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New River Estuary 2007

Broad Scale Habitat Mapping and Sedimentation Rate

Prepared for **Environment Southland**
November 2007

Cover Photo: Royal Spoonbills over New River Estuary

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By

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All photos by Wriggle except where noted otherwise.

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EXECUTIVE SUMMARY

The present report summarises the results of the 2007 broad scale monitoring for New River Estuary, one of the key estuaries in Environment Southland's (ES's) long-term estuary monitoring programme. As part of this programme, ES contracted Wriggle Coastal Management (Wriggle) to undertake and report on the following work:

- Broad scale mapping of estuary sediment types.
- Assessment of the recent historical sedimentation rate (using radio-isotopes).
- Establishment of sediment rate monitoring plates.
- Broad scale mapping of macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria, Enteromorpha*).
- Broad scale mapping of seagrass beds (i.e. *Zostera*).
- Broad scale mapping of saltmarsh vegetation.
- Broad scale mapping of the 200m terrestrial margin surrounding the estuary.

The methods used are based on tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), and a number of extensions to the EMP developed by Wriggle (see Robertson & Stevens 2006, 2007). The following table summarises the 2007 monitoring results for New River Estuary:

Habitat	Results
Unvegetated Substrate	Firm mud/sand and mobile mud/sand dominated the estuary (77%, 2,063ha), most located in the central estuary basin and towards the estuary mouth. However, a large portion of the estuary was dominated by soft and very soft mud (21%, 567ha), mostly in the upper northern reaches including the Waihopai Arm. The average rate of sedimentation was estimated as 1967-2007: 12.7mm/year, and 1907-1967: 3.0mm/year.
Macroalgae	Potentially nuisance macroalgae were present, 3.7% (99ha) of the estuary rated as having a low-moderate / moderate cover and 6.9% (186ha) rated with high / very high cover. High densities were in the east, west and north arms, and near the Oreti River mouth. Most of the intertidal area (89%) was rated as having a low or very low percentage cover.
Seagrass	Seagrass was most dense in very soft muds in the north by the Waihopai River mouth, near the edge of rushland in the east, along the margins of the Oreti River, and in subtidal channels. It was also widespread at low densities throughout the eastern side of the estuary.
Saltmarsh	Saltmarsh covered 17% of the estuary (554ha) of which 42% was rushland (97% jointed wire rush - *Leptocarpus similis*), 23% grassland (predominantly tall fescue among rushland), and 18% herbfield. It was most extensive in the eastern arm where wide beds of rushland extended out over large intertidal flats. Reclamation and artificial seawalls have historically replaced large areas of this type of habitat elsewhere in the estuary.
Terrestrial Margin	The terrestrial margin was dominated by grassland (59%), then a combination of scrub and forest (28%) and residential and industrial development (10%). Grassland generally extended to artificial seawalls along the estuary edge, or to floodbanks bordering industrial and residential developments, where there was a relatively abrupt change from terrestrial cover to the estuary. In these areas, limited natural buffering capacity remained and saltmarsh vegetation was either absent or restricted to narrow bands.

EXECUTIVE SUMMARY (CONTINUED)

ESTUARY CONDITION

Condition ratings for individual indicators used to assess New River Estuary are summarised in the table below for the three major estuary issues being monitored; sedimentation, eutrophication, and habitat/margin loss. An overall rating for these major issues, assessing changes to the estuary since it was first mapped in 2001, is given based on a comparison of the 2007 monitoring results with the baseline established in 2001.

Major Estuary Issue	Indicator	Condition Rating	Overall Issue Rating
Sedimentation	Sedimentation rate	High	Moderate
	Change in soft mud area	Very Good/Good	
Eutrophication	Macroalgal cover	Fair	Moderate
Habitat/Margin loss	Saltmarsh area	Very Good/Good	Good
	Seagrass cover	Very Good/Good	
	Terrestrial margin	Baseline established	-

Sedimentation: Historical sedimentation rates in the northern arm were relatively low (~3mm/year for 1906-1967), however recent rates (12.7-16.4mm/year) are rated high for NZ estuaries. Here, deep soft muds now overlay areas that were previously sandy. Although the area of soft mud throughout the estuary was high (21%), there was no significant change in the area of soft mud from 2001 to 2007 placing it in the very good/good category. Based on these results, sedimentation is rated a MODERATE issue overall.

Eutrophication: The extent of enrichment indicated by the cover of macroalgae indicated that macroalgal growth is present and causing localised nuisance conditions in some parts of the estuary. The level of cover (>10% of the estuary with >10% cover) places it in the MODERATE category overall, but the widespread growth in the eastern arm highlights that this part of the estuary may be susceptible to more widespread nuisance growths under favourable growing conditions.

Habitat loss: No significant change to the total area of saltmarsh or seagrass was observed between 2001 and 2007 placing both in the VERY GOOD-GOOD category. The successful eradication of *Spartina* and the establishment of herbfields in its place has greatly increased the amount of herbfield in the estuary (3ha in 2001 to 38ha in 2007).

RECOMMENDED MONITORING

New River Estuary has been identified by ES as a priority for monitoring, and is a key part of ES's existing estuary monitoring programme being undertaken in a staged manner throughout Southland. Based on existing monitoring results and improvements made to the EMP to produce better outputs for ES to manage key issues facing their estuaries, it is recommended that monitoring continue as outlined below:

Fine Scale Monitoring	Repeat fine scale monitoring at five yearly intervals (next scheduled for 2010) and as deemed necessary thereafter based on the condition ratings. Due to the high sediment and nutrient deposition in the Waihopai Arm, a new upper estuary fine scale site should also be monitored.
Broad Scale Macroalgal Mapping	Map macroalgal cover in January-March 2008. After this, schedule monitoring as deemed necessary based on the condition ratings.
Broad Scale Sedimentation Rate Mapping	Measure sediment plate depths in January-March 2008. Monitor annually thereafter.
Broad Scale Habitat Mapping	Repeat broad scale habitat mapping at five yearly intervals (next scheduled for 2012).

The ongoing monitoring, coupled with an Ecological Vulnerability Assessment of Southland's coastline and estuaries scheduled for 2008, will provide a robust framework for identifying, evaluating and providing management options for New River Estuary.

1. INTRODUCTION

OVERVIEW

Northern arm of New River Estuary.

To assess the major issues faced by New Zealand estuaries (Table 1), Environment Southland (ES) established a long-term monitoring programme in the 1990's based on the tools included in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002). The EMP consists of two main elements:

- Broad scale habitat mapping (using Geographic Information System (GIS) computer software).
- Fine scale (i.e. detailed) monitoring of dominant intertidal habitat in the mid estuary area.

Broad scale habitat mapping records the location and type of vegetation (e.g. saltmarsh, seagrass, macroalgae) and substrate (e.g. mud, sand, gravel); and is used to provide information primarily on the issues of habitat and margin loss, sedimentation (through the mapping of substrate type), and eutrophication (by mapping macroalgae percent cover).

Fine scale monitoring focuses primarily on the physical, chemical, and biological characteristics of estuary sediments as these tend to be the most sensitive to degradation (Church 1975). Fine scale monitoring includes various indicators of estuary condition to provide information on sedimentation, eutrophication, and toxins (i.e. sediment particle size, organic matter, nutrients, heavy metals, and sediment macrofauna).

In 2006, ES contracted Wriggle Coastal Management (Wriggle) to review the EMP monitoring undertaken by ES between 2001 and 2006, and to provide an overview "State of the Environment" assessment of the condition of Southland's estuaries (Robertson & Stevens 2006). The report expanded the reporting of EMP monitoring data by developing key condition indicators (summarised in Table 2) and proposing interim condition ratings to evaluate estuary condition. A suggested monitoring or management response was linked to each condition rating, while recommendations were made to address any identified gaps in the existing monitoring programme.

Table 1. Summary of the major issues affecting NZ estuaries.

Issue	Impact
Sedimentation	If sediment inputs are excessive, they infill quickly with muds, reducing biodiversity and human values and uses.
Eutrophication	If nutrient inputs are excessive, they experience macroalgal and/or phytoplankton blooms, anoxic sediments, lowered biodiversity and nuisance effects for local residents.
Disease Risk	If pathogen inputs are excessive, the disease risk from bathing, wading or eating shellfish increases to unacceptable levels.
Toxins	If potentially toxic contaminant inputs (e.g. heavy metals, pesticides) are excessive, estuary biodiversity is threatened and shellfish and fish may be unsuitable for eating.
Habitat Loss	If habitats (such as salt marsh) are lost or damaged through drainage, reclamation, building of structures, stock grazing or vehicle access, biodiversity and estuary productivity declines.
Margin Loss	If the natural terrestrial margin around the estuary is degraded through such actions as roading, stormwater outfalls, property development and weed growth, the natural character is diminished and biodiversity reduced.

1. INTRODUCTION (CONTINUED)

OVERVIEW (CONTINUED)

Following from this work, Wriggle developed a number of extensions to the EMP and its monitoring outputs in order to help address issues raised under the existing monitoring programme. The extensions developed include:

- Establishment of sedimentation rate measures (using plates buried in sediment).
- Estimation of historical sedimentation rates (using radio-isotope ageing of sediment cores).
- Assessment of the percentage cover of macroalgae and seagrass (as separate GIS layers).
- Broad scale mapping of a 200m terrestrial margin surrounding the estuary.
- Further development and refinement of condition ratings for key indicators.
- Provision of georeferenced digital photos (as a GIS layer).
- Development of an Upper Estuary Monitoring and Assessment Protocol.
- Development of an Estuary Vulnerability Matrix.

Where relevant, these extensions have been integrated into the existing ES estuary monitoring programme to assist in the interpretation of monitoring results, and to help ES determine appropriate management options.

SCOPE

New River Estuary was broad scale mapped in 2001, with fine scale monitoring undertaken in 2001, 2003, 2004 and 2005. Results for New River, along with other key estuaries in the ES monitoring programme, have been presented in a series of separate reports (e.g. Robertson et al. 2002, Robertson & Asher 2003, Robertson et al. 2004, Stevens & Asher 2005, Robertson & Stevens, 2006).

As part of ES's estuary long term estuary monitoring programme, Wriggle was contracted by ES to undertake a series of studies for New River Estuary in February and March 2007 when a variety of Southland estuaries were visited and monitored over a three week period. Within New River, the following work was undertaken:

- Broad scale mapping of estuary sediment types.
- Assessment of the recent historical sedimentation rate (using radio-isotopes).
- Establishment of sediment rate monitoring plates.
- Broad scale mapping of macroalgal beds (i.e. *Ulva* (sea lettuce), *Gracilaria, Enteromorpha*).
- Broad scale mapping of seagrass beds (i.e. *Zostera muelleri*).
- Broad scale mapping of estuary vegetation.
- Broad scale mapping of the 200m terrestrial margin surrounding the estuary.

Table 2. Summary of the broad and fine scale EMP indicators used by Environment Southland.

