher than at Porirua), and the lowest at Pauatahanui Stream. Similarly moderate nitrogen concentrations were recorded at Duck Creek, Kakaho and Ration streams (Table 10.6). Based on the total nitrogen rating (Robertson & Stevens, 2010), all sites are within the "good" range, but all sites had higher nitrogen concentration than the sites studied by Robertson & Stevens (2010) apart from Wainui Stream.

Table 10.6: Intertidal sediment quality data.

	Kakaho	Pauatahanui	Duck	Horokiri	Porirua	Rations	Wainui	ARC ERC Green	ISQG Low
Copper (mg/kg dry wt)	8.2	2.3	5.4	6.4	9.3	4.6	3.6	<19.0	65.0
Lead (mg/kg dry wt)	11.0	5.0	9.3	10.3	20.0	3.5	4.2	<30.0	50.0
Zinc (mg/kg dry wt)	56.5	26.0	59.0	51.5	155.0	19.0	24.0	<124.0	200.0
HMW PAHs (mg/kg dry wt)	0.01	0.03	0.10	0.02	0.40	0.01	0.01	<0.66	1.70
Phosphorus (mg/kg dry wt)	345.00	155.00	260.00	295.00	260.00	130.00	280.00	-	-
Nitrogen (mg/kg dry wt)	1025.0	755.00	980.00	1350.0	1200.0	980.00	25.00	-	-

In general, common stormwater contaminants (copper, lead, zinc and HMW-PAHs) were typically detected in lower concentrations in sediment from the Pauatahanui Inlet compared to the Onepoto Inlet, whereas mercury, dieldrin and total DDT were detected in elevated concentrations in both inlets, reflecting to some extent the historic and present rural landuse practices in these catchments.

Subtidal Sediment Contaminants

In order to build a more comprehensive understanding of the quality of the primary marine receiving environment (i.e. Porirua Harbour), the contaminant data collected from this study (Tables 10.7 and 10.8) has been mapped with data from the existing literature (Figures 10.4a to 10.4n). Data has been categorised based on the ARC's ERC or ANZECC's ISQG (see Appendix 10A).

Contaminant concentrations in subtidal surficial sediment collected as part of this Transmission Gully Project from sites within the Pauatahanui Inlet and the Onepoto Inlet were approximately >50% of the ARC ERC green threshold (ARC, 2004) at most sites (Table 10.7). Sites P9 to P13 had higher concentrations of metals compared to the other sites within the Pauatahanui Inlet, with concentrations approximately 70% of the ARC ERC green threshold.

Site O1, which is located adjacent to the mouth of the Porirua Stream, had elevated zinc and lead (Table 10.8). The concentration of copper in sediment from site O1 was detected at a concentration approaching the ARC ERC green threshold (Table 10.8, Figures 10.2a and 10.4a), whereas lead was detected at threshold concentration (placing it in the amber zone) (Table 10.8, Figures 10.2a and 10.4c), and zinc was detected above the ARC ERC red threshold concentration of 150 mg/kg dry weight and approaching the ANZECC ISQG Low of 200 mg/kg dry weight (Table 10.8, Figures 10.2a and 10.4e). The concentration of contaminants was higher at the more centrally located sites (O5 and O6) compared to near shore sites (O1 to O4).

In general contaminant concentrations in sediment are low in the Pauatahanui Inlet (Table 10.7), and whilst only detected above effects threshold concentrations at one site in the Onepoto Inlet (Table 10.8), it is likely, given the surrounding catchment landuse, that other hotspots may be present in more quiescent areas of the subtidal environment.

Table 10.7: Pautahanui subtidal sediment quality data.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	ARC ERC Green	ISQG Low
Copper (mg/kg dry wt)	4.5	5.0	5.1	1.4	1.4	9.9	2.3	4.0	12.0	12.0	12.0	12.0	12.0	6.0	9.0	9.0	<19.0	65.0
Lead (mg/kg dry wt)	7.9	10.6	11.2	3.9	3.9	18.5	5.3	9.5	21.0	22.0	21.0	22.0	22.0	10.4	17.8	17.1	<30.0	50.0
Zinc (mg/kg dry wt)	42.0	44.0	43.0	16.1	15.8	68.0	23.0	39.0	80.0	81.0	81.0	81.0	84.0	53.0	72.0	67.0	<124.0	200.0
HMW PAHs (mg/kg dry wt)	0.03	0.03	0.02	0.06	0.04	0.04	0.03	0.03	0	0.1	0	0	0.10	0.10	0	0	<0.66	1.70

Table 10.8: Onepoto subtidal sediment quality data.

	O1	O2	O3	O4	O5	O6	ARC ERC Green	ISQG Low
Copper (mg/kg dry wt)	18.1	4.8	5.7	3.8	6.0	11.0	<19.0	65.0
Lead (mg/kg dry wt)	30.0	12.4	14.1	6.1	16.3	21.0	<30.0	50.0
Zinc (mg/kg dry wt)	192.0	67.0	63.0	39.0	103.0	81.0	<124.0	200.0
HMW PAHs (mg/kg dry wt)	0.14	0.00	0.06	0.04	0.15	0.03	<0.66	1.70

The following sections (6.1.3 to 6.1.7) are a discussion of the contaminant data sourced from literature in addition to that collected for this project.

6.1.3 Copper

The concentration of copper varied within the Onepoto Inlet (Figure 10.4a), with low concentrations (below effects thresholds) at the mouth of the Porirua Stream (and a short distance upstream), in fine subtidal sediment adjacent to the mouth of the Onepoto Stream and near the mouth of the Onepoto Inlet. Low effects threshold concentrations were detected in total sediment samples collected from two central subtidal sites and a short distance upstream within the Porirua Stream and the Onepoto Stream. Sediment samples collected in 2011 from adjacent to the Porirua Stream mouth indicated copper concentrations approaching ERC-green threshold concentration. Sediment from two sites had concentrations above the ERC-red threshold concentration, one located central subtidally and one adjacent to a stormwater drain discharge point 200 m to the west of the mouth of the Porirua Stream.

All samples collected from the Pauatahanui Inlet were below low effects thresholds (Figures 10.4a to 10.4n), apart from one central subtidal sample which had copper concentration in the ERC-amber range (Figure 10.4b).

6.1.4 Lead

In general lead showed a similar pattern to copper in the Onepoto Inlet (Figure 10.4c), though with more sites having concentrations in the ERC-amber and ERC-red range. Several sampling sites around the mouth of Porirua Stream, an upstream site, a site adjacent to the Onepoto Stream mouth and a site near the mouth of the Onepoto Inlet had lead below effects threshold concentrations. ERC-amber concentrations were detected also at the mouth of Porirua Stream (including the 2011 subtidal sample), upstream within Porirua Stream, at two central subtidal sites and at the mouth of the Onepoto Stream. The two sites that exceeded the ERC-red threshold for copper also exceeded the ERC-red concentration for lead.

Only the central subtidal site within the Pauatahanui Inlet exceeded the ERC-amber effects threshold concentration (Figure 10.4d), with lead at all the remaining sites detected below effects threshold concentrations.

6.1.5 Zinc

Zinc was detected at above ERC-amber or ERC-red effects threshold concentrations at most sites within the Onepoto Inlet (Figure 4e), with only three sites having concentrations below effects threshold concentrations (near the mouth of Porirua Stream and Onepoto Stream and the mouth of the Onepoto Inlet). Sediment samples collected subtidally adjacent to the Porirua Stream mouth had zinc concentrations above ARC ERC Red threshold concentration and approaching the ANZECC ISQG concentration.

Only the one central subtidal site in the Pauatahanui Inlet had a concentration above ERC-amber threshold (Figure 10.4f).

6.1.6 HMW-PAHs

HMW PAHs were detected at either below effects thresholds or above the ERC-amber threshold at almost all of the intertidal sampling sites in the Onepoto Inlet (Figure 10.4g). The two central subtidal sites and one site at the mouth of the Onepoto Stream had concentrations above the ERC-red threshold concentration. Subtidal samples collected in 2011 revealed low concentrations in surficial sediment.

The same pattern was evident in the Pauatahanui Inlet, with intertidal sites below effects thresholds or above the ERC-amber threshold, whereas three subtidal sites had HMW-PAH concentration above ERC-red thresholds (Figure 10.4h). Subtidal samples collected in 2011 revealed low concentrations in surficial sediment.

6.1.7 Other non-roading related contaminants

Total DDT showed a similar pattern to mercury, with ISQG low threshold concentration exceeded throughout both inlets (Figures 10.4i and 10.4j), although at a small number of sites the concentration was below detection limit.

Dieldrin was detected above the ISQG-low threshold concentration at the mouth of Porirua and Onepoto Streams, subtidally within the Onepoto Inlet and subtidally within the Pauatahanui Inlet (Figures 10.4k and 10.4l).

Mercury was detected above the ISQG low threshold concentration throughout the Onepoto Inlet and at all but one site within the Pauatahanui Inlet (Figures 10.4n and 10.4m).

6.2 Marine Invertebrates

6.2.1 Intertidal Sediment Surface Features and Epifauna

Benthic sediment differed among stream mouth sites: Kakaho Stream (Plates 10.1 and 10.2, Appendix 10C) and Duck Creek (Plates 10.3 and 10.4, Appendix 10C) were characterised by gravelly sand; Pauatahanui Stream was characterised by sandy cockle shellbanks (Plates 10.5 and 10.6, Appendix 10C); Horokiri Stream comprised sandflats (Plates 10.7 and 10.8, Appendix 3); and Ration (Plates 10.9 and 10.10, Appendix 10C) and Porirua Stream (Plates 10.11 and 10.12, Appendix 10C) mouths were characterised by patchy sandflats and mudflats. In contrast, Wainui Stream discharges to a sandy, exposed, high energy beach (Plates 10.13 and 10.14, Appendix 10C).

The abundance of epifaunal invertebrates varied significantly among quadrats both within and between sample sites. Duck Creek had the highest average abundance of individuals (approximately 250 per $0.25m^2$), while Porirua Stream had the lowest (less than five per $0.25m^2$) (see Figure 10.8). The variability in the number of individuals among quadrats was high at Duck Creek, due to the patchy nature of the intertidal benthic habitat. No epifaunal invertebrates were detected at the mouth of the Wainui Stream.

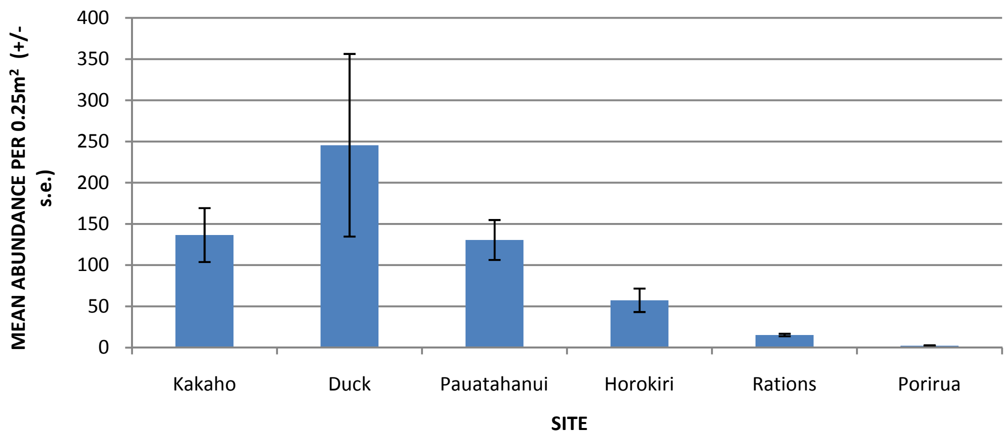


Figure 10.8: Mean abundance of intertidal epifaunal marine invertebrates.

The dominant taxa at Duck Creek were barnacles and a small limpet (*Notoacmea* sp.) that were present on cobbles and shell material. The Kakaho Stream site was dominated by *Notoacmea* sp., gastropods (*Diloma* sp., *Cominella glandiformis*, *Zeacumantus* sp.). Pauatahanui and Horokiri Stream mouths similarly were dominated by *Zeacumantus* sp., *Diloma* sp., *Notoacmea* sp., in addition to barnacles at Pauatahanui Stream and mud crabs at Horokiri Stream. Epifauna from Ration Stream mouth was dominated by mud crabs and the occasional tube worm, whereas Porirua Stream mouth had very low numbers of the estuarine snail *Potamapyrgus* sp.

Whilst the number of individuals was highest at Duck Creek, Horokiri Stream had the highest mean number of species (approximately four per quadrat) and Porirua Stream had the lowest (an average of less than one species per quadrat) (see Figure 10.9).

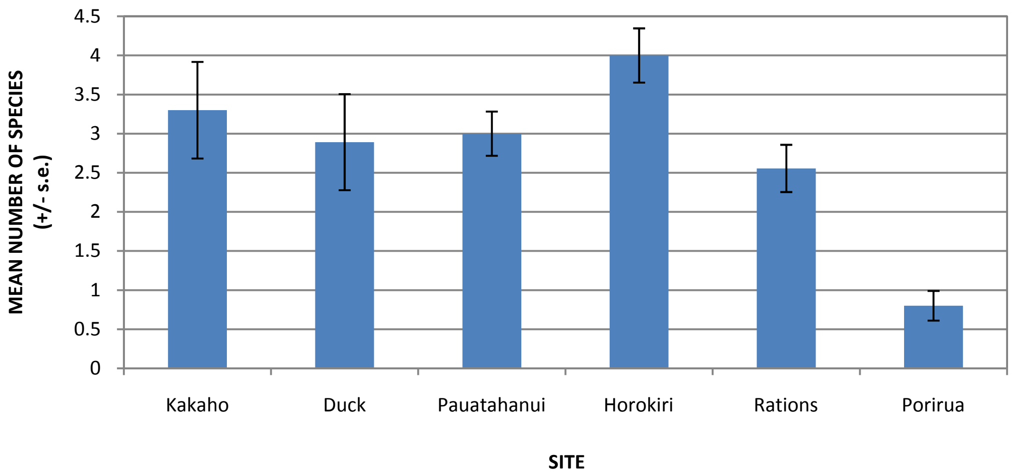


Figure 10.9: Mean number of intertidal epifaunal invertebrate species.

The depth of surficial oxygenated sediment (RDL) was approximately 1 cm to 2 cm for most sampled sites, which is classified as 'fair' according to the scale developed by Robertson & Stevens (2009). At sites where gravel was a dominant portion of the sediment (e.g. Kakaho and Duck Streams; Figure 10.6), it was difficult to collect a core sample for this test. None of the sites sampled throughout the Porirua Harbour had very poor oxygenation of the surface sediment. Anoxic sediment was not detected at Wainui Stream mouth.

Surface macroalgae was present at all sites apart from Ration Stream. Duck Creek had an average of 18% cover within the 0.25 m^2 quadrats (predominantly *Enteromorpha* sp.), Horokiri 14% (mostly *Ulva* sp.), Pauatahanui 6% (predominantly *Enteromorpha* sp.), Kakaho 4% (a combination of *Ulva* sp. and *Gracilaria* sp.) and Porirua <2% (algal genus unidentified). As would be expected at an exposed sandy beach, no surface macroalgae was detected at Wainui Stream mouth.

6.2.2 Subtidal Sediment Surface Features and Epifauna

Summary results are presented below for surficial sediment types, dominant epifauna and macroalgae, followed by a more-detailed description of these aspects at a site-specific level. Table 10.9 provides a summary of the main components examined and habitat rankings as per Tables 10.1 and 10.2.

<u>Depth, surficial sediment types and habitat complexity</u>

The subtidal sites located near the stream mouths were extremely shallow. Sites P1, P3, P4, P5, P7, P8, O1, O2, O3 and O4 were all < 0.5 m depth with sites P2 and P6 > 1 m depth. Sites located more centrally were deeper but still relatively shallow. Depth at sites P9 to P16 ranged between 1.6m and 2.5m, and depth at sites O5 and O6 was less than 2 m. Depths corresponded well with the 2009 bathymetric survey of the harbour.

The nature of the surficial sediment varied in accordance with location. For shallow sites (< 1m depth) east of Ration Point in the Pauatahanui Inlet (P1, P5 and P7), the surficial sediment was predominantly firm sand with very small (< 0.25 m^2) patches of mud. These sites had a habitat ranking between 1.5 and 1.75 and sediment anoxic layers between 4 cm and 7 cm beneath the surface. For shallow sites (< 1 m depth) located west of Ration Point (P3, P4, P8) the surficial sediment was also comprised of fine sand, but with larger mud patches (> 0.25 m^2). The habitat rankings for these sites were between 1.25 and 1.5 with sediment anoxic layers ranging between 5 and 6 cm (Table 9). Sediment at Sites P2, P6, and P9-P16 comprised fine, soft mud with corresponding habitat rankings of one and sediment anoxic layers < 1 cm (Table 10.9).

Within the Onepoto Inlet, southern sites (O1, O2, O3 and O6) were characterised by predominantly soft mud with discrete patches of small pebbles, equating to a habitat ranking of 1. The sediment anoxic layer for these sites was typically < 1 cm (Table 9). In contrast, the surficial sediment at Site O4 was firm sand with a corresponding habitat ranking of 1.75 and a sediment anoxic layer approximately 5 cm below the sediment surface (Table 10.9). Sediment at Site O5 comprised muddy sand, had a habitat ranking of 1.25, and depth of anoxic sediment was estimated at 2 cm below the sediment surface.

Biological habitats

Based on observational dives and epifaunal and infaunal identifications, a total of five main biological habitat types were encountered within the Porirua Harbour. These were cockle (*Austrovenus stutchburyi*) dominated (Sites P1 and P5); polychaete worm dominated (Sites P2, P3, P4, P6, P9 to P16, O5, O6); *Nucula hartvigiana* dominated (Sites P7, P8, O1, O2); serpulid worm habitat (Site O3) and *Zostera* sp habitat (Site O4) (refer to Appendix 10D for more detailed site descriptions).

