coastalmanagement

Waikawa Estuary 2007

Fine Scale Monitoring & Historical Sediment Coring

Prepared for

Environment Southland

June 2007

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Monitoring, Macroalgal Mapping & Historical Sediment Coring

Prepared for
Environment Southland

By

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Cover Photo: Mid Waikawa Estuary near Un-named Island.

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WAIKAWA ESTUARY - EXECUTIVE SUMMARY

Developing an understanding of the condition and risks to estuarine habitats is critical to resource management in the Southland region. The present report summarises the results of the 2007 fine scale monitoring for the Waikawa Estuary, which is one of the key estuaries in the Southland Estuary long term monitoring programme. The report also provides information on the previous 2 years of monitoring in 2005 and 2006, the recently initiated broad scale mapping of sedimentation rate (including historical sedimentation rates), the broad scale mapping of macroalgal cover, the condition ratings for each indicator, recommended management responses, and a completed "estuary risk matrix". Monitoring will be undertaken again in Feb 2008.

Indicators and Ratings	Results	Management Response
Nutrients Rating: Very Good	The indicators of nutrient enrichment (total nitrogen and total phosphorus) at both sites were at low concentrations for all years, and consequently were rated in the "very good" (or "good" in the case of TP) rating categories for Southland estuary condition.	Continue monitoring (5 yearly after baseline).
Organic matter Rating: Very Good	The indicator of organic enrichment (organic content) at both sites was at low concentrations for all years, and consequently was rated in the "very good" category.	Continue monitoring (5 yearly).
Toxicants Rating: Very Good	In terms of potential toxicants, both sites had very low concentrations of heavy metals (cadmium, chromium, copper, nickel, lead and zinc), with all values well below the ANZECC (2000) ISQG Low trigger values. Such low values place these sites in the "very good" condition rating for potential toxicants.	Continue monitoring (5 yearly).
Sedimentation Rate Rating: High	In the period, 1996-2007 the average sedimentation rate was in the **high** range (11 mm/yr). As such, an evaluation and response plan is recommended to identify the likely source and management options. If such sedimentation continues unchecked, the relatively pristine nature of much of this estuary will be in jeopardy. The historical coring also showed that in the period, 1967-96 the sedimentation rate was much lower (moderate range at 4 mm/yr) and in the period, 1879-1967 it was in the low range at 1 mm/yr. Sedimentation plates have been deployed in the estuary to enable long term monitoring of sedimentation rates.	Continue monitoring (5 yearly). Also undertake Evaluation and Response Plan.
Macroalgal Cover Rating: Good	Although potentially nuisance algae were present in the estuary (*Gracilaria* and sea lettuce), they were generally at low densities except for small areas of greater than 80% cover in the mid estuary. The condition rating for the estuary fits the "good" category, which means that monitoring should continue at 5 yearly intervals, without a need for any focused management action.	Continue monitoring (5 yearly).
Infauna	Overall the infauna community composition and abundance was typical of most New Zealand estuaries (Robertson et al. 2002). Although there were differences in abundance and diversity between years, they were relatively small and likely to be within the bounds of natural variation.	Continue monitoring (5 yearly).
Grain Size	Both Waikawa sites were dominated by sandy sediments (>90% sand) with a >10% mud content. The site closest to the sea, Site B, had the least amount of mud. As expected there was also a small variation between successive years.	Continue monitoring (5 yearly).

EXECUTIVE SUMMARY (continued)

ISSUES

An estuary risk assessment was undertaken to identify any major ecological issues in the Waikawa Estuary. Two key issues were identified as follows:

- **Excessive Sedimentation**: Approximately half of the estuary is now full of soft muds and recent sedimentation rates are high. The likely ecological response is one of lowered biodiversity and aesthetic values in the upper estuary.
- **Past reclamation of salt marsh habitat and margin development**: The vegetation around the terrestrial fringe of the estuary is now dominated by grazed pasture which means that any buffering function from the pre-existing bush-covered margin is minimised. Additionally, there has been significant areas of saltmarsh drained for pastoral use in the past and this also has almost certainly contributed to reduced biodiversity and increased sedimentation in the estuary.

Despite these issues, the ecological vulnerability for the majority of estuary habitats are rated in the low or low to moderate class.

FUTURE MONITORING AND MANAGEMENT

Given the developed nature of the catchment, the high human use and value ratings, and the presence of existing condition issues, the following monitoring and management actions are recommended.

Fine Scale Monitoring	Complete baseline monitoring in Jan-March 2008 and continue at 5 yearly intervals
Broad Scale Macroalgal Mapping	Next due in Jan-March 2008
Broad Scale Habitat Mapping	Next due in 2009
Broad Scale Sedimentation Rate Mapping	Next due in Jan-March 2008
Evaluation and Response Plan for Sedimentation Rate Issue	Undertake during 2007

1. INTRODUCTION

SCOPE

Figure 1 Mid Waikawa Estuary near Un-named Island.

Developing an understanding of the distribution of, and risks to, coastal and estuarine habitats is critical to the management of biological resources in the Southland Region. In the 1990s, Environment Southland established a long-term monitoring programme to assess the condition of key estuaries (including the Waikawa Estuary) in its region using the tools provided in the National Estuary Monitoring Protocol (Robertson et al. 2002). This approach consisted of two main elements:

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

More recently, Wriggle Coastal Management, has developed a number of improvements to the EMP in the form of additional tools for estuary monitoring as follows:

- An Upper Estuary Monitoring and Assessment Protocol
- Broad scale mapping of sedimentation rate
- Broad scale mapping of macroalgal cover
- Condition ratings for key indicators
- An Estuary Risk Matrix

In 2006, the results of the first 5 years of monitoring were reviewed (Robertson and Stevens, 2006) and condition ratings for each estuary identified (see references for list of reports for individual years).

The present report summarises the results of the 2007 fine scale monitoring for the Waikawa Estuary. The report also provides information on the recently initiated broad scale mapping of sedimentation rate, the broad scale mapping of macroalgal cover, the condition ratings for each fine scale indicator and a completed "estuary risk matrix".

The data for the current study was collected during February/March 2007 when a variety of Southland estuaries were visited and monitored over a 3 week period. The following sections provide information on the methods, results, condition ratings, risks and any recommended monitoring changes or management actions.

STRUCTURE

Figure 2 Looking from Curio Bay towards the entrance to Waikawa Estuary.

Section 1 provides an introduction to the scope and structure of the study.
Section 2 provides the methods for the fine scale assessment, sedimentation rate, and the broad scale mapping of macroalgal cover.
Section 3 provides the criteria used to establish condition ratings for Southland estuaries.
Section 4 provides the fine scale results and condition ratings for key indicators monitored in the fine scale survey.
Section 5 provides the results of the historical core analysis and sedimentation rate.
Section 6 provides the broad scale macroalgal cover mapping results and the condition ratings for this key indicator.
Section 7 provides the completed "estuary risk matrix" for the estuary.
Section 8 provides the conclusions and recommendations.
Section 9 provides the list of references.

Appendix 1: Details of analytical methods.
Appendix 2: Details of historical coring including results - Waikawa Estuary 2007.
Appendix 3: Detailed fine scale monitoring results - Waikawa Estuary 2007.

Map of Waikawa Estuary

Figure 3 Waikawa estuary habitat map and site locations.

2. METHODS

FINE SCALE MONITORING

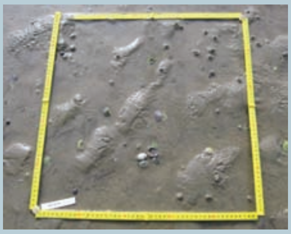


Figure 4 Quadrat for epifauna sampling

Fine scale monitoring focuses on providing detailed information on the quality of the dominant habitat type (intertidal mudflats at low-mid water) in the estuary. To achieve this 2 representative sites have been chosen from the estuary, using the information provided in the broad scale habitat mapping exercise. Sampling at each site generally follows that outlined in the National Estuary Monitoring Protocol (Robertson et al. 2002) but includes some recent improvements. In particular, sample replication for chemistry has been reduced from 10 replicates to 3 composite replicates per site for estuaries where results are in the low-moderate range (i.e. Waikawa Estuary). This shift is based on extensive monitoring and analysis of results from other New Zealand estuaries (particularly in Southland) which has shown that reduced replication provides an appropriate balance between management needs and cost in estuaries with low contaminant loads. For infauna, 10 replicate samples have been collected. Additionally, salinity measurements of the overlying water at each site were taken during low tide periods, in order to provide a better definition of habitat type so that existing indices can be used to define condition.

At each site, 3 replicate composite sediment samples were collected and analysed for the following variables;

- Grain size (% mud, sand, gravel)
- Organic Matter: Ash free dry weight (organic content)
- Nutrients: Total nitrogen, Total phosphorus
- Heavy metals: Cadmium, Chromium, Copper, Lead, Nickel and Zinc

At each site, 10 sediment samples were collected and analysed for the following variables;

- Macroinvertebrate abundance and diversity (infauna and epifauna)

Metal analyses were based on whole sample fractions which are not normalised to allow direct comparison with ANZECC guidelines. Details on analytical methods are provided in Appendix 1.

Nutrients and Contaminants in Waikawa Estuary

Based on the presence of low concentrations of nutrients and contaminants in the estuary and the absence of intensive farming, horticulture, or urban and industrial development in the Waikawa Catchment, it is therefore recommended that replication within sites be minimised (i.e. 3 per site)

Figure 5 Core sample from Waikawa Estuary.