Level	#	Indicator	Method
Broad Habitat	1	Saltmarsh Habitat Index	Broad scale mapping - estimates the change in saltmarsh habitat over time.
Broad Habitat	2	Seagrass Habitat Index	Broad scale mapping - estimates the change in seagrass habitat over time.
Nutrient Enrichment	3	Nuisance Macroalgal Cover Index	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Sedimentation	4	Soft Mud Sediment Index	Broad scale mapping - estimates change in the amount of soft mud habitat over time.
Organic & Nutrient Enrichment	5	Organic and Nutrient Enrichment Indicator	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.
Contamination	6	Contamination in Bottom Sediments Indicator	Chemical analysis of indicator metals (cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Biodiversity	7	Condition of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna) - 0.0133m^2 replicate cores. Type and number of animals living on the sediment surface (epifauna) - 0.25m^2 replicate quadrats.

1. INTRODUCTION (CONTINUED)

SCOPE (CONTINUED)

This report presents the results of the 2007 monitoring of New River Estuary. It incorporates several extensions to the monitoring previously undertaken. The major extensions are:

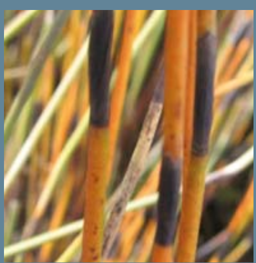
Inclusion of upper estuary sedimentation monitoring: Sedimentation has been identified as a major issue and has been addressed in two ways. Firstly through the radio-isotope analysis of a sediment core to age the sediment and determine historical sedimentation rates in the estuary. Secondly, through the establishment of sediment plates so that rates of sediment accumulation from the present and into the future can be measured. Both methods are described in Section 2.

Separation of macroalgal and seagrass GIS layers: Previously areas dominated by seagrass and macroalgae were mapped, but the underlying substrate was not recorded, and no measure was made of the density of the vegetated cover. Separating these into discrete GIS layers allows density to be recorded as a percentage cover, and the substrate underlying this vegetation to be mapped. Assessment methods are described in Section 2.

Inclusion of nuisance macroalgal monitoring: Eutrophication, commonly observed through the presence of nuisance macroalgae, has been identified as a potential problem that may require frequent (annual) monitoring. Macroalgal percent cover is reported as a separate GIS layer enabling mapping to be undertaken and updated as needed.

Inclusion of condition ratings for reporting: Interim condition ratings (see Robertson & Stevens 2006, 2007) developed specifically for the EMP indicators used by ES for Southland's estuaries (Table 2), have been further developed and proposed to evaluate the monitoring results. These are described in Section 3.

REPORT STRUCTURE



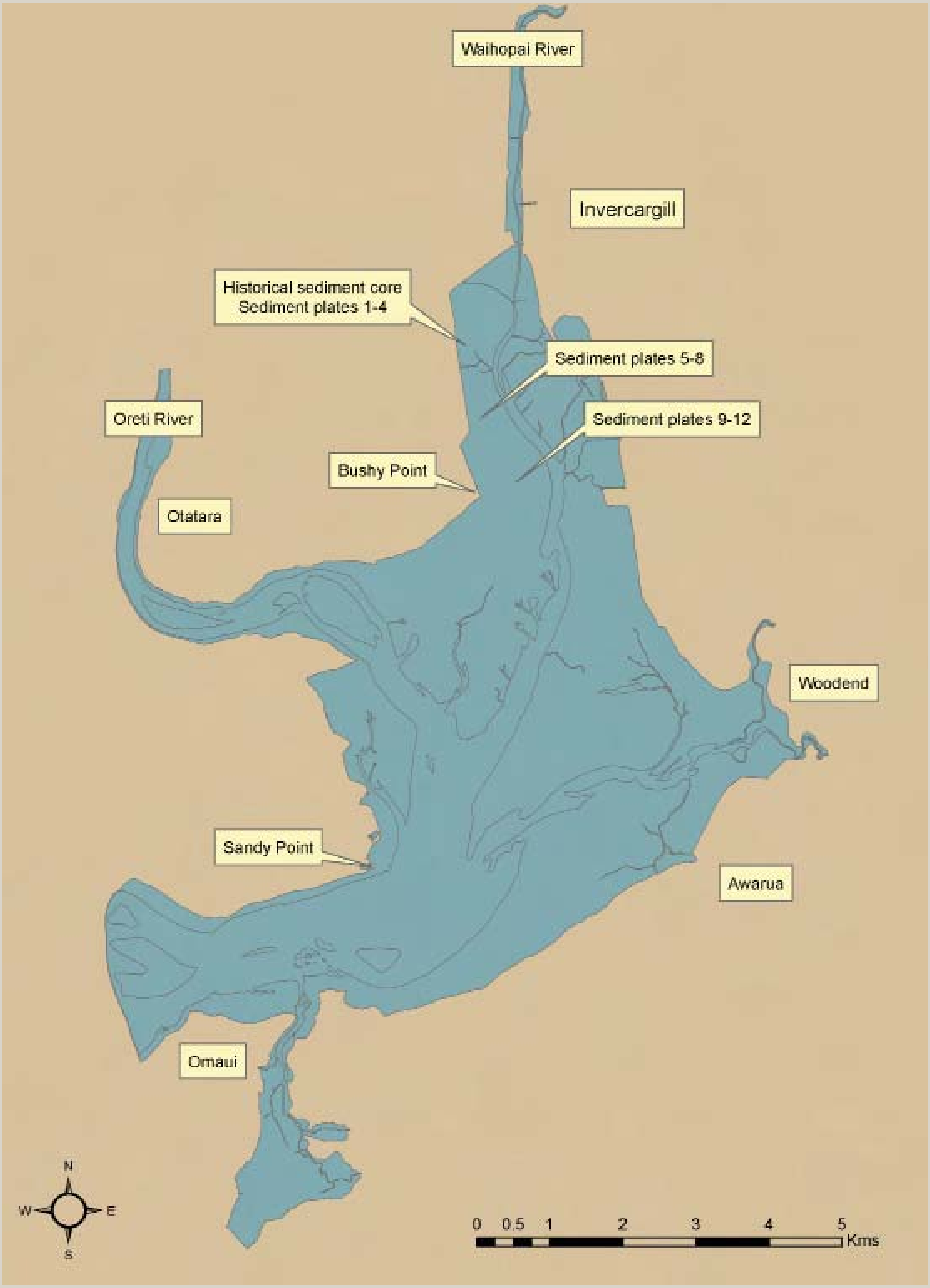
The report is structured in the following general sections:

Section 1 Introduction to the scope and structure of the study.
Section 2 Methods - broad scale mapping (substrate, vegetation, macroalgae, seagrass), sedimentation rate monitoring, and historical core dating.
Section 3 Estuary condition ratings.
Section 4 Results and discussion.
Section 5 Changes in the estuary: 2001-2007
Section 6 Summary and recommendations.
Section 7 Acknowledgements.
Section 8 References.

Appendix 1: Substrate and vegetation classification.
Appendix 2: Lead dating of sediment.

ArcMap 9.2 GIS shapefiles summarised in the current report are provided on a separate CD.

Figure 1. New River Estuary location map and sampling sites.



2. METHODS

BROAD SCALE HABITAT MAPPING

Broad scale mapping in the Waihopai Arm.

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: seagrass, macroalgae, rushland, etc). The approach, originally described for use in NZ estuaries by Robertson et al. (2002), uses a combination of aerial photography, together with detailed ground-truthing and GIS-based digital mapping, 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 2007 study, ES supplied ~1.6m/pixel resolution aerial photos flown in two series in March and May 2007. The individual photos were mosaiced and then georeferenced to rectified LINZ images using rubber-sheet splining within ArcMap. This resulted in a reduction in photo quality (primarily a loss of colour and increase in pixelisation) giving a final photo resolution of ~1.9m/pixel. Colour aerial photos covering the estuary at a scale of 1:5,000 were then laminated and two scientists ground-truthed the spatial extent of dominant habitat and substrate types by recording features directly on the laminated aerial photos over five days using lots of walking to reach the various habitat types.

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

- Dominant substrate.
- Percent cover of dominant macroalgae (e.g. *Enteromorpha*).
- Percent cover of dominant seagrass (*Zostera*).
- Dominant wetland vegetation.
- 200m wide terrestrial margin vegetation/landuse.

Substrate and vegetation were classified using the class definitions listed in Appendix 1. Vegetation was further 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).

Rushland, eastern side of New River Estuary.

BROAD SCALE HABITAT MAPPING (CONTINUED)

Figure 2. 20-50% *Gracilaria* cover south of the Oreti River mouth.

Figure 3. *Enteromorpha* (80-100% cover) in the lower Oreti River.

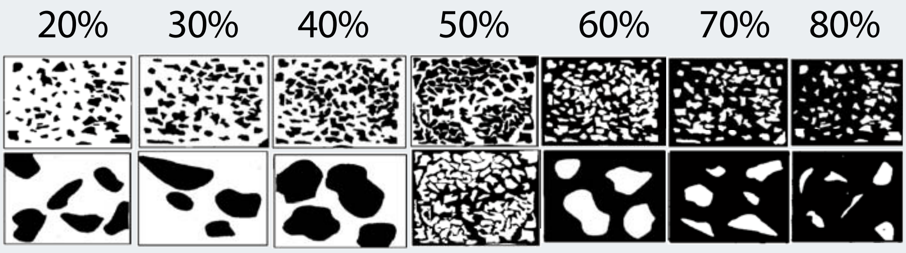
Macroalgae and Seagrass percentage cover

Using the same broad scale methods described above, macroalgae and seagrass within the estuary were visually classified based on six bands of percentage cover:

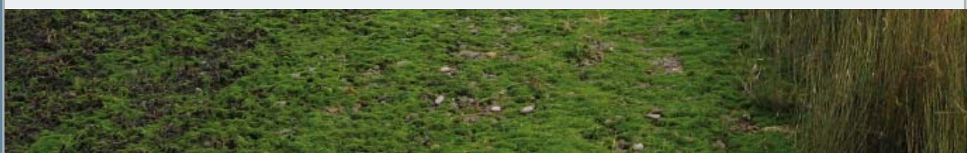
>1 %
1-10 %
10-20 %
20-50 %
50-80 %
80-100 %

Estimates of percentage cover were made by experienced scientists and recorded on aerial photos using a visual rating scale as presented below, with field examples shown in Figures 2 and 3. Subtidal macroalgal or seagrass beds were not mapped.

Visual rating scale for percentage cover estimates



This enabled a spatial picture (recorded in separate GIS layers) to be presented of where different densities of macroalgae and seagrass were concentrated within the lagoon.



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 lagoon 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.

As the GIS structure allows data to be easily managed, and contains a much greater level of detail than can be concisely presented in a summary report, the GIS should be used as the primary resource for assessing broad scale data. Results are summarised in the current report in Section 3.

2. METHODS (CONTINUED)

HISTORICAL SEDIMENTATION RATE

Figure 4. Inserting the sediment core.

Figure 5. Digging out the sediment core for removal.

