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Whanganui River Estuary

Broad Scale Habitat Mapping 2008/09

Prepared for

Department of Conservation

June 2009

Cover Photo: Lower Whanganui River looking upstream from the coastal dune.

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By

Leigh Stevens and Barry Robertson

Wriggle Limited, PO Box 1622, Nelson 7001, Ph 021 417 936, 0275 417 935, www.wriggle.co.nz

Contents

List of Figures

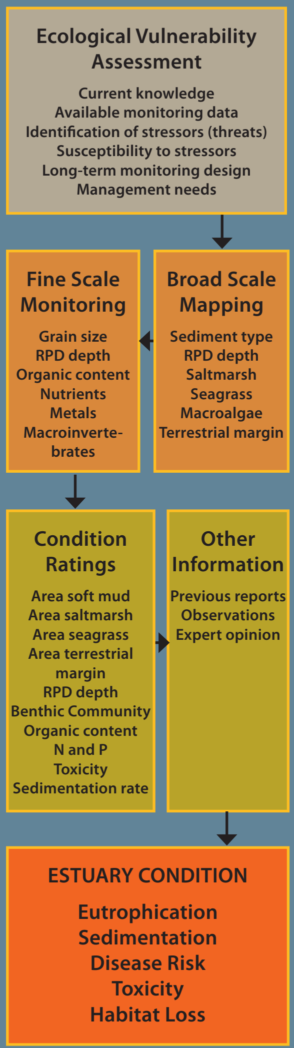
List of Tables

All photos by Wriggle except where noted otherwise.

EXECUTIVE SUMMARY

OVERVIEW

Typical approach to evaluating the condition and risks to estuarine habitats



Developing an understanding of the condition and risks to estuarine habitats is critical to their effective management. As part of its estuary programme, the Department of Conservation (DOC) contracted Wriggle Coastal Management to undertake broad scale mapping of the lower reaches of the Whanganui River Estuary and the adjoining terrestrial margin, including the barrier spit.

This report describes the mapping undertaken in January 2009. Broad scale habitat mapping is a tool used to assess the condition of estuaries. It includes mapping and condition ratings for key habitat elements including: estuary sediment types, macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria, Enteromorpha*), macrophytes (e.g. *Zostera* - seagrass), saltmarsh vegetation, and the 200m terrestrial margin surrounding the estuary. The methods used were based on the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), and a number of extensions.

The outcome is a series of GIS-based habitat maps (often complex), that provide measures of the extent of different types of habitat cover. Taken in combination with fine scale physical, chemical and biological monitoring results, these measures are applied into different rating scales which are used alongside other relevant information to assess the condition of the estuary in relation to the key issues of sedimentation, eutrophication and habitat loss. Toxicity is addressed as part of fine scale monitoring, while disease risk is monitored and reported separately, principally through recreational water quality monitoring programmes. A summary of the approach is outlined in the figure in the sidebar. An ecological vulnerability assessment has yet to be undertaken for the Whanganui River Estuary and fine scale monitoring was not carried out as part of the current study.

A broad scale summary map is presented on the next page (much reduced but included as an example of the more user-friendly GIS-based maps that accompany this report).

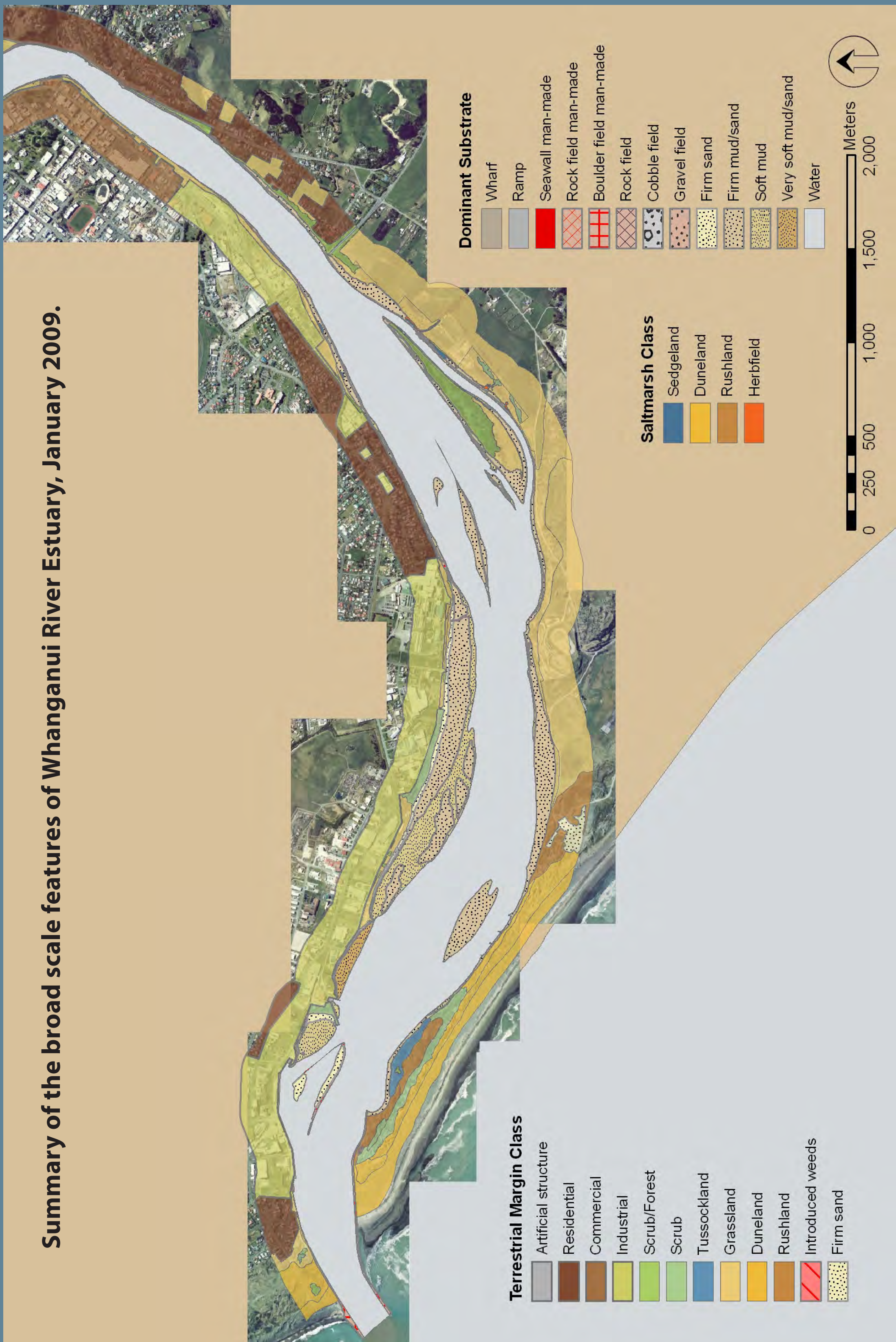
Whanganui Estuary is a relatively large "tidal river mouth" type estuary within the well flushed lower reaches of the Whanganui River. The broad scale mapping showed that at low tide the estuary is 76% water, 24% unvegetated intertidal flats, and only 0.3% saltmarsh. Such characteristics are typical of tidal river mouth estuaries, although the saltmarsh cover is low. The intertidal areas comprised predominantly firm mud/sand (65%) and soft mud (28%) sediments. These large sand and mudflats provide very important habitat for a range of animals, and are particularly important as feeding areas for birds. Sediments were generally well oxygenated and in good condition, with the Redox Potential Discontinuity (RPD) depth 2cm to >5cm across most of the estuary. Seagrass and macroalgae were not recorded from intertidal areas.

Saltmarsh (predominantly searush and herbfield) was constricted by the extensive development of the margin through flood protection work, and drainage and reclamation adjacent to industrial, residential and grazing areas. The most intact natural vegetated feature remaining was the large coastal dune which was generally in good condition, although a range of introduced weeds pose an obvious threat if they are not controlled.