Epifauna

The hermit crab *Pagurus* sp. (Figure 10.10) was the dominant epifaunal taxon observed within the Pauatahanui Inlet of the Porirua Harbour occurring at all sites with the exception of Site P6. Other common taxa included the speckled whelk *Cominella adspersa* and the cushion starfish *Patriella regularis*, which were patchily distributed among sites. The gastropod *Diloma subrostrata,* was predominantly associated with firm sandy sediment at Sites P1, P5 and P7 east of Ration Point within the Pauatahanui Inlet, as was the small limpet *Notoacmea elongata* that occurred attached to the underside of dead cockle shells – a preferable habitat type for this species (Morley, 2004). Sites P3 and P8 were notable for the occurrence of a pink/white finger sponge present within and adjacent to sample quadrats. Average species diversity was low ranging from 0.33 to 3.33 across sites (Table 10.9). Due to the relatively poor visibility at all sites surveyed, it is likely that abundance estimates and species diversity are underestimated and therefore results should be treated with a degree of caution.

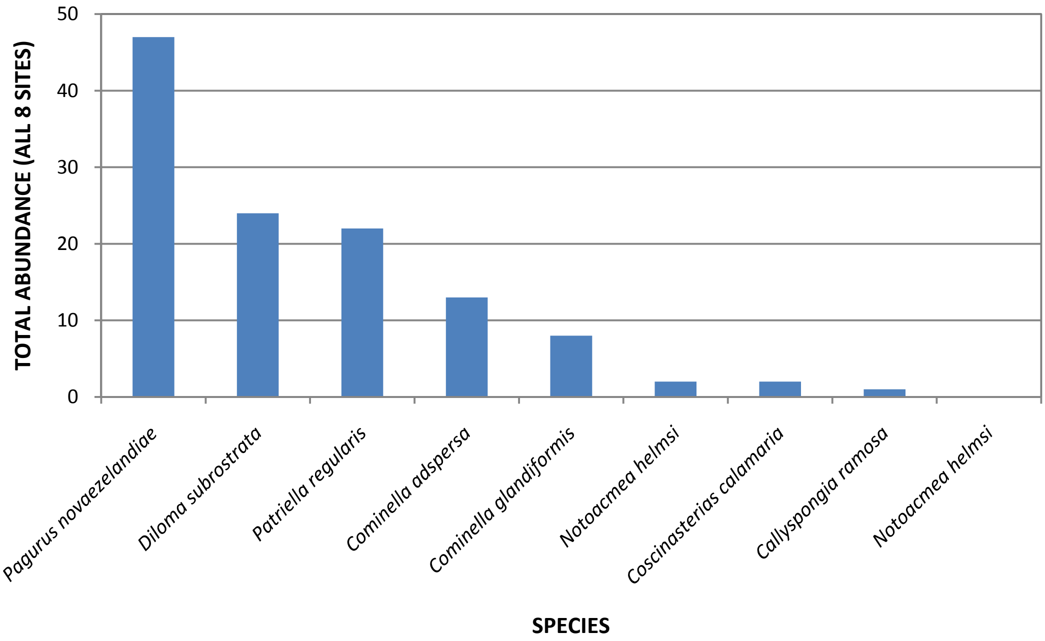


Figure 10.10: Abundance (pooled across Sites P1 to P8) of the dominant epifaunal organisms from the Pauatahanui subtidal sampling sites.

Pagurus sp. was the dominant taxon enumerated within the Onepoto Inlet of the harbour followed by *Cominella adspersa, Notoacmea elongata*, and *Diloma subrostrata* suggesting these species are widespread within the Porirua Harbour (Figure 10.11). The feathery sea hare *Bursatella leachii* was unique to Site O4 and is commonly associated with *Zostera* habitat (Morley, 2004). Average species diversity ranged from 0.67 to 2.67 across sites (Table 10.9). Again, as for the Pauatahanui Inlet, diversity is likely to be an underestimate due to the poor visibility experienced while undertaking the survey.

The visibility during survey of Sites P9 to P16 and O5 to O6 was extremely low. It was not possible to gather quantitative epifaunal data for these sites. However, hermit crabs were detected in low abundance at Sites P9, P13, P14 and O6. Speckled whelk were observed at Sites P9, P10 and P13, *Diloma subrostrata* was detected at Site O5, eleven-armed star fish (*Coscinasterias calamaria*) was detected at Site P15 and horse mussels (*Atrina zelandica*) were observed at site P14. Crab burrow holes were observed at sites P9-P16. All epifauna were observed to have low abundance at these more centrally located subtidal sites.

Table 10.9: Summary of key components at each subtidal survey site within the Pauatahanui Inlet and Onepoto Inlet.

(See Appendix 10D for more detailed subtidal sampling site descriptions).

Site	Depth	Biological habitat/ community classification: see Table 1	Habitat complexity classification based on surficial sediment type(s): see Table 2	General surficial sediment description	Anoxic layer depth	Epifaunal diversity: mean (SE)	Biogenic habitat type
P1	0.5	3	1.75	Firm sand intermixed with very small patches of muddy sand	7 cm	3.3 (0.7)	Cockles (*Austrovenus stutchburyi*) living and dead
P2	1.96	10	1	Fine soft anoxic mud	< 1 cm	0.3 (0.3)	
P3	0.5	10	1.5	Firm sand intermixed with patches of muddy sand	6 cm	1.3(0.6)	
P4	0.5	10	1.5	Firm sand intermixed with patches of muddy sand	5 cm	1.3(0.7)	
P5	0.5	3	1.75	Firm sand intermixed with very small patches of muddy sand	6 cm	3 (0.6)	Cockles (*Austrovenus stutchburyi*) living and dead
P6	1.78	10	1	Fine soft anoxic mud	< 1 cm	1 (-)	
P7	0.5	6	1.5	Fine mud interspersed with patches of sandy mud	5 cm	3.3(0.3)	
P8	0.5	6	1.25	Fine mud interspersed with patches of sandy mud	5 cm	1.7 (0.7)	
P9	1.9	10	1	Fine, soft, anoxic mud. Featureless apart from gastropod/hermit crab tracks	< 1 cm	1.0 (1.0)	
P10	2.1	10	1	Fine, soft, anoxic mud. Featureless apart from gastropod/hermit crab tracks	< 1 cm	0.3(0.6)	
P11	2.2	10	1	Fine, soft, anoxic mud.	< 1 cm		
P12	1.9	10	1	Fine, soft, anoxic mud.	< 1 cm		
P13	2.3	10	1	Fine, soft, anoxic mud. Featureless apart from gastropod/hermit crab tracks	< 1 cm	0.7(0.6)	
P14	2.4	10 (8)	1	Fine, soft, anoxic mud. Featureless apart from gastropod/hermit crab tracks	< 1 cm	1.3(0.6)	*Atrina zelandica*
P15	1.8	10	1	Fine, soft, anoxic mud. Featureless apart from gastropod/hermit crab tracks	< 1 cm	0.3(0.6)	
O1	0.5	6	1	Fine soft anoxic mud	< 1 cm	1.7 (0.3)	
O2	0.5	6	1	Fine soft anoxic mud	< 1 cm	0.7 (0.3)	
O3	0.5	15	1*	Fine soft anoxic mud and small pebbles	< 1 cm	2.7 (0.3)	Colonial serpulid worm *Spirobranchus cariniferus*
O4	0.5	14	1.75	Firm sand	6 cm	1.67 (0.9)	*Zostera* sp (low % cover)
O5	1.3	10 (3)	1.25	Sandy mud	2 cm	0.7(0.6)	Cockles (*Austrovenus stutchburyi*) living and dead
O6	1.6	10	1	Fine, soft, anoxic mud	< 1 cm	0.3(0.6)	

**Note*: No classification rank is provided for the occurrence of fine mud and small pebbles, therefore the rank is based on the principal habitat type, i.e., fine mud.

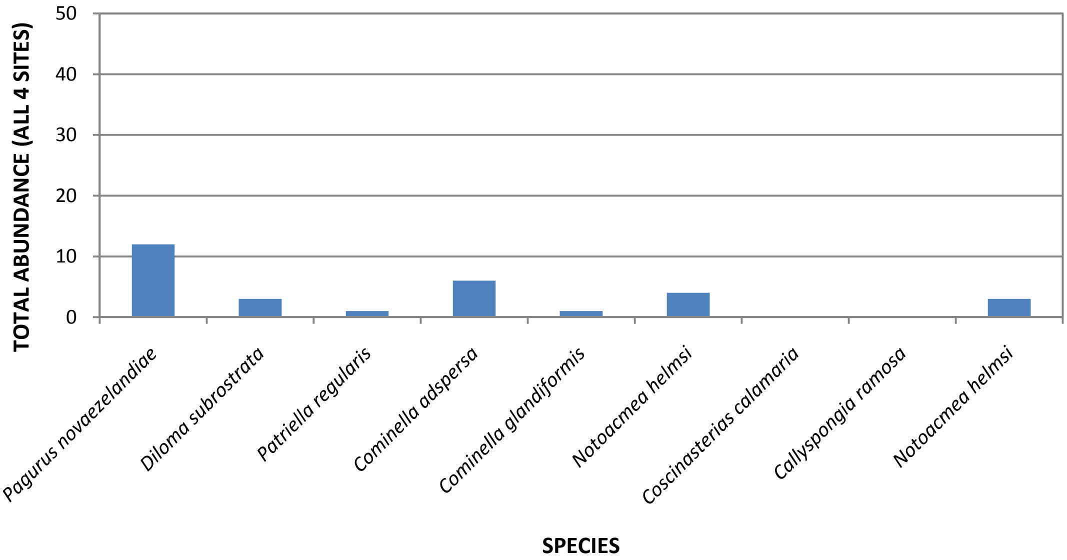


Figure 10.11: Abundance (pooled across Sites O1 to O4) of the dominant epifaunal organisms enumerated within the Onepoto Inlet of the Porirua Harbour.

Macroalgae

Macroalgal assemblages were present within the Pauatahanui Inlet at northeastern Sites P1, P5 and P7 being typically associated with dead cockle shells as well as live individuals. *Gracilaria* sp. and *Ceramium apiculatum* commonly occurred together with percent covers < 20 % per 0.25 m^2 (Figure 10.12) and also occurring as drift algae. Small patches of *Ulva* sp. were also common, < 5 % per 0.25 m^2 (Figure 10.12).

Within the Onepoto Inlet the red alga *Rhodymenia dichotoma* occurred in discrete patches < 5% per 0.25 m^2 on small pebbles at Site O1 and also occurred at Site O3 adjacent tube worm patches together with *Gracilaria* sp. (Figure 10.13). A suite of macroalgal species were associated with the *Zostera* sp. habitat at Site O4 including green algae *Enteromorpha* sp., and *Ulva* sp.; red algae *Rhodymenia dichotoma* and *Polysiphonia* spp.; and, the brown alga *Colpomenia sinuosa*. All taxa were patchily distributed with percent covers < 10% per 0.25 m^2 (Figure 10.13).

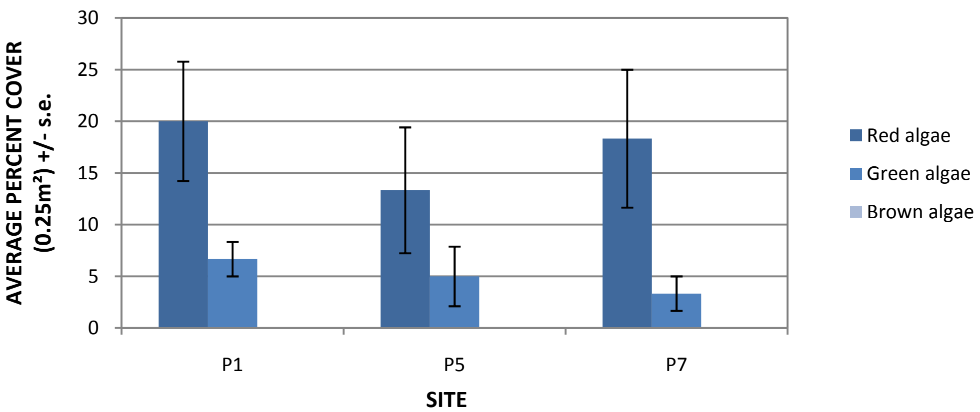


Figure 10.12: Percent cover of macroalgae at Pautahanui sites.

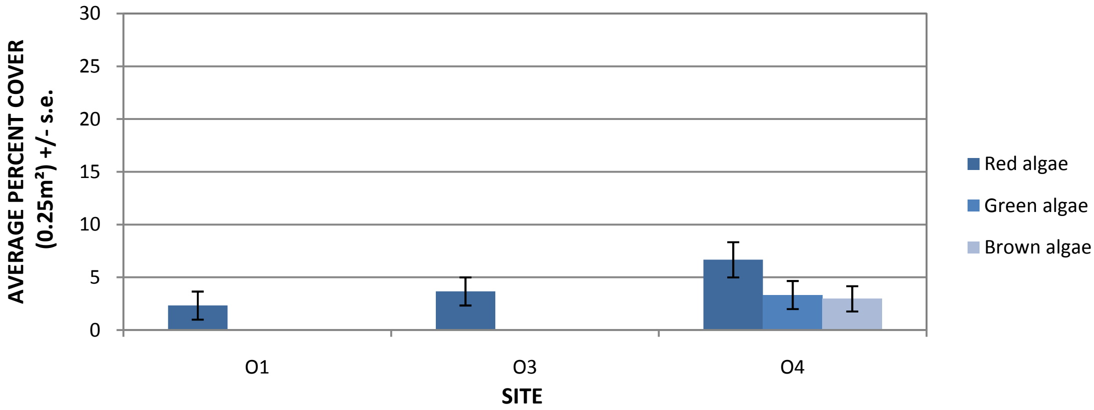


Figure 10.13: Percent cover of macroalgae at Onepoto Inlet sites.

6.2.3 Infaunal Community Composition

Intertidal Infaunal Community Composition

Analysis of core sediment samples revealed that the benthic fauna communities sampled within the Pauatahanui Inlet were dominated by polychaete worms, bivalves, and oligochaete worms, whereas the samples from the Onepoto Inlet were dominated by amphipods and gastropods (Table 10.10, Figures 10.14 and 10.15). Only one organism (a polychaete worm) was detected at Wainui Stream mouth, which is typical of high energy exposed sandy habitats.

Cockles were present at all intertidal sites within the Pauatahanui Inlet, with the highest densities at Pauatahanui Stream, Kakaho Stream, Horokiri Stream and Duck Creek. Cockle densities in Pauatahanui Inlet ranged from 218 per m^2 (at Kakaho Stream mouth) to 602 per m^2 (at Pauatahanui Stream mouth), yet were only 75 per m^2 adjacent to Porirua Stream. Cockles were typically small (<20 mm shell width) across all sites, though some specimens were detected in the 30 to 50 mm shell width range.

Of the molluscs (bivalve and gastropods), the highest average diversity was detected at Pauatahanui Stream mouth (6.2 taxa per core sample), followed by Duck Creek (4 taxa), Kakaho Stream (3.9 taxa), Horokiri Stream (3.3 taxa), and Rations Stream (2.8 taxa). The lowest diversity was at Porirua Stream mouth (2.7 taxa per core sample).

Table 10.10: Average abundance of dominant intertidal taxa.

	Porirua	Duck	Pauatahanui	Ration	Horokiri	Kakaho	Wainui
Amphipods	190	0	0	0	1	0	0
Bivalva	1	9	10	6	7	5	0
Gastropoda	95	12	11	1	3	10	0
Oligochaeta	18	31	21	1	3	5	0
Polychaeta	5	58	45	12	25	56	0.1
Other	2	32	5	1	2	1	0
TOTAL	311	141	92	21	42	78	0

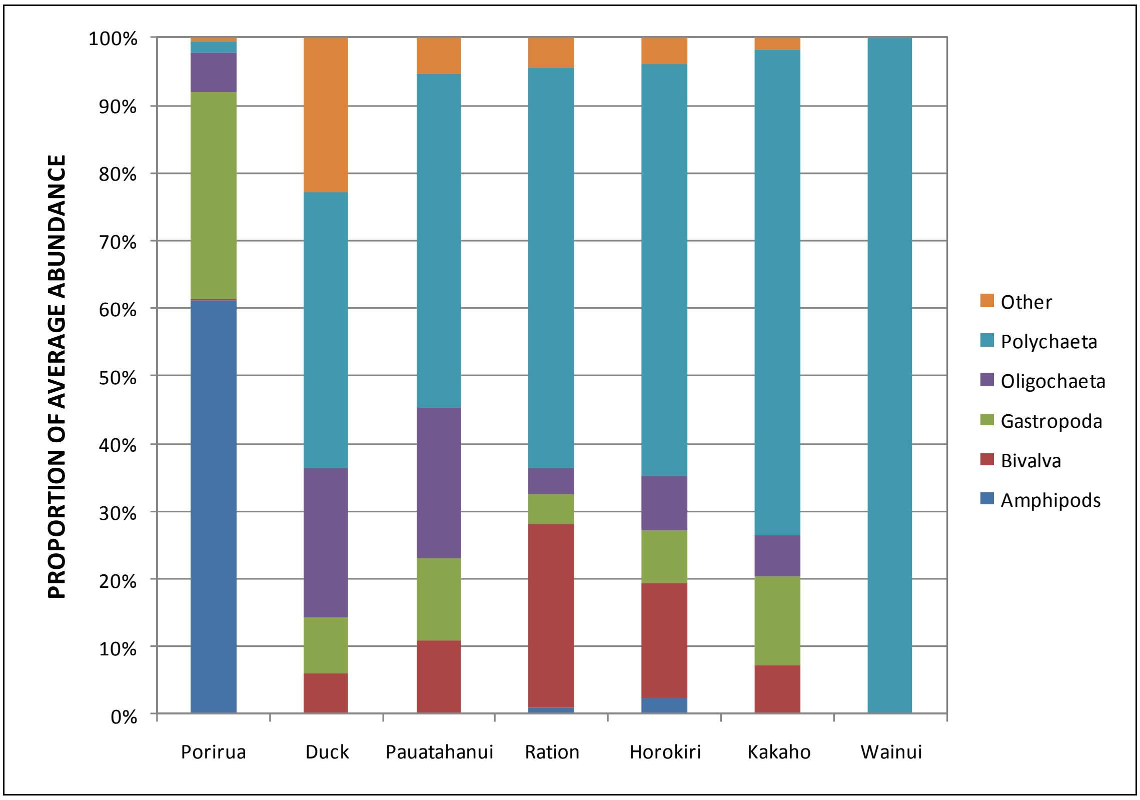


Figure 10.14: Proportion of average abundance of dominant intertidal taxa.