To age sediment using radio-isotopes and calculate recent sediment deposition to ~100 years before present, a historical sediment core was taken from soft intertidal muds in the north of New River Estuary near the Waihopai Arm on 5 March 2007 (Figure 1). The core was collected by slowly inserting a 1m long, 10cm diameter PVC pipe into the estuary muds (Figure 4), measuring core compression, then removing the pipe (and intact core) from the estuary bed (Figure 5) and transporting it upright on a sled to the estuary margin for processing. From here, the PVC pipe was laid horizontally, split in half, the core photographed, and then cut into 2cm slices. Each slice was described, bagged and labelled. Samples from representative depths were selected based on the visual character of the core (e.g. changes grain size/texture/colour/biota) for analysis at the National Radiation Laboratory, Christchurch for the following:

Beryllium (^{7}Be): a natural isotope (very short half-life) used to indicate the depth of surface mixing (i.e. it will not be present in older sediments).
Caesium (^{137}Cs): an isotope with a half life of 30 years that was introduced by atmospheric nuclear weapons tests beginning in 1953 (i.e. will only be present in sediments post 1953).
Lead (^{210}Pb): a natural isotope (half life of 22 years); useful in dating sediments younger than 100-150 years. The difference between the ^{210}Pb concentration in the core sample below the surface and the concentration at the surface is used to age the sediment.
Radium (^{226}Ra & ^{228}Ra): the two most common isotopes of radium. ^{226}Ra has a long half-life (1,600 years) compared to that of ^{228}Ra (5.75 years). ^{226}Ra decays by emitting the nucleus of a helium atom (alpha particle), whereas ^{228}Ra emits an electron (beta particle).

At the National Radiation Laboratory, 15g samples of dried sediment were ground, homogenised, embedded in epoxy resin, and then left for 30 days to allow equilibration between ^{226}Ra, ^{214}Bi (Bismuth - a radon decay product), and ^{214}Pb. Samples were then placed on a Hyper Pure Germanium gamma detector, counted for 23 hours, and then counts were analysed with GENIE-2000 software. This allowed total ^{7}Be, ^{137}Cs, ^{210}Pb, ^{226}Ra, and ^{228}Ra to be calculated with a 95% confidence interval. Appendix 2 details methods used to calculate the historic sedimentation rates using lead isotope results.

FUTURE SEDIMENTATION RATE

Digging a hole to insert a sediment plate.

Determining the sedimentation rate from now into the future involves a simple method of measuring how much sediment builds up over a buried plate over known period of time. Once a plate has been buried, levelled, and the elevation measured, probes are pushed into the sediment until they hit the plate and the penetration depth is measured. A number of measurements on each plate are averaged to account for irregular sediment surfaces, and a number of plates are buried to account for small scale variance.

Three sites were established in New River Estuary southwest of the Waihopai Arm (Figure 1). At each of the three sites, four plates (20cm square concrete blocks) were buried approximately 30m apart in a square configuration deep in the sediments where stable substrate was located.

The position of each plate was marked with wooden stakes driven into the sediment, their GPS positions logged, and the depth from the undisturbed mud surface to the top of the sediment plate and the top of the wooden stakes was recorded. In the future, these distances will be measured annually and, over the long term, will provide a measure of rates of sedimentation in the estuary.

3. ESTUARY CONDITION RATINGS

OVERVIEW

RATING
Very Good
Good
Fair
Poor
Early Warning Trigger

At present, there are no formal criteria for rating the overall condition of estuaries in NZ, and development of scientifically robust and nationally applicable condition ratings requires a significant investment in research and is unlikely to produce immediate answers.

Therefore, to help ES interpret their monitoring data, a series of interim broad and fine scale estuary condition ratings have been proposed for Southland's estuaries (Robertson & Stevens 2006, 2007, this report). The interim broad scale condition ratings presented below are based on a review of monitoring data and expert opinion. They indicate whether monitoring results reflect poor, fair, good, or very good conditions, and also include an "early warning trigger" so that ES is alerted where rapid or unexpected change occurs. For each of the condition ratings, a recommended monitoring frequency is proposed and a recommended management response is suggested. In most cases the management recommendation is simply that ES develop a plan to further evaluate an issue and consider what response actions may be appropriate.

The interim condition ratings for New River Estuary, based on Robertson & Stevens (2006, 2007) are presented below along with a brief rationale for their use. At this stage, they reflect the best guidance able to be provided based on the available information and budget. It is expected that the proposed ratings will continue to be revised and updated as better information becomes available. Most of the broad scale condition ratings are based around a percentage change from baseline conditions (the baseline being the first broad scale map of the estuary). While this focuses on recent change (broad scale mapping baselines have been established in Southland estuaries in a staged manner since 2001), and does not include often major historical changes to the estuary (other than for historical sedimentation rate), it does focus monitoring and assessment effort where most pressures and current management initiatives are concentrated.

Soft Mud Area

Estuaries are a sink for sediments. However, the extent of build-up of soft muds in estuaries can be increased by catchment developments. Excessive sedimentation of muds in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access.

SOFT MUD CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Area of cover (ha) not increasing	Monitor at 5 year intervals after baseline established
Good	Increase in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Increase in area of cover (ha) 5-15% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Poor	Increase in area of cover (ha) >15% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Trend of increase in area of cover (ha)	Initiate Evaluation and Response Plan

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	>20 mm/yr	Monitor annually. Manage source
High	10-20 mm/yr	Monitor annually. Manage source
Moderate	5-10 mm/yr	Monitor at 5 yearly intervals
Low	1-5 mm/yr	Monitor at 5 yearly intervals
Very Low	<1mm/yr (typical pre-European rate)	Monitor at 5 yearly intervals
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

3. ESTUARY CONDITION RATINGS (CONTINUED)

Macroalgae Percent Cover

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.

MACROALGAE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	%cover <1%. No nuisance conditions	Monitor at 5 year intervals after baseline established
Good	%cover 1-10%. No nuisance conditions	Monitor at 5 year intervals after baseline established
Fair	%cover 10-50%. Isolated nuisance conditions	Monitor yearly. Initiate Evaluation & Response Plan
Poor	%cover >50%. Widespread nuisance conditions	Monitor yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Trend of % cover increasing	Initiate Evaluation and Response Plan

Seagrass Percent Cover

Seagrass (*Zostera* sp) grows in soft sediments in NZ estuaries. 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 lack of oxygen and production of sulphide).

SEAGRASS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Area of cover (ha) not declining	Monitor at 5 year intervals after baseline established
Good	Decline in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Decline in area of cover (ha) 5-20% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Poor	Decline in area of cover (ha) >20% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Trend of decline in area of cover (ha)	Initiate Evaluation and Response Plan

Saltmarsh Area

A variety of saltmarsh species 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. They are sensitive to a wide range of pressures including land reclamation, margin development, flow regulation, sea level rise, grazing, wastewater contaminants, and weed invasion.

SALTMARSH CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Area of cover (ha) not decreasing	Monitor at 5 year intervals after baseline established
Good	Decline in area of cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Decline in area of cover (ha) 5-20% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Poor	Decline in area of cover (ha) >20% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Trend of decrease in area of cover (ha)	Initiate Evaluation and Response Plan

Terrestrial Margin Area

The presence of a terrestrial margin dominated by native vegetation almost certainly acts as an important buffer between developed areas and the wetland and lagoon. This buffer protects against introduced weeds and grasses, and naturally filters sediments and nutrients.

TERRESTRIAL MARGIN CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	Terrestrial margin is 100% native	Monitor at 5 year intervals after baseline established
Good	Decline in native cover (ha) <5% from baseline	Monitor at 5 year intervals after baseline established
Fair	Decline in native cover (ha) 5-10% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Poor	Decline in native cover (ha) >10% from baseline	Monitor 5 yearly. Initiate Evaluation & Response Plan
Early Warning Trigger	Decline in area of native cover in margin (ha)	Initiate Evaluation and Response Plan

4. RESULTS AND DISCUSSION

BROAD SCALE MAPPING OF SEDIMENT TYPE

The results show that a variety of sediment types occur in the estuary (Table 3 and Figure 6). Excluding subtidal areas covered by water at low tide (1,336.4ha), sand is by far the most dominant substrate in the estuary (77% firm mud/sand and mobile mud/sand), with most of this substrate located in the central estuary basin and towards the estuary mouth.

Soft and very soft mud is another major feature, comprising 21% of the estuary and dominating in the upper northern reaches, including the Waihopai Arm (where very deep soft mud is widespread), and less extensively in sheltered arms to the east and west. There is a sharp transition near Windy Point where the substrate changes from sand in the central basin to soft muds in the northern arm over a distance of only a few metres. This contrasts with more common transition distances of 10's of metres seen in other Southland estuaries, and may reflect a physical constraint on soft sediment buildup related to either the Oreti River or the physical conditions in the central basin of the estuary.

Very soft mud in the northern arm of New River Estuary.

Another major feature of the estuary is the artificial structures (e.g. rockwalls) protecting the reclaimed shorelines in the north and east of the estuary. Although they do not cover a large spatial area, they extend long distances along the shoreline, commonly have steep faces, and generally create conditions unsuitable for rushland (see photo).

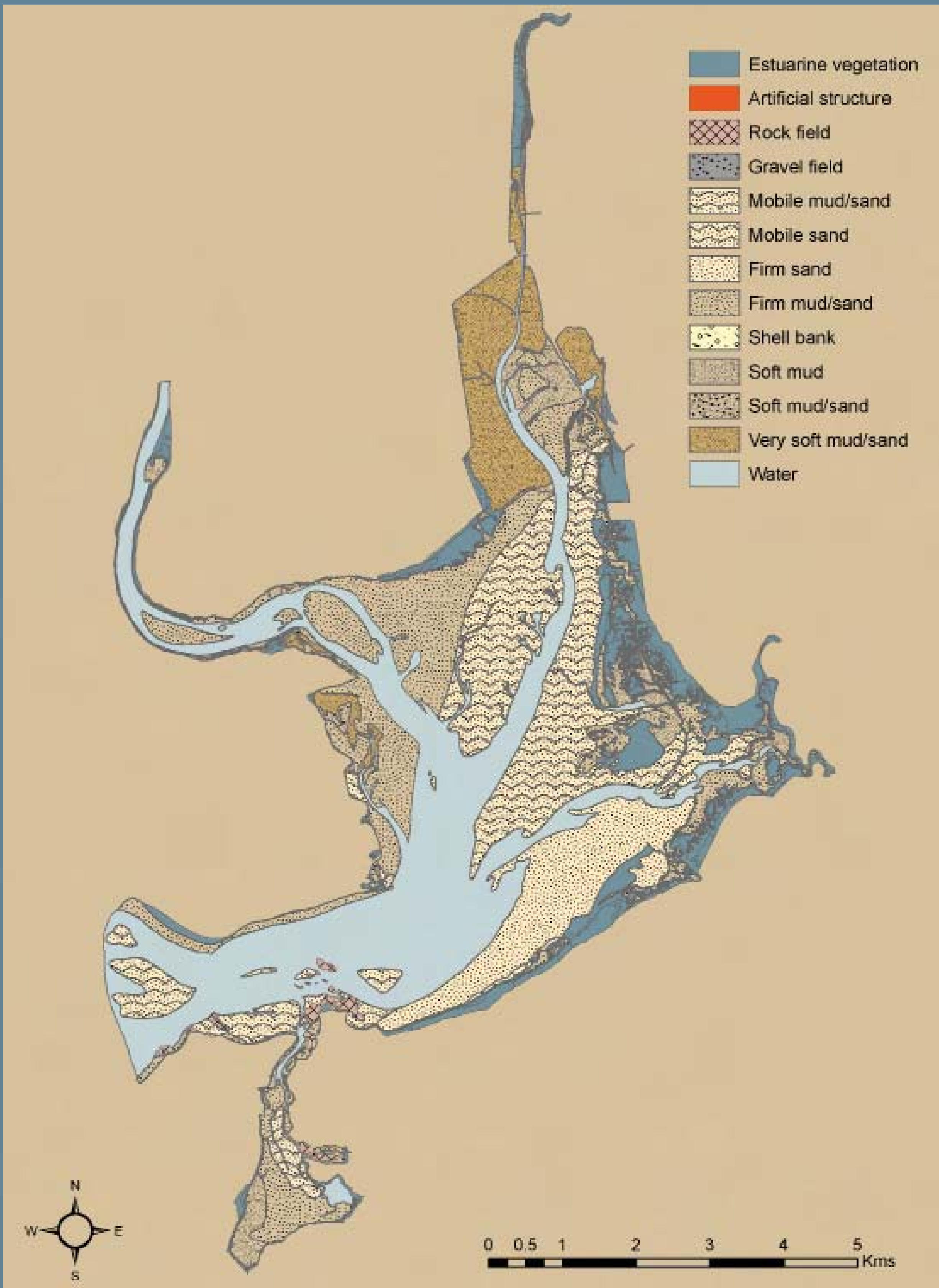
Rock, cobble, and gravel fields were relatively uncommon and were located predominantly around Omaui and the inlet on the southern shore of the estuary.