FINE SCALE MONITORING (CONTINUED)

Two fine scale sampling sites were selected in unvegetated, mid-low water habitat of the dominant substrate type (avoiding areas of significant vegetation and channels). At each site, a 60m x 30m area in the lower intertidal was marked out and divided into 12 equal sized plots. At each of 10 plots, a random position was defined and the following sampling undertaken:

Sediment core profiles (and depth of RPD)

- One random 60 mm core was collected to a depth of at least 100 mm and photographed alongside a ruler and a corresponding label.
- Colour and texture were described and average depth of the RPD (Redox Potential Discontinuity) recorded.

Figure 6 Sampling RPD layer

Epifauna (surface-dwelling animals):

- Epifauna were assessed from one randomly placed 0.25 m^2 quadrat within each plot. All animals observed on the sediment surface were identified and counted, and any visible microalgal mat development noted. The species, abundance and related descriptive information were recorded on specifically designed, waterproof field sheets containing a checklist of expected species. Photographs of quadrats were taken and archived for future reference.
- Field notes were transferred to a spreadsheet or database for statistical analyses.

Figure 7 Counting epifauna

Infauna (animals within sediments):

- One randomly placed sediment core was taken from each plot using a 130 mm diameter (area = 0.0133 m2) PVC tube.
- The core tube was manually driven 150 mm into the sediments, removed with core intact and inverted into a labelled plastic bag.
- Once all replicates had been collected at a site, the plastic bags were transported to a nearby source of seawater and the contents of the core washed through a 0.5 mm nylon mesh bag. The infauna remaining were carefully emptied into a plastic container with a waterproof label and preserved in 70% isopropol alcohol with 1% glyoxol fixative.
- The samples were then transported to a commercial laborartory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants).

Physical and chemical analyses:

- Three samples from each site (each a composite from 4 plots) of the top 20 mm of sediment (each approx 250 gms) were collected adjacent to the infauna cores.
- All samples were either preserved in the field or stored on ice as appropriate.
- The chilled samples were sent to an analytical laboratory (R.J Hill Laboratories), where they were analysed for the following characteristics:
  * Particle size distribution (% mud, sand, gravel)
  * Nutrients (total nitrogen and total phosphorus)
  * Ash free dry weight (AFDW) as a measure of total organic content
  * Trace metal contaminants (copper, cadmium, nickel, lead, zinc and chromium)
- Samples were tracked using standard Chain of Custody forms and results are checked and transferred electronically to avoid transcription errors.
- Photographs were taken to provide a record of the general site appearance.

SECTION 2 METHODS

SEDIMENTATION RATE

Figure 8 Measuring sediment plate depth

Figure 9 Digging hole to place sediment plate

Sedimentation rate is calculated by a simple method of measuring the amount of sediment over a buried level plate in a certain 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 within the plate are averaged to take into account irregular sediment surfaces.

For the Waikawa Estuary, 12 sedimentation plates (approx 20 cm square concrete blocks) were buried deep in the sediments (where stable substrate is located) of the Waikawa Estuary on 2 March 2007 at representative locations around the estuary. The position of each plate was marked with wooden stakes driven into the sediment and their GPS locations logged. 4 plates were buried at each of the Upper Sth, Upper Nth and Lower Sth sites (Figure 3). At each site, the plates were distributed at each corner of a square and buried approximately 30-50m apart.

Immediately after placement of each plate, the depth from the undisturbed mud surface to the top of the sediment plate was recorded. In the future, this distance will be measured annually at each plate and, over the long term, will provide a measure of rates of sedimentation in the upper end of the estuary where the areas of soft muds are greatest.

Results will be used annually to produce a GIS layer of sedimentation rate in the estuary. In addition a sedimentation condition rating will be developed for the estuary to provide a means of assessing existing state and the extent of any changes.

BROAD SCALE MACROALGAL MAPPING

Broad scale mapping of the percentage cover of macroalgae throughout the Waikawa Estuary was undertaken using a combination of aerial photography, together with detailed ground-truthing and digital mapping using GIS technology (ArcMap 9.2) to record the percentage cover. The groundtruthing was undertaken in March 2007. The procedure, originally described for use in NZ estuaries by Robertson et al. (2002), has subsequently been modified and successfully applied to various estuaries to develop a separate GIS macroalgal layer.

SECTION 2 METHODS - HISTORICAL SEDIMENTATION RATE

(2) HISTORICAL CORING

One 106 cm sediment core was taken from the area of soft muds within the intertidal zone of the Waikawa Estuary on 4 March 2007 (Figure 3, Upper South). The core was collected by slowly inserting a 10cm diameter PVC pipe into the estuary muds, measuring compression, then removing the pipe with intact core from the estuary bed and transporting it upright on a sledge to the estuary margin for processing. From here, the PVC tube was split in half and the core photographed and then cut into 2cm slices and each slice, described, bagged and labeled. Selected labeled sample bags were then delivered to the National Radiation Laboratory, Christchurch for analysis for the following:

Beryllium 7	A natural isotope with a very short half-life that is used to indicate the depth of surface mixing (i.e. it will not be present in older sediments).
Caesium 137	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	A natural isotope that has a half life of 22 years and is therefore useful in dating sediments younger than 100-150 years. The difference between the Pb-210 concentration in the core sample below the surface and the concentration at the surface is used to age the sediment.
Radium 226 and 228	The two most common isotopes of radium are radium-226 and radium-228. Radium-226 has a long half-life (1,600years) compared to that of radium-228 (5.75 years). Radium-226 decays by emitting the nucleus of a helium atom (alpha particle), whereas radium-228 emits an electron (beta particle).

Samples of dried sediment (15g) were ground, homogenised, and then analysed at the National Radiation Laboratory. Samples were imbedded in epoxy resin and then left for 30 d to allow equilibration between 226Ra, 214 Bi, and 214Pb. Samples were placed on a Hyper Pure Germanium gamma detector, counted for 23 hours, and then counts were analysed with GENIE-2000 software. This allowed for total 137Cs, 210Pb, 226Ra, and 228Ra to be calculated with a 95% confidence interval.

Details on the methods used to calculate the historic sedimentation rates using the isotope results are presented in Appendix 2.

Figure 10 Collecting sediment core and cutting for analysis.

3. ESTUARY CONDITION RATINGS

Metals

Sediments polluted with heavy metals are a starting point for contamination throughout the food chain.

RATING	DEFINITION	RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 yr intervals after baseline established.
Good	<ISQG-Low	Monitor at 5 yr intervals after baseline established.
Fair	<ISQG-Hi but >ISQG-Low	Monitor at 2 yr intervals. Manage source.
Poor	>ISQG-Hi	Monitor at 2 yr intervals. Manage source.
Early Warning Change Trigger	>1.3 x Mean of highest baseline year	Undertake Evaluation and Response Plan.

Total Nitrogen

In shallow estuaries like those in Southland, the sediment compartment is often the largest nutrient pool in the system, and N exchange between the water column and sediments can play a large role in determining the growth of algae and trophic status.

RATING	DEFINITION	RESPONSE
Very Good	<500mg/kg	Monitor at 5 yr intervals after baseline established.
Low-Moderate Enrichment	500-2000mg/kg	Monitor at 5 yr intervals after baseline established.
Enriched	2000-4000 mg/kg	Monitor at 2 yr intervals. Manage source.
Very Enriched	>4000 mg/kg	Monitor at 2 yr intervals. Manage source.
Early Warning Change Trigger	>1.3 x Mean of highest baseline year	Undertake Evaluation and Response Plan.

Total Phosphorus

In shallow estuaries like those in Southland, the sediment compartment is often the largest nutrient pool in the system, and P exchange between the water column and sediments can play a large role in determining the growth of algae and trophic status.

RATING	DEFINITION	RESPONSE
Very Good	<200 mg/kg	Monitor at 5 yr intervals after baseline established.
Low-Moderate Enrichment	200-500 mg/kg	Monitor at 5 yr intervals after baseline established.
Enriched	500-1000 mg/kg	Monitor at 2 yr intervals. Manage source.
Very Enriched	>1000 mg/kg	Monitor at 2 yr intervals. Manage source.
Early Warning Change Trigger	>1.3 x Mean of highest baseline year	Undertake Evaluation and Response Plan.

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients and adverse impacts to biota - all symptoms of eutrophication.

RATING	DEFINITION	RESPONSE
Very Good	<1%	Monitor at 5 yr intervals after baseline established.
Low-Moderate Enrichment	1-2%	Monitor at 5 yr intervals after baseline established.
Enriched	2-5%	Monitor every 2 yrs. Evaluate and manage source.
Very Enriched	>5%	Monitor every 2 yrs. Evaluate and manage source.
Early Warning Change Trigger	>1.3 x Mean of highest baseline year	Undertake Evaluation and Response Plan.

Sedimentation Rate

In shallow estuaries like those in Southland, elevated sedimentation rates can cause adverse changes to habitat and biodiversity.

RATING	DEFINITION	RESPONSE
Very High	>20mm/yr	Monitor annually. Manage source.
High	10-20mm/yr	Monitor annually. Manage source.
Moderate	5-10mm/yr	Monitor at 5 yrly intervals
Low	1-5 mm/yr	Monitor at 5 yrly intervals
Very Low	>1mm/yr (typical pre-European rate)	Monitor at 5 yrly intervals
Early Warning Change Trigger	Rate increasing	

3. ENVIRONMENT SOUTHLAND ESTUARY CONDITION RATINGS

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.

RATING	DEFINITION	RESPONSE
Very Good	%cover <1%. No nuisance conditions.	Monitor at 5 yr intervals after baseline established.
Good	%cover 1-10% widespread. No nuisance conditions.	Monitor at 5 yr intervals after baseline established.
Fair	%cover 10-50% widespread. Nuisance conditions isolated areas.	Monitor % cover and density annually. Evaluation and Response Plan.
Poor	%cover >50% widespread. Widespread nuisance conditions.	Monitor % cover and density annually. Evaluation and Response Plan.
Early Warning Change Trigger	Trend of % cover increasing.	Undertake Evaluation and Response Plan.

