Manawatu-Wanganui Region Estuaries

Habitat Mapping Vulnerability Assessment and Monitoring Recommendations Related to Issues of Eutrophication and Sedimentation

horizons regional council

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coastalmanagement

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Cover Photo: Owahanga Estuary (East Coast), middle reaches - showing green colouration from elevated algal matter

Kai Iwi Estuary mouth

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Contents

List of Tables

List of Figures

All photos by Wriggle except where noted otherwise.

EXECUTIVE SUMMARY

As part of their coastal State of the Environment (SOE) monitoring programme, Horizons Regional Council (HRC) recently contracted Wriggle Coastal Management to identify and assess the vulnerability of the estuaries in the Manawatu-Wanganui Region to the key estuary issues of eutrophication (excessive nutrients) and sedimentation (excessive muddiness), and to recommend regional estuary monitoring priorities. Based on use of the recently developed NZ Estuary Trophic Index (ETI) toolbox (Robertson et al. 2016a, 2016b), the assessment used a combination of existing monitoring information, field visits to all of the larger estuaries, broad-scale GIS-based mapping of dominant habitat and substrate types, and modelled estimates of catchment derived sediment and nutrient loads, to produce: i. broad-scale maps of current habitat and substrate types within each estuary (ArcMap GIS dataset for 30 estuaries), ii. an assessment of both the "vulnerability" and "existing condition" of estuarine habitats to eutrophication and sedimentation, and iii. a recommended estuary monitoring programme to manage estuarine biological resources in the region.

BROAD SCALE MAPPING RESULTS

The results showed that all the surveyed estuaries were shallow, short residence time, tidal river estuaries (SSRTREs), with each estuary fitting into one of four subcategories as follows.

- **Type 1 Short length, low flow SSRTREs**: <1km long, beach located, low freshwater inflows (<1$m^3.s^{-1}$), mouth sometimes restricted/closed.
- **Type 2 Moderate length, low flow SSRTREs**: 1-3km long, low freshwater inflows (<2$m^3.s^{-1}$), mouth sometimes restricted/closed.
- **Type 3 Long length, moderate flow SSRTREs**: 3-12km long, moderate freshwater inflows (4-6$m^3.s^{-1}$), mouth always open.
- **Type 4 Long length, high flow SSRTREs**: 3-12km long, high freshwater inflows (7-220$m^3.s^{-1}$), mouth always open.

As is typical for tidal river estuaries, these estuaries generally had only small areas of intertidal flats and saltmarsh cover and no seagrass (except for those where the mouth is closed or restricted for long periods and the waters are mainly brackish).

VULNERABILITIES TO EUTROPHICATION AND SEDIMENTATION

Type 1. Short length, low flow SSRTREs

Type 1 estuaries were the least vulnerable of the Manawatu-Wanganui Region estuaries to eutrophication and sedimentation. The main reason for this was their small size, low ecological diversity, and regular periods of high flushing (even though some examples experience periodic mouth closure/restriction). Consequently, although estimated nutrient and sediment loads to the estuaries were generally large, they are unlikely to be subjected to prolonged periods of eutrophication and muddiness. Synoptic surveys of this estuary type in February 2016 confirmed the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms) or sedimentation (extensive areas of soft muddy sediments).

Type 2. Moderate length, low flow SSRTREs

Type 2 estuaries which had excessive nutrient/sediment loads and whose mouths were mostly closed (and therefore very poorly flushed) were identified as moderately to highly vulnerable. Those that had excessive nutrient/sediment loads, but were mostly open to the sea were rated as moderately vulnerable. When nutrient/sediment loads were low and estuaries were open to the sea, estuaries were rated as low vulnerability. Characteristic symptoms of eutrophication were opportunistic macroalgal blooms and/or green stained waters symptomatic of phytoplankton blooms, with symptoms of sedimentation being extensive areas of soft fine muddy sediments. The expression of such symptoms was variable because of the flushing regime - being highly flushed during high flow events, and poorly flushed during summer low flows when their mouths become restricted and the upstream waters stratify. This meant that under high nutrient/sediment loads, the estuaries were likely to exhibit eutrophication and muddiness symptoms only during periods of mouth constriction or poor flushing.

Type 3. Long length, moderate flow SSRTREs

Type 3 estuaries all had moderate vulnerability despite their high nutrient/sediment loads. The main reason for the moderate rating was that for estuaries where the nutrient load was excessive, the estuary was likely to oscillate between low and moderate-high levels of eutrophication; i.e. low levels of eutrophication and sedimentation in winter, and immediately during and following high flow events in the warmer months, and moderately eutrophic conditions with some sedimentation during summer base-flow conditions. This latter situation arises from the extensive estuary length and moderate freshwater inflow, which means that the residence time for water and nutrients is sufficient to allow for phytoplankton blooms under baseflow conditions (given that the time taken for a parcel of water to travel the length of the estuary under baseflow is ~1-3 days for these estuaries).

Type 4. Long length, high flow SSRTREs

Type 4 estuaries all had low vulnerability, despite their high nutrient/sediment loads. The main reason for this was that flushing in these estuaries was found to be high, even during summer low flows (a consequence of the high freshwater inflows, extensive tidal intrusion, mouths always open and narrow channels). Synoptic surveys of each estuary in February 2016 confirmed the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms) or sedimentation (extensive areas of soft muddy sediments).

Executive Summary (continued)

MONITORING RECOMMENDATIONS

Type 1. Short length, low flow SSRTREs

Given such low-moderate vulnerabilities for both eutrophication and sedimentation in these very small, highly flushed estuaries, it is recommended that any ongoing monitoring be limited to low frequency (once every 10 years) screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating. In small estuaries, located on the beach below cliffs, ongoing monitoring is not recommended.

Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 1. Short length, low flow SSRTREs - <1km long, beach located, low freshwater inflows (<1$m^3.s^{-1}$), mouth sometimes restricted/closed.

WEST COAST ESTUARIES		EAST COAST ESTUARIES
Ototoka Stream Estuary	Unnamed stream south Waimahora Estuary	Papuka Stream Estuary
Omapu Stream Estuary	Unnamed stream north Ruamai Range Estuary	Waimata Stream Estuary
Mowhanau Stream Estuary	Raumai Range Stream	- also nine unnamed discharges of small streams directly to the beach, eight between the northern coast regional boundary and Akitio, and another just south of Akitio
Okehu Stream Estuary	Pukepuke Stream Estuary	
Kaitoke Stream Estuary	Kaikokopu Stream	
Koitiata Stream Estuary	Three Mile Creek	
Lake Koitiata Outflow Estuary	Wairarawa Stream Estuary	
Waimahora Stream Estuary	Waiwiri Stream Estuary	

Type 2. Moderate length, low flow SSRTREs

- For "moderate-length Type 2 SSRTREs" with low nutrient/sediment loads it is recommended that any ongoing monitoring be limited to low frequency (once every 10 years) screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.
- For "moderate-length (mouth mostly open) Type 2 SSRTREs" with high nutrient/sediment loads it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address potential for eutrophication, it is recommended that water column chlorophyll a, dissolved oxygen, and nutrient concentrations be monitored annually (during summer low flows) at a site representative of general (rather than localised) worst case conditions (e.g. a long pool), and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over the whole estuary. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.
- For "moderate-length (mouth mostly closed) Type 2 SSRTREs" with high nutrient/sediment loads it is recommended that regular monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address the eutrophication/sedimentation issue (including both benthic and water column effects), the following monitoring is recommended at each of 3 transects across the estuary (representative of the lower, mid and upper estuary): monitor annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March) for: opportunistic macroalgal cover and biomass, seagrass cover and biomass, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 2. Moderate length, low flow SSRTREs - 1-2km long, low freshwater inflows (<2$m^3.s^{-1}$), mouth mainly open, high nutrient/sediment loads.

WEST COAST ESTUARIES	EAST COAST ESTUARIES
Kai Iwi Estuary	None

Type 2. Moderate length, low flow SSRTREs - 1-2km long, low freshwater inflows (<2$m^3.s^{-1}$), mouth closed for 1 month or more, high nutrient/sediment loads.

WEST COAST ESTUARIES	EAST COAST ESTUARIES
Waikawa Estuary	Tautane Estuary
Hokio Stream Estuary	Wainui Estuary

Executive Summary (continued)

MONITORING RECOMMENDATIONS (CONTINUED)

Type 3. Long length, moderate flow SSRTREs

For Type 3 estuaries (i.e. Owahanga and Akitio Estuaries) it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address potential for eutrophication, it is recommended that water column chlorophyll a, dissolved oxygen and nutrient concentrations be monitored monthly during the period Nov-March each year at a site representative of general conditions (it is noted that this is already undertaken each year in the Akitio as part of the current long term monitoring programme) and, at the same time, intertidal/shallow subtidal macroalgal cover be assessed. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only. Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 3. Long length, moderate flow SSRTREs - 3-12km long, moderate freshwater inflows (4-6$m^3.s^{-1}$), mouth always open.	
WEST COAST ESTUARIES	**EAST COAST ESTUARIES**
None	Akitio River Estuary Owahanga River Estuary

Type 4. Long length, high flow SSRTREs

For the larger examples of this estuary type (e.g. Manawatu and Whanganui Estuaries), which have very high nutrient and sediment loads and high human use and ecological values, it is recommended that both broad scale habitat mapping and fine scale intertidal monitoring be undertaken on a long term basis to assess trends in estuary ecological condition.

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is usually repeated at 5 yearly intervals. Broad scale intertidal mapping of Manawatu Estuary was undertaken in 2016 (Stevens and Robertson 2016) and in Whanganui Estuary in 2009 (Stevens and Robertson 2009). Fine scale monitoring measures the condition of the high susceptibility intertidal sediments through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at two sites), and thereafter at 5 yearly intervals. This component has not yet been measured in these two estuaries.

For the remaining examples of this estuary type, it is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that these low-moderate risk estuaries have not changed their risk rating.

To address any "High" sedimentation ratings in these estuary types (e.g. in Whangaehu Estuary), it is recommended that annual sedimentation rate (including grain size) monitoring and 5 yearly broad scale mapping of soft muds, be undertaken to provide data on long term sedimentation trends.

Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 4. Long length, high flow SSRTREs - 3-12km long, high freshwater inflows (7-220$m^3.s^{-1}$), mouth always open.	
WEST COAST ESTUARIES	**EAST COAST ESTUARIES**
Turakina River Estuary Ohau River Estuary Whangaehu River Estuary Rangitikei River Estuary Manawatu River Estuary Whanganui Estuary	None

East Coast Manawatu-Wanganui Region

Kai Iwi Estuary mouth

Kaikokopu Estuary

1. INTRODUCTION

AIM AND SCOPE

Current knowledge of estuarine life and how such ecosystems work is not adequate to show whether we are sustainably managing New Zealand's coastal biodiversity. In particular we lack the integration of impacts into an ecosystem-based framework with explicit biodiversity objectives (The Parliamentary Commissioner for the Environment's report "Setting Course for a Sustainable Future: the Management of New Zealand's Marine Environment", 2000). The need to gather information to inform the assessment of effects on the environment is implicit in New Zealand's legislation for sustainable management. A key mechanism in this process is to undertake estuary vulnerability assessments, which are designed to assess the vulnerability of estuaries in the region to major issues (see Table 1) and to identify appropriate monitoring design.

Recently, Horizons Regional Council (HRC) contracted Wriggle Coastal Management to identify the habitat vulnerability and monitoring priorities associated with the key estuarine issues of eutrophication and sedimentation for estuarine ecological resources in the Manawatu-Wanganui Region using a similar approach to that recently used in the coastal vulnerability assessments in the Southland, Greater Wellington and Tasman regions (Robertson and Stevens 2007a, 2007b, 2007c, 2008, 2012) and in the NZ Estuary Trophic Index (ETI) toolbox (Robertson et al. 2016a, 2016b). The approach targets all estuaries in the Manawatu-Wanganui Region (Figures 1 and 2; 25 on the west coast and 15 on the east coast) and includes three main components which produce the following outputs:

- **Estuarine Habitat Maps:** An ArcMap GIS dataset depicting current broad-scale habitat and substrate types within each estuary, using aerial photographs and ground truthing techniques (e.g. Robertson and Stevens 2011). Habitat and substrate maps for 30 estuaries are presented in the main document (also provided to HRC as electronic GIS files).
- **Vulnerability Assessments**: An assessment of the "vulnerability" and "existing condition" of the estuarine habitats to key estuarine issues of eutrophication (excessive nutrients) and sedimentation (excessive muddiness) using the recently developed NZ Estuary Trophic Index (ETI) toolbox (Robertson et al. 2016a, 2016b).
- **Monitoring Priorities:** A recommended estuary monitoring programme for the management of estuarine biological resources in the region.

Field assessment and mapping was funded by HRC with reporting funded under NIWA Envirolink Project 1624-HZLC127.

Owahanga Estuary

Akitio Estuary

STRUCTURE

Section 1 provides an introduction to the scope and structure of the study.

Section 2 introduces the methods used for the habitat mapping, vulnerability assessments and for identifying monitoring recommendations.

Section 3 provides the summary detail for each estuary, in an estuary by estuary approach beginning with the west coast and finishing on the east coast. For each estuary, it describes their characteristics (including photos), values and uses, vulnerabilities to eutrophication and sedimentation, existing condition and recommended monitoring. These summary details are derived from the following outputs:

- Detailed summary information on estuaries (presented in Appendix 1).
- Broad scale habitat maps (presented with each estuary as a hard copy output and as accompanying GIS files) based on ground-truthing and field assessments for all of the larger estuaries.
- Vulnerability assessments presented as completed matrices with each estuary.

Section 4 provides an overview of the vulnerability assessment results and monitoring recommendations.

Kai Iwi Estuary

Table 1. Summary of the major environmental issues affecting most New Zealand estuaries

1. Fine Sediment

Because estuaries are a sink for sediments, their natural cycle is to slowly infill. Prior to European settlement they were dominated by sandy sediments and had low sedimentation rates (<1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill rapidly with fine sediments. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived (e.g. see Abrahim 2005, Gibb and Cox 2009, Robertson and Stevens 2007, 2010, and Swales and Hume 1995). Soil erosion and sedimentation can also contribute to turbid conditions and poor water quality, particularly in shallow, wind-exposed estuaries where re-suspension is common. These changes to water and sediment result in negative impacts to estuarine ecology that are difficult to reverse. They include:

- habitat loss such as the infilling of saltmarsh and tidal flats,
- prevention of sunlight from reaching aquatic vegetation such as seagrass meadows,
- increased toxicity and eutrophication by binding toxic contaminants (e.g. heavy metals and hydrocarbons) and nutrients,
- a shift towards mud-tolerant benthic organisms which often means a loss of sensitive shellfish (e.g. pipi) and other filter feeders; and
- making the water unappealing to swimmers.

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Sedimentation	Soft Mud Area	GIS Based Broad scale mapping - estimates the area and change in soft mud habitat over time.
	Seagrass Area/Biomass	GIS Based Broad scale mapping - estimates the area and change in seagrass habitat over time.
	Saltmarsh Area	GIS Based Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
	Mud Content	Grain size - estimates the % mud content of sediment.
	Water Clarity/Turbidity	Secchi disc water clarity or turbidity.
	Sediment Toxicants	Sediment heavy metal concentrations (see toxicity section).
	Sedimentation Rate	Fine scale measurement of sediment infilling rate (e.g. using sediment plates).
	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in 0.0133m^2 replicate cores), and on the sediment surface (epifauna in 0.25m^2 replicate quadrats).

2. Eutrophication

Eutrophication is a process that adversely affects the high value biological components of an estuary, in particular through the increased growth, primary production and biomass of phytoplankton, macroalgae (or both); loss of seagrass, changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services (Ferriera et al. 2011). Susceptibility of an estuary to eutrophication is controlled by factors related to hydrodynamics, physical conditions and biological processes (National Research Council, 2000) and hence is generally estuary-type specific. However, the general consensus is that, subject to available light, excessive nutrient input causes growth and accumulation of opportunistic fast growing primary producers (i.e. phytoplankton and opportunistic red or green macroalgae and/or epiphytes - Painting et al. 2007). In nutrient-rich estuaries, the relative abundance of each of these primary producer groups is largely dependent on flushing, proximity to the nutrient source, and light availability. Notably, phytoplankton blooms are generally not a major problem in well flushed estuaries (Valiela et al. 1997), and hence are not common in the majority of NZ estuaries. Of greater concern are the mass blooms of green and red macroalgae, mainly of the genera *Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose, both within the estuary and adjacent coastal areas. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there (Anderson et al. 2002, Valiela et al. 1997).

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Eutrophication	Macroalgal Cover/Biomass	Broad scale mapping - macroalgal cover/biomass over time.
	Phytoplankton (water column)	Chlorophyll *a* concentration (water column).
	Sediment Organic and Nutrient Enrichment	Chemical analysis of sediment total nitrogen, total phosphorus, and total organic carbon concentrations.
	Water Column Nutrients	Chemical analysis of various forms of N and P (water column).
	Redox Profile	Redox potential discontinuity profile (RPD) using visual method (i.e. apparent Redox Potenial Depth - aRPD) and/or redox probe. Note: Total Sulphur is also currently under trial.
	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in 0.0133m^2 replicate cores), and on the sediment surface (epifauna in 0.25m^2 replicate quadrats).

Table 1. Summary of major environmental issues affecting New Zealand estuaries (continued)

3. Disease Risk

Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time (e.g. Stewart et al. 2008). Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Human diseases linked to such organisms include gastroenteritis, salmonellosis and hepatitis A (Wade et al. 2003). Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds.

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Disease Risk	Shellfish and Bathing Water faecal coliforms, viruses, protozoa etc.	Bathing water and shellfish disease risk monitoring (Council or industry driven).

4. Toxic Contamination

In the last 60 years, NZ has seen a huge range of synthetic chemicals introduced to the coastal environment through urban and agricultural storm-water runoff, groundwater contamination, industrial discharges, oil spills, antifouling agents, leaching from boat hulls, and air pollution. Many of them are toxic even in minute concentrations, and of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlo-rinated biphenyls (PCBs), endocrine disrupting compounds, and pesticides. When they enter estuaries these chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to marine life and humans. In addition, natural toxins can be released by macroalgae and phytoplankton, often causing mass closures of shellfish beds, potentially hindering the supply of food resources, as well as introducing economic implications for people depending on various shellfish stocks for their income. For example, in 1993, a nationwide closure of shellfish harvesting was instigated in NZ after 180 cases of human illness following the consumption of various shellfish contaminated by a toxic dinoflagellate, which also lead to wide-spread fish and shellfish deaths (de Salas et al. 2005). Decay of organic matter in estuaries (e.g. macroalgal blooms) can also cause the production of sulphides and ammonia at concentrations exceeding ecotoxicity thresholds.

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Toxins	Sediment Contaminants	Chemical analysis of heavy metals (total recoverable cadmium, chromium, copper, nickel, lead and zinc) and any other suspected contaminants in sediment samples.
	Biota Contaminants	Chemical analysis of suspected contaminants in body of at-risk biota (e.g. fish, shellfish).
	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in 0.0133m^2 replicate cores), and on the sediment surface (epifauna in 0.25m^2 replicate quadrats).

5. Habitat Loss

Estuaries have many different types of high value habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), tidal flats, forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of such habitat negatively affects fisheries, animal populations, filtering of water pollut-ants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes being sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff, and wastewater discharges (IPCC 2007 and 2013, Kennish 2002).

Recommended Key Indicators:

Issue	Recommended Indicators	Method
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.
	Shellfish Area	Broad scale mapping - estimates the area and change in shellfish habitat over time.
	Unvegetated Habitat Area	Broad scale mapping - estimates the area and change in unvegetated habitat over time, broken down into the different substrate types.
	Sea level	Measure sea level change.
	Others e.g. Freshwater Inflows, Fish Surveys, Floodgates, Wastewater Discharges	Various survey types.

1. Introduction (continued)

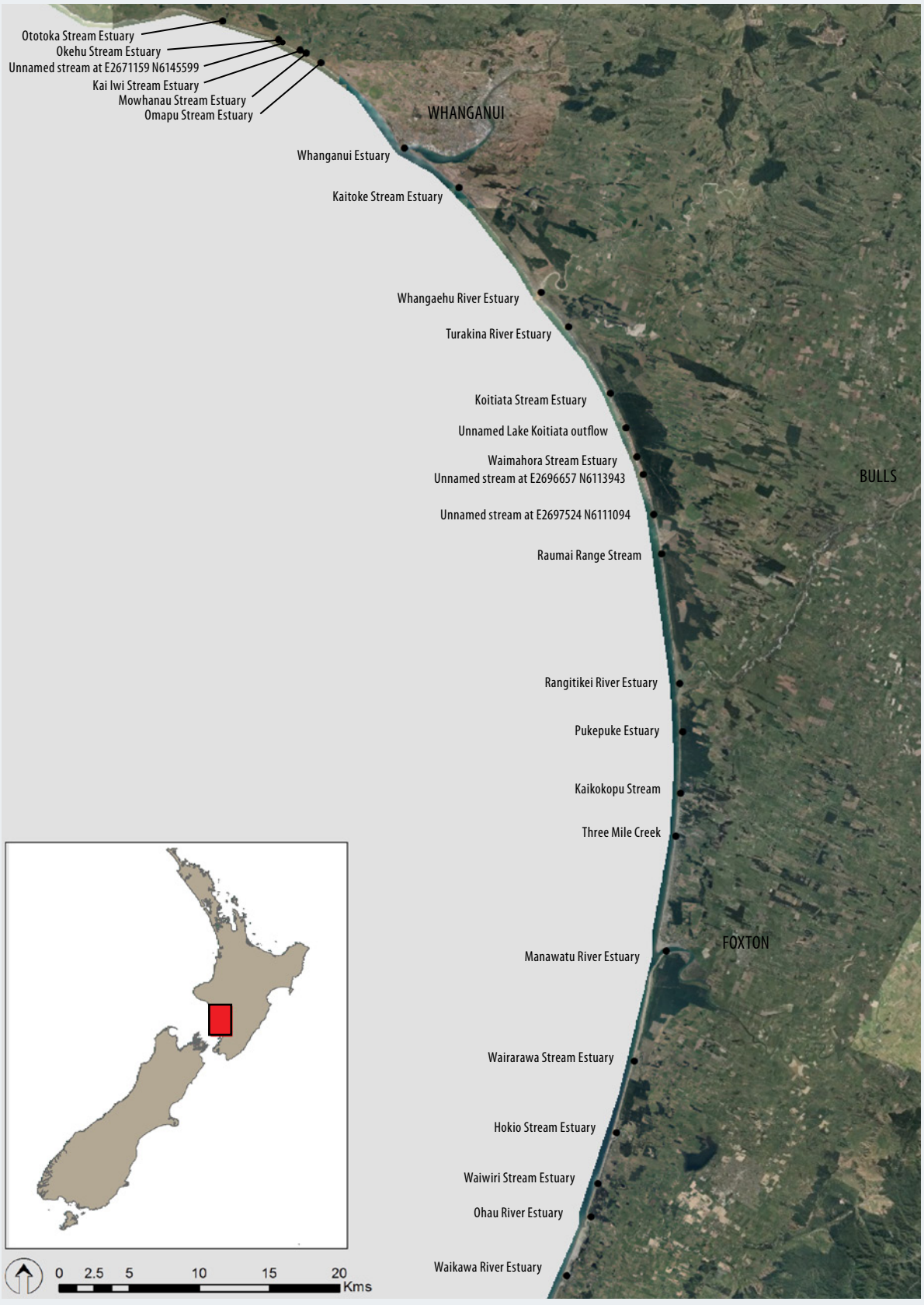


Figure 1. Map of Manawatu-Wanganui Region west coast estuaries

1. Introduction (continued)

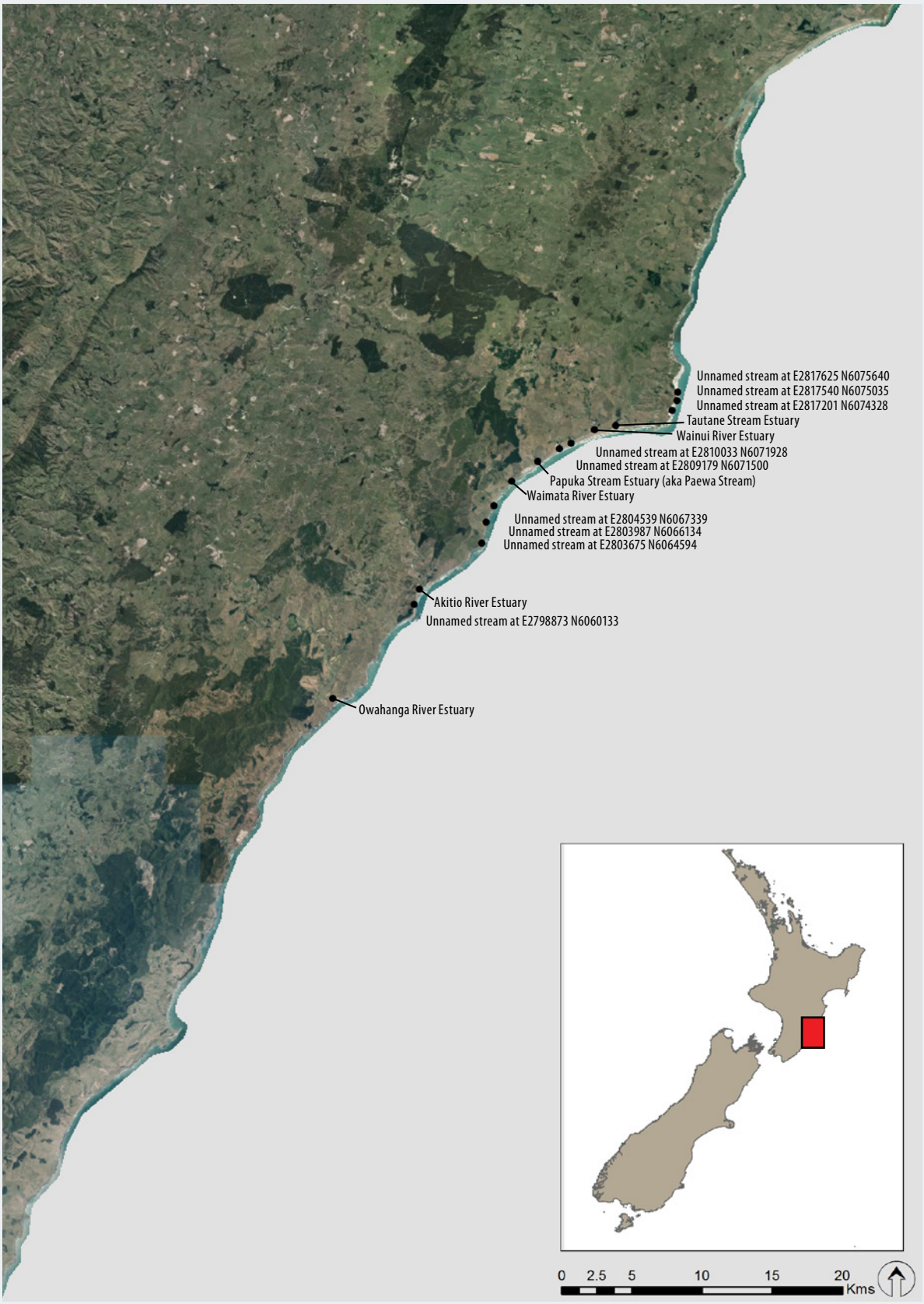


Figure 2. Map of Manawatu-Wanganui Region east coast estuaries

2. METHODS

VULNERABILITY ASSESSMENTS AND MONITORING RECOMMENDATIONS

The Manawatu-Wanganui Region Estuary Vulnerability Assessment (EVA) follows the NZ Estuary Trophic Index (ETI) approach (Robertson et al. 2016a, 2016b) (see summary inset below), which is designed to be used by experts to represent how estuarine ecosystems are likely to react to the effects of excessive nutrients and fine sediment, and how to monitor and assess their existing level of eutrophication and sedimentation. A summary outline of the approach used for the Manawatu-Wanganui Region EVA is presented in Figure 3, with a detailed step-wise outline of the methods presented in Table 2. An example of the final matrix used for recording the findings for each of the key steps is presented in Table 3.

Summary of NZ Estuary Trophic Index (ETI) Tool

The ETI is a stand-alone, hard-copy methodology that includes two sets of tools that provide screening guidance for assessing where an estuary sits in the eutrophication (and associated sedimentation) gradient, what is required to shift it to a different location in the gradient, and which indicators are required for monitoring. Each tool is presented in a separate report with supporting appendices. Although the ETI focuses on the issue of eutrophication, it includes relevant thresholds for determining the influence of fine sediments on estuary condition, in particular, sedimentation rate and area (spatial extent) of soft muds.

Screening Tool 1. Physical and Nutrient Susceptibility Tool

This method is designed to provide a relatively robust and cost effective approach to enable the prioritisation of estuaries for more rigorous monitoring and management. It applies a desktop susceptibility approach that is based on estuary physical characteristics, and nutrient input load/estuary response relationships for key NZ estuary types. The tool produces a single physical susceptibility score that can be used to classify either the ***physical susceptibility*** (i.e. very high, high, moderate, low susceptibility), and/or be combined with nutrient load data to produce a ***combined physical and nutrient load susceptibility*** rating. Nutrient areal load/trophic state bands for each estuary eutrophication type will be developed as a long term goal, with data currently available for some estuary types, but not all as yet. This section also provides guidance on the use of a simple load/response model tool provided in the ETI toolbox, and recommendations for the use of more robust approaches for setting load limits.

Screening Tool 2. Trophic Condition Assessment Tool

This tool is a monitoring approach that characterises the ecological gradient of estuary trophic condition for relevant ecological response indicators (e.g. macroalgal biomass, dissolved oxygen), and provides a means of translating these ratings into an overall estuary trophic condition rating/score (the ETI). It provides guidance on which condition indicators to use for monitoring the various estuary types (and why they have been chosen), and on assessing the trophic state based on the indicator monitoring results and their comparison to numeric impairment bands (e.g. very high, high, moderate, low). The latter involves measurement of the expression of both primary (direct) eutrophication symptoms (e.g. macroalgae phytoplankton) and supporting indicators for secondary (indirect) symptoms of trophic state.

Manawatu-Wanganui Region Estuary Vulnerability Outline

For determining eutrophication and sedimentation susceptibility using physical and nutrient/sediment load data and monitoring priorities

(adapted from NZ ETI Toolbox - Robertson et al. 2016a and 2016b)

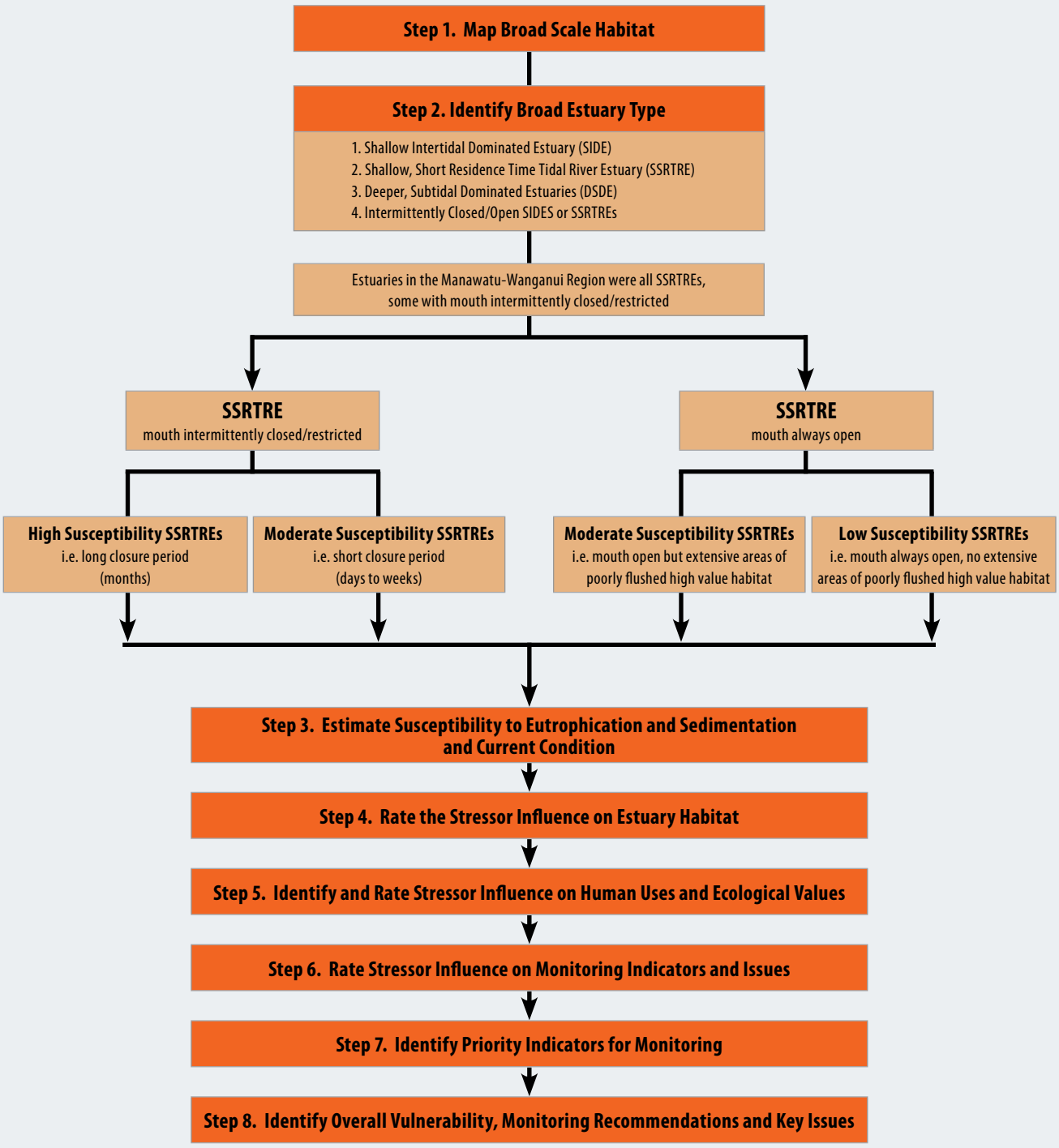


Figure 3. Screening Tool - Eutrophication and Sedimentation - outline flow diagram.