Example of a manmade rockwall in the Waihopai Arm.

Table 3. Summary of dominant substrate type results, March 2007.

Dominant Substrate Type	Area (ha)	Percentage	Comments
Artificial Structure	4.97	0.2	Predominantly narrow strips along the edge of reclaimed land to the north and east consisting of Rockfield (4.69ha) Boulderfield (0.24ha) Seawall (0.04ha).
Rockfield	28.72	1.1	Relatively uncommon and located predominantly near Omaui and around the inlet on the southern shore of the estuary.
Cobblefield	0.69	0.0	
Gravelfield	10.30	0.4	
Shellbank	19.45	0.7	Narrow banks along the southeast of the estuary.
Mobile Sand	448.71	16.6	Predominantly located in the central part of the estuary and around the estuary mouth.
Mobile Mud/Sand	435.83	16.2	
Firm Sand	339.00	12.6	Mostly in the southeast of the estuary.
Firm Mud/Sand	839.12	31.1	Predominantly to the west around the Oreti River mouth.
Soft Mud/Sand	7.73	0.3	
Soft Mud	214.06	7.9	Predominantly in the northern arm of the estuary north of Bushy Point and in the Waihopai arm.
Very Soft Mud	347.07	12.9	
TOTAL	**2695.7**	**100**	

Figure 6. Map of Sediment Type - New River Estuary, 2007.



HISTORICAL SEDIMENT CORE ANALYSIS

0-6 cm	Very soft mud Mud snail (*Amphibola*) shells
6-20 cm	Soft mud Live worms
20-34 cm	Soft mud No shell
34-48 cm	Soft mud Brittle (old) mud snail shells
52-56 cm	Muddy sand Cockle & *Mactra* shells
56-62 cm	Sandy mud Large *Mactra* shells
62-69 cm	Sand Large *Mactra* shells

Figure 7. New River Estuary historical sediment core.

The New River Estuary core was collected from offshore, intertidal sediments located at the northern end of the estuary in very soft muds (Figure 1, Table 4) on 5 March 2007. The core was compressed by 33% (340mm) during collection (total corer depth 1030mm, compressed core depth 690mm). While it is possible that some sediment bypass occurred, it was assumed that all core shortening was a result of sediment compaction spread equally over the entire core. A description of the core is summarised in Figure 7, while compressed and uncompressed core depths, along with the results of the radio-isotope analysis by the National Radiation Laboratory are presented in Table 5.

The upper part of the core (Figure 7) was soft mud, the top 20cm well oxygenated, with live worms present. Mud snail (*Amphibola*) shells were present near the surface. Between 6cm and 52cm the core was predominantly smooth mud, largely free of shells other then a few fragments between 34 and 48cm. At the lower end of the core, soft mud became gradually mixed with sand at 52-56cm and cockle and *Mactra* shells appeared. From 56-62cm the sand content steadily increased and the mud content decreased and large *Mactra* shells were present. From 62-69cm the core was crumbly sand with no obvious mud component. The estimated age of the sediments, derived from radio-isotope analysis, is shown on Figure 7 and described below.

Beryllium: Because it has a short half life (53.3 days) and originates from the atmosphere, ^{7}Be is used to determine the depth of aquatic sediments that have been recently exposed to the atmosphere (i.e. the upper mixed sediment layer exposed within the past few months). The presence of ^{7}Be in the upper 6cm of the New River core and its absence below 6-8cm (Table 5) indicates a 6-8cm deep well-mixed layer at this site. This is consistent with evidence of both physical and biological mixing in the core (Figure 7). Below this depth, there was a relatively uniform decrease in isotope values providing data suitable for ageing the core to an uncompressed depth of 56-58cm for ^{137}Cs, and to 50-52cm for ^{210}Pb.

Table 4. Location of New River Estuary historical sediment core.

Site	No.	DATE	NZMG EAST	NZMG NORTH
Upper North Arm	1	5/3/07	2150741	5409458

HISTORICAL SEDIMENT CORE ANALYSIS (CONT.)

Caesium: Peak atmospheric fallout of ^{137}Cs in New Zealand occurred in 1964, with elevated levels occurring from 1959-1964 (Cambray et al. 1979; Loughran et al. 1988). Based on this, the maximum depth of ^{137}Cs activity has been ascribed to 1960 and used to estimate a gross sedimentation rate over the past 47 years (1960-2007) of 16.4mm/year. As ^{137}Cs activity could also have been present in sediments from 58-68cm that were not analysed, an upper range is 19.8mm/year. ^{137}Cs activity extends down to the sand portion of the lower core, indicating that the deposition of mud in this part of the estuary has occurred predominantly over the past 40-50 years.

Table 5. Results of the radio-isotope analysis of the historical sediment core.

Compressed Depth (cm)	Uncom-pressed Depth (cm)	Total ^{210}Pb	^{226}Ra (=Supported ^{210}Pb)	Unsupported ^{210}Pb	^{137}Cs	^{7}Be
0-4	5.32	54.9	18.6	36.3	1.26	30.0
4-6	7.89	57.6	17.9	39.7	1.89	19.8
6-8	10.64	54.5	17.4	37.1	1.79	5.4
10-12	15.96	51.4	17.9	36.2	1.55	<6.0
16-18	23.94	41.2	17.7	23.5	1.62	<6.0
22-24	31.92	36.3	17.8	18.5	1.51	<6.3
36-38	50.54	29.4	17.8	11.6	1.58	<6.4
50-52	69.17	16.5	14.8	1.7	1.24	<6.4
56-58	77.15	14.2	15.8	-1.6	0.46	<6.6
68-70	93.11	10.1	11.6	-1.5	<0.49	<6.3

Lead: ^{210}Pb is used to determine sedimentation rates over the last 100-150 years and enables an estimate to be made of different deposition rates within this period. Calculation details are provided in Appendix 2 and results are presented in Table 6 and Figure 7. The results show that the sediment deposition rate prior to ~1967 was relatively low (3mm/year) and occurred when there was a transition from muddy sand to soft mud. The muddy sand sediments at 50-52cm are aged at around 100 years old. Since ~1967, sedimentation rates have been much higher (range 7-28mm/year, average 12.7mm/year). This is consistent with the ^{137}Cs results indicating muddy sediments have been deposited mainly in the past 40-50 years.

The ^{210}Pb and ^{137}Cs results show an overlap in ages at the bottom of the core with ^{137}Cs indicating sediments at 56-58cm are ~50 years old, while ^{210}Pb indicates overlying (theoretically younger) sediments at 52-56cm are ~100 years old. Rechecking with the National Radiation Laboratory has confirmed the validity of the results and provided a likely explanation. As the date discrepancy occurs within a 4-8cm band when the sediment changes from sand to mud it is consistent with older underlying sands (historically present in this part of the estuary) mixing with younger overlying muds. With surface mixing likely to be in the order of 6-8cm (based on the ^{7}Be results), and recent deposition rates averaging 12.7mm/year, mixing of layers within this band would occur across decades of deposition, more than enough to explain the discrepancy. This process would be amplified by the mixing of material laid down during periods with low sedimentation rates, during which small vertical differences reflect long time intervals. Locals we talked to thought that mud was being deposited when the Waihopai River flooded, with a large flood in 1984 being a potentially significant source.

HISTORICAL SEDIMENT CORE ANALYSIS (CONT.)

Sedimentation Rating for New River Estuary.

RATING	PERIOD
High	1967-2007
Low	1906-1967

Overall, the historical core indicated the following key results:

- The upper sediments (0-8cm depth) are rapidly mixed by physical/biological processes.
- Average sedimentation rates over the past 40-47 years were 12.7-16.4mm/year based on lead and caesium dating respectively.
- Between 1906 to 1967 sedimentation rates based on lead dating were in the low range at 3.0mm/year.
- The sedimentation rate since the 1960's is very high by comparison with pre-European times, and is in the high category for NZ estuaries.
- The upper New River Estuary was historically sandy, with surf clams and cockles common in areas now covered by deep soft muds.

Table 6. Sedimentation rates using unsupported lead profiles.

Compressed Depth (cm)	Uncom-pressed Depth (mm)	Unsupported ^{210}Pb	Years Before Present (date)	Period (years)	Period Length (years)	Sediment Depth Deposited in Period (mm)	Sedimentation Rate in Period (mm/yr)
10-12	160	33.5	6 (2001)	2001-2007	5.7	159.6	28.0
16-18	239	23.5	17 (1990)	1990-2001	11.4	79.8	7.0
22-24	319	18.5	25 (1982)	1982-1990	7.7	79.8	10.4
36-38	505	11.6	40 (1967)	1967-1982	15.0	186.2	12.4
50-52	692	1.7	101 (1906)	1906-1967	61.7	186.2	3.0

SEDIMENTATION PLATES

The location of the 12 sedimentation plates buried in soft muddy sediments near the Waihopai Arm are shown in Figure 1, while the distance (mm) from the sediment surface to the buried plate, and the height of the two marker stakes either side of each plate above the sediment surface is shown in Table 7. Following establishment of this baseline, ongoing monitoring results can be used to determine the sedimentation rate in the estuary, with a sediment condition rating developed and used to assess any changes.

Table 7. Location and depth of sedimentation plates and height of marker stakes.

Site	No.	DATE	NZMG EAST	NZMG NORTH	Height of West Stake (mm)	Height of East Stake (mm)	Plate Depth (mm)
Upper Nth Arm	1	27/2/07	2150718	5409452	185	195	403
Upper Nth Arm	2	27/2/07	2150729	5409477	190	190	290
Upper Nth Arm	3	27/2/07	2150758	5409471	190	190	325
Upper Nth Arm	4	27/2/07	2150744	5409431	190	190	270
Central Nth Arm	5	28/2/07	2150922	5408407	190	190	280
Central Nth Arm	6	28/2/07	2150937	5408433	190	190	382
Central Nth Arm	7	28/2/07	2150971	5408421	190	190	300
Central Nth Arm	8	28/2/07	2150955	5408391	190	190	400
Lower Nth Arm	9	11/3/07	2151415	5407525	190	190	226
Lower Nth Arm	10	11/3/07	2151441	5407549	190	190	265
Lower Nth Arm	11	11/3/07	2151459	5407526	190	190	240
Lower Nth Arm	12	11/3/07	2151435	5407506	170	190	265


Measuring sediment depth: New River Estuary

MACROALGAL MAPPING

Enteromorpha (>80% cover) along the north bank of the Oreti River.