Seagrass Area

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).

RATING	DEFINITION	RESPONSE
Very Good	Area of cover (ha) not declining.	Monitor at 5 yr intervals after baseline established.
Good	Decline in area of cover (ha) <5% from baseline.	Monitor at 5 yr intervals after baseline established.
Fair	Decline in area of cover (ha) 5-20% from baseline.	Monitor 5 yrly. Undertake management through Evaluation and Response Plan.
Poor	Decline in area of cover (ha) >20% from baseline.	Monitor 5 yrly. Undertake management through Evaluation and Response Plan.
Early Warning Change Trigger	Trend of decline in area of cover (ha).	Undertake Evaluation and Response Plan.

Saltmarsh Area

A variety of saltmarsh species grow in the upper margins of most NZ estuaries. They 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.

RATING	DEFINITION	RESPONSE
Very Good	Area of cover (ha) not declining.	Monitor at 5 yr intervals after baseline established.
Good	Decline in area of cover (ha) <5% from baseline.	Monitor at 5 yr intervals after baseline established.
Fair	Decline in area of cover (ha) 5-20% from baseline.	Monitor 5 yrly. Undertake management through Evaluation and Response Plan.
Poor	Decline in area of cover (ha) >20% from baseline.	Monitor 5 yrly. Undertake management through Evaluation and Response Plan.
Early Warning Change Trigger	Trend of decline in area of cover (ha).	Undertake Evaluation and Response Plan.

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 soft muds in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access.

RATING	DEFINITION	RESPONSE
Very Good	Area of cover (ha) not increasing.	Monitor at 5 yr intervals after baseline established.
Good	Increase in area of cover (ha) <5% from baseline.	Monitor at 5 yr intervals after baseline established.
Fair	Increase in area of cover (ha) 5-15% from baseline.	Monitor 5 yrly. Undertake management through Evaluation and Response Plan.
Poor	Increase in area of cover (ha) >15% from baseline.	Monitor 5 yrly. Undertake management through Evaluation and Response Plan.
Early Warning Change Trigger	Trend of increase in area of cover (ha).	Undertake Evaluation and Response Plan.

4. RESULTS AND RATINGS

- A summary of the Waikawa Estuary results and condition ratings for key indicators are presented in the Executive Summary.
- Detailed results are presented in Appendix 3.
- The location of the Waikawa Estuary sampling sites are shown in Figure 3.
- Graphs summarising all three years physical, chemical and biological sampling results to date are presented in Figures 11 to 22. These figures also show the results in relation to relevant guideline criteria and Southland Estuary Condition Ratings.

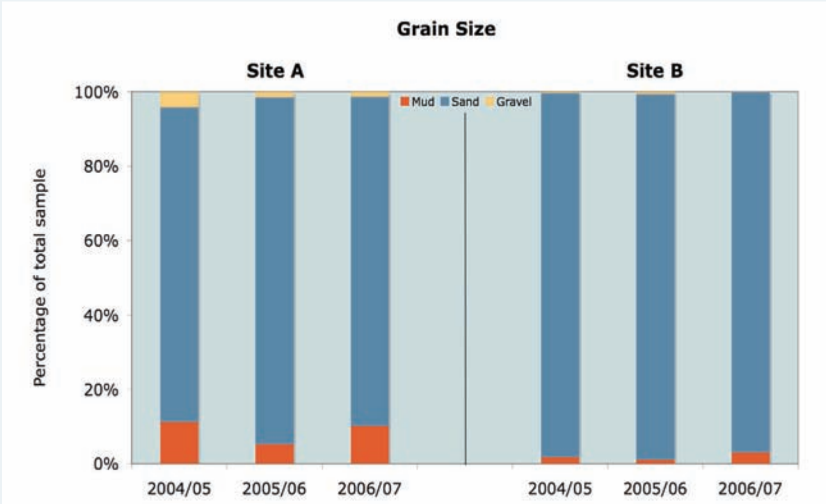
The results are summarised as follows:

Grain Size		Both Waikawa sites were dominated by sandy sediments (>90% sand) with a >10% mud content (Figure 11). The site closest to the sea, Site B, had the least amount of mud. As expected there was also a small variation between successive years.
Infauna		In terms of abundance for all years (Figure 12), the infauna was dominated by polychaetes at both sites (>50% are polychaetes). Crustacea and molluscs (snails and bivalves) were the next most abundant groups. The total number of species at each site (Figure 13) ranged from 32 to 39 and the mean from 14 to 20. Overall the infauna community composition and abundance was typical of most New Zealand estuaries (Robertson et al. 2002). Although there were differences in abundance and diversity between years, they were relatively small and likely to be within the bounds of natural variation.
Nutrients Rating	Very Good	The indicators of nutrient enrichment (total nitrogen and total phosphorus) at both sites were at low concentrations for all years, and consequently were rated in the "very good" (or "good" in the case of TP) rating categories for Southland estuary condition (Figures 21 and 22).
Organic matter Rating	Very Good	The indicator of organic enrichment (organic content) at both sites was at low concentrations for all years, and consequently was rated in the "very good" category (Figure 20).
Toxicants Rating	Very Good	In terms of potential toxicants, both sites had very low concentrations of heavy metals (cadmium, chromium, copper, nickel, lead and zinc), with all values well below the ANZECC (2000) ISQG Low trigger values. Such low values place these sites in the "very good" category in terms of the Southland estuary ratings for potential toxicants (Figures 14-19).
Sedimentation Rate Rating	High	In the period, 1996-2007 the average sedimentation rate was in the high range at 11 mm/yr. In the period, 1967-96 the average sedimentation rate was in the moderate range at 4 mm/yr. In the period, 1879-1967 the average sedimentation rate was in the low-moderate range at 1 mm/yr. Sedimentation plates have been deployed in estuary to enable long term monitoring of sedimentation rates.
Macroalgal Cover Rating	Good	Although potentially nuisance algae were present in the estuary (*Gracilaria* and sea lettuce) they were generally at low densities except for small areas of greater than 80% cover in the mid estuary. The condition rating for the estuary fits the "good" category, which means that monitoring should continue at 5 yearly intervals, without a need for any focused management action.

FINE SCALE MONITORING RESULTS

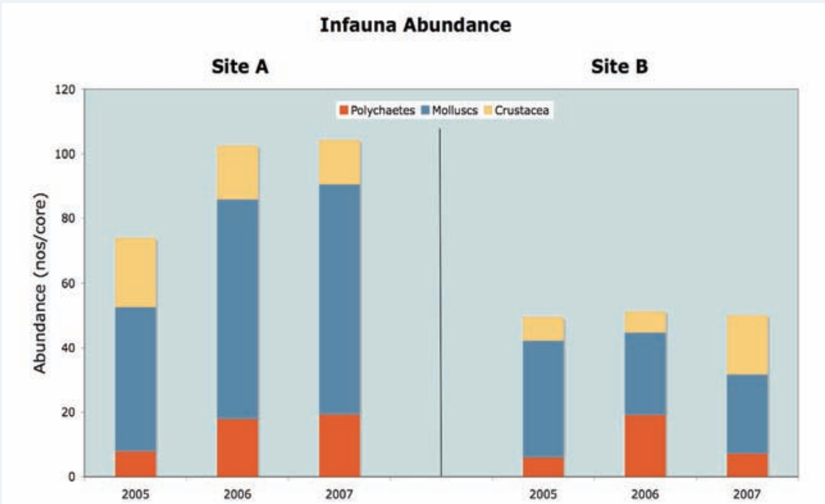
(1) Grain Size

Figure 11 Mean sediment grain size - Waikawa Estuary



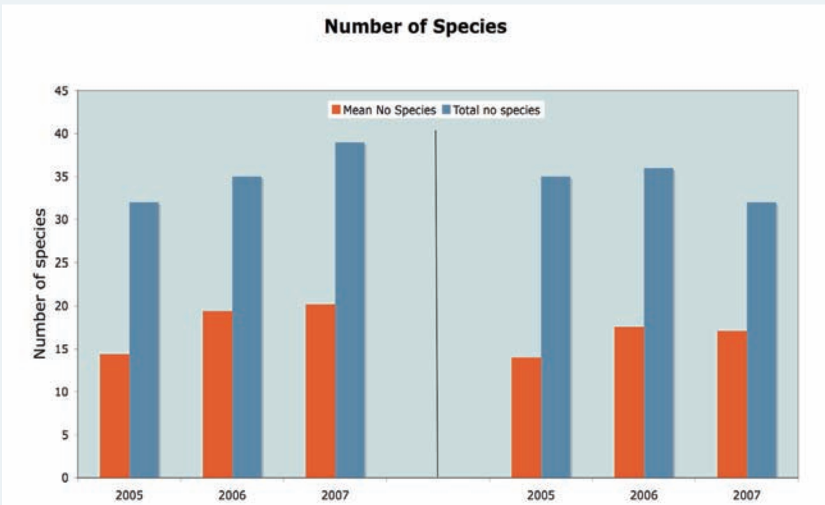
(2) Infauna Abundance

Figure 12 Mean abundance of major groups of infauna - Waikawa Estuary



(3) Infauna No. Species

Figure 13 Mean number of species and total number of species in 10 cores - Waikawa Estuary