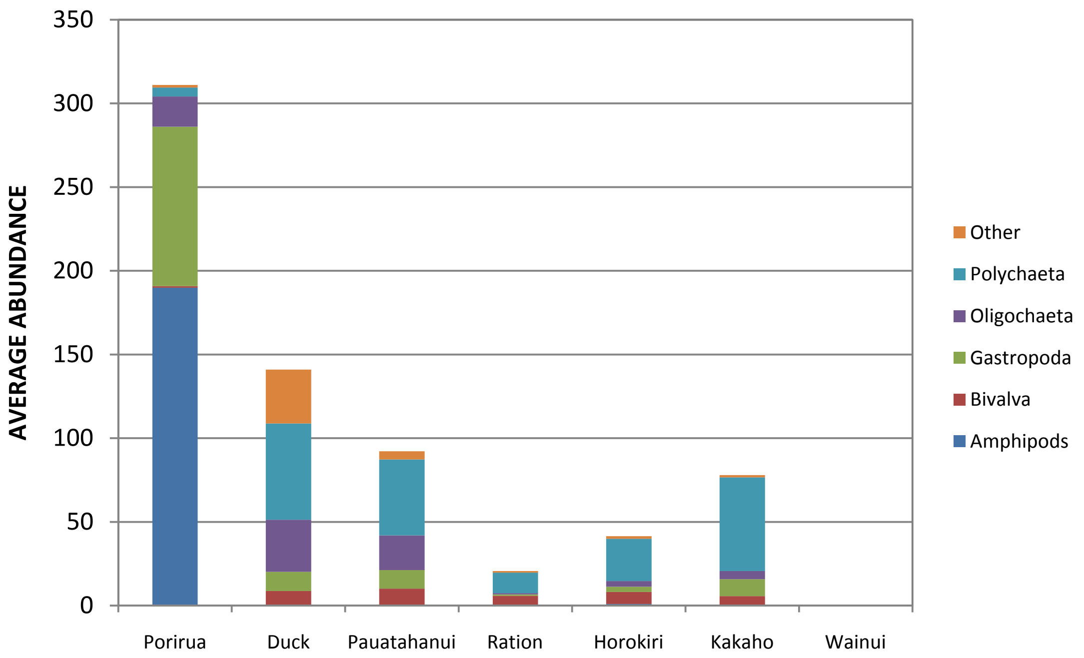


Figure 10.15: Average abundance of dominant intertidal taxa.

Across the 56 core samples collected within Porirua Harbour, species richness ranged from three to 22. In terms of the sample sites, mean species richness was greatest at the Pauatahanui site (14.2) and lowest at the Porirua site (8.2) (Figure 10.16). Average species richness of 0.1 detected at Wainui Stream reflects the fact that only one organism was detected.

The Shannon-Wiener Diversity Index ranged across the 56 samples collected with Porirua Harbour from 0.18 to 2.47. The mean Shannon-Wiener Diversity Index was highest at the Rations site (2.0) and lowest at the Porirua site (0.95) (Figure 10.17).

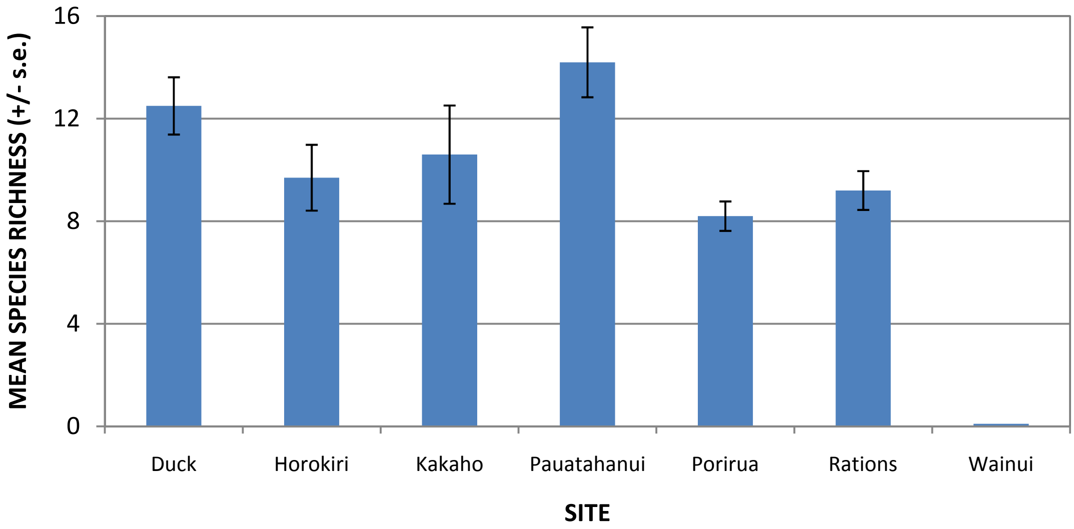


Figure 10.16: Mean intertidal benthic species richness per site.

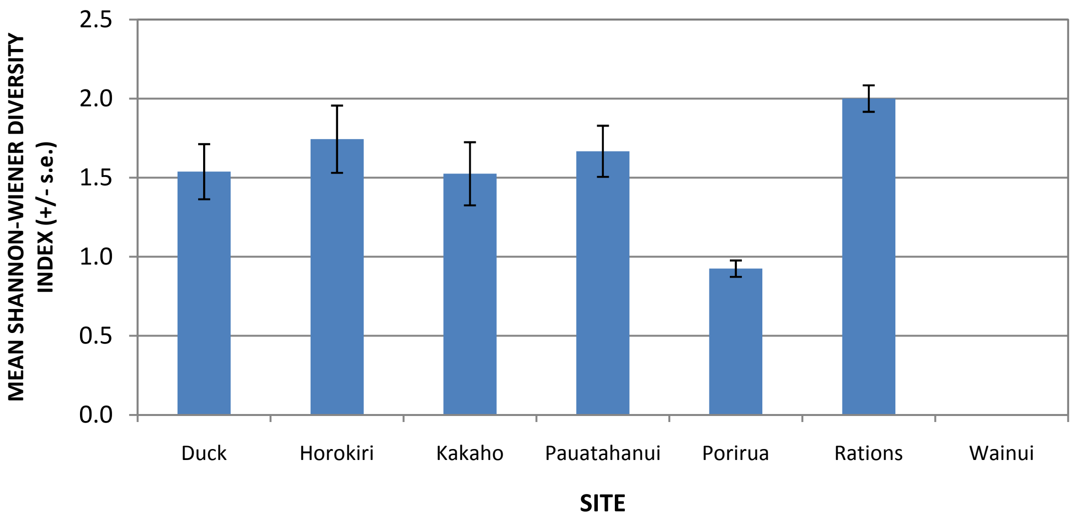


Figure 10.17: Mean intertidal benthic species diversity per site.

Multivariate statistical analysis using MDS indicates that the invertebrate assemblage at Porirua Stream mouth has relatively high similarity (60%) between replicate core samples, and further that all of the Porirua Stream samples are relatively different to those collected within the Pauatahanui Inlet (see Figure 10.18). This is primarily due to the dominance of amphipods and gastropods at this site (see Figure 10.15 above).

Rations Stream mouth samples cluster separately to most of the other Pauatahanui Inlet sites, but there is some similarity with Horokiri and Pauatahanui Stream mouth samples (Figure 18). In general, samples collected from Duck, Pauatahanui, Horokiri and Kakaho have similarities, with some outlying sites (see Kakaho Sites KE, KJ and Horokiri Sites HI, HD in Figure 10.18 below).

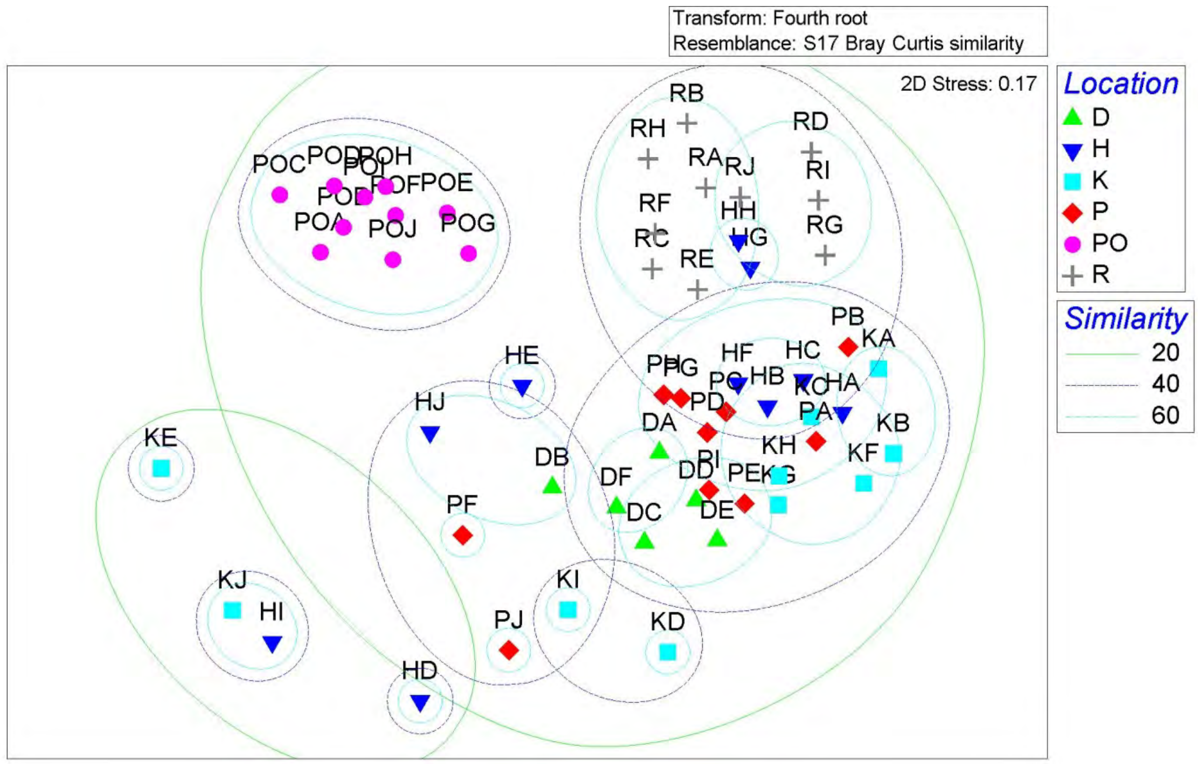


Figure 10.18: MDS Plot of Intertidal Invertebrate Community Composition Similarity.

(D=Duck, H=Horokiri, K=Kakaho, P=Pauatahanui, PO=Porirua, R=Rations, Wainui not included in analyses).

Subtidal Infaunal Community Composition

The abundance of organisms within subtidal sediment cores was significantly lower than the abundance detected in the majority of intertidal cores (Tables 10.11a and 10.11b, Figures 10.19 and 10.20). The dominant taxa were largely polychaete worms and bivalves, but patterns differed significantly among some sites (Figures 10.19 and 10.20). Within the Pauatahanui Inlet, Site P1 (adjacent to the Horokiri Stream mouth) had the highest abundance of organisms, with a dominance of bivalves, polychaetes, and gastropods. Site P1 also had the highest average species richness of 11 and the highest Shannon-Weiner Diversity Index of approximately 2 (see Figures 10.21 and 10.22 respectively). Average abundance and species richness was less than half that of Site P1 at all of the other subtidal sites sampled within the Pauatahanui Inlet (Figures 10.20 and 10.21). Shannon-Weiner Diversity Index at the other subtidal sites within the Pauatahanui Inlet varied between approximately 0.2 and 1.4 (see Figure 10.22). Sites located within central parts of the inlet had low abundance and diversity, with polychaete worms comprising the dominant taxa (Figures 10.19 to 10.22).

Within the Onepoto Inlet, Site O3 had the highest average abundance of organisms, with a dominance of polychaete worms (comprising almost 80% of the organisms detected) (Figure 10.20). However, average species richness at this site was only seven (Figure 10.21), and average Shannon-Weiner Diversity Index approximately 0.75 (Figure 10.22). Species richness was highly variable at this site, as shown by the large standard error bars (Figure 10.21). The most diverse site within the Onepoto Inlet was Site O4, which had a similar species richness and diversity to Site P1, but the abundance was approximately 50% of that of Site P1 (16 organisms) (see Tables 10.11a and 10.11b and Figures 10.19 and 10.20). Site O2 appeared to have a somewhat different species composition to that of the other Onepoto Inlet sites, with a dominance of bivalves, primarily the nut shell (*Nucula hartvigiana*) (Figure 10.20). Site O6 had the lowest abundance and diversity of organisms within the Onepoto Inlet samples (see Table 10.11b and Figure 10.20), an average of four for species richness (Figure 10.21) and a Shannon-Weiner Diversity Index of approximately 1.1 (Figure 10.22).

Cockles were detected primarily at subtidal sampling Sites P1 and P5, adjacent to the Pauatahanui and Horokiri Streams respectively.

Table 10.11a: Average abundance of dominant subtidal taxa – Pauatahanui Arm.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Amphipoda	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Bivalva	13	5	1	0	6	0	3	6	0	5	0	4	1	1	1	1
Gastropoda	3	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0
Polychaeta	9	5	3	3	7	2	0	1	5	12	12	2	14	4	3	3
Other	7	0	1	5	2	0	2	2	6	1	1	0	0	0	1	1
TOTAL	31	10	5	9	15	2	7	9	11	19	13	6	16	5	5	5

Table 10.11b: Average abundance of dominant subtidal taxa – Onepoto Inlet

	O1	O2	O3	O4	O5	O6
Amphipoda	1	0	0	0	0	0
Bivalva	2	16	2	1	15	0
Gastropoda	0	0	1	2	1	0
Polychaeta	3	0	27	12	2	4
Other	1	1	4	1	0	0
TOTAL	7	17	34	16	18	4

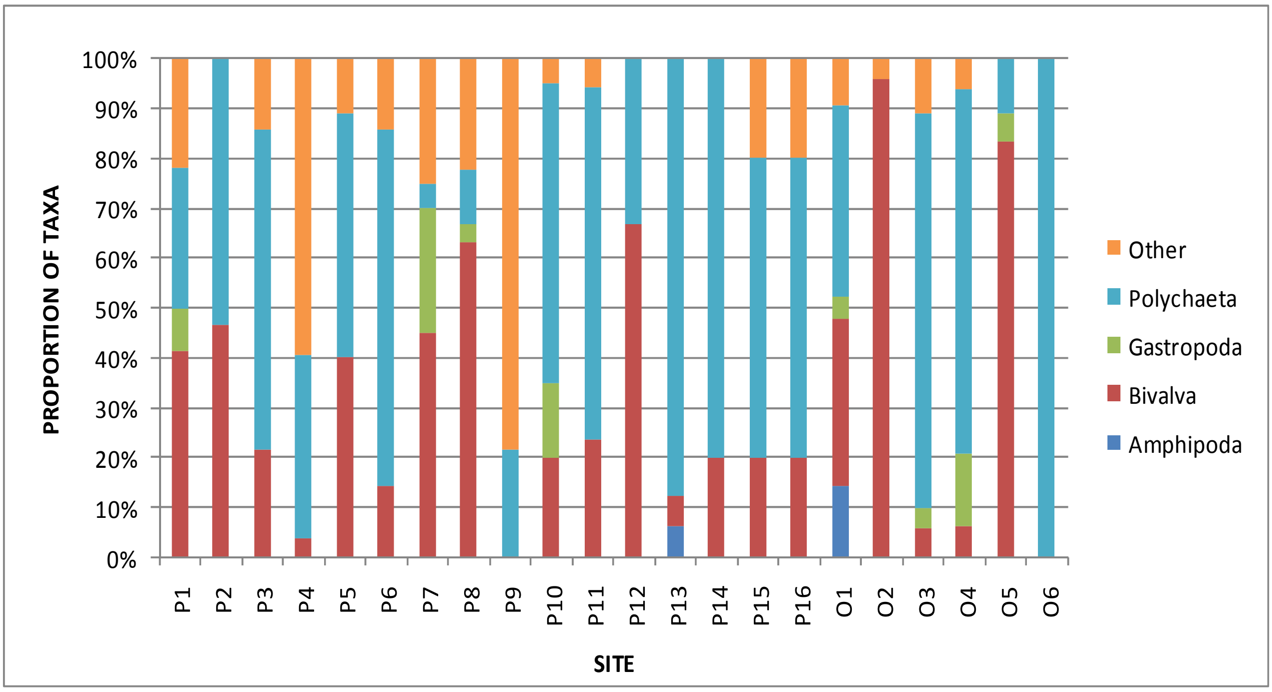


Figure 10.19: Proportion of average abundance of dominant subtidal taxa.

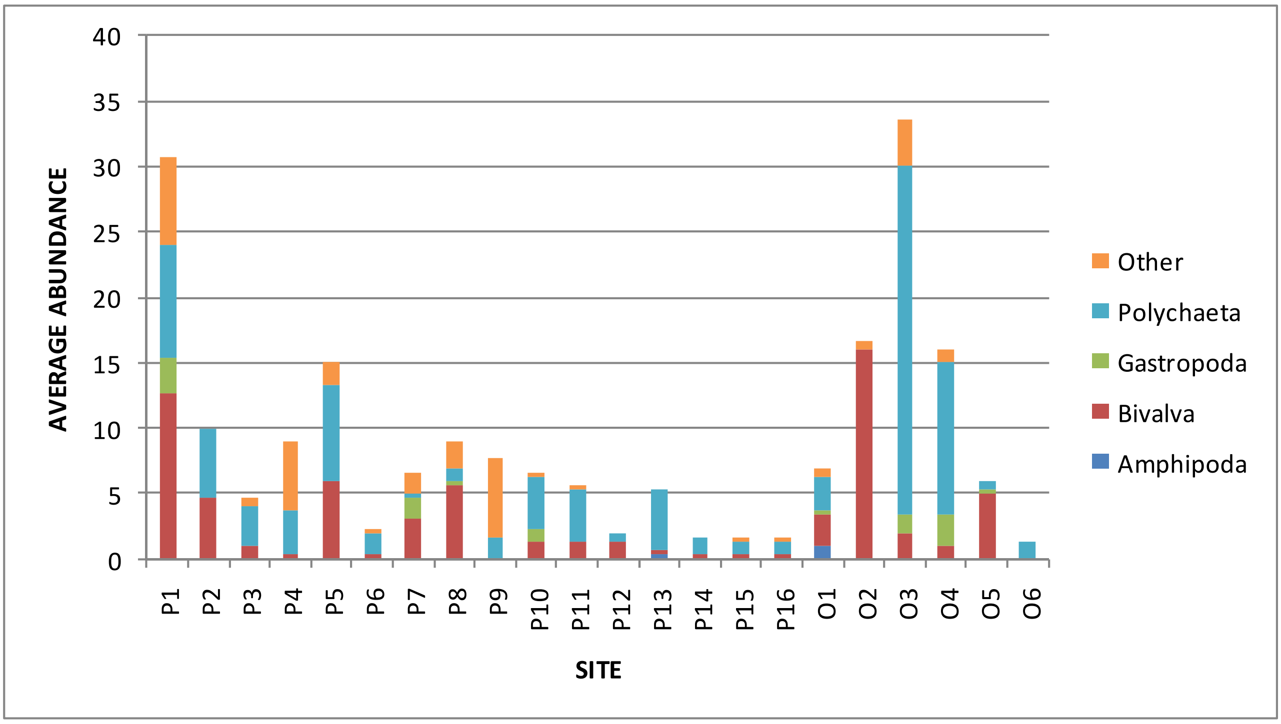


Figure 10.20: Average abundance of dominant subtidal taxa.