Macroalgal Rating for New River Estuary, 2007.

RATING	DEFINITION
Fair	Cover 10-50%. Isolated nuisance conditions

Enteromorpha and *Gracilaria* (20-50% cover) in northern New River Estuary.

The results of the intertidal macroalgal survey (Table 8 and Figure 8) showed:

- Most of the intertidal area (89%) was rated as having a low or very low percentage cover.
- The dominant macroalgae were *Gracilaria chilensis* and the green alga *Enteromorpha* sp.
- Because of the size of New River Estuary, areas rated as low-moderate to moderate (3.7%) and high to very high (6.9%) represent relatively large areas (99.4ha and 185.9ha respectively).
- Growth was present in certain preferred locations.

Table 8. Summary of macroalgal cover results, March 2007.

Percent Cover Rating and Category		Area (ha)	Percentage	Dominant Species
Very low	<1%	1565.29	58.1	
Low	1-10%	845.17	31.4	*Gracilaria chilensis*
Low-Moderate	10-20%	40.42	1.5	*Gracilaria chilensis*
Moderate	20-50%	58.97	2.2	*Gracilaria chilensis, Enteromorpha*
High	50-80%	41.58	1.5	*Enteromorpha, Gracilaria chilensis*
Very High	>80%	144.27	5.4	*Gracilaria chilensis, Enteromorpha*
TOTAL		**2695.7**	**100**	

Although macroalgal growth was relatively low throughout most of the estuary in March 2007, it was present in relatively high densities at certain locations, particularly near channels, at the seaward base of rushland, and in sheltered embayments.

To the east, *Enteromorpha* had established extensively in the residual root systems of *Spartina* that had been sprayed and killed, and was widespread throughout the intertidal area (mostly 1-10% cover). *Enteromorpha* had also established on the residual roots of rushland that had been eroded by wave action on the north bank of the Oreti River mouth (see photo left). In these areas cover was very high, although *Enteromorpha* plants were relatively small.

Dense mats of *Gracilaria* were present in the centre, west and north of the estuary, and were also present in clumps throughout the estuary (see photo below). Where dense mats were present, sediments were commonly very soft, anaerobic, and sulphide rich. Subtidal beds of both *Gracilaria* and *Enteromorpha* were also observed in the central basin.

Because nutrient concentrations almost always exceed levels that limit sea lettuce growth (Pederson and Borum 1997), the absence of large areas of nuisance macroalgal cover may be attributed to (primarily) exposure to strong winds and other limiting factors such as salinity stress, or grazing within the estuary.

Overall, macroalgal cover was rated fair, reflecting that more than 10% of the estuary had a macroalgal cover >10%, and isolated nuisance conditions were observed.

Figure 8. Map of Macroalgal Cover - New River Estuary, March 2007.

4. RESULTS AND DISCUSSION (CONTINUED)

SEAGRASS MAPPING

The results of the intertidal seagrass survey (Table 9 and Figure 9) showed:

- Most of the intertidal area (91.5%) was rated as having a low or very low percentage cover.
- The dominant seagrass was *Zostera*.
- Highest densities of *Zostera* were in the northern arm, the eastern arm, near Omaui, and in the Oreti River.
- Because of the size of New River Estuary, areas rated as low-moderate to moderate (3.3%) and high to very high (3.5%) represent relatively large areas (88.8ha and 95.1ha respectively).

Table 9. Summary of seagrass cover results, March 2007.

Percent Cover Rating and Category		Area (ha)	Percentage	Dominant Species
Very low	<1%	2466.3	91.5	
Low	1-10%	45.5	1.7	*Zostera*
Low-Moderate	10-20%	50.6	1.9	*Zostera*
Moderate	20-50%	38.2	1.4	*Zostera*
High	50-80%	40.4	1.5	*Zostera*
Very High	>80%	54.7	2.0	*Zostera*
TOTAL		**2695.7**	**100**	

Seagrass growth was most widespread in the very soft muds in the northern arm of the estuary as a mix of dense *Zostera* patches interspersed with soft muds and lower density *Zostera* patches (see photo below right). The beds appeared healthy, relatively stable and, despite the soft muds present in this part of the estuary, relatively free of sediment (see photo below left).

To the east, seagrass was in sandier sediments and beds tended to be less dense than in the north. *Zostera* shoots with a <1% cover were observed throughout the eastern side of the estuary.

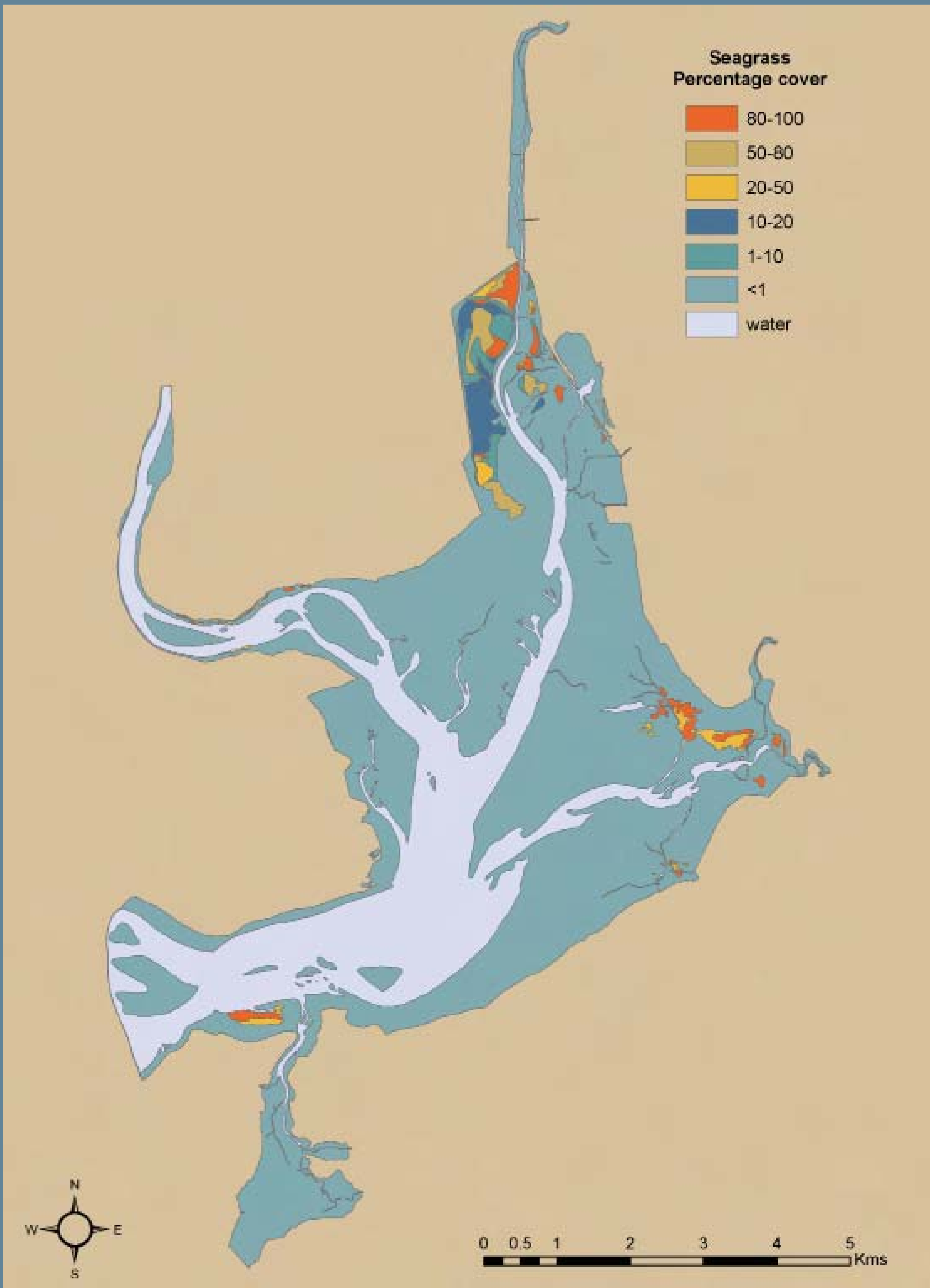
Patches of *Zostera* were also common along the banks of the Oreti River, and while outside the scope of the current work, subtidal beds were common in this area.

The current survey provides a baseline for comparing future changes using the condition ratings proposed in Section 3.

Examples of extensive cover of *Zostera* in northern New River Estuary.

Photo: Environment Southland

Figure 9. Map of Seagrass Cover - New River Estuary, March 2007.



SALTMARSH MAPPING

The results of the wetland vegetation survey (Table 10 and Figure 10) showed:

- 17% (554ha) of the intertidal area of the estuary was vegetated.
- The most extensively vegetated saltmarsh areas were in the east, and adjacent to Bushy Point in the northwest.
- Saltmarsh vegetation was relatively sparse where the estuary had been historically reclaimed.
- The dominant vegetation (42%) was rushland (97% jointed wire rush - *Leptocarpus similis*), followed by grassland (23%), and herbfield (18%).
- Extensive herbfields had established in front of duneland in the Oreti River, and on the residual root systems of the invasive cord grass *Spartina* that had been sprayed and killed in the eastern part of the estuary.

Table 10. Summary of saltmarsh vegetation results, March 2007.

Class	Dominant Vegetation	Area (ha)	Percentage
Scrub		6.1	1.1
	Coprosma propinqua (mingimingi) *Ulex europaeus* (gorse)	5.5 0.6	1.0 0.1
Estuarine shrubs		48.2	8.7
	Plagianthus divaricatus (saltmarsh ribbonwood)	48.2	8.7
Tussockland		12.7	2.3
	Puccinella stricta (salt grass) *Phormium tenax* (NZ flax) *Poa cita* (silver tussock)	10.1 1.7 0.9	1.8 0.3 0.2
Duneland		18.9	3.4
	Ammophila arenaria (marram grass)	18.9	3.4
Sedgeland		6.9	1.2
	Schoenoplectus pungens (three square) *Isolepis cernea* (slender clubrush)	6.0 0.9	1.1 0.2
Grassland		126.9	22.9
	Festuca arundinacea (tall fescue)	126.9	22.9
Rushland		234.8	42.4
	Leptocarpus similis (jointed wire rush) *Juncus gerardii* (saltmarsh rush) *Isolepis nodosa* (knobby clubrush) *Juncus gregiflorus*	227.8 6.7 0.2 0.1	41.1 1.2 0.0 0.0
Herbfield		99.5	18.0
	Enteromorpha (green ribbon) *Samolus repens* (primrose) *Selliera radicans* (primrose) *Leptinella dioica* *Sarcocornia quinqueflora* (glasswort) *Cotula coronopifolia* (bachelors button) *Crassula helmsii*	56.2 34.5 5.5 2.0 0.8 0.5 0.03	10.1 6.2 1.0 0.4 0.1 0.1 0.0
TOTAL		**554**	**100**

4. RESULTS AND DISCUSSION (CONTINUED)

SALTMARSH MAPPING (CONTINUED)

Saltmarsh vegetation was most extensive in the eastern arm of the estuary where wide beds of rushland extended out over intertidal flats. Reclamation and artificial seawalls have historically replaced large areas of this type of habitat in the estuary.