(4) Metals

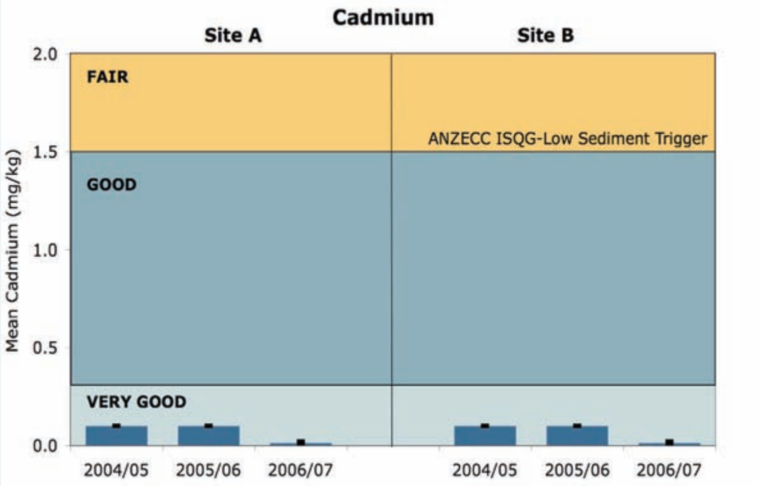


Figure 14 Mean and range sediment cadmium concentrations - Waikawa Estuary

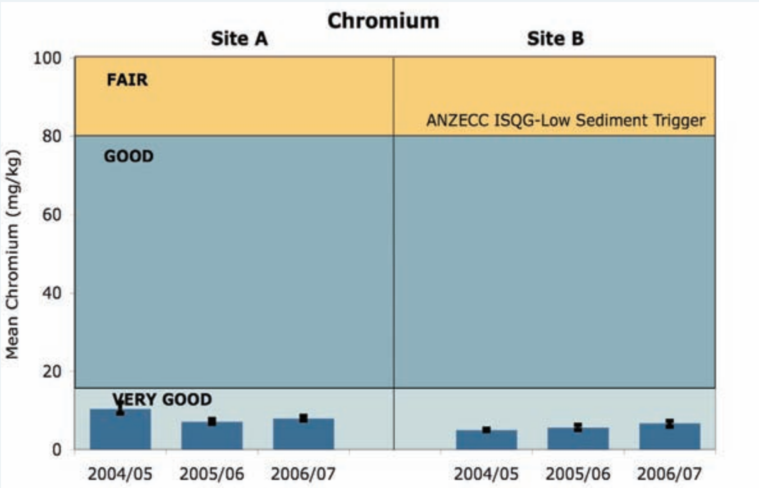


Figure 15 Mean and range sediment chromium concentrations - Waikawa Estuary

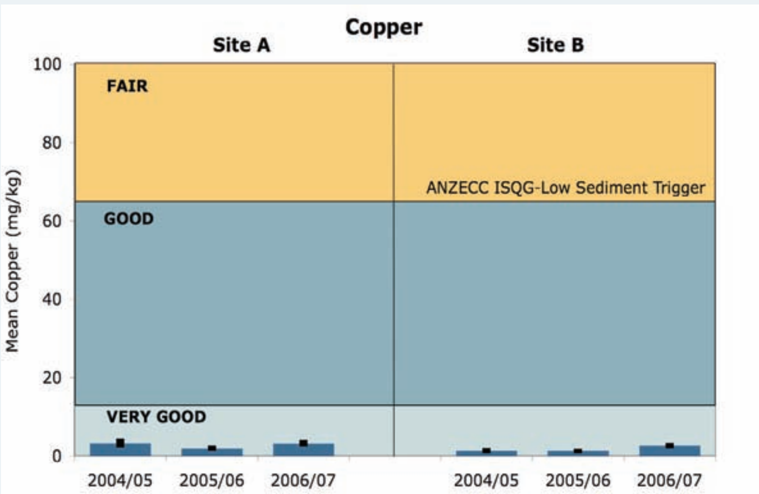


Figure 16 Mean and range sediment copper concentrations - Waikawa Estuary

SUMMARY METAL RATINGS

Cadmium	Very Good
Chromium	Very Good
Copper	Very Good

Figure 17 Mean and range sediment nickel concentrations - Waikawa Estuary

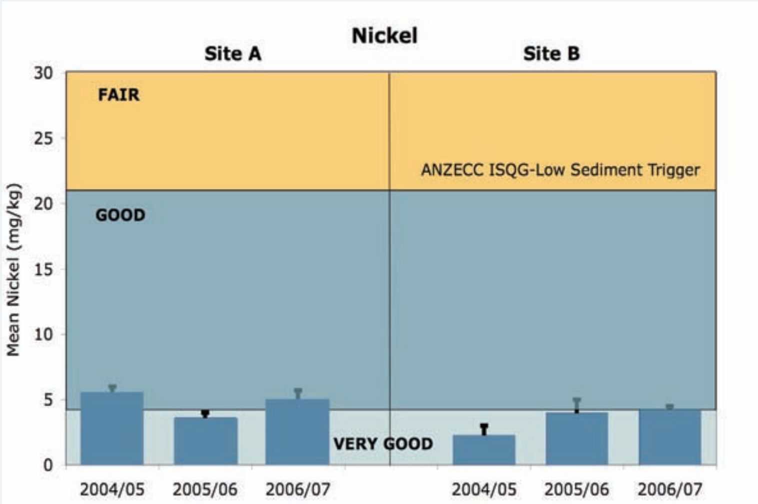


Figure 18 Mean and range sediment lead concentrations - Waikawa Estuary

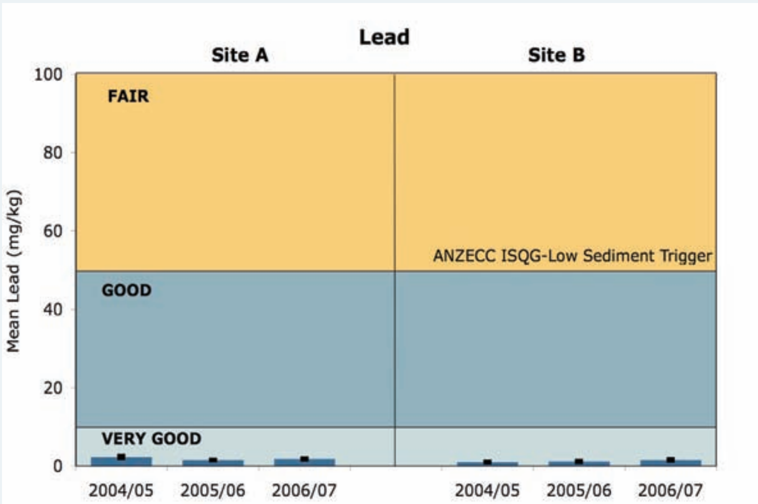
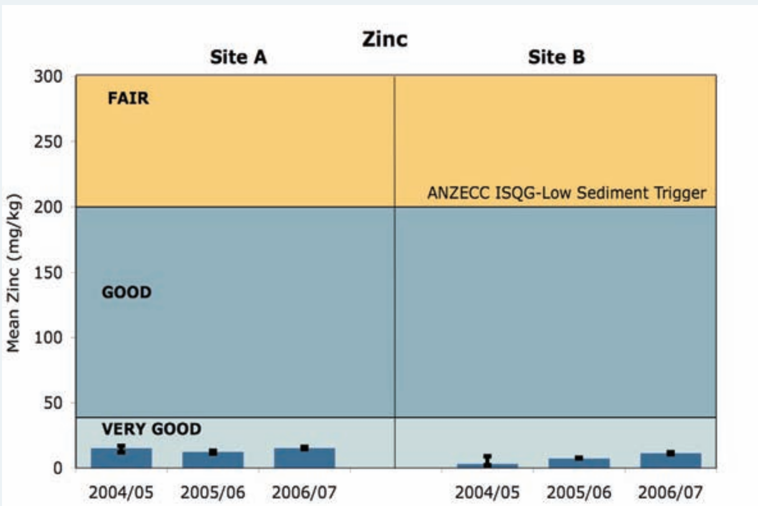