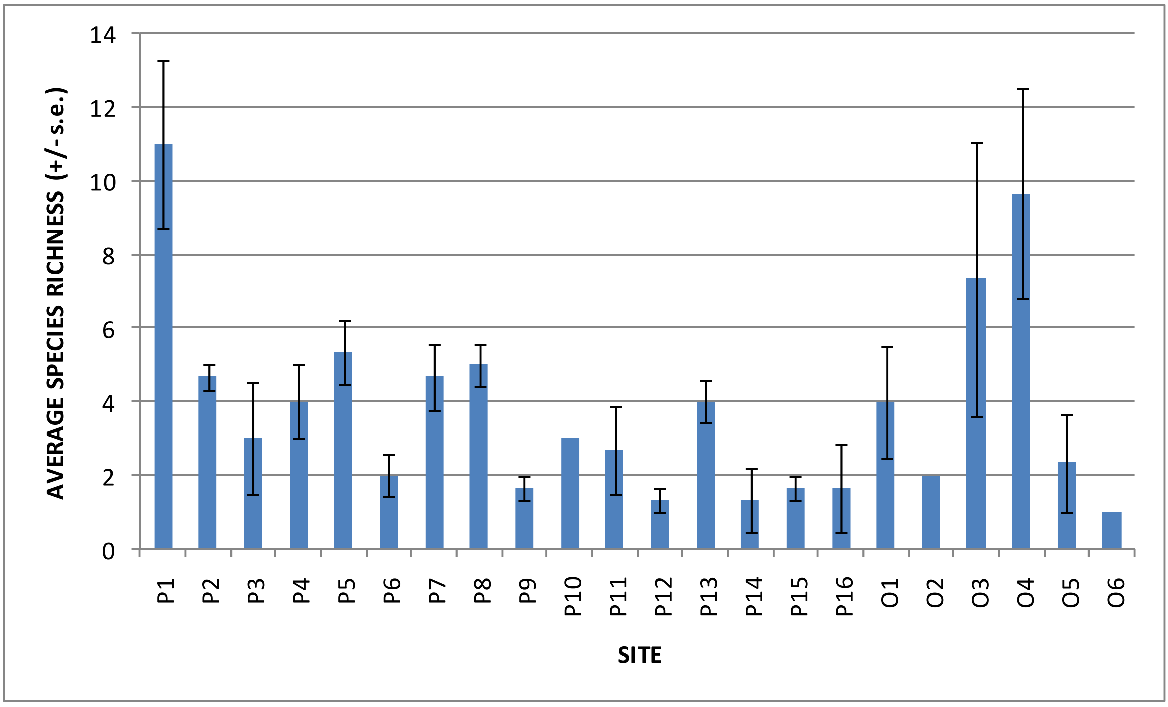


Figure 10.21: Mean subtidal benthic species richness per site.

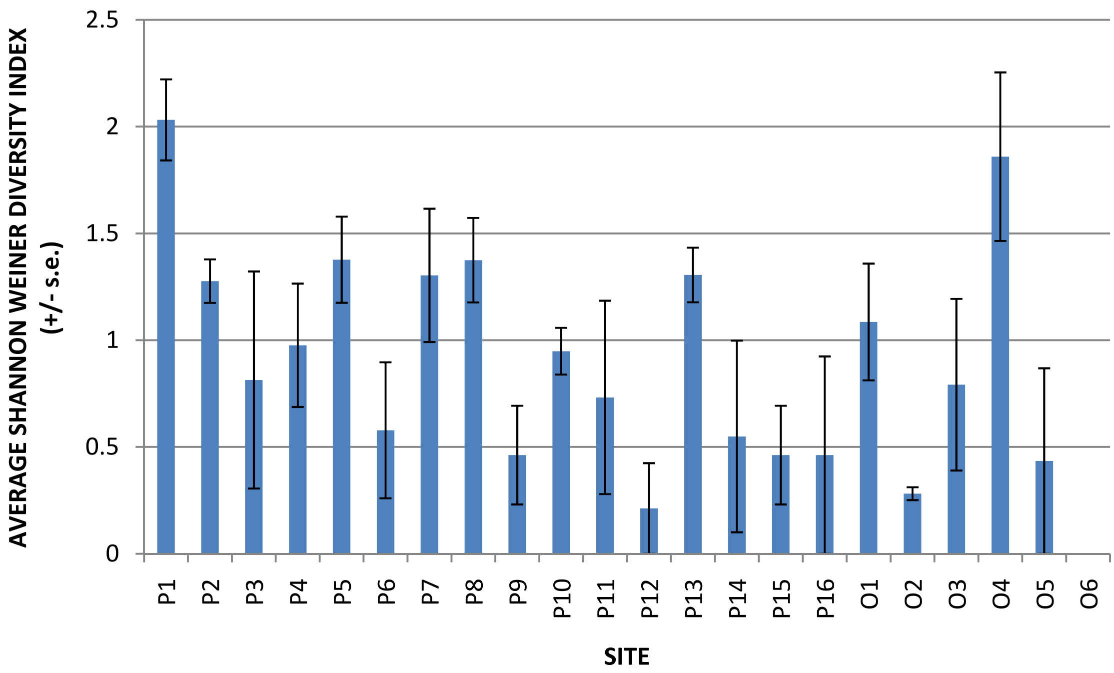


Figure 10.22: Mean subtidal benthic invertebrate diversity per site.

Two-dimensional representation of the multivariate statistical analysis of the subtidal invertebrate community composition does not show clear patterns or associations (Figure 10.23). However, when the survey sites are categorised as either being near shore sites or central subtidal basin sites and represented in a three-dimensional image, a relatively clear distinction between site location type is apparent (Figure 10.24). This pattern reflects the dominance of polychaete worms, low diversity and low abundance of invertebrates in the central subtidal basin sites as discussed above.

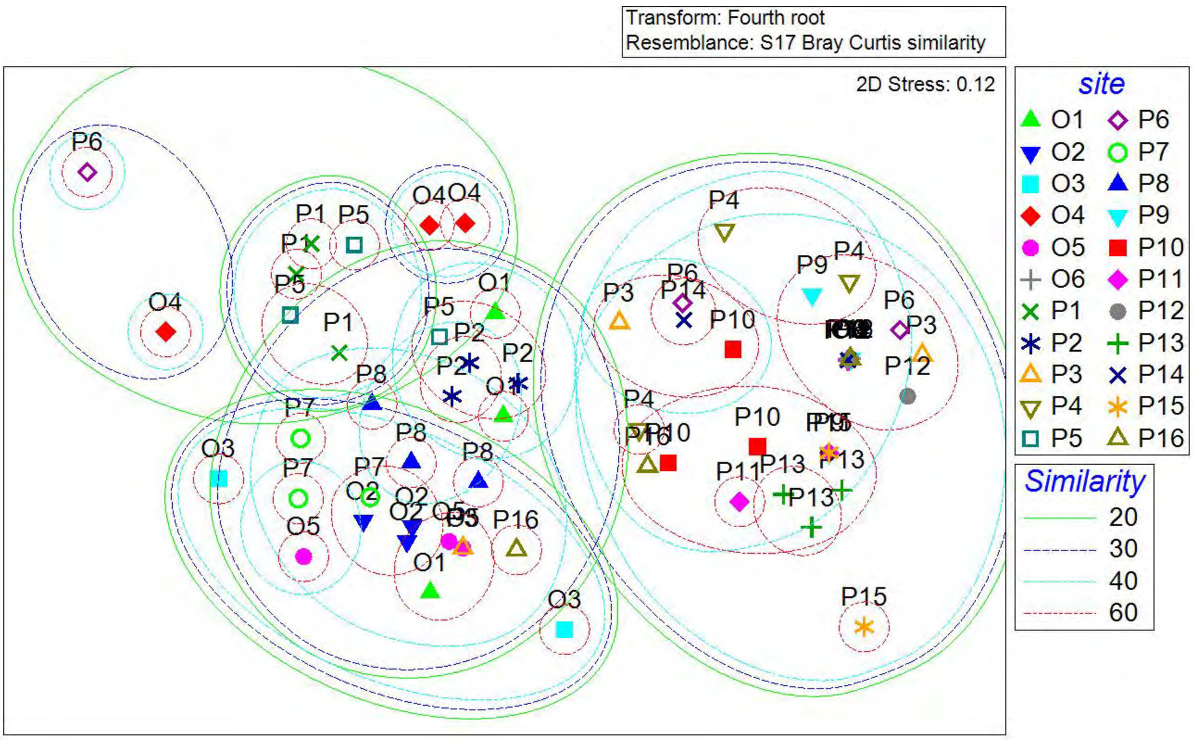


Figure 10.23: MDS Plot of Subtidal Invertebrate Community Composition Similarity.

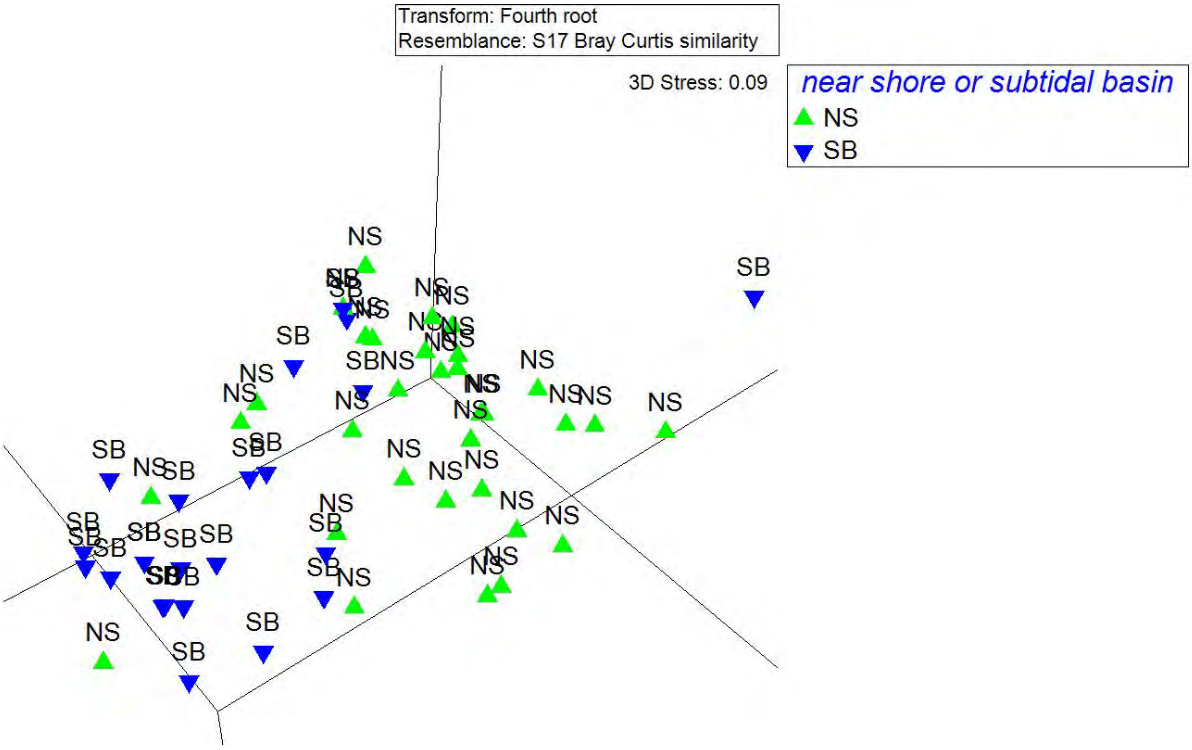


Figure 10.23: MDS Plot of Subtidal Invertebrate Community Composition Similarity comparing sites located near to shore (NS) and central subtidal basin sites (SB).

7. DISCUSSION

7.1 Marine Invertebrates

The invertebrate assemblage, both intertidally and subtidally, based on the existing literature and samples collected specifically for this project in 2009 to 2011, indicate that the Pauatahanui Inlet has a high diversity and abundance of epifaunal and infaunal benthic invertebrates, with many sensitive taxa present. The assemblage in the Onepoto Inlet is slightly less diverse and has a higher proportion of tolerant species (see Appendix 10E). However, species that are sensitive to organic enrichment were detected in both Inlets. The number of species that have a strong sand preference was only slightly higher in samples collected in the Pauatahanui Inlet compared to the Onepoto Inlet (see Appendix 10E).

The Wainui and Whareroa Streams discharge onto the high energy exposed sandy beaches of the Kapiti Coast. As is typical for this type of habitat, the intertidal area adjacent to these stream mouths has highly mobile sand, low concentrations of contaminants in sediment, and naturally low invertebrate community diversity.

At all sites surveyed the invertebrate communities detected reflected the sediment quality and grain size characteristics and the different hydrodynamic environments. The species detected are common and can be found in other similar marine habitats within New Zealand.

7.1.1 Intertidal

Porirua Harbour

Species diversity and species richness, whilst high, were lower in the present study compared to that reported by Robertson & Stevens (2010). However, this is likely due to sampling in different parts of the harbour with somewhat different habitat characteristics.

The number of epifaunal species detected in the 2009 field investigations was similar to those reported by Robertson & Stevens (2010), with typically between one to four species detected per quadrat. In comparison, the benthic invertebrate species richness was lower in the present study (average of eight to 14) compared to Robertson & Stevens (2009) (average of approximately 15 to 24). However, the sites sampled by Robertson & Stevens were not at stream mouths, which is likely to influence the species present.

Infaunal invertebrate taxa detected in the present survey are consistent with that reported by Robertson & Stevens (2010), with both data sets having a dominance of polychaete worms, bivalves and gastropods. In the present survey oligochaete worms were an additional dominant feature of samples collected from both estuary inlets, and amphipods were abundant in samples collected adjacent to Porirua Stream mouth. As mentioned above, these minor differences in dominant taxa between the two studies could be due to different sampling locations, with the present survey focusing on stream mouths (where sediment characteristics and water physic-chemical parameters may be different to estuarine intertidal areas with less direct freshwater influence), whereas Robertson & Stevens (2010) sampled in areas of intertidal sandflat not adjacent to stream mouths.

Cockles were detected at all sites sampled in the present survey at a variety of densities. However, cockle density is likely to be higher at sites lower on the intertidal sand and mudflats and also in subtidal sediment. Sediment grain size and sediment quality are likely to be factors that influence the density and distribution of cockles in the harbour. However, sediment grain size and sediment quality at the sites sampled in the present survey do not fully explain the difference in cockle density among sites.

A high diversity of molluscs (bivalves and gastropods) was detected in the present survey, with Pauatahanui Stream having the highest diversity. Typically this group of organisms is less diverse or absent when the habitat quality is low. This was reflected in the fact that Porirua and Rations Streams (and Horokiri Stream to a lesser extent) which had the lowest proportion of gravel and the highest proportions of three smallest grain size categories, also had the lowest diversity of molluscs.

Wainui and Whareroa Stream Mouths

A naturally low diversity and abundance of marine/estuarine invertebrates was detected at these sites. Only one organism was detected in the samples from Wainui Stream mouth. At Whareroa Stream mouthy amphipods were present in the mobile sands, along with an occasional polychaete or oligochaete worm (Stevens & Robertson, 2006). This data is typical for the habitat type. It is likely that bivalves may be present in the near shore subtidal habitat.

7.1.2 Subtidal

Porirua Harbour

The subtidal survey of the Pauatahanui and Onepoto Inlets of the Porirua Harbour revealed five main biological types; cockle (*Austrovenus stutchburyi*) dominated, *Nucula hartvigiana* dominated, polychaete dominated, *Zostera* sp. habitat and serpulid worm habitat. No subtidal rocky reef habitat was encountered at any of the survey sites, but does occur at the harbour mouth and outer harbour (Blashcke *et al.,* 2010), areas outside of the scope of the present study.

Subtidal surficial sediment types ranged from firm sand, typical of the shallowest sites < 1 m depth, to fine soft anoxic mud at sites > 1 m depth matching previous descriptions (Blaschke *et al*., 2010) and reflecting extensions of intertidal habitats presented in Stevens and Robertson (2008). Patches of small pebbles and mud were apparent in the southern part of the Porirua Harbour associated with Sites O1, O2 and O3.

Soft sediment epifaunal species described for this study appear typical of those commonly found in North Island estuaries and harbours (Morton and Millar, 1968, Gibbs and Hewitt, 2004, Hewitt and Funnel, 2005). However, epifaunal diversity was low compared to other estuarine/harbour environments in New Zealand (see Robertson et al., 2002). Shallow-water sites (P1, P5 and P7) located in the north-eastern area of the Pauatahanui Inlet were generally comprised of firm sandy sediment with smaller patches of mud. The common cockle *Austrovenus stutchburyi*, the nut shell *Nucula hartvigiana* and the wedge shell *Macomona liliana* were associated with this substratum type. Shallow-water sites in the northern and north-western part of the Pauatahanui Inlet (P3, P5 and P8) were generally dominated by polychaete worms with the surficial sediment comprised of firm sand with larger patches of sandy mud relative to the north-eastern part of the inlet.

The majority of centrally located sites comprised anoxic and amorphous mud concomitant with low epifaunal abundance and diversity. These sites typically had lower epifaunal abundance and diversity than the near shore subtidal sites surveyed.