In the east of the estuary at the seaward margin of the rushland, the residual root systems of the invasive cord grass *Spartina* that had been sprayed and killed had been colonised by macroalgae (*Enteromorpha*) (left photo), as well as a variety of herbfield species (right photo). The removal of *Spartina* and the extensive herbfields that have established in its place was the most noticeable change in the estuary vegetation since 2001. It is also obvious that this part of the estuary is well supplied with nutrients with macroalgae growing wherever firm substrate was present.

***Spartina* roots colonised by macroalgae and herbfield in the Eastern Arm.**

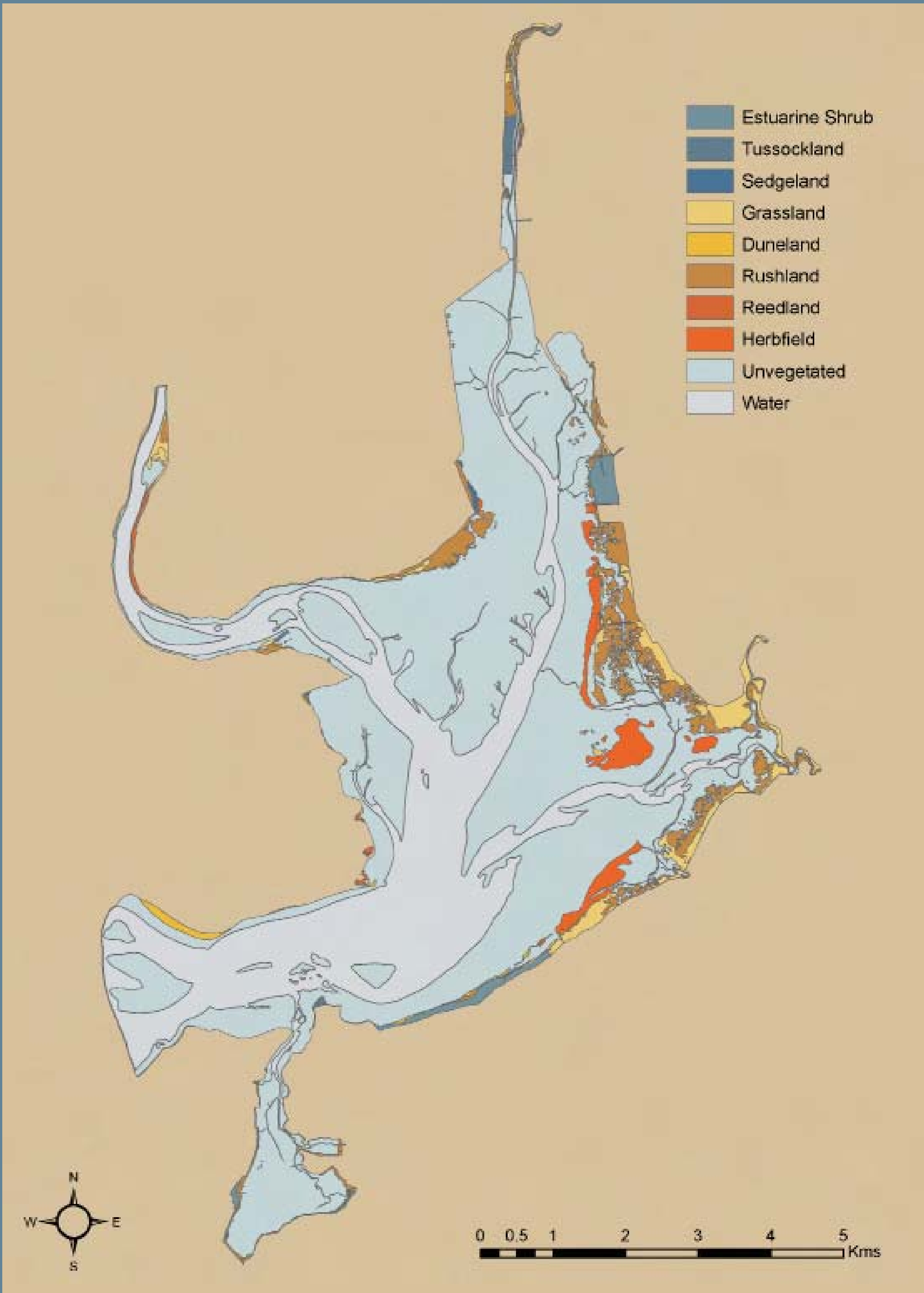
In the Waihopai Arm, mixed areas of tussockland, grassland and herbfields were a common feature between the floodbanks and the main channel.

Tussock, grass and herbfield vegetation: Waihopi Arm.

Bushy Point, north of the Oreti River mouth, was one of the few areas where there was a natural transition from rushland to terrestrial forest. Although the western side of the estuary is flanked by forest areas, it is mostly separated from the estuary by low cliffs.

Duneland was a notable feature near Omaui where steep marram grass dunes flank the estuary (see photo below), at the back of Oreti Beach, and on the east bank of the Oreti River.

Figure 10. Map of Saltmarsh Vegetation - New River Estuary, March 2007.



TERRESTRIAL MARGIN MAPPING

The results of the 200m terrestrial margin survey (Table 11 and Figure 11) showed:

- The 200m wide terrestrial vegetation buffer covered 1,366ha.
- Vegetation was dominated by grassland (59%), then a combination of scrub and forest (28%).
- The eastern estuary margin was almost exclusively channelled and drained grazed pasture.
- Forest and scrub were most common to the west of the estuary.

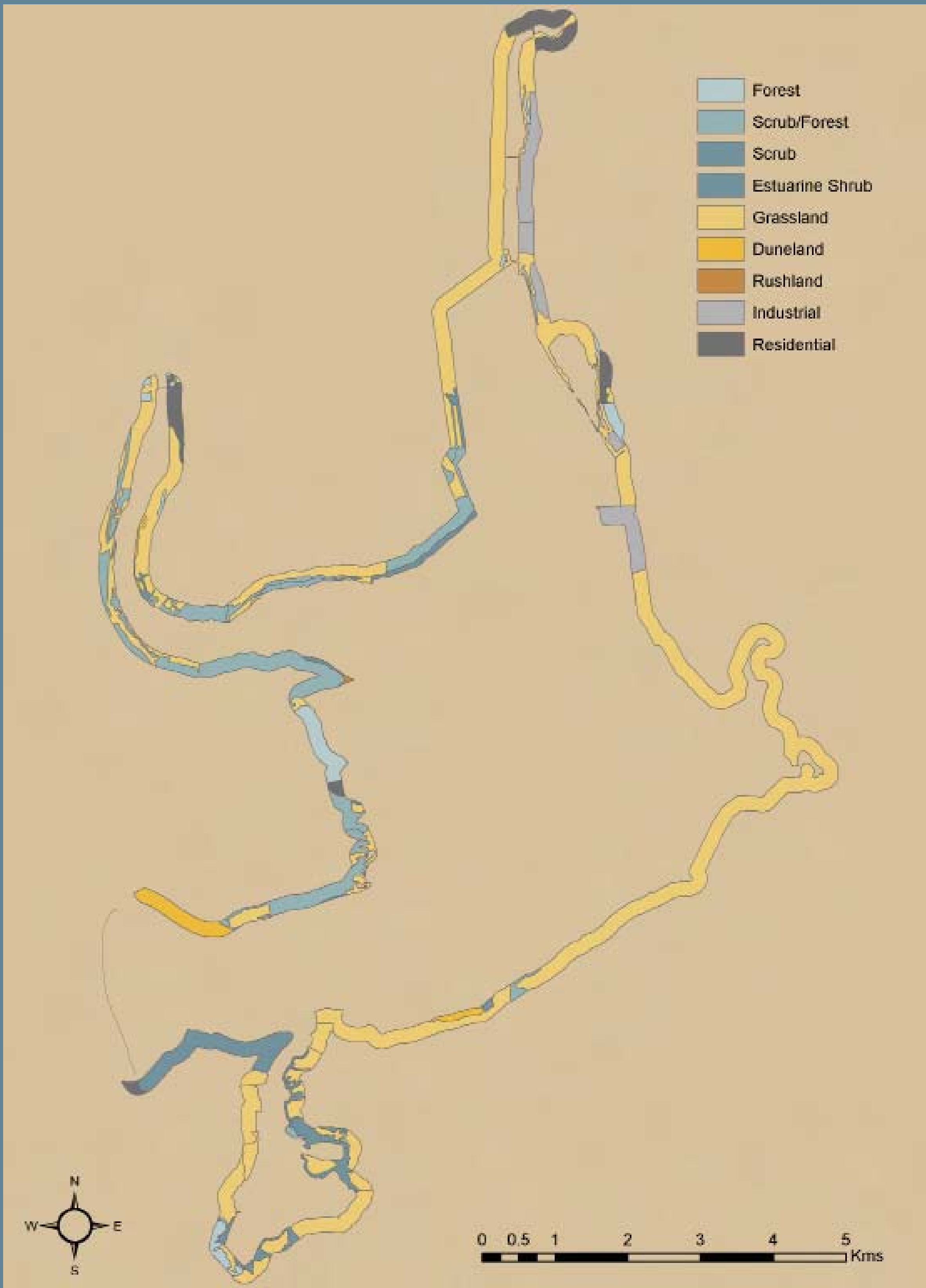
Terrestrial grassland generally extended to artificial seawalls along the estuary edge, or to floodbanks bordering industrial and residential developments. In these areas, there was a relatively abrupt change from terrestrial cover to the estuary and very limited natural buffering capacity remained. To the west, forest and scrub were the dominant cover, often mixed with grassland particularly around the Oreti River. Immediately west of Bushy Point was one of the few remaining areas in New River where there is a natural transition from wetland rushland to estuarine shrubs to terrestrial scrub and forest.

Natural duneland was limited to a strip on the eastern bank of the Oreti River, a narrow band near Awarua, and at Oreti Beach at the mouth of the estuary.

Table 11. Summary of 200m terrestrial margin vegetation, March 2007.

Class	Dominant Vegetation	Area (ha)	Percentage
Forest		55.5	4.1
	Exotic forest Mixed native and exotic forest Native forest	35.9 10.8 8.8	2.6 0.8 0.6
Scrub/Forest		209.9	15.4
	Mixed native and exotic scrub/forest *Pinus radiata* (pine tree) Native scrub/forest *Cupressus macrocarpa* (macrocarpa)	87.3 75.4 44.4 2.8	6.4 5.5 3.2 0.2
Scrub		115.1	8.4
	Mixed native and exotic scrub Native scrub *Ulex europaeus* (gorse) Exotic Scrub	74.2 24.0 15.8 1.1	5.4 1.8 1.2 0.1
Estuarine shrubs		4.3	0.3
	Plagianthus divaricatus (saltmarsh ribbonwood)	4.3	0.3
Duneland		35.7	2.6
	Ammophila arenaria (marram grass)	35.7	2.6
Grassland		806.0	59.0
	Grassland (unidentified mixed grasses) *Festuca arundinacea* (tall fescue)	800.8 5.1	58.6 0.4
Rushland		1.2	0.1
	Isolepis nodosa (knobby clubrush)	1.2	0.1
Residential		62.5	4.6
Industrial		76.0	5.6
TOTAL		**1366.2**	**100**

Figure 11. Map of 200m Terrestrial Margin Vegetation - New River Estuary, March 2007.