Figure 19 Mean and range sediment zinc concentrations - Waikawa Estuary



SUMMARY METAL RATINGS

Nickel	Very Good/ Good
Lead	Very Good
Zinc	Very Good

FINE SCALE MONITORING RESULTS

(5) Total Organic Carbon

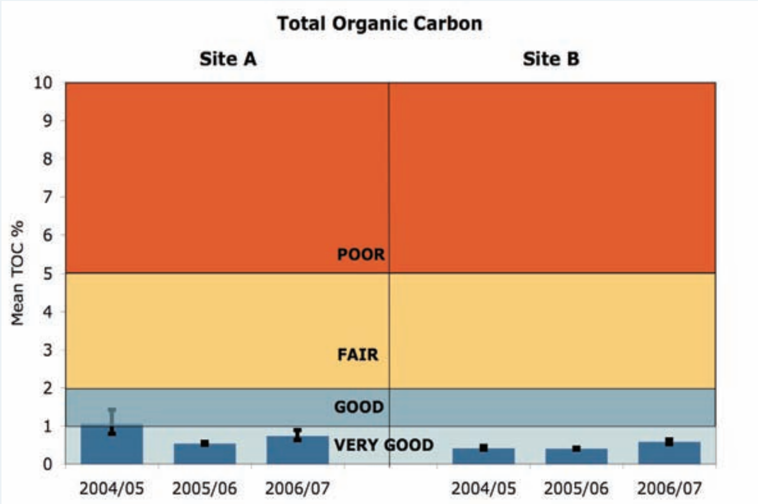


Figure 20 Mean and range sediment TOC concentrations - Waikawa Estuary

(6) Total Nitrogen

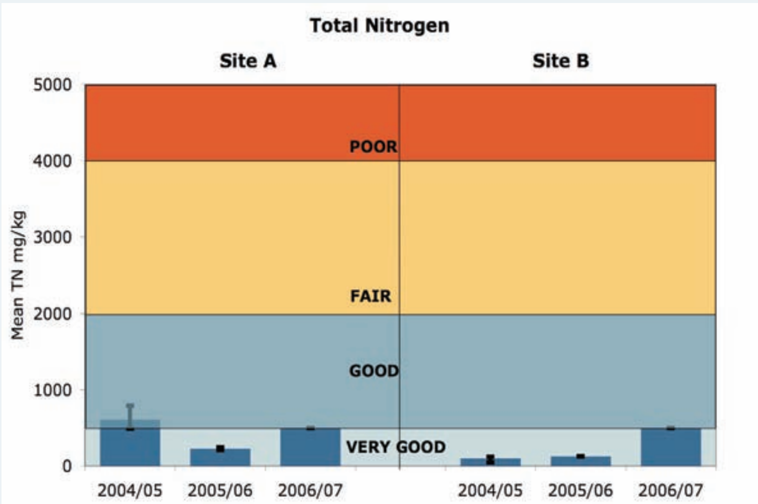


Figure 21 Mean and range sediment TN concentrations - Waikawa Estuary

(7) Total Phosphorus

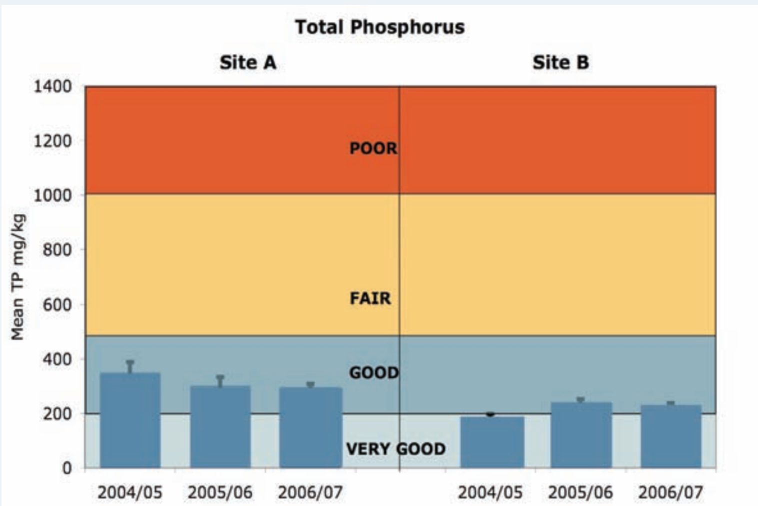


Figure 22 Mean and range sediment TP concentrations - Waikawa Estuary

SUMMARY RATINGS

TOC	Very Good
TN	Very Good
TP	Good

5. SEDIMENTATION RATE MONITORING

SEDIMENTATION PLATE DEPLOYMENT

Figure 23 Measuring sediment height - New River Estuary

Figure 24 Sledding materials to sites - New River Estuary

Figure 25 Hammering in stakes - New River Estuary

PLATE DEPLOYMENT

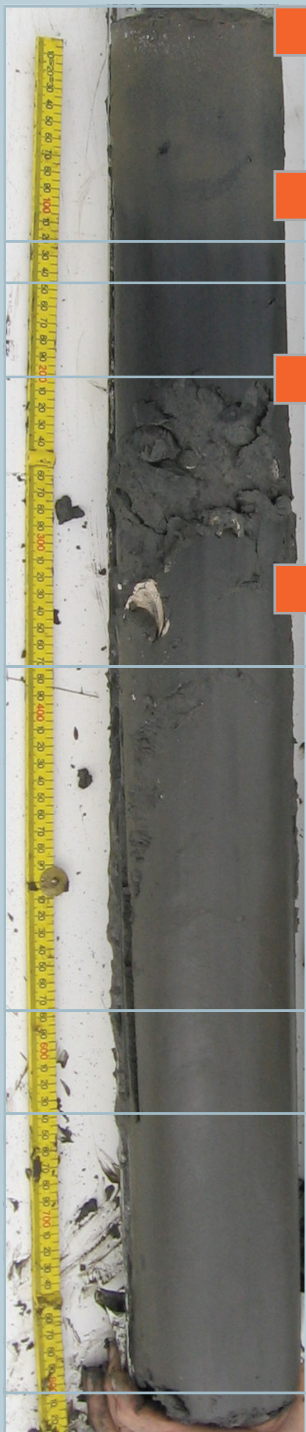
A total of 12 sedimentation plates were buried in the sediments of the estuary. The depth of the plate below the sediment surface and the plate locations are shown in Table 1. Three sites were chosen and at each site 4 plates were buried - one at each of the 4 corners of a square approximately 30-50m apart. The two upper sites (Upper Sth and Upper Nth) were located, one on each side of the main channel, in the upper estuary very soft mud area. These sites were chosen to represent the sedimentation rates in the top third of the estuary, where sedimentation of muds is expected to be the greatest. The other site (Lower Sth) was located just inside the boundary between soft mud and firm muddy sand, on the firm muddy sand side. This site was chosen to provide information on sedimentation rate at the edge of the soft mud front and to indicate any expansion or contraction of this front. It is proposed that the depth of the plates to the surface will be next measured in 2008 and annually thereafter.

Table 1. Location and depth of plates below surface, and height of two marker pegs above surface.

Site	No.	DATE	NZMG EAST	NZMG NORTH	Nth Peg (mm)	Sth peg (mm)	Surface to Brick (mm)
Upper Sth	1	2/3/07	2213599	5392276	190	190	212
Upper Sth	2	2/3/07	2213604	5392304	190	190	223
Upper Sth	3	2/3/07	2213643	5392302	190	190	215
Upper Sth	4	2/3/07	2213632	5392270	190	190	230
Upper Nth	5	2/3/07	2213876	5392947	190	190	253
Upper Nth	6	2/3/07	2213872	5392914	190	190	210
Upper Nth	7	2/3/07	2213841	5392915	190	190	270
Upper Nth	8	2/3/07	2213839	5392947	185	190	257
Lower Sth	9	4/3/07	2214340	5391474	185	190	258
Lower Sth	10	4/3/07	2214367	5391470	190	190	225
Lower Sth	11	4/3/07	2214366	5391440	190	190	250
Lower Sth	12	4/3/07	2214339	5391440	190	190	255

5. SEDIMENTATION RATE MONITORING

HISTORICAL SEDIMENT CORE ANALYSIS



Core photo	2007 1996	0-14cm Worms, *Amphibola* shells
		14-16cm RPD Boundary
		16-22 cm Live worms
	1969 1879	22-38 cm Cockle, *Amphibola, Mactra, Soletellina* shells
		38-58 cm Smooth grey mud with no shells
		58-68 cm Old shell fragments
		68-80 cm Smooth grey mud, no shell
		80-86 cm Black mud
		86-90 cm Amphibola shells

Figure 26 Waikawa sediment core.

Historical Sedimentation Rate

The Waikawa Estuary core was collected from offshore, intertidal sediments located at the western end of the estuary in very soft muds (Upper Sth site, Figure 3) on 4 March 2007.

The analysis of the historical core (see details in Appendix 2) provided the following key findings:

- The upper sediments (6-8cm depth) are rapidly mixed by physical/biological processes.
- In the period, 1996-2007 the average sedimentation rate was in the high range at 11 mm/yr.
- In the period, 1967-96 the average sedimentation rate was in the moderate range at 4 mm/yr.
- In the period, 1879-1967 the average sedimentation rate was in the low-moderate range at 1 mm/yr.

These results indicate that recent sedimentation rates are in the moderate to high category for NZ estuaries and consequently require further investigation, particularly as to likely sources and management of these sources.

The data also shows that prior to 1879, the upper Waikawa Estuary was still covered with at least 0.5m of smooth grey mud. The absence of shell fragments in this layer is a bit of a mystery and possibly points to a period of very rapid sedimentation (perhaps a result of land clearance in the mid 1800s).