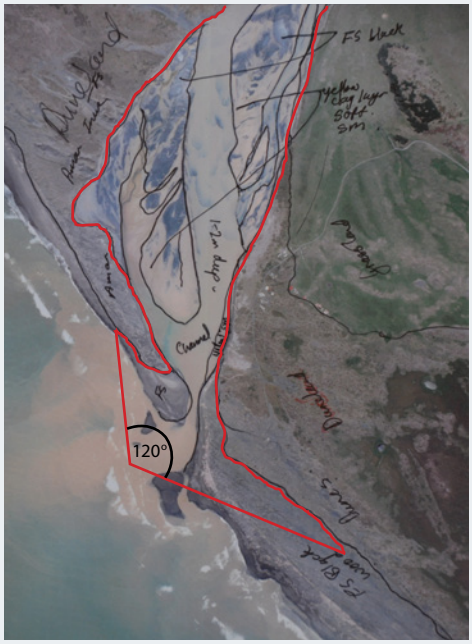
Table 2. Summary of the steps used in the Manawatu-Wanganui Region Estuary Vulnerability Assessment

Step 1. Generate Broad Scale Estuary Habitat Maps

In order to identify habitats in Manawatu-Wanganui Region estuaries, broad scale mapping based on the National Estuarine Monitoring Protocol - NEMP (Robertson et al. 2002) was used to record the primary habitat features at a structural class level e.g. saltmarsh, seagrass, macroalgae, mud, sand, rock. Features were ground-truthed on 1:3000 0.4m/pixel colour aerials flown in 2010 and provided by LINZ and digitised into ArcMAP 10.2 to produce GIS maps of dominant intertidal substrate, saltmarsh, and seagrass (*Zostera* or *Ruppia*) and a shapefile of georeferenced digital field photos.

Estuaries were mapped from a 120° angle from the low tide channel entering the sea (see photos below) to the upper extent of saline intrusion (directly measured or estimated based on the presence of salt intolerant plants). In several remote low priority areas on both the west and east coasts, ground-truthing was not undertaken. Instead, habitat type was identified by an experienced scientist from aerial photographs. Because the Whanganui Estuary has been previously mapped (Stevens and Robertson 2009), the existing habitat map was used for the present assessment.

Appendix 3 lists the class definitions used to classify substrate and vegetation. For the purposes of this EVA, saltmarsh vegetation was grouped to include all of the various subcategories of vegetation (e.g. rushland, sedgeland, herbfield). Substrate features were mapped separately, with the total area of soft mud used as a primary indicator of fine sediment impacts. Seagrass and macroalgae were assessed using measures of biomass and percentage cover, as described in the ETI (Robertson et al. 2016a, 2016b) and elsewhere (e.g. Stevens and Robertson 2015). Broad scale habitat features were digitised into ArcMap 10.2 shapefiles using a Wacom Cintiq21UX drawing tablet, and combined with field notes and georeferenced photographs to produce habitat maps showing the dominant cover of: substrate, macroalgae (e.g. *Ulva, Gracilaria*), seagrass, and saltmarsh vegetation. These broad scale results are summarised in Section 3, with the supporting GIS files (supplied as a separate electronic file) providing a more detailed data set designed for easy interrogation to address specific monitoring and management questions.



Step 2. Identify Estuary Eutrophication Type

Susceptibility to eutrophication and sedimentation in estuaries is influenced by specific physical modifying characteristics including dilution, flushing, residence time, depth and intertidal extent. The ETI adopted a simple four category typology (described further in Table 4) specifically suited to the assessment of estuarine eutrophication susceptibility in NZ (an adaptation of the more detailed New Zealand Coastal Hydrosystems Typology, Hume 2016), as follows:

1. Shallow intertidal dominated estuaries (SIDEs)
2. Shallow, short residence time tidal river and tidal river with adjoining lagoon estuaries (SSRTREs)
3. Deeper subtidal dominated, longer residence time estuaries (DSDEs)
4. The ETI classed SIDEs and SSRTREs whose mouths intermittently close for short or long periods as ICOLLs (intermittently closed/open lakes and lagoons estuaries), but ICOLLs are more accurately sub types of SIDEs and SSRTREs.

The results of the broad scale assessment indicated that all the Manawatu-Wanganui Region estuaries assessed were SSRTREs, some of which have intermittently open/closed mouths, and that they could be grouped in the following four categories:

Table 2. Summary of the steps used in the Manawatu-Wanganui Region Estuary Vulnerability Assessment (continued)

General categories of estuaries identified in the Manawatu-Wanganui Region (further details in Appendix 1):

- Type 1 Short length, low flow SSRTREs: <1km long, beach located, low freshwater inflows (<1m^3.s^{-1}), mouth sometimes restricted/closed.
- Type 2 Moderate length, low flow SSRTREs: 1-3km long, low freshwater inflows (<2m^3.s^{-1}), mouth sometimes restricted/closed.
- Type 3 Long length, moderate flow SSRTREs: 3-12km long, moderate freshwater inflows (4-6m^3.s^{-1}), mouth always open.
- Type 4 Long length, high flow SSRTREs: 3-12km long, high freshwater inflows (7-220m^3.s^{-1}), mouth always open.

Step 3. Assess Key Stressor Influence Based on Magnitude, Existing Condition and Susceptibility

Eutrophication of shallow SSRTREs in NZ is a process driven by the enrichment of water by nutrients, especially compounds of nitrogen (N) and, to a lesser extent, phosphorus (P), whereas sedimentation is a process driven by the enrichment of water by sediments, especially fine sediments (i.e. muds). Because fine sediments often contain elevated nutrients, the two issues of eutrophication and sedimentation are generally interlinked. Catchment inputs are the primary source of nutrients and fine sediments and, if individually present in excess, they result in ecological degradation, which is exacerbated when they occur together (e.g. muddy, nutrient-rich sediments leads to lower pore water exchange, increased sediment bound nutrients, increased organic matter, reduced sediment oxygenation, elevated toxic sulphide levels).

In this section, the likely influence of the key stressors of nutrients and fine sediment on the ecological condition of Manawatu-Wanganui Region estuaries is assessed as follows (and includes the use of detailed estuary data presented in Appendices 1 and 2):

Susceptibility to Eutrophication	Based on a modification of the ETI, nutrient load thresholds for SSRTREs are recommend as follows: **1. High susceptibility SSRTREs i.e. with long periods of mouth closure or restriction (months)** Eutrophic conditions unlikely at estimated areal TN load <35mg.m^{-2}.d^{-1} **2. Moderate susceptibility SSRTRE i.e short periods of mouth closure or restriction (days to weeks), or with extensive poorly flushed high value habitat i.e. estuaries with long water column residence time** Eutrophic conditions unlikely at estimated areal TN load <100-250mg.m^{-2}.d^{-1} **3. Low susceptibility SSRTRE i.e mouth always open or mouth generally open with short periods of mouth closure or restriction (days to weeks) and no significant areas of poorly flushed high value habitat i.e. a well flushed water column** Eutrophic conditions unlikely at estimated areal TN load <2000mg.m^{-2}.d^{-1} Areal N load = TN estuary load (mgNd^{-1})/estuary area (m^2). For the Manawatu-Wanganui Region estuaries, TN load estimates were derived using the NIWA CLUES model (Version 10.3, released May 2016 default setting using REC2 and LCBB3 (2008/2009) land cover), (Elliot et al. submitted, Semadeni-Davies et al. 2011).
Current Eutrophication Condition	The current trophic state of the Manawatu-Wanganui Region estuaries was assessed using the ETI Tool 2 approach. This approach requires data or expert opinion for at least one primary indicator and one supporting indicator. For the Manawatu-Wanganui Region estuaries, chlorophyll a and macroalgal cover data or expert opinion was used for the primary indicator and redox potential for the supporting indicator to develop an ETI trophic state score (note that other indicator data is also presented where available in order to provide additional support).
Susceptibility to Sedimentation (Muddiness)	The susceptibility of estuaries to the accumulation of fine sediments is related both to the suspended sediment input load and the physical (sediment trapping) characteristics of each estuary. Currently, there is insufficient information to identify robust sedimentation susceptibility thresholds for NZ estuaries, but for screening level purposes it is appropriate to use the Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio as a means of identifying catchments with excessive sediment loads. For the Manawatu-Wanganui Region estuaries, the chosen CSSL/NSSL ratio thresholds were as follows: low 1-1.1, moderate 1.1-2, high 2-5, very high >5. Catchment sediment load estimates were derived from the NIWA CLUES model (Version 10.3, released May 2016)[1]. The load threshold ratings were then combined (using the matrix below) with ratings for the likelihood of sediment trapping based on the assumption that high susceptibility SSRTRE estuaries are physically susceptible to fine sediment accumulation. [1] CSSL estimated using CLUES (default setting of REC2 and LCBB3 (2008/2009) land cover), NSSL estimated by setting CLUES land cover to native forest, with a further 75% reduction applied to account for high expected sediment retention in wetlands in the catchment under natural state (Elliot et al. submitted, Semadeni-Davies et al. 2011).

	Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL)			
Estuary Category	CSSL = 1 to 1.1 x NSSL	CSSL = 1.1 to 2 x NSSL	CSSL = 2 to 5 x NSSL	CSSL > 5 x NSSL
SSRTREs with extensive areas of poorly flushed habitat	Very Low Susceptibility	Low Susceptibility	Moderate Susceptibility	High Susceptibility
SSRTREs with no extensive areas of poorly flushed habitat	Very Low Susceptibility	Very Low Susceptibility	Very Low Susceptibility	Low Susceptibility

Current Sedimentation Condition	The current ETI thresholds for % estuary area dominated by soft mud substrate (i.e. sediment mud content >25%) were used to assess the current sedimentation (or muddiness) of the Manawatu-Wanganui Region estuaries as follows: low 1%, moderate 1-5%, high 5-15%, very high >15%.
Determine Overall Eutrophication and Sedimentation Vulnerability	This step combines the susceptibility and current condition ratings to get an overall vulnerability rating. If the estuary was assessed for condition during reasonable worst case times, then the existing condition rating is used as the final rating. However, if there is considerable uncertainty around the condition rating, then the more conservative susceptibility rating (or combination) is used.

Step 4. Rate the Stressor Influence on Habitat

The influence of key stressors on the ecological condition of each listed coastal and estuarine habitat type is rated based on the results of Steps 1-3.

Table 2. Summary of the steps used in the Manawatu-Wanganui Region Estuary Vulnerability Assessment (continued)

Step 5. Identify and Rate Stressor Influence on Human Uses and Ecological Values

Human uses and ecological values were identified and their presence assessed using four broad rating categories (Very Low, Low, Moderate, High) based on a UNESCO (2000) methodology. Expert judgement is used to provide an overall rating for stressor influence on each use as follows:

1. Human Uses and Values. The information used to rate human uses and values of coastal habitat is based on local knowledge and available information. The estimated number of people involved are used to guide the rating:

- Very Low: <10 per year.
- Low: 10 to 50 per year (<30 per day in summer).
- Moderate: >30 per day (may be only in summer) but <200 per day.
- High: >200 per day (any time during year).

2. Ecological Values (Richness). Ecological value defines an ecosystem's natural riches (generally interpreted as habitat diversity and biodiversity). It can be supposed that the richer and more diversified an ecosystem is, the greater the losses will be in the event of a disruption. The ecological richness component is divided into four subcategories; birds, vegetation, fish, and other biota. The information used to rate the ecological value will be drawn from local knowledge, available reports and information, and expert opinion.

Step 6. Rate Stressor Influence on Monitoring Indicators and Issues

Monitoring indicators that can be used to assess the influence of stressors are identified. For each, a rating is applied based on the extent that each monitoring indicator is likely to be affected by the stressor influence that was estimated in Step 3. Because each monitoring indicator is assigned into an appropriate issue category, then it is straightforward to assess which issues are likely to arise and what should be monitored. In this section, the overall stressor influence rating for each indicator is also determined using an appropriate weighting for each stressor.

Step 7. Identify Priority Indicators for Monitoring

Combine the results of Steps 4 and 6 to determine the priority indicators for monitoring.

Step 8. Identify Overall Vulnerability, Key Issues, Monitoring Recommendations

Finally, determine overall vulnerability by combining total stressor influence, total human use rating and total ecological values rating. Identify key issues for monitoring. Make monitoring recommendations based on priority monitoring indicators.

Typical west coast tidal river estuary - Waikawa Estuary

Table 3. Steps in Filling out The Vulnerability Matrix

Steps 1 & 2
Broad Scale Mapping and Definition of Estuary Type

Step 3
For Eutrophication and Sedimentation - Rate Susceptibility and Existing Condition (average of the ratings above each final rating cell)

Step 4
Rate the stressor influence on habitat

Step 5
Identify and Rate Human Uses and Ecological Values

Step 6
Rate the stressor influence on monitoring indicators and hence issues

Step 7
Identify priority indicators for monitoring

Step 8
Determine the overall ratings, key issues and monitoring recommendations

MANAWATU-WANGANUI ESTUARIES - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION

SITE: WAIKAWA ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS			
Low		Moderate	
Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	0.77	High
Dilution Potential:	1.32×10^{-7}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility:		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	90th percentile (2010-2015, n=46) = 16.89ug/l	High
Macroalgae (EQR)	High cover in well-lit shallows	High
Supporting Indicators		
Redox Potential	aRPD ~1 cm in subtidal zone of mid and upper estuary	Moderate
Sediment % Mud	50-60% of subtidal estuary area was soft mud	Not Measured
Seagrass	0.005% of estuary area was seagrass (*Ruppia* sp)	
Clarity (SD, cm)	SD not visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN was 0.96 mgN/l, mean DIN was 0.7 mgN/l. This exceeds the ETI interim guidance of 400ug/l TN as boundary between high and moderate eutrophication.	
Existing Condition Eutrophication Rating		Mod - High

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	4.8	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - poorly flushed at low flows.	Low
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 50-60% of estuary subtidal area was soft muds. Local residents indicated that the estuary had got muddier in recent years. But sandy in lower estuary.	Moderate
Sedimentation Existing Condition Rating		Moderate Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES							ECOL. VALUES						Eutrophication												Sedimentation					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eutroph.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that:

At each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

Notes:
Flushing Potential (FP): calculated as freshwater inflow ($m^3.d^{-1}$) divided by estuary volume (m^3) and adjusted for tidal height (m) (Robertson et al. 2016a).
Dilution Potential (DP): calculated as: DP = 1 ÷ estuary volume (ft^3) (Robertson et al. 2016a).
Export Potential (EP): calculated as the overall susceptibility of an estuary to dilution and flushing by combining the physical susceptibility (FP and DP) information in a matrix (Robertson et al. 2016a). Note that EP should be rated as high susceptibility if "high risk" features are present, i.e. deep poorly flushed holes and/or banks or bed lined with stable substrate for attachment of nuisance macroalgal growths.

Table 4. Main Estuary Categories used in Eutrophication Susceptibility Analysis	
1. Shallow, Intertidal Dominated Estuaries (SIDEs)	
For NZ's dominant estuary types (i.e. shallow, short residence time (<3 days), and predominantly intertidal, tidal lagoon estuaries and parts of other estuary types where extensive tidal flats exist e.g. Firth of Thames, Kaipara Harbour, Freshwater Estuary - Stewart Island), flushing is too strong for significant retention of dissolved nutrients. Nevertheless, retention can still be sufficient to allow for retention of fine sediment and nutrients (particularly if these are excessive), deleterious for healthy growths of seagrass and saltmarsh, and nuisance growths of macroalgae in at-risk habitat. In these latter estuary types, assessment of the susceptibility to eutrophication must focus on the quantification of at-risk habitat (generally upper estuary tidal flats), based on the assumption that the risk of eutrophication symptoms increases as the habitat that is vulnerable to eutrophication symptoms expands. Nitrogen has been identified as the element most limiting to algal production in most estuaries in the temperate zone and is therefore the preferred target for eutrophication management in these estuaries (Howarth and Marino 2006). Susceptibility to Nutrient Loads: Moderate to High Major Primary Producers: Macroalgae	 Freshwater Estuary (Stewart Island): high susceptibility pristine estuary
2. Shallow, Short Residence Time Tidal River, and Tidal River with Adjoining Lagoon, Estuaries (SSRTREs)	
NZ also has a number of shallow, short residence time (<3 days) tidal river estuaries (including those that exit via a very well-flushed small lagoon) that have such a large flushing potential (freshwater inflow/estuary volume ratio >0.16) that the majority of fine sediment and nutrients are exported to the sea. Tidal Rivers with mouth restrictions or closure periods of days rather than months and high freshwater inflows (e.g. Lake Onoke) can also fit in this category. In general, these estuary types have extremely low susceptibilities and can often tolerate nutrient loads an order of magnitude greater than shallow, intertidal dominated estuaries. These shallow estuary types are generally N limited. Susceptibility to Nutrient Loads: Low to Very Low Major Primary Producers: Macroalgae, but low production, especially if freshwater inflow high.	 Waimatuku Estuary (Southland)
3. Deeper, Subtidal Dominated, Estuaries (DSDEs)	
Mainly subtidal, moderately deep (>3m to 15m mean depth) coastal embayments (e.g. Firth of Thames) and tidal lagoon estuaries (e.g. Otago Harbour) with moderate residence times >7 to 60 days, can exhibit both sustained phytoplankton blooms, and nuisance growths of opportunistic macroalgae (especially *Ulva* sp. and *Gracilaria* sp.) if nutrient loads are excessive. The latter are usually evident particularly on muddy intertidal flats near river mouths and in the water column where water clarity allows. Deeper, long residence time embayments and fiords are primarily phytoplankton dominated if nutrient loads are excessive. Outer reaches of such systems which sustain vertical density stratification can be susceptible to oxygen depletion and low pH effects (Sunda and Cai 2012, Zeldis et al. 2015). In both cases, it is expected that the US ASSETS approach will adequately predict their trophic state susceptibility. These deeper estuary types are generally N limited. Susceptibility to Nutrient Loads: Moderate to Low Major Primary Producers: Macroalgae (moderately deep) and phytoplankton (deeper sections).	 Pelorus Sound (Marlborough)
4. Intermittently Closed/Open Estuaries (SIDEs and SSRTREs)	
Shallow tidal lagoon and tidal river type estuaries (<3m deep) that experience periodical mouth closure or constriction have the highest susceptibility to nutrient retention and eutrophication, with the most susceptible being those with closure periods of months (e.g. Waituna Lagoon, Southland) rather than days (e.g. Lake Onoke, Wellington). In general, the tidal rivers have shorter periods of mouth closure (unless they are very small) than the more buffered tidal lagoons. The high susceptibility arises from reduced dilution (absence of tidal exchange at times) and increased retention (through both enhanced plant uptake and sediment deposition). Excessive phytoplankton and macroalgal growths and reduced macrophyte growth are characteristic symptoms of eutrophication in mouth restricted or closed estuaries. In such situations, which vary between marine and close to freshwater salinities, a co-limiting situation between N and P is expected, and as a consequence nutrient load/estuary response relationships should consider both N and P. Susceptibility to Nutrient Loads: Very High Major Primary Producers: Both Macroalgae and Phytoplankton	 Waituna Lagoon (Southland): high susceptibility intermittently open/closed estuary

Coastline looking north towards Herbertville, east coast Manawatu-Wanganui Region

Mowhanau Beach at estuary mouth, on west coast Manawatu-Wanganui Region

3. RESULTS

WAIKAWA ESTUARY - WEST COAST

The Waikawa Estuary is a moderate length, shallow, often poorly-flushed tidal river estuary whose mouth is intermittently open/closed. It has a moderate freshwater inflow and is located at Waikawa township. Sediments are dominated by subtidal muds and intertidal sands and include a significant area of high tide saltmarsh (*Juncus krausii* and *Schoenoplectus pungens*) vegetation. The estuary mouth is mostly open to the sea but can become restricted and consequently the estuary is often brackish. The estuary catchment is mixed native forest, exotic forest, dairy and sheep and beef farming.

Uses and Values. High use with good access - valued for its aesthetic appeal, bathing, biodiversity, and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate with some of its intertidal vegetation, saltmarsh and seagrass (in this case *Ruppia* sp.) intact. However, the natural vegetated margin has been lost and is now developed for grazing and urban use. The estuary is recognized as an important nursery area for marine and freshwater fish and birds.

Eutrophication Status. The estuary is moderately to highly susceptible to eutrophication at times based on; its poorly flushed nature (the upper estuary experiences salinity stratification during stable baseflows, i.e. salt wedge effect and the mouth is often restricted) and its high nutrient load (the current estimated N areal loading of 1195 $mgN.m^{-2}.d^{-1}$ exceeds the tentative guideline for high susceptibility SSRTRE estuaries of ~250 $mgN.m^{-2}.d^{-1}$).

The synoptic survey in February 2016, confirmed the presence of nuisance phytoplankton blooms (in this case coffee-coloured cryptomonads) in the sluggish bottom waters of the middle and upper estuary. The lower estuary was generally more well-flushed with cryptomonad blooms less visually obvious.

Nuisance opportunistic macroalgal blooms were less apparent, but were present as moderate density (50-80% cover) growths of *Ulva intestinalis* in shallow margin areas. Their low incidence was likely related to light limitation (from cryptomonad blooms) and flushing during flood periods.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), excess sediments are likely to be flushed to the sea during high flows, and that the synoptic survey showed that the estuary is dominated by muddy sediments in the mid-upper reaches.

Waikawa Estuary

Estuary Type/Area	SSRTRE Type 2, 21.5ha
Intertidal/Subtidal	28% subtidal
Mouth Opening	Mostly open, constricted
Mean Depth, Length	0.5-1.0m, 2km
Catchment	78.5km^2
FW Inflow	Mean annual 1.9$m^3.s^{-1}$
Saltmarsh, Seagrass	3.1ha saltmarsh, 80m^2 seagrass
Soft Mud	No intertidal soft muds
Macroalgae	0.12ha with 50-80% cover
Dairy Cow Nos.	1496
SS Loading	10.4kt/yr
Nitrogen Loading	93.8t/yr
Phosphorus Loading	7.9t/yr
Landuse: 35% native forest,13% exotic forest, 23% dairy, 26% sheep/beef.	
Geology: gravel 33%, sand 17%, sandstone 50%.	

SUMMARY

Issues

Muddiness	Low-Mod
Eutrophication	Moderate - High

For "moderate-length (mouth mostly closed or restricted) SSRTREs" with moderate-high nutrient/sediment loads it is recommended that monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends.

Monitoring and Investigations

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

WAIKAWA ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Waikawa Estuary mid reaches with crypto-monad bloom and macroalgae

Waikawa Estuary intertidal sedge growth

Waikawa Estuary - growth of lake clubrush

Shag colony Waikawa Estuary

Waikawa estuary - seagrass (*Ruppia* sp.) growing in shallows of mid estuary

Waikawa estuary upper reaches

Channelised upper estuary

Upper estuary mainly developed dune-land

Waikawa Estuary lower reaches with macroalgal bloom

Waikawa Estuary as it broadens onto beach

Waikawa Estuary at beach

Waikawa Estuary at beach

WAIKAWA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAIKAWA ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	0.77	High
Dilution Potential:	1.32×10^{-7}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility:		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	90th percentile (2010-2015, n=46) = 16.89ug/l	High
Macroalgae (EQR)	High cover in well-lit shallows	High
Supporting Indicators		
Redox Potential	aRPD ~1 cm in subtidal zone of mid and upper estuary	Moderate
Sediment % Mud	50-60% of subtidal estuary area was soft mud	Not Used
Seagrass	190m^2 of estuary area (0.09%) was seagrass (*Ruppia* sp)	
Clarity (SD, cm)	SD not visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN was 0.96 mgN/l, mean DIN was 0.7 mgN/l. This exceeds the ETI interim guidance of 400ug/l TN as boundary between high and moderate eutrophication for tidal lagoons.	
Existing Condition Eutrophication Rating		Mod - High

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	4.8	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - poorly flushed at low flows.	Low
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 50-60% of subtidal estuary area was soft muds. Local residents indicated that the estuary had got muddier in recent years. But sandy in lower estuary.	Moderate
Sedimentation Existing Condition Rating		Moderate Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES														
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

Figure 4. Waikawa Estuary Broad Scale Habitat Map

3. Results (continued)

OHAU ESTUARY - WEST COAST

The Ohau Estuary is a relatively long, shallow, moderately-highly flushed tidal river estuary (SSRTRE) that has a moderate-high freshwater inflow, extends approximately 3km inland, and is located near Ohau township. The estuary includes a 2km long poorly flushed, shallow arm to the south that predominantly empties at low tide.

Sediments are dominated by muds and sands in the mid-upper estuary and sands in the lower. A small area of high tide saltmarsh (*Schoenoplectus tabernaemontani* and *Schoenoplectus pungens*) vegetation occurs in the middle reaches. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach.

The estuary mouth is mostly open to the sea, but at times it migrates along the beach and can be semi-restricted, which means the estuary is often brackish. A main feature of the estuary is that the majority of its area is located on the beach where tidal exposure is high. The estuary catchment is mixed native forest, exotic forest, dairy and sheep and beef farming.

Uses and Values. Moderate use with good access - valued for its aesthetic appeal, bathing, biodiversity, and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate with some of its intertidal saltmarsh intact. However, the natural vegetated margin has been lost through past drainage and is now developed for grazing. The estuary is recognized as an important nursery area for marine and freshwater fish and birds.

Eutrophication Status. The estuary has low susceptibility to eutrophication based on:

- its well flushed nature (mouth not often restricted)
- its moderate nutrient load (the current estimated N areal loading of 1570 $mgN.m^{-2}.d^{-1}$ does not exceed the guideline for low susceptibility SSRTRE estuaries of ~2000 $mgN.m^{-2}.d^{-1}$, (Robertson et al. 2016).

The synoptic survey in February 2016 confirmed the absence of opportunistic macroalgal blooms in all areas except some natural poorly flushed areas in the lower estuary and generally clear waters in the lower and mid estuary.

Sedimentation Status. The estuary has low vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by sands particularly in the lower and mid estuary, but the mouth may be occasionally restricted.

Ohau Estuary

Estuary Type/Area	SSRTRE Type 4, 62ha
Intertidal/Subtidal	Approx 32% subtidal
Mouth Opening	Mostly open, constricted
Mean Depth, Length	0.5-1.0m, 3km
Catchment	$189km^2$
FW Inflow	Mean annual $8.43m^3.s^{-1}$
Saltmarsh, Seagrass	1.9ha saltmarsh, No seagrass
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	4776
SS Loading	23.8kt/yr
Nitrogen Loading	85t/yr
Phosphorus Loading	12.3t/yr
Landuse: Dairy 14%, Exotic Forest 9%, Native Forest 50.5%, Sheep/beef 23.4%.	
Geology: gravel 38%, greywacke 10%, sand 6%, sandstone 46%.	

SUMMARY

Issues

Muddiness	Low-Moderate
Eutrophication	Low

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only. It is noted that the vulnerability of the inshore coastal habitats from the river plume has not been assessed in this report, given it was outside the study brief.

Monitoring and Investigations

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that these low-moderate risk estuaries have not changed their risk rating.

OHAU ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Ohau Estuary upper reaches with sedge on margins

Ohau Estuary intertidal sedge growth

Ohau Estuary - channelised and winding through pasture in upper reaches

Ohau Estuary at beach (looking Nth)

Ohau Estuary at beach (looking Sth)

Ohau Estuary lower reaches at beach, including rushlands and herbfields

Ohau Estuary, macroalgal growth in poorly flushed lower estuary channel

Ohau estuary, bare sandflats in lower estuary

Ohau Estuary, poorly flushed southern arm in lower reaches.

Ohau Estuary looking towards mouth

Ohau Estuary, pooly flushed southern arm

Ohau Estuary southern Arm

OHAU ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: OHAU ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	1.17	High
Dilution Potential:	4.5×10^{-8}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: <2000mgN.m^{-2}.d^{-1}		Low
Susceptibility to Eutrophication Rating		Low

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	Insufficient for 90th %ile (2010-2015, n=8) = mean 4.0 ug/l	Low
Macroalgae (EQR)	Low cover except in relatively stagnant arms	Low
Supporting Indicators		
Redox Potential	aRPD >1 cm in subtidal zone of mid and upper estuary	Low
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD not visible on bed lower estuary	
Water Total N (mg/l)	Mean TN was 0.78 mgN/l, mean DIN was 0.35 mgN/l. This exceeds the ETI screening guidance of 400ug/l TN as boundary between high and moderate eutrophication of tidal lagoons.	
Existing Condition Eutrophication Rating		Low

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	4.9	Moderate
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted	Low-Mod
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 90% of estuary area was sands (mostly subtidal) - accuracy low	Low
Sedimentation Existing Condition Rating		Low Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES															
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																			
Fine Sediment																																			
Priorities For Monitoring																																			

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that these low-moderate risk estuaries have not changed their risk rating.

Figure 5. Ohau Estuary Broad Scale Habitat Map

3. Results (continued)

WAIWIRI ESTUARY - WEST COAST

The Waiwiri Estuary is a very small, shallow, poorly-flushed, brackish tidal river estuary (SSRTRE), that extends from the sea to the inner edge of the dunes. It is perched at the high water zone, has a low freshwater inflow and is located between the Ohau and Hokio estuaries. The estuary drains a small coastal lake, Lake Waiwiri (Papaitonga). Sediments are dominated by sands and includes margin growths of high tide brackish plants water celery (*Apium nodiflorum*) and native celery (*Apium prostatum*) in the upper estuary/lower stream near the beach. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouth is mostly open to the sea but can become restricted or closed and consequently the estuary is often brackish. The estuary catchment is predominantly sheep, beef and dairy farming.

Uses and Values. Moderate use with beach access - valued for its aesthetic appeal, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some of its intertidal vegetation intact. However, the natural vegetated margin has been lost and is now developed for grazing. The estuary is important for freshwater fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 1,138 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for low susceptibility tidal river estuaries of ~250 $mgN.m^{-2}.d^{-1}$, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because a large proportion of the load is expected to be assimilated in the upstream lake and because of its highly flushed nature, given that it is predominantly located on the beach and is therefore strongly affected by tidal currents. However, on occasions the mouth is expected to close, resulting in periods of poor flushing and nuisance algal/macrophyte growth.

The synoptic survey in February 2016, which was undertaken when the estuary mouth was open, confirmed the absence of either opportunistic macroalgal blooms or phytoplankton blooms in all areas. However, there were extensive growths of introduced rooted macrophytes in the channel margins near the beach, which were likely a result of the elevated nutrients in the water column and sediments.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be <5 times the estimated natural state SS load (NSSL) (given the presence of a lake in the catchment) and the estuary is dominated by sandy sediments.

Waiwiri Estuary

Estuary Type/Area	SSRTRE Type 1, 3.9ha
Intertidal/Subtidal	Approx 18% subtidal
Mouth Opening	Very constricted
Mean Depth, Length	0.5m, 0.5km
Catchment	$15.2km^2$
FW Inflow	Mean annual $0.17m^3.s^{-1}$
Saltmarsh, Seagrass	None
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	350
SS Loading	0.2kt/yr (reduced by lake)
Nitrogen Loading	16.2t/yr (reduced by lake)
Phosphorus Loading	0.6t/yr (reduced by lake)
Landuse: Dairy 21.8%, Exotic Forest 16.6%, Native Forest 6.5%, Sheep/beef 51.4%	
Geology: gravel 19%, sand 75%	

SUMMARY

Issues

Muddiness	Low-Mod
Eutrophication	Low -Mod

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

WAIWIRI ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Waiwiri Estuary as it enters beach, mainly as freshwater

Waiwiri Estuary margin growth of water celery in upper reaches on beach

Waiwiri Estuary - growth of water celery

Middle reaches Waiwiri Estuary on beach

Waiwiri Estuary - on beach

Waiwiri Estuary as it traverses the beach

Waiwiri Estuary channel on beach

Introduced water celery (*Apium nodiflorum*)

Beach area in vicinity of Waiwiri Estuary mouth

Beach north of Waiwiri Estuary

Waiwiri Estuary mouth

Introduced water celery (*Apium nodiflorum*)

WAIWIRI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAIWIRI ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	0.75	High
Dilution Potential:	1.45×10^{-6}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility:		Moderate - High
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed.	Low
Supporting Indicators		
Redox Potential	aRPD >5 cm in subtidal zone of mid and upper estuary	Low
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	Mean TN was very elevated at 2.5 mgN/l (4 samples only) in the upstream stream area but likely to be well diluted in estuary at beach, except when mouth closed.	
Existing Condition Eutrophication Rating (includes closed periods)		Low

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	14.4 but presence of lake means this rating is low	Low
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted/closed	Moderate
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 90% of estuary area was sands (mostly were subtidal) - accuracy low	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

Figure 6. Waiwiri Estuary Broad Scale Habitat Map

3. Results (continued)

HOKIO ESTUARY - WEST COAST

The Hokio Estuary is a moderate length, shallow, poorly-flushed, brackish tidal river estuary (SSRTRE), that is located primarily on the beach near Hokio township. It is perched at the high water zone, has a low freshwater inflow and is located between the Waiwiri and Waiwarawa estuaries. The estuary drains the coastal lake, Lake Horowhenua. Sediments are dominated by sands and include margin growths of high tide brackish plants water celery (*Apium nodiflorum*) and other introduced species in the upper estuary/lower stream near the beach. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouth is mostly open to the sea but access of tidal water to the upper estuary is restricted by a change in channel gradient 100m inland of the mouth. As a consequence, the majority of the estuary generally has a very low salinity and grows predominantly low salinity tolerant aquatic plants. The estuary catchment is very developed with predominantly sheep, beef and dairy farming, but also some urban development.

Uses and Values. High use area with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some of freshwater dominated intertidal vegetation. However, the natural vegetated margin has been mostly lost. The estuary is important for freshwater fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated N areal loading of 3,700 mgN.m^{-2}.d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2000 mgN.m^{-2}.d^{-1}, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because a large proportion of the load is expected to be assimilated in the upstream lake and because the estuary is predominantly located on the beach and is therefore affected by tidal currents. However, on occasions the mouth is expected to close or be restricted, resulting in periods of poor flushing and nuisance algal/macrophyte growth (brackish species).

The synoptic survey in February 2016, which was undertaken when the estuary mouth was open (but restricted), confirmed the presence of extensive growths of introduced rooted macrophytes in the channel margins, which were likely a result of the elevated nutrients in the water column and sediments.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be <5 times the estimated natural state SS load (NSSL) (given the presence of a lake in the catchment) and the estuary is dominated by sandy sediments.