5. CHANGES IN THE ESTUARY: 2001-2007

CHANGES IN THE ESTUARY: 2001-2007

When New River Estuary was first mapped during development of the EMP in 2001 (see Robertson et al 2002) the results established a baseline for measuring future changes in the estuary. Recently developed condition ratings (Section 3) provide a way to assess changes for key indicators. However, it is not possible to directly compare the 2001 and 2007 results based on GIS shapefiles because:

- The total area mapped in 2007 included additional areas not covered by the 2001 photos.
- Some 2001 habitat was reclassified in 2007 to better reflect the features present.
- There were differences in the positional accuracy of the 2001 and 2007 aerial photos supplied.
- Reduced photo clarity and resolution (0.4m/pixel in 2001 to 1.9m/pixel in 2007) limited the detail able to be mapped in 2007 and subsequently the ability to detect small-scale change.
- Assessment methods for macroalgae and seagrass had changed.

Consequently, assessment of changes in the estuary between 2001 and 2007 have been based on a combined assessment of the GIS shapefiles adjusted to the area mapped in 2001, aerial and field photography, and field observations. The following tables present the key changes in the estuary between 2001 and 2007 and, where appropriate, condition ratings are used to evaluate the changes and make recommendations for future monitoring.

SALTMARSH VEGETATION: Overall, the total area of saltmarsh vegetation changed little since 2001, although there were significant changes in composition, primarily reedland and herbfield, and some re-classification of rushland to provide better definition of the vegetation features present. Table 12 shows the key broad scale saltmarsh vegetation changes from 2001 and 2007 were as follows:

- **Reedland:** The absence of reedland in 2007 is directly attributable to the successful eradication of *Spartina* between 2001 and 2007.
- **Herbfield:** The increase of herbfield in 2007 is due to the colonisation of the dead *Spartina* beds with a variety of herbfield species (as well as the macroalgae *Enteromorpha*).
- **Rushland:** The apparent decrease from 2001 is primarily due to rushland being more accurately classified in 2007 as rushland, grassland, estuarine shrubs and scrub. A small area of localised erosion of rushland was evident on the north bank of the Oreti River.
- **Grassland:** The apparent increase from 2001 is due to some areas of rushland being more accurately classified in 2007 as grassland.
- **Duneland:** The apparent increase from 2001 is due to some areas of grassland being more accurately classified in 2007 as duneland.
- **Tussockland, Scrub and Estuarine Shrubs:** Changes relate to reclassification in 2007.

Table 12. Summary of 2001 and 2007 broad scale vegetation mapping results.

Vegetation Class	2001 Area (ha)	2001 Percent	2007 Area (ha)	2007 Percent
Scrub		0.0	6.1	1.3
Estuarine shrubs		0.0	48.2	10.4
Tussockland	14.9	3.2	12.64	2.7
Duneland	2.6	0.6	5.3	1.1
Sedgeland	4.3	0.9	6.13	1.3
Grassland	14.4	3.1	113.8	24.6
Reedland	112.3	23.9	0	0.0
Rushland	318.9	67.8	232.3	50.3
Herbfield	3.1	0.6	37.8	8.2
TOTAL	470.4	100	462.3	100

CHANGES IN THE ESTUARY: 2001-2007

Soft Mud Rating for New River Estuary, 2007.

RATING	DEFINITION
Good to Very Good	Increase in area of cover (ha) <5% from baseline

Saltmarsh Rating for New River Estuary, 2007.

RATING	DEFINITION
Good	Decrease in area of cover (ha) <5% from baseline

Macroalgae Rating for New River Estuary, 2007.

RATING	DEFINITION
Fair	Cover 10-50%. Isolated nuisance conditions

SOFT MUD: Changes in the classification of substrate precludes a direct comparison of 2001 and 2007 data. However, grouping substrate into broad categories (Table 13) enables the major features of the estuary to be summarised, and the soft mud condition rating to be used to assess the extent of any changes.

Table 13. Comparison of 2001 and 2007 broad substrate categories.

Substrate Class	2001 Area (ha)	2001 Percent	2007 Area (ha)	2007 Percent
Sand	2,034.6	77.8	2,062.7	76.5
Soft Mud	547.7	20.9	568.9	21.1
Other	34.43	1.3	64.1	2.4
TOTAL	2,616.8	100	2,695.7	100

The proposed condition rating for soft mud area measures a percentage change from an established baseline. Based on the summary information in Table 13, the soft mud condition rating is in the very good-good category with a less than 5% increase in the area of soft mud cover. This is consistent with field observations with only localised increases in soft mud associated with macroalgal (*Gracilaria*) beds in the west of the estuary noted.

SALTMARSH: Saltmarsh includes all estuarine vegetation able to tolerate saline conditions in the upper estuary, and where terrestrial plants are unable to survive. It is commonly dominated by rushland but includes scrub, sedge, tussock, grass, reed, and herb fields. Table 14 shows the saltmarsh area in 2001 and 2007, with the 2007 data adjusted to the boundary of the area mapped in 2001.

Table 14. Comparison of 2001 and 2007 saltmarsh area.

	2001 Area (ha)	2001 Percent	2007 Area (ha)	2007 Percent
Saltmarsh	470.4	11.1	462.3	10.8

The proposed condition rating for saltmarsh area measures a percentage change from an established baseline. Based on the summary information in Table 14, the saltmarsh condition rating is in the very good-good category with a less than 5% decrease in the area of saltmarsh. The slight decrease in saltmarsh since 2001 is attributable primarily to the successful eradication of *Spartina* in the east of the estuary, although there was also a small area of localised erosion of rushland evident on the north bank of the Oreti River.

SEAGRASS: Because of the reduced resolution of the 2007 aerial photos, it was not possible to directly compare the 2001 and 2007 results. Based on field observations, there was no obvious change in the distribution of seagrass between 2001 and 2007.

MACROALGAE: Because macroalgae mapping was not developed under the EMP in 2001, a macroalgal baseline has not previously been established. However, based on field observations and aerial photos, there has been a noticeable change in macroalgal cover. In 2007, there was a much greater proliferation of *Enteromorpha* present in the eastern arm of the estuary, while there was a localised expansion of *Gracilaria* in the western arm resulting in nuisance conditions.

6. SUMMARY AND RECOMMENDATIONS

OVERVIEW

Broad scale habitat mapping of New River Estuary in March 2007 showed that the estuary is predominantly sandy (77% firm mud/sand and mobile mud/sand) with most of this substrate located in the central estuary basin and towards the estuary mouth. Soft and very soft mud comprised 21% of the estuary, and was the dominant feature in the upper northern reaches including the Waihopai Arm (where very deep soft mud is widespread), and was also common in sheltered arms to the east and west. Rock, boulder, cobble and gravel were uncommon, although extensive artificial structures (e.g. rockwalls, floodbanks) protecting historically reclaimed shorelines were a feature in the north and east.

Saltmarsh vegetation covered 17% of the estuary (554ha) of which 42% was rushland (97% jointed wire rush - *Leptocarpus similis*), 23% grassland (predominantly tall fescue among rushland), and 18% herbfield. Saltmarsh vegetation was most extensive in the eastern arm of the estuary where wide beds of rushland extended out over large intertidal flats. Reclamation and artificial seawalls have historically replaced large areas of this type of habitat elsewhere in the estuary.

Macroalgal growth was relatively low throughout most of the estuary in March 2007, but was present in relatively high densities at certain locations. To the east, *Enteromorpha* had established extensively in the residual root systems of *Spartina* that had been sprayed and killed, and was widespread throughout the intertidal area (mostly 1-10% cover). *Enteromorpha* had also established on the residual roots of rushland that had been eroded by wave action on the north bank of the Oreti River mouth. *Gracilaria* was present in high density beds in the centre, west and north of the estuary, and in low density clumps throughout the estuary. Where dense mats were present, sediments were commonly very soft, anaerobic, and sulphide rich. Subtidal beds of both *Gracilaria* and *Enteromorpha* were also observed in the central basin and near the Oreti and Waihopai River mouths.

Seagrass (*Zostera*) growth was most widespread in the very soft muds in the northern arm of the estuary. It was present as a mix of dense patches interspersed with soft muds and lower density patches. The beds appeared healthy, relatively stable and, despite the soft muds present in this part of the estuary, relatively free of sediment. *Zostera* shoots with a <1% cover were observed throughout the eastern side of the estuary with dense seagrass beds growing in sandy sediments near the edge of rushland in the east. *Zostera* beds were also present along the margins of the Oreti River and in subtidal channels.

The terrestrial margin surrounding the estuary was dominated by grassland (59%), then a combination of scrub and forest (28%) and residential and industrial development (10%). Grassland generally extended to artificial seawalls along the estuary edge, or to floodbanks bordering industrial and residential developments, where there was a relatively abrupt change from terrestrial cover to the estuary. In these areas, limited natural buffering capacity remained and saltmarsh vegetation was either absent or restricted to narrow bands.

CONDITION RATINGS

The condition ratings for individual indicators used to assess New River Estuary are summarised in Table 15. Indicators are grouped within the three major estuary issues being monitored under this programme; sedimentation, eutrophication, and habitat/margin loss. An overall rating for these major issues, assessing changes to the estuary since it was first mapped in 2001, is given based on a comparison of the 2007 monitoring results with the baseline established in 2001.

CONDITION RATINGS (CONTINUED)

Table 15. Summary of monitoring indicators and condition ratings for New River Estuary, March 2007.

Major Estuary Issue	Indicator	Condition Rating	Overall Issue Rating
Sedimentation	Sedimentation rate	High	Moderate
	Area of soft mud	Very Good/Good	
Eutrophication	Macroalgal cover	Fair	Moderate
Habitat/Margin loss	Saltmarsh area	Very Good/Good	Good
	Seagrass cover	Very Good/Good	
	Terrestrial margin	Baseline established	-

Sedimentation:
The historical sediment core analysis indicated that while sedimentation rates were relatively low for the period 1906-1967 (~3mm/year) recent rates in the north of the estuary are in the HIGH rating category for NZ estuaries (12.7-16.4mm/year). In this part of the estuary deep soft muds now overlay areas that were previously sandy.

Although the area of soft mud in the estuary was high (21% of the estuary), there was no significant change in the area of soft mud from 2001 to 2007 placing it in the VERY GOOD-GOOD category.

Based on these results, sedimentation is rated a MODERATE issue overall. It is recommended that broad scale mapping of substrate be undertaken at five yearly intervals, with sediment rate measures in the upper estuary assessed annually. The likely source and magnitude of sediment inputs, and management options will be addressed as part of an Ecological Vulnerability Assessment being undertaken by ES in 2008.

