Habitat Mapping of the Kakanui River Estuary

Otago Regional Council State of the Environment Report

Prepared by

Ryder Consulting

January 2009

ryderconsulting
ecology + planning + project management

Habitat Mapping of the Kakanui River Estuary

Otago Regional Council State of the Environment Report

Prepared by

Brian Stewart PhD and Cressida Bywater MSc

Ryder Consulting

January 2009

Cover photo: Whitebaiter at the mouth of the Kakanui River Estuary.

Ryder Consulting Ltd.
PO Box 1023
Dunedin
New Zealand
Ph: 03 477 2119
Fax: 03 477 3119

Table of Contents

1. Introduction

The Otago Regional Council (ORC) has identified a need to gather information on the biological resources of river estuaries present within Otago to assist in both strategic planning and in the management of specific issues associated with resource consents, pollution, and state of the environment monitoring.

Although the Kakanui River Estuary is considered to be of regional importance in terms of its ecological, scenic, spiritual and/or cultural values, it is not designated as a Coastal Protection Area under the Otago Regional Council's Regional Plan: Coast. Kakanui Beach, at the mouth of the estuary, however, is important for swimming, fishing, SCUBA diving and walking and is designated as a Coastal Recreational Area (CRA2) under the Plan. It is recognised that there is the potential for adverse effects on the intertidal ecosystem of the Kakanui River Estuary from sedimentation, runoff, discharges, stormwater, recreational use and alterations to the stream processes.

To gather robust baseline data against which future changes may be compared a comprehensive estuarine environmental assessment is essential. Such an assessment will comprise broad and fine scale mapping.

The ORC has engaged Ryder Consulting to carry out the estuary mapping.

2. Objectives

To carry out broad and fine scale mapping of the Kakanui River Estuary in accordance with the National Estuary Monitoring Protocol and produce a report outlining:

1) The methodology used in the mapping and sampling programme and any problems encountered.
2) A record of the references cited and used to assist in the sampling.
3) Photographs of all the sites surveyed.
4) MapInfo GIS maps of all the surveyed areas with dominant cover habitats shown and sampling site locations.
5) A discussion for each fine-scale site of the fauna and flora identified and any nationally or regionally significant species, and any other information relevant to the Client.

6) An identification of the pressures at each site that will become part of the sensitivity matrix.
7) A set of recommendations on the most suitable method(s) for resource management of identified problems.

Broad scale mapping is a robust GIS-based methodology for mapping the spatial distribution of intertidal estuarine habitats and consists of:

I. Visiting each site to record and ground-truth the key habitat types and substrate features on rectified aerial photographs supplied by the Client.
II. Providing a subjective assessment of the ecological health and vulnerabilities from pressures (human influences). This information will become part of the sensitivity matrix.
III. Digitising habitat and substrate features into MapInfo or other suitable GIS software.

Fine-scale mapping involves measuring environmental characteristics that are known to be indicative of estuary or coastal condition, and are likely to provide a means for detecting habitat degradation, as well as providing a measure of subsequent change. In other words, fine-scale mapping examines the spatial variation and inter-relationships of a suite of commonly measured indicators and consists of:

I. Selecting at least two representative sites within the dominant intertidal habitat.
II. Taking replicate sediment samples at each site and analysing for known important variables.

3. Methodology

3.1 Broad scale mapping

Aerial photographs, supplied by the ORC, were used to generate base maps of vegetation and substrata within the estuary. The photographs were ground truthed by Ryder Consulting staff during field surveys using obvious landmarks and a handheld Garmin GPS unit. A minimum of six landmarks were identified and used, in conjunction with GIS software, to rectify each aerial photograph in an attempt to keep on-ground spatial errors to <5m.

Field surveys were conducted on foot by an experienced coastal marine scientist to verify vegetation and substrate types, and to identify features not distinguishable

through aerial photography alone. Using GPS and 100m measuring tapes, the spatial extent of all substrate and habitat features encountered in the field was transcribed to hard copies of photographs/maps with locations accurately defined in relation to obvious landmarks. Positional accuracy was recorded by calculating the root mean square (RMS) error for each landmark. Hard copies of maps and photographs were to be digitised to enable transfer of data to a GIS computer program. However, all images supplied by the ORC were in digital format and this was, therefore, unnecessary. All sites/features visited in the field were digitally photographed.

Classification for wetland types was based on the Atkinson System (Atkinson 1985) that covers four levels, ranging from broad to fine-scale. The broad-scale mapping to be carried out for this project focused on Levels III and IV (below).