Hokio Estuary

Estuary Type/Area	SSRTRE Type 2, 4ha
Intertidal/Subtidal	Approx 44% subtidal
Mouth Opening	Very constricted
Mean Depth, Length	0.5m, 1.5km
Catchment	69.7km^2
FW Inflow	Mean annual 0.97m^3.s^{-1}
Saltmarsh, Seagrass	None
Soft Mud	No intertidal muds
Macroalgae	Absent
Dairy Cow Nos.	2465
SS Loading	0.3kt/yr (reduced by lake)
Nitrogen Loading	54.2t/yr (but reduced by lake)
Phosphorus Loading	0.9t/yr (but reduced by lake)
Landuse: Urban 12%, Crop/hort 6%, Dairy 18%, Exotic Forest 3.5%, Native Forest 3.5%, Sheep/beef 50.5%	
Geology: gravel 54%, sand 35%.	

SUMMARY

Issues

Muddiness	Low-Mod
Eutrophication	Moderate

For "moderate-length (mouth mostly closed/restricted) SSRTREs" with moderate-high nutrient/sediment loads it is recommended that monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends.

Monitoring and Investigations

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass/macrophyte biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

HOKIO ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Upper Hokio Estuary, mainly freshwater

Upper Hokio Estuary with introduced water celery (*Apium nodiflorum*)

Upper Hokio Estuary - near beach

Middle reaches Hokio Estuary on beach (still mainly freshwater at this point)

Hokio Estuary - on beach, with water celery in channel

Hokio Estuary as it traverses the beach

Hokio Estuary with surface growths of the floating fern *Azolla filiculoides*

Hokio Estuary as it traverses the beach

Beach area in vicinity of Hokio Estuary mouth

Hokio Estuary mouth

Hokio Estuary mouth

Hokio Stream

HOKIO ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: HOKIO ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	4.19	High
Dilution Potential:	1.4 x 10^{-6}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate-High
Susceptibility to Eutrophication Rating		Moderate-High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed.	Moderate
Supporting Indicators		
Redox Potential	aRPD >1 cm in subtidal zone of mid and upper estuary	Moderate
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	Mean TN (at Lake Horowhenua) was very elevated at 1.9mgN/l). Therefore lower river eutrophic but estuary flushed by tides.	
Existing Condition Eutrophication Rating (includes closed periods)		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	14.7 but presence of lake means this rating is low	Low
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted/closed	Moderate
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 90% of estuary area was sands (mostly were subtidal) - (accuracy low)	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass/ macrophyte biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

Figure 7. Hokio Estuary Broad Scale Habitat Map

3. Results (continued)

WAIRARAWA ESTUARY - WEST COAST

The Wairarawa Estuary is a very small, shallow, poorly-flushed, brackish tidal river estuary (SSRTRE), that extends from the sea to the inner edge of the dunes (~200m long). It is perched at the high water zone, has a low freshwater inflow and is located at Waitarere Beach township. Sediments are dominated by sands and include margin growths of high tide brackish plants water celery (*Apium nodiflorum*) in the upper estuary/lower stream near the beach. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouth is mostly open to the sea but can become restricted or closed and consequently the estuary is often brackish. The estuary catchment is predominantly sheep, beef and dairy farming and exotic forestry.

Uses and Values. Moderate use with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some of its margin duneland vegetation intact. The estuary is used by fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 20,000 mgN.m^{-2}.d^{-1} exceeds the guideline for tidal river estuaries of ~2000 mgN.m^{-2}.d^{-1}, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because of its highly flushed nature, given that it is predominantly located on the beach and is therefore strongly affected by tidal currents. However, on occasions the mouth is expected to close, resulting in periods of poor flushing and nuisance algal/macrophyte growth.

The synoptic survey in February 2016, which was undertaken when the estuary mouth was open, confirmed the absence of either opportunistic macroalgal blooms or phytoplankton blooms in all areas. However, there were extensive growths of introduced rooted macrophytes in the channel margins near the beach, which were likely a result of the elevated nutrients in the water column and sediments.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that while the current suspended sediment load (CSSL) is likely to be >5 times the estimated natural state SS load (NSSL), the catchment geology is mainly sand and the estuary is dominated by sandy sediments and periodically well-flushed.

Wairarawa Estuary

Estuary Type/Area	SSRTRE Type 1, 0.3ha
Intertidal/Subtidal	Approx 33% subtidal
Mouth Opening	Very constricted
Mean Depth, Length	0.5m, 0.2km
Catchment	13.7km^2
FW Inflow	Mean annual 0.88m^3.s^{-1}
Saltmarsh, Seagrass	None
Soft Mud	No intertidal muds
Macroalgae	Absent
Dairy Cow Nos.	1500
SS Loading	0.1kt/yr
Nitrogen Loading	21.9t/yr
Phosphorus Loading	0.5t/yr
Landuse: Urban 4.5%, Dairy 45.7%, Exotic Forest 26.7%, Native Forest 1.5%, Sheep/beef 20.3%	
Geology: sand 100%.	

SUMMARY

Issues

Muddiness	Low-Moderate
Eutrophication	Low-Moderate

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

WAIRARAWA ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Mouth of Wairarawa Estuary at Waitarere Beach

Wairarawa Estuary at Waitarere Beach

WAIRARAWA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAIRARAWA ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	50.9	High
Dilution Potential:	1.8×10^{-5}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate - High
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed.	Low
Supporting Indicators		
Redox Potential	aRPD >1 cm in subtidal zone of beach estuary	Moderate
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	Mean of 5.18 mg/l (n=15) between 2010-2015, indicates likely eutrophication at times.	
Existing Condition Eutrophication Rating (includes closed periods)		Low-Mod

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	12.4 but catchment geology is 100% sand	Low
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted/closed	Moderate
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 90% of estuary area was sands (mostly were subtidal) - (accuracy low)	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION												SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																						
Fine Sediment																																						
Priorities For Monitoring																																						

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

Figure 8. Wairarawa Estuary Broad Scale Habitat Map

3. Results (continued)

MANAWATU ESTUARY - WEST COAST

The Manawatu Estuary is a large, shallow, generally well-flushed, tidal river estuary (SSRTRE), that is located near Foxton township and extends its tidal influence approximately 11km inland. It has a large freshwater inflow which, along with the tidal inflow, is expected to flush most nutrients and fine sediment from the estuary. Sediments, while dominated by sands, include large areas of intertidal mud (46ha) and saltmarsh (161ha). Saltmarsh was dominated by extensive areas of rushland (searush *Juncus kraussii* and jointed wire rush *Apodasmia similis*), sedgeland (three square *Schoenoplectus pungens*) and large herbfields (remuremu *Selliera radicans* and primrose *Samolus repens*). Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominated the terrestrial margins near the beach. The estuary mouth is always open to the sea with the upper estuary characterised by low salinity waters, predominantly brackish aquatic plants. The estuary catchment is very developed predominantly sheep, beef and dairy farming, but also some urban.

Uses and Values. High use area with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate-high with some seagrass and saltmarsh intact but the natural vegetated margin mostly lost. The estuary is important for freshwater fish and internationally important for birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 3,245 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for low susceptibility tidal river estuaries of ~2000 $mgN.m^{-2}.d^{-1}$, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, has high freshwater inflow, is strongly affected by tidal currents and is often turbid (mean 35 NTU). However, on occasions during low flows when the estuary is stratified, nuisance algal/macrophyte growth may occur.

The synoptic survey in February 2016, confirmed the absence of opportunistic macroalgal blooms at nuisance levels and no estuary-driven phytoplankton blooms. The presence of elevated chlorophyll a concentrations at times are likely attributable to freshwater sources upstream of the estuary.

Sedimentation Status. The estuary is rated as moderately vulnerable to muddiness issues based on the facts that although the current suspended sediment load (CSSL) is likely to be >10 times the estimated natural state SS load (NSSL), the estuary is well-flushed and dominated by sandy sediments in the lower reaches.

Manawatu Estuary

Estuary Type/Area	SSRTRE Type 4, 533ha
Intertidal/Subtidal	Approx 48% subtidal
Mouth Opening	Always open
Mean Depth, Length	1.0m, 7.5km
Catchment	$5881km^2$
FW Inflow	Mean annual $124m^3.s^{-1}$
Saltmarsh, Seagrass	161ha, 0.005%
Soft Mud	46ha intertidal
Macroalgae	0.7ha
Dairy Cow Nos.	209,271
SS Loading	2567kt/yr
Nitrogen Loading	6313t/yr
Phosphorus Loading	1270t/yr
Landuse: Dairy 18.1%, Exotic Forest 4%, Native Forest 17.1%, Sheep/beef 58.1%	
Geology: gravel 40%, greywacke 14%, mudstone 15%, sand 4%, sandstone 18%	

SUMMARY

Issues

Muddiness	Low-Moderate
Eutrophication	Moderate

For the larger examples of this estuary type (e.g. Manawatu and Whanganui Estuaries), which have very significant intertidal areas, high nutrient and sediment loads and high human use and ecological values, but low-moderate eutrophication and muddiness symptoms, it is recommended that both broad scale habitat mapping and fine scale intertidal monitoring be undertaken on a long term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002) plus subsequent improvements (Robertson and Stevens 2015, Stevens and Robertson 2015). It is noted that the vulnerability of the inshore coastal habitats from the river plume has not been assessed in this report, given it was outside the study brief.

Monitoring and Investigations

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is usually repeated at 5 yearly intervals. Broad scale intertidal mapping of Manawatu Estuary was undertaken in 2016 (Stevens and Robertson 2016) and in Whanganui Estuary in 2009 (Stevens and Robertson 2009). Fine scale monitoring measures the condition of the high susceptibility intertidal sediments through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at two sites), and thereafter at 5 yearly intervals. This component has not yet been measured in this estuary.

MANAWATU ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Upper Manawatu Estuary with wetland plant dominated margins.

Channelised freshwater dominated upper estuary.

Middle estuary saltmarsh (still a strong freshwater influence at this point).

Middle estuary showing herbfields growing among rushland.

Lower Manawatu Estuary - herbfield adjacent to duneland in clean sands.

Lower Manawatu Estuary - herbfield adjacent to rushland in muddy sands.

Estuary margin next to the Foxton Beach settlement.

Lower Manawatu Estuary - example of localised macroalgal growth in low tide channel.

Seawall and exotic plantings adjacent to the Foxton Beach settlement.

Lower Manawatu Estuary - extensive sand and mud flats with coastal duneland in the background.

Lower Manawatu Estuary - mudflats downstream of the wharf.

Lower Manawatu Estuary - soft muds along the channel edge.

MANAWATU ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: MANAWATU ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	2.0	High
Dilution Potential:	5.31 x 10^{-9}	Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	27/1/2016 (range 4.1-18.7, n=10) but likely from river source	Low
Macroalgae (EQR)	Low cover, except for short periods in low flows	Low
Supporting Indicators		
Redox Potential	aRPD ~1 cm in subtidal zone of mid and upper estuary	Moderate
Sediment % Mud	60% of estuary area was soft mud mainly subtidal	Not Used
Seagrass	0.005% of estuary area was seagrass (*Ruppia* sp)	
Clarity (SD, cm)	SD not visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN was 0.93 mgN/l, mean DIN was 0.5 mgN/l. This exceeds the ETI interim guidance of 400ug/l TN as boundary between high and moderate eutrophication for tidal lagoons.	
Existing Condition Eutrophication Rating		Low-Mod

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	12.6	High
Presence of Poorly Flushed Habitat	Estuary channelised with no poorly flushed areas	Low
Sedimentation Susceptibility Rating		Low Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	9% soft muds (with mud content 46-92%, n=5)	Moderate
Sedimentation Existing Condition Rating		Moderate Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

For the larger examples of this estuary type (e.g. Manawatu and Whanganui estuaries), which have very significant intertidal areas, high nutrient and sediment loads and high human use and ecological values, but low-moderate eutrophication and muddiness symptoms, it is recommended that both broad scale habitat mapping and fine scale intertidal monitoring be undertaken on a long term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002) plus subsequent improvements (Robertson and Stevens 2015, Stevens and Robertson 2015).

Figure 9. Manawatu Estuary Broad Scale Habitat Map

3. Results (continued)

THREE MILE CREEK ESTUARY - WEST COAST

The Three Mile Creek Estuary is very small, shallow, poorly-flushed, brackish tidal river estuary (SSRTRE), that extends from the sea to the inner edge of the dunes. It is perched at the high water zone, has a low freshwater inflow and is located between the Manawatu and Kaikokopu estuaries. The estuary drains a small coastal lake, Lake Koputara. Sediments are dominated by sands and the estuary includes margin growths of high tide brackish plants water celery (*Apium nodiflorum*) and native celery (*Apium prostatum*) in the upper estuary/lower stream near the beach. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouth is mostly open to the sea but can become restricted or closed and consequently the estuary is often brackish. The estuary catchment is predominantly sheep, beef and dairy farming.

Uses and Values. Moderate use with beach access - valued for its aesthetic appeal, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some freshwater vegetation intact and the natural vegetated margin dominated by dune species. The estuary is used by fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 4,258 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for high susceptibility tidal river estuaries of ~250 $mgN.m^{-2}.d^{-1}$), the estuary has low susceptibility to eutrophication. This is primarily because a large proportion of the load is expected to be assimilated in the upstream lake and because of its highly flushed nature, given that it is predominantly located on the beach and is therefore strongly affected by tidal currents. However, on occasions the mouth is expected to close, resulting in periods of poor flushing and nuisance algal/macrophyte growth.

The synoptic survey in February 2016, which was undertaken when the estuary mouth was open, confirmed the absence of either opportunistic macroalgal blooms or phytoplankton blooms in all areas. However, there were extensive growths of introduced rooted macrophytes in the channel margins near the beach, which were likely a result of the elevated nutrients in the water column and sediments.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be <5 times the estimated natural state SS load (NSSL) (given the presence of a lake in the catchment and the catchment geology mostly sand) and the estuary is dominated by sandy sediments.

Three Mile Creek Estuary

Estuary Type/Area	SSRTRE Type 1, 2.4ha
Intertidal/Subtidal	Approx 17% subtidal
Mouth Opening	Very constricted
Mean Depth, Length	0.5m, 0.5km
Catchment	$27km^2$
FW Inflow	Mean annual $0.25m^3.s^{-1}$
Saltmarsh, Seagrass	None
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	3360
SS Loading	0.1kt/yr (reduced by lake)
Nitrogen Loading	37.3t/yr (reduced by lake)
Phosphorus Loading	0.93t/yr (reduced by lake)
Landuse: Dairy 41.7%, Exotic Forest 16.6%, Native Forest 4.1%, Sheep/beef 37.2%,	
Geology: sand 100%.	

SUMMARY

Issues

Muddiness	Low-Moderate
Eutrophication	Moderate

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

Coastline immediately north of Three Mile Creek Estuary

High use of beach area immediately north of Three Mile Creek Estuary and adjacent to Kaikokopu Estuary mouth

THREE MILE CREEK ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: THREE MILE CREEK ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	1.8	High
Dilution Potential:	2.3 x 10^{-6}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >250mgN.m^{-2}.d^{-1}		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed	Low
Supporting Indicators		
Redox Potential	aRPD >5 cm in subtidal zone of mid and upper estuary	Low
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	Mean TN was very elevated at 2.5 mgN/l (4 samples only) in the upstream stream area but likely to be well diluted in estuary at beach, except when mouth closed	
Existing Condition Eutrophication Rating (includes closed periods)		Low-Mod

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	9.3 but presence of lake means this rating is low	Low
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted/closed	Moderate
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 90% of estuary area was sands (mostly subtidal) - accuracy low	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																		
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																						
Fine Sediment																																						
Priorities For Monitoring																																						

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

Figure 10. Three Mile Creek Estuary Broad Scale Habitat Map

3. Results (continued)

KAIKOKOPU ESTUARY - WEST COAST

The Kaikokopu Estuary is a very small, shallow, poorly-flushed, brackish tidal river estuary (SSRTRE), that extends from the sea to the inner edge of the dunes at Himatangi Beach. It is perched at the high water zone, has a low freshwater inflow and drains a small coastal lake, Lake Kaikokopu. Sediments are dominated by sands and the estuary includes margin growths of high tide brackish plants water celery (*Apium nodiflorum*) and floating duckweed in the upper estuary/ lower stream near the beach. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouth is mostly open to the sea but can become restricted or closed and consequently the estuary is often brackish. The estuary catchment is predominantly dairy and sheep/beef farming and exotic forestry.

Uses and Values. High use with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some intertidal freshwater vegetation intact. However, the natural vegetated margin has been lost and is now developed primarily for urban use. The estuary is used by fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 1868 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for high susceptibility tidal river estuaries of ~250 $mgN.m^{-2}.d^{-1}$), the estuary has low susceptibility to eutrophication. This is primarily because a large proportion of the load is expected to be assimilated in the upstream lake and because of its highly flushed nature, given that it is predominantly located on the beach and is therefore strongly affected by tidal currents. However, on occasions the mouth is expected to close, resulting in periods of poor flushing and nuisance algal/ macrophyte growth.

The synoptic survey in February 2016, which was undertaken when the estuary mouth was open, confirmed the absence of either opportunistic macroalgal blooms or phytoplankton blooms in all areas. However, there were extensive growths of introduced rooted macrophytes and floating duckweed in the channel margins near the beach, which were likely a result of the elevated nutrients in the water column and sediments.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be <5 times the estimated natural state SS load (NSSL) (given the presence of a lake in the catchment and the catchment geology mostly sand) and the estuary is dominated by sandy sediments.

Kaikokopu Estuary

Estuary Type/Area	SSRTRE Type 1, 5ha
Intertidal/Subtidal	Approx 40% subtidal
Mouth Opening	Constricted
Mean Depth, Length	0.5m, 0.5km
Catchment	$56km^2$
FW Inflow	Mean annual $1m^3.s^{-1}$
Saltmarsh, Seagrass	None
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	5605
SS Loading	0.2kt/yr (reduced by lake)
Nitrogen Loading	34.1t/yr (reduced by lake)
Phosphorus Loading	0.86t/yr (reduced by lake)
Landuse: Dairy 41.7%, Exotic Forest 16.6%, Native Forest 4.1%, Sheep/beef 37.2%,	
Geology: sand 100%.	

SUMMARY

Issues

Muddiness	Low-Moderate
Eutrophication	Moderate

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/ restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

KAIKOKOPU ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Upper Kaikokopu Estuary, mainly fresh-water

Upper Kaikokopu Estuary with introduced water celery (*Apium nodiflorum*).

Upper Kaikokopu Estuary - with water celery and filamentous macroalgae

Middle reaches Kaikokopu Estuary, with floating duckweed (still freshwater)

Kaikokopu Estuary - duckweed (*Lemna* sp.)

Kaikokopu Estuary as it nears the beach

Kaikokopu Estuary at beach

Kaikokopu Estuary as it traverses the beach

Kaikokopu Estuary upstream of beach

Kaikokopu Estuary upstream

Kaikokopu Estuary swimming

Kaikokopu Estuary mouth area - high human use

KAIKOKOPU ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: KAIKOKOPU ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	3.46	High
Dilution Potential:	1.1 x 10^{-6}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >250mgN.m^{-2}.d^{-1}		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed	Low
Supporting Indicators		
Redox Potential	aRPD >5 cm in subtidal zone of mid and upper estuary	Low
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	Mean TN was very elevated at 2.5 mgN/l (4 samples only) in the upstream stream area but likely to be well diluted in estuary at beach, except when mouth closed	
Existing Condition Eutrophication Rating (includes closed periods)		Low-Mod

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	15 but presence of lake means this rating is low	Low
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted/closed	Moderate
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 90% of estuary area was sands (mostly were subtidal) - (accuracy low)	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																						
Fine Sediment																																						
Priorities For Monitoring																																						

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

Figure 11. Kaikokopu Estuary Broad Scale Habitat Map

3. Results (continued)

PUKEPUKE ESTUARY - WEST COAST

The Pukepuke Estuary is a very small, shallow, poorly-flushed, brackish tidal river estuary (SSRTRE), that extends from the sea to the inner edge of the dunes. It is perched at the high water zone, has a low freshwater inflow and is located just south of the Rangitikei Estuary. The estuary drains a series a small coastal lakes. Sediments are dominated by sands and the estuary includes margin growths of high tide brackish plants water celery (*Apium nodiflorum*)) in the upper estuary/ lower stream near the beach. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouth is mostly open to the sea but can become restricted or closed and consequently the estuary is often brackish. The estuary catchment is predominantly dairy and sheep/beef farming and exotic forestry.

Uses and Values. Moderate use with beach access - valued for its aesthetic appeal, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some freshwater vegetation intact and the natural vegetated margin dominated by dune and exotic forest species. The estuary is used by fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 36,300 mgN.m^{-2}.d^{-1} exceeds the guideline for high susceptibility tidal river estuaries of ~250 mgN.m^{-2}.d^{-1}, the estuary has low-moderate susceptibility to eutrophication. This is primarily because a large proportion of the load is expected to be assimilated in the upstream lake and because of its highly flushed nature (given that it is predominantly located on the beach and is therefore strongly affected by tidal currents). However, on occasions the mouth is expected to close, resulting in periods of poor flushing and nuisance algal/macrophyte growth.

The synoptic survey in February 2016, which was undertaken when the estuary mouth was open, confirmed the absence of either opportunistic macroalgal blooms or phytoplankton blooms in all areas. However, there were extensive growths of introduced rooted macrophytes in the channel margins near the beach, which were likely a result of the elevated nutrients in the water column and sediments.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be <5 times the estimated natural state SS load (NSSL) (given the presence of a lake in the catchment and the catchment geology mostly sand) and the estuary is dominated by sandy sediments.

Pukepuke Estuary

Estuary Type/Area	SSRTRE Type 1, 0.6ha
Intertidal/Subtidal	Approx 25% subtidal
Mouth Opening	Very constricted
Mean Depth, Length	0.5m, 0.5km
Catchment	41km^2
FW Inflow	Mean annual 0.11m^3.s^{-1}
Saltmarsh, Seagrass	None
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	3360
SS Loading	0.1kt/yr (reduced by lake)
Nitrogen Loading	79.7t/yr (reduced by lake)
Phosphorus Loading	1.61t/yr (reduced by lake)
Landuse: Dairy 48.4%, Exotic Forest 15.3%, Sheep/ beef 34%	
Geology: sand 100%.	

SUMMARY

Issues

Muddiness	Low-Moderate
Eutrophication	Low-Moderate

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/ restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

PUKEPUKE ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: PUKEPUKE ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	3.23	High
Dilution Potential:	9.4×10^{-6}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >250mgN.m^{-2}.d^{-1}		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed.	Low
Supporting Indicators		
Redox Potential	aRPD >5 cm in subtidal zone of mid and upper estuary	Low
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	Mean TN was very elevated at 2.5 mgN/l (4 samples only) in the upstream stream area but likely to be well diluted in estuary at beach, except when mouth closed	
Existing Condition Eutrophication Rating (includes closed periods)		Low-Mod

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	13.3 but presence of lake means this rating is low	Low
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted/closed	Moderate
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 90% of estuary area was sands (mostly subtidal) - accuracy low	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION							
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

In terms of ecological vulnerability to eutrophication and sedimentation, this estuary was identified with low-moderate vulnerability. The main reason for this was its small size, lower ecological value, and regular periods of high flushing (even though it likely experiences periodic mouth closure/restriction), which means that, although estimated nutrient and sediment loads to the estuary were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

3. Results (continued)

RANGITIKEI ESTUARY - WEST COAST

The Rangitikei Estuary is a large, shallow, generally well-flushed, tidal river estuary (SSRTRE), that is located near Scotts Ferry village and extends approximately 3-4km inland. It has a large freshwater inflow which, along with the tidal inflow, is expected to flush most nutrients and fine sediment from the estuary. Sediments are dominated by sands and gravels, but there was a small intertidal area along the main mid-upper estuary channel dominated by soft, moderately well oxygenated muds. The estuary includes small areas of high tide saltmarsh (*Schoenoplectus tabernaemontani* and *Schoenoplectus pungens*) vegetation and relatively extensive elevated areas of herbfield and rushland, with extensive evidence of past saltmarsh drainage and reclamation. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The upper estuary generally has a very low salinity and grows predominantly low salinity tolerant aquatic plants. The estuary catchment is mostly developed predominantly sheep, beef and dairy farming, but also some native forest.

Uses and Values. High use area with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation intact. However, the natural vegetated margin has been mostly lost. The estuary is important for freshwater fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 4,900 mgN.m^{-2}.d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2000 mgN.m^{-2}.d^{-1}, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, has high freshwater inflow, is strongly affected by tidal currents and is often turbid (mean 35 NTU).

The synoptic survey in February 2016, confirmed the absence of either opportunistic macroalgal blooms or estuary-driven phytoplankton blooms. The presence of elevated chlorophyll a concentrations at times are likely attributable to freshwater sources upstream of the estuary.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that although the current suspended sediment load (CSSL) is likely to be >10 times the estimated natural state SS load (NSSL), the estuary is dominated by coarse sediments and is well flushed.

Rangitikei Estuary

Estuary Type/Area	SSRTRE Type 4, 118ha
Intertidal/Subtidal	34% subtidal
Mouth Opening	Always open
Mean Depth, Length	1.0m, 3.0km
Catchment	3924km^2
FW Inflow	Mean annual 72m^3.s^{-1}
Saltmarsh, Seagrass	22.2ha
Soft Mud	1.4ha
Macroalgae	Absent
Dairy Cow Nos.	42,389
SS Loading	1231kt/yr
Nitrogen Loading	2133t/yr
Phosphorus Loading	364t/yr
Landuse: Dairy 4.2%, Exotic Forest 3.3%, Native Forest 28.4%, Sheep/beef 54.1%	
Geology: gravel 23%, limestone 23%, mudstone 12%, sand 2%, sandstone 32%	

SUMMARY

Issues

Muddiness	Low-Mod
Eutrophication	Low-Mod

The low-moderate rating for both eutrophication and sedimentation in this relatively large SSRTRE estuary reflects the capacity of this estuary to flush excess nutrients and fine sediment to the sea. As a result, it is recommended that long term monitoring be limited to low frequency, broad scale, screening level assessments only. It is noted that the vulnerability of the inshore coastal habitats from the river plume has not been assessed in this report, given it was outside the study brief.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

RANGITIKEI ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Upper Rangitikei Estuary, mainly freshwater, near Scotts Ferry

Mid Rangitikei Estuary with sedge growth and soft mud intertidal area

Saltmarsh - lake clubrush (*Schoenoplectus tabernaemontani*)

Middle reaches Rangitikei Estuary towards sea (still mainly freshwater at this point)

Mid Rangitikei Estuary - looking upstream

Rangitikei Estuary and land bordering it

Rangitikei Estuary as it braids near the beach

Rangitikei Estuary as it traverses the beach

Beach area in vicinity of Rangitikei Estuary mouth

Rangitikei Estuary saltmarsh area to north of mouth

Rangitikei Estuary mouth area

Rangitikei Estuary looking towards mouth

RANGITIKEI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: RANGITIKEI ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	5.3	High
Dilution Potential:	2.4 x 10^{-8}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate-High
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	Mean 2.56 ug/l (n = 52, 2010-2015)	Low
Macroalgae (EQR)	Absent in 2016 survey	Low
Supporting Indicators		
Redox Potential	aRPD >3 cm in intertidal zone of mid and upper estuary	Low
Sediment % Mud	2% of estuary area was intertidal soft mud	Not Used
Seagrass	no seagrass	
Clarity (SD, cm)	SD not visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN was 0.375 mgN/l, mean DIN was 0.16mgN/l. This does not exceed ETI interim guidance of 400ugN/l as boundary between high and moderate eutrophication for tidal lagoons.	
Existing Condition Eutrophication Rating		Low

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	10.6	High
Presence of Poorly Flushed Habitat	Estuary channelised with no poorly flushed areas	Very Low
Sedimentation Susceptibility Rating		Low Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	2% intertidal soft muds, mainly coarser subtidally	Low
Sedimentation Existing Condition Rating		Low Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION												SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

Figure 12. Rangitikei Estuary Broad Scale Habitat Map

3. Results (continued)

7 SMALL ESTUARIES BETWEEN RANGITIKEI AND WHANGANUI ESTUARIES - WEST COAST

(Ruamai Range, Un-named Streams (2), Waimahora Stream, Lake Koitiata Outflow, Koitiata Stream and Kaitoke Stream Estuaries)

The seven small estuaries located between the Rangitikei and Turakina estuaries are all very small, shallow, brackish tidal river estuaries (SSRTRE), that extend from the sea to the inner edge of the dunes. The upper estuary area in each consists of a narrow channel, perched at the high water zone, with a low freshwater inflow. Several of the estuaries drain small coastal lake/ponds. Sediments are dominated by sands and most include margin growths of high tide brackish plants water celery (*Apium nodiflorum*)) in the upper estuary/lower stream near the beach. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouths can be open to the sea but are often restricted or closed and consequently the estuaries are often brackish. The estuary catchments are predominantly exotic forestry and sheep, beef and dairy farming.

Uses and Values. Low use with beach access - valued for their aesthetic appeal, fishing near the mouths and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some of their intertidal vegetation intact. However, the natural vegetated margin has been lost and is now mostly developed for forestry/grazing. The estuaries are used by fish and birds.

Eutrophication Status. Despite their high nutrient loads (the current estimated catchment N areal loading from each estuary likely exceeds the guideline for high susceptibility tidal river estuaries of ~250 $mgN.m^{-2}.d^{-1}$), the estuaries have low susceptibility to eutrophication. This is primarily because of their highly flushed natures (given that they are predominantly located on the beach and therefore strongly affected by tidal currents). However, on occasions their mouths are expected to close, resulting in periods of poor flushing and nuisance algal/macrophyte growth.

The synoptic surveys in February 2016, which were undertaken when the estuaries mouths were open, confirmed the absence of either opportunistic macroalgal blooms or phytoplankton blooms in all areas. However, there were extensive growths of introduced rooted macrophytes in the channel margins near the beach in most estuaries.

Sedimentation Status. The estuaries are rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be <5 times the estimated natural state SS load (NSSL) (given the presence of a lakes in the catchments and the catchment geology mostly sand) and the estuaries are dominated by sandy sediments.

Data for 7 estuaries presented as one for parameters where data for each is the same, and where different the data is presented in the same order as shown in the title to this page.	
Estuary Type/Area	SSRTRE Type 1, 1.6, 0.25, 0.1, 0.75, 0.27, 2.4, 3.5ha
Intertidal/Subtidal	% subtidal: 13, 36, 10, 27, 93, 29, 11%
Mouth Opening	Often constricted/closed
Mean Depth, Length	~0.5m, 0.5km
Catchment	37, 22, 10, 35, 19, 48, 49km^2
FW Inflow (mean annual)	First 4 <0.1, next two 0.1-0.5 and last 0.5-1$m^3.s^{-1}$
Saltmarsh, Seagrass	Absent
Soft Mud	No intertidal soft muds
Macroalgae	Absent
Dairy Cow Nos.	0, 1849, 575, 0, 1260, 1200, 360
SS Loading	0.3, 0.2, 0.1, 0.4, 0.1, 0.3, 1.2kt/yr (some reduced by lake)
Nitrogen Loading	40, 24, 13, 32, 11, 26, 39t/yr (some reduced by lake)
Phosphorus Loading	0.9, 0.9, 0.4, 1, 0.3, 0.9, 1.7t/yr (reduced by lake)
Landuse: Ruamai Range; Dairy 7.2%, Exotic Forest 31.4%, Sheep/beef 60.6%. 1st Un-named; Dairy 34.6%, Exotic Forest 33.8%, Sheep/beef 30.6%. 2nd Un-named; Dairy 29.6%, Exotic Forest 49.5%, Sheep/beef 20.8%. Waimahora; Dairy 1.9%, Exotic Forest 43.7%, Sheep/beef 53.5%. L. Koitiata Outflow; Dairy 12.9%, Exotic Forest 26.4%, Sheep/beef 55.3%. Koitiata Stream; Dairy 1.6%, Exotic Forest 21.2%, Sheep/beef 75%. Kaitoke Stream; Dairy 5.2%, Exotic Forest 8.1%, Native Forest 2.1%, Sheep/beef 82.9%.	
Geology: sand 90-100% except for Koitiata which is gravel 66%, sand 25%, sandstone 7%.	

SUMMARY

Issues

Muddiness	Low-Moderate
Eutrophication	Low-Moderate

In terms of ecological vulnerability to eutrophication and sedimentation, these estuaries were identified with low-moderate vulnerability. The main reason for this was their small size, lower ecological value, and regular periods of high flushing (even though they both experience periodic mouth closure/restriction), which meant that, although estimated nutrient and sediment loads to the estuaries were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

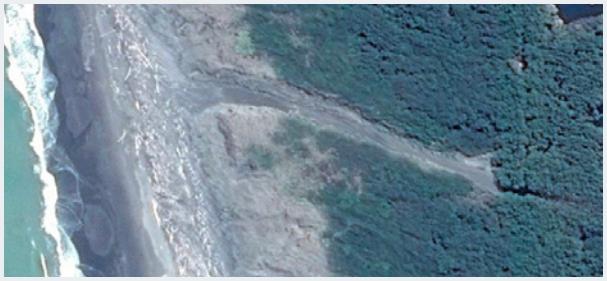
It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

7 SMALL ESTUARIES BETWEEN RANGITIKEI AND WHANGANUI ESTUARIES - WEST COAST

(Ruamai Range, 2 Un-named Streams, Waimahora Stream, Lake Koitiata Outflow, Koitiata Stream and Kaitoke Stream Estuaries).