Eutrophication:
The extent of enrichment indicated by the cover of macroalgal species indicated that macroalgal growth is present and causing localised nuisance conditions in some parts of the estuary. The level of cover (>10% of the estuary with >10% cover) places it in the MODERATE category overall, but the widespread growth in the eastern arm highlights that this part of the estuary may be susceptible to more widespread nuisance growths under favourable growing conditions.

Based on the extent of the change, and the high nutrient loads known to enter New River Estuary, annual monitoring of macroalgae is recommended. Estimates of nutrient inputs and factors controlling macroalgal growth will be addressed as part of an Ecological Vulnerability Assessment being undertaken by ES in 2008.

Habitat loss:
No significant change to the total area of saltmarsh was observed between 2001 and 2007. Similarly, seagrass appeared to have changed little over the same period placing both in the VERY GOOD-GOOD category. The successful eradication of *Spartina* and the establishment of herbfields in its place has greatly increased the amount of herbfield in the estuary (3ha in 2001 to 38ha in 2007). The herbfields have also provided substrate for the macroalgae *Enteromorpha* to establish.

Repeat monitoring at five yearly intervals is recommended, with seagrass mapped using the percentage cover method used to establish the 2007 baseline.

6. SUMMARY AND RECOMMENDATIONS (CONTINUED)

MONITORING RECOMMENDATIONS

New River Estuary has been identified by ES as a priority for monitoring, and is a key part of ES's existing estuary monitoring programme being undertaken in a staged manner throughout Southland. Based on existing monitoring results and improvements made to the EMP to produce better outputs for ES to manage key issues facing their estuaries, it is recommended that monitoring continue as outlined below.

Fine Scale Monitoring	Repeat fine scale monitoring at five yearly intervals (next scheduled for 2010) and as deemed necessary thereafter based on the condition ratings. Due to the high sediment and nutrient deposition in the Waihopai Arm, a new upper estuary fine scale site should be monitored.
Broad Scale Macroalgal Mapping	Map macroalgal cover in January-March 2008. After this, schedule monitoring as deemed necessary based on the condition ratings.
Broad Scale Sedimentation Rate Mapping	Measure sediment plate depths in January-March 2008. Monitor annually thereafter.
Broad Scale Habitat Mapping	Repeat broad scale habitat mapping at five yearly intervals (next scheduled for 2012).

Based on field observations during the current work the main issues likely to require management in the future are:

- **Excessive Sedimentation**: Much of the upper northern arm including the Waihopai River is covered by soft muds, and recent sedimentation rates are high. The likely ecological response is one of lowered biodiversity and lowered aesthetic and human use values in the upper estuary.

- **Nuisance Macroalgae**: Nuisance macroalgae were present throughout the estuary, and were at nuisance levels in some locations. Existing nutrient inputs are known to be high with macroalgal growth most likely to be limited by physical conditions (e.g. wind and wave action). An increase in nuisance growths will result in reduced public amenity values, reduced biodiversity and increased sediment enrichment in the estuary.

- **Loss of saltmarsh habitat and margin development**: Historical clearance of bush around the terrestrial fringe of the estuary means it is now dominated by grazed pasture, greatly reducing the buffering function provided previously by the bush-covered margin. Additionally, there have been significant areas of saltmarsh drained and reclaimed for pastoral use, while industrial development has been established and continues to expand along the eastern side of the estuary. This has almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary.

The ongoing monitoring, coupled with the Ecological Vulnerability Assessment of Southland's coastline and estuaries scheduled for 2008, will provide a robust framework for identifying, evaluating and providing management options for any significant issues within New River Estuary.

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8. REFERENCES

Cited 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.

Appleby, P. G. and Oldfield, F.1992: Applications of 210Pb to sedimentation studies. In Ivanovich, M. and Harmon, R.S., editors, Uranium-series Disequilibrium. Applications to Earth, Marine and Environmental Sciences. Oxford: Oxford University Press, 731-778.

Cambray, R. S., Fisher, E. M. R., Playford, K., Eakins, J. D. and Peirson, D. H. 1979: Radioactive fall-out in air and rain. Results to the end of 1978. Atomic Energy Research Establishment Report R9441. London: H.M.S.O.

Church, T.M. (Ed.) 1975: Marine Chemistry in the Coastal Environment. ACS Symposium Series 18. American Chemical Society, Washington D.C. 710p.

Loughran, R. J., Campbell, B. L. and Elliott, G. L. 1988: Determination of Erosion and Accretion Rates using Caesium-137. In, Warner, R.F., Editor, Fluvial Geomorphology of Australia. Sydney: Academic Press.

Pedersen, M.F., Borum, J. 1997. Nutrient control of estuarine macroalgae: growth strategy and the balance between nitrogen requirements and uptake. Marine Ecology Progress Series 161: 151-163.

Robertson B.M., and Asher R. 2003. Environment Southland Estuary Monitoring 2003. Prepared for Environment Southland.

Robertson B.M., Asher R., Sneddon R. 2004. Environment Southland Estuary Monitoring 2004. Prepared for Environment Southland.

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., and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Report prepared by Wriggle Coastal Management for Environment Southland.

Robertson, B., and Stevens, L. 2007. Waikawa Estuary 2007 Fine Scale Monitoring and Historical Sediment Coring. Report prepared by Wriggle Coastal Management for Environment Southland. 29p.

Stevens, L., and Asher, R. 2005. Environment Southland Estuary Monitoring 2005. Prepared for Environment Southland.

Environment Southland Coastal Monitoring Reports

Robertson, B., and Stevens, L. 2007. Waikawa Estuary 2007 Fine Scale Monitoring and Historical Sediment Coring. Report prepared by Wriggle Coastal Management for Environment Southland. 29p.

Robertson B.M., Asher, R. 2006. Environment Southland Estuary Monitoring 2006. Prepared for Environment Southland.

Robertson, B., and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Report prepared by Wriggle Coastal Management for Environment Southland.

Robertson B.M., Asher R., Sneddon R. 2004. Environment Southland Estuary Monitoring 2004. Prepared for Environment Southland.

Robertson, B., Stevens, L., Thompson, S., and Robertson, B. 2004. Broad scale intertidal habitat mapping of Awarua Bay. Prepared for Environment Southland.

Robertson, B., Stevens, L., Thompson, S., and Robertson, B. 2004. Broad scale intertidal habitat mapping of Bluff Harbour. Prepared for Environment Southland.

Robertson, B., Stevens, L., Thompson, S., and Robertson, B. 2004. Broad scale intertidal habitat mapping of Waikawa Estuary. Prepared for Environment Southland.

Robertson B.M., and Asher R. 2003. Environment Southland Estuary Monitoring 2003. Prepared for Environment Southland.

Robertson B.M., Tuckey B.J., and Robertson B. 2003. Broadscale mapping of Jacobs River Estuary intertidal habitats. Prepared for Environment Southland.

Robertson B.M., Tuckey B.J., and Robertson B. 2003. Broadscale mapping of Fortrose Estuary intertidal habitats. Prepared for Environment Southland.

Robertson, B.M. 1997. Southland Coastal Ecology Programme 1996-7. Report prepared for Southland Regional Council. Barry Robertson, Env. Consultant, Nelson. 50p.

Robertson, B.M. 1995. Southland Estuaries: heavy metal monitoring. Report prepared for the Southland Regional Council. Robertson Ryder & Associates, Dunedin. 35p.

Robertson, B.M. 1992. Aparima Catchment Water Quality Review. Report prepared for the Southland Regional Council. Barry Robertson & Associates, Dunedin. 67p.

Robertson, B.M. 1992. New River Estuary: Review of Existing Water Quality. Report prepared for Southland Regional Council. Barry Robertson & Assoc, Dunedin. 76p.

Stevens, L. and Robertson, B., 2007. Waituna Lagoon 2007. Broad Scale Habitat Mapping and Historical Sediment Coring. Report prepared by Wriggle Coastal Management for Environment Southland. 36p.

Stevens, L. and Robertson, B., 2007. Waituna Lagoon 2007. Ecological Vulnerability Assessment and Monitoring Recommendations. Report prepared by Wriggle Coastal Management for Environment Southland. 40p.

Stevens, L., and Asher, R. 2005. Broad scale intertidal habitat mapping of Haldane Estuary. Prepared for Environment Southland.

Stevens, L., and Asher, R. 2005. Environment Southland Estuary Monitoring 2005. Prepared for Environment Southland.

Stevens, L. and Clarke, M. 2004. Broad scale mapping of subtidal habitat and ecology of Bluff Harbour, 2004. Prepared for Environment Southland.

APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

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: Area that is dominated by both live and dead cockle shells.
Mussel reef: Area that is dominated by one or more mussel species.
Oyster reef: Area that is dominated by one or more oysters species.
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.

APPENDIX 2. LEAD DATING OF HISTORICAL CORES

Lead Dating (detailed methods in Appleby and Oldfield 1992)

^{210}Pb is used to determine sedimentation rates over the last 100-150 years (from the present until the start of the Industrial Age) as the ^{210}Pb radionuclide has a relatively short half life of about 22 years. The "total ^{210}Pb" content of estuary sediments is derived from two sources;

- from within the sediments, and
- from the atmosphere.

Both sources begin within the earth's crust where the decay of ^{226}Ra (half-life 1622 years) occurs. Within the estuary sediments this decays to ^{222}Rn (half-life 3.83 days), which then decays to ^{210}Pb (called the "supported ^{210}Pb" content). Within the atmosphere, the decay products are the same and the resulting ^{210}Pb quickly precipitates out of the atmosphere and is deposited at the estuary surface (called the "unsupported ^{210}Pb" content). The total ^{210}Pb content is the sum of the two and is what is measured when the sediments are analysed. However, to "date" the sediments, the concentration profile of the ^{210}Pb from the atmosphere (i.e. the unsupported lead) is used. Assuming a constant supply rate from the atmosphere (and constant initial concentration), and the rate of decay of ^{210}Pb, it is relatively straightforward to then date a sediment layer based on the difference in concentration of unsupported ^{210}Pb between the surface and the chosen layer.

If a rate of sedimentation is constant, the decay process results in an exponential decrease in ^{210}Pb activity with depth that can be used to estimate sedimentation rates and therefore sediment age back about 100–150 years. The activity of ^{210}Pb samples where the curve becomes asymptotic with respect to ^{210}Pb activity is assumed to be the supported ^{210}Pb level; that is, the amount of ^{210}Pb produced from the decay of ^{222}Rn within the sediment column and not deposited from the atmosphere. Alternatively, one can use the ^{226}Ra activity to equal the supported ^{210}Pb activity as, in the absence of atmospheric ^{210}Pb fallout, ^{210}Pb will be in radioactive equilibrium with ^{226}Ra in the sediment. These supported ^{210}Pb values are subtracted from the total ^{210}Pb values obtained in the analysis, resulting in an unsupported ^{210}Pb profile (from atmospheric deposition).

The age in years since the sediment layer at depth x was deposited (t) can then be calculated by using the relationship:

$$\mathbf{t = 1/k.logN(C_o/C_x)}$$

where:
C_o = the unsupported activity of ^{210}Pb in the modern surface sediments,
C_x = the unsupported activity of ^{210}Pb at (uncompressed) depth x, and
k = the ^{210}Pb decay constant (0.03114 yr^{-1}).