Level I Hydrosystem (*e.g.* intertidal estuary)
Level II Wetland Class (*e.g.* saltmarsh, mud/sand flat)
Level III Structural Class (*e.g.* marshland, mobile sand)
Level IV Dominant Cover (*e.g. Zostera muelleri*)

Substrate classification was based on surface layers only and did not consider underlying substrate; e.g., cobble or gravel fields covered by sand were classed as sand flat.

Level III structural classes formed the basis of the broad scale mapping and are detailed below.

Definitions of Classification of Level III Structural Class – Estuaries (from Robertson et al. *2002*).

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 in which the 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 in which the lichen cover exceeds that of any other growth form or bare ground.
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. If the reed is broken the stem is both round and hollow – somewhat like a soda straw. The flowers will

each bear six tiny petal-like structures – neither grasses nor sedges will bear flowers, which look like that. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Example include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata*, and *Baumea articulata*.

Rushland: Vegetation in which the cover of rushes in the canopy is 20-100% and in which the rush cover exceeds that of any other growth form or bare ground. A tall grass like, often hollow-stemmed plant, included in the rush growth form are some species of *Juncus* and all species of, *Leptocarpus*. Tussock-rushes are excluded.

Sedgeland: Vegetation in which the cover of 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*. Tussock-sedges and reed-forming sedges (c.f. REEDLAND) are excluded.

Grassland: Vegetation in which the cover of grass in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth-form.

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*.

Shrubland: Cover of shrubs in canopy 20-80%. Shrubs are woody plants <10 cm diameter at breast height (dbh).

Scrub: Woody vegetation in which the cover of shrubs and trees in the canopy is > 80% and in which shrub cover exceeds that of trees (c.f. FOREST).

Treeland: Cover of trees in canopy 20-80%. Trees are woody plants >10cm dbh.

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 dbh. Tree ferns = >10 cm dbh are treated as trees.

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 chlorophyll, 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.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking on the substrate 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 walking on the substrate 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 on the substrate you'll sink greater than 5 cm.

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 less than 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 impossible.
Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink greater than 2 cm.
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 of = 1%.
Cobble field: Land in which the area of unconsolidated cobbles/stones (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%.
Boulder field: Land in which the area of unconsolidated bare boulders (> 200 mm diam.) exceeds the area covered by any one class of plant growth-form. Boulderfields are named from the leading plant species when plant cover is =1%.
Rock/Rock field: Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. Cliff vegetation often includes rocklands. They are named from the leading plant species when plant cover is = 1%

During the field visit to the estuary any obvious environmental pressures were noted. A simple risk assessment matrix (Table 1) was used to define the level of concern associated with different environmental pressures on habitats encountered and a colour ranking (red = high, green = low) was used to indicate risk or level of concern. The use of letters and numbers (A1 – D4) enables further definition of the drivers for the level of concern based on the percentage of the resource affected and the likely recovery time. For example. if an environmental pressure affects say 30% of the area and the area would take approximately 3 years to recover from that impact a risk of B3 would be assigned for that pressure (e.g. see Table 1). It is important to note that the matrix does not confirm the presence of an impact, merely the presence of pressures and possible consequences of that pressure on the environment.

Table 1. *Risk assessment matrix for evaluating levels of concern regarding habitat pressures at each site. Red = high; yellow = moderate concern; green = low.*

		Recovery from impact			
		(Slow) >10 years	5-10 years	1-4 years	(Rapid) <1 year
% of habitat affected		1	2	3	4
>50% (Large)	A	A1	A2	A3	A4
30-50%	B	B1	B2	B3	B4
10-30%	C	C1	C2	C3	C4
0-10% (Small)	D	D1	D2	D3	D4

The environmental pressures identified during this survey include:

- Flooding
- Introduced weeds
- Nutrient pollution
- Stormwater
- Vehicles
- Stock
- Erosion
- Litter
- Reclamation

This report gives a broad overview of the activities that may influence the environmental quality within the estuary, and possible significance of each.

3.2 Fine scale mapping

The Kakanui River Estuary is not particularly large so just two representative sites were selected within the estuary, based on broad scale mapping and field observations. The sites were located in the mid- to low-water zone within the dominant habitat type, taking care to avoid channels and areas of significant vegetation. Each site comprised an area 60m x 30m divided into 12 sub-areas (Figure 1). Within each sub-area a randomly selected plot was sampled as follows:

1 **Sediment core profiles** (and depth of Redox Discontinuity Layer):

- One randomly positioned 80mm diameter core was collected to a depth of at least 100mm from each plot.
- The core was extruded onto a white plastic tray, labelled, and photographed alongside a ruler for scale.
- The stratification of colour and texture, particularly the occurrence of any black (anoxic) zones, was used to assess the depth of any lighter-coloured surface layer - the depth of the Redox Discontinuity Layer (RDL).