Sedimentation Rating for Waikawa Estuary

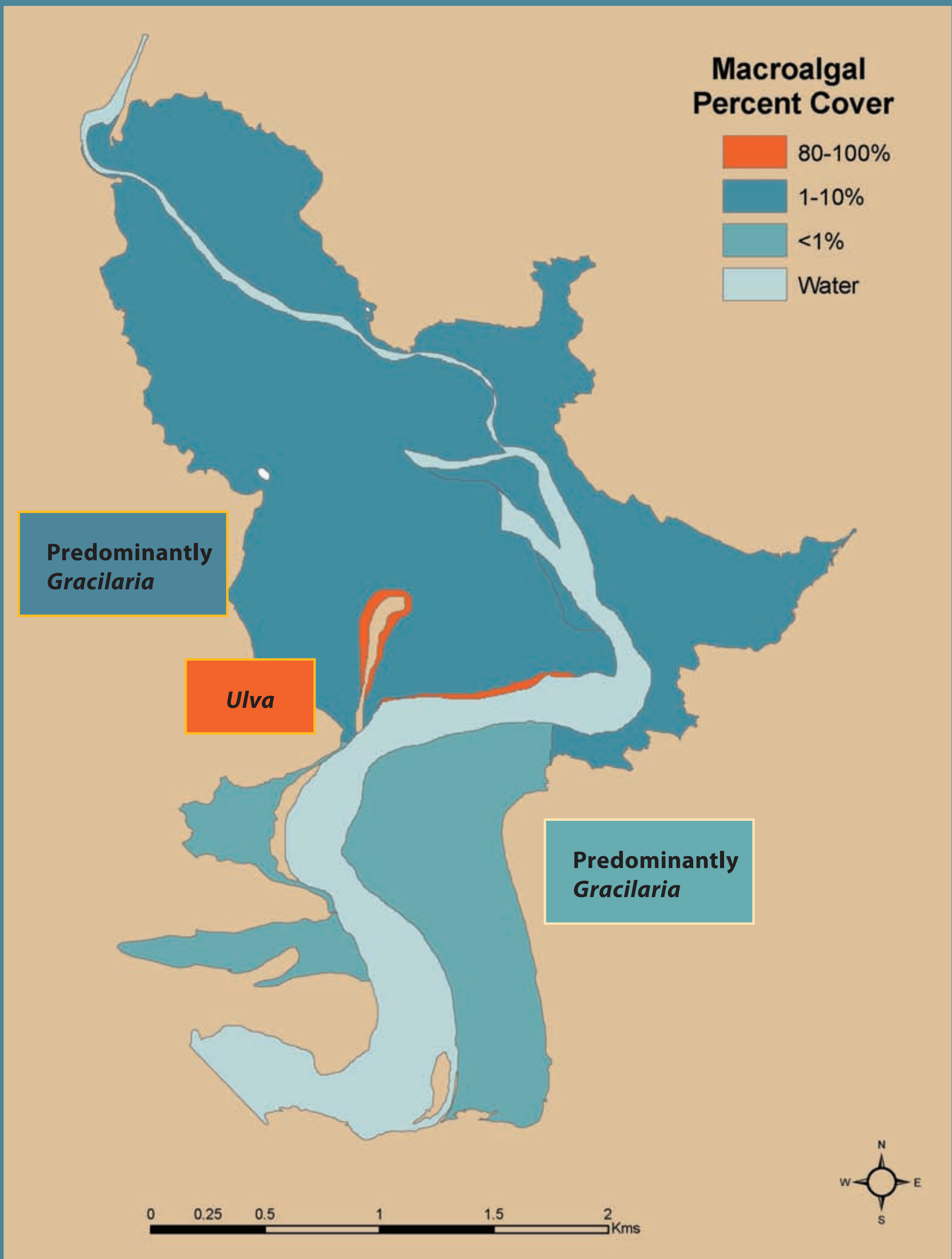
RATING	DEFINITION
High	1996-2007
Moderate	1967-96
Low	1879-1967

6. MACROALGAL COVER

Macroalgal Rating	Good

Figure 27. Percentage Macroalgal cover Waikawa Estuary March 2007.

Although potentially nuisance algae were present in the estuary (Figure 27), they were generally at low densities (1-10% cover in the upper estuary and <1% cover in the lower estuary), except for small areas of greater than 80% cover in the mid estuary. In terms of species, the low density areas were dominated by the red algae *Gracilaria* sp. and the high density areas by sea lettuce, *Ulva* sp. The macroalgal condition rating for the estuary fits the "good" category, which means that monitoring should continue at 5 yearly intervals, without a need for any focused management action.



7. ESTUARY RISK ASSESSMENT

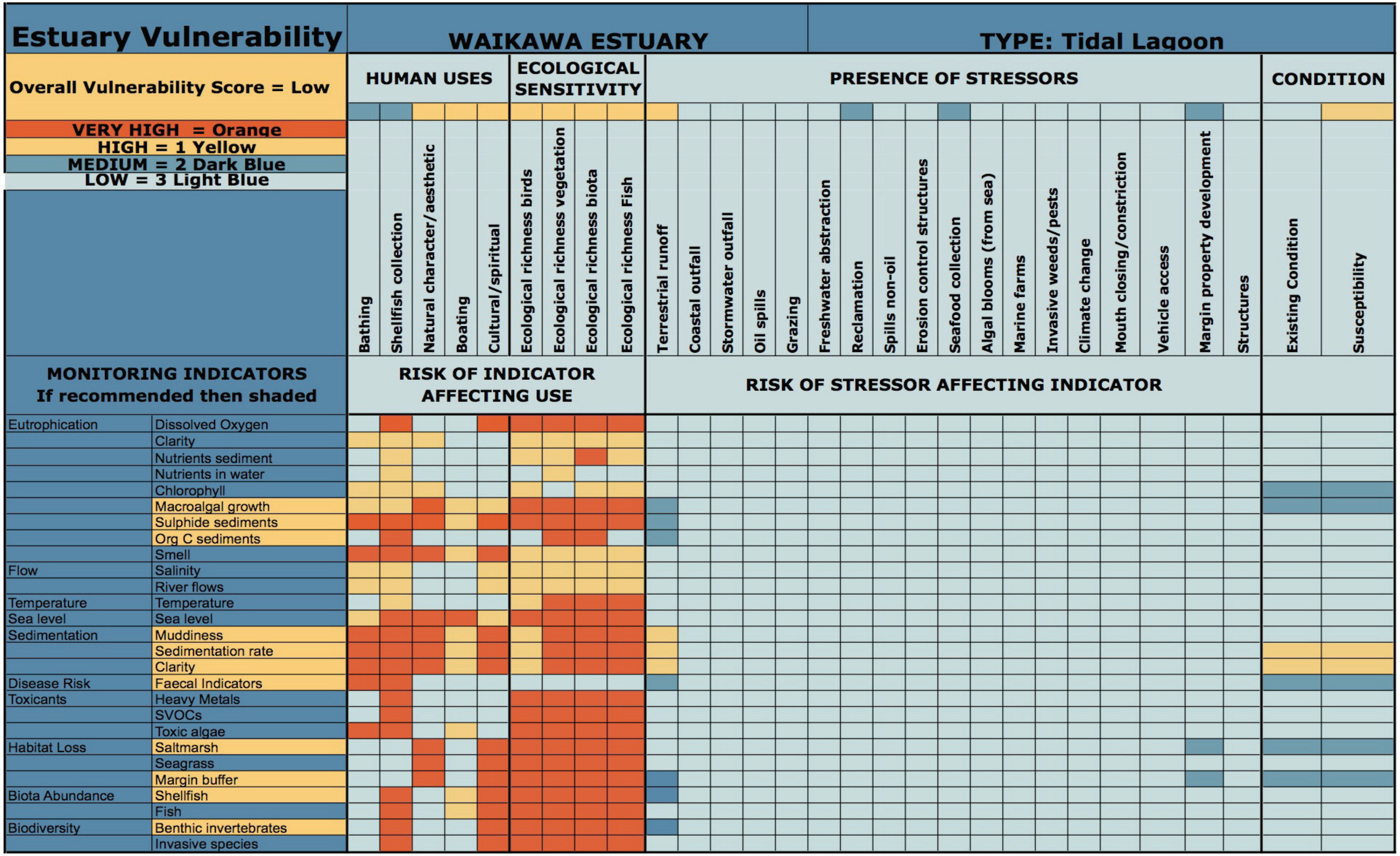
To address the susceptibilities and risks for Waikawa estuary, and identify the environmental information requirements, an "Estuary Risk Matrix" (see page 18) has been completed. This risk matrix consists of a series of steps that use available information to identify the following:

- The uses and values and ecological sensitivities
- The stressors (e.g. sediment runoff, urban stormwater, invasive pests)
- The risks of each stressor affecting some aspect of the estuaries overall condition (e.g. muddiness, algal blooms, disease risk)
- The existing condition and future susceptibility
- What indicators should be monitored.

In overview, the outcome of the risk assessment for the estuary indicates that it is shallow and well-flushed (residence time less than 3 days), with extensive areas of tidal flats which are primarily sandy in the lower estuary and muddy in the upper estuary. It has a relatively simple shape, lacking large sheltered tidal arms where muddy sediments tend to settle and accumulate. In terms of uses and values, it has strong spiritual and cultural affinities, is well-used for fishing, boating, swimming and walking, and it provides a natural focal point for the people that live near or visit its shores. The estuary has been modified over the years, particularly the margins where saltmarsh areas have been reclaimed. There is also a small area near the wharf where the inlet is lined with rockwalls.

The available information for the estuary also indicates that it has a naturally low susceptibility to sedimentation and nutrient enrichment effects based on dilution and flushing rates (i.e. in terms of its physical characteristics, it is not prone to sedimentation and enrichment effects). However, if inputs are high enough, then adverse effects could be expected. Waikawa Estuary has a primarily moderately hard rock type (sandstone/siltstone conglomerate) catchment, dominated by grassland and bush. As a consequence, it is expected to provide only low-moderate loads of sediment, nutrients, pathogens and potentially toxic contaminants to the estuary. Nevertheless, some activities in the catchment have the potential to increase loads to excessive levels, e.g. drainage works, forest clearance and intensification of agricultural landuse. This situation of low susceptibility and low-moderate inputs of nuisance materials, has resulted in an estuary with condition ratings that also fall into the low or moderate range (except for recent sedimentation rates) as follows:

WAIKAWA ESTUARY	Sedimentation	Eutrophication	Disease Risk	Contaminants	Habitat Loss	Invaders	Shellfish Issues
Existing Condition Rating	Moderate	Low	Low	Low	Moderate	Low	Low
Susceptibility Rating	Moderate	Low	Low	Low	Moderate	Low	Low



Estuary Vulnerability
WAIKAWA ESTUARY
TYPE: Tidal Lagoon
Overall Vulnerability Score = Low
VERY HIGH = Orange
HIGH = 1 Yellow
MEDIUM = 2 Dark Blue
LOW = 3 Light Blue
HUMAN USES
ECOLOGICAL SENSITIVITY
PRESENCE OF STRESSORS
CONDITION
Bathing
Shellfish collection
Natural character/aesthetic
Boating
Cultural/spiritual
Ecological richness birds
Ecological richness vegetation
Ecological richness biota
Ecological richness Fish
Terrestrial runoff
Coastal outfall
Stormwater outfall
Oil spills
Grazing
Freshwater abstraction
Reclamation
Spills non-oil
Erosion control structures
Seafood collection
Algal blooms (from sea)
Marine farms
Invasive weeds/pests
Climate change
Mouth closing/constriction
Vehicle access
Margin property development
Structures
Existing Condition
Susceptibility
MONITORING INDICATORS
If recommended then shaded
RISK OF INDICATOR AFFECTING USE
RISK OF STRESSOR AFFECTING INDICATOR
Eutrophication
Dissolved Oxygen
Clarity
Nutrients sediment
Nutrients in water
Chlorophyll
Macroalgal growth
Sulphide sediments
Org C sediments
Smell
Flow
Salinity
River flows
Temperature
Temperature
Sea level
Sea level
Sedimentation
Muddiness
Sedimentation rate
Clarity
Disease Risk
Faecal Indicators
Toxicants
Heavy Metals
SVOCs
Toxic algae
Habitat Loss
Saltmarsh
Seagrass
Margin buffer
Biota Abundance
Shellfish
Fish
Biodiversity
Benthic invertebrates
Invasive species

8. CONCLUSIONS

The 2007 monitoring results for the Waikawa Estuary sediments confirm the following:

Potential Toxicants

The extent of contamination with toxic substances was low as indicated by the low levels of heavy metals (cadmium, chromium, copper, lead, nickel and zinc) in the intertidal sediments.