The presence of cockles in the Pauatahanui Inlet are an important biological component as cockles are food source for a variety of organisms, affect the distribution of predator species, affect nitrogen and oxygen fluxes between water and sediment and are an important substrate for the attachment of algae and other molluscs (Gibbs and Hewitt, 2004; Morley, 2004; this study). Similarly, *Nucula hartvigiana* and *Macomona liliana* affect nitrogen and oxygen fluxes between water and sediment and are important as prey items.

Cockle surveys carried out between 1976 and 2007 within the Pauatahanui Inlet demonstrated a large reduction in numbers between 1976 and 1995 declining from between 400-600 million to around 200 million, thereafter remaining stable at around 220 million (see summary in Blaschke *et al.,* 2010). Specific mechanisms for the decline remain unclear; however, a reduction in the extent of seagrass and resultant increased sedimentation has been suggested to be a principal factor.

Although having low coverage, another biogenic habitat of importance was *Zostera* sp., present in the shallow subtidal at Site O4. Unfortunately due to the poor visibility it was not clear as to the exact spatial extent of this habitat. In a recent survey, intertidal *Zostera* habitat in the Porirua Inlet equated to 17.3 ha (described as low-to-moderate abundance) and 45.2 ha in the Pauatahanui Inlet (described as moderate abundance) (Stevens and Robertson, 2008). Presently, the extent of subtidal *Zostera* sp. habitat across the entire harbour is unknown, but may exist only on the intertidal/subtidal margins given that much of the subtidal substrate consists of fine mud (Stevens and Robertson, 2008).

Zostera habitat is considered as being ecologically significant due to its contribution to primary productivity and detrital food webs (trophic linkages) and through its structural complexity, providing habitat for a range of species (Schwarz *et al*., 2006). Seagrass meadows have also been shown to enhance bottom stability, reduce sediment accumulation, and enhance nutrient cycling (Ruiz *et al*., 2001; Turner and Schwarz, 2006).

Of further note was the occurrence of patches of the colonial serpulid *Spirobranchus cariniferus* (perhaps better known as *Pomatoceros caeruleus*) at Site O3 in the southern Onepoto Inlet of the Harbour, loosely attached to small pebbles and the muddy substratum. Again this appears to be an important predominantly intertidal biogenic habitat (see Stevens and Robertson, 2008) within the harbour with macroalgae and encrusting invertebrates associated with it.

Studies have suggested that the Porirua Harbour faunal communities are under threat from effects associated with sedimentation (Stevens and Robertson, 2008), which was evident at the two deepest sites (P2, P6) surveyed in the Pauatahanui Inlet where the substrate was comprised of soft anoxic mud. Consequently, these sites were largely devoid of common epifaunal taxa observed at many of the other sites. If sedimentation continues to affect the harbour then epifaunal taxa such as *Cominella glandiformis*, *Diloma subrostrata* and *Austrovenus stutchburyi* which have been described as being sensitive to increased sedimentation (muddiness) are likely to be adversely affected (Gibbs and Hewitt 2004). Moreover, habitats such as *Zostera* sp, may also be negatively impacted through direct smothering and increased turbidity.

7.2 Sediment Grain Size

Porirua Harbour

The proportion of very fine sand plus silt and clay in surficial sediment samples varied significantly among sites within each of the inlets.

Within Pauatahanui Inlet, the intertidal habitat adjacent to the mouths of Rations and Horokiri Streams comprised approximately 60% very fine sand and silt and clay. Sediment collected from the central subtidal areas of the Pauatahanui Inlet approached 100% of these finest grain size fractions, which aligns with the current knowledge on the hydrodynamic environment.

Within the Onepoto Inlet, the Porirua Stream mouth is characterised by a large proportion of gravel and coarser sand grain fractions. However, the subtidal environment adjacent to this stream mouth comprises a high proportion of very fine sand and silt and clay. It is likely that fine sediment is flushed from the intertidal area to the subtidal habitat in flood flows.

Wainui and Whareroa Stream Mouths

Sediment was dominated by sand at both sites; 100% at Wainui Stream mouth and 99% at Whareroa Stream mouth (Stevens & Robertson, 2006). The high proportion of sand is typical for this habitat type along the Kapiti Coast.

7.3 Sediment Quality

Porirua Harbour

In general, based on the results of the 2009 field investigations and those obtained from the literature review, sediment quality is lower in the Onepoto Inlet compared to the Pauatahanui Inlet with regard to the common stormwater heavy metals copper, lead and zinc (Botherway & Gardner, 2002; Glasby et al., 1990; Hooper, 2001; Milne & Sorrensen, 2009; Robertson & Stevens, 2010; Sorrensen & Milne, 2009; Stephenson & Mills, 2006. While biological effects threshold concentrations were commonly exceeded within the Onepoto Inlet, this was rarely the case in the Pauatahanui Inlet. This pattern is consistent with the current and historic land-uses within the catchments that feed into these estuaries, with the Onepoto

Inlet being primarily industrial and residential and the Pauatahanui Inlet being primarily residential and rural.

It is concluded that some contaminants in benthic within the Onepoto Inlet present a moderate to high risk to sensitive marine organisms. There may be sublethal and lethal effects occurring, which could have resulted in loss of invertebrate species and consequent changes in community composition. Based on the collected and reviewed, it is considered unlikely that sediment bound contaminants in the Pauatahanui Inlet have caused significant adverse effects to marine organisms and invertebrate assemblages.

The two estuary Inlets have similar patterns for HMW-PAHs (Sorrensen & Milne, 2009; Stephenson & Mills, 2006), mercury (Milne & Sorrensen, 2009; Sorrensen & Milne, 2009; Stephenson & Mills, 2006), total-DDT (Robertson & Stevens, 2010; Sorrensen & Milne, 2009; Stephenson & Mills, 2006) and dieldrin (Sorrensen & Milne, 2009; Stephenson & Mills, 2006) concentration. Subtidally, many of these contaminants are found at higher concentrations compared to intertidal sediment. This may be due to the subtidal accumulation of fine sediment, which is likely to have a higher organic content and therefore a higher concentration of bound contaminants. The presence of DDT (and its derivatives) and dieldrin in sediment, decades after these agricultural chemicals were banned, indicates the persistence of these contaminants. Furthermore, it is possible that these contaminants continue to leach from rural land due to their historic use.

Nutrients in marine sediment were detected at low concentrations (Robertson & Stevens, 2010), which is consistent with the results presented and conclusions drawn by Healy (1980) and Kennedy (1980) i.e. good tidal flushing assists with preventing the accumulation of nutrients in marine sediment. In addition, a reduction in rural landuse surrounding the Pauatahanui Inlet since the 1970’s, when the research reported in Healy (1980) was carried, will contribute to a reduction in nutrients discharged.

From the sampling carried in 2009 for this project, sediment grain size analyses suggests that the mouths of Duck Creek, Pauatahanui Stream and Kakaho Stream are dominated by larger grain sizes, whereas Horokiri, Rations and Porirua Streams have a larger proportion of fine and very fine sands, and silt and clay grain sizes. However, the fine sediments at these latter sites are not also associated with higher contaminant concentrations compared to the more coarsely grained sites.

It may be that sediment and associated contaminants entering the Pauatahanui Inlet, given the strong tidal flushing and dominance of subtidal habitat, are removed from the intertidal habitat and deposited subtidally. Some of these subtidal depositions may be removed from the system with tidal flows under certain wind and wave conditions. With respect to the Onepoto Inlet, the fetch may be more constricted which may lead to a higher accumulation of contaminants subtidal in sediment. However, land-use in this catchment is likely to deliver significantly greater contaminant concentrations compared to the Pauatahanui Inlet.

Wainui and Whareroa Stream Mouths

Very low concentrations of copper, lead and zinc were detected in surficial sediment at these two sites (Stevens & Robertson, 2006). HMW PAHs were not analysed at Whareroa Stream mouth, but are likely to be similarly low as that detected at Wainui Stream mouth. The low concentration of contaminants is expected, given the largely rural catchments, and the nature of the receiving environment (i.e. high energy beach).

8. ASSESSMENT OF ECOLOGICAL VALUES

The assessment of ecological value is based on Table 10.3, which details some of the common characteristics of estuarine 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 a weight of evidence approach, guided by the characteristics in Table 10.3. This process involves the condensing of a large volume of information and data into single descriptors. It should be noted that there exists more information about the Pauatahanui Inlet than the Onepoto Inlet, which may have some influence on the data, for example, the greater the sampling effort typically results in the detection of more species.

The Inlets did not fit neatly into one of the classifications of ecological value. However, the characteristics that applied to each of the Inlets have been extracted from Table 10.3 and are listed below:

Pauatahanui Inlet

ECOLOGICAL VALUE	CHARACTERISTIC
LOW	• Central subtidal basin areas comprise almost 100% anoxic silt and clay at most sites surveyed. • Benthic invertebrate diversity and abundance, within the central subtidal basins, is low.
MODERATE	• Subtidal surficial sediments typically comprise approximately 50-70% very fine sand and silt/clay (although central basin sites approaching 100%). • Habitat modification limited.
HIGH	• Near shore intertidal and subtidal benthic invertebrate community typically highly diverse with high species richness. • Near shore intertidal and subtidal benthic invertebrate community contains many taxa that are sensitive to organic enrichment and mud. • Intertidal surficial sediments typically comprise approximately 50-70% very fine sand and silt/clay. • Depth of oxygenated surface sediment typically >1.0 cm. • Contaminant concentrations in surface sediment rarely exceed low effects threshold concentrations. • Connected to saltmarsh habitat. • Habitat and feedings areas for birds and fish extensive. • Keystone species present i.e. cockle beds. • Seagrass beds present.

Onepoto Inlet

ECOLOGICAL VALUE	CHARACTERISTIC
LOW	• Elevated contaminant concentrations in surface sediment, above ISQG-High or ARC-red effects threshold concentrations. • Habitat highly modified.
MODERATE	• Benthic invertebrate community typically has moderate species richness and diversity. • Benthic invertebrate community contains many taxa that are sensitive to organic enrichment and mud. • Depth of oxygenated surface sediment typically >0.5 cm. • Habitat and feeding areas for birds and fish present but modified/limited.
HIGH	• Marine sediments typically comprise <50% very fine sand and silt/clay. • Seagrass beds present.

Both inlets contained relatively diverse invertebrate assemblages and species that are known to be sensitive to organic enrichment and to silt and clay. Sediment grain varied amongst sites in each of the inlets, with some sites in each inlet having a high proportion of silt and clay and some having a high proportion of sand and gravel. These differences are largely due to different historic and current land use practices, in addition to having somewhat different hydrodynamic environments. Sediment contaminants were significantly higher in the Onepoto Inlet compared to the Pauatahanui Inlet, primarily due to activities occurring within the catchments. Further, habitat modification is more extensive in the Onepoto Inlet, compared to the Pauatahanui Inlet.

Overall, we conclude that the Pauatahanui Inlet has high marine/estuarine ecological values in the near shore intertidal and subtidal areas, moderate to low ecological values in the central subtidal basins, and the Onepoto Inlet has moderate marine/ecological values.

Wainui and Whareroa Stream mouths cannot be assessed using Table 10.3, as the receiving environment is an open sandy high energy beach not a quiescent estuary. We can conclude that whilst the abundance and diversity of organisms is low at these sites, the ecological values are high and the risks of degradation low due to the hydrodynamic environment of the ultimate receiving environment.

9. CONCLUSIONS

The ecological values of the intertidal marine habitat in Porirua Harbour are considered to be moderate in the Onepoto Inlet, whereas values are high in the near shore areas and moderate-low in the central subtidal basin areas of the Pauatahanui Inlet. The Wainui and Whareroa Stream mouth intertidal habitat is considered to have high ecological values.

For the Onepoto Inlet this is based on moderate to high species richness and diversity of invertebrates, a dominance of tolerant taxa but the presence of sensitive taxa, a predominance of finer sediment grain sizes, a high degree of coastal edge habitat modification, and contaminants present above effects thresholds.

In comparison, the near shore intertidal and subtidal areas within the Pauatahanui Inlet are characterised as having a high diversity and abundance of invertebrates, a diversity of sensitive taxa and the presence of tolerant taxa, variable grain size characteristics, low concentrations of heavy metals, significant areas of unmodified coastal fringe habitat (containing native coastal vegetation), but elevated concentrations of agrichemicals and PAHs detected in some sediment samples. However, the central subtidal basin areas within the Pauatahanui Inlet comprise almost entirely silt and clay sediment, a very thin layer of oxygenated surficial sediment, and a low abundance and diversity of invertebrates.

Throughout the literature investigated for this assessment, the common dominant threats to the harbour are recognised as sedimentation of the intertidal and subtidal benthic habitat and the discharge of contaminants. In order to maintain the moderate to high ecological values ascribed to Porirua Harbour, a key aim for large scale projects in the catchments should be to minimise sediment discharges (and associated contaminants) to the harbour.

10. REFERENCES

Allibone, R., David, B., Hitchmough, R., Jellyman, D., Ling, N., Ravenscroft, P., Waters, J. (2010). Conservation status of New Zealand freshwater fish, 2009. New Zealand Journal of Marine and Freshwater Research, 1-17.

Anstey, C., & Blaschke, P. (2003). Pauatahanui Inlet Restoration Plan Stage 1: Northern and Eastern Public Reserves. Report to Porirua City Council and Wellington Regional Council.

Auckland Regional Council (2004). Blueprint for monitoring urban receiving environments. Auckland Regional Council Technical Publication No. 168, Auckland.

Australian and New Zealand Environment and Conservation Council (ANZECC) (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1, The Guidelines.

BML, (2000). The Pauatahanui Estuary and its catchment: a literature summary and review. Report to Wellington Regional Council and Porirua City Council.

Bellingham, N. (1998). Pauatahanui Inlet - a living resource. Guardians of Pauatahanui Inlet, Wellington. Unpublished report.

Blaschke, P., Woods, J., Forsyth, F. (2010) The Porirua Harbour and its catchment: A literature summary and review. Report for Porirua City Council & Wellington City Council by Blaschke and Rutherford Environmental Consultants 101pp.

Borja, A., & Muxika, H. (2005). Guidelines for the use of AMBI (AZTI's Marine Biotic Index) in the assessment of the benthic ecological quality. Marine Pollution Bulletin, 50: 787-789.

Botherway, K. (1999). The effect of stormwater discharge on the soft shore ecology of Porirua Harbour. Unpublished thesis for B.Sc. (Hons), Victoria University of Wellington.

Botherway, K.J., & Gardner, J.P.A. (2002). Effect of storm drain discharge on the soft shore ecology of Porirua Inlet, New Zealand. *New Zealand Journal of Marine and Freshwater Research 36:* 241-255.

Cawthron Institute (2002). Estuarine Environmental Assessment and Monitoring: A National Protocol. Report to the Ministry for the Environment, Sustainable Management Fund Project.

Cummings, V., Hatton, S., Nicholls, P. (2002). Upper Waitemata Harbour (UWH) Benthic Habitat Survey. Unpublished report for the Auckland Regional Council. NIWA Client Report ARC02285, August 2002 49pp.

Department of Conservation (DOC) (1996). Conservation Management Strategy for Wellington: 1996-2005. Department of Conservation, Wellington.

Ford, R.B., Anderson, M.J., Davison, B. (2004) Ecological monitoring of the Okura Estuary, 2003-2004: testing the continued application of regional modes. Auckland Regional Council Technical Publication 258, 56pp.

Fuller, S. (1995). Designation of Inland Route (Transmission Gully) Assessment of Ecological Impacts. Report to Beca Stevens

Gibb, J.G., & Cox, G.J. (2009). Patterns and rates of sedimentation within Porirua Harbour. Report prepared for Porirua City Council, Wellington.

Gibbs, M., Hewitt J. (2004) Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC. Auckland Regional Council Technical Publication 264, 48 pp.

Glasby, G.P., Moss, R.L., Stoffers, P. (1990). Heavy-metal pollution in Porirua Harbour, New Zealand. *New Zealand Journal of Marine and Freshwater Research 24:* 233-237.

Goff, J.R., Nichol, S.L., Rouse, H.L. (Eds) (2003). *The New Zealand Coast.* Dunmore Press (Palmerston North) and Whitireia Publishing with Daphne Brasell Associates (Wellington), New Zealand.

Grange, K.R. (1993). Distribution, abundance, and population structure of cockles (*Austrovenus stutchburyi*) in Pauatahanui Inlet. Report prepared for Guardians of the Inlet, Wellington.

Grange, K., & Tovey, A. (2002). Cockles in Pauatahanui Inlet: Results of the 2001 sampling programme. Report to the Guardians of Pauatahanui Inlet.

Greater Wellington Regional Council (2008). Queen Elizabeth Park Resource Statement.

Greater Wellington Regional Council (2000). Regional Coastal Plan for the Wellington Region. Greater Wellington Regional Council Publication No. WRC/RP-G-00/02.

Healy, W.B. (1980). Pauatahanui Inlet - an environmental study. New Zealand Department of Scientific and Industrial Research, DSIR Information Series 141, Wellington.

Hewitt, J.E., & Funnell, G.A. (2005). Benthic marine habitats and communities of the southern Kaipara. Auckland Regional Council Technical Publication 275, 81 pp.

Hooper, K.L. (2002). The impact of stormwater discharges on freshwater, marine water and marine sediments and the implications for environmental management of the Pauatahanui Inlet, Porirua, New Zealand. Unpublished thesis, Masters of Applied Science, Massey University.

Jones, J.B., Hadfield, J.D. (1985). Fishes from Porirua and Pauatahanui Inlets: occurrence in gill nets. New Zealand Journal of Marine and Freshwater Research 19: 477-484.

Kennedy, P. (1980). Pauatahanui Inlet: A closer look. Soil and Water, 1980, p7-10.

McDougall, J.C. (1976). Distribution of surface sediments of Pauatahanui Inlet. NZOI Oceanographic Field Report 7.

MacDonald, A., Joy, M. (2009). Freshwater Biodiversity in the Wellington Region. Unpublished Report for the Department of Conservation, Wellington Conservancy.

Milne, J.R., & Watts, L. (2008). Stormwater contaminants in urban streams in the Wellington Region. Report to Greater Wellington Regional Council.

Milne, J.R. & Sorensen, P.G. (2009). Porirua Harbour subtidal sediment quality monitoring. Report to Greater Wellington Regional Council.