The intertidal broad scale mapping data were used to determine condition ratings for key broad scale indicators. The results were as follows:

BROAD SCALE CONDITION RATINGS

BROAD SCALE RATING 2009	% COVER SOFT MUD	% COVER SALTMARSH	RPD DEPTH	MACROALGAE	SEAGRASS	TERRESTRIAL BUFFER
WHANGANUI ESTUARY	POOR	VERY LOW	FAIR/GOOD	VERY GOOD	POOR	POOR



Summary of the broad scale features of Whanganui River Estuary, January 2009.

EXECUTIVE SUMMARY (CONTINUED)

CONCLUSIONS

In conclusion, the broad scale habitat mapping showed the Whanganui Estuary to be a typical large tidal river mouth estuary draining a partially developed (farmed) catchment. The estuary's major habitats were subtidal water, and unvegetated intertidal flats. Saltmarsh was also present but at a low incidence. Because of its location within urban Wanganui, the terrestrial margin and river mouth were highly modified. However, its intertidal flats still provide important foraging areas for birds, subtidal reaches are important for many fish, and the remaining saltmarsh and particularly the dunes provide important plant and animal habitat.

The condition of the mapped habitats indicated problems associated with sedimentation (extensive muddy sediments and turbid water) and historical habitat loss (little saltmarsh, no seagrass, and a highly modified vegetated terrestrial margin). However, there were few nutrient enrichment issues (sparse nuisance macroalgal growth and good sediment oxygenation).

The estimated high suspended sediment from the catchment (WRENZ: 700 t/km^2/yr) is the likely cause of the sedimentation problem, and the absence of nutrient enrichment can be attributed to the estimated low nitrogen loading from the catchment (WRENZ: 4.6 kg/ha/yr), and good estuary flushing. Historical habitat loss has mainly resulted from drainage, reclamation, flood protection and river works.

Although a vulnerability assessment has not been undertaken, there are obvious risks to the estuary e.g. flooding, flood protection works, sedimentation, introduced weeds, and sea level rise and climate change. The presence of such stressors place the estuary under a relatively high risk of change, and consequently it requires ongoing monitoring and management.

MANAGEMENT RECOMMENDATIONS

The condition ratings trigger repeat broad scale mapping in 5 years time. In addition the following management actions are recommended to address key issues in the Whanganui Estuary:

Undertake an Ecological Vulnerability Assessment

- Obvious stressors (risks) to the estuary are present (e.g. flooding and flood protection works, sea level rise, weed invasion, margin development, stormwater, sewage and industrial discharges), and these stressors are likely to result in changes to existing high value habitats (dunes, saltmarsh, intertidal flats). A vulnerability assessment with focused synoptic monitoring is recommended to assess the range of stressors present, the susceptibility of the estuary to each and, based on this, define prioritised long-term broad and fine scale monitoring requirements and management needs for the estuary.

Identify and Implement Catchment BMPs

- Catchment runoff is one of the major stressors in estuaries with the likely ecological response one of lowered biodiversity and lowered aesthetic and human use values. To prevent avoidable inputs, best management practices (BMPs) should be identified and implemented to reduce sediment and pathogen runoff from catchment "hotspots", and to maintain current low nutrient inputs.

Restore Saltmarsh Habitat

- The almost complete loss of saltmarsh from the estuary has certainly contributed to reduced biodiversity and increased sedimentation reaching subtidal areas of the estuary, while also lowering aesthetic and human use values. It has also allowed rubbish and weeds to enter the estuary. Because of the importance of saltmarsh, and the risk of further loss from flood control measures and sea level rise, it is recommended that a plan be developed to encourage its re-establishment, particularly in areas where a suitable gradient remains, or as suitable land becomes available for restoration.

Reinstate Margin Buffer

- Human development of the estuary margin has resulted in clearance of surrounding bush, and construction of artificial structures around much of the estuary. This has almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary. Many areas are also adversely affected by nuisance weeds and rubbish. Because of the importance of a natural vegetated margin around the estuary, it is recommended that a strategy be developed to encourage its re-establishment where possible, and to support the existing planting initiatives.

Manage Dune Habitat

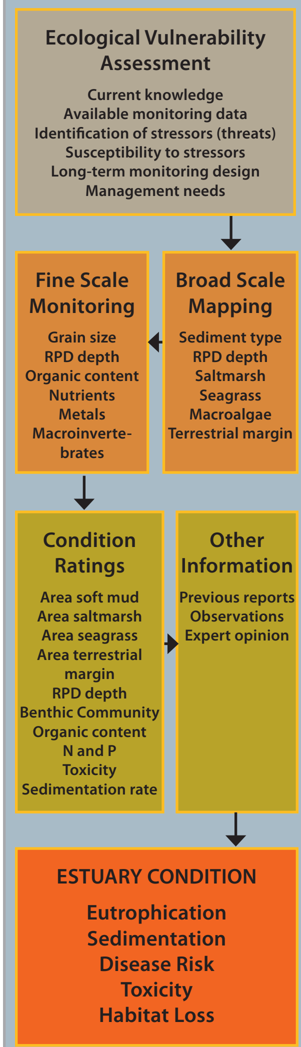
- The coastal dune systems are very sensitive and important areas. Introduced weeds, and pest plants and animals, are likely to reduce biodiversity and habitat values, while sea level rise and climate change will increase vulnerability to erosion and flooding. While a vulnerability assessment is needed to better describe the risks present, a initial step is to develop and implement a management plan to remove or prevent the spread of key weed species, and to look at the need for restricting vehicle access and managing foot traffic where necessary. This process has begun for the Castlecliff area (e.g. Wanganui District Council 2005).

Assess Risks to Water Quality

- The broad scale mapping does not address water quality issues related to pathogens or toxins. Because of the high contact recreation use of the water is recommended that ongoing initiatives to improve water quality are supported, and the specific risk posed by existing inputs from point and non-point sources be assessed and addressed as appropriate.

1. INTRODUCTION

Figure 1. Typical approach to evaluating the condition and risks to estuarine habitats.



Developing an understanding of the condition and risks to estuarine habitats is critical to their effective management, and typically follows the approach summarised in Figure 1. In recognition of the large size of the Whanganui River Estuary, its national significance (for bird habitat), regional significance for botanical values (Fechney et al. 1990), important fish breeding areas (Strickland et al. 1982), and the limited information on the types of habitats present and their existing condition, the Department of Conservation (DOC) contracted Wriggle Coastal Management to undertake the broad scale habitat mapping of the lower estuary using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions (see Tables 1 and 3). EMP results can be compared with estuaries throughout NZ monitored using the same method.

This work, undertaken in January 2009, documents the habitat features of the estuary including sediment types, redox potential discontinuity (RPD) depth, saltmarsh vegetation, seagrass, macroalgae, and the estuary's 200m terrestrial margin. Condition ratings (based on Robertson & Stevens, 2006, 2007, 2008) are used to assess estuary health in relation to key issues of sedimentation, eutrophication and habitat loss (see Table 2 for a summary of issues). Monitoring and management recommendations are provided.

INTRODUCTION TO TIDAL RIVER MOUTH ESTUARY CHARACTERISTICS

Tidal river mouth estuaries typically comprise simple elongate basins with a large subtidal component, often deep channels, and relatively small intertidal flats. They have high rates of flushing, with freshwater river flows dominating over tidal flows, although the tidal influence can extend for many kilometres upstream. Sediments are typically muddy (except in high flow areas), and sediment re-suspension from wind and wave fetch is relatively low. Floods can quickly deposit and remove significant quantities of sediment from the estuary, and can also expel much of the seawater from the system. Saltmarsh vegetation is generally limited in extent (the freshwater dominance allows terrestrial plants to establish close to the estuary margin), while seagrass is restricted to small areas close to the mouth. A vegetated dune system is sometimes present at the mouth of the river.