Extent of Eutrophication

The extent of enrichment with organic matter and nutrients, and therefore the potential for eutrophication, was low as indicated by the low or low-moderate levels of TOC, TP and TN in the intertidal sediments.

The extent of the estuary covered with nuisance macroalgae (*Gracilaria, Enteromorpha* and sea lettuce), and therefore the extent of eutrophication, was low-moderate as indicated by the generally low-moderate cover of macroalgal species (mostly in the 1-10% range) in the intertidal sediments. It was noted that the estuary subtidal channels had much higher concentrations of *Gracilaria* and *Enteromorpha.*

The ratio of TN:TP in the intertidal sediments was close to 1:1 or in many cases less than 1:1, indicating a strong likelihood of nitrogen as the nutrient most likely to be limiting eutrophication in the Waikawa Estuary.

Sedimentation Rate

The historical analysis of the sediment core taken from the soft mud area of the upper estuary indicated that recent sedimentation rates are in the moderate to high category for NZ estuaries and consequently require further investigation, particularly as to likely sources and management of these sources. Further back in time, prior to 1996, sedimentation rates were lower. In the period, 1967-96 the average sedimentation rate was in the moderate range at 4 mm/yr and in the period, 1879-1967 it was in the low-moderate range at 1 mm/yr.

The particle size analysis for the 3 years of records showed little difference between years, indicating that increased sedimentation of mud-sized particles is not occuring in the firm sandy areas that dominate the lower two-thirds of the estuary. In future, sedimentation rates within the estuary will be measured using the 12 sedimentation plates deployed in this survey.

Recommendations

The only issue raised in this years monitoring of the Waikawa estuary was the excessive sedimentation rate measured since 1996. It is recommended that this issue should be further evaluated as to its likely cause (e.g. was it a huge input during a large flood?) and a management response plan initiated. The estuary risk assessment also raised the issue of historical margin development (bush clearance) and salt marsh reclamation. It is recommended that this issue also be addressed (e.g. through landcare programmes).

Acknowledgements

This survey and report has been undertaken with help from various people, local farmers who provided access to the estuary, and staff of Environment Southland, particularly Chris Arbuckle, Jane Kitson, Kirsten Meijer, and Les McGraw.

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APPENDIX 1 DETAILS ON ANALYTICAL METHODS

Indicator	Analytical Laboratory	Method	Detection Limit
Infauna Sorting and ID	Gary Stephenson, Coastal Marine Ecology Consultants		N/A
Grain Size (% sand, gravel, silt)	R.J Hill Laboratories	Air dry (35 degC, sieved to pass 2mm and 63 um sieves, gravimetric.	N/A
AFDW (% organic matter)	R.J. Hill Laboratories	Ignition in muffle furnace 550degC, 1 hr, gravimetric. APHA 2540 G 20th ed 1998.	0.04 g/100g dry wgt
Total recoverable cadmium	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.01 mg/kg dry wgt
Total recoverable chromium	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable copper	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable nickel	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable lead	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.04 mg/kg dry wgt
Total recoverable zinc	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.4 mg/kg dry wgt
Total recoverable phosphorus	R.J. Hill Laboratories	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total nitrogen	R.J. Hill Laboratories	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05 g/100g dry wgt

APPENDIX 2 DETAILS ON HISTORICAL SEDIMENTATION RATE RESULTS

Core Shortening
The Waikawa Estuary core was collected from offshore, intertidal sediments located at the western end of the estuary in very soft muds. Core shortening occurred in the core as it was compressed during collection. 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. The compressed core measured 900mm long with 130mm shortening (12.6% shortening).

Beryllium Dating
^{7}Be is used to determine short term mixing (i.e. a few months) of aquatic sediments. Because it has a short half life (53.3 days) and originates from the atmosphere, it will only be present at measurable levels in sediments that have been recently exposed to the atmospheric source (i.e. the upper mixed sediment layer). The presence of ^{7}Be in the upper 6-8cm of the Waikawa core and its absence below 8cm (Table A1) indicates a 6-8cm deep well-mixed layer at this site.

Lead Dating (detailed methods in Appleby and Oldfield 1992)
210-Pb is used to determine sedimentation rates over the last 100-150 years (from present until the start of the Industrial time) 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 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:

$$t = 1/k.\log N(C_0/C_t)$$

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

Caesium Dating
Peak atmospheric fallout of 137-Cesium in New Zealand occurred in 1964, with elevated levels occurring from 1959-1964 (Cambray et al. 1979; Loughran et al. 1988). The maximum depth of 137-Cs activity in the sediment core was taken to coincide with the year 1960. The depth of sediment above that maximum depth was used to estimate the sedimentation rate since 1960.

APPENDIX 2 DETAILS ON HISTORICAL SEDIMENTATION RATE RESULTS

Detailed Radio-isotope Results

Table A2.1. Waikawa Site Upper Sth: core collected March 2007

Compressed Depth (cm)	Uncompressed Depth (cm)	Total 210Pb	226Ra (=Supported 210Pb)	Unsupported 210Pb	137Cs	7Be
0-2	2.3	57.2	19.8	37.4	0.7	19.3
2-4	4.5	61.9	17.6	44.3	0.86	9.8
6-8	6.8	59	17.8	41.2	0.47	4.3
8-10	11.3	49.1	17.4	31.7	0.83	<0.64
16-18	20.3	31.3	18.6	12.7	0.48	<0.64
28-30	33.8	20.8	20	0.8	<0.53	<0.69
40-42	47.3	19.7	20.8	-1.1	<0.52	<0.68
60-62	69.8	22.8	23.2	-0.4	<0.50	<0.69
78-80	90.1	20.6	23.2	-2.6	<0.50	<0.72

The 7-Be and 210-Pb data (Table A2.1) both indicate a well-mixed upper layer of 6-8cm depth.
The maximum depth of 137-Cs activity in the sediment core was measured at 18-28cm (Table A2.1) and was taken to coincide with the year 1960. The estimated gross sedimentation rate over this 47 yr period (1960-2007) was therefore 3.8-5.9 mm/yr.
The unsupported 210-Pb profile below the well-mixed upper layer, provides evidence to suggest sedimentation rates have varied (Table A2.2) as follows:

- 10.7 mm/yr in period 1996-2007
- 3.7 mm/yr in period 1967-96
- 1.4 mm/yr in period 1879-1967

Table A2.2. Sedimentation rates using unsupported Pb profiles.

Uncompressed Depth (mm) (=x)	Unsupported 210Pb	Year BP (=t)	Period (P)	Period Length (PL) (yrs)	Sediment Depth Deposited in Period (mm)	Sedimentation Rate (SR) in peiriod (mm/yr)
113	31.7	11 (1996)	1996-2007	11	112.6	10.7
203	12.7	35 (1967)	1967-1996	24	90.08	3.7
338	0.8	129 (1879)	1879-1967	94	135.12	1.4

APPENDIX 3 2007 DETAILED RESULTS

Physical and Chemical Results

Estuary	Site	Repl.	AFDW	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
			%				mg/kg							
Waikawa	A	01	1.3	10.2	89	0.9	0.01	7.4	2.9	4.6	1.67	14.3	500	287
Waikawa	A	02	1.68	11.9	86.7	1.4	0.02	8.6	3.5	5.7	1.94	16.2	500	309
Waikawa	A	03	1.2	8.3	90.2	1.5	0.01	7.8	3	4.7	1.73	15	500	297
Waikawa	B	01	1.16	3.5	96.5	0.01	0.02	7	2.7	4.4	1.53	11.8	500	236
Waikawa	B	02	0.99	3.5	96.5	0.1	0.01	7.3	2.7	4.5	1.61	12	500	237
Waikawa	B	03	1.21	2.3	97.5	0.2	0.01	5.8	2.5	3.9	1.33	10.5	500	215

Epifauna (numbers per 0.25m^2 quadrat) and Site Locations,

Waikawa A (RPD >20cm at all locations). Salinity at low water 20.8ppt @15 degC										
Station	1	2	3	4	5	6	7	8	9	10
NZMG260 East	2214588	2214575	2214562	2214548	2214545	2214554	2214567	2214585	2214589	2214579
NZMG260 North	5391469	5391467	5391469	5391472	5391461	5391460	5391458	5391458	5391449	5391448
Cominella glandiformis Mudflat whelk	2	0	1	0	1	0	0	1	0	0
Diloma subrostrata Mudflat topshell	9	4	4	2	0	3	3	2	0	2
Notoacmea helmsi Estuarine limpet	1	0	0	0	0	0	0	0	0	0
Austrovenus stutchburyi Cockle	2	1	0	3	0	0	0	0	0	0
Anthopleura aureoradiata Mudflat anemone	0	0	0	0	0	0	0	0	2	0
Gracilaria (% cover)	5	5	5	5	5	1	1	0	1	1