Morley, M.S. (2004) Seashells of New Zealand. New Holland Publishers Ltd, 143 pp.

Morton, J.E., & Miller, M.C. (1968). The New Zealand Seashore. Williams Collins Sons and Co. Ltd, Glasglow, Great Britain.

Nicholls, P., Norkkok, A., Ellis, J., Hewitt, J., Bull, D. (2009). Short term behavioural responses of selected benthic invertebrates inhabiting muddy habitats to burial by terrestrial clay. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2009/116.

Nilsen, J.P., Marshall, G.J., Patterson, R.F., Tonkin, N.P., Keogh, C.M. (1988). Coastal Resources Management Plan. Report to the Porirua Harbour Authority.

Owen, K. (1984). Pauatahanui Wildlife Management Reserve Management Plan. NZ Wildlife Service, Department of Internal Affairs, Wellington.

Page, M., Heron, D., Trustrum, N. (2004). Pauatahanui Inlet - Analysis of historical catchment land use and land use change. Geological and Nuclear Sciences Ltd Report to Porirua City Council.

Ravine, D.A. (1992). Foxton Ecologiocal District: Survey Report for the Protected Natural Areas Programme. Department of Conservation, Wanganui Conservancy.

Porirua Harbour Bathymetric Survey (2009) http://www.pcc.govt.nz/Publications.

Read, G.B. (1984). Persistence of infaunal polychaete zonation patterns on a sheltered, intertidal sand flat. *New Zealand Journal of Marine and Freshwater Research 18*(4): 399-416.

Robertson, B.M., Gillespie, P.A., Asher, R.A., Frisk, S., Keeley, N.B., Hopkins, G.A., Thompson, S.J., Tuckey, B.J. (2002). Estuarine Environmental Assessment and Monitoring: A National Protocol. Part A. Development, Part B. Appendices, and Part C. Application. Prepared for supporting Councils and the Ministry for the Environment, Sustainable Management Fund Contract No. 5096. Part A. 93pp, Part B. 159pp, Part C. 40pp plus fieldsheets.

Robertson, B., & Stevens, L. (2007). Kapiti, Southwest, South Coasts and Wellington Harbour: Risk Assessment and Monitoring Recommendations. Report prepared by Wriggle Ltd for Greater Wellington Regional Council.

Robertson, B., & Stevens, L. (2009). Porirua Harbour Intertidal Fine Scale Monitoring 2008/09. Report to Greater Wellington Regional Council.

Robertson, B., & Stevens, L. (2010). Porirua Harbour Intertidal Fine Scale Monitoring 2009/10. Report to Greater Wellington Regional Council.

Rosier, J. (1994). Management of Pauatahanui Inlet: Discussion Document. Wellington Regional Council Publication WRC/PP-T-93/67.

Ruiz, J.M., Pérez, M., Romero, J. (2001). Effects on fish farm loadings on seagrass (*Posidonia oceanica*) distribution, growth and photosynthesis. Marine Pollution Bulletin 42:749-760.

Schwarz, A.M., Morrison, M.A., Hawes, I., Halliday, J. (2006). Physical and biological characteristics of a rare marine habitat: sub-tidal seagrass beds of offshore islands. Department of Conservation Science for Conservation 269, 39 pp.

SKM (2010). Harbour Sediment Transport Assessment, Transmission Gully Phase II: Workstream 12, Technical Report 12d: Volume 1. Report to NZTA.

Sorensen, P.G. & Milne, J.R. (2009). Porirua Harbour targeted intertidal sediment quality assessment. Report to Greater Wellington Regional Council and Porirua City Council.

Stevens, L., & Robertson, B. (2006). Broad Scale Habitat Mapping of Sandy Beaches and River Estuaries on the Western Wellington Coasts. Report prepared by Cawthron Institute for Greater Wellington Regional Council.

Stevens, L., & Robertson, B. (2008). Porirua Harbour Broad Scale Habitat Mapping 2007/2008. Report to Greater Wellington Regional Council.

Stevens, L., & Robertson, B. (2009). Porirua Harbour Intertidal Macroalgal Monitoring 2008/09. Report to Greater Wellington Regional Council.

Stevenson, M.L.L., Field, K.D., Holton, A., Baxter, A. (1987). Regional background discussion paper on areas to be investigated for proposed marine protected areas in the Central Fisheries Management Area. Unpublished report, Ministry of Agriculture and Fisheries, Wellington.

Stephenson, G., & Mills, G.N. (2006). Porirua Harbour long-term baseline monitoring programme: Sediment chemistry and benthic ecology results from the October 2005 survey. Report prepared for Greater Wellington Regional Council, Wellington.

Swales, A., Bentley, S.J., McGlone, M.S., Ovenden, R., Hermanspahn, N., Budd, R., Hill, A., Pickmere, S., Haskew, R., Okey, M.J. (2005). Pauatahanui Inlet: effects of historical catchment landcover changes on inlet sedimentation. Report prepared for Greater Wellington Regional Council and Porirua City Council, Wellington.

Taylor, M.J., & Kelly, G.R. (2001). Inanga spawning habitats in Wellington. NIWA Report to Wellington Regional Council, NIWA, Christchurch.

Turner, S., Schwarz, A.M. (2006). Management and conservation of seagrass in New Zealand: an introduction. Department of Conservation Science for Conservation 264, 90 pp.

Wellington Regional Council, Porirua City Council, Department of Conservation, MAF Fisheries (1995). Integrated Management of Pauatahanui Inlet. Wellington Regional Council, Wellington.

Appendix 10A: Contaminant analysis methods and trigger levels

Analysis methodology

HILL LABORATORIES - SUMMARY OF METHODS		
The following table gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.		
Sample Type: Sediment		
Test	**Method Description**	**Default Detection Limit**
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction.	-
Polycyclic Aromatic Hydrocarbons Trace in Soil	Sonification extraction, SPE cleanup, GC-MS SIM analysis US EPA 8270C. Tested on as received sample.	-
Dry Matter (Env)	Dried at 103°C (removes 3-5% more water than air dry) for 18hr, gravimetry. US EPA 3550.	0.10 g/100g as rcvd
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-
Total Recoverable Copper	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.2 mg/kg dry wt
Total Recoverable Lead	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2.	0.04 mg/kg dry wt
Total Recoverable Phosphorus*	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2	40 mg/kg dry wt
Total Recoverable Zinc	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, trace level. US EPA 200.2	0.4 mg/kg dry wt
Total Organic Carbon	Acid pretreatment to remove carbonates if present, Elementar Combustion Analyser.	0.05 g/100g dry wt
Total Nitrogen	Catalytic Combusion (900°C, O_2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt

Trigger levels

Concentrations of copper, lead, zinc and high molecular weight polycyclic aromatic hydrocarbons (HMW-PAHs) are compared against Auckland Regional Councils (ARC) Environmental Response Criteria (ERC) (ARC 2004), whereas mercury, DDT and dieldrin are compared against Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) Interim Sediment Quality Guidelines (ISQG). The table below provides the trigger and threshold limits for both the ARC ERC and ISQG.

ARC ERC thresholds were developed based on ANZECC (2000) ISQG and other internationally recognised sediment quality guidelines. Contaminant concentrations in the green range indicate that the biology of the site is unlikely to be impacted, whereas the amber range indicates possible impact and the red range indicates probable impact.

CONTAMINANT	ARC ERC Green	ARC ERC Amber	ARC ERC Red	ISQG-Low	ISQG-High
Copper	<19	19-34	>34	65	270
Lead	<30	30-50	>50	50	220
Zinc	<124	124-150	>150	200	410
HMW-PAHs	<0.66	0.66-1.7	>1.7	1.7	9.6
Mercury	-	-	-	0.15	1
Total DDT	<3.9	-	>3.9	1.6	46
Dieldrin	<0.72	-	>0.72	0.02	8

Appendix 10B: Fish species known to use the Porirua Harbour

(Source: Healy, 1980; Jones & Hadfield, 1985; Stevenson et al., 1987)

Species	Common name
Geotria australis	Lamprey *
Mustelus lenticulatus	Rig
Callorhynchus milii	Elephant fish
Myliobatis tenuicaudatus	Eagle ray
Arripis trutta	Kahawai
Adrichetta forsteri	Yellow-eyed mullet
Sardinops neopilchardus	Pilchard
Engraulis australis	Anchovy
Hemirhamphus ihi	Garfish
Retropinna retropinna	Smelt
Syngnathus norae	Pipefish *
Stigmatophora longirostris	Long-snout pipefish
Hippocampus abdominalis	Seahorse
Scomber australasicus	Blue mackerel
Trachurus novaezelandiae	Jack mackerel
Thyrsites atun	Barracouta
Caranx georgianus	Trevally
Nemadactylus macropterus	Tarakihi
Chrysophrys auratus	Snapper
Latridopsis ciliaris	Blue moki
Seriolella brama	Warehou
Mugil cephalus	Grey mullet
Pseudophysis bacchus	Red cod
Lotella rachinus	Rock cod
Cheilidorichthys kumu	Gurnard
Pseudolabrus celidotus	Spotty
Pseudolabrus fucicola	Banded parrotfish
Rhombosolea plebeia	Sandflounder
Rhombosolea leporina	Yellowbelly flounder
Peltorhamphus novaezeelandiae	New Zealand sole
Peltorhamphus latus	Dwarf common sole
Leptoscopus macropygus	Striped stargazer
Genyagnus novaezelandiae	Spotted stargazer
Forsterygion varium	Cockabully
Trypterygion robustum	Robust blenny
Grahamichthys radiatus	Graham's gudgeon
Salmo trutta	Brown trout
Conger verrauxi	Conger eel
Anguilla australis	Shortfin eel
Anguilla dieffenbachii	Longfin eel*
Galaxias argenteus	)
Galaxias fasciatus	)Whitebait*
Galaxias maculatus	)

*At Risk Species (Allibone *et al*., 2010)

Appendix 10C: Photos of sample sites and intertidal benthic sediment.

Plate 10.1: Kakaho Stream mouth

Plate 10.2: Intertidal benthic sediment at Kakaho Stream mouth

Plate 10.3: Duck Creek mouth

Plate 10.4: Intertidal benthic sediment at Duck Creek mouth

Plate 10.5: Pauatahanui Stream mouth

Plate 10.6: Intertidal benthic sediment at Pauatahanui Stream mouth

Plate 10.7: Horokiri Stream mouth

Plate 10.8: Intertidal benthic sediment at Horokiri Stream mouth

Plate 10.9: Rations Stream mouth

Plate 10.10: Intertidal benthic sediment at Rations Stream mouth

Plate 10.11: Porirua Stream mouth

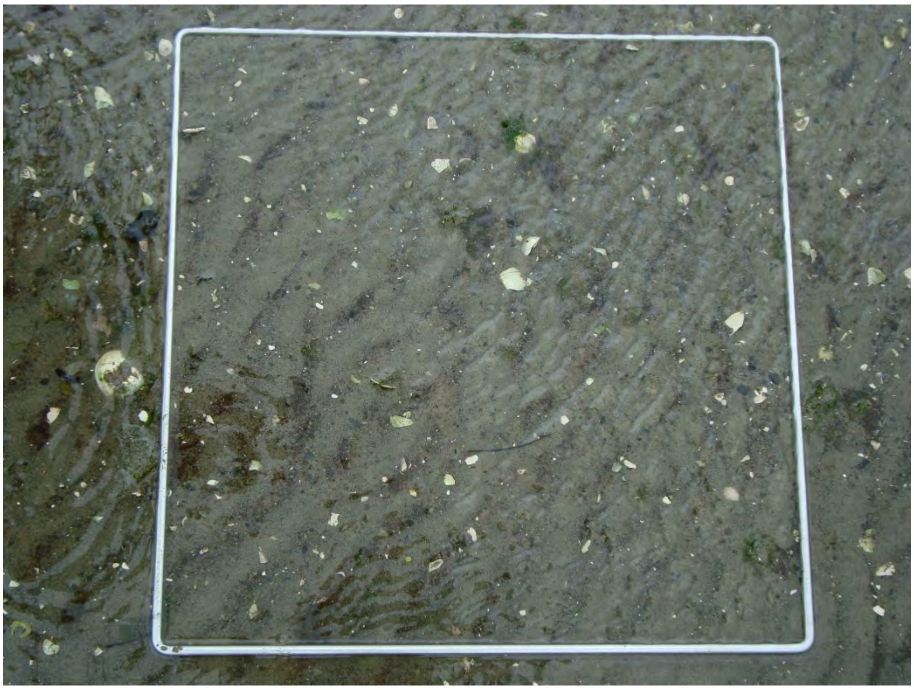


Plate 10.12: Intertidal benthic sediment at Porirua Stream mouth

Plate 10.13: Wainui Stream mouth

Plate 10.14: Intertidal benthic sediment at Wainui Stream mouth

Plate 10.15: Whareroa Stream mouth viewed from top of coastal dunes.

Plate 10.16: Whareroa Stream mouth - view downstream of foot bridge.

Plate 10.17: Whareroa Stream discharging to Whareroa Beach (note the humic coloured water, intertidal sandflats and driftwood).

Appendix 10D: Detailed Subtidal Site Descriptions

Pauatahanui Inlet

Site P1

The surficial sediment at Site P1 was predominantly firm sand interspersed with small (<0.1 m^2) patches of sandy mud. A combination of living cockles (*Austrovenus stutchburyi*) and dead *Austrovenus stutchburyi* shells at the surface was a notable biogenic habitat. The sediment anoxic layer was approximately 7cm deep.

Biologically, Site P1 was predominantly characterised by the cockle *Austrovenus stutchburyi* present in low to moderate densities and down to a depth of 4 to 5 cm. The green alga *Ulva* sp. and red alga *Gracilaria* sp. occurred attached to living and dead *Austrovenus stutchburyi*, with the latter also conspicuous as drift. Occasional patches of *Enteromorpha intestinalis* were observed. Common epifauna included the cushion star *Patriella regularis*, the topshell *Diloma subrostrata*, the speckled whelk *Cominella adspersa* and hermit crab *Pagurus* sp.

Site P2

Fine, soft anoxic mud was characteristic of Site P2. The sediment surface was generally featureless apart from a patchily distributed fine filamentous alga (unidentified). The sediment anoxic layer was < 1 cm deep.

Occasional worm/crab holes were observed within sample quadrats. No epifaunal organisms were encountered, but the assessment was restricted by very poor visibility. Note: old tyres and construction materials (concrete and reinforcing iron) were also present at this site.

Site P3

The surficial sediment was relatively featureless apart from occasional dead cockle shells' being a mixture of firm sand and smaller patches of sandy mud. The sediment anoxic layer was approximately 6 cm below the sediment surface.

Epifauna included the hermit crab *Pagurus* sp., the purple-mouthed whelk *Cominella glandiformis*, and white/pink finger sponge (unidentified). Several crab/worm holes were observed at the sediment surface.

Site P4

The surficial sediment was generally featureless sediment being a mixture of fine silty sand and mud patches, although was predominately sandy in nature. The anoxic layer was approximately 4 to 5 cm below the sediment surface.

Epifaunal organisms included the cushion star *Patriella regularis*, hermit crab *Pagurus* sp. and a white/pink finger sponge (unidentified). Occasional crab/worm holes were observed at the sediment surface.

Site P5

The surficial sediment was predominantly firm sand, interspersed with smaller patches of sandy mud (< 0.25 m^2). Live *Austrovenus stutchburyi* and dead *Austrovenus stutchburyi* shells were present at the sediment surface (as for Site P1). The sediment anoxic layer was approximately 5 to 6 cm deep.

Austrovenus stutchburyi was present at low densities and down to a depth of 2 to 3 cm. *Gracilaria* sp. occurred attached to both living and dead *Austrovenus stutchburyi*, being also present as drift. Small patches of *Ulva* sp. were also evident attached to the immediate substratum and on dead *Austrovenus stutchburyi* shells. Epifauna included the cushion star *Patriella regularis*, the topshell *Diloma subrostrata*, the speckled whelk *Cominella adspersa* and hermit crab *Pagurus* sp. Crab/worm holes were observed at the sediment surface.

Site P6
The surficial sediment was typified by fine, featureless and predominantly anoxic sediment. Anoxic layer was present < 1 cm below the sediment surface.

Occasional worm/crab holes were observed. Epifaunal organisms were represented by several hermit crabs and one eleven-armed starfish *Coscinasterias calamaria*.

Site P7
The surficial sediment at Site P7 was predominantly muddy, with sand patches also common. The surface was generally featureless apart from small patches of dead *Austrovenus stutchburyi* shells. The anoxic layer was approximately 4 cm beneath the sediment surface. *Gracilaria* sp. and *Ulva* sp. were common attached to dead *Austrovenus stutchburyi* shells and as drift.

Epifauna included the hermit crab *Pagurus* sp., the speckled whelk *Cominella adspersa*, purple-mouthed whelk *Cominella glandiformis* and the topshell *Diloma subrostrata*.

Site P8
Featureless substratum being a mixture of mud and sand patches, although predominantly muddy. The anoxic layer was approximately 3 cm below the sediment surface.

Epifauna comprised of the hermit crab *Pagurus* sp., the speckled whelk *Cominella adspersa*, and a white finger sponge (unidentified).

Site P9
Underwater visibility approximately 0.5 m; surficial sediment typified by fine, amorphous mud. Anoxic layer was present < 1 cm below the sediment surface.

Worm/crab holes present. Epifauna included *Pagurus* spp and *Cominella adspersa.*

Site P10
Underwater visibility approximately 0.5 m; surficial sediment typified by fine, amorphous mud. Anoxic layer was present < 1 cm below the sediment surface.

Worm/crab holes present. Epifauna included *Cominella adspersa.*

Site P11
Underwater visibility approximately 0.5 m; surficial sediment typified by fine, amorphous mud. Anoxic layer was present < 1 cm below the sediment surface.

Worm/crab holes present. No epifauna in sample quadrats.

Site P12
Underwater visibility approximately 0.5 m; surficial sediment typified by fine, amorphous mud. Anoxic layer was present < 1c m below the sediment surface.

Worm/crab holes present. No epifauna in sample quadrats.

Site P13
Underwater visibility approximately 0.5 m; surficial sediment typified by fine, amorphous mud. Anoxic layer was present < 1 cm below the sediment surface.

Worm/crab holes present. Epifauna included *Pagurus* spp. and *Cominella adspersa.*

Note: Searched site for the occurrence of *Atrina zelandica*, but none found.