In a good state, these well flushed estuaries have reasonable water clarity, low nutrient and sediment inputs, high sediment quality and biodiversity, and an intact saltmarsh and terrestrial margin that buffers against weed and pest invasions. Disease risk and toxicity are low, and there are no extensive growths of nuisance macroalgae, microalgae or phytoplankton.

Following catchment development, sediment and nutrient inputs increase, and modification of the estuary margin (e.g. drainage, reclamation, flood and erosion protection work) commonly occurs.

If inputs of sediment and nutrients are high, there will be a shift to increased eutrophication. Eutrophication indicators are the presence of extensive nuisance macroalgal growths, thick benthic microalgal mats, phytoplankton rich water (a slightly green appearance), and sediments that are poorly oxygenated, sulphide rich, have nuisance odours, and have low sediment biodiversity.

High sediment inputs will also generally result in extensive areas of soft mud accumulating along estuary margins and on sheltered tidal flats, decreasing water clarity, and seagrass is likely to be lost.

Farm runoff, human wastewater, and inputs from urban and agricultural stormwater runoff, industrial discharges and air pollution will increase disease risk and toxicity.

Modification of the upper intertidal margins and terrestrial buffer vegetation will result in habitat loss, particularly saltmarsh and whitebait spawning areas, will facilitate the encroachment of weeds into saltmarsh and dune areas, reduce natural assimilation and filtering of sediment and nutrients, and reduce its role in flood attenuation.

1. INTRODUCTION (CONTINUED)

Table 1. Coastal Monitoring Tools (Wriggle Coastal Management).

Resource	Tools for Monitoring and Management
Estuaries	Estuary vulnerability matrix. Broad scale estuary and 200m terrestrial margin habitat mapping. Fine scale estuary monitoring. Sedimentation rate measures (using plates buried in sediment). Historical sedimentation rates (using radio-isotope ageing of sediment cores). Macroalgae and seagrass mapping (reported as separate GIS layers). Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer). Upper estuary monitoring and assessment.
Beaches, Dunes	Beach and dune vulnerability matrix. Broad scale beach, dune and terrestrial margin mapping. Fine scale beach monitoring. Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer).
Rocky Shores	Rocky shore vulnerability matrix. Broad scale rocky shore and terrestrial margin mapping. Fine scale rocky shore monitoring. Georeferenced digital photos (as a GIS layer).

Table 2. Summary of the major issues affecting most NZ river mouth estuaries.

Key Estuary Issues	
Sedimentation	Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. 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. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived.
Nutrients	Increased nutrient richness of estuarine ecosystems stimulates the production and abundance of fast-growing algae, such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Fortunately, because most New Zealand estuaries are well flushed, phytoplankton blooms are generally not a major problem. Of greater concern is the mass blooms of green and red macroalgae, mainly of the genera *Enteromorpha, 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. 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.
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. 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. 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. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), toxic heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), 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 habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as 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.

Table 3. Summary of the broad and fine scale EMP indicators.

Issue	Indicator	Method
Sedimentation	Soft Mud Area	Broad scale mapping - estimates the area and change in soft mud habitat over time.
Sedimentation	Sedimentation Rate	Fine scale measurement of sediment deposition.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon (calculated from ash free dry weight) in replicate samples from the upper 2cm of sediment.
Eutrophication	Redox Profile	Measurement of depth of redox potential discontinuity profile (RPD) in sediment estimates likely presence of deoxygenated, reducing conditions.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (total recoverable cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Toxins, Eutrophication, Sedimentation	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).
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Habitat Loss	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
Habitat Loss	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.

The waka crew - Hemi Gray, Barry Robertson (Wriggle), Hannah Rainforth (DOC), Manahi Cribb and Toiora Hawira. A great way to see and appreciate the estuary.

2. METHODS

BROAD SCALE HABITAT MAPPING

Unvegetated
1-5%
5-10 %
10-20 %
20-50 %
50-80 %
80-100 %

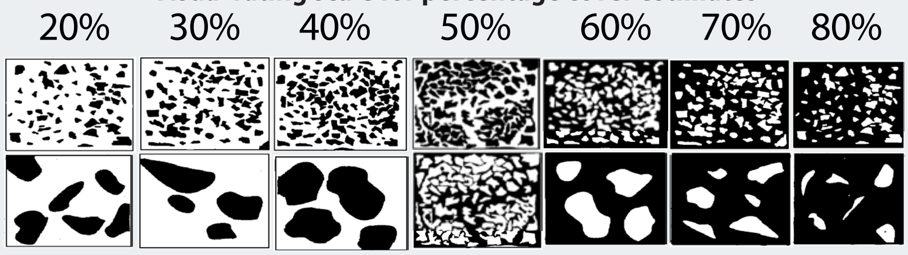
Broad-scale mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: macrophyte, macroalgae, rushland, etc). It follows the EMP approach originally described for use in NZ estuaries by Robertson et al. (2002) with a combination of aerial photography, detailed ground-truthing, and GIS-based digital mapping used to record the primary habitat features present. Very simply, the method involves three key steps:

- Obtaining laminated aerial photos for recording dominant habitat features.
- Carrying out field identification and mapping (i.e. ground-truthing).
- Digitising the field data into GIS layers (ArcMap 9.2).

For the 2009 study, Wanganui City Council supplied rectified ~0.45m/pixel resolution colour aerial photos with coverage extending from the mouth to Moutoa Gardens. Photos covering this part of the estuary at a scale of 1:5,000 were laminated, and two scientists ground-truthed the spatial extent of dominant habitat and substrate types by walking the extent of the estuary recording features directly on the laminated aerial photos over three days in January 2009. The upstream margin of the mapping was determined by the coverage of the supplied photos.

Where present, macroalgae and macrophyte percentage cover within the estuary was assessed and classified using a seven category visual rating scale (see examples below and left). The results are used to describe macroalgae and macrophyte density and distribution within the estuary.

Visual rating scale for percentage cover estimates



Sampling positions and photographs were georeferenced and the information collected was used to produce GIS-based habitat maps showing the following:

- Dominant substrate.
- Dominant saltmarsh vegetation.
- Depth of the Redox Potential Discontinuity (RPD).
- 200m wide terrestrial margin vegetation/landuse.

Maps of seagrass and macroalgal cover were not produced as these features were not present in the estuary.

Appendix 1 lists the class definitions used to classify substrate and vegetation.

Digital mapping results were entered by digitising features directly off aerial photos in the GIS using a Wacom Intuos3 electronic drawing tablet within ArcMap 9.2. The spatial location, size, and type of broad scale habitat features in the estuary are provided as ArcMap 9.2 GIS shapefiles on a separate CD. Georeferenced digital field photos (GPS-Photolink) are also supplied as a GIS layer. The broad scale results are summarised in the current report in Section 3, with the supporting GIS files providing much more detail in a data set designed for easy interrogation to address specific monitoring and management questions.

2. METHODS (CONTINUED)

CONDITION RATINGS

A series of interim broad scale estuary "condition ratings" (presented below) have been proposed for use in Whanganui Estuary (based on the ratings developed for NZ estuaries - e.g. Robertson & Stevens 2006, 2007, 2008). The ratings are based on a review of estuary monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an "early warning trigger" to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Soft Mud Percent Cover

Soft mud in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access. Increases in the area of soft mud indicate where changes in catchment land use management may be needed.

SOFT MUD PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	<2% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Good	2%-5% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Fair	5%-15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Poor	>15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	>5% of estuary substrate is soft mud	Initiate ERP (Evaluation and Response Plan)

Saltmarsh Percent Cover

A variety of saltmarsh species (commonly dominated by rushland but including scrub, sedge, tussock, grass, reed, and herb fields) grow in the upper margins of most NZ estuaries where vegetation stabilises fine sediment transported by tidal flows. Saltmarshes have high biodiversity, are amongst the most productive habitats on earth and have strong aesthetic appeal. Where saltmarsh cover is limited, these values are decreased.