Ruamai Range Estuary (freshwater above beach)

Un-named estuary immediately up coast from Ruamai Range Estuary (freshwater above beach)



Un-named estuary 2nd up coast from Ruamai Range Estuary (freshwater above beach) small ponds in catchment

Waimahora Estuary 3rd up coast from Ruamai Range Estuary (freshwater above beach) - small ponds/lake in catchment

Lake Koitiata Outflow Estuary (freshwater above beach)

Koitiata Estuary (freshwater above beach) - drains Lake Dudding

Kaitoke Stream Estuary (freshwater above beach)

7 SMALL ESTUARIES BETWEEN RANGITIKEI AND WHANGANUI ESTUARIES - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: 7 SMALL ESTUARIES BETWEEN RANGITIKEI AND WHANGANUI ESTUARIES
DATE: (FEB 2016)

KEY FOR RATINGS	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	all high	High
Dilution Potential:	all very low	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >250mgN.m^{-2}.d^{-1}		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed	Low
Supporting Indicators		
Redox Potential	aRPD >5 cm in subtidal zone of mid and upper estuary	Low
Sediment % Mud	Most of estuary area was sandy sediment, mud in upper reaches	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	No data.	
Existing Condition Eutrophication Rating (includes closed periods)		Low-Mod

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	8.3-15.6 but presence of lake means this rating is low	Low
Presence of Poorly Flushed Habitat	Estuary mouth generally open - but may become restricted/closed	Moderate
Sedimentation Susceptibility Rating		Low-Mod Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	<10% (possibly some subtidal muds in upper reaches - accuracy low). Intertidal area dominated by sands	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION							
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

In terms of ecological vulnerability to eutrophication and sedimentation, these estuaries were identified with low-moderate vulnerability. The main reason for this was their small size, lower ecological value, and regular periods of high flushing (even though they both experience periodic mouth closure/restriction), which meant that, although estimated nutrient and sediment loads to the estuaries were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

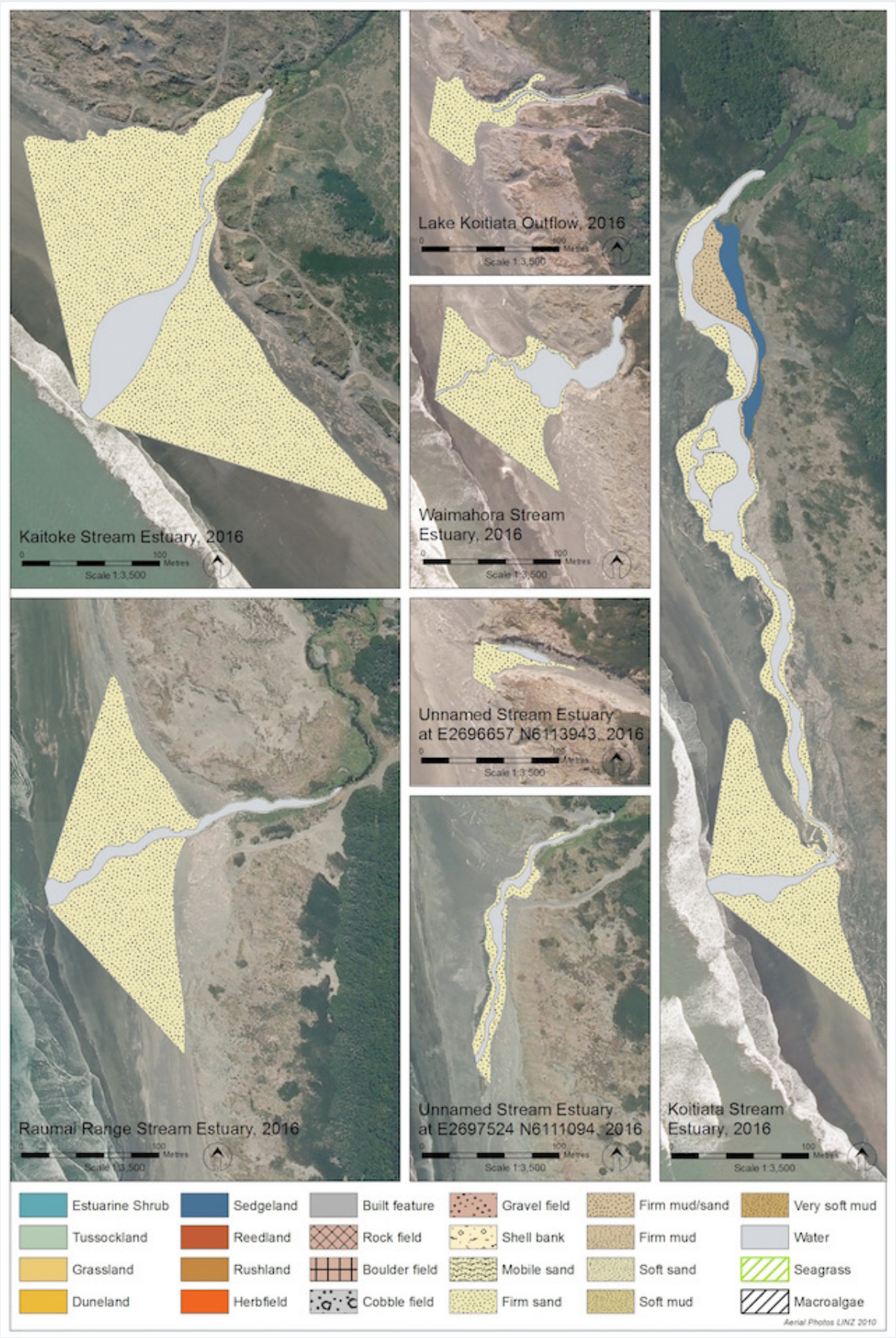


Figure 13. Seven small estuaries between Rangitikei and Whanganui Estuaries - West Coast

(Ruamai Range, 2 Un-named Streams, Waimahora Stream, Lake Koitiata Outflow, Koitiata Stream and Kaitoke Stream Estuaries)

3. Results (continued)

TURAKINA RIVER ESTUARY - WEST COAST

The Turakina Estuary is a large, shallow, generally well-flushed, tidal river estuary (SSRTRE), that is located near Koitiata village and extends approximately 3-4km inland (the majority along the beach). It has a large freshwater inflow which, along with the tidal inflow, is expected to flush most nutrients and fine sediment from the estuary. Sediments are dominated by sands and gravels, but the small intertidal areas along the main mid-upper estuary channel are dominated by soft, moderately well oxygenated muds. The estuary includes small areas of high tide saltmarsh (*Schoenoplectus tabernaemontani* and *Schoenoplectus pungens*) vegetation. Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*) and marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The upper estuary generally has a very low salinity and grows predominantly low salinity tolerant, aquatic plants. The estuary catchment is mostly developed predominantly sheep, beef and dairy farming.

Uses and Values. High use area with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation intact. However, the natural vegetated margin has been mostly lost. The estuary is important for freshwater fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 2600 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for low susceptibility tidal river estuaries of ~2000 $mgN.m^{-2}.d^{-1}$, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, has high freshwater inflow, is strongly affected by tidal currents and is often turbid (mean 190 NTU).

The synoptic survey in February 2016, confirmed the absence of opportunistic macroalgal and phytoplankton blooms in all areas except some natural poorly flushed areas in the lower estuary with generally clear waters in the lower and mid estuary.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >10 times the estimated natural state SS load (NSSL) but the estuary is dominated by coarse sediments and is well flushed.

Turakina Estuary

Estuary Type/Area	SSRTRE Type 4, 59ha
Intertidal/Subtidal	38% subtidal
Mouth Opening	Always open
Mean Depth, Length	1.0m, 4.0km
Catchment	$957km^2$
FW Inflow	Mean annual $7.2m^3.s^{-1}$
Saltmarsh, Seagrass	1.2ha
Soft Mud	0.7ha (~1%)
Macroalgae	Present only in stagnant arms
Dairy Cow Nos.	3440
SS Loading	559kt/yr
Nitrogen Loading	558t/yr
Phosphorus Loading	131t/yr
Landuse: Dairy 2.5%, Exotic Forest 7.2%, Native Forest 8.5%, Sheep/beef 81.2%	
Geology: gravel 17%, limestone 3%, mudstone 34%, sand 2%, sandstone 32%	

SUMMARY

Issues

Muddiness	Low
Eutrophication	Low-Mod

The low-moderate rating for both eutrophication and sedimentation in this relatively large SSRTRE estuary reflects the capacity of this estuary to flush excess nutrients and fine sediment to the sea. As a result, it is recommended that long term monitoring be limited to low frequency, broad scale, screening level assessments only. It is noted that the vulnerability of the inshore coastal habitats from the river plume has not been assessed in this report, given it was outside the study brief.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that these low-moderate risk estuaries have not changed their risk rating.

TURAKINA ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Upper Turakina Estuary, sandflat on beach.

Upper Turakina Estuary, sandflat.

Upper estuary shoreline.

1st mouth Turakina Estuary.

Mid Turakina Estuary - beach area.

Muddy margin waters mid Turakina Estuary.

Turakina Estuary bordered by sandhills-near the beach.

Turakina Estuary as it traverses the beach and showing 2nd mouth.

South end Turakina Estuary.

Turakina Estuary view looking north.

Turakina Estuary eutrophic isolated shallow pool.

Turakina Estuary isolated ponding to south.

TURAKINA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: TURAKINA ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	1.06	High
Dilution Potential:	4.88×10^{-8}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll a	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	Absent in 2016 survey	Low
Supporting Indicators		
Redox Potential	aRPD >3 cm in intertidal zone of mid and upper estuary	Low
Sediment % Mud	~1% of estuary area was soft mud (mainly intertidal)	Not Used
Seagrass	no seagrass	
Clarity (SD, cm)	SD not visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN was 0.375 mgN/l, mean DIN was 0.16mgN/l. This does not exceed ETI interim guidance of 400ugN/l as boundary between high and moderate eutrophication for tidal lagoons.	
Existing Condition Eutrophication Rating		Low

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	14.7	High
Presence of Poorly Flushed Habitat	Estuary channelised with no poorly flushed areas	Very Low
Sedimentation Susceptibility Rating		Low Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	<1% soft muds	Low
Sedimentation Existing Condition Rating		Low Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that these low-moderate risk estuaries have not changed their risk rating.

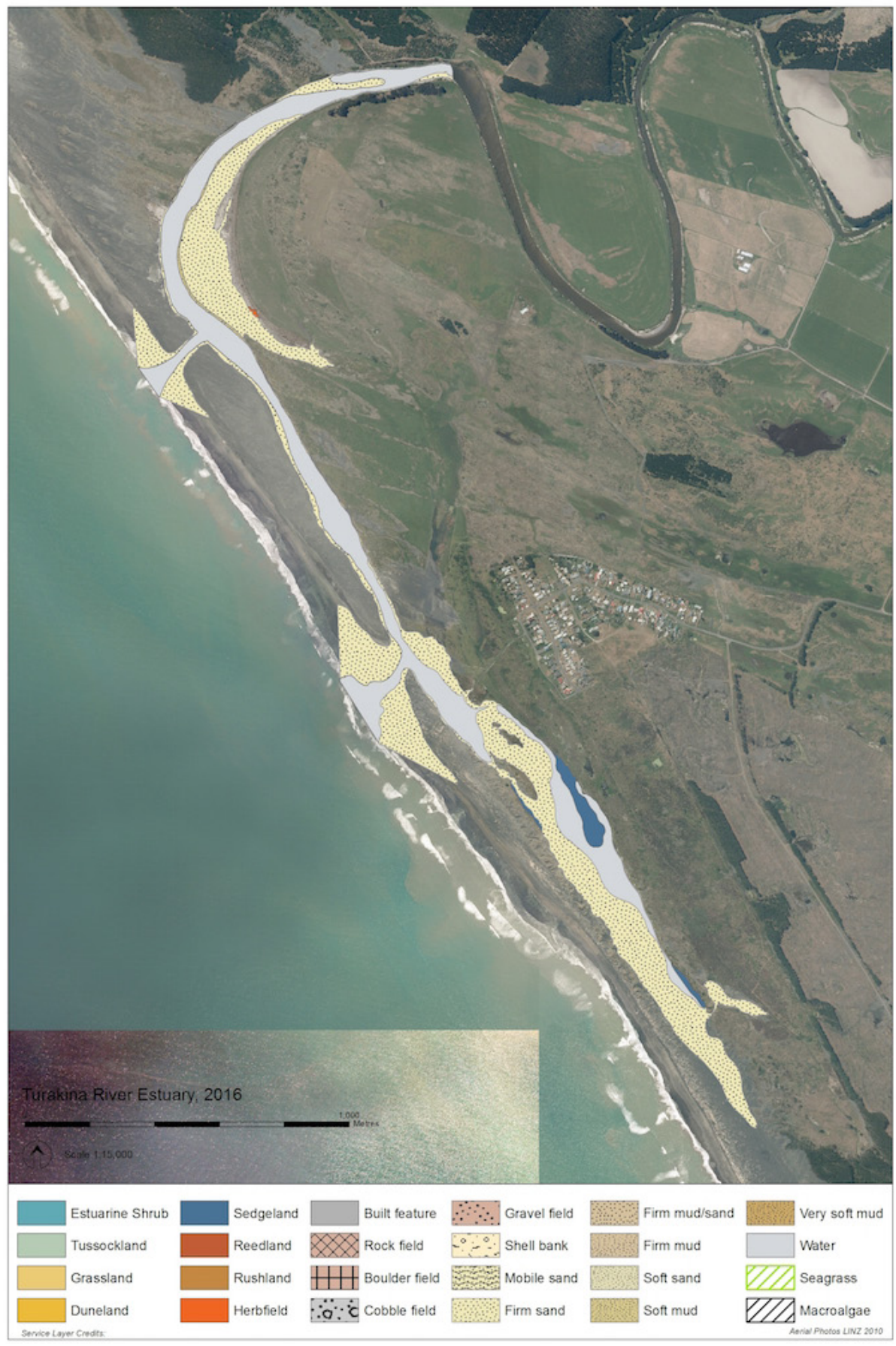


Figure 14. Turakina Estuary Broad Scale Habitat Map

3. Results (continued)

WHANGAEHU RIVER ESTUARY - WEST COAST

The Whangaehu Estuary is a large, shallow, generally well-flushed, tidal river estuary (SSRTRE), that is located near Whangaehu village and extends approximately 4-5km inland (the majority near the beach). It has a large freshwater inflow which, along with the tidal inflow, is expected to flush most nutrients and fine sediment from the estuary. The subtidal sediments in the main channel are dominated by sands and gravels, but the large intertidal areas along the main mid-upper estuary channel are covered by recent clay mud deposits. The estuary is lacking areas of saltmarsh vegetation. Beach duneland vegetation, primarily marram grass (*Ammophila arenaria*) and spinifex (*Spinifex sericeus*), dominates the terrestrial margins near the beach. The upper estuary generally has a very low salinity. The estuary catchment is mostly developed and is predominantly sheep, beef and dairy farming.

Uses and Values. Moderate use area with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate-high but it lacks high value intertidal vegetation. The estuary is important for freshwater fish and birds.

Eutrophication Status. Despite its high nutrient load (the current estimated catchment N areal loading of 5,200 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for tidal river estuaries of ~2000 $mgN.m^{-2}.d^{-1}$, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, has high freshwater inflow, is strongly affected by tidal currents and is often turbid (mean upstream 214 NTU, 2010-2015 HRC data).

The synoptic survey in February 2016, confirmed a low presence of eutrophication symptoms, in particular an absence of opportunistic macroalgal and phytoplankton blooms in all areas.

Sedimentation Status. The estuary is rated as highly vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >10 times the estimated natural state SS load (NSSL) and that the Feb 2016 survey found that the majority of the estuary intertidal flats were dominated by a layer of thick mud overlying coarse sands/gravels. The length of time that these muddy surficial sediments stay in the estuary is currently unknown.

Whangaehu Estuary (2013, Google)

Estuary Type/Area	SSRTRE Type 4, 73ha
Intertidal/Subtidal	54% subtidal
Mouth Opening	Always open
Mean Depth, Length	1.0m, 4.0km
Catchment	$1992km^2$
FW Inflow	Mean annual $7.2m^3.s^{-1}$
Saltmarsh, Seagrass	Absent
Soft Mud	21ha, 62% of intertidal area
Macroalgae	Absent
Dairy Cow Nos.	9897
SS Loading	1160kt/yr
Nitrogen Loading	1389t/yr
Phosphorus Loading	283t/yr
Landuse: Dairy 1.6%, Exotic Forest 11.6%, Native Forest 21.1%, Sheep/beef 60.5%	
Geology: gravel 32%, limestone 3%, mudstone 27%, sand 1%, sandstone 25%	

SUMMARY

Issues

Muddiness	Mod-High
Eutrophication	Low-Mod

The high rating for sedimentation in this relatively large SSRTRE estuary reflects the elevated sediment load and the presence of large areas of soft muds despite the capacity of this estuary to flush much of the excess fine sediment to the sea. As a result, it is recommended that high frequency monitoring of targeted sedimentation indicators be undertaken to provide data on long term sedimentation trends. The low-moderate rating for eutrophication reflects the capacity of this estuary to flush excess nutrients to the sea and the absence of poorly flushed intertidal flats. As a result, it is recommended that long term eutrophication monitoring be limited to low frequency, broad scale, screening level assessments only. It is noted that the vulnerability of the inshore coastal habitats from the river plume has not been assessed in this report, given it was outside the study brief.

Monitoring and Investigations

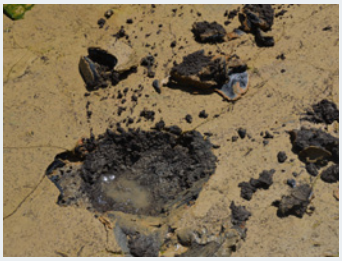
To address the "High" sedimentation rating, it is recommended that annual sedimentation rate (including grain size) monitoring and 5 yearly broad scale mapping of soft muds, be undertaken to provide data on long term sedimentation trends.
To address the "Low" eutrophication rating, undertake estuary vulnerability assessment (screening level assessment) at 10 yearly intervals to confirm moderate risk estuaries have not changed their risk rating.

WHANGAEHU ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Upper Whangaehu Estuary, mud/sand/ gravel flat on far bank

Upper Whangaehu Estuary

Mudflats (fresh) in mid estuary



Fresh muds over sands Whangaehu Estuary

Mid Whangaehu Estuary - turbid muddy waters

Muddy margin waters mid Whangaehu Estuary

Whangaehu Estuary fresh muds

Whangaehu Estuary muddy tidal flats

Pasture margins Whangaehu Estuary

Whangaehu Estuary lower estuary near beach

Whangaehu Estuary towards sea and mouth

Whangaehu Estuary mid reaches looking towards mouth

WHANGAEHU ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WHANGAEHU ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	4.7	High
Dilution Potential:	3.8×10^{-8}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	Absent in 2016 survey	Low
Supporting Indicators		
Redox Potential	aRPD >3 cm in intertidal zone of mid and upper estuary	Low
Sediment % Mud	62% of intertidal estuary area was soft mud	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	Turbid	
Water Total N (mg/l)	Mean TN was 0.99 mgN/l, upstream in river. This exceeds ETI interim guidance of 400ugN/l as boundary between high and moderate eutrophication for tidal lagoons.	
Existing Condition Eutrophication Rating		Low

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	13.4	High
Presence of Poorly Flushed Habitat	Estuary channelised with extensive intertidal flats	Moderate
Sedimentation Susceptibility Rating		Mod-High Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	21ha (62%) of intertidal flats were covered with recent clay deposits	High
Sedimentation Existing Condition Rating		Mod-High Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

To address the "High" fine sediment rating, it is recommended that annual sedimentation rate (including grain size) monitoring and 5 yearly broad scale mapping of soft muds, be undertaken to provide data on long term sedimentation trends.
To address the "Low" eutrophication rating, undertake estuary vulnerability assessment (screening level assessment) at 10 yearly intervals to confirm moderate risk estuaries have not changed their risk rating.

Figure 15. Whangaehu Estuary Broad Scale Habitat Map

3. Results (continued)

WHANGANUI ESTUARY - WEST COAST

The Whanganui Estuary is a large, shallow, generally well-flushed, tidal river estuary (SSRTRE), that is located at Whanganui city and has a tidal influence that extends approximately 11km inland. It has a large freshwater inflow which, along with the tidal inflow and permanently open mouth, is expected to flush most nutrients and fine sediment from the estuary.

Broad scale intertidal mapping of Whanganui Estuary was undertaken in 2009 (Stevens and Robertson 2009). This survey indicates that sediments are dominated by sands and include margin growths of high tide brackish plants searush (*Juncus kraussii*) and three square (*Schoenoplectus pungens*). Beach duneland vegetation, primarily spinifex (*Spinifex sericeus*), dominates the terrestrial margins near the beach.

Intertidal sandflats are present but occupy only 20% of the estuary area. Because of its location in urban Whanganui, the terrestrial margin and river mouth were highly modified.

The estuary catchment is moderately developed with sheep, beef and dairy farming, some urban, but still has extensive native forest cover.

Uses and Values. High use area with beach access - valued for its port, aesthetic appeal, boating, bathing, fishing and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation intact. However, the natural vegetated margin has been mostly lost. The estuary is important for fish and birdlife.

Eutrophication Status. Despite its moderate nutrient load (the current estimated catchment N areal loading of 3,140 mgN.m^{-2}.d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2000 mgN.m^{-2}.d^{-1}, Robertson et al. 2016), the estuary has low susceptibility to eutrophication. This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, has high freshwater inflow, and is strongly affected by tidal currents.

The synoptic survey in February 2016, confirmed the absence of either opportunistic macroalgal blooms or estuary-driven phytoplankton blooms.

Sedimentation Status. The estuary is rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >5 times the estimated natural state SS load (NSSL) but the estuary is well-flushed and dominated by sandy sediments in the lower reaches.

Whanganui Estuary

Estuary Type/Area	SSRTRE Type 4, 354ha
Intertidal/Subtidal	76% subtidal
Mouth Open	Always open
Mean Depth, Length	1.0m, 11km
Catchment	7169km^2
FW Inflow	Mean annual 210m^3.s^{-1}
Saltmarsh, Seagrass	0.9ha, absent
Soft Mud	28% of intertidal area
Macroalgae	Absent
Dairy Cow Nos.	14,779
SS Loading	5898kt/yr
Nitrogen Loading	4062t/yr
Phosphorus Loading	1257t/yr
Landuse: Dairy 0.8%, Exotic Forest 9.7%, Native Forest 54.5%, Sheep/beef 34.2%	
Geology: gravel 10%, ignimbrite 11%, limestone 1%, mudstone 19%, sandstone 52%	

SUMMARY

Issues

Muddiness	Moderate
Eutrophication	Low-Moderate

For the larger examples of this estuary type (e.g. Manawatu and Whanganui Estuaries), which have very significant intertidal areas, high nutrient and sediment loads and high human use and ecological values, but low-moderate eutrophication and muddiness symptoms, it is recommended that both broad scale habitat mapping and fine scale intertidal monitoring be undertaken on a long term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002) plus subsequent improvements (Robertson and Stevens 2015, Stevens and Robertson 2015). It is noted that the vulnerability of the inshore coastal habitats from the river plume has not been assessed in this report, given it was outside the study brief.

Monitoring and Investigations

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is usually repeated at 5 yearly intervals. Broad scale intertidal mapping of Whanganui Estuary was undertaken in 2009 (Stevens and Robertson 2009). Fine scale monitoring measures the condition of the high susceptibility intertidal sediments through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at two sites), and thereafter at 5 yearly intervals. This component has not yet been measured in Whanganui Estuary.

WHANGANUI ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Upper Whanganui Estuary

Sea coast and mid reaches of Whanganui Estuary

Whanganui Estuary - fishing in mid reaches

Sand/mudflats in mid estuary

Whanganui Estuary - near mouth.

Whanganui Estuary mid reaches

Whanganui Estuary near mouth

Soft muddy sands in mid estuary

Presence of rockwalls

Presence of saltmarsh

Whanganui Estuary sandy beach near mouth

Whanganui Estuary fishing wharf

WHANGANUI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WHANGANUI ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	2.6	High
Dilution Potential:	4 x 10^{-9}	Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	Mean 2.83ug/l (2010-2015; HRC data)	Low
Macroalgae (EQR)	Very low cover	Low
Supporting Indicators		
Redox Potential	aRPD 1 cm	Moderate
Sediment % Mud	60% of estuary area was soft mud, mainly subtidal	Not Used
Seagrass	Absent	
Clarity (SD, cm)	SD not visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN was 0.4 mgN/l and does not exceed the ETI interim guidance of 400ug/l TN as boundary between high and moderate eutrophication for tidal lagoons	
Existing Condition Eutrophication Rating		Low-Mod

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	7.1	High
Presence of Poorly Flushed Habitat	Estuary channelised with some moderately flushed areas	Low-Moderate
Sedimentation Susceptibility Rating		Moderate Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	Soft muds occupied 28% of the intertidal substrate in the estuary (Stevens and Robertson 2009) but only 6% of the total estuary area	Moderate
Sedimentation Existing Condition Rating		Moderate

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES															
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

For the larger examples of this estuary type (e.g. Manawatu and Whanganui estuaries), which have very significant intertidal areas, high nutrient and sediment loads and high human use and ecological values, but low-moderate eutrophication and muddiness symptoms, it is recommended that both broad scale habitat mapping and fine scale intertidal monitoring be undertaken on a long term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002) plus subsequent improvements (Robertson and Stevens 2015, Stevens and Robertson 2015).

Figure 16. Whanganui Estuary Broad Scale Habitat Map (Stevens and Robertson 2009)

3. Results (continued)

KAI IWI ESTUARY - WEST COAST

The Kai Iwi Estuary is a moderate-sized, shallow, brackish tidal river estuary (SSRTRE), that extends from the sea to approximately 1km inland. It is perched at the high water zone, has a moderate freshwater inflow and is located 12km north of the Whanganui Estuary and immediately to the north west of Mowhanau Village (to the south east is the smaller Mowhanau Estuary). Sediments are dominated by subtidal muds and sands and include a small area of saltmarsh, predominantly the sedge, three square (*Schoenoplectus pungens*). The steep cliffs of the north Whanganui coastline, through which the estuary enters the sea, carry in their many layers a world-class record of climate change during the past three million years. At Mowhanau, the base of the cliff is composed of massive grey mudstone, overlain by unconsolidated coastal-marine sediments. The estuary mouth is mostly open to the sea but can become restricted and consequently the estuary is often brackish. The estuary catchment is predominantly sheep, beef farming and native and exotic forestry.

Uses and Values. High use with beach access - valued for its aesthetic appeal, bathing, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with some of its intertidal vegetation intact. However, the natural vegetated margin is dominated by steep cliffs and partialy developed for grazing. The estuary is important for freshwater fish and birds.

Eutrophication Status. The Kai Iwi Estuary has a high nutrient load (the current estimated catchment N areal loading of 7,580 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for tidal river estuaries of ~2000 $mgN.m^{-2}.d^{-1}$, Robertson et al. 2016), which combined with its moderate length and likely presence of deeper stratified areas makes it susceptible to excessive phytoplankton growth, but only during summer low flow periods.

The synoptic survey in February 2016, which was undertaken when the estuary mouth was open, confirmed the absence of opportunistic macroalgal blooms but the strong green coloration of the water indicated elevated phytoplankton concentrations (likely the result of the elevated nutrients in the water column).

Sedimentation Status. The estuary is rated as moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >5 times the estimated natural state SS load (NSSL), excess sediments are likely to be flushed to the sea during high flows and that the synoptic survey showed that the estuary is mixed mud and sand sediments.

Kai Iwi Estuary

Estuary Type/Area	SSRTRE Type 2, 3ha
Intertidal/Subtidal	33% subtidal
Mouth Open	Constricted
Mean Depth, Length	0.5m, 1km
Catchment	$191km^2$
FW Inflow	Mean annual $1.45m^3.s^{-1}$
Saltmarsh, Seagrass	0.09ha, No seagrass
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	54
SS Loading	90kt/yr
Nitrogen Loading	84t/yr
Phosphorus Loading	21t/yr
Landuse: Dairy 1.1%, Exotic Forest 28.9%, Native Forest 18.7%, Sheep/beef 50.8%	
Geology: gravel 25%, limestone 30%, mudstone 33%, sandstone 12%	

SUMMARY

Issues

Muddiness	Moderate
Eutrophication	Moderate

For "moderate-length (mouth mostly open) with high nutrient/sediment loads it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends.

Monitoring and Investigations

To address potential for eutrophication, it is recommended that water column chlorophyll *a*, dissolved oxygen and nutrient concentrations be monitored annually (during summer low flows) at a site representative of general (rather than localised) worst case conditions (e.g. a long pool), and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over the whole estuary. Because these estuary types are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.

KAI IWI ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Kai Iwi Estuary as it enters beach

Kai Iwi Estuary near mouth

Kai Iwi Estuary near mouth

Kai Iwi Estuary on beach - high use for bathing and picnics

Kai Iwi estuary - paddling

Kai Iwi Estuary saltmarsh

Kai Iwi Estuary saltmarsh

Kai Iwi Estuary and mudstone cliffs

Middle estuary, firm mud sand tidal flats and turbid waters

Terrestrial margin scrub and introduced grasses in mid reaches

Mid Kai Iwi Estuary - greenish, turbid water

Kai Iwi Estuary mouth - bathing

KAI IWI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: KAI IWI ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	8.6	High
Dilution Potential:	1.9 x 10^{-6}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Moderate - High
Susceptibility to Eutrophication Rating		Moderate - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - synoptic survey; mod-high in summer low flows	Moderate
Macroalgae (EQR)	Absent, but potential in low flows	Moderate
Supporting Indicators		
Redox Potential	aRPD ~1 cm in subtidal zone of mid and upper estuary	Moderate
Sediment % Mud	Subtidal soft muds common	Not Used
Seagrass	Absent	
Clarity (SD, cm)	SD ~0.8m	
Water Total N (mg/l)	Mean TN upstream was 1.07 mgN/l. This exceeds the ETI interim guidance of 400ug/l TN as boundary between high and moderate eutrophication for tidal lagoons.	
Existing Condition Eutrophication Rating		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	8.9	High
Presence of Poorly Flushed Habitat	Estuary channelised with some moderately flushed areas	Moderate
Sedimentation Susceptibility Rating		Mod-High Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	0% intertidal. Estimated 20-40% of subtidal estuary area was soft muds (predominantly sandy in lower estuary).	Moderate
Sedimentation Existing Condition Rating		Moderate Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES															
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

To address potential for eutrophication, it is recommended that water column chlorophyll a, dissolved oxygen and nutrient concentrations be monitored annually (during summer low flows) at a site representative of general (rather than localised) worst case conditions (e.g. a long pool), and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over the whole estuary. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.

Figure 17. Kai Iwi Estuary Broad Scale Habitat Map

3. Results (continued)

FOUR SMALL ESTUARIES NORTH OF WHANGANUI ESTUARY - WEST COAST

(Omapu, Mowhanau, Okehu and Ototoka Estuaries)

The four small estuaries located north of the Whanganui Estuary and in the vicinity of Kai Iwi estuary are all very small, shallow, brackish tidal river estuaries (SSRTREs), that extend from the sea to not much further inland than the inner edge of the beach. Each estuary is fed by small streams that enter the beach through deep narrow valleys with steep sides.

Sediments are dominated by sands and most have only very limited margin vegetation. The estuary mouths are mostly open to the sea but can become restricted at times and consequently they are often brackish. The estuary catchments are predominantly sheep, beef and dairy farming.

Uses and Values. Generally low use with beach access, except for Mowhanau which has high use for bathing - valued for their aesthetic appeal, fishing near the mouth and whitebaiting.

Ecological Values. Ecologically, habitat diversity is low-moderate with little intertidal vegetation. The estuaries are used by fish and birds.

Eutrophication Status. Despite their high nutrient load (the current estimated catchment N areal loading from each estuary exceeds the guideline for tidal river estuaries of ~2000 $mgN.m^{-2}.d^{-1}$, Robertson et al. 2016), the estuaries have low susceptibility to eutrophication. This is primarily because of their highly flushed natures (given that they are predominantly located on the beach and therefore strongly affected by tidal currents). However, on occasions their mouths are expected to be restricted, resulting in periods of poor flushing and nuisance algal/macrophyte growth in the small upper estuary at the top of the beach.

The synoptic survey in February 2016, which was undertaken when the estuary mouths were open, confirmed the absence of either opportunistic macroalgal blooms or phytoplankton blooms in all estuary areas, although in most, the upstream freshwater regions had symptoms of excessive macroalgal and phytoplankton growths.

Sedimentation Status. The estuaries were all rated with low vulnerability to muddiness issues based on the facts that the current suspended sediment loads (CSSL) were likely >5 times the estimated natural state SS load (NSSL) but the estuaries were highly flushed and dominated by sandy sediments.

Data for 4 estuaries are presented as one for parameters where data for each is the same, and where different the data is presented in the same order as shown in the title to this page.	
Estuary Type/Area	SSRTRE Type 1, 0.1, 0.8, 2.2, 2.3 ha
Intertidal/Subtidal	20, 13, 14, 22% subtidal
Mouth Opening	Often constricted
Mean Depth, Length	0.5m, 0.1-0.5km
Catchment	6, 29, 68, 29 km^2
FW Inflow (mean annual)	0.027, 0.1-0.5, 0.5-1, 0.1-0.5 $m^3.s^{-1}$
Saltmarsh, Seagrass	None
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	1600, 750, 360, 1099
SS Loading	0.3, 6.1, 37, 5.7 kt/yr
Nitrogen Loading	5.5, 23.5, 35, 17 t/yr
Phosphorus Loading	0.36, 2.8, 9, 2.7 t/yr
Landuse: Omapu; Dairy 52.1%, Exotic Forest 2.6%, Sheep/beef 42.5%. Mowhanau; Dairy 27.4%, Exotic Forest 2.9%, Native Forest 2.4%, Sheep/beef 65.5%. Okehu; Dairy 2.2%, Exotic Forest 23.2%, Native Forest 17.9%, Sheep/beef 55.1%%. Ototoka; Dairy 13.1%, Exotic Forest 2.8%, Native Forest 3.3%, Sheep/beef 79.7%.	
Geology: Omapu; gravel 48%, sand 51%. Mowhanau; gravel 71%, mudstone 27%, sand 2%. Okehu; gravel 35%, limestone 14%, mudstone 48%, sand 2%. Ototoka; gravel 94%, sand 6%.	