2. **Epifauna** (surface-dwelling animals):

- Epifauna was assessed from one randomly placed 0.25m^2 quadrat within 1m of the core sample in 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 data sheets containing a checklist of expected species.

- Field notes were transferred to a spreadsheet or database for statistical analyses.

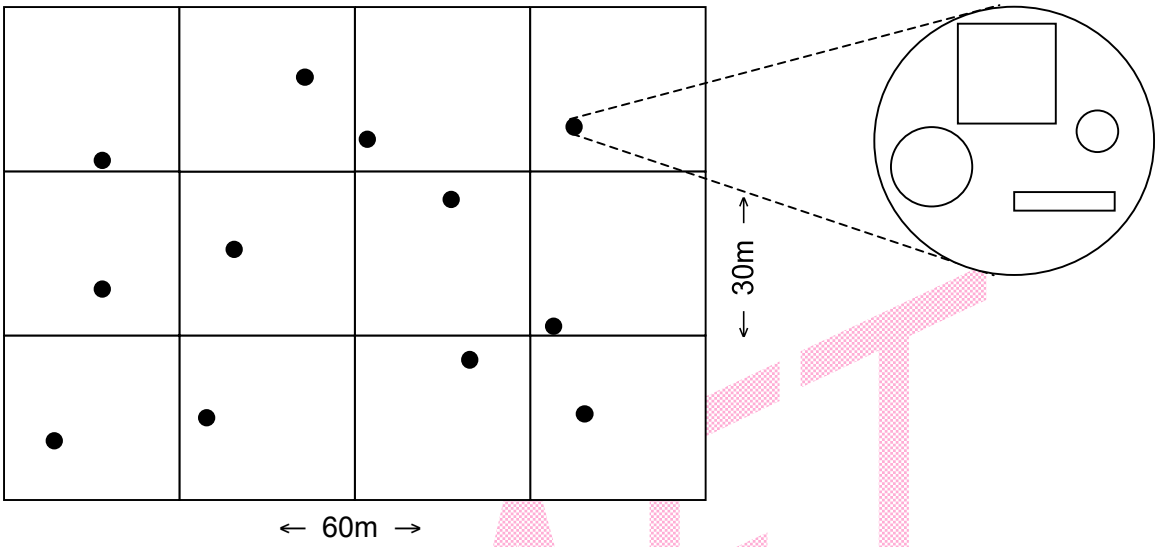


Figure 1. *Layout of sampling area. Squares are sub-areas; black dots are randomly located sampling plots. Circle on right is an enlargement of a sampling plot showing 0.25m^2 quadrat for epibiota analysis, small sediment core for RDL determination, large sediment core for infauna analysis, and small rectangle for sediment physico/chemical analysis.*

3. **Macroalgae** (seaweeds) % cover:

- Where a significant macroalgal cover existed, the percent coverage was estimated using a grid quadrat.

4. **Infauna** (animals living buried in the sediments):

- Three replicate sediment cores were collected from each site at random positions (i.e. six per estuary) using a 125mm diameter (area = 0.0039m^2) corer.
- The corer was driven into the sediments to a depth of 150mm, removed with core intact and the contents washed through 0.5mm Endicott® sieve using local seawater. Captured material and fauna was carefully emptied into labelled plastic containers and preserved using 95% ethanol.
- Samples were returned to the laboratory and examined using a 10X dissecting microscope.
- Invertebrate species were identified to the lowest taxonomic level possible, counted and recorded.
- Data was transferred to a spreadsheet/database for future comparisons.

3.3 Chemical analyses

- Twelve replicate sediment samples (each of approximately 250 grams, with one from each plot) were collected from the top 20mm of fine sediment within each sub-area. The 12 samples were thoroughly mixed to provide one composite sample per site (i.e. a total of two samples for the estuary), as done by Stevens *et al*. (2004) for a similar exercise around Wellington and by Stewart (2007, 2008a,b) for other Otago estuaries. Samples were placed into pre-labelled ziplock plastic bags and stored on ice in the field before being frozen prior to shipping to the Hill Laboratories in Hamilton for analysis.
- The following analyses was carried out:

  Grain size (% mud silt and sand)
  Ash free dry weight
  Total nitrogen
  Total phosphorus
  Cadmium
  Chromium
  Copper
  Lead
  Nickel
  Zinc

4. Results

4.1 Environmental Pressures

A summary of environmental pressures identified at each site and a subjective assessment of the level of concern for each is shown in Table 2 using the matrix presented in Table 1. Blank spaces indicate that the identified pressure is not considered significant or relevant, while a "?" indicates that the pressure may be present, but needs confirmation.