SALTMARSH PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	>20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
High	10%-20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Moderate	5%-10% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Low	2%-5% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Very Low	<2% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<5% of estuary area is saltmarsh	Initiate ERP (Evaluation and Response Plan)

Seagrass Index

Seagrass (*Zostera capricorni*) grows in soft sediments in NZ estuaries where its presence enhances estuary biodiversity. Though tolerant of a wide range of conditions, it is vulnerable to fine sediments in the water column and sediment quality (particularly if there is a lack of oxygen and production of sulphide). A continuous index (the seagrass coefficient - SC) has been developed to rate seagrass condition based on the percentage cover of seagrass in defined categories using the following equation: ***SC=((0 x %seagrass cover <1%)+(1 x %cover 1-5%)+(3 x %cover 5-10%)+(6 x %cover 10-20%)+(9 x %cover 20-50%)+(12x %cover 50-80%)+(15 x %cover >80%))/100.***

SEAGRASS CONDITION RATING

RATING	DEFINITION (+Seagrass Coefficient)	RECOMMENDED RESPONSE
Poor	Very Low (0.0 - 0.2)	Post baseline, monitor 5 yearly. Initiate ERP
Fair	Low (0.2 - 0.8)	Post baseline, monitor 5 yearly. Initiate ERP
	Low Low-Moderate (0.8 - 1.5)	Post baseline, monitor 5 yearly. Initiate ERP
Good	Low-Moderate (1.5 - 2.2)	Monitor at 5 year intervals after baseline established
	Moderate (2.2 - 4.5)	Monitor at 5 year intervals after baseline established
Very Good	High (4.5 - 7.0)	Monitor at 5 year intervals after baseline established
	Very High (>7.0)	Monitor at 5 year intervals after baseline established
Early Warning Trigger	Trend of decreasing Seagrass Coefficient	Initiate ERP (Evaluation and Response Plan)

2. METHODS (CONTINUED)

Macroalgae Index

Certain types of macroalgae can grow to nuisance levels in nutrient-enriched estuaries causing sediment deterioration, oxygen depletion, bad odours and adverse impacts to biota. A continuous index (the macroalgae coefficient - MC) has been developed to rate macroalgal condition based on the percentage cover of macroalgae in defined categories using the following equation: ***MC=((0 x %macroalgal cover <1%)+(0.5 x %cover 1-5%)+(1 x %cover 5-10%)+(3 x %cover 10-20%)+(4.5 x %cover 20-50%)+(6 x %cover 50-80%)+(7.5 x %cover >80%))/100.*** Overriding the MC is the presence of either nuisance conditions within the estuary, or where >5% of the intertidal area has macroalgal cover >50%. In these situations the estuary has a minimum rating of FAIR, should be monitored annually, and an Evaluation & Response Plan initiated.

MACROALGAE CONDITION RATING

RATING	DEFINITION (+Macroalgae Coefficient)	RECOMMENDED RESPONSE
Over-riding rating: Fair	Nuisance conditions exist, or >50% cover over >5% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
Very Good	Very Low (0.0 - 0.2)	Monitor at 5 year intervals after baseline established
Good	Low (0.2 - 0.8)	Monitor at 5 year intervals after baseline established
	Low Low-Moderate (0.8 - 1.5)	Monitor at 5 year intervals after baseline established
Fair	Low-Moderate (1.5 - 2.2)	Monitor yearly. Initiate ERP
	Moderate (2.2 - 4.5)	Monitor yearly. Initiate ERP
Poor	High (4.5 - 7.0)	Monitor yearly. Initiate ERP
	Very High (>7.0)	Monitor yearly. Initiate ERP
Early Warning Trigger	Trend of increasing Macroalgae Coefficient	Initiate ERP (Evaluation and Response Plan)

Redox Potential Discontinuity (RPD)

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and is an effective ecological barrier for most, but not all, sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. In addition, nutrient availability in estuaries is generally much greater where sediments are anoxic, with consequent exacerbation of the eutrophication process. The majority of the other eutrophication indicators (e.g. macroalgal blooms, soft muds, sediment organic C, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts to aquatic life. The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

RPD CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Post baseline, monitor 2 yearly. Initiate ERP
Poor	<1cm depth below sediment surface	Post baseline, monitor 2 yearly. Initiate ERP
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate ERP (Evaluation and Response Plan)

Terrestrial Vegetated Buffer Percent Cover

The presence of a terrestrial margin dominated by a dense assemblage of scrub/shrub and forest vegetation acts as an important buffer between developed areas and the saltmarsh and estuary. This buffer protects against introduced weeds and grasses, naturally filters sediments and nutrients, and provides valuable ecological habitat.

TERRESTRIAL VEGETATED BUFFER PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	80%-100% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
High	50%-80% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
Fair	25%-50% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Poor	5%-25% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<50% cover of terrestrial vegetated buffer	Initiate ERP (Evaluation and Response Plan)

3. RESULTS AND DISCUSSION

OVERVIEW

This section summarises the dominant habitats of the estuary and their likely condition, particularly in relation to the key estuary issues of sedimentation, eutrophication and habitat loss. The broad scale mapping showed that at low tide the estuary is 76% water, 24% unvegetated intertidal flats, and only 0.3% saltmarsh (Table 4). Such characteristics are typical of tidal river mouth estuaries, although the saltmarsh cover is low.

Table 4. Summary of dominant estuary features, January 2009.

Dominant Estuary Feature	Area (Ha)	Area (%)
Saltmarsh	0.9	0.3
Intertidal flats	84.5	23.9
Water	268.4	75.9
TOTAL (excludes terrestrial margin features)	**353.8**	**100**

WATER

The large and mainly freshwater subtidal component of the lower estuary (76%), means that this estuary is likely to be less diverse and productive than the typical NZ seawater dominated tidal lagoon estuaries (e.g. Ohiwa Estuary, near Whakatane). Also, because the river flow dominates over tidal flow, the majority of water-borne sediments and nutrients will be carried directly out to sea by the river.

UNVEGETATED INTERTIDAL FLATS

The broad scale substrate mapping results (Table 5, Figure 2) showed the intertidal area was dominated by firm sand and firm mud/sand (55.8ha, 65.3%). Sands were cleanest near the mouth of the river suggesting fresh inputs from beach sands either blown or washed into the lower estuary, with firm mud/sands generally in areas well flushed by river and tidal flows. These sand flats will support a healthy sediment invertebrate community and provide extensive foraging areas for shorebirds (e.g. Stephenson 1991).

Extensive intertidal firm mud/ sand flats.

Soft mud and very soft mud (23.6ha, 27.7%) was present mostly along the lower intertidal area near the edge of the river channel. The soft mud condition rating placed the estuary in the "poor" category (>25% of the estuary is soft mud). Its presence detracts from human use of the estuary, contributes to decreased water clarity, and is commonly associated with reduced sediment oxygenation and biodiversity. While rated "poor", the extent of soft mud was still considered relatively low for such a large river mouth estuary with a modified catchment.