SUMMARY

Issues

Muddiness	Low
Eutrophication	Low

In terms of ecological vulnerability to eutrophication and sedimentation, these estuaries were identified with low vulnerability. The main reason for this was their small size, lower ecological value, and regular periods of high flushing (even though they both experience periodic mouth closure/restriction), which meant that, although estimated nutrient and sediment loads to the estuaries were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

FOUR SMALL ESTUARIES NORTH OF WHANGANUI ESTUARY - WEST COAST

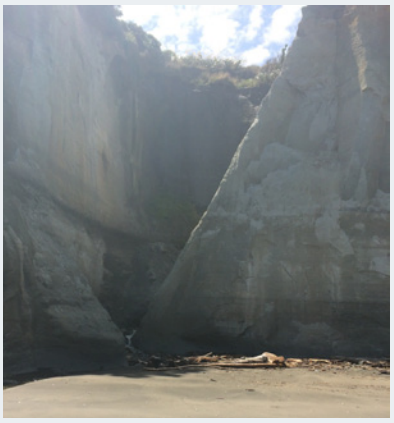
(Omapu, Mowhanau, Okehu and Ototoka Estuaries)

Omapu Estuary as it enters beach

Mowhanau Estuary beginning at bridge where stream spills onto beach

Okehu Estuary as it leaves cliff base and spills onto beach as freshwater

Ototoka Estuary beginning at cliff edge where stream spills onto beach



Omapu Estuary as it leaves cliff base and spills onto beach as freshwater

Mowhanau Estuary as it enters beach - high use for bathing and picnics

Mowhanau Estuary just upstream of bridge showing excessive algal growth

Ototoka Stream and Estuary as it leaves cliff base and spills onto beach

Ototoka Estuary as it enters beach

FOUR SMALL ESTUARIES NORTH OF WHANGANUI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: 4 SMALL ESTUARIES NORTH OF WHANGANUI ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	all high	High
Dilution Potential:	all very low	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: >2000mgN.m^{-2}.d^{-1}		Low
Susceptibility to Eutrophication Rating		Low-Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	No macroalgae; estuary on beach area is too well flushed	Low
Supporting Indicators		
Redox Potential	aRPD >5 cm in subtidal zone of mid and upper estuary	Low
Sediment % Mud	Estuaries dominated by sand, mud present in freshwater reaches	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	Mean TN was elevated at 0.8 mg/l in Mowhanau. No data for others.	
Existing Condition Eutrophication Rating (includes closed periods)		Low

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	9-17	High
Presence of Poorly Flushed Habitat	Estuary mouths generally open	Low
Sedimentation Susceptibility Rating		Low Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	0% intertidal. Majority of subtidal estuary beds are also sands	Low
Sedimentation Existing Condition Rating		Low Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

In terms of ecological vulnerability to eutrophication and sedimentation, these estuaries were identified with low vulnerability. The main reason for this was their small size, lower ecological value, and regular periods of high flushing (even though they both experience periodic mouth closure/restriction), which meant that, although estimated nutrient and sediment loads to the estuaries were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

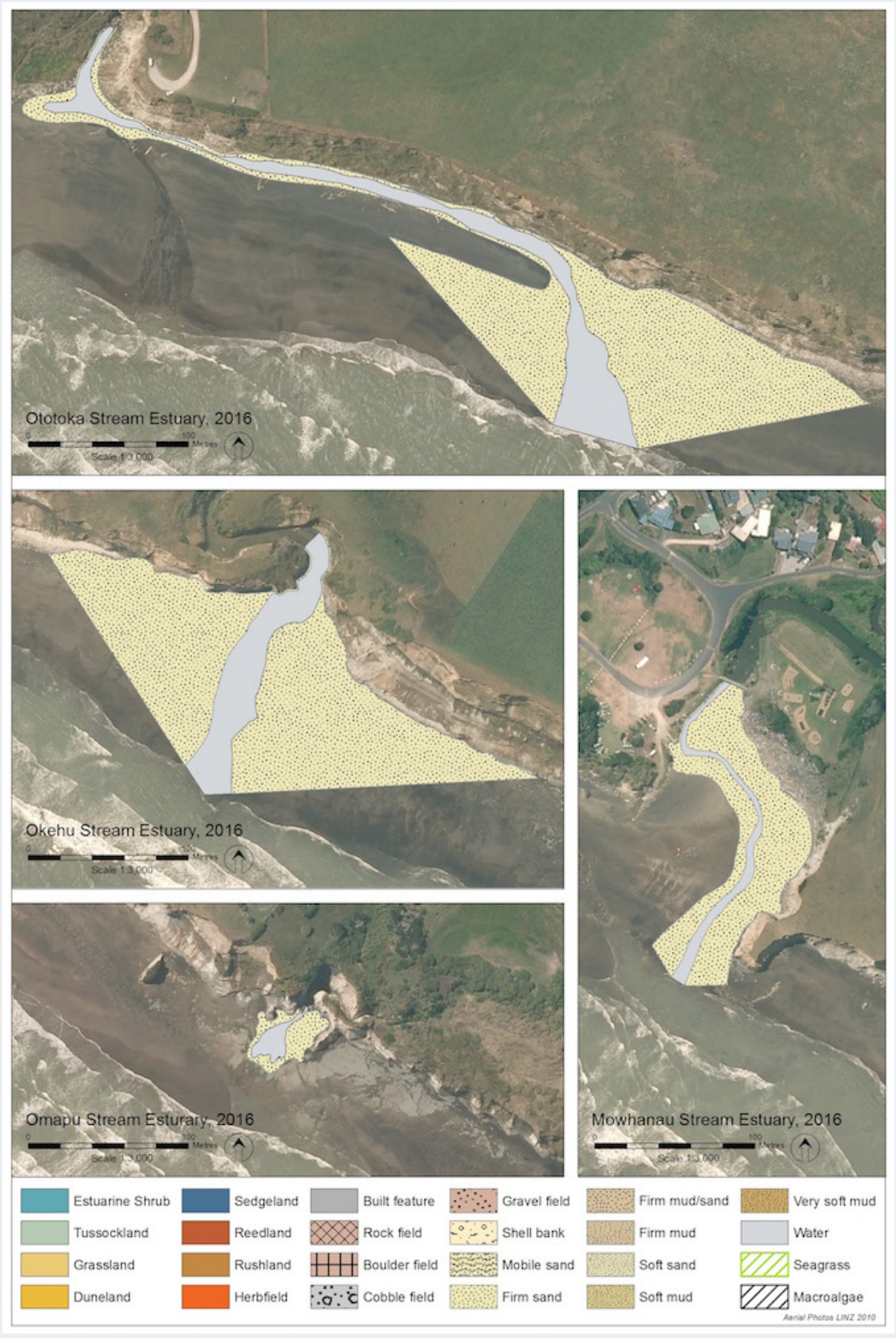


Figure 18. Omapu, Mowhanau, Okehu and Ototoka Estuaries Broad Scale Habitat Map

3. Results (continued)

TAUTANE ESTUARY - EAST COAST

The Tautane Estuary is a small-sized, shallow, generally poorly-flushed tidal river estuary whose mouth is intermittently open/closed. It has a moderate freshwater inflow and is located just north of Herbertville township on the east coast. Sediments are dominated by muds and sands and include an extensive margin growth of saltmarsh (*Schoenoplectus pungens*) and subtidal seagrass (*Ruppia* sp.) along the whole length of the estuary. Because the estuary mouth is mostly closed to the sea the estuary is generally brackish, which makes ideal conditions for growth of the low salinity tolerant *Ruppia* sp. The estuary catchment is dominated by sheep and beef farming.

Uses and Values. High use with good access - valued for its aesthetic appeal, bathing, biodiversity, and whitebaiting.

Ecological Values. Ecologically, habitat diversity is high with extensive cover of both saltmarsh and seagrass (in this case *Ruppia* sp.). However, the natural vegetated margin has been lost and is now developed for grazing. The estuary is an important nursery area for marine and freshwater fish and birds.

Eutrophication Status. The estuary is highly susceptible to eutrophication based on;

- its poorly flushed nature (the upper estuary likely experiences salinity stratification during stable baseflows (i.e. salt wedge effect) and the mouth is usually closed) and,
- its high nutrient load (the current estimated N areal loading of 1105 $mgN.m^{-2}.d^{-1}$ exceeds the guideline for high susceptibility tidal river estuaries (~100-250 $mgN.m^{-2}.d^{-1}$) and intermittently closed/open estuaries (35 $mgN.m^{-2}.d^{-1}$) (Robertson et al. 2016).

The synoptic survey in February 2016, confirmed the presence of nuisance phytoplankton blooms (green coloured waters) and high growths of aquatic macrophytes with accompanying nuisance opportunistic macroalgal/epiphyte cover. Such findings indicate that the estuary is receiving excessive nutrient loads. Maintaining healthy seagrass growth is recommended as the primary focus for any ongoing monitoring of this estuary.

Sedimentation Status. The estuary is rated as moderately to highly vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >10 times the estimated natural state SS load (NSSL), excess sediments are poorly flushed and that the synoptic survey showed that the estuary is dominated by muddy sediments in mid-upper reaches.

Tautane Estuary

Estuary Type/Area	SSRTRE Type 2, 3ha
Intertidal/Subtidal	37% subtidal
Mouth Opening	Often blocked or closed
Mean Depth, Length	0.5-2.0m, 1km
Catchment	$22.3km^2$
FW Inflow	Mean annual $1.9m^3.s^{-1}$
Saltmarsh, Seagrass	1.8ha, 0.8ha
Soft Mud	No intertidal soft mud
Macroalgae	Present (subtidal)
Dairy Cow Nos.	0
SS Loading	18kt/yr
Nitrogen Loading	12.1t/yr
Phosphorus Loading	5.3t/yr
Landuse: Native Forest 4.5%, Sheep/beef 94.4%.	
Geology: gravel 10%, mudstone 90%	

SUMMARY

Issues

Muddiness	Moderate
Eutrophication	Moderate - High

For "moderate-length (mouth mostly closed) SSRTREs" with moderate-high nutrient/sediment loads it is recommended that monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends.

Monitoring and Investigations

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll *a*, dissolved oxygen and nutrient concentrations.

TAUTANE ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Tautane Estuary upper reaches with heavy margin macrophyte growth

Tautane Estuary intertidal sedge growth and *Ruppia* in water

Tautane Estuary - mid reaches with heavy *Schoenoplectus pungens* growth

Mid reaches Tautane Estuary

Tautane estuary - seagrass (*Ruppia* sp.) growing in shallows of mid estuary

Tautane estuary mid reaches

Schoenoplectus pungens on left and *Ruppia* in shallows of mid estuary

Ruppia growths with associated high nuisance macroalgal/epiphyte cover

Tautane Estuary lower reaches with heavy *Ruppia* growth

Tautane Estuary as it broadens onto beach

Tautane Estuary at beach with mouth closed

Tautane Estuary looking upstream from beach

TAUTANE ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: TAUTANE ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	Poor because mouth closed often	Low
Dilution Potential:	Poor because mouth closed often	Very Low
Physical Susceptibility:		Mod - High
Combined Nutrient Load and Physical Susceptibility:		High
Susceptibility to Eutrophication Rating		Mod - High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data but expert opinion indicates mod-high when closed	Mod - High
Macroalgae (EQR)	High *Ruppia* and epiphyte growth.	Mod - High
Supporting Indicators		
Redox Potential	aRPD ~1 cm in subtidal zone of mid and upper estuary	Moderate
Sediment % Mud	Approx. 60% of estuary area was soft mud mainly subtidal	Not Used
Seagrass	26% of estuary area was seagrass (*Ruppia* sp)	
Clarity (SD, cm)	SD not visible on bed over 90% of estuary	
Water Total N (mg/l)	No data	
Existing Condition Eutrophication Rating		Mod - High

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	17	High
Presence of Poorly Flushed Habitat	Poorly flushed when mouth closed - length of mouth closure uncertain	Mod - High
Sedimentation Susceptibility Rating		Mod-High Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 60% of estuary area was soft muds (mostly were subtidal)	Moderate-High
Sedimentation Existing Condition Rating		Mod-High Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT								STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
												HUMAN USES						ECOL. VALUES						EUTROPHICATION											SEDIMENTATION							
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																								
Fine Sediment																																								
Priorities For Monitoring																																								

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

Figure 19. Tautane Estuary Broad Scale Habitat Map

3. Results (continued)

WAINUI ESTUARY - EAST COAST

The Wainui Estuary is a moderate length, shallow, often poorly-flushed tidal river estuary whose mouth is intermittently open/closed. It has a moderate freshwater inflow and is located near Herbertville township. Sediments are dominated by muds and sands and include margin growths of mainly introduced grasses and shrubs along the length of the estuary. Because the estuary mouth is often closed to the sea the estuary is at times brackish. The estuary catchment is dominated by sheep and beef farming with some exotic forestry.

Uses and Values. High use with good access - valued for its aesthetic appeal, bathing, biodiversity, and whitebaiting.

Ecological Values. Ecologically, habitat diversity is moderate with limited cover of saltmarsh and no seagrass. In addition, the natural vegetated margin has been lost and is now developed for grazing. The estuary is important for fish and birds.

Eutrophication Status. The estuary is moderately susceptible to eutrophication based on:

- its often poorly flushed nature (the upper estuary likely experiences salinity stratification during stable baseflows (i.e. salt wedge effect) and the mouth is often closed) and,
- its moderate nutrient load (the current estimated N areal loading of 875 $mgN.m^{-2}.d^{-1}$ does not exceed the guideline for tidal river estuaries (~2000 $mgN.m^{-2}.d^{-1}$) but does for mainly closed high susceptibility tidal river estuaries (~100-250 $mgN.m^{-2}.d^{-1}$) (Robertson et al. 2016).

The synoptic survey undertaken in February 2016 when the mouth had been closed for 1 month, confirmed the presence of elevated phytoplankton levels (green coloured waters) but low growths of subtidal nuisance opportunistic macroalgal cover. Such findings indicate that the estuary is moderately eutrophic but only when the mouth is closed. Ensuring such conditions do not deteriorate is recommended as the primary focus for any ongoing monitoring of this estuary.

Sedimentation Status. The estuary is rated as moderately to highly vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >5 times the estimated natural state SS load (NSSL), excess sediments are likely to be flushed to the sea during high flows and that the synoptic survey showed that the estuary is dominated by muddy sediments in mid-upper reaches.

Wainui Estuary (mouth closed)

Estuary Type/Area	SSRTRE Type 2, 16ha
Intertidal/Subtidal	77% subtidal
Mouth Opening	Often blocked or closed
Mean Depth, Length	1m, 2.5km
Catchment	101km^2
FW Inflow	Mean annual 1.7$m^3.s^{-1}$
Saltmarsh, Seagrass	Absent
Soft Mud	1.2 ha, 32% of intertidal area
Macroalgae	Absent
Dairy Cow Nos.	0
SS Loading	61.8kt/yr
Nitrogen Loading	51t/yr
Phosphorus Loading	22t/yr
Landuse: Exotic Forest 18.8%, Native Forest 4.9%, Sheep/beef 76.2%.	
Geology: gravel 7%, mudstone 57%, sandstone 31%	

SUMMARY

Issues

Muddiness	Moderate-High
Eutrophication	Moderate

For "moderate-length (mouth mostly closed) SSRTREs" with moderate-high nutrient/sediment loads it is recommended that monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends.

Monitoring and Investigations

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll a, dissolved oxygen and nutrient concentrations.

WAINUI ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Just upstream of Wainui Estuary showing macroalgal growth in lower stream

Wainui Estuary mid reaches with green stained water

Wainui Estuary - mid reaches, mouth had been closed for 1 month

Lower reaches Wainui Estuary

Lower reaches Wainui Estuary

Lower reaches Wainui Estuary (mouth had been closed for 1 month)

WAINUI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAINUI ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	Poor when mouth closed	Moderate
Dilution Potential:	Poor when mouth closed	Moderate
Physical Susceptibility:		Moderate
Combined Nutrient Load and Physical Susceptibility:		Moderate
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data but expert opinion indicates moderate when closed	Moderate
Macroalgae (EQR)	Moderate macroalgal growth when closed	Moderate
Supporting Indicators		
Redox Potential	aRPD ~1-3 cm in subtidal zone of mid and upper estuary	Moderate
Sediment % Mud	Approx. 40% of estuary area was soft mud mainly subtidal	Not Used
Seagrass	None observed	
Clarity (SD, cm)	SD visible on bed over 90% of estuary	
Water Total N (mg/l)	No data - but based on estimated TN load the mean estuary TN concentration is likely to exceed 700 mg/l	
Existing Condition Eutrophication Rating		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	13.2	High
Presence of Poorly Flushed Habitat	Poorly flushed when mouth closed - but well flushed in high flows	Moderate
Sedimentation Susceptibility Rating		Mod-High Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 30% of estuary area was soft muds	Moderate-High
Sedimentation Existing Condition Rating		Mod-High Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION												SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

To address the eutrophication/sedimentation issue (including both benthic and water column effects), it is recommended that, at each of 3 transects across the estuary (representative of the lower, mid and upper estuary), the following is monitored annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March): opportunistic macroalgal cover and biomass, seagrass biomass and cover, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll *a*, dissolved oxygen and nutrient concentrations.

Figure 20. Wainui Estuary Broad Scale Habitat Map

3. Results (continued)

PAPUKA AND WAIMATA ESTUARIES - EAST COAST

The Papuka and Waimata Estuaries are very small, shallow, poorly-flushed, brackish tidal river estuaries (SSRTREs), that extend from the sea to just inland of the inner edge of the dunes (~200m long). They are perched at the high water zone, have a low freshwater inflow and are located at the base of steep hill country between Herbertville and Akitio villages.

Sediments are dominated by sands and include margin growths of high tide saltmarsh vegetation (*Schoenoplectus tabernaemontani* and *Schoenoplectus pungens*). Beach duneland vegetation, primarily marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach.

The estuary mouths are often blocked or constricted and consequently the estuaries are often brackish. The estuary catchment is predominantly sheep, beef farming and exotic forestry.

Uses and Values. Low-moderate use with some beach access - valued for their aesthetic appeal, fishing near the mouth and whitebaiting.

Ecological Values. Some of the margin duneland vegetation and saltmarsh is intact. The estuaries are used by fish and birds. The small size and low habitat diversity mean ecological values are low-moderate.

Eutrophication Status. Despite their high nutrient loads [the current estimated catchment N areal loading for both estuaries (600 and 5000 $mgN.m^{-2}.d^{-1}$ for Pakuka and Waimata respectively) exceeds the guideline for low susceptibility tidal river estuaries of ~250 $mgN.m^{-2}.d^{-1}$], the estuaries have only moderate susceptibility to eutrophication. This is primarily because of their highly flushed nature when their mouths are open, given that they are predominantly located on or near the beach and are therefore strongly affected by tidal currents. However, the mouths are often closed, resulting in periods of poor flushing and possibly nuisance algal/macrophyte growth.

The synoptic survey in February 2016, which was undertaken when the estuary mouths were closed or very restricted, confirmed the presence of moderate growths of subtidal opportunistic macroalgal blooms in both estuaries. In addition, there were extensive growths of opportunistic macroalgae in the estuary seepage between the mouth of the blocked Waimata Estuary and the ocean.

Sedimentation Status. The estuaries are rated as low-moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >5 times the estimated natural state SS load (NSSL) and the estuaries are mostly periodically well-flushed and dominated by sandy sediments.

Waimata Estuary

Data for 2 estuaries are presented as one for parameters where data for each are the same, and where different the data are presented in the same order as shown in the title to this page.

Estuary Type/Area	SSRTRE Type 1, 1.2, 0.6ha
Intertidal/Subtidal	Approx 83% and 69% subtidal
Mouth Opening	Very constricted/closed
Mean Depth, Length	0.5m, 0.2km
Catchment	5.8, 27.8km^2
FW Inflow	Mean annual 0.09, 0.4$m^3.s^{-1}$
Saltmarsh, Seagrass	Absent
Soft Mud	No intertidal soft mud
Macroalgae	20-50% cover, subtidal
Dairy Cow Nos.	0
SS Loading	8.1, 8.3kt/yr
Nitrogen Loading	2.6, 9.9t/yr
Phosphorus Loading	1.7, 4.5t/yr
Landuse: Papuka; Exotic Forest 2.4%, Native Forest 2.7%, Sheep/beef 94.9%. Waimata; Exotic Forest 30.8%, Native Forest 27.8%, Sheep/beef 41.5%	
Geology: Papuka; mudstone 30%, sandstone 69%. Waimata; mudstone 66%, sandstone 34%	

SUMMARY

Issues

Muddiness	Low-Mod
Eutrophication	Moderate

In terms of ecological vulnerability to eutrophication and sedimentation, these estuaries were identified with low-moderate vulnerability. The main reason for this was their small size, lower ecological value, and regular periods of high flushing (even though they both experience periodic mouth closure/restriction), which meant that, although estimated nutrient and sediment loads to the estuaries were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

PAPUKA ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Papuka Estuary as it enters beach

Papuka Estuary above beach

Papuka Estuary near mouth with margin saltmarsh (*Schoenoplectus pungens)*

Papuka Estuary near beach

Papuka Estuary - sluggish, and includes macroalgal growth

Papuka Estuary mouth constricted

WAIMATA ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Waimata Stream immediately upstream of estuary

Waimata Estuary upper reaches with margin saltmarsh

Lower estuary, near beach, clean clear waters - gravel/mud/sand bed

Blocked Waimata Estuary mouth

Waimata Estuary - mouth and surrounding landscape

Waimata Estuary mouth looking upstream

PAPUKA AND WAIMATA ESTUARIES- VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: PAPUKA AND WAIMATA ESTUARIES
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	1.3, 14.	High
Dilution Potential:	4.7×10^{-6}, 1.0×10^{-5}	Very Low
Export Potential (Physical Susceptibility):		Moderate
Combined Nutrient Load and Physical Susceptibility: N load excessive, but regular high flushing between mouth closed/restricted periods		Moderate
Susceptibility to Eutrophication Rating		Moderate

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	No data - expert opinion indicates low rating	Low
Macroalgae (EQR)	Macroalgae present when mouth closed/restricted	Moderate
Supporting Indicators		
Redox Potential	aRPD >1 cm in subtidal zone of mid and upper estuary	Low-Mod
Sediment % Mud	Most of estuary area was sandy sediments, mud in upper	Not Used
Seagrass	No seagrass	
Clarity (SD, cm)	SD visible on bed lower estuary	
Water Total N (mg/l)	No data	
Existing Condition Eutrophication Rating (includes closed periods)		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	9.7, 17	High
Presence of Poorly Flushed Habitat	Poorly flushed when mouth closed - but well flushed in high flows	Moderate
Sedimentation Susceptibility Rating		Moderate Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Estimated Percentage of estuary with soft mud (~>25% sediment mud content)	Approximately 20% of estuary area was mud/sands (mostly were subtidal) - accuracy low	Low-Mod
Sedimentation Existing Condition Rating		Low-Mod Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION												SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

In terms of ecological vulnerability to eutrophication and sedimentation, these estuaries were identified with low-moderate vulnerability. The main reason for this was their small size, lower ecological value, and regular periods of high flushing (even though they both experience periodic mouth closure/restriction), which meant that, although estimated nutrient and sediment loads to the estuaries were generally large, they were unlikely to cause prolonged periods of eutrophication and muddiness. It is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.

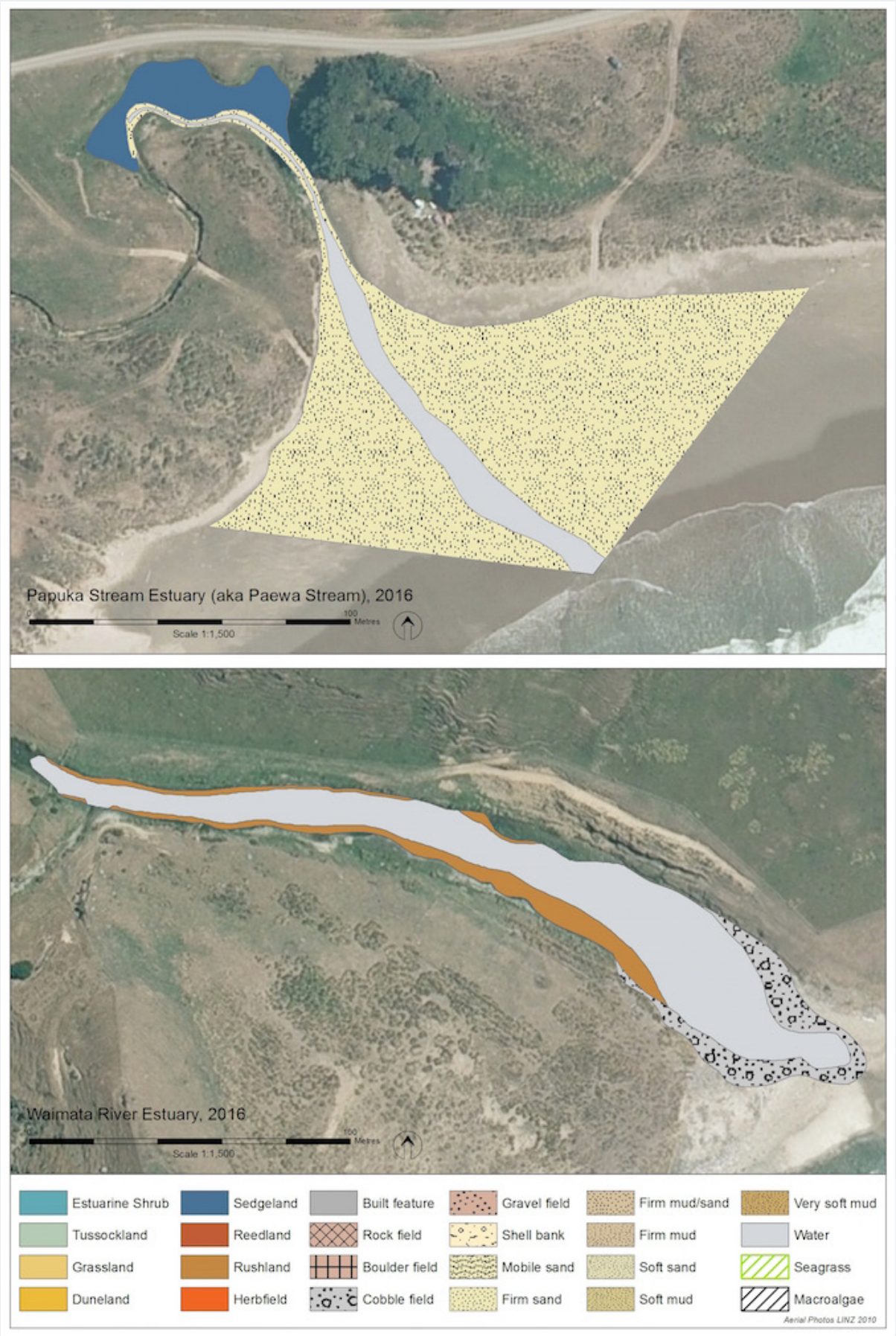


Figure 21. Papuka and Waimata Estuaries Broad Scale Habitat Map

3. Results (continued)

AKITIO ESTUARY - EAST COAST

The Akitio Estuary is a relatively long length (7km), shallow, moderately-flushed tidal river estuary. It has a moderate freshwater inflow and is located near Akitio village. Sediments are dominated by muds, with increasing sand near the mouth. The terrestrial margin is primarily pastoral landuse, with a narrow immediate border of mainly introduced grasses and shrubs along the length of the estuary. The estuary catchment is dominated by sheep and beef farming with some exotic forestry.

Uses and Values. High use with good access - valued for its aesthetic appeal, bathing, biodiversity, fishing and whitebaiting.

Ecological Values. Some of the margin duneland vegetation and saltmarsh is intact. The estuary is well-used by fish and birds. The large size and moderate habitat diversity (limited cover of saltmarsh, no seagrass, but good subtidal habitat) mean ecological values are moderate-high. In addition, the natural vegetated margin has been lost and is now developed for grazing.

Eutrophication Status. The estuary is moderately susceptible to eutrophication and has moderate nutrient loads (1255 $mgN.m^{-2}.d^{-1}$). The main reason for the moderate rating is that the estuary is likely to oscillate between low and moderate-high levels of eutrophication; i.e. low levels of eutrophication and sedimentation in winter, and immediately during and following high flow events in the warmer months, and moderately eutrophic conditions with some sedimentation during summer base-flow conditions. This latter situation arises from the extensive estuary length and moderate freshwater inflow, which means that the residence time for water and nutrients is sufficient to allow for phytoplankton blooms under baseflow conditions (given that the time taken for a parcel of water to travel the length of the estuary under baseflows is at least several days for these estuaries). Additionally, in times of prolonged base-flows much of the estuary is likely to stratify and further reduce potential for flushing.

The synoptic survey, undertaken during baseflows in February 2016, confirmed elevated phytoplankton levels (green coloured waters) and some opportunistic macroalgal cover. Ensuring such conditions do not deteriorate is recommended as the primary focus for any ongoing monitoring of this estuary.

Sedimentation Status. The estuary is rated as moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >5 times the estimated natural state SS load (NSSL), excess sediments are likely to be flushed to the sea during high flows and that the synoptic survey showed that the estuary is dominated by muddy sediments in mid-upper reaches.

Akitio Estuary (mouth open)

Estuary Type/Area	SSRTRE Type 3, 58ha
Intertidal/Subtidal	Approx 80% subtidal
Mouth Opening	Mouth always open
Mean Depth, Length	1.1m, 7km
Catchment	$589km^2$
FW Inflow	Mean annual $4.8m^3.s^{-1}$
Saltmarsh, Seagrass	0.1ha, absent
Soft Mud	6.4ha intertidal
Macroalgae	0.1ha
Dairy Cow Nos.	0
SS Loading	338kt/yr
Nitrogen Loading	265t/yr
Phosphorus Loading	112t/yr
Landuse: Exotic Forest 9.2%, Native Forest 12.6%, Sheep/beef 77.8%	
Geology: gravel 5%, mudstone 57%, sandstone 35%	

SUMMARY

Issues

Muddiness	Moderate
Eutrophication	Moderate

For the Akitio Estuary it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends.

Monitoring and Investigations

To address potential for eutrophication, it is recommended that water column chlorophyll a, dissolved oxygen and nutrient concentrations be monitored monthly during the period Nov-March each year at a site representative of general conditions (e.g. road bridge) (it is noted that this is already undertaken each year in the Akitio as part of the current long term monitoring programme) and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over 200m of the estuary at the same site. Because this estuary is generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.

AKITIO ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Akitio River upstream of estuary with heavy introduced macrophyte growth (*Potamogeton crispus*)

Akitio Estuary upper reaches with muddy intertidal flat and algal growth

Akitio Estuary - upper reaches with heavy macroalgal growth in bedrock section

Muddy sulphide rich intertidal sediments upper Akitio Estuary

Upper Akitio estuary - extensive macroalgal growth in certain areas

Akitio estuary mid reaches with soft mud intertidal flats

Mid estuary looking downstream from road bridge

Mid estuary intertidal flats

Akitio Estuary lower reaches tidalflat with *Schoenoplectus pungens* growth

Akitio Estuary tidal flat in lower reaches (firm mud sands and soft muds)

Akitio Estuary near mouth

Akitio Estuary looking towards mouth

AKITIO ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: AKITIO ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	0.64	Moderate
Dilution Potential:	4.4×10^{-8}	Very Low
Physical Susceptibility:		High
Combined Nutrient Load and Physical Susceptibility: >250 $mgN.m^{-2}.d^{-1}$		Moderate
Susceptibility to Eutrophication Rating		Moderate-High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	Mean 3.7ug/l, Max 25ug/l (2010-2015; HRC data)	Moderate
Macroalgae (EQR)	Moderate macroalgal growth	Moderate
Supporting Indicators		
Redox Potential	aRPD ~1cm in intertidal zone of mid and upper estuary	Moderate
Sediment % Mud	Approx. 40% of estuary area was soft mud mainly subtidal	Not Used
Seagrass	None observed	
Clarity (SD, cm)	SD visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN in mid estuary was 0.51mg/l at road bridge (Horizons Council data n=45; 2010-2015)	
Existing Condition Eutrophication Rating		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	14.5	High
Presence of Poorly Flushed Habitat	Poorly flushed in baseflows - but well flushed in high flows	Moderate
Sedimentation Susceptibility Rating		Mod-High Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	Estimated 20-50% of estuary area was soft muds	Moderate
Sedimentation Existing Condition Rating		Moderate Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

For the Akitio Estuary it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address potential for eutrophication, it is recommended that water column chlorophyll *a*, dissolved oxygen and nutrient concentrations be monitored monthly during the period Nov-March each year at a site representative of general conditions (e.g. road bridge) and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over 200m of the estuary at the same site. Because this estuary is generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.

Figure 22. Akitio Estuary Broad Scale Habitat Map

3. Results (continued)

OWAHANGA ESTUARY - EAST COAST

The Owahanga Estuary is a relatively long length (11km tidal influence), shallow, moderately-flushed tidal river estuary. It has a moderate freshwater inflow and is located 10km south of Akitio village. Sediments are dominated by muds, with increasing sand near the mouth. The terrestrial margin is primarily pastoral landuse, with a narrow immediate border of mainly introduced grasses and shrubs along some of the length of the estuary. The estuary catchment is dominated by sheep and beef farming and native forest with some exotic forestry.

Uses and Values. High use by locals with good access - valued for its aesthetic appeal, bathing, biodiversity, fishing and whitebaiting.

Ecological Values. Some of the margin duneland vegetation and saltmarsh is intact in the lower estuary. The estuary is well-used by fish and birds. The large size and moderate habitat diversity (limited cover of saltmarsh, no seagrass, but good subtidal habitat) mean ecological values are moderate-high. In addition, the natural vegetated margin has been lost and is now developed for grazing.

Eutrophication Status. The estuary is moderately susceptible to eutrophication. The main reason for the moderate rating is that the estuary is likely to oscillate between low and moderate-high levels of eutrophication; i.e. low levels of eutrophication and sedimentation in winter, and immediately during and following high flow events in the warmer months, and moderately eutrophic conditions with some sedimentation during summer base-flow conditions. This latter situation arises from the extensive estuary length, the moderate N load (1040 $mgN.m^{-2}.d^{-1}$) and the moderate freshwater inflow, which means that the residence time for water and nutrients is sufficient to allow for phytoplankton blooms under baseflow conditions (given that the time taken for a parcel of water to travel the length of the estuary under baseflows is at least 1-3 days for these estuaries). Additionally, in times of prolonged base-flows much of the estuary is likely to stratify and further reduce potential for flushing.

The synoptic survey, undertaken during baseflows in February 2016, confirmed elevated phytoplankton levels (green coloured waters) and some growths of opportunistic macroalgal cover. Ensuring such conditions do not deteriorate is recommended as the primary focus for any ongoing monitoring of this estuary.

Sedimentation Status. The estuary is rated as moderately vulnerable to muddiness issues based on the facts that the current suspended sediment load (CSSL) is likely to be >5 times the estimated natural state SS load (NSSL), excess sediments are likely to be flushed to the sea during high flows and that the synoptic survey showed that the estuary is dominated by muddy sediments in mid-upper reaches.

Owahanga Estuary (mouth open)

Estuary Type/Area	SSRTRE Type 3, 64.5ha
Intertidal/Subtidal	56% subtidal
Mouth Opening	Mouth always open
Mean Depth, Length	1m, 11km
Catchment	408km^2
FW Inflow	Mean annual 5.5$m^3.s^{-1}$
Saltmarsh, Seagrass	2.6ha, absent
Soft Mud	10.3ha
Macroalgae	0.1ha
Dairy Cow Nos.	0
SS Loading	253kt/yr
Nitrogen Loading	224t/yr
Phosphorus Loading	95t/yr
Landuse: Exotic Forest 3.3%, Native Forest 18.4%, Sheep/beef 76.9%	
Geology: gravel 9%, mudstone 65%, sandstone 26%	

SUMMARY

Issues

Muddiness	Moderate
Eutrophication	Moderate

For the Owahanga Estuary it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends.