Site P14
Underwater visibility approximately 0.5 m; surficial sediment was typified by fine, anoxic mud being amorphous in nature. Anoxic layer was present < 1 cm below the sediment surface. The site was characterised by the horse mussel *Atrina zelandica* which occurred at low densities. Worm/crab holes were also observed.

The above-surface portion of the *Atrina zelandica* shells were covered in red and green algae and encrusting invertebrates (not identified). Other epifauna were hermit crabs (*Pagurus* spp.).
Note: Searched site for the occurrence of high-density patches of *Atrina zelandica*, but none found, just low-density patches.

Site P15
Underwater visibility approximately 0.25 m; surficial sediment typified by fine, amorphous mud. Anoxic layer was present < 1 cm below the sediment surface.

Worm/crab holes present. Epifauna consisted of *Coscinasterias calamaria.*
Note: Searched site for the occurrence of *Atrina zelandica*, but none found.

Site P16
Underwater visibility approximately 0.25 m; surficial sediment typified by fine, amorphous mud. Anoxic layer was present < 1 cm below the sediment surface.

Worm/crab holes present. No epifauna in sample quadrats.

Note: Searched site for the occurrence of *Atrina zelandica*, but none found.

<u>Onepoto Inlet</u>
Site O1
The surficial sediment comprised of fine, soft, featureless and primarily anoxic sediment with the anoxic layer < 1 cm beneath the surface. Occasional worm/crab holes were observed on the sediment surface.

Epifaunal organisms included the hermit crab *Pagurus* sp., the speckled whelk *Cominella adspersa* the purple-mouthed whelk *Cominella glandiformis*. The red algae *Gracilaria* sp. and *Rhodymenia dichotoma* were also present in low abundance.

Site O2
As for Site O1, the surficial sediment consisted of fine, soft featureless anoxic mud with the anoxic layer < 1 cm from the surface.

The hermit crab *Pagurus* sp. was the only epifauna observed. Occasional worm/crab holes were observed on the sediment surface.

Site O3
Site O3 was unique based on the presence of small clumps of the colonial serpulid worm *Spirobranchus cariniferus* (commonly known as *Pomatoceros caeruleus*) attached to very small pebbles and surficial mud. Surrounding and directly beneath the tube worm patches the predominant substrate type was fine anoxic mud, with the anoxic layer < 1 cm from the surface. Small sponges, bryozoa and algae

(*Enteromorpha* sp, *Gracilaria* sp and *Ceramium apiculatum*) were associated with the *Spirobranchus cariniferus* patches (biogenic habitat). *Gracilaria* sp. was also present as drift.

Epifauna included the cushion star *Patriella regularis,* the speckled whelk *Cominella adspersa,* the purple-mouthed whelk *Cominella glandiformis*, and limpet *Notoacmea helmsi.*

Site O4

The surficial sediment at Site O4 was predominantly firm sand with the sediment anoxic layer occurring approximately 5 to 6 cm below the surface. The site was notable due to the presence of *Zostera* sp. Employing the coverage classification presented in Schwarz *et al*., (2006), seagrass cover ranged from one to two, i.e., generally low cover.

The brown alga *Colpomenia sinuosa* occurred in association with *Zostera* sp. as well as on the sediment surface. Other algal species co-occurring with *Zostera* sp. were the red algae *Polysiphonia* spp., *Gracilaria* sp. and green algae *Enteromorpha* sp. and *Ulva* sp.

Epifauna associated with *Zostera* habitat included the hermit crab *Pagurus* sp., the speckled whelk *Cominella adspersa* and the cushion star *Patriella regularis.* Several individuals of the feathery sea hare *Bursatella leachii* were also observed. Crab/worm holes were present throughout the *Zostera* habitat.

Site O5

Underwater visibility nil; surficial sediment (based on trowel sampling) was predominantly silty sand with mud patches also apparent. Dead *Austrovenus stutchburyi* shells were collected from the sediment surface. The anoxic layer was approximately 2 cm beneath the sediment surface. *Gracilaria* sp. and *Ulva* sp. were attached to dead *Austrovenus stutchburyi* shells taken from the sediment surface.

Epifauna consisted of *Diloma subrostrata.*

Site O6

Underwater visibility nil; surficial sediment (based on trowel sampling) anoxic mud. Anoxic layer was present < 1 cm below the sediment surface. *Gracilaria* sp. and *Ulva* sp. were attached to dead *Austrovenus stutchburyi* shells and possibly occurred as drift.

Epifauna consisted of *Pagurus* spp.

Appendix 10E: Invertebrate Sensitivity Characteristics

Sources: NIWA Website, Wikipedia, Robertson & Stephens (2009) and Nicholls et al. (2009)

Tolerance Scales: enrichment (based on Borja et al., 2000) and mud (based on Gibbs & Hewitt, 2004; Norkko et al., 2001) and on authors own experience.

Group and Species		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
Porifera	*Porifera sp.1*	NA	NA	YES	YES	Unidentified sponge.
Anthozoa	*Anthozoa sp.1*	**Indifferent**	NA			Unidentified anemone. An upright, stout, pale cream-coloured species.
	Edwardsia sp.#1	**Indifferent**	NA	YES		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.
Nemertea	*Nemertea sp.1, 2, 3, 4*	**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%.
Nematoda	*Nematoda sp*	**Tolerant**	**Mud tolerant**	YES		Small unsegmented roundworms. Very common. Feed on a range of materials. Common inhabitant of muddy sands. Many are so small that they are not collected in the 0.5mm mesh sieve. Generally reside in the upper 2.5cm of sediment. Intolerant of anoxic conditions.
Polychaeta	*Aglaophamus macroura*	**Indifferent**	NA			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 sp.1	**Tolerant**	**Strong sand preference**	YES	YES	A small surface deposit-feeding spionid polychaete that lives throughout the sediment to a depth of 10cm. Although Aonides is free-living, it is not very mobile and prefers to live in fine sands. Aonides is very sensitive to changes in the silt/clay content of the sediment. In general, polychaetes are important prey items for fish and birds. Optimum range 0-=5% mud, distribution 0-5% mud.
	Armandia maculata	**Sensitive**	NA		YES	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.

Group and Species		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
	Axiothella serrata	**Sensitive**	NA			Subsurface deposit-feeder. Belongs to Family Maldanidae. Found intertidally in enclosed harbours/estauries only. Prefers fine to very fine sands where it builds a loosely-cemented sand-grain tube or burrow shaped like a J to about 15cm depth. Pollution and mud intolerant.
	Boccardia (Paraboccardia) syrtis and acus	**Sensitive**	**Sand preference**	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.
	Cirratulidae sp.	**Opportunistic**	**Sand preference**	YES		Subsurface deposit feeder that prefers sands. Small sized, tolerant of slight unbalanced situations. Optimum range 10-15% mud, distribution range 5-70% mud.
	Capitella capitata	**Opportunistic and Anoxia Tolerant**	**Prefers some mud but not high percentage**			A blood red capitellid polychaete which is very pollution tolerant. Common in suphide rich anoxic sediments. Optimum range 10-15% or 20-40% mud, distribution range 0-95% mud, based on *Heteromastus filiformis*.
	Dorvilleidae sp.1	NA	NA			Active surface-dwelling omnivores with chitinous jaw elements consisting of four longitudinal rows of minute, toothed, black plates, and with two pairs of appendages on the rounded prostomium. Not generally common.
	Glyceridae	**Indifferent**	**Prefers some mud but not high percentage**			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.
	Goniada sp.1	**Indifferent**	**Prefers some mud but not high percentage**	YES		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.1	**Indifferent**	NA			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, *Hetromastus* 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.
	Microspio maori	**Tolerant**	**Prefers sand**			A small, common intertidal spionid. Can handle moderately enriched situations. Tolerant of high and moderate mud contents. Prey item for fish and birds. Optimum range expected to be 0-20% mud.

Group and Species		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
	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.
Polychaeta	*Paraonidae sp. 1*	**Tolerant**	Uncertain			Slender burrowing worms that are probably selective feeders on grain-sized organisms such as diatoms and protozoans. *Aricidea sp.*, a common estuarine paraonid, 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 changes in the mud content of the sediment. Some species of *Aricidea* are associated with the sediments with high organic content. *Arcidea* sp. prefers some mud but not a high percentage. Optimum range 35-50%, distribution range 0-70%.
	Pectinaria australis	**Sensitive**	NA			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 seagrass beds. Intolerant of anoxic conditions.
	Pectinaria vallata	**Tolerant**	**Prefers mud**			An intertidal soft shore nereid (which are common and very active, omnivorous worms). Prefers sandy sediments. Optimum range 55-60% of 35-55% mud, distribution range 0-100% mud.
	Phyllodocidae	**Indifferent**	NA			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.
	Platynereis australis	**Tolerant**	**Prefers mud**			An intertidal soft shore nereid (which are common and very active, omnivorous worms). Prefers mud/sand sediments. Optimum range 55-60% or 35-55%, distribution range 0-100%.
	Sabellariidae sp. 1	NA	NA			*Sabellariids* live in thick-walled sand and shell-fragment tubes cemented to rock or to any durable surface. As such they often modify the habitat. Some colonial species form conspicuous hummocks and substantial reefs. *Sabellariids* are filter feeders and detritus feeders. Pollution and mud intolerant.
	Sabellidae sp. 1	**Sensitive**	NA			*Sabellids* are not usually present in intertidal sands, though some minute forms do occur low on the shore. They are referred to as a fan or feather-duster worms and are so-called from the appearance of the feeding appendages, which comprise a crown of two semicircular fans of stiff filaments projected from their tube.
	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.

Group and Species		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
	Scoloplos (Scoloplos) cylindrifer	**Sensitive**	**Prefers sand**			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**			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.
	Spionidae sp. 1 and 2	NA	NA			An unknown spionid polychaete. Feed at the sediment-water interface - as either deposit or suspension feeders.
	Spirobranchus cariniferus	**Indifferent**	NA			Better known as *Pomatocerus caeruleus* this conspicuous serpulid was the first NZ polychaete to be given a name. Currently in genus *Spirobranchus*, but further study may place it back in *Pomatoceros*. This species is the common colonial serpulid of NZ shores. It is found mostly on the lower shore on shaded rock faces, becoming more prominent in the cooler south, where tube layers up to 30cm thick may occur. On soft shores, small groups occur on top of any suitable hard object, such as small stones and dead shells.
	Syllidae	**Indifferent**	**Prefers sand**	YES	YES	Belongs to Family *Syllidae*. Delicate and colourful predators. Very common, often hidden amongst epifauna. Small size and delicate in appearance. Prefers mud/sand sediment. Optimum range 25-30% mud, distribution range 0-40%.
	Terebellidae sp. 1	**Indifferent**	NA			Large tube or crevice dwellers with a confusion of constantly active head tentacles and a few pairs of anterior gills.
	Travisia olens	**Sensitive**	**Strong sand preference**		YES	Belongs to the *Opheliids*. Short-bodies, cigar-shaped, muscular sand burrowers. *Ophelliids* 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.
Oligochaeta	*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.
	Amphibola crenata	NA				Surface deposit feeder with average mobility. Prefers a muddy habitat. Is sensitive to depth and duration of deposited sediment.
	Chiton glaucus	**Indifferent**	NA			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 surrdounded by a girdle, is fairly large, up to 55mm in length.
Gastropoda	*Cominella glandiformis*	NA	**Strong sand preference**	YES	YES	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.

Group and Species		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
	Diloma subrostrata	NA	**Strong sand preference**	YES	YES	The mudflat top shell, lives on mudflats, but prefers a more solid substrate such as shells, stones, etc. Endemic to NZ and feeds on the film of microscopic algae on top of the mud. Optimum range 5-10% mud, distribution range 0-15% mud.
	Eatoniella olivacea	NA	NA			A small smooth conical gastropod, 2 mm long and dark brown to black. It lives by scraping the detritus or diatomaceous film from the surfaces of algae.
	Gastropoda sp. 1 and 2	NA	NA			Yet to be identified.
	Haminoea zelandiae	NA	NA			The white bubble shell is a species of medium-sized sea snail or bubble snail, a marine opisthobranch gastropod mollusc in the Family *Haminoeidae*, the bubble snails. This bubble snail is common on intertidal mudflats in sheltered situations associated with seagrass. This species is endemic to NZ. It is found around the North Island and the northern part of the South Island.
	Notoacmaea helmsi	NA	**Strong sand preference**	YES	YES	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.
	Potamopyrgus antipodarum	**Tolerant**	**Prefers mud**	YES	YES	Endemic to NZ. Small snail that can live in freshwater as well as brackish conditions. In estuaries, it can tolerate up to 17-24% salinity. Shell varies in colour from gray to light/dark brown. Feeds on decomposing animal and plant matter, bacteria, and algae. Intolerant of anoxic surface muds but can tolerate organically enriched conditions. Tolerant of muds. Populations in saline conditions produce fewer offspring, grow more slowly and undergo longer gestation periods.
	Potamopyrgus estuarinus	**Tolerant**	**Prefers mud.**			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. Tolerant of muds and organic enrichment.
	Trochus tiaratus	NA	NA			A small top snail from the Family *Trochidae* and is endemic to NZ.
	Xymene plebeius	NA	NA			Belongs to the Family Muricidae, or murex snails, which are a large and varied taxonomic family of small to large predatory sea snails.
	Zeacumantus lutulentus	NA	NA			A medium-sized mud snail. Endemic to the North Island and the northern half of the South Island of NZ. Very common on intertidal mudflats. On the mudflats, these snails plough their way across the surface, leaving recognisable tails. Each snail passes huge quantities of mud through its gut as it extracts organic matter from the mud.
Bivalvia	*Arthritica sp.1*	**Tolerant**	**Prefers mud but not high percentage**	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.

Group and Species		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
	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.
	Mocomona 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		This 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 deposition. Adults optimum range 0-5% mud, distribution 0-5% mud. Juveniles often found in muddier sediment.
	Solemya parkinsoni	NA	NA			The razor mussel. The elongate cylindrical shell valves have the brown, smooth shining epidermis extending beyond the margin forming a characteristic and distinctive fringe; interior of the shell a dull grey-white; grows up to 5 cm in length. A common species on sand banks at depths up to 25 cm.
Crustacea	*Amphipoda sp. 1*	NA	NA			An unidentified amphipod.
	Cephalocarida sp. 1	NA	NA			*Cephalocarida* (horseshoe shrimps) is a class of only about nine shrimp-like benthic species. Discovered in 1955. Found from the intertidal zone down to a depth of 1,500 m, in all kinds of sediments. They feed on marine detritus.
	Colurostylis lemurum	NA	**Prefers sand**			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.

Group and Species	Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
Copepoda	NA	NA			Copepods are a group of small crustaceans found in the sea and nearly every freshwater habitat. They constitute the biggest source of protein in the oceans. Usually have six pairs of limbs on the thorax. The benthic group of copepods (*Harpactacoida*) have worm-shaped bodies.
Halicarcinus varius	NA	NA			Pillbox crabs are usually found on the sand and mudflats but may also be encountered under stones on the rocky shore. *Halicarcinus varius* (10 mm) has a pear-shaped carapace, its upperhalf covered in small hairs. Males have hairy nippers. Its colour varies from white/green to yellow, found in sheltered areas on brown seaweeds or under stones.
Halicarcinus whitei	NA	NA			Another species of pillbox crab. Lives in intertidal and subtidal sheltered sandy environments.
Hemigrapsus crenulatus	NA	NA			The hairy-handed crab is commonly found on mudflats and sandflats, but it may also occur under boulders on the rocky shore intertidal. Is a very effective scavenger and tolerates brackish conditions.
Macrophthalmus hirtipes	NA	**Prefers mud, but not high percentage**	YES	YES	The stalk-eyed mud crab is endemic to NZ and prefers waterlogged areas at the mid to low water level. Makes extensive burrows in the mud. Tolerates moderate mud levels. This crab does not tolerate brackish or fresh water (<4ppt). Like the tunnelling mud crab, it feeds from the nutritious mud. Optimum range 45-50% mud, distribution range 0-95% mud.
Helice crassa	NA	**Strong mud preference**	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.
Mysidacea sp.1	**Indifferent**	NA			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.
Ostracoda sp. 1 and 2	NA	NA			*Ostracods* or seed shrimps, have a body which is encased by two valves.
Paracorophium sp.	**Indifferent**	**Strong mud preference**	YES	YES	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**				A family of amphipods.
Sphaeroma quoyanum	**Tolerant**	NA			A marine boring isopod found in estuarine waters of NZ, Australia and California. Forms burrows in a variety of substrates. Well known as an invader that forms burrows along marsh edges which encourages erosion.

Group and Species		Tolerance to Organic Enrichment	Tolerance to Mud	Present in Pauatahanui Inlet	Present in Onepoto Inlet	Details
	Chironomidae	**Tolerant**	NA			A member of this non-biting midge family.
Holothuroidea	*Trochodota dendyi*	**Sensitive**	NA			A sea cucumber that is soft bodied and worm-like in appearance and burrows up to 20cm into sand. A deposit feeder and sediment disturber.

Appendix 10F: Broad scale Habitat maps for Porirua Harbour

Source: Stevens & Robertson (2008)

Figure 3. Map of Macroalgal Cover - Porirua Harbour, December 2007.