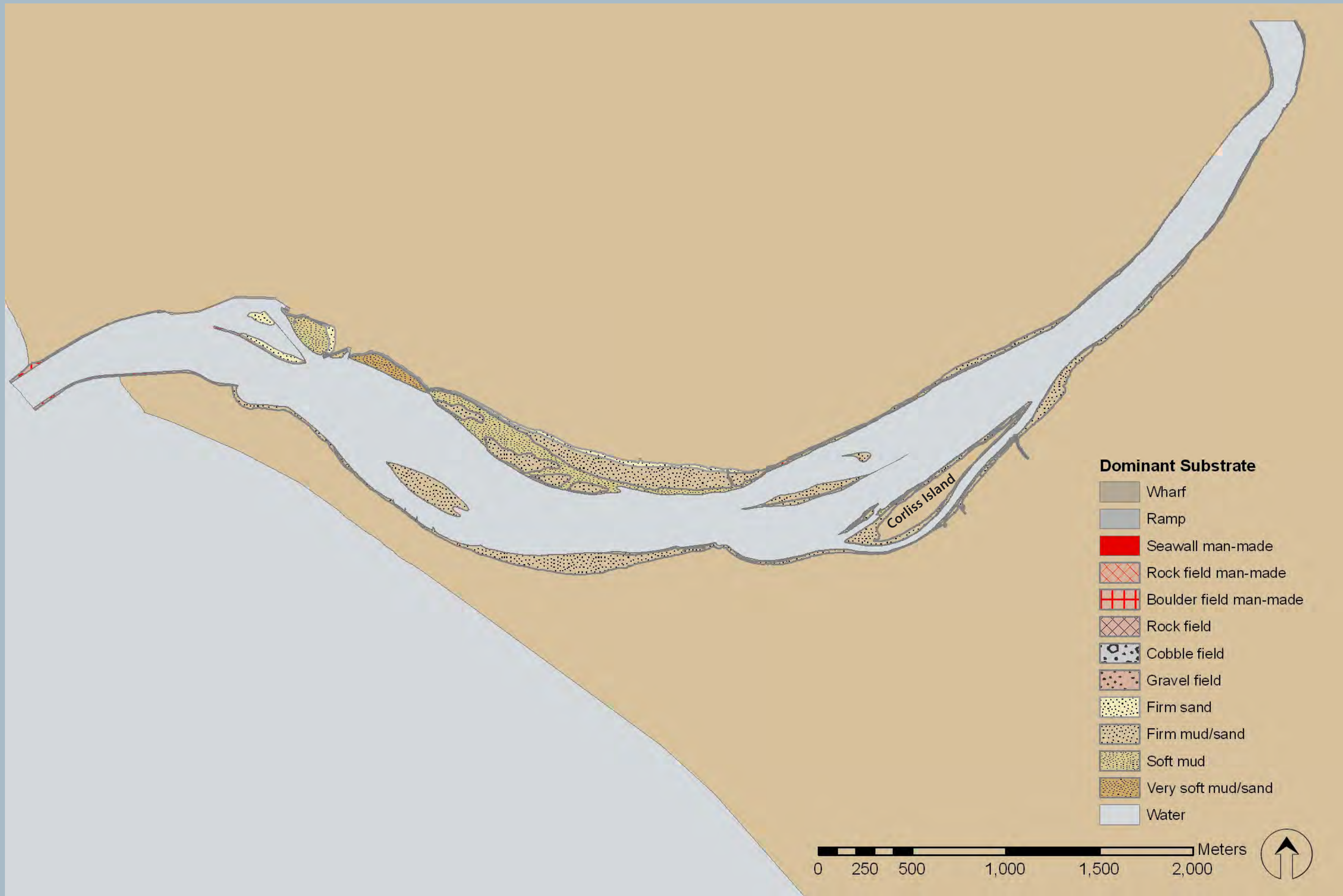
Soft mud at the river edge downstream of Matarawa Stream.

Clean sand along the upper intertidal margin.

Table 5. Summary of dominant intertidal substrate, January 2009.

Dominant Substrate	Area (ha)	%	Comments
Artificial substrates	5.3	6.2	Mostly along the estuary terrestrial margin.
Wharf	*0.7*	*0.8*	On the true right bank, near the port and Moutoa Quay.
Ramp	*0.1*	*0.2*	Several locations on both banks.
Rock field man-made	*0.01*	*0.01*	Primarily bridge supports.
Boulder field man-made	*4.1*	*4.9*	River moles and groynes, flood armour along river banks.
Seawall man-made	*0.3*	*0.3*	Groynes, flood armour along river banks.
Rock field	0.1	0.1	Outcrop adjacent to Anzac Parade/Purua Stream.
Cobble field	0.05	0.1	On the true left bank, near Corliss Island.
Gravel field	0.6	0.7	On the main river channel side of Corliss Island.
Firm sand	5.4	6.3	Upper intertidal areas on the lower true right bank.
Firm mud/sand	50.4	59.0	Mid to upper intertidal areas on both banks.
Soft mud	21.2	24.9	Flats by Beach Rd. Lower intertidal margin on both banks.
Very soft mud/sand	2.4	2.8	Beach at west end of Gilberd Street (lower true right bank).
Grand Total	**85.4**	**100.0**	

Figure 2. Map of Dominant Substrate - Whanganui Estuary, January 2009



Man-made boulder field - mole and wharf at the river mouth.

Concrete rubble flood and erosion protection on the true right bank.

Another common feature in the estuary were hard substrates (largely artificial rockfield, boulderfield, seawalls, and river training walls to direct flow), located primarily along the upper intertidal margins and extending along ~80% of the estuary margin.

The seawalls and training walls direct and confine river flows which help maintain the depth of the river channel and this, along with the river flow, contributes to the high rate of flushing in the lower estuary. Consequently, the bulk of the estuary is in relatively good condition and free from eutrophication problems commonly arising from elevated sediment nutrient concentrations and increased muddiness (e.g. increased nutrients, reduced sediment oxygenation, increased organic matter degradation by anoxic processes, shallowing, and decreased diversity of invertebrate communities).

The most significant impact of the artificial hard substrates was the modification of margin slope and substrate. The steep (often vertical) artificial margin has greatly reduced the area and substrate previously available for saltmarsh habitat, and now provides little capacity for saltmarsh to re-establish, or to respond to sea level rise.

The only relatively unmodified margin areas remaining were on the true left bank - a small area around Corliss Island including the side channel of the river, and parts of the beach dune system near the mouth of the estuary. Without doing a vulnerability assessment, flooding - exacerbated by sea level rise and climate change - is an obvious risk to saltmarsh, dune and intertidal habitat in the estuary.

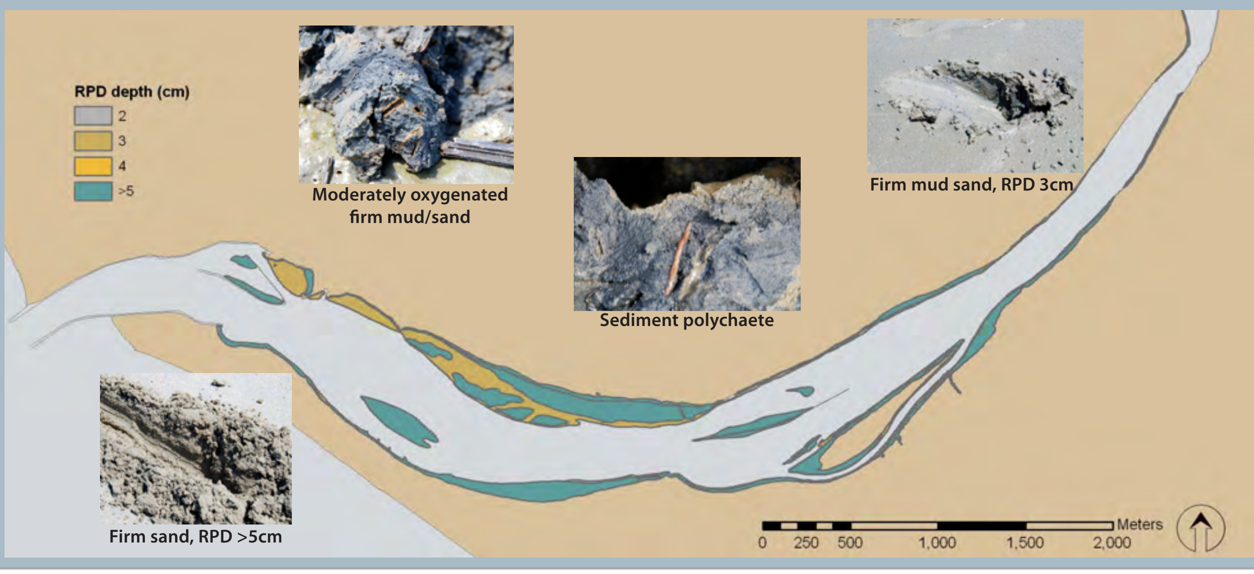
Table 6. Percent of substrate in each RPD depth class.