Monitoring and Investigations

To address potential for eutrophication, it is recommended that water column chlorophyll *a*, dissolved oxygen and nutrient concentrations be monitored monthly during the period Nov-March each year at a site representative of general conditions and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over 200m of the estuary at the same site. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.

OWAHANGA ESTUARY: PHOTOGRAPHS TAKEN FEBRUARY 2016

Owahanga Estuary upper reaches - strong green coloration

Owahanga Estuary upper reaches from road bridge

Owahanga Estuary - upper reaches with some trees and pasture margins

Middle reaches Owahanga Estuary

Mid Owahanga Estuary

Owahanga Estuary mid reaches with mac-roalgal growth and high turbidity

Mid estuary looking downstream at bedrock section

Mid estuary

Owahanga Estuary mid reaches

Owahanga Estuary tidal flat in mid-lower reaches

Owahanga Estuary tidal flat in lower reaches near mouth

Owahanga Estuary looking towards mouth

OWAHANGA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: OWAHANGA ESTUARY
DATE: (FEB 2016)

KEY FOR RATINGS				
	Low		Moderate	
	Very Low		High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Flushing Potential:	0.62	Moderate
Dilution Potential:	3.7×10^{-8}	Very Low
Physical Susceptibility:		High
Combined Nutrient Load and Physical Susceptibility: >250 $mgN.m^{-2}.d^{-1}$		Moderate
Susceptibility to Eutrophication Rating		Moderate-High

2. EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll a	No data; expert opinion indicates elevated in baseflow	Moderate
Macroalgae (EQR)	Moderate macroalgal growth	Moderate
Supporting Indicators		
Redox Potential	aRPD ~1cm in intertidal zone of mid and upper estuary	Moderate
Sediment % Mud	Approx. 40% of estuary area was soft mud mainly subtidal	Not Used
Seagrass	None observed	
Clarity (SD, cm)	SD visible on bed over 90% of estuary	
Water Total N (mg/l)	Mean TN in mid estuary was 0.51mg/l at road bridge (Horizons Council data n=45; 2010-2015)	
Existing Condition Eutrophication Rating		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	13.4	High
Presence of Poorly Flushed Habitat	Poorly flushed in baseflows - but well flushed in high flows	Moderate
Sedimentation Susceptibility Rating		Mod-High Susceptibility

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	Estimated 20-60% of estuary area was soft muds	Moderate
Sedimentation Existing Condition Rating		Moderate Muddiness

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES																	
											HUMAN USES					ECOL. VALUES					EUTROPHICATION											SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																					
Fine Sediment																																					
Priorities For Monitoring																																					

For the Owahanga Estuary it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address potential for eutrophication, it is recommended that water column chlorophyll a, dissolved oxygen and nutrient concentrations be monitored monthly during the period Nov-March each year at a site representative of general conditionsß and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over 200m of the estuary at the same site. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.

Figure 23. Owahanga Estuary Broad Scale Habitat Map

3. Results (continued)

NINE UN-NAMED SMALL ESTUARIES (BEACH LOCATED) - EAST COAST

The nine remaining small estuaries located between the north and south regional boundaries on the east coast are all very small, shallow, brackish tidal river estuaries (SSRTREs), that begin where the streams leave the steep coastal catchment and discharge onto the beach. The upper estuary area in each consists of a narrow channel, perched at the high water zone, with a low freshwater inflow. Sediments are dominated by beach and stream sands and vegetation is mostly absent. Beach duneland vegetation is also generally very limited below these steep catchment areas. The estuary mouths are mostly open to the sea but can become restricted or closed and consequently the upper estuary is often brackish. The estuary catchments are predominantly sheep and beef landuse.

Uses and Values. Low use with beach access - valued for their aesthetic appeal, fishing near the mouth and whitebaiting.

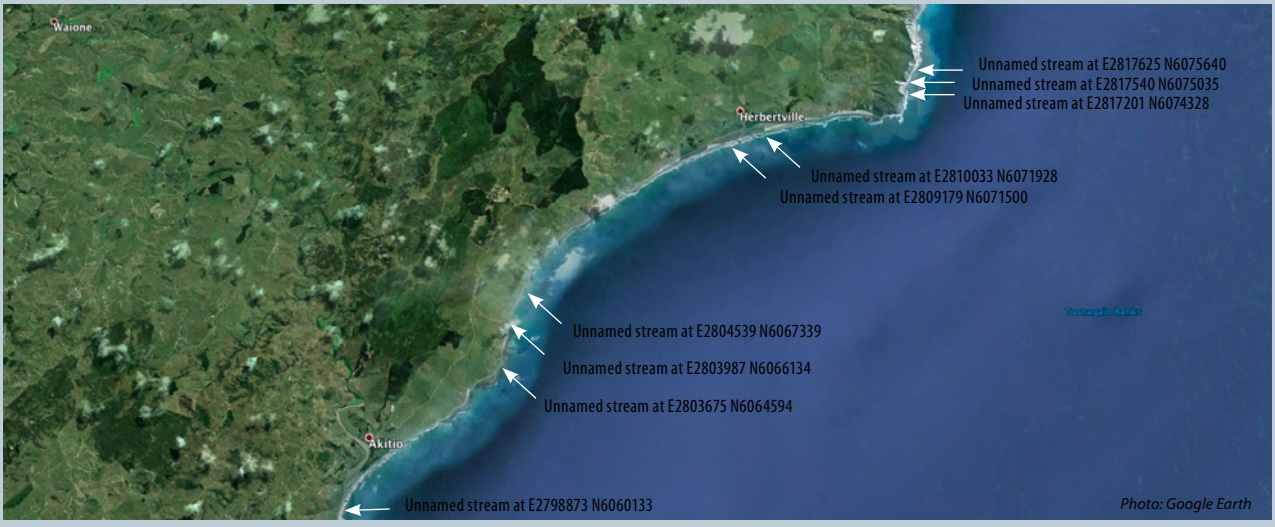
Ecological Values. Some of the margin duneland vegetation is intact, but saltmarsh is absent. The estuaries are used by fish and birds. The small size and low habitat diversity mean ecological values are low.

Eutrophication Status. These estuaries have low susceptibility to eutrophication. This is primarily because of their highly flushed natures (given that they are predominantly located on the beach and therefore strongly affected by tidal currents). However, on occasions their mouths may close, resulting in small periods of poor flushing and nuisance algal/macrophyte growth.

Sedimentation Status. The estuaries are rated as low-moderately vulnerable to muddiness issues based on the fact that they were located on highly flushed beach areas.

A synoptic survey was not undertaken but aerial photography and expert opinion indicated that opportunistic macroalgal blooms or phytoplankton blooms, and muddiness, were unlikely in all estuaries.

Estuary Type/Area	SSRTRE Type 1, approx <0.5ha
Intertidal/Subtidal	Approx 90% subtidal
Mouth Opening	Sometimes constricted
Mean Depth, Length	<0.5m, <0.2km
Catchment	<2.5 km^2
FW Inflow (mean annual)	<0.1$m^3.s^{-1}$
Saltmarsh, Seagrass	None
Soft Mud	No soft muds
Macroalgae	Absent
Dairy Cow Nos.	0
SS Loading	<3.5kt/yr
Nitrogen Loading	<1t/yr
Phosphorus Loading	<0.5t/yr
Landuse: Mainly sheep/beef	
Geology: mainly sandstone, gravel, mudstone	



SUMMARY

Issues

Muddiness	Very Low
Eutrophication	Very Low

In terms of ecological vulnerability to eutrophication and sedimentation, these estuaries were identified with very low vulnerability. The main reason for this was their very small size, low ecological value, and regular periods of high flushing (even though they may experience periodic mouth closure/restriction), which meant that, although estimated nutrient and sediment loads to the estuaries may be elevated, they were unlikely to cause prolonged periods of eutrophication and muddiness.

Monitoring and Investigations

No ongoing monitoring is recommended.

4. SUMMARY AND CONCLUSIONS

OUTPUTS

In summary, the 2016 vulnerability assessment of estuaries in the Manawatu-Wanganui Region provides three main outputs:

- **Estuarine Habitat Maps:** An ArcMap GIS dataset depicting current broad-scale habitat cover types within each estuary, using aerial photographs and ground truthing techniques.
- **Vulnerability Assessments**: An assessment of the "vulnerability" and "existing condition" of the estuarine habitats to key estuarine issues of eutrophication (excessive nutrients) and sedimentation (excessive muddiness) using the recently developed NZ Estuary Trophic Index (ETI) toolbox (Robertson et al. 2016a, 2016b).
- **Monitoring Priorities:** A recommended estuary monitoring programme for the management of estuarine ecological resources in the region.

ESTUARY TYPES

The results showed that all the surveyed estuaries were shallow, short residence time, tidal river estuaries (SSRTREs) with each estuary fitting into one of four subcategories as follows:

- **Type 1. Short length, low flow SSRTREs** - <1km long, beach located, low freshwater inflows (<1$m^3.s^{-1}$), mouth sometimes restricted/closed.
- **Type 2. Moderate length, low flow SSRTREs** - 1-3km long, low freshwater inflows (<2$m^3.s^{-1}$), mouth sometimes restricted/closed.
- **Type 3. Long length, moderate flow SSRTREs** - 3-12km long, moderate freshwater inflows (4-6$m^3.s^{-1}$), mouth always open.
- **Type 4. Long length, high flow SSRTREs** - 3-12km long, high freshwater inflows (7-220$m^3.s^{-1}$), mouth always open.

VULNERABILITIES TO EUTROPHICATION AND SEDIMENTATION AND MONITORING RECOMMENDATIONS

Type 1. Short length, low flow SSRTREs: <1km long, beach located, low freshwater inflows (<1$m^3.s^{-1}$), mouth sometimes restricted or closed.

Physical Characteristics

Very short length, beach located SSRTREs consist of relatively narrow channels situated between the upper edge of the beach and the tidal level. In some situations the channel meanders along the back of the beach for a small distance before entering the sea, whereas in others the discharge path is more direct. A few expand into small lagoons around the upper high water area. In very high tides and storm surges, saline water enters the stream inland of the beach for a small distance. At times the mouth is often restricted and can sometimes close for short periods, during which time the upper beach lagoon may expand and show eutrophication/sedimentation symptoms. These very small estuary types are the most common in the Manawatu-Wanganui Region with 24 examples included in this EVA.

Vulnerability

Type 1 estuaries were the least vulnerable of the Manawatu-Wanganui Region estuaries to eutrophication and sedimentation. The main reason for this was their small size, low ecological diversity, and regular periods of high flushing (even though some examples experience periodic mouth closure/restriction). Consequently, although estimated nutrient and sediment loads to the estuaries were generally large, they are unlikely to be subjected to prolonged periods of eutrophication and muddiness. Synoptic surveys of this estuary type in February 2016 confirmed the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms) or sedimentation (extensive areas of soft muddy sediments). In most situations where nutrient and sediment loads were high, the waters immediately upstream of the estuary showed symptoms of excessive aquatic plant/algal growth.

Monitoring Recommendation

- Given such low-moderate vulnerabilities for both eutrophication and sedimentation in these very small, highly flushed estuaries, it is recommended that any ongoing monitoring be limited to low frequency (once every 10 years) screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating. In small estuaries, located on the beach below cliffs, ongoing monitoring is not recommended.

Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 1. Short length, low flow SSRTREs - <1km long, beach located, low freshwater inflows (<1m^3.s^{-1}), mouth sometimes restricted/ closed.		
WEST COAST ESTUARIES		**EAST COAST ESTUARIES**
Ototoka Stream Estuary	Unnamed stream south Waimahora Estuary	Papuka Stream Estuary
Omapu Stream Estuary	Unnamed stream north Ruamai Range Estuary	Waimata Stream Estuary
Mowhanau Stream Estuary	Raumai Range Stream	- also nine unnamed discharges of small streams directly to the beach, eight between the northern coast regional boundary and Akitio and another just south of Akitio.
Okehu Stream Estuary	Pukepuke Stream Estuary	
Kaitoke Stream Estuary	Kaikokopu Stream	
Koitiata Stream Estuary	Three Mile Creek	
Lake Koitiata Outflow Estuary	Wairarawa Stream Estuary	
Waimahora Stream Estuary	Waiwiri Stream Estuary	

Type 2. Moderate length, low flow SSRTREs: 1-3km long, low freshwater inflows (<2m^3.s^{-1}), mouth sometimes restricted/ closed.

Physical Characteristics

Moderate length SSRTRE estuaries consist of relatively narrow channels situated between the tidal level and approximately 1-3km inland. In some situations the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct. A few expand into small lagoons around the upper high water area. The estuary mouth is generally open to the sea but in others it is mostly closed.

Vulnerability

Type 2 estuaries which had excessive nutrient/sediment loads and whose mouths were mostly closed (and therefore very poorly flushed) were identified as moderately to highly vulnerable. Those that had excessive nutrient/sediment loads, but were mostly open to the sea were rated as moderately vulnerable. When nutrient/sediment loads were low and estuaries were open to the sea, estuaries were rated as low vulnerability. Characteristic symptoms of eutrophication were opportunistic macroalgal blooms and/or green stained waters symptomatic of phytoplankton blooms, with symptoms of sedimentation being extensive areas of soft fine muddy sediments. The expression of such symptoms was variable because of the flushing regime - being highly flushed during high flow events, and poorly flushed during summer low flows when their mouths become restricted and the upstream waters stratify. This meant that under high nutrient/sediment loads, the estuaries were likely to exhibit eutrophication and muddiness symptoms only during periods of mouth constriction or poor flushing.

Monitoring Recommendation

- For "moderate-length Type 2 SSRTREs" with low nutrient/sediment loads it is recommended that any ongoing monitoring be limited to low frequency (once every 10 years) screening level (synoptic) monitoring only, to confirm that low-moderate risk estuaries have not changed their risk rating.
- For "moderate-length (mouth mostly open) Type 2 SSRTREs" with high nutrient/sediment loads it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address potential for eutrophication, it is recommended that water column chlorophyll *a*, dissolved oxygen and nutrient concentrations be monitored annually (during summer low flows) at a site representative of general (rather than localised) worst case conditions (e.g. a long pool), and at the same time, intertidal/shallow subtidal macroalgal cover be assessed over the whole estuary. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.
- For "moderate-length (mouth mostly closed) Type 2 SSRTREs" with high nutrient/sediment loads it is recommended that regular monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address the eutrophication/sedimentation issue (including both benthic and water column effects), the following monitoring is recommended at each of 3 transects across the estuary (representative of the lower, mid and upper estuary): monitor annually for the first three years to establish a baseline and thereafter at 5 yearly intervals (between Nov-March) for: opportunistic macroalgal cover and biomass, seagrass cover and biomass, sediment redox potential, TN, TOC, and grain size, and water column temperature, secchi depth, chlorophyll *a*, dissolved oxygen and nutrient concentrations.

Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 2. Moderate length, low flow SSRTREs - 1-2km long, low freshwater inflows (<2m^3.s^{-1}), mouth mainly open, high nutrient/sediment loads.	
WEST COAST ESTUARIES	**EAST COAST ESTUARIES**
Kai Iwi Estuary	None

Type 2. Moderate length, low flow SSRTREs - 1-2km long, low freshwater inflows (<2m^3.s^{-1}), mouth closed for 1 month or more, high nutrient/sediment loads.	
WEST COAST ESTUARIES	**EAST COAST ESTUARIES**
Waikawa Estuary Hokio Stream Estuary	Tautane Estuary Wainui Estuary

Type 3. Long length, moderate flow SSRTREs: 3-12km long, moderate freshwater inflows (4-6m^3.s^{-1}), mouth always open.

Physical Characteristics

Long SSRTREs, with moderate freshwater inflows and mouths always open, consist of a relatively narrow channel that extends inland for approximately 3-12km. In some situations the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct.

Vulnerability

Type 3 estuaries all had moderate vulnerability despite their high nutrient/sediment loads. The main reason for the moderate rating was that, for estuaries where the nutrient load was excessive, the estuary was likely to oscillate between low and moderate-high levels of eutrophication; i.e. low levels of eutrophication and sedimentation in winter, and immediately during and following high flow events in the warmer months, and moderately eutrophic conditions with some sedimentation during summer base-flow conditions. This latter situation arises from the extensive estuary length and moderate freshwater inflow, which means that the residence time for water and nutrients is sufficient to allow for phytoplankton blooms under baseflow conditions (given that the time taken for a parcel of water to travel the length of the estuary under baseflow is ~1-3 days for these estuaries).

Nutrient concentrations during base-flows were likely sufficient to drive moderate sized blooms, similar to those observed during the base-flow synoptic survey undertaken in February 2016.

Monitoring Recommendation

For Type 3 estuaries (i.e. Owahanga and Akitio Estuaries) it is recommended that annual monitoring of targeted eutrophication and sedimentation indicators be undertaken to provide data on long term trophic state trends. To address potential for eutrophication, it is recommended that water column chlorophyll *a*, dissolved oxygen and nutrient concentrations be monitored monthly during the period Nov-March each year at a site representative of general conditions and, at the same time, intertidal/shallow subtidal macroalgal cover be assessed at the same site. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long term monitoring for sedimentation be limited to low frequency (5 yearly), broad scale, screening level assessments only.

Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 3. Long length, moderate flow SSRTREs - 3-12km long, moderate freshwater inflows (4-6m^3.s^{-1}), mouth always open.	
WEST COAST ESTUARIES	**EAST COAST ESTUARIES**
None	Akitio River Estuary Owahanga River Estuary

Type 4. Long length, high flow SSRTREs: 3-12km long, high freshwater inflows (7-220m^3.s^{-1}), mouth always open.

Physical Characteristics

Long SSRTREs, with high freshwater inflows and mouths always open, consist of relatively narrow channels situated between the tidal level and approximately 3-12km inland. In some smaller estuaries the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct. Some of the smaller estuaries expand into lagoons around the upper high water area. In the larger examples (e.g. Manawatu and Whanganui Estuaries), significant areas of intertidal flats are found in the mid-lower estuary.

4. Summary and Conclusions (continued)

Vulnerability

Type 4 estuaries all had low vulnerability, despite their high nutrient/sediment loads. The main reason for this was that flushing in these estuaries was found to be high, even during summer low flows (a consequence of the high freshwater inflows, extensive tidal intrusion, mouths always open and narrow channels). Synoptic surveys of each estuary in February 2016 confirmed the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms) or sedimentation (extensive areas of soft muddy sediments). These findings are broadly consistent with the evidence presented for these estuariues in the One Plan (Zeldis 2009). It is also noted that the vulnerability of the inshore coastal habitats from the river plumes of these large estuaries has not been assessed in this report, given it was outside the study brief.

Monitoring Recommendation

For the larger examples of this estuary type (e.g. Manawatu and Whanganui Estuaries), which have very high nutrient and sediment loads and high human use and ecological values, it is recommended that both broad scale habitat mapping and fine scale intertidal monitoring be undertaken on a long term basis to assess trends in estuary ecological condition.

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is usually repeated at 5 yearly intervals. Broad scale intertidal mapping of Manawatu Estuary was undertaken in 2016 (Stevens and Robertson 2016) and in Whanganui Estuary in 2009 (Stevens and Robertson 2009). Fine scale monitoring measures the condition of the high susceptibility intertidal sediments through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-Mar (usually at two sites), and thereafter at 5 yearly intervals. This component has not yet been measured in these two estuaries.

For the remaining examples of this estuary type, it is recommended that any ongoing monitoring be limited to low frequency (once every 10 years), screening level (synoptic) monitoring only, to confirm that these low-moderate risk estuaries have not changed their risk rating.

To address any "High" sedimentation ratings in these estuary types (e.g. Whangaehu Estuary), it is recommended that annual sedimentation rate (including grain size) monitoring and 5 yearly broad scale mapping of soft muds, be undertaken to provide data on long term sedimentation trends.

Manawatu-Wanganui Region estuaries that fit into this category include the following:

Type 4. Long length, high flow SSRTREs - 3-12km long, high freshwater inflows (7-220$m^3.s^{-1}$), mouth always open.	
WEST COAST ESTUARIES	**EAST COAST ESTUARIES**
Turakina River Estuary Ohau River Estuary Whangaehu River Estuary Rangitikei River Estuary Manawatu River Estuary Whanganui Estuary	None

Lower Owahanga Estuary

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6. REFERENCES

Atkinson, I.A.E. 1985. Derivation of vegetation mapping units for an ecological survey of Tongariro National Park, North Island, New Zealand. New Zealand Journal of Botany 23: 361-378.

Elliot, A.H., A.F. Semadeni-Davies, U. Shankar, J.R. Zeldis, D.M. Wheeler, D.R. Plew, G.J. Rys and S.R. Harris. Submitted. A national-scale GIS-based system for modelling impacts of land use on water quality. Environmental Modelling & Software.

Hume, T (2016). The fit of the ETI trophic state susceptibility typology to the NZ coastal hydrosystems typology. Prepared by Hume Consulting Ltd. NIWA Client report (in review).

Robertson, B.M., Gillespie, P.A., Asher, R.A., Frisk, S., Keeley, N.B., Hopkins, G.A., Thompson, S.J. and 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. 93p. Part B. 159p. Part C. 40p plus field sheets.

Robertson, B.M. and Stevens, L. 2007a. Wairarapa Coastal Habitats: Mapping, Risk Assessment and Monitoring. Prepared for Greater Wellington Regional Council. 120p.

Robertson, B.M. and Stevens, L. 2007b. Wellington Harbour, Kapiti, Southwest and South Coasts - Risks and Monitoring. Prepared for Greater Wellington Regional Council. 57p.

Robertson, B.M. and Stevens, L. 2007c. Lake Onoke 2007 - Vulnerability Assessment & Monitoring Recommendations. Prepared for Greater Wellington Regional Council. 57p.

Robertson, B.M., and Stevens, L.M. 2008. Southland Coast - Te Waewae Bay to the Catlins, habitat mapping, risk assessment and monitoring recommendations. Report prepared for Environment Southland. 165p.

Robertson, B.M. and Stevens, L.M. 2011. Tasman Coast - Waimea Inlet to Kahurangi Point, habitat mapping, risk assessment and monitoring recommendations. Prepared for Tasman District Council. 167p.

Robertson, B.M., Stevens, L., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T. and Oliver, M. 2016a. NZ Estuary Trophic Index. Screening Tool 1. Determining eutrophication susceptibility using physical and nutrient load data. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 47p.

Robertson, B.M., Stevens, L., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T. and Oliver, M. 2016b. NZ Estuary Trophic Index. Screening Tool 2. Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 68p.

Semadeni-Davies, A., S. Elliott and U. Shankar 2011. The CLUES Project: Tutorial Manual for CLUES 3.1. In NIWA client report prepared for Ministry of Agriculture and Forestry.

Stevens, L.M. and Robertson, B.M. 2009. Whanganui Estuary. Broad Scale Habitat Mapping 2008/09. Report prepared by Wriggle Coastal Management for Department of Conservation. 17p.

Stevens, L.M. and Robertson, B.M. 2015. Ruataniwha Estuary 2015: Broad Scale Habitat Mapping. Report prepared by Wriggle Coastal Management for Tasman District Council. 34p.

Sunda, W.G. and Cai, W-J. 2012. Eutrophication induced CO2 - acidification of subsurface coastal waters: interactive effects of temperature, salinity, and atmospheric pCO2, Environmental Science & Technology, 46: 10651–10659.

UNESCO, 2000. Guidelines for Vulnerability Mapping of Coastal Zones in the Indian Ocean. IOC Manuals and Guides No. 38.

Zeldis, J. 2009. Proposed One Plan. Section 42A Report of Dr John R. Zeldis on behalf of Horizons Regional Council. Prepared August 2009.

Zeldis, J., Swales, A., Currie, K., Safi, K., Nodder, S., Depree, C., Elliott, F., Pritchard, M., Gall, M., O'Callaghan, J., Pratt, D., Chiswell, S., Pinkerton, M., Lohrer, D. and Bentley, S. 2015. Firth of Thames Water Quality and Ecosystem Health – Data Report. NIWA Client Report No. CHC2014-123, prepared for Waikato Regional Council and DairyNZ. 185p.

8. References (continued)

References for Table 1

Abrahim, G. 2005. Holocene sediments of Tamaki Estuary: characterisation and impact of recent human activity on an urban estuary in Auckland, NZ. PhD Thesis, University of Auckland, Auckland, NZ, p 361.

Anderson, D., Gilbert, P. and Burkholder, J. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition, and consequences. Estuaries 25, 704–726.

Ferreira, J., Andersen, J. and Borja, A. 2011. Overview of eutrophication indicators to assess environmental status within the European Marine Strategy Framework Directive. Estuarine, Coastal and Shelf Science 93, 117–131.

Gibb, J.G. and Cox, G.J. 2009. Patterns & Rates of Sedimentation within Porirua Harbour. Consultancy Report (CR 2009/1) prepared for Porirua City Council. 38p plus appendices.

Gibbs, M. and Hewitt, J. 2004. Effects of sedimentation on macrofaunal communities : a synthesis of research studies for ARC. Prepared for Auckland Regional Council. NIWA Client Report: HAM2004-060. 48p.

IPCC. 2007. Intergovernmental Panel on Climate Change web site. https://www.ipcc.ch/publications_and_data/ar4/wg1/ (accessed December 2009).

IPCC. 2013. Intergovernmental Panel on Climate Change web site. https://www.ipcc.ch/report/ar5/wg1/ (accessed March 2014).

Kennish, M.J. 2002. Environmental threats and environmental future of estuaries. Environmental Conservation 29, 78–107.

National Research Council. 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. Ocean Studies Board and Water Science and Technology Board, Commission on Geosciences, Environment, and Resources. Washington, DC: National Academy Press. 405p.

Painting, S.J., Devlin, M.J., Malcolm, S.J., Parker, E.R., Mills, D.K., Mills, C. and Winpenny, K. 2007. Assessing the impact of nutrient enrichment in estuaries: susceptibility to eutrophication. Marine pollution bulletin 55(1-6), 74–90.

Robertson, B.M. and Stevens, L.M. 2007. Waikawa Estuary 2007 Fine Scale Monitoring and Historical Sediment Coring. Prepared for Environment Southland. 29p.

Robertson, B.M. and Stevens, L.M. 2010. New River Estuary: Fine Scale Monitoring 2009/10. Report prepared by Wriggle Coastal Management for Environment Southland. 35p.

de Salas, M.F., Rhodes, L.L., Mackenzie, L.A. and Adamson, J.E. 2005. Gymnodinoid genera Karenia and Takayama (Dinophyceae) in New Zealand coastal waters. New Zealand Journal of Marine and Freshwater Research 39,135–139.

Stewart, J.R., Gast, R.J., Fujioka, R.S., Solo-Gabriele, H.M., Meschke, J.S., Amaral-Zettler, L.A., Castillo, E. Del., Polz, M.F., Collier, T.K., Strom, M.S., Sinigalliano, C.D., Moeller, P.D.R. and Holland, A.F. 2008. The coastal environment and human health: microbial indicators, pathogens, sentinels and reservoirs. Environmental Health 7 Suppl 2, S3.

Swales, A., and Hume, T. 1995. Sedimentation history and potential future impacts of production forestry on the Wharekawa Estuary, Coromandel Peninsula. Prepared for Carter Holt Harvey Forests Ltd. NIWA report no. CHH004.

Valiela, I., McClelland, J., Hauxwell, J., Behr, P., Hersh, D. and Foreman, K. 1997. Macroalgal blooms in shallow estuaries: Controls and ecophysiological and ecosystem consequences. Limnology and Oceanography 42, 1105–1118.

Wade, T.J., Pai, N., Eisenberg, J.N.S. and Colford, J.M., 2003. Do U.S. Environmental Protection Agency Water Quality Guidelines for Recreational Waters Prevent Gastrointestinal Illness? A Systematic Review and Meta-analysis. Environmental Health Perspective 111, 1102–1109.

APPENDIX 1. DETAILED DATA MANAWATU-WANGANUI REGION ESTUARIES

	Estuary	Estuary Type	HW estuary area (ha)	Mean depth (m)	Estuary Volume (m^3)	Estimated FW Inflow (m^3/s)	Flushing Potential	Dilution Potential	Catchment Load TN (t/yr) [1]	Catchment Load TP (t/yr) [1]	Catchment Load TSS (kt/yr) [1]	N Areal Load ($mgN/m^2/d$)	Catchment area (km^2) [2]	Cow numbers [2]	Daily water abstraction (m^3/day) [2]
1	Ototoka Stream Estuary	SSRTRE Type 1	2.3	0.5	11500	0.25	1.88	2.46E-06	16.4	2.7	5.7	1954	29.3	1099	0
2	Okehu Stream Estuary	SSRTRE Type 1	2.2	0.5	11000	0.75	5.89	2.57E-06	35.4	9	37.0	4408	68.6	360	0
3	Unnamed stream at E2671159 N6145599	SSRTRE Type 1	No discharge to coast						0.61	0.02	0.02	NA	1.0	0	0
4	Kai Iwi Stream Estuary	SSRTRE Type 2	3	0.5	15000	1.5	8.64	1.89E-06	83	21.2	90.5	7580	191.8	54	192
5	Mowhanau Stream Estuary	SSRTRE Type 1	0.8	0.5	4000	0.25	5.40	7.08E-06	23.5	2.8	6.1	8048	29.1	750	1762
6	Omapu Stream Estuary	SSRTRE Type 1	0.1	0.2	200	0.025	10.80	1.42E-04	5.5	0.36	0.3	15068	5.7	1600	0
7	Whanganui Estuary	SSRTRE Type 4	354	2	7080000	210	2.56	4.00E-09	4062.5	1257.1	5898.6	3144	7169.3	14779	20169.3
8	Kaitoke Stream Estuary	SSRTRE Type 1	3.5	0.5	17500	0.75	3.70	1.62E-06	39.3	1.67	1.2	3076	49.1	360	0
9	Whangaehu River Estuary	SSRTRE Type 4	73.2	1	732000	39.78	4.70	3.87E-08	1389.1	283.3	1160.8	5199	1992.3	9897	129643
10	Turakina River Estuary	SSRTRE Type 4	58.5	1	585000	7.19	1.06	4.84E-08	558.2	131.7	559.5	2614	957.0	3440	114
11	Koitiata Stream Estuary	SSRTRE Type 1	2.4	0.5	12000	0.25	1.80	2.36E-06	26.5	0.93	0.3	3025	48.7	1200	189
12	Unnamed Lake Koitiata outflow	SSRTRE Type 1	0.27	0.5	1350	0.25	16.00	2.10E-05	10.9	0.32	0.1	11060	19.0	1260	0
13	Waimahora Stream Estuary	SSRTRE Type 1	0.75	0.5	3750	0.05	1.15	7.55E-06	32.1	0.99	0.4	11726	35.7	0	0
14	Unnamed stream at E2696657 N6113943	SSRTRE Type 1	0.1	0.5	500	0.05	8.64	5.66E-05	13.4	0.41	0.1	36712	10.5	575	0
15	Unnamed stream at E2697524 N6111094	SSRTRE Type 1	0.25	0.5	1250	0.08	5.53	2.27E-05	23.7	0.89	0.2	25973	22.7	1849	0
16	Raumai Range Stream	SSRTRE Type 1	1.6	0.5	8000	0.12	1.30	3.54E-06	39.8	0.95	0.3	6815	38.0	0	0
17	Rangitikei River Estuary	SSRTRE Type 4	118	1	1180000	72.28	5.29	2.40E-08	2133.3	364.2	1231.0	4953	3924.9	42389	227645.8
18	Pukepuke Estuary	SSRTRE Type 1	0.6	0.5	3000	0.112	3.23	9.44E-06	79.7	1.61	0.1	36393	41.0	3955	0
19	Kaikokopu Stream	SSRTRE Type 1	5	0.5	25000	1	3.46	1.13E-06	34.1	0.86	0.2	1868	56.4	5605	0
20	Three Mile Creek	SSRTRE Type 1	2.4	0.5	12000	0.25	1.80	2.36E-06	37.3	0.93	0.1	4258	27.4	3360	0
21	Manawatu River Estuary	SSRTRE Type 4	533	1	5330000	124	2.01	5.31E-09	6313.2	1270.2	2567.9	3245	5881.4	209271	357976.8
22	Wairarawa Stream Estuary	SSRTRE Type 1	0.3	0.5	1500	0.884	50.92	1.89E-05	21.9	0.5	0.1	20000	13.7	1500	0
23	Hokio Stream Estuary	SSRTRE Type 2	4	0.5	20000	0.97	4.19	1.42E-06	54.2	0.9	0.3	3712	69.7	2465	0
24	Waiwiri Stream Estuary	SSRTRE Type 1	3.9	0.5	19500	0.17	0.75	1.45E-06	16.2	0.6	0.2	1138	15.2	350	0
25	Ohau River Estuary	SSRTRE Type 4	62.3	1	623000	8.43	1.17	4.55E-08	236.8	20.5	28.8	1041	189.0	4776	21131
26	Waikawa River Estuary	SSRTRE Type 2	21.5	1	215000	1.917	0.77	1.32E-07	93.8	7.9	10.4	1195	78.6	1495	2040
27	Unnamed stream at E2817625 N6075640	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	0.149	0.07	0.6	408	0.5	0	0
28	Unnamed stream at E2817540 N6075035	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	0.26	0.128	0.8	712	0.7	0	0
29	Unnamed stream at E2817201 N6074328	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	0.27	0.1	1.0	740	0.8	0	0
30	Tautane Stream Estuary	SSRTRE Type 2	3	1	30000	0.37	1.07	9.44E-07	12.1	5.3	17.9	1105	22.3	0	0
31	Wainui River Estuary	SSRTRE Type 2	16	1.5	240000	1.7	0.61	1.18E-07	51.1	21.7	61.8	875	101.3	0	0
32	Unnamed stream at E2810033 N6071928	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	1.82	0.79	3.4	4986	1.0	0	0
33	Unnamed stream at E2809179 N6071500	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	1.23	0.54	2.7	3370	2.4	0	0
34	Papuka Stream Estuary (aka Paewa Stream)	SSRTRE Type 1	1.2	0.5	6000	0.09	1.30	4.72E-06	2.6	1.68	8.1	594	5.8	0	0
35	Waimata River Estuary	SSRTRE Type 1	0.55	0.5	2750	0.44	13.82	1.03E-05	9.96	4.5	8.3	4961	27.8	0	0
36	Unnamed stream at E2804539 N6067339	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	0.6	0.45	2.2	1644	1.6	0	0
37	Unnamed stream at E2803987 N6066134	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	0.43	0.299	3.5	1178	1.3	0	0
38	Unnamed stream at E2803675 N6064594	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	0.25	0.18	0.5	685	0.6	0	0
39	Akitio River Estuary	SSRTRE Type 3	58	1.1	638000	4.8	0.65	4.44E-08	265.6	112.9	337.9	1255	589.6	0	3068
40	Unnamed stream at E2798873 N 6060133	SSRTRE Type 1	0.1	0.2	200	0.05	21.60	1.42E-04	0.4	0.21	0.4	1096	1.2	0	0
41	Owahanga River Estuary	SSRTRE Type 3	77	1	770000	5.5	0.62	3.68E-08	224.1	95	253.0	797	408.7	0	140

1. Data provided by Horizons Regional Council
2. Estimates sourced from NIWA CLUES Model run 16 May 2016 in ARCMap 10.2.2 (CLUES 10.3 default setting using REC2 and LCBB3 (2008/2009) land cover)

APPENDIX 1. DETAILED DATA MANAWATU-WANGANUI REGION ESTUARIES (cont...)