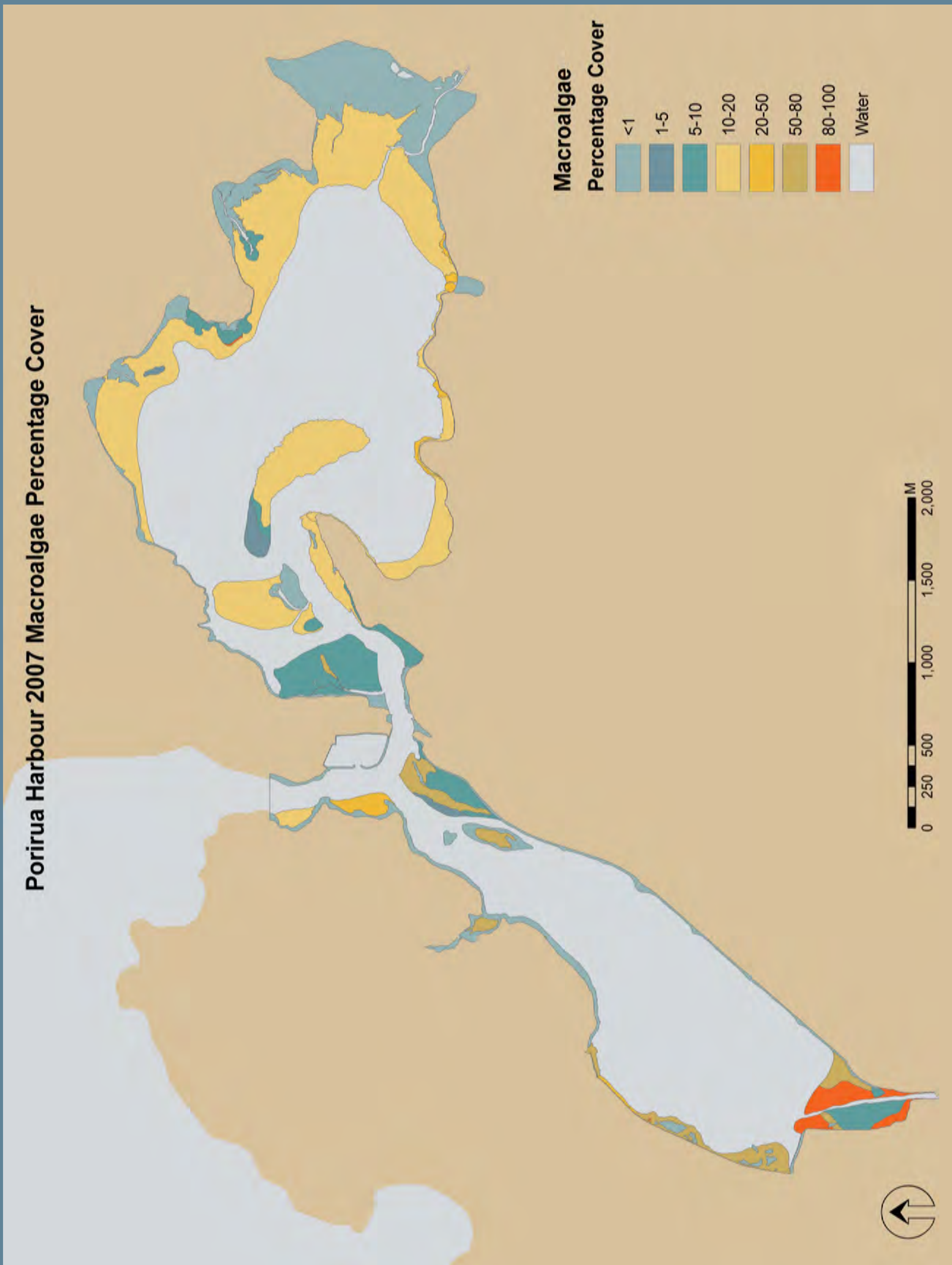


Figure 5. Map of Saltmarsh Vegetation Class - Porirua Harbour, December 2007.

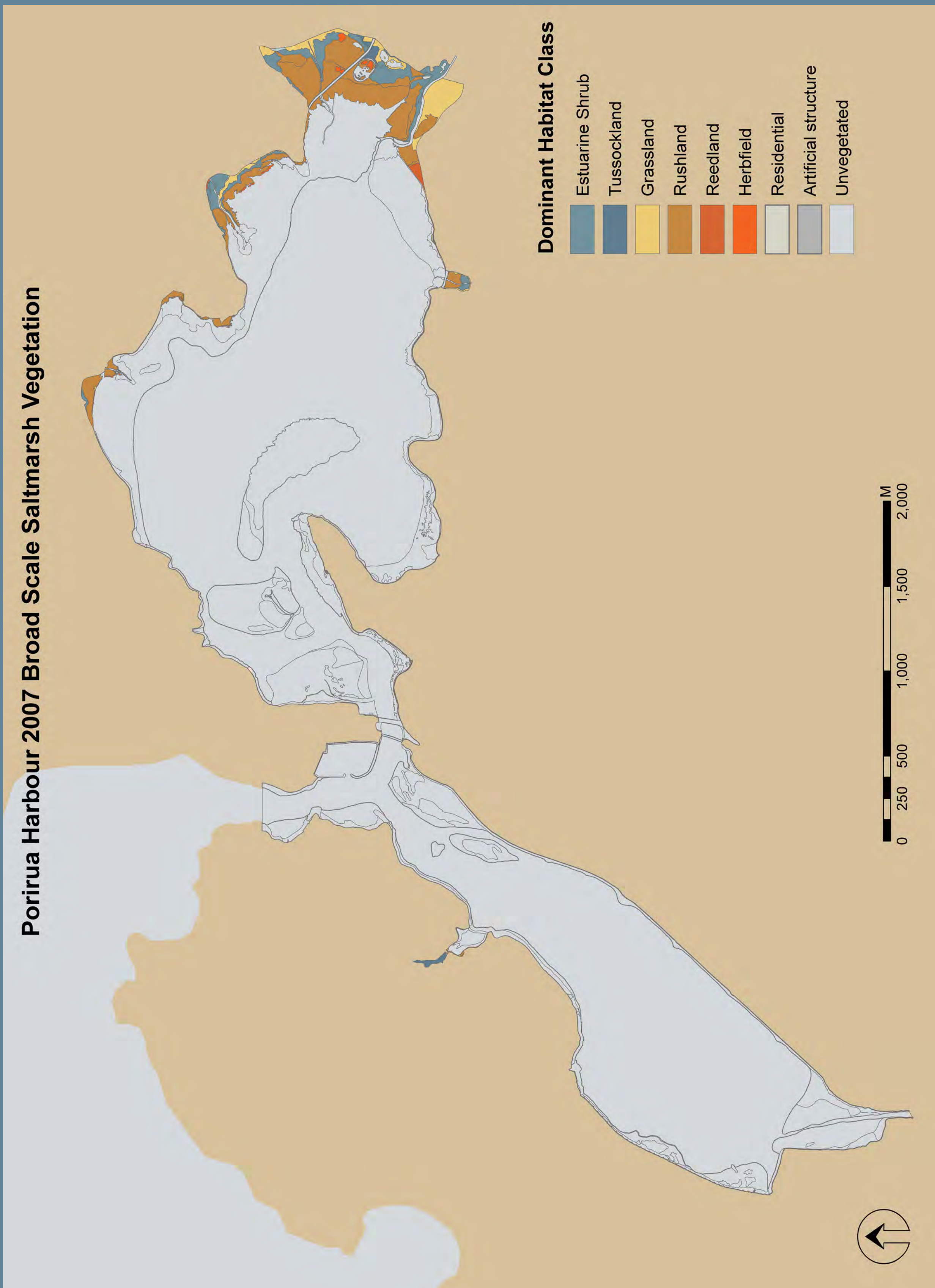


Figure 4. Map of Seagrass Cover - Porirua Harbour, December 2007.

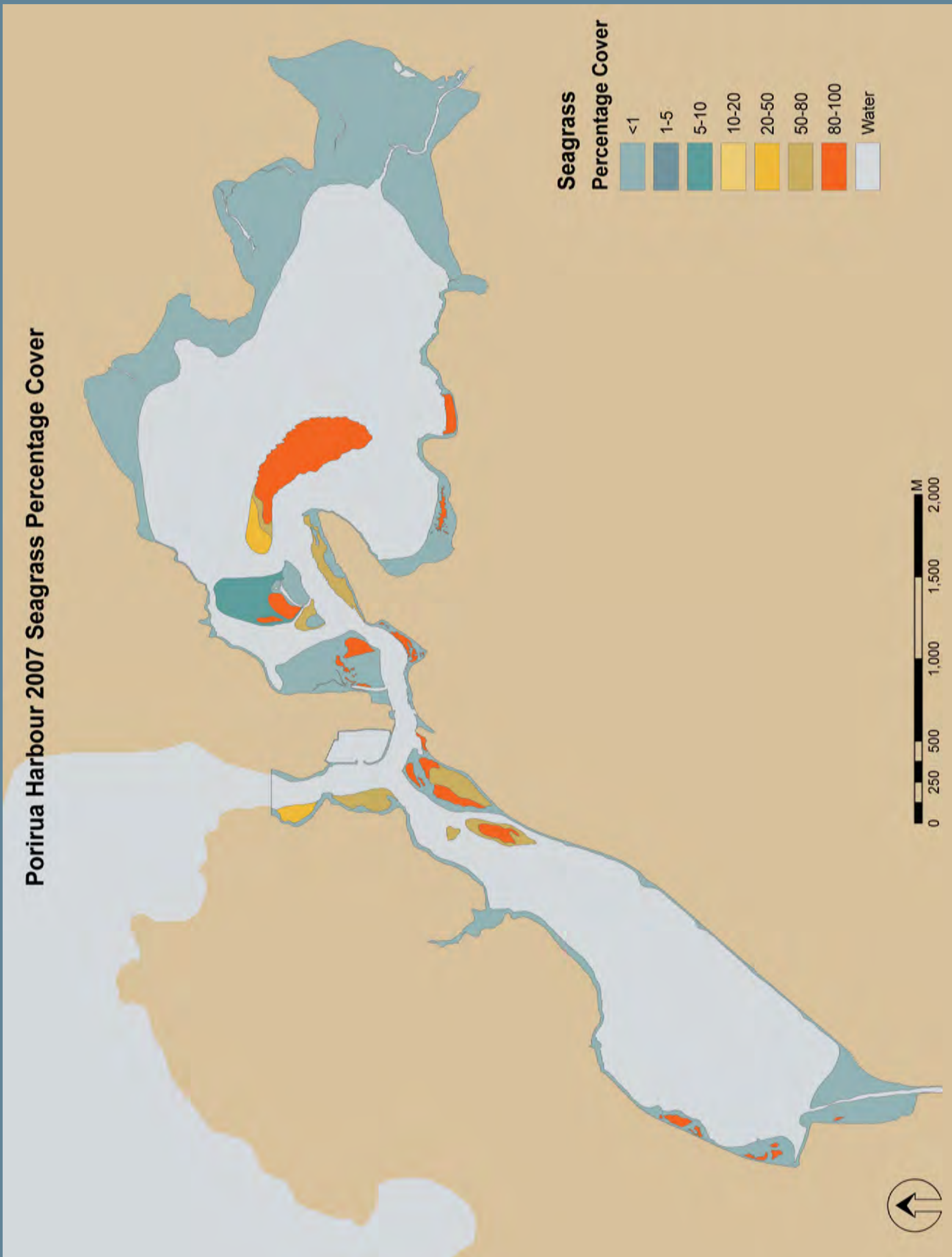
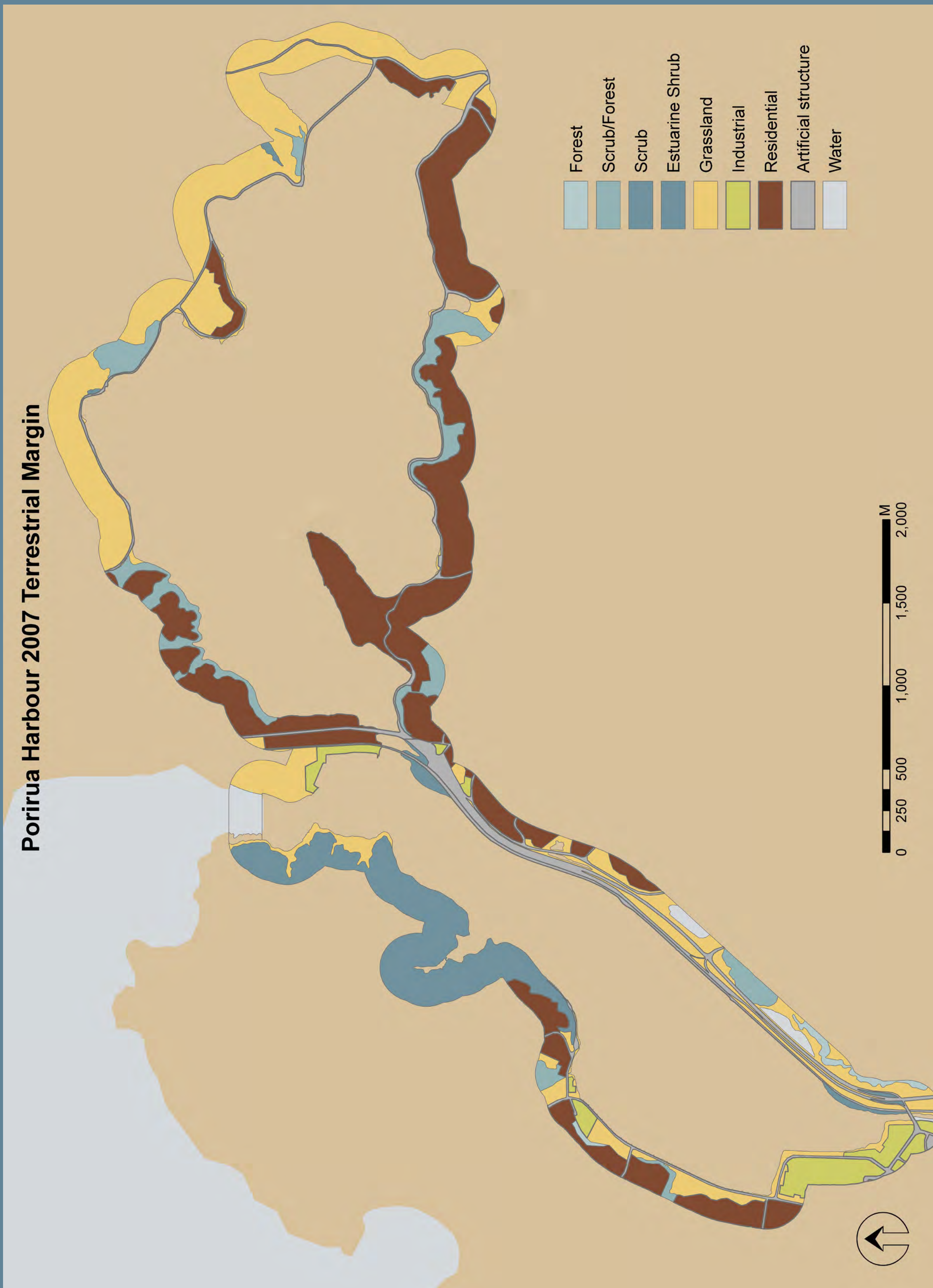
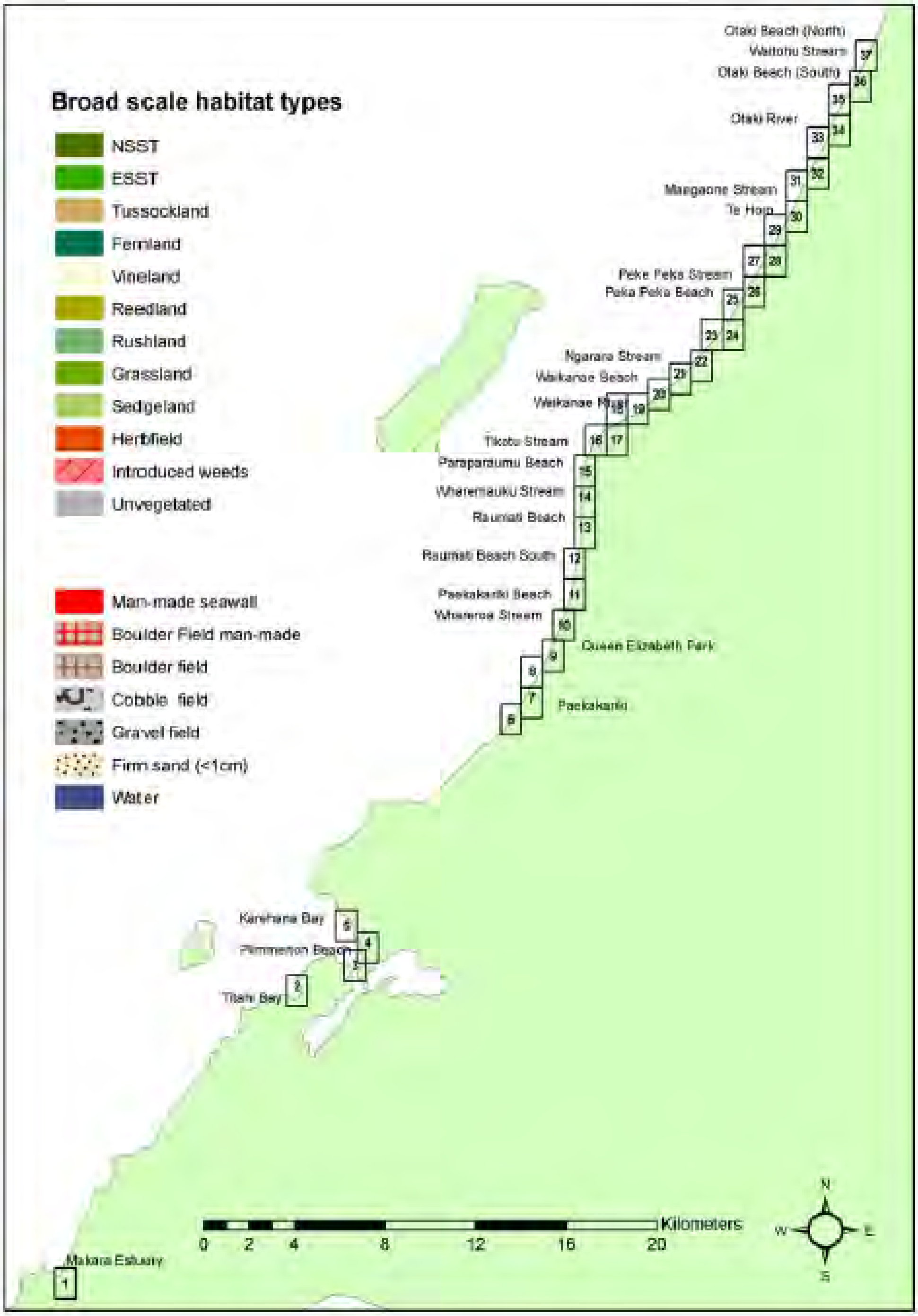


Figure 8. Map of 200m Terrestrial Margin Mapping - Porirua Harbour, December 2007.



Appendix 10g: Broad scale Habitat maps for Whareroa Stream mouth

Source: Stevens & Robertson (2006)



GWRC Coastal Mapping 2005

Sheet 10 of 37 Scale 1:5000

0 50 100 200 300 400 500 Metres