Waikawa B (RPD >20cm at all locations). Salinity at low water 20.8ppt @15 degC										
Station	1	2	3	4	5	6	7	8	9	10
NZMG260 East	2214930	2214941	2214961	2214977	2214971	2214956	2214941	2214925	2214926	2214935
NZMG260 North	5390793	5390795	5390800	5390805	5390811	5390808	5390801	5390804	5390811	5390818
Cominella glandiformis Mudflat whelk	1	0	0	0	0	0	0	0	0	0
Diloma subrostrata Mudflat topshell	8	11	3	5	2	2	5	3	5	1
Notoacmea helmsi Estuarine limpet	1	0	0	0	0	0	0	0	0	0
Austrovenus stutchburyi Cockle	0	0	0	0	0	0	0	1	0	0
Elminius modestus Estuarine barnacle	0	0	0	1	0	0	0	1	0	0
Ulva (% cover)	0	0	0	0	0	0	1	0	0	0

APPENDIX 3 2007 DETAILED RESULTS (INFAUNA)

Group	Species	WK A-01	WK A-02	WK A-03	WK A-04	WK A-05	WK A-06	WK A-07	WK A-08	WK A-09	WK A-10
ANTHOZOA	Anthopleura aureoradiata	3	3	6	3	0	4	6	2	3	5
	Edwardsia sp.#1	0	1	1	0	1	0	2	0	0	3
NEMERTEA	Nemertea sp.#1	0	0	1	0	0	0	0	1	0	0
	Nemertea sp.#2	0	0	0	0	0	0	0	0	0	0
NEMATODA	Nematoda	0	0	0	1	0	0	0	3	0	0
POLYCHAETA	Aglaophamus sp.#1	0	1	1	1	0	0	1	1	1	1
	Aonides sp.#1	0	0	0	0	0	0	0	0	0	1
	Boccardia (Paraboccardia) acus	4	1	1	1	1	3	0	0	1	0
	Boccardia (Paraboccardia) syrtis	4	6	5	4	4	4	7	5	1	2
	Capitella capitata	2	0	0	0	0	0	0	0	0	0
	Cirratulidae sp.#1	0	0	0	0	0	0	0	0	0	0
	Glycera lamellipodia	0	0	0	0	0	0	1	0	0	0
	Goniadidae sp.#1	0	1	1	0	0	0	0	2	0	0
	Hemipodus simplex	2	0	1	1	0	0	0	0	0	0
	Heteromastus filiformis	1	4	3	0	0	6	4	2	4	1
	Macroclymenella stewartensis	26	13	11	13	14	24	13	8	16	10
	Nicon aestuariensis	0	0	0	0	0	1	0	0	0	0
	Orbinia papillosa	0	0	0	0	0	0	0	0	0	0
	Paraonidae sp.#1	18	10	17	27	23	26	14	17	24	9
	Paraonidae sp.#2	0	0	0	0	0	0	0	0	0	0
	Perinereis vallata	0	0	0	2	0	0	0	0	0	0
	Phyllodocidae sp.#1	1	0	1	0	0	0	0	0	0	0
	Prionospio aucklandica	4	4	1	3	2	2	9	2	4	4
	Scolecolepides benhami	1	1	0	0	0	0	0	0	0	0
	Sphaerosyllis sp.#1	15	22	20	13	37	31	33	26	33	9
	Syllidae sp.#1	0	0	0	0	0	0	0	0	0	0
	Travisia olens	0	0	0	0	0	0	0	0	0	0
OLIGOCHAETA	Oligochaeta sp.#1	4	2	1	0	5	2	2	0	0	0
GASTROPODA	Cominella glandiformis	0	0	2	0	0	0	2	0	0	0
	Diloma subrostrata	0	0	0	0	0	1	1	1	1	0
	Notoacmaea helmsi	1	0	1	0	0	1	2	0	0	0
BIVALVIA	Arthritica sp.#1	1	1	3	2	2	4	4	1	2	0
	Austrovenus stutchburyi	7	3	9	3	3	12	7	6	7	5
	Macomona liliana	3	3	1	2	3	0	3	2	2	1
	Nucula sp.#1	3	6	3	9	6	12	11	8	12	7
	Paphies australis	0	0	0	0	0	0	0	0	1	0
	Soletellina sp.#1	0	0	0	0	0	0	0	0	0	0
CRUSTACEA	Amphipoda sp.#1	5	3	5	12	2	11	1	10	5	0
	Austrominius modestus	0	0	0	0	0	0	0	0	0	0
	Colurostylis lemurum	7	3	3	4	1	10	2	3	5	0
	Halicarcinus whitei	0	1	0	1	0	0	0	0	0	0
	Isocladus sp.#1	2	0	1	0	0	1	2	1	0	1
	Mysidacea sp.#1	0	2	0	0	0	0	1	0	0	0
	Phoxocephalidae sp.#1	1	0	0	0	0	2	0	0	0	0
	Pontophilus australis	0	0	0	0	0	0	0	0	0	1
	Tanaidacea sp.#1	1	3	1	5	1	7	4	3	1	3
OSTEICHTHYES	Peltorhamphus sp.#1	0	0	1	0	0	0	0	0	0	0
Total species in sample		47	47	47	47	47	47	47	47	47	47
Total individuals in sample		116	94	101	107	105	164	132	104	123	63

APPENDIX 2 2007 RESULTS (INFAUNA)

Group	Species	WK B-01	WK B-02	WK B-03	WK B-04	WK B-05	WK B-06	WK B-07	WK B-08	WK B-09	WK B-10
ANTHOZOA	Anthopleura aureoradiata	8	1	1	2	1	5	3	1	3	3
	Edwardsia sp.#1	0	0	0	1	2	1	2	1	2	0
NEMERTEA	Nemertea sp.#1	0	0	0	0	0	0	0	0	0	0
	Nemertea sp.#2	0	0	0	1	0	0	0	0	1	0
NEMATODA	Nematoda	0	0	0	0	0	0	0	0	0	0
POLYCHAETA	Aglaophamus sp.#1	1	0	1	0	1	0	1	0	0	1
	Aonides sp.#1	8	8	5	3	1	6	3	3	2	5
	Boccardia (Paraboccardia) acus	0	0	0	0	0	0	0	0	0	0
	Boccardia (Paraboccardia) syrtis	1	1	0	5	2	1	4	10	1	9
	Capitella capitata	0	0	0	0	0	0	0	0	0	0
	Cirratulidae sp.#1	11	7	2	8	0	8	9	6	2	4
	Glycera lamellipodia	1	0	0	0	0	0	0	0	0	0
	Goniadidae sp.#1	0	0	0	0	0	0	0	0	0	0
	Hemipodus simplex	0	2	0	1	0	1	2	1	2	1
	Heteromastus filiformis	2	4	0	1	0	0	1	2	2	1
	Macroclymenella stewartensis	1	1	3	3	2	2	2	1	3	2
	Nicon aestuariensis	0	0	0	0	0	1	0	0	0	0
	Orbinia papillosa	0	2	1	1	1	1	2	1	2	1
	Paraonidae sp.#1	1	0	2	0	0	0	0	3	0	1
	Paraonidae sp.#2	0	0	0	0	0	0	1	0	0	0
	Perinereis vallata	0	0	0	0	0	0	0	0	0	0
	Phyllodocidae sp.#1	0	0	0	0	0	0	0	0	0	1
	Prionospio aucklandica	1	0	1	1	0	0	0	1	2	2
	Scolecolepides benhami	0	0	0	0	1	0	0	2	0	0
	Sphaerosyllis sp.#1	0	0	0	1	0	0	0	2	0	0
	Syllidae sp.#1	3	0	0	1	1	1	2	0	1	0
	Travisia olens	0	3	1	0	4	3	3	1	0	1
OLIGOCHAETA	Oligochaeta sp.#1	0	0	0	0	0	0	0	0	0	0
GASTROPODA	Cominella glandiformis	0	0	0	0	0	0	0	0	0	0
	Diloma subrostrata	0	0	0	0	0	0	0	0	0	0
	Notoacmaea helmsi	0	0	0	0	0	1	0	0	2	0
BIVALVIA	Arthritica sp.#1	0	0	0	0	0	0	0	1	0	0
	Austrovenus stutchburyi	8	5	6	3	3	7	8	2	3	3
	Macomona liliana	1	2	0	0	1	2	1	0	0	0
	Nucula sp.#1	0	0	0	0	0	0	0	0	0	0
	Paphies australis	3	2	0	0	1	0	0	0	0	0
	Soletellina sp.#1	1	1	1	0	0	1	0	0	0	3
CRUSTACEA	Amphipoda sp.#1	0	1	0	0	2	1	4	1	2	2
	Austrominius modestus	13	2	15	8	1	10	1	10	10	2
	Colurostylis lemurum	19	6	13	10	4	10	14	5	8	8
	Halicarcinus whitei	0	0	0	0	0	0	0	0	0	0
	Isocladus sp.#1	0	1	0	0	0	0	0	0	0	1
	Mysidacea sp.#1	0	0	0	0	0	0	0	0	0	0
	Phoxocephalidae sp.#1	0	0	0	0	0	0	0	1	0	0
	Pontophilus australis	0	0	0	0	0	0	0	0	0	0
	Tanaidacea sp.#1	0	0	0	0	0	0	0	0	0	0
OSTEICHTHYES	Peltorhamphus sp.#1	0	0	0	0	0	0	0	0	0	0
Total species in sample		47	47	47	47	47	47	47	47	47	47
Total individuals in sample		83	49	52	50	28	62	63	55	48	51