	Estuary	Intertidal Area (ha)	Saltmarsh area (ha)	Seagrass (ha)	Intertidal Soft Mud Area (ha)	Intertidal Macroalgal Cover (ha)	Intertidal soft mud (%)	Subtidal extent (%)	Natural State Catchment Load TN (t/yr) [1]	Natural State Catchment Load TP (t/yr) [1]	Natural State Catchment Load TSS (kt/yr) [1]	Natural State N Areal Load (mgN/m²/d) [2]	Current State Sediment Load / Natural State Sediment Load ratio (CSSL/NSSL ratio) [3]
1	Ototoka Stream Estuary	1.8	0	0	0	0	0.0	22	9.1	1.0	1.5	542	15.2
2	Okehu Stream Estuary	1.9	0	0	0	0	0.0	14	23.0	3.5	16.2	1432	9.1
3	Unnamed stream at E2671159 N6145599	No discharge to coast					NA	NA	0.2	0.01	0.01	NA	14.7
4	Kai Iwi Stream Estuary	2	0.09	0	0	0	0.0	33	65.4	6.6	40.5	2986	8.9
5	Mowhanau Stream Estuary	0.7	0	0	0	0	0.0	13	11.6	1.2	1.4	1986	17.4
6	Omapu Stream Estuary	0.08	0	0	0	0	0.0	20	1.9	0.2	0.1	2603	17.0
7	Whanganui Estuary	84.5	0.9	0	23.6	0	27.9	76	2393.6	865.4	3331.6	926	7.1
8	Kaitoke Stream Estuary	3.1	0	0	0	0	0.0	11	15.0	1.1	0.3	587	15.6
9	Whangaehu River Estuary	33.6	0	0	20.7	0	61.6	54	757.9	152.1	345.9	1418	13.4
10	Turakina River Estuary	36.1	1.2	0	0	0	0.0	38	373.8	63.9	152.0	875	14.7
11	Koitiata Stream Estuary	1.7	0.13	0	0	0	0.0	29	17.5	0.7	0.1	999	12.0
12	Unnamed Lake Koitiata outflow	0.02	0	0	0	0	0.0	93	6.7	0.3	0.03	3399	8.3
13	Waimahora Stream Estuary	0.55	0	0	0	0	0.0	27	16.3	0.8	0.2	2977	11.5
14	Unnamed stream at E2696657 N6113943	0.09	0	0	0	0	0.0	10	5.2	0.3	0.04	7123	11.0
15	Unnamed stream at E2697524 N6111094	0.16	0	0	0	0	0.0	36	10.3	0.5	0.1	5644	12.6
16	Raumai Range Stream	1.4	0	0	0	0	0.0	13	16.1	0.8	0.1	1378	12.9
17	Rangitikei River Estuary	78	22.2	0	1.4	0	1.8	34	1341.3	224.9	464.5	1557	10.6
18	Pukepuke Estuary	0.45	0	0	0	0	0.0	25	27.0	0.8	0.03	6164	13.3
19	Kaikokopu Stream	3	0	0	0	0	0.0	40	10.2	0.4	0.04	279	15.0
20	Three Mile Creek	2	0	0	0	0	0.0	17	12.9	0.5	0.1	736	9.3
21	Manawatu River Estuary	279	161	0	46	0.7	16.5	48	3010.0	756.3	813.4	774	12.6
22	Wairarawa Stream Estuary	0.2	0	0	0	0	0.0	33	5.1	0.2	0.02	2329	12.4
23	Hokio Stream Estuary	2.26	0	0	0	0	0.0	44	12.8	0.4	0.1	438	14.7
24	Waiwiri Stream Estuary	3.2	0.05	0	0	0	0.0	18	5.1	0.3	0.1	179	14.4
25	Ohau River Estuary	42.1	1.9	0	0	0	0.0	32	85.3	12.3	23.8	188	4.9
26	Waikawa River Estuary	15.5	3.1	0.008	0	0	0.0	28	35.1	3.8	8.7	224	4.8
27	Unnamed stream at E2817625 N6075640	0.03	0	0	0	0	0.0	70	0.1	0.03	0.2	153	10.9
28	Unnamed stream at E2817540 N6075035	0.03	0	0	0	0	0.0	70	0.2	0.1	0.2	273	13.0
29	Unnamed stream at E2817201 N6074328	0.03	0	0	0	0	0.0	70	0.2	0.1	0.3	260	13.9
30	Tautane Stream Estuary	1.9	1.8	0.8	0	0	0.0	37	8.6	2.9	4.2	393	17.0
31	Wainui River Estuary	3.7	0	0	1.2	0	32.4	77	38.3	13.1	18.7	328	13.2
32	Unnamed stream at E2810033 N6071928	0.03	0	0	0	0	0.0	70	1.2	0.4	0.8	1644	16.4
33	Unnamed stream at E2809179 N6071500	0.03	0	0	0	0	0.0	70	0.8	0.3	0.7	1134	16.4
34	Papuka Stream Estuary (aka Paewa Stream)	0.2	0.1	0	0	0	0.0	83	2.6	0.9	1.9	297	17.1
35	Waimata River Estuary	0.17	0.01	0	0	0	0.0	69	8.7	3.0	3.4	2162	9.7
36	Unnamed stream at E2804539 N6067339	0.03	0	0	0	0	0.0	70	0.7	0.3	0.5	945	17.6
37	Unnamed stream at E2803987 N6066134	0.03	0	0	0	0	0.0	70	0.4	0.2	0.8	589	17.2
38	Unnamed stream at E2803675 N6064594	0.03	0	0	0	0	0.0	70	0.3	0.1	0.1	356	16.7
39	Akitio River Estuary	13	0	0	6.4	0	49.2	78	198.2	55.1	93.2	468	14.5
40	Unnamed stream at E2798873 N 6060133	0.03	0	0	0	0	0.0	70	0.3	0.1	0.1	452	16.0
41	Owahanga River Estuary	30.3	2.6	0	10.3	0	34.0	61	161.7	47.2	75.3	288	13.4

1. Estimates sourced from NIWA CLUES Model run 16 May 2016 in ARCMap 10.2.2 (CLUES 10.3 REC2 default setting with all landuse set to native forest cover).
2. A 50% reduction was applied to Natural State TN loads (estimated by setting CLUES land cover to native forest) to account for expected nutrient uptake and retention in wetlands present under natural state.
3. A 75% reduction was applied to Natural State Sediment loads (estimated by setting CLUES land cover to native forest) to account for high expected sediment retention in wetlands present under natural state.

APPENDIX 1. DETAILED DATA MANAWATU-WANGANUI REGION ESTUARIES (cont...)

	Estuary	Estuary Type	Summary Geology[1]
1	Ototoka Stream Estuary	SSRTRE Type 1	gravel 94%, sand 6%
2	Okehu Stream Estuary	SSRTRE Type 1	gravel 35%, limestone 14%, mudstone 48%, sand 2%
3	Unnamed stream at E2671159 N6145599	SSRTRE Type 1	gravel 12%, sand 88%
4	Kai Iwi Stream Estuary	SSRTRE Type 2	gravel 25%, limestone 30%, mudstone 33%, sandstone 12%
5	Mowhanau Stream Estuary	SSRTRE Type 1	gravel 71%, mudstone 27%, sand 2%
6	Omapu Stream Estuary	SSRTRE Type 1	gravel 48%, sand 51%
7	Whanganui Estuary	SSRTRE Type 4	gravel 10%, ignimbrite 11%, mudstone 19%, sandstone 52%
8	Kaitoke Stream Estuary	SSRTRE Type 1	gravel 66%, sand 25%, sandstone 7%
9	Whangaehu River Estuary	SSRTRE Type 4	gravel 32%, limestone 3%, mudstone 27%, sandstone 25%
10	Turakina River Estuary	SSRTRE Type 4	gravel 17%, limestone 3%, mudstone 34%, sandstone 32%
11	Koitiata Stream Estuary	SSRTRE Type 1	gravel 16%, sand 83%
12	Unnamed Lake Koitiata outflow	SSRTRE Type 1	gravel 3%, sand 96%
13	Waimahora Stream Estuary	SSRTRE Type 1	sand 100%
14	Unnamed stream at E2696657 N6113943	SSRTRE Type 1	sand 100%
15	Unnamed stream at E2697524 N6111094	SSRTRE Type 1	sand 100%
16	Raumai Range Stream	SSRTRE Type 1	gravel 8%, sand 92%
17	Rangitikei River Estuary	SSRTRE Type 4	gravel 23%, limestone 23%, mudstone 12%, sand 2%, sandstone 32%
18	Pukepuke Estuary	SSRTRE Type 1	sand 99%
19	Kaikokopu Stream	SSRTRE Type 1	sand 99.7%
20	Three Mile Creek	SSRTRE Type 1	sand 100%
21	Manawatu River Estuary	SSRTRE Type 4	gravel 40%, greywacke 14%, mudstone 15%, sand 4%, sandstone 18%
22	Wairarawa Stream Estuary	SSRTRE Type 1	sand 100%
23	Hokio Stream Estuary	SSRTRE Type 2	gravel 54%, sand 35%
24	Waiwiri Stream Estuary	SSRTRE Type 1	gravel 19%, sand 75%
25	Ohau River Estuary	SSRTRE Type 4	gravel 38%, greywacke 10% sand 6%, sandstone 46%
26	Waikawa River Estuary	SSRTRE Type 2	gravel 33%, sand 17%, sandstone 50%
27	Unnamed stream at E2817625 N6075640	SSRTRE Type 1	mudstone 100%
28	Unnamed stream at E2817540 N6075035	SSRTRE Type 1	mudstone 100%
29	Unnamed stream at E2817201 N6074328	SSRTRE Type 1	mudstone 100%
30	Tautane Stream Estuary	SSRTRE Type 2	gravel 10%, mudstone 90%
31	Wainui River Estuary	SSRTRE Type 2	gravel 7%, mudstone 57%, sandstone 31%
32	Unnamed stream at E2810033 N6071928	SSRTRE Type 1	gravel 8%, sand 11%, sandstone 81%
33	Unnamed stream at E2809179 N6071500	SSRTRE Type 1	gravel 2%, sand 6%, sandstone 91%
34	Papuka Stream Estuary (aka Paewa Stream)	SSRTRE Type 1	mudstone 30%, sand 1%, sandstone 69%
35	Waimata River Estuary	SSRTRE Type 1	mudstone 66%, sandstone 34%
36	Unnamed stream at E2804539 N6067339	SSRTRE Type 1	mudstone 41%, sandstone 59%
37	Unnamed stream at E2803987 N6066134	SSRTRE Type 1	mudstone 3%, sandstone 97%
38	Unnamed stream at E2803675 N6064594	SSRTRE Type 1	gravel 47%, sandstone 53%
39	Akitio River Estuary	SSRTRE Type 3	gravel 5%, mudstone 57%, sandstone 35%
40	Unnamed stream at E2798873 N6060133	SSRTRE Type 1	gravel 4%, mudstone 96%
41	Owahanga River Estuary	SSRTRE Type 3	gravel 9%, mudstone 65%, sandstone 26%

1. Data provided by Horizons Regional Council

APPENDIX 1. DETAILED DATA MANAWATU-WANGANUI REGION ESTUARIES (cont...)

	Estuary	Estuary Type	Landuse Summary[1]
1	Ototoka Stream Estuary	SSRTRE Type 1	Urban 0.1%, Cropping 0.7%, Dairy 13.1%, Exotic Forest 2.8%, Hort 0.3%, Native Forest 3.3%, Sheep/beef 79.7%, Water 0%
2	Okehu Stream Estuary	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 2.2%, Exotic Forest 23.2%, Hort 0.2%, Native Forest 17.9%, Sheep/beef 55.1%, Water 0%
3	Unnamed stream at E2671159 N6145599	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 0%, Hort 0%, Native Forest 0%, Sheep/beef 100%, Water 0%
4	Kai Iwi Stream Estuary	SSRTRE Type 2	Urban 0.1%, Cropping 0.1%, Dairy 1.1%, Exotic Forest 28.9%, Hort 0.1%, Native Forest 18.7%, Sheep/beef 50.8%, Water 0%
5	Mowhanau Stream Estuary	SSRTRE Type 1	Urban 0%, Cropping 0.1%, Dairy 27.4%, Exotic Forest 2.9%, Hort 1%, Native Forest 2.4%, Sheep/beef 65.5%, Water 0%
6	Omapu Stream Estuary	SSRTRE Type 1	Urban 0.1%, Cropping 1.1%, Dairy 52.1%, Exotic Forest 2.6%, Hort 0.3%, Native Forest 0.3%, Sheep/beef 42.5%, Water 0%
7	Whanganui Estuary	SSRTRE Type 4	Urban 0.4%, Cropping 0%, Dairy 0.8%, Exotic Forest 9.7%, Hort 0%, Native Forest 54.5%, Sheep/beef 34.2%, Water 0.2%
8	Kaitoke Stream Estuary	SSRTRE Type 1	Urban 0.2%, Cropping 1.1%, Dairy 5.2%, Exotic Forest 8.1%, Hort 0%, Native Forest 2.1%, Sheep/beef 82.9%, Water 0.4%
9	Whangaehu River Estuary	SSRTRE Type 4	Urban 0.2%, Cropping 0.1%, Dairy 1.6%, Exotic Forest 11.6%, Hort 0.2%, Native Forest 21.1%, Sheep/beef 60.5%, Water 0.2%
10	Turakina River Estuary	SSRTRE Type 4	Urban 0%, Cropping 0.5%, Dairy 2.5%, Exotic Forest 7.2%, Hort 0%, Native Forest 8.5%, Sheep/beef 81.2%, Water 0.1%
11	Koitiata Stream Estuary	SSRTRE Type 1	Urban 0%, Cropping 0.8%, Dairy 1.6%, Exotic Forest 21.2%, Hort 0%, Native Forest 0.9%, Sheep/beef 75%, Water 0.1%
12	Unnamed Lake Koitiata outflow	SSRTRE Type 1	Urban 0%, Cropping 1.1%, Dairy 12.9%, Exotic Forest 26.4%, Hort 0%, Native Forest 1.7%, Sheep/beef 55.3%, Water 0%
13	Waimahora Stream Estuary	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 1.9%, Exotic Forest 43.7%, Hort 0%, Native Forest 0.9%, Sheep/beef 53.5%, Water 0%
14	Unnamed stream at E2696657 N6113943	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 29.6%, Exotic Forest 49.5%, Hort 0%, Native Forest 0.1%, Sheep/beef 20.8%, Water 0%
15	Unnamed stream at E2697524 N6111094	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 34.6%, Exotic Forest 33.8%, Hort 0%, Native Forest 0.2%, Sheep/beef 30.6%, Water 0%
16	Raumai Range Stream	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 7.2%, Exotic Forest 31.4%, Hort 0%, Native Forest 0.3%, Sheep/beef 60.6%, Water 0%
17	Rangitikei River Estuary	SSRTRE Type 4	Urban 0.3%, Cropping 0.4%, Dairy 4.2%, Exotic Forest 3.3%, Hort 0%, Native Forest 28.4%, Sheep/beef 54.1%, Water 0.3%
18	Pukepuke Estuary	SSRTRE Type 1	Urban 0.8%, Cropping 0%, Dairy 56%, Exotic Forest 23.2%, Hort 0.7%, Native Forest 0.9%, Sheep/beef 17.9%, Water 0%
19	Kaikokopu Stream	SSRTRE Type 1	Urban 0.8%, Cropping 0%, Dairy 56%, Exotic Forest 23.2%, Hort 0.7%, Native Forest 0.9%, Sheep/beef 17.9%, Water 0%
20	Three Mile Creek	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 41.7%, Exotic Forest 16.6%, Hort 0%, Native Forest 4.1%, Sheep/beef 37.2%, Water 0%
21	Manawatu River Estuary	SSRTRE Type 4	Urban 1.1%, Cropping 0.8%, Dairy 18.1%, Exotic Forest 4%, Hort 0.3%, Native Forest 17.1%, Sheep/beef 58.1%, Water 0.2%
22	Wairarawa Stream Estuary	SSRTRE Type 1	Urban 4.5%, Cropping 1.3%, Dairy 45.7%, Exotic Forest 26.7%, Hort 0%, Native Forest 1.5%, Sheep/beef 20.3%, Water 0.1%
23	Hokio Stream Estuary	SSRTRE Type 2	Urban 12%, Cropping 3%, Dairy 18%, Exotic Forest 3.5%, Hort 3.5%, Native Forest 3.5%, Sheep/beef 50.5%, Water 4.3%
24	Waiwiri Stream Estuary	SSRTRE Type 1	Urban 0%, Cropping 0.3%, Dairy 21.8%, Exotic Forest 16.6%, Hort 0%, Native Forest 6.5%, Sheep/beef 51.4%, Water 3.2%
25	Ohau River Estuary	SSRTRE Type 4	Urban 0.1%, Cropping 1.1%, Dairy 14%, Exotic Forest 9%, Hort 1.4%, Native Forest 50.5%, Sheep/beef 23.4%, Water 0.2%
26	Waikawa River Estuary	SSRTRE Type 2	Urban 0.6%, Cropping 0.3%, Dairy 23.6%, Exotic Forest 12.6%, Hort 1.2%, Native Forest 35.3%, Sheep/beef 26.3%, Water 0.1%
27	Unnamed stream at E2817625 N6075640	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 0%, Hort 0%, Native Forest 18.3%, Sheep/beef 81.7%, Water 0%
28	Unnamed stream at E2817540 N6075035	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 0%, Hort 0%, Native Forest 23.1%, Sheep/beef 76.9%, Water 0%
29	Unnamed stream at E2817201 N6074328	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 0%, Hort 0%, Native Forest 0.1%, Sheep/beef 99.9%, Water 0%
30	Tautane Stream Estuary	SSRTRE Type 2	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 1.2%, Hort 0%, Native Forest 4.5%, Sheep/beef 94.4%, Water 0%
31	Wainui River Estuary	SSRTRE Type 2	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 18.8%, Hort 0%, Native Forest 4.9%, Sheep/beef 76.2%, Water 0%
32	Unnamed stream at E2810033 N6071928	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 4.3%, Hort 0%, Native Forest 0%, Sheep/beef 95.7%, Water 0%
33	Unnamed stream at E2809179 N6071500	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 3.3%, Hort 0%, Native Forest 4.1%, Sheep/beef 92.6%, Water 0%
34	Papuka Stream Estuary (aka Paewa Stream)	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 2.4%, Hort 0%, Native Forest 2.7%, Sheep/beef 94.9%, Water 0%
35	Waimata River Estuary	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 30.8%, Hort 0%, Native Forest 27.8%, Sheep/beef 41.5%, Water 0%
36	Unnamed stream at E2804539 N6067339	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 4.3%, Hort 0%, Native Forest 0%, Sheep/beef 95.7%, Water 0%
37	Unnamed stream at E2803987 N6066134	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 0%, Hort 0%, Native Forest 0%, Sheep/beef 100%, Water 0%
38	Unnamed stream at E2803675 N6064594	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 0%, Hort 0%, Native Forest 9.7%, Sheep/beef 90.3%, Water 0%
39	Akitio River Estuary	SSRTRE Type 3	Dairy 0.3%, Exotic Forest 9.2%, Native Forest 12.6%, Sheep/beef 77.8%
40	Unnamed stream at E2798873 N6060133	SSRTRE Type 1	Urban 0%, Cropping 0%, Dairy 0%, Exotic Forest 0.5%, Hort 0%, Native Forest 8%, Sheep/beef 91.5%, Water 0%
41	Owahanga River Estuary	SSRTRE Type 3	Urban 0.2%, Cropping 0%, Dairy 0%, Exotic Forest 3.3%, Hort 0%, Native Forest 18.4%, Sheep/beef 76.9%, Water 0.1%

1. Data provided by Horizons Regional Council

APPENDIX 2. WATER QUALITY DATA

Manawatu-Wanganui Region Rivers/Estuaries (data provided by Horizons Regional Council)

Site Name		Sample size	Minimum	Maximum	Mean	Median	Standard deviation (denom. = n-1)
Akitio Estuary at Coast Rd Bridge	E. coli (MPN/100ml)	39	12	10670	2951.518	480	3906.546
Akitio Estuary at Coast Rd Bridge	Enterococci (MPN/100ml)	5	4	358	112.6	24	153.025
Akitio Estuary at Coast Rd Bridge	Black disc (m)						
Akitio Estuary at Coast Rd Bridge	Field Temperature (°C)	53	8.9	21.4	14.669	14.5	3.44
Akitio Estuary at Coast Rd Bridge	Field DO (%sat)	43	76.8	123.9	96.598	93.7	9.699
Akitio Estuary at Coast Rd Bridge	Field DO (mg/l)	43	6.07	11.33	8.821	8.73	1.204
Akitio Estuary at Coast Rd Bridge	Field Conductivity (µS/cm)	52	70.3	53482	29264.906	32512	18536.596
Akitio Estuary at Coast Rd Bridge	Field pH	48	7.38	8.32	8.03	8.055	0.198
Akitio Estuary at Coast Rd Bridge	TSS (g/m3)	9	37	2586	384.778	90	830.416
Akitio Estuary at Coast Rd Bridge	Turbidity EPA (NTU)						
Akitio Estuary at Coast Rd Bridge	Ammoniacal-N (g/m3)	45	0	0.28	0.037	0.012	0.057
Akitio Estuary at Coast Rd Bridge	TN (g/m3)	45	0.018	1.8	0.51	0.41	0.402
Akitio Estuary at Coast Rd Bridge	TON (g/m3-N	43	0.002	0.675	0.115	0.072	0.138
Akitio Estuary at Coast Rd Bridge	Nitrate (g/m3-N)	45	0.002	0.669	0.114	0.069	0.135
Akitio Estuary at Coast Rd Bridge	Nitrite (g/m3-N)	45	0	0.009	0.003	0.003	0.002
Akitio Estuary at Coast Rd Bridge	DRP (g/m3)	45	0.001	0.022	0.008	0.009	0.005
Akitio Estuary at Coast Rd Bridge	TDP (g/m3)						
Akitio Estuary at Coast Rd Bridge	TP (g/m3)	45	0.005	0.865	0.103	0.036	0.193
Akitio Estuary at Coast Rd Bridge	Chlorophyll a (mg/m3)	52	0.6	25	3.707	2.2	4.085
Akitio Estuary at Coast Rd Bridge	Turbidity ISO-NTU (NTU)	53	1.69	1940	123.359	18.1	369.848
Hokio at Lake Horowhenua	E. coli (MPN/100ml)	26	0	2452	146.292	34	474.125
Hokio at Lake Horowhenua	Enterococci (MPN/100ml)						
Hokio at Lake Horowhenua	Black disc (m)	19	0.2	3.6	0.734	0.41	0.817
Hokio at Lake Horowhenua	Field Temperature (°C)	27	7.7	24.3	16.165	15.8	5.021
Hokio at Lake Horowhenua	Field DO (%sat)	26	20.7	157	86.019	87.85	28.716
Hokio at Lake Horowhenua	Field DO (mg/l)	26	4.19	14.66	8.858	8.65	2.392
Hokio at Lake Horowhenua	Field Conductivity (µS/cm)	27	211.9	313.7	255.73	256.8	24.375
Hokio at Lake Horowhenua	Field pH	28	6.87	10.1	8.213	7.525	1.106
Hokio at Lake Horowhenua	TSS (g/m3)	27	3	158	18.815	10	29.794
Hokio at Lake Horowhenua	Turbidity EPA (NTU)	28	3.68	76.6	12.589	7.45	15.404
Hokio at Lake Horowhenua	Ammoniacal-N (g/m3)	28	0	0.281	0.039	0.024	0.056
Hokio at Lake Horowhenua	TN (g/m3)	28	0.85	4.514	1.987	1.787	0.918
Hokio at Lake Horowhenua	TON (g/m3-N	28	0	2.7	0.831	0.46	0.931
Hokio at Lake Horowhenua	Nitrate (g/m3-N)	27	0	2.68	0.834	0.336	0.944
Hokio at Lake Horowhenua	Nitrite (g/m3-N)	27	0	0.022	0.007	0.006	0.005
Hokio at Lake Horowhenua	DRP (g/m3)	28	0.002	0.625	0.103	0.018	0.177
Hokio at Lake Horowhenua	TDP (g/m3)	27	0.007	0.629	0.102	0.031	0.162
Hokio at Lake Horowhenua	TP (g/m3)	28	0.033	0.935	0.217	0.11	0.249
Hokio at Lake Horowhenua	Chlorophyll a (mg/m3)						
Hokio at Lake Horowhenua	Turbidity ISO-NTU (NTU)	27	3.84	95.8	14.83	7.9	19.429
Hokio Estuary at Muaupoko St Bridge	E. coli (MPN/100ml)	98	0.9	5700	391.774	237	615.391
Hokio Estuary at Muaupoko St Bridge	Enterococci (MPN/100ml)						
Hokio Estuary at Muaupoko St Bridge	Black disc (m)						
Hokio Estuary at Muaupoko St Bridge	Field Temperature (°C)	94	13.06	24.1	19.406	19.5	2.44
Hokio Estuary at Muaupoko St Bridge	Field DO (%sat)	16	47.2	115.9	79.231	76.65	21.937
Hokio Estuary at Muaupoko St Bridge	Field DO (mg/l)	16	4.39	10.98	7.322	6.73	2.16
Hokio Estuary at Muaupoko St Bridge	Field Conductivity (µS/cm)	94	166	849	288.012	281.5	72.571
Hokio Estuary at Muaupoko St Bridge	Field pH	61	6.9	9.9	8.079	8	0.513
Hokio Estuary at Muaupoko St Bridge	TSS (g/m3)						
Hokio Estuary at Muaupoko St Bridge	Turbidity EPA (NTU)						
Hokio Estuary at Muaupoko St Bridge	Ammoniacal-N (g/m3)						
Hokio Estuary at Muaupoko St Bridge	TN (g/m3)						
Hokio Estuary at Muaupoko St Bridge	TON (g/m3-N						
Hokio Estuary at Muaupoko St Bridge	Nitrate (g/m3-N)						
Hokio Estuary at Muaupoko St Bridge	Nitrite (g/m3-N)						
Hokio Estuary at Muaupoko St Bridge	DRP (g/m3)						
Hokio Estuary at Muaupoko St Bridge	TDP (g/m3)						
Hokio Estuary at Muaupoko St Bridge	TP (g/m3)						
Hokio Estuary at Muaupoko St Bridge	Chlorophyll a (mg/m3)						
Hokio Estuary at Muaupoko St Bridge	Turbidity ISO-NTU (NTU)						

APPENDIX 2. WATER QUALITY DATA

Manawatu-Wanganui Region Rivers/Estuaries (data provided by Horizons Regional Council) continued

Site Name		Sample size	Minimum	Maximum	Mean	Median	Standard deviation (denom. = n-1)
Kai Iwi at Handley Road	E. coli (MPN/100ml)						
Kai Iwi at Handley Road	Enterococci (MPN/100ml)						
Kai Iwi at Handley Road	Black disc (m)						
Kai Iwi at Handley Road	Field Temperature (°C)	5	6.52	14.06	11.06	12.15	3.183
Kai Iwi at Handley Road	Field DO (%sat)	5	96.2	101.1	98.24	96.8	2.277
Kai Iwi at Handley Road	Field DO (mg/l)	5	10.09	12.15	10.926	10.89	0.819
Kai Iwi at Handley Road	Field Conductivity (µS/cm)	5	253.7	380.3	332.64	358.2	52.037
Kai Iwi at Handley Road	Field pH	5	7.91	8.09	8.004	8.01	0.064
Kai Iwi at Handley Road	TSS (g/m3)	5	6	529	135.6	30	222.68
Kai Iwi at Handley Road	Turbidity EPA (NTU)	5	5.17	506	125.454	23.2	214.652
Kai Iwi at Handley Road	Ammoniacal-N (g/m3)	5	0.009	0.009	0.009	0.009	0
Kai Iwi at Handley Road	TN (g/m3)	5	0.82	1.81	1.074	0.83	0.426
Kai Iwi at Handley Road	TON (g/m3-N	5	0.46	0.68	0.536	0.5	0.094
Kai Iwi at Handley Road	Nitrate (g/m3-N)	5	0.445	0.669	0.525	0.502	0.091
Kai Iwi at Handley Road	Nitrite (g/m3-N)	5	0.003	0.022	0.011	0.012	0.008
Kai Iwi at Handley Road	DRP (g/m3)	5	0.005	0.009	0.007	0.008	0.002
Kai Iwi at Handley Road	TDP (g/m3)	5	0.006	0.019	0.012	0.011	0.006
Kai Iwi at Handley Road	TP (g/m3)	5	0.041	0.46	0.145	0.069	0.178
Kai Iwi at Handley Road	Chlorophyll a (mg/m3)						
Kai Iwi at Handley Road	Turbidity ISO-NTU (NTU)	5	5.47	550	135.494	24.7	233.616
Kaikokopu Stream at Himatangi Beach	E. coli (MPN/100ml)	130	4	10670	609.254	154	1412.93
Kaikokopu Stream at Himatangi Beach	Enterococci (MPN/100ml)						
Kaikokopu Stream at Himatangi Beach	Black disc (m)						
Kaikokopu Stream at Himatangi Beach	Field Temperature (°C)	124	10.95	25.8	19.025	18.91	2.596
Kaikokopu Stream at Himatangi Beach	Field DO (%sat)	23	42.2	115	80.665	78	22.855
Kaikokopu Stream at Himatangi Beach	Field DO (mg/l)	23	4.14	10.33	7.289	7.26	1.973
Kaikokopu Stream at Himatangi Beach	Field Conductivity (µS/cm)	122	3.08	30567.699	1531.379	817.25	3608.877
Kaikokopu Stream at Himatangi Beach	Field pH	88	7.2	9.8	8.123	8	0.54
Kaikokopu Stream at Himatangi Beach	TSS (g/m3)						
Kaikokopu Stream at Himatangi Beach	Turbidity EPA (NTU)						
Kaikokopu Stream at Himatangi Beach	Ammoniacal-N (g/m3)						
Kaikokopu Stream at Himatangi Beach	TN (g/m3)						
Kaikokopu Stream at Himatangi Beach	TON (g/m3-N						
Kaikokopu Stream at Himatangi Beach	Nitrate (g/m3-N)						
Kaikokopu Stream at Himatangi Beach	Nitrite (g/m3-N)						
Kaikokopu Stream at Himatangi Beach	DRP (g/m3)						
Kaikokopu Stream at Himatangi Beach	TDP (g/m3)						
Kaikokopu Stream at Himatangi Beach	TP (g/m3)						
Kaikokopu Stream at Himatangi Beach	Chlorophyll a (mg/m3)						
Kaikokopu Stream at Himatangi Beach	Turbidity ISO-NTU (NTU)	26	1.36	15.5	4.783	4.645	2.819

APPENDIX 2. WATER QUALITY DATA

Manawatu-Wanganui Region Rivers/Estuaries (data provided by Horizons Regional Council) continued