Substrate	1-3cm	3->5cm
Rating	"FAIR"	"GOOD"
Cobble field	-	0.1
Gravel field	0.1	0.6
Firm sand	-	6.8
Firm mud/sand	0.1	62.8
Soft mud	26.1	0.4
Very soft mud/sand	3.0	-
Grand Total	**29.3**	**70.7**

The Redox Potential Discontinuity (RPD) depth, which marks the transition between oxygenated and reduced conditions, was between 3cm and >5cm deep across the majority of the estuary, a condition rating of "good", with remaining areas in the 1-3cm deep range, a condition rating of "fair" (Figure 3 and Table 6, based on approximately 50 data points).

The RPD was generally closer to the surface in soft and very soft muds, and deeper in sediments with more porous sediments which allow greater oxygen penetration (Table 6). Sediment was not particularly sulphide enriched and did not represent eutrophic conditions that commonly create an ecological barrier to sediment dwelling macrofauna. In the dominant intertidal sand flats particularly, a healthy sediment dwelling community was evident, and the sediments appeared to be well oxygenated and in good condition (see photos below).

Figure 3. Map of RPD depth - Whanganui Estuary, January 2009



SALTMARSH MAPPING

Vertical seawall limiting saltmarsh habitat.

Accumulation of driftwood in the upper intertidal zone restricting saltmarsh growth.

Overall, very little saltmarsh was present (0.9ha, 0.3% - Table 7), a condition rating of "very low". It comprised a mix of sedgeland (three square - 54%), rushland (searush - 20%) and herbfield (primrose, glasswort, remuremu, bachelors button - 26%). Sedgeland was present in small patches on both banks (Figure 4) while most rushland was located on Corliss Island or adjacent to the island on the true left bank where it was sheltered from the main river flow.

The downstream tip of Corliss Island contained the most intact sequence of saltmarsh in the estuary, although a large number of terrestrial grasses and weeds were also present.

The extent of saltmarsh was low even for a modified river mouth estuary and reflects both the freshwater dominated nature of the estuary (which allows many terrestrial plants and grasses to establish right to the edge of the estuary), and the extensively modified margins where seawalls, flood protection works and land drainage have all greatly limited the area inundated by tidal flows. Driftwood also poses another limitation on saltmarsh growth, particularly in the lower estuary where it strands at the top of the tidal range where herbfields and rushland would commonly be found. While a natural feature of river estuaries, in many areas driftwood completely covered the underlying substrate (see sidebar photo).

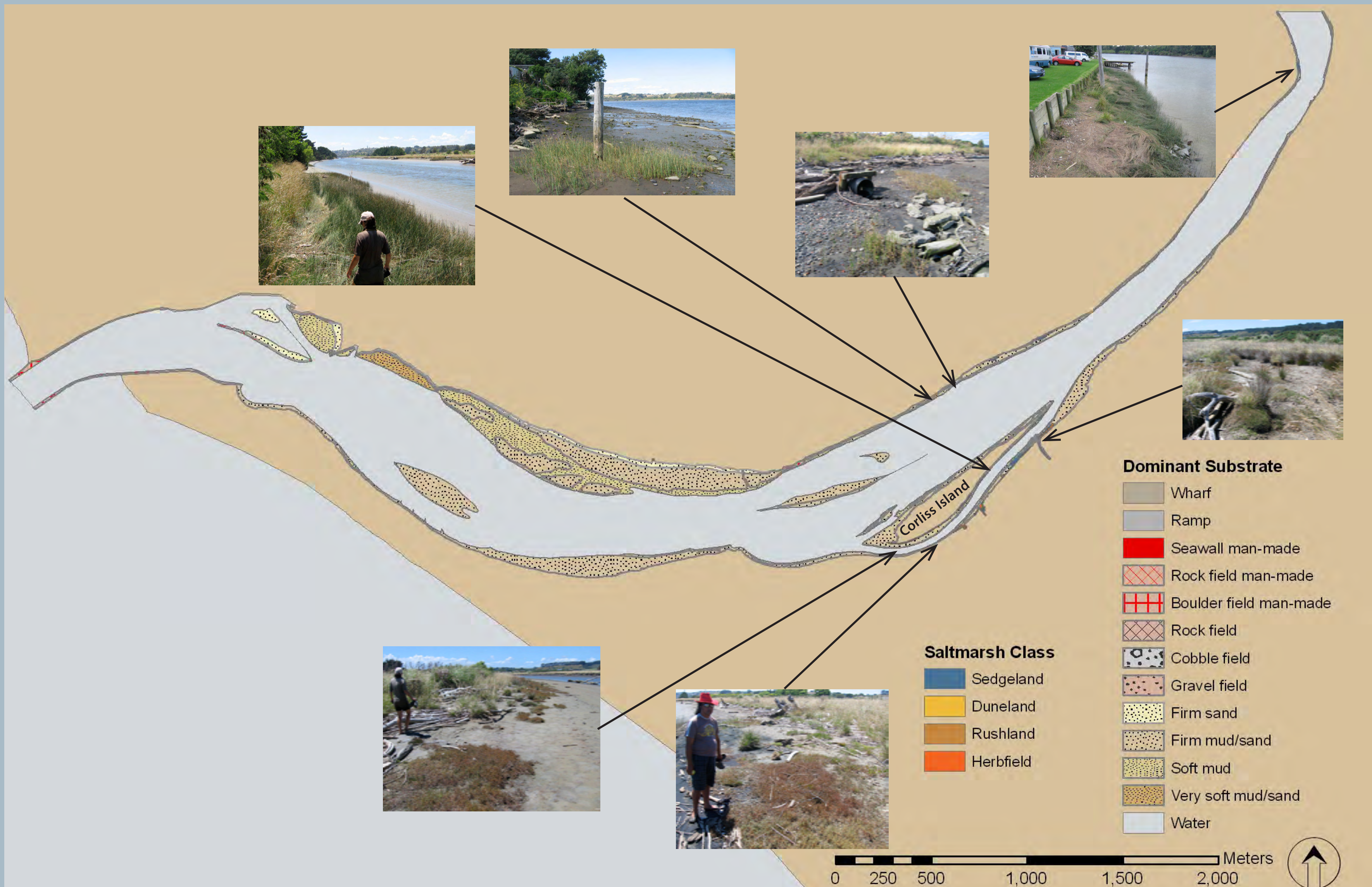
Because saltmarsh is highly productive, provides important habitat for a variety of species (including whitebait), naturally filters sediments and nutrients, and acts as an important buffer that protects against introduced weeds and grasses, its small extent detracts from the value of the estuary.

Table 7. Summary of saltmarsh vegetation results, January 2009.

Class	Dominant Species	Primary subdominant species	Ha	%
Duneland			0.001	0.1
	Spinifex sericeus (Silvery grass)		*0.49*	*53.8*
Sedgeland			0.49	53.8
	Schoenoplectus pungens (Three-square)		*0.49*	*53.8*
Rushland			0.19	20.4
	Juncus kraussii (Searush)		*0.18*	*19.6*
	Juncus kraussii (Searush)	*Sarcocornia quinqueflora (Glasswort)*	*0.01*	*0.8*
Herbfield			0.23	25.7
	Samolus repens (Primrose)	*Sarcocornia quinqueflora (Glasswort)*	*0.18*	*20.2*
	Samolus repens (Primrose)	*Selliera radicans (Remuremu)*	*0.04*	*4.7*
	Cotula coronopifolia (Bachelor's button)		*0.01*	*0.7*
	Sarcocornia quinqueflora (Glasswort)		*0.001*	*0.1*
Total			0.91	100

Saltmarsh by Corliss Island. Narrow band of searush bordered by tall fescue. Herbfield in foreground.

Figure 4. Map of Saltmarsh Vegetation - Whanganui Estuary, January 2009



Note because of the small size of saltmarsh areas, detail is best viewed in the GIS files that accompany this report.

TERRESTRIAL MARGIN MAPPING

The results of the 200m terrestrial margin mapping showed most of the margin surrounding the estuary had been modified in some way (Figure 5, Table 8). Industrial, residential, and commercial areas (predominantly unvegetated) accounted for 54% of the margin, while grassland (27%) dominated the vegetative cover. Dense vegetated cover comprised both duneland (10%) and mostly exotic scrub and forest (6%), a condition rating of "poor".

In terms of ecological value, by far the most significant areas of margin vegetation were the coastal dunes on both sides of the river mouth (see box at bottom of the page). These dunes play a vital role in coastal protection and provide important habitat for many plants and animals. The dune vegetation is notable for the almost exclusive cover of the native sand-binder spinifex (*Spinifex sericeus* - Silvery grass) on the foredune, a feature now lost from most NZ dunes. The biggest current threat to the dunes is weed invasion.

The back dune in particular, and dune hollows, support a variety of introduced weeds (e.g. brush wattle, gorse, blackberry, boneseed, pampas, blue morning glory). These were also previously recorded by Ogle et al. (2004) who recommended selective removal of these problem weeds, something that should ideally be done before they become more extensively established. Introduced marram grass, a problem plant in native dunes (see box at bottom of page) has also established on the back of the frontal dune and is a dominant feature on the secondary and back dunes.

Elsewhere, the lack of a densely vegetated margin means it has a limited capacity to filter sediments and nutrients entering the estuary, to act as a buffer protecting against introduced weeds and grasses, and to provide habitat for a variety of species.

Despite past modification, recent improvements are obvious, particularly along the true right bank. Here a variety of native shrubs have been planted, weeds cleared and boardwalks, jettys, and pathways established which make the area an inviting and accessible place to go. While plants are still establishing, continued sensitive development of these recreation areas will further improve the amenity and ecological value of the margin.

Outside of maintained public amenity spaces, introduced grasses, weeds and trees are the dominant cover, particularly in the unkempt margins of industrial sites, and on steep roadside and river banks.

Residential properties along the river represent a mixed view of how the river is appreciated - many have directly connected to the river through their gardens and decks, while others have blocked themselves off with large fences. It was common to see garden refuse dumped over riverside fences adjacent to seating areas.

COASTAL DUNES: Dunes establish when dry beach sand is blown inland and trapped by plants and other obstructions such as driftwood. As sand accumulates, the dunes become higher and wider, facilitating the development of more complex plant communities in areas protected from salt water inundation, sea spray and strong winds. Aside from ecological values, sand dunes also play an important part in protecting the coastline as they act as a buffer against wave damage during storms (they form a reservoir of sand, replenished when beach levels are high and released to nourish the foreshore during storm erosion). Given climate change will accelerate sea level rise, this function of dunes is expected to become even more important in the future. The key threats to dune condition are; sea level rise, grazing by stock, agricultural development, vehicle and pedestrian damage, weed invasion, displacement of native sand binding grasses by exotic species, and displacement by seawalls, roads and buildings.

To function effectively, dunes and dune vegetation particularly, need to be in good condition. The loss of even small patches of vegetation on the seaward slopes of dunes (the foredune, secondary dunes and backdunes), allow strong onshore winds to initially produce sand blowouts, which develop into transverse mobile dunes and, finally, a completely unstable dune system which moves inland. Natural recovery from damage is slow because environmental conditions are unfavourable for plant growth. The introduced sand binder marram grass (which is prolific and has tended to out-compete the native sand-binders spinifex and/or pingao in many areas) can exacerbate dune instability from overstabilisation of the dune system. Marram grass dunes are generally taller, have a steeper front, and occupy more area than native dunes. Such dunes tend to lock up sand, limiting replenishment of sand to the beach and being susceptible to erosion of the dune front during storms. They also tend to contribute to the loss of biodiversity and natural character with blow-outs being common (Hilton 2006).

Figure 5. Map of 200m Terrestrial Margin Features - Whanganui Estuary, January 2009

TERRESTRIAL MARGIN MAPPING (CONTINUED)

Table 8. Summary of dominant terrestrial margin vegetation, January 2009.

Class	Dominant Species	Primary subdominant species	Area (Ha)	% area
Scrub/Forest			9.6	2.9
	Pinus radiata (Pine tree)	*Paraserianthes lophantha (Brush wattle)*	5.6	1.7
	Myoporum laetum (Ngaio)	*Native forest*	2.2	0.7
	Populus alba (Silver poplar)	*Paraserianthes lophantha (Brush wattle)*	0.9	0.3
	Myoporum laetum (Ngaio)	*Coprosma repens (Taupata)*	0.2	0.1
	Acacia sophorae (Sand wattle)	*Lycium ferocissimum (Boxthorn)*	0.2	0.1
	Pinus radiata (Pine tree)		0.2	0.1
	Myoporum laetum (Ngaio)		0.1	0.0
	Myoporum laetum (Ngaio)	*Phormium tenax (New Zealand flax)*	0.1	0.03
	Paraserianthes lophantha (Brush wattle)		0.05	0.01
Scrub			8.5	2.6
	Lupinus arboreus (Tree lupin)	*Ammophila arenaria (Marram grass)*	4.6	1.4
	Lupinus arboreus (Tree lupin)	*Festuca arundinacea (Tall fescue)*	1.9	0.6
	Ulex europaeus (Gorse)	*Foeniculum vulgare (Fennel)*	0.7	0.2
	Ulex europaeus (Gorse)		0.6	0.2
	Ulex europaeus (Gorse)	*Muehlenbeckia complexa (Wire vine)*	0.5	0.1
	Lycium ferocissimum (Boxthorn)	*Native scrub*	0.1	0.03
	Chrysanthemoides monilifera (Boneseed)		0.1	0.02
	Coprosma repens (Taupata)	*Pittosporum crassifolius (Karo)*	0.02	0.01
Tussockland			2.1	0.6
	Cortaderia selloana (Pampas grass)	*Phormium tenax (New Zealand flax)*	2.1	0.6
Grassland			90.6	27.4
	Unidentified grass (pasture)		34.3	10.4
	Unidentified grass (pasture)	*Unidentified introduced weeds*	28.1	8.5
	Festuca arundinacea (Tall fescue)	*Unidentified introduced weeds*	16.1	4.9
	Festuca arundinacea (Tall fescue)	*Salix sp. (Willow - species not identified)*	2.9	0.9
	Unidentified grass (maintained park)	*Native scrub*	2.6	0.8
	Unidentified grass (introduced)	*Festuca arundinacea (Tall fescue)*	2.2	0.7
	Festuca arundinacea (Tall fescue)	*Isolepis nodosa (Knobby clubrush)*	1.7	0.5
	Unidentified grass (maintained park)	*Native forest*	0.8	0.2
	Unidentified grass (maintained park)	*Myoporum laetum (Ngaio)*	0.5	0.1
	Festuca arundinacea (Tall fescue)	*Cordyline australis (Cabbage tree)*	0.4	0.1
	Festuca arundinacea (Tall fescue)		0.4	0.1
	Festuca arundinacea (Tall fescue)	*Ulex europaeus (Gorse)*	0.3	0.1
	Festuca arundinacea (Tall fescue)	*Foeniculum vulgare (Fennel)*	0.2	0.1
Duneland			31.4	9.5
	Spinifex sericeus (Silvery grass)	*Ammophila arenaria (Marram grass)*	14.7	4.4
	Ammophila arenaria (Marram grass)	*Lupinus arboreus (Tree lupin)*	10.0	3.0
	Ammophila arenaria (Marram grass)	*Festuca arundinacea (Tall fescue)*	3.9	1.2
	Spinifex sericeus (Silvery grass)	*Lupinus arboreus (Tree lupin)*	1.6	0.5
	Spinifex sericeus (Silvery grass)		1.3	0.4
	Ammophila arenaria (Marram grass)		0.002	0.001
Rushland			10.9	3.3
	Isolepis nodosa (Knobby clubrush)	*Lupinus arboreus (Tree lupin)*	9.0	2.7
	Isolepis nodosa (Knobby clubrush)	*Lycium ferocissimum (Boxthorn)*	1.9	0.6
Introduced weeds			0.04	0.01
	Rubus fruticosus (Blackberry)	*Paraserianthes lophantha (Brush wattle)*	0.04	0.01
Unvegetated substrate			177.3	53.7
	Industrial		85.8	26.0
	Residential		68.4	20.7
	Commercial		20.7	6.3
	Firm sand		2.2	0.7
Grand Total			**330.4**	**100**

4. CONCLUSIONS

In conclusion, the broad scale habitat mapping showed the Whanganui Estuary to be a typical large tidal river mouth estuary draining a partially developed (farmed) catchment.