Site Name		Sample size	Minimum	Maximum	Mean	Median	Standard deviation (denom. = n-1)
Manawatu at d/s PPCS Shannon	E. coli (MPN/100ml)	42	6	17000	1188.762	196	2833.877
Manawatu at d/s PPCS Shannon	Enterococci (MPN/100ml)						
Manawatu at d/s PPCS Shannon	Black disc (m)	9	0.03	1.4	0.48	0.5	0.438
Manawatu at d/s PPCS Shannon	Field Temperature (°C)	41	6.9	22.5	14.907	14.1	3.913
Manawatu at d/s PPCS Shannon	Field DO (%sat)	40	45.3	143.9	92.528	93.65	16.018
Manawatu at d/s PPCS Shannon	Field DO (mg/l)	40	4.61	14.61	9.432	9.475	1.739
Manawatu at d/s PPCS Shannon	Field Conductivity (µS/cm)	41	53.1	271.1	159.8	166.6	63.325
Manawatu at d/s PPCS Shannon	Field pH	40	6.91	8.39	7.566	7.495	0.353
Manawatu at d/s PPCS Shannon	TSS (g/m3)	42	4	1700	157.448	32	358.886
Manawatu at d/s PPCS Shannon	Turbidity EPA (NTU)	42	3.81	402	50.989	14.8	86.643
Manawatu at d/s PPCS Shannon	Ammoniacal-N (g/m3)	42	0	0.344	0.115	0.101	0.081
Manawatu at d/s PPCS Shannon	TN (g/m3)	42	0.42	3.1	1.103	0.899	0.574
Manawatu at d/s PPCS Shannon	TON (g/m3-N	42	0.019	1.302	0.559	0.508	0.323
Manawatu at d/s PPCS Shannon	Nitrate (g/m3-N)	42	0.017	1.3	0.544	0.5	0.325
Manawatu at d/s PPCS Shannon	Nitrite (g/m3-N)	42	0.002	0.067	0.016	0.014	0.013
Manawatu at d/s PPCS Shannon	DRP (g/m3)	42	0.005	0.091	0.023	0.022	0.015
Manawatu at d/s PPCS Shannon	TDP (g/m3)	17	0.007	0.058	0.026	0.028	0.012
Manawatu at d/s PPCS Shannon	TP (g/m3)	42	0.026	0.394	0.099	0.069	0.077
Manawatu at d/s PPCS Shannon	Chlorophyll a (mg/m3)						
Manawatu at d/s PPCS Shannon	Turbidity ISO-NTU (NTU)	1	507	507	507	507	0
Manawatu at Foxton	E. coli (MPN/100ml)	172	0	13000	897.552	135.5	2112.108
Manawatu at Foxton	Enterococci (MPN/100ml)						
Manawatu at Foxton	Black disc (m)						
Manawatu at Foxton	Field Temperature (°C)	193	8.5	24.09	17.63	18.3	3.251
Manawatu at Foxton	Field DO (%sat)	73	73.5	174.2	92.758	90.7	13.722
Manawatu at Foxton	Field DO (mg/l)	73	6.5	14.28	8.638	8.43	1.277
Manawatu at Foxton	Field Conductivity (µS/cm)	139	-1	55804.602	11400.193	2244	17510.495
Manawatu at Foxton	Field pH	139	7.2	9.7	8	8	0.469
Manawatu at Foxton	TSS (g/m3)	8	12	96	36.875	25	29.425
Manawatu at Foxton	Turbidity EPA (NTU)						
Manawatu at Foxton	Ammoniacal-N (g/m3)	52	0	0.36	0.052	0.032	0.065
Manawatu at Foxton	TN (g/m3)	52	0.16	6.2	0.929	0.821	0.839
Manawatu at Foxton	TON (g/m3-N	50	0	1.21	0.454	0.455	0.292
Manawatu at Foxton	Nitrate (g/m3-N)	52	-0.011	1.195	0.44	0.441	0.288
Manawatu at Foxton	Nitrite (g/m3-N)	52	0	0.043	0.012	0.011	0.008
Manawatu at Foxton	DRP (g/m3)	52	0.004	0.035	0.018	0.02	0.008
Manawatu at Foxton	TDP (g/m3)						
Manawatu at Foxton	TP (g/m3)	52	0.009	2.206	0.108	0.058	0.299
Manawatu at Foxton	Chlorophyll a (mg/m3)	7	1.71	16	5.311	3.6	5.004
Manawatu at Foxton	Turbidity ISO-NTU (NTU)	82	3.43	439	35.93	12.95	64.205
Manawatu at Whirokino	E. coli (MPN/100ml)	59	4	7700	751.61	167	1303.882
Manawatu at Whirokino	Enterococci (MPN/100ml)						
Manawatu at Whirokino	Black disc (m)	41	0.03	1.3	0.483	0.4	0.383
Manawatu at Whirokino	Field Temperature (°C)	59	8	25.3	14.971	14.8	4.264
Manawatu at Whirokino	Field DO (%sat)	59	39.6	141.2	90.129	89.5	14.289
Manawatu at Whirokino	Field DO (mg/l)	59	4.04	12.28	9.124	9.08	1.468
Manawatu at Whirokino	Field Conductivity (µS/cm)	57	81	21754	1217.733	170.5	4047.763
Manawatu at Whirokino	Field pH	57	7.13	8.57	7.704	7.64	0.343
Manawatu at Whirokino	TSS (g/m3)	60	5	1160	121.483	37	220.984
Manawatu at Whirokino	Turbidity EPA (NTU)	60	5.08	612	57.833	18.35	102.285
Manawatu at Whirokino	Ammoniacal-N (g/m3)	60	0	0.193	0.056	0.046	0.045
Manawatu at Whirokino	TN (g/m3)	60	0.364	5.2	1.042	0.912	0.665
Manawatu at Whirokino	TON (g/m3-N	60	0.002	1.154	0.526	0.462	0.292
Manawatu at Whirokino	Nitrate (g/m3-N)	60	0.002	1.14	0.501	0.44	0.297
Manawatu at Whirokino	Nitrite (g/m3-N)	60	0	0.469	0.025	0.013	0.064
Manawatu at Whirokino	DRP (g/m3)	60	0.005	0.05	0.018	0.018	0.009
Manawatu at Whirokino	TDP (g/m3)	60	0.009	0.079	0.027	0.026	0.012
Manawatu at Whirokino	TP (g/m3)	60	0.029	0.52	0.115	0.075	0.114
Manawatu at Whirokino	Chlorophyll a (mg/m3)						
Manawatu at Whirokino	Turbidity ISO-NTU (NTU)	60	5.87	740	71.173	21.95	135.965

APPENDIX 2. WATER QUALITY DATA

Manawatu-Wanganui Region Rivers/Estuaries (data provided by Horizons Regional Council) continued

Site Name		Sample size	Minimum	Maximum	Mean	Median	Standard deviation (denom. = n-1)
Mowhanau Stream at Footbridge	E. coli (MPN/100ml)	156	16	10670	1045.173	419	1617.528
Mowhanau Stream at Footbridge	Enterococci (MPN/100ml)						
Mowhanau Stream at Footbridge	Black disc (m)	32	0.1	4.4	1.368	1.325	0.898
Mowhanau Stream at Footbridge	Field Temperature (°C)	168	6.3	23.1	16.174	16.55	2.987
Mowhanau Stream at Footbridge	Field DO (%sat)	82	42.5	219.6	89.385	87.1	28.849
Mowhanau Stream at Footbridge	Field DO (mg/l)	82	3.78	17.94	8.851	8.845	2.626
Mowhanau Stream at Footbridge	Field Conductivity (µS/cm)	154	48.4	41154	2853.511	707.5	6674.544
Mowhanau Stream at Footbridge	Field pH	134	6.9	9.7	7.876	7.81	0.541
Mowhanau Stream at Footbridge	TSS (g/m3)	60	0.9	120	11.74	7	16.986
Mowhanau Stream at Footbridge	Turbidity EPA (NTU)	112	2.62	52.2	8.099	6.415	6.905
Mowhanau Stream at Footbridge	Ammoniacal-N (g/m3)	52	0	0.16	0.05	0.054	0.042
Mowhanau Stream at Footbridge	TN (g/m3)	52	0.17	2.1	0.834	0.72	0.361
Mowhanau Stream at Footbridge	TON (g/m3-N	52	0	0.893	0.292	0.196	0.278
Mowhanau Stream at Footbridge	Nitrate (g/m3-N)	52	0	0.881	0.283	0.187	0.274
Mowhanau Stream at Footbridge	Nitrite (g/m3-N)	52	0	0.056	0.009	0.009	0.009
Mowhanau Stream at Footbridge	DRP (g/m3)	52	0.009	0.049	0.029	0.029	0.01
Mowhanau Stream at Footbridge	TDP (g/m3)	52	0.015	0.055	0.036	0.037	0.011
Mowhanau Stream at Footbridge	TP (g/m3)	52	0.023	0.388	0.086	0.074	0.053
Mowhanau Stream at Footbridge	Chlorophyll a (mg/m3)						
Mowhanau Stream at Footbridge	Turbidity ISO-NTU (NTU)	86	2.47	61.6	9.014	6.37	9.563
Ohau at Estuary	E. coli (MPN/100ml)						
Ohau at Estuary	Enterococci (MPN/100ml)						
Ohau at Estuary	Black disc (m)						
Ohau at Estuary	Field Temperature (°C)	8	10.78	15.65	13.182	12.765	1.982
Ohau at Estuary	Field DO (%sat)	8	95.4	117.9	102.15	99.1	8.05
Ohau at Estuary	Field DO (mg/l)	8	8.7	11.56	10.088	10.08	0.904
Ohau at Estuary	Field Conductivity (µS/cm)	8	712.9	42370.102	15952.601	5542.4	17583.709
Ohau at Estuary	Field pH	8	7.28	8.1	7.739	7.815	0.31
Ohau at Estuary	TSS (g/m3)						
Ohau at Estuary	Turbidity EPA (NTU)						
Ohau at Estuary	Ammoniacal-N (g/m3)	8	0.009	0.05	0.021	0.01	0.017
Ohau at Estuary	TN (g/m3)	8	0.59	1.27	0.789	0.74	0.22
Ohau at Estuary	TON (g/m3-N	8	0.394	1.16	0.603	0.53	0.255
Ohau at Estuary	Nitrate (g/m3-N)	8	0.391	1.15	0.599	0.527	0.253
Ohau at Estuary	Nitrite (g/m3-N)	8	0.002	0.005	0.003	0.003	0.001
Ohau at Estuary	DRP (g/m3)	8	0.005	0.019	0.01	0.009	0.005
Ohau at Estuary	TDP (g/m3)	8	0.01	0.104	0.035	0.024	0.031
Ohau at Estuary	TP (g/m3)	8	0.018	0.173	0.069	0.061	0.053
Ohau at Estuary	Chlorophyll a (mg/m3)	8	1.71	13	4.019	1.71	4.026
Ohau at Estuary	Turbidity ISO-NTU (NTU)	8	2.05	48.7	11.353	6.78	15.543
Ohau at Haines Property	E. coli (MPN/100ml)	58	8	14000	424.483	84.5	1861.775
Ohau at Haines Property	Enterococci (MPN/100ml)						
Ohau at Haines Property	Black disc (m)	49	0.03	11	4.917	5.4	2.959
Ohau at Haines Property	Field Temperature (°C)	59	6.1	20.2	13.422	12.9	3.329
Ohau at Haines Property	Field DO (%sat)	59	43.9	135.2	98.407	98.1	10.585
Ohau at Haines Property	Field DO (mg/l)	59	5	14.82	10.322	10.29	1.375
Ohau at Haines Property	Field Conductivity (µS/cm)	56	39.5	104.1	82.064	82.35	10.838
Ohau at Haines Property	Field pH	56	6.99	8.26	7.502	7.455	0.274
Ohau at Haines Property	TSS (g/m3)	59	0	578	16.293	2.7	76.165
Ohau at Haines Property	Turbidity EPA (NTU)	59	0.45	275	8.092	1	36.469
Ohau at Haines Property	Ammoniacal-N (g/m3)	59	0	0.097	0.011	0.006	0.017
Ohau at Haines Property	TN (g/m3)	59	0.195	1.3	0.474	0.456	0.227
Ohau at Haines Property	TON (g/m3-N	59	0.01	1.092	0.351	0.303	0.218
Ohau at Haines Property	Nitrate (g/m3-N)	59	0.008	1.09	0.348	0.3	0.219
Ohau at Haines Property	Nitrite (g/m3-N)	59	0	0.008	0.003	0.002	0.002
Ohau at Haines Property	DRP (g/m3)	59	0.001	0.019	0.008	0.008	0.003
Ohau at Haines Property	TDP (g/m3)	59	0.004	0.048	0.011	0.01	0.007
Ohau at Haines Property	TP (g/m3)	59	0.005	0.452	0.025	0.012	0.059
Ohau at Haines Property	Chlorophyll a (mg/m3)						
Ohau at Haines Property	Turbidity ISO-NTU (NTU)	59	0.51	316	9.407	1.26	42.084

APPENDIX 2. WATER QUALITY DATA

Manawatu-Wanganui Region Rivers/Estuaries (data provided by Horizons Regional Council) continued

Site Name		Sample size	Minimum	Maximum	Mean	Median	Standard deviation (denom. = n-1)
Owahanga at Branscombe Bridge	E. coli (MPN/100ml)	63	16	17890	970.73	188	2478.61
Owahanga at Branscombe Bridge	Enterococci (MPN/100ml)						
Owahanga at Branscombe Bridge	Black disc (m)	55	0.02	2.45	0.521	0.3	0.541
Owahanga at Branscombe Bridge	Field Temperature (°C)	61	6.5	23.3	14.4	14.4	4.636
Owahanga at Branscombe Bridge	Field DO (%sat)	56	70.4	121.8	96.018	97.85	8.171
Owahanga at Branscombe Bridge	Field DO (mg/l)	57	6.11	14.58	9.981	9.79	1.652
Owahanga at Branscombe Bridge	Field Conductivity (µS/cm)	57	217.9	546.8	367.068	366.2	77.991
Owahanga at Branscombe Bridge	Field pH	55	6.57	9.49	8.238	8.24	0.344
Owahanga at Branscombe Bridge	TSS (g/m3)	72	1.8	5700	556.353	28.5	1297.376
Owahanga at Branscombe Bridge	Turbidity EPA (NTU)	72	0.94	3990	426.714	24.4	994.277
Owahanga at Branscombe Bridge	Ammoniacal-N (g/m3)	62	-0.003	0.079	0.019	0.011	0.02
Owahanga at Branscombe Bridge	TN (g/m3)	62	0.278	1.731	0.6	0.512	0.279
Owahanga at Branscombe Bridge	TON (g/m3-N	62	0	0.647	0.1	0.017	0.129
Owahanga at Branscombe Bridge	Nitrate (g/m3-N)	62	0	0.64	0.097	0.013	0.128
Owahanga at Branscombe Bridge	Nitrite (g/m3-N)	62	0	0.014	0.004	0.002	0.003
Owahanga at Branscombe Bridge	DRP (g/m3)	62	0	0.033	0.007	0.005	0.006
Owahanga at Branscombe Bridge	TDP (g/m3)	62	0.005	0.092	0.018	0.012	0.016
Owahanga at Branscombe Bridge	TP (g/m3)	62	0.009	0.9	0.109	0.04	0.194
Owahanga at Branscombe Bridge	Chlorophyll a (mg/m3)						
Owahanga at Branscombe Bridge	Turbidity ISO-NTU (NTU)	72	0.93	2960	350.821	31.9	733.388
Rangitikei at McKelvies	E. coli (MPN/100ml)	58	0	18600	871.114	96.5	2749.829
Rangitikei at McKelvies	Enterococci (MPN/100ml)						
Rangitikei at McKelvies	Black disc (m)	25	0.1	7	1.611	0.5	2.011
Rangitikei at McKelvies	Field Temperature (°C)	59	6.1	26.34	14.568	14.2	5.098
Rangitikei at McKelvies	Field DO (%sat)	59	66.5	130.3	98.876	97	9.174
Rangitikei at McKelvies	Field DO (mg/l)	59	6.08	13.42	10.133	10.31	1.297
Rangitikei at McKelvies	Field Conductivity (µS/cm)	58	115.6	258.4	168.484	152.2	37.314
Rangitikei at McKelvies	Field pH	59	6.99	8.83	7.983	7.95	0.324
Rangitikei at McKelvies	TSS (g/m3)	60	0.9	1306	92.573	19	222.604
Rangitikei at McKelvies	Turbidity EPA (NTU)	60	0.26	536	35.337	6.59	83.664
Rangitikei at McKelvies	Ammoniacal-N (g/m3)	60	0	0.079	0.011	0.007	0.016
Rangitikei at McKelvies	TN (g/m3)	60	0.051	1.9	0.378	0.226	0.409
Rangitikei at McKelvies	TON (g/m3-N	60	0	0.69	0.131	0.045	0.175
Rangitikei at McKelvies	Nitrate (g/m3-N)	60	0	0.683	0.128	0.044	0.173
Rangitikei at McKelvies	Nitrite (g/m3-N)	60	0	0.018	0.004	0.002	0.004
Rangitikei at McKelvies	DRP (g/m3)	60	0.005	0.087	0.014	0.011	0.012
Rangitikei at McKelvies	TDP (g/m3)	60	0.003	0.076	0.019	0.017	0.014
Rangitikei at McKelvies	TP (g/m3)	60	0.009	0.911	0.079	0.028	0.161
Rangitikei at McKelvies	Chlorophyll a (mg/m3)						
Rangitikei at McKelvies	Turbidity ISO-NTU (NTU)	60	0.28	652	43.977	7.645	103.552
Rangitikei Estuary at River mouth	E. coli (MPN/100ml)	41	0.9	15970	1360.822	287	2998.186
Rangitikei Estuary at River mouth	Enterococci (MPN/100ml)						
Rangitikei Estuary at River mouth	Black disc (m)						
Rangitikei Estuary at River mouth	Field Temperature (°C)	54	7.4	25.3	15.189	15.5	4.616
Rangitikei Estuary at River mouth	Field DO (%sat)	43	80.3	132.9	95.137	96.3	8.522
Rangitikei Estuary at River mouth	Field DO (mg/l)	43	6.9	14.78	9.469	9.27	1.593
Rangitikei Estuary at River mouth	Field Conductivity (µS/cm)	52	114.6	36518	4689.037	945.5	7646.144
Rangitikei Estuary at River mouth	Field pH	50	7.54	8.71	8.006	7.985	0.265
Rangitikei Estuary at River mouth	TSS (g/m3)	11	8	385	94.636	74	103.589
Rangitikei Estuary at River mouth	Turbidity EPA (NTU)						
Rangitikei Estuary at River mouth	Ammoniacal-N (g/m3)	46	0	0.5	0.042	0.01	0.101
Rangitikei Estuary at River mouth	TN (g/m3)	46	0.04	1.6	0.375	0.243	0.326
Rangitikei Estuary at River mouth	TON (g/m3-N	44	0	0.841	0.129	0.049	0.193
Rangitikei Estuary at River mouth	Nitrate (g/m3-N)	46	-0.001	0.828	0.122	0.045	0.187
Rangitikei Estuary at River mouth	Nitrite (g/m3-N)	46	0	0.013	0.003	0.002	0.003
Rangitikei Estuary at River mouth	DRP (g/m3)	46	0.004	0.065	0.017	0.014	0.011
Rangitikei Estuary at River mouth	TDP (g/m3)						
Rangitikei Estuary at River mouth	TP (g/m3)	46	0.013	0.35	0.057	0.04	0.058
Rangitikei Estuary at River mouth	Chlorophyll a (mg/m3)	52	0	14.8	2.256	1.9	2.147
Rangitikei Estuary at River mouth	Turbidity ISO-NTU (NTU)	54	0.66	281	27.651	10.25	47.118

APPENDIX 2. WATER QUALITY DATA

Manawatu-Wanganui Region Rivers/Estuaries (data provided by Horizons Regional Council) continued

Site Name		Sample size	Minimum	Maximum	Mean	Median	Standard deviation (denom. = n-1)
Turakina at ONeills Bridge	E. coli (MPN/100ml)	59	12	29090	1494.695	150	4699.994
Turakina at ONeills Bridge	Enterococci (MPN/100ml)						
Turakina at ONeills Bridge	Black disc (m)	47	0.015	4.7	1.005	0.55	1.222
Turakina at ONeills Bridge	Field Temperature (°C)	60	5.4	27.8	15.408	15.21	5.412
Turakina at ONeills Bridge	Field DO (%sat)	59	29	190.3	104.942	99.1	20.539
Turakina at ONeills Bridge	Field DO (mg/l)	59	2.77	15.79	10.474	10.35	1.788
Turakina at ONeills Bridge	Field Conductivity (µS/cm)	58	53.9	850.4	389.41	384.85	199.116
Turakina at ONeills Bridge	Field pH	60	7.18	8.96	8.098	8.155	0.342
Turakina at ONeills Bridge	TSS (g/m3)	62	0.9	8756	276.211	22	1162.87
Turakina at ONeills Bridge	Turbidity EPA (NTU)	62	0.55	6276	189.075	17.05	828.047
Turakina at ONeills Bridge	Ammoniacal-N (g/m3)	60	0	0.272	0.032	0.018	0.043
Turakina at ONeills Bridge	TN (g/m3)	60	0.226	11	0.999	0.78	1.386
Turakina at ONeills Bridge	TON (g/m3-N	60	0	1.224	0.239	0.17	0.269
Turakina at ONeills Bridge	Nitrate (g/m3-N)	60	0	1.204	0.23	0.154	0.264
Turakina at ONeills Bridge	Nitrite (g/m3-N)	60	0	0.033	0.009	0.007	0.009
Turakina at ONeills Bridge	DRP (g/m3)	60	0.005	0.075	0.029	0.026	0.016
Turakina at ONeills Bridge	TDP (g/m3)	60	0.005	0.1	0.038	0.036	0.02
Turakina at ONeills Bridge	TP (g/m3)	60	0.034	0.826	0.126	0.086	0.124
Turakina at ONeills Bridge	Chlorophyll a (mg/m3)						
Turakina at ONeills Bridge	Turbidity ISO-NTU (NTU)	62	0.52	5800	187.97	20.45	768.595
Waikawa at Huritini	E. coli (MPN/100ml)	59	74	18000	1024.627	331	2561.005
Waikawa at Huritini	Enterococci (MPN/100ml)						
Waikawa at Huritini	Black disc (m)	44	0.04	6.6	2.419	2	1.883
Waikawa at Huritini	Field Temperature (°C)	60	6.9	21.2	13.986	13.7	3.224
Waikawa at Huritini	Field DO (%sat)	60	38.5	128.1	94.058	93.9	12.186
Waikawa at Huritini	Field DO (mg/l)	60	4.37	13.76	9.71	9.81	1.485
Waikawa at Huritini	Field Conductivity (µS/cm)	59	58.8	235.6	140.349	139.2	31.019
Waikawa at Huritini	Field pH	58	6.91	8.98	7.371	7.315	0.332
Waikawa at Huritini	TSS (g/m3)	60	1	153	14.748	6.25	26.278
Waikawa at Huritini	Turbidity EPA (NTU)	60	1.37	73.6	8.544	4.625	13.158
Waikawa at Huritini	Ammoniacal-N (g/m3)	60	0	0.132	0.032	0.024	0.032
Waikawa at Huritini	TN (g/m3)	60	0.42	2.13	1.177	1.149	0.452
Waikawa at Huritini	TON (g/m3-N	60	0.113	1.984	0.888	0.913	0.448
Waikawa at Huritini	Nitrate (g/m3-N)	60	0.111	1.98	0.881	0.907	0.446
Waikawa at Huritini	Nitrite (g/m3-N)	60	0.002	0.042	0.008	0.006	0.007
Waikawa at Huritini	DRP (g/m3)	60	0.006	0.08	0.016	0.014	0.01
Waikawa at Huritini	TDP (g/m3)	60	0.01	0.084	0.022	0.02	0.012
Waikawa at Huritini	TP (g/m3)	60	0.016	0.235	0.05	0.04	0.041
Waikawa at Huritini	Chlorophyll a (mg/m3)						
Waikawa at Huritini	Turbidity ISO-NTU (NTU)	60	1.48	87.2	10.117	4.94	15.922
Waikawa Estuary at Footbridge	E. coli (MPN/100ml)	160	8	26000	982.169	295	2480.145
Waikawa Estuary at Footbridge	Enterococci (MPN/100ml)						
Waikawa Estuary at Footbridge	Black disc (m)						
Waikawa Estuary at Footbridge	Field Temperature (°C)	152	6.8	26.07	17.74	18.2	3.767
Waikawa Estuary at Footbridge	Field DO (%sat)	61	67.2	195.6	96.93	88.4	24.048
Waikawa Estuary at Footbridge	Field DO (mg/l)	61	6.36	17.16	9.037	8.63	1.819
Waikawa Estuary at Footbridge	Field Conductivity (µS/cm)	138	6.46	52230	6278.303	1188.5	10636.677
Waikawa Estuary at Footbridge	Field pH	119	6.79	9.07	7.682	7.56	0.497
Waikawa Estuary at Footbridge	TSS (g/m3)	11	6	75	24.091	19	21.04
Waikawa Estuary at Footbridge	Turbidity EPA (NTU)						
Waikawa Estuary at Footbridge	Ammoniacal-N (g/m3)	40	0	0.6	0.077	0.049	0.115
Waikawa Estuary at Footbridge	TN (g/m3)	40	0.166	2	0.963	0.96	0.404
Waikawa Estuary at Footbridge	TON (g/m3-N	38	0	1.76	0.648	0.64	0.422
Waikawa Estuary at Footbridge	Nitrate (g/m3-N)	40	0	1.748	0.627	0.627	0.416
Waikawa Estuary at Footbridge	Nitrite (g/m3-N)	40	0	0.02	0.006	0.005	0.005
Waikawa Estuary at Footbridge	DRP (g/m3)	40	0.002	0.046	0.022	0.021	0.01
Waikawa Estuary at Footbridge	TDP (g/m3)						
Waikawa Estuary at Footbridge	TP (g/m3)	40	0.02	0.206	0.063	0.056	0.039
Waikawa Estuary at Footbridge	Chlorophyll a (mg/m3)	46	0.9	176.4	8.809	2	26.715
Waikawa Estuary at Footbridge	Turbidity ISO-NTU (NTU)	48	2.35	55.2	9.967	6.42	9.856

APPENDIX 2. WATER QUALITY DATA

Manawatu-Wanganui Region Rivers/Estuaries (data provided by Horizons Regional Council) continued

Site Name		Sample size	Minimum	Maximum	Mean	Median	Standard deviation (denom. = n-1)
Wairarawa Stream at Waitarere Beach	E. coli (MPN/100ml)	116	4	>9678	469.897	120	1150.907
Wairarawa Stream at Waitarere Beach	Enterococci (MPN/100ml)						
Wairarawa Stream at Waitarere Beach	Black disc (m)						
Wairarawa Stream at Waitarere Beach	Field Temperature (°C)	106	11.14	32.4	21.065	20.55	3.981
Wairarawa Stream at Waitarere Beach	Field DO (%sat)	15	4.9	112.3	59.76	65.9	35.374
Wairarawa Stream at Waitarere Beach	Field DO (mg/l)	15	0.46	9.06	5.187	5.76	2.933
Wairarawa Stream at Waitarere Beach	Field Conductivity (µS/cm)	104	100	4360	818.122	735	488.421
Wairarawa Stream at Waitarere Beach	Field pH	76	6.6	10.1	7.796	7.7	0.633
Wairarawa Stream at Waitarere Beach	TSS (g/m3)						
Wairarawa Stream at Waitarere Beach	Turbidity EPA (NTU)						
Wairarawa Stream at Waitarere Beach	Ammoniacal-N (g/m3)						
Wairarawa Stream at Waitarere Beach	TN (g/m3)						
Wairarawa Stream at Waitarere Beach	TON (g/m3-N						
Wairarawa Stream at Waitarere Beach	Nitrate (g/m3-N)						
Wairarawa Stream at Waitarere Beach	Nitrite (g/m3-N)						
Wairarawa Stream at Waitarere Beach	DRP (g/m3)						
Wairarawa Stream at Waitarere Beach	TDP (g/m3)						
Wairarawa Stream at Waitarere Beach	TP (g/m3)						
Wairarawa Stream at Waitarere Beach	Chlorophyll a (mg/m3)						
Wairarawa Stream at Waitarere Beach	Turbidity ISO-NTU (NTU)	26	1.17	11	5.964	6.47	2.636
Waiwiri at d/s Flaxmill Drain Confl	E. coli (MPN/100ml)	4	83	42000	10570.5	99.5	20953.003
Waiwiri at d/s Flaxmill Drain Confl	Enterococci (MPN/100ml)						
Waiwiri at d/s Flaxmill Drain Confl	Black disc (m)	4	0.25	0.4	0.32	0.315	0.062
Waiwiri at d/s Flaxmill Drain Confl	Field Temperature (°C)	4	15.3	18	17.225	17.8	1.297
Waiwiri at d/s Flaxmill Drain Confl	Field DO (%sat)	4	5.3	85.4	54.225	63.1	34.297
Waiwiri at d/s Flaxmill Drain Confl	Field DO (mg/l)	4	0.51	8.12	5.165	6.015	3.259
Waiwiri at d/s Flaxmill Drain Confl	Field Conductivity (µS/cm)	4	206.5	370.4	308	327.55	71.838
Waiwiri at d/s Flaxmill Drain Confl	Field pH	4	7	8.2	7.612	7.625	0.496
Waiwiri at d/s Flaxmill Drain Confl	TSS (g/m3)	4	18	690	211.75	69.5	321.462
Waiwiri at d/s Flaxmill Drain Confl	Turbidity EPA (NTU)	4	6.9	50.6	22.6	16.45	19.787
Waiwiri at d/s Flaxmill Drain Confl	Ammoniacal-N (g/m3)	4	0.031	0.21	0.138	0.155	0.078
Waiwiri at d/s Flaxmill Drain Confl	TN (g/m3)	4	1.5	3.5	2.525	2.55	0.866
Waiwiri at d/s Flaxmill Drain Confl	TON (g/m3-N	4	0.021	0.434	0.147	0.066	0.193
Waiwiri at d/s Flaxmill Drain Confl	Nitrate (g/m3-N)	4	0.003	0.401	0.129	0.056	0.183
Waiwiri at d/s Flaxmill Drain Confl	Nitrite (g/m3-N)	4	0.009	0.033	0.018	0.015	0.011
Waiwiri at d/s Flaxmill Drain Confl	DRP (g/m3)	4	0.013	0.134	0.068	0.063	0.063
Waiwiri at d/s Flaxmill Drain Confl	TDP (g/m3)	4	0.035	0.23	0.124	0.116	0.097
Waiwiri at d/s Flaxmill Drain Confl	TP (g/m3)	4	0.25	0.434	0.329	0.315	0.079
Waiwiri at d/s Flaxmill Drain Confl	Chlorophyll a (mg/m3)						
Waiwiri at d/s Flaxmill Drain Confl	Turbidity ISO-NTU (NTU)	4	6.75	78.8	28.863	14.95	33.533
Waiwiri at Lake Papaitonga	E. coli (MPN/100ml)	13	6	7900	2094.692	1210	2378.375
Waiwiri at Lake Papaitonga	Enterococci (MPN/100ml)						
Waiwiri at Lake Papaitonga	Black disc (m)	3	0.12	0.3	0.223	0.25	0.093
Waiwiri at Lake Papaitonga	Field Temperature (°C)	13	3.4	18.4	11.215	11.2	4.132
Waiwiri at Lake Papaitonga	Field DO (%sat)	13	1.7	77.1	26.208	20.4	23.192
Waiwiri at Lake Papaitonga	Field DO (mg/l)	13	0.18	9.82	3.021	2.39	2.886
Waiwiri at Lake Papaitonga	Field Conductivity (µS/cm)	13	236.4	483.2	345.277	351.7	68.851
Waiwiri at Lake Papaitonga	Field pH	13	6.51	7.2	6.852	6.85	0.215
Waiwiri at Lake Papaitonga	TSS (g/m3)	13	5	3289	589.385	40	1042.291
Waiwiri at Lake Papaitonga	Turbidity EPA (NTU)	13	2.75	1177	209.222	8.18	367.717
Waiwiri at Lake Papaitonga	Ammoniacal-N (g/m3)	13	0.056	0.79	0.227	0.113	0.225
Waiwiri at Lake Papaitonga	TN (g/m3)	13	1	30	9.038	3	10.433
Waiwiri at Lake Papaitonga	TON (g/m3-N	13	0.005	1.263	0.252	0.136	0.368
Waiwiri at Lake Papaitonga	Nitrate (g/m3-N)	13	0.003	1.26	0.243	0.114	0.366
Waiwiri at Lake Papaitonga	Nitrite (g/m3-N)	13	0.002	0.029	0.01	0.006	0.009
Waiwiri at Lake Papaitonga	DRP (g/m3)	13	0.256	5.587	1.823	1.331	1.552
Waiwiri at Lake Papaitonga	TDP (g/m3)	13	0.549	5.62	1.886	1.215	1.611
Waiwiri at Lake Papaitonga	TP (g/m3)	13	0.701	10.16	4.449	2.64	3.454
Waiwiri at Lake Papaitonga	Chlorophyll a (mg/m3)						
Waiwiri at Lake Papaitonga	Turbidity ISO-NTU (NTU)	12	3.36	1500	319.346	48.95	560.264

APPENDIX 3. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

Vegetation was classified using an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not always based on percentage cover, but the subjective observation of which vegetation is the dominant or subdominant species within the patch. A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10cm dbh are treated as trees. Commonly sub-grouped into native, exotic or mixed forest.

Treeland: Cover of trees in the canopy is 20-80%. Trees are woody plants >10cm dbh. Commonly sub-grouped into native, exotic or mixed treeland.

Scrub: Cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed scrub.

Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed shrubland.

Tussockland: Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia,* and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia*.

Duneland: Vegetated sand dunes in which the cover of vegetation in the canopy (commonly Spinifex, Pingao or Marram grass) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.

Grassland: Vegetation in which the cover of grass (excluding tussock-grasses) in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground.

Sedgeland: Vegetation in which the cover of sedges (excluding tussock-sedges and reed-forming sedges) in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. "Sedges have edges." Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of *Carex, Uncinia,* and *Scirpus*.

Rushland: Vegetation in which the cover of rushes (excluding tussock-rushes) in the canopy is 20-100% and where rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in rushland are some species of *Juncus* and all species of *Leptocarpus*.

Reedland: Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata,* and *Baumea articulata*.

Cushionfield: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Vegetation in which the cover of herbs in the canopy is 20-100% and where herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Lichenfield: Vegetation in which the cover of lichens in the canopy is 20-100% and where lichen cover exceeds that of any other growth form or bare ground.

Introduced weeds: Vegetation in which the cover of introduced weeds in the canopy is 20-100% and in which the weed cover exceeds that of any other growth form or bare ground.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries and is mapped separately to the substrates they overlie.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope. Macroalgal density, biomass and entrainment are classified and mapped separately to the substrates they overlie.

Cliff: A steep face of land which exceeds the area covered by any one class of plant growth-form. Cliffs are named from the dominant substrate type when unvegetated or the leading plant species when plant cover is ≥1%.

Rock field: Land in which the area of residual rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulder fields are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Cobble fields are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. Gravel fields are named from the leading plant species when plant cover is ≥1%.

Mobile sand: Granular beach sand characterised by a rippled surface layer from strong tidal or wind-generated currents. Often forms bars and beaches.

Firm or soft sand: Sand flats may be mud-like in appearance but are granular when rubbed between the fingers and no conspicuous fines are evident when sediment is disturbed e.g. a mud content <1%. Classified as firm sand if an adult sinks <2 cm or soft sand if an adult sinks >2 cm.

Firm muddy sand: A sand/mud mixture dominated by sand with a moderate mud fraction (e.g. 1-10%), the mud fraction conspicuous only when sediment is mixed in water. The sediment appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm sandy mud, firm or soft mud, and very soft mud. When walking an adult sinks 0-2 cm. Granular when rubbed between the fingers.

Firm sandy mud: A sand/mud mixture dominated by sand with an elevated mud fraction (e.g. 10-25%), the mud fraction visually conspicuous when walking on it. The surface appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm muddy sand, firm or soft mud, and very soft mud. When walking an adult sinks 0-2 cm. Granular when rubbed between the fingers, but with a smoother consistency than firm muddy sand.

Firm or soft mud: A mixture of mud and sand where mud is a major component (e.g. >25% mud). Sediment rubbed between the fingers retains a granular component but is primarily smooth/silken. The surface appears grey or brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm muddy sand, firm sandy mud, and very soft mud. Classified as firm mud if an adult sinks <5 cm (usually if sediments are dried out or another component e.g. gravel prevents sinking) or soft mud if an adult sinks >5 cm.

Very soft mud: A mixture of mud and sand where mud is the major component (e.g. >50% mud), the surface appears brown, and may have a black anaerobic layer below. When walking an adult sinks >5 cm unless another component e.g. gravel prevents sinking. From a distance appears visually similar to firm muddy sand, firm sandy mud, and firm or soft mud. Sediment rubbed between the fingers may retain a slight granular component but is primarily smooth/silken.

Cockle bed /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

Artificial structures: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.

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