The estuary's major habitats were subtidal water, and unvegetated intertidal flats. Saltmarsh was also present but at a low incidence. Because of its location within urban Wanganui, the terrestrial margin and river mouth were highly modified. However, its intertidal flats still provide important foraging areas for birds, subtidal reaches are important for many fish, and the remaining saltmarsh and particularly the dunes provide important plant and animal habitat.

The condition of the mapped habitats indicated problems associated with sedimentation (extensive muddy sediments and turbid water) and historical habitat loss (little saltmarsh, no seagrass, and a highly modified vegetated terrestrial margin). However, there were few nutrient enrichment issues (sparse nuisance macroalgal growth and good sediment oxygenation).

The estimated high suspended sediment from the catchment (WRENZ: 700 $t/km^2/yr$) is the likely cause of the sedimentation problem, and the absence of nutrient enrichment can be attributed to the estimated low nitrogen loading from the catchment (WRENZ: 4.6 kg/ha/yr), and good estuary flushing. Historical habitat loss has mainly resulted from drainage, reclamation, flood protection and river works.

Although a vulnerability assessment has not been undertaken, there are obvious risks to the estuary e.g. flooding (and proposed flood protection works), sedimentation, introduced weeds, and sea level rise and climate change. The presence of such stressors place the estuary under a relatively high risk of change, and consequently it requires detailed assessment of its key vulnerabilities.

5. MANAGEMENT RECOMMENDATIONS

The condition ratings trigger repeat broad scale mapping in 5 years time. In addition the following management actions are recommended to address key issues in the Whanganui Estuary:

Undertake an Ecological Vulnerability Assessment

- Obvious stressors (risks) to the estuary are present (e.g. flooding and flood protection works, sea level rise, weed invasion, margin development, stormwater, sewage and industrial discharges), and these stressors are likely to result in changes to existing high value habitats (dunes, saltmarsh, intertidal flats). A vulnerability assessment with focused synoptic monitoring is recommended to assess the range of stressors present, the susceptibility of the estuary to each and, based on this, define prioritised long-term broad and fine scale monitoring requirements and management needs for the estuary.

Identify and Implement Catchment BMPs

- Catchment runoff is one of the major stressors in estuaries with the likely ecological response one of lowered biodiversity and lowered aesthetic and human use values. To prevent avoidable inputs, best management practices (BMPs) should be identified and implemented to reduce sediment and pathogen runoff from catchment "hotspots", and to maintain current low nutrient inputs.

Restore Saltmarsh Habitat

- The almost complete loss of saltmarsh from the estuary has certainly contributed to reduced biodiversity and increased sedimentation reaching subtidal areas of the estuary, while also lowering aesthetic and human use values. It has also allowed rubbish and weeds to enter the estuary. Because of the importance of saltmarsh, and the risk of further loss from flood control measures and sea level rise, it is recommended that a plan be developed to encourage its re-establishment, particularly in areas where a suitable gradient remains, or as suitable land becomes available for restoration.

Reinstate Margin Buffer

- Human development of the estuary margin has resulted in clearance of surrounding bush, and construction of artificial structures around much of the estuary. This has almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary. Many areas are also adversely affected by nuisance weeds and rubbish. Because of the importance of a natural vegetated margin around the estuary, it is recommended that a strategy be developed to encourage its re-establishment where possible, and to support the existing planting initiatives.

5. MANAGEMENT RECOMMENDATIONS (CONTINUED)

Manage Dune Habitat

- The coastal dune systems are very sensitive and important areas. Introduced weeds, and pest plants and animals, are likely to reduce biodiversity and habitat values, while sea level rise and climate change will increase vulnerability to erosion and flooding. While a vulnerability assessment is needed to better describe the risks present, a initial step is to develop and implement a management plan to remove or prevent the spread of key weed species, and to look at the need for restricting vehicle access and managing foot traffic where necessary. This process has begun for the Castlecliff area (e.g. Wanganui District Council 2005).

Assess Risks to Water Quality

- The broad scale mapping does not address water quality issues related to pathogens or toxins. Because of the high contact recreation use of the water is recommended that ongoing initiatives to improve water quality are supported, and the specific risk posed by existing inputs from point and non-point sources be assessed and addressed as appropriate.

6. REFERENCES

Atkinson, I.A.E. 1985. Derivation of vegetation mapping units for an ecological survey of Tongariro National Park Nth Island, NZ. NZ Journal of Botany, 23; 361-378.

Fechney, L. Wilson, T. Ravine, D. Ogle, C. Brookes, J. Marsh, N. Halsey, B. Nicolls, M. McColl, T. 1990. Coastal Resource Inventory First Order Survey – Wanganui Conservancy. Department of Conservation.

Hilton, M.J. 2006. The loss of New Zealand's active dunes and the spread of marram grass (Ammophila arenaria). NZ Geographer 62, 105-120.

Ogle, C. Campbell, J. La Cock, G. Wilson, F. 2004. Ecological significance of sections of the Wanganui coastal and inland dunes: Kaitoke Stream to South Beach and Whanganui River entrance. Report prepared by Department of Conservation Wanganui. 15p.

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

Robertson, B.M. and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Prepared for Environment Southland.

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

Robertson, B.M. and Stevens, L. 2008. Southland Coast, Te Waewae Bay to the Catlins Habitat Mapping, Risk Assessment, and Monitoring. Prepared for Environment Southland.

Stephenson, G. 1991. Intertidal biology of proposed alternative port dredgings disposal site, Wanganui River Estuary. Coastal Marine Ecology Consultants.

Strickland, R. Tierney, L. and Cudby, E. 1982. Submission on the Wanganui River Flow Management Plan. Fisheries Environmental Report No. 24. Ministry of Agriculture and Fisheries, Wellington.

Wanganui District Council (2005). Castlecliff Coastal Reserve Management Plan. Wanganui District Council.

7. ACKNOWLEDGEMENTS

This work has been undertaken with help from a range of people who made working in the Wanganui Estuary a pleasure, particularly the locals who willingly shared their experiences with the river and granted access to the estuary margins.

Jim Campbell and especially Hannah Rainforth (DOC) provided a great deal of local knowledge and support during the field work.

Michael and the waka crew extended us their warm hospitality, and the chance to see the estuary from the water, which was very much appreciated.

Joanne Tiki (Wanganui City Council) supplied the high resolution ortho-rectified colour aerial photographs.

Maz Robertson (Wriggle) for her editorial input .

Finally, many thanks to Helen Kettles (DOC) who initiated and managed and reviewed the project, and collated comments from DOC Wanganui on the draft report.

APPENDIX 1. 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.

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.

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: The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When walking on the substrate you'll sink <1 cm.

Firm sand: Firm sand flats may be mud-like in appearance but are granular when rubbed between the fingers, and solid enough to support an adult's weight without sinking more than 1-2 cm. Firm sand may have a thin layer of silt on the surface making identification from a distance difficult.

Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink >2 cm.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink 0-2 cm.

Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When you'll sink 2-5 cm.

Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking you'll sink >5 cm.

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.