Introduced weeds were widely present, but, as in Stevens *et al*. (2004) and Stewart (2007, 2008a,b) any influence from this pressure has not been defined due to the fact that impact and recovery from this pressure is species and location specific. Although common, the coverage of introduced weeds was often extremely patchy and, where this happened, they were not recorded under broad scale mapping in this survey. However, where dense stands of gorse (*Ulex europaeus*) or lupins (*Lupinus arboreus*) were encountered these were recorded as scrubland.

A subjective assessment of the degree of modification to the estuary has also been included. In the case of the Kakanui River Estuary modification is generally limited to reclamation, the formation of vehicle tracks, installation of fences, and the construction of bridges and stop banks.

Table 2. *Summary of environmental pressures at Kakanui River Estuary and level of concern. Red = high concern; yellow = moderate concern; green = low concern (Refer to Table 1).*

Pressure	Kakanui River Estuary
Flooding	B4
Introduced weeds	✓
Nutrient pollution	B3
Stormwater	D4
Vehicles	D3
Litter and dumped items	D2
Stock (grazing/trampling)	C3
Erosion	D3
Reclamation	D2
Degree of modification*	M

* VH = Very High, H = High, M = Moderate, L = Low.

This identification and ranking of pressures should be viewed as a starting point for discussion. Detailed information is likely to be available on many aspects, and local knowledge could be of great benefit. Such further investigation is beyond the scope of this survey. It is envisaged that this summary will provide a starting point for deciding whether further investigation is justified, and, if so, where priorities may lie.

Considering the amount of cultivated farmland upstream or adjacent to the estuary, nutrient enrichment is likely, but is difficult to quantify without further investigation.

Reclamation has certainly occurred in past years, but the majority of pasture and fencing on reclaimed land appears to be very well established and may be in the order of many decades old. There is no evidence of more recent reclamation in the estuary.

For Kakanui River Estuary the absence of any red cells in Table 2 shows there is little need for any further investigation and/or action with respect to environmental stressors on the estuary.

Erosion appears to be an issue at the Kakanui River Estuary. There is evidence of relatively recent bank collapse along parts of the true right bank (Figure 2) and true left bank (Figure 3) in the upper estuary, but such erosion events appear not to be common.

Figure 2. *Bank erosion along the true right bank of the Kakanui River Estuary.*

Figure 2. *Bank erosion along the true left bank of the Kakanui River Estuary.*

4.2 Broad Scale Mapping – Kakanui River Estuary

4.2.1 Ground-truthing and digitising habitat

The Kakanui River Estuary was visited for the purpose of broad scale mapping on the 17th of November 2008. Six prominent landmarks were located using aerial photographs (Figure 4) and GPS readings taken at points either end of each landmark. The distance between points on each landmark was measured using a 100m tape, then compared with maps generated using aerial photographs and tfw files supplied by the ORC. Aerial photographs were ortho-rectified using MAPublisher® 6.2. All distances measured on photographs corresponded with ground truth measurements to within 2m.

Estuary boundaries were set by EHWS (extreme high water spring tide) and ELWS (extreme low water spring tide). The entire estuary was walked with notes being taken on substrate type, vegetation cover and type, and any other distinguishing features. At the same time, drawings were made on field copies of aerial photographs to aid in the digitising of field information. Vegetation and substrate features identified during the field surveys were digitally mapped as precisely as possible on-screen from the rectified photograph. GIS shape files were then used to visually represent each specific feature, as well as to calculate the area of cover for different habitat/substrate types.

4.2.2 Habitat and Substrate Features

The Kakanui River has a long (2.2km) and relatively narrow (no more than 230m wide) estuary (Figures 4 and 5) covering slightly less than 27ha, excluding deep water (Table 3). A relatively small percentage of the estuary area is exposed at low water. It should be noted that the mouth of the estuary appears to be quite mobile and, at the time of the survey, was some 20-30m north of the location shown in Figure 5. It would appear that the morphology of the estuary is such that very little of the area has been reclaimed for farming. However, some tracts on the true left bank near the mouth can be described as flood plain and, although currently used for grazing, may become inundated at times of high flood. Portions of this floodplain are currently being replanted quite extensively with native trees and shrubs (Figure 6).

Figure 4. *Kakanui River Estuary with ground truthing sites marked as yellow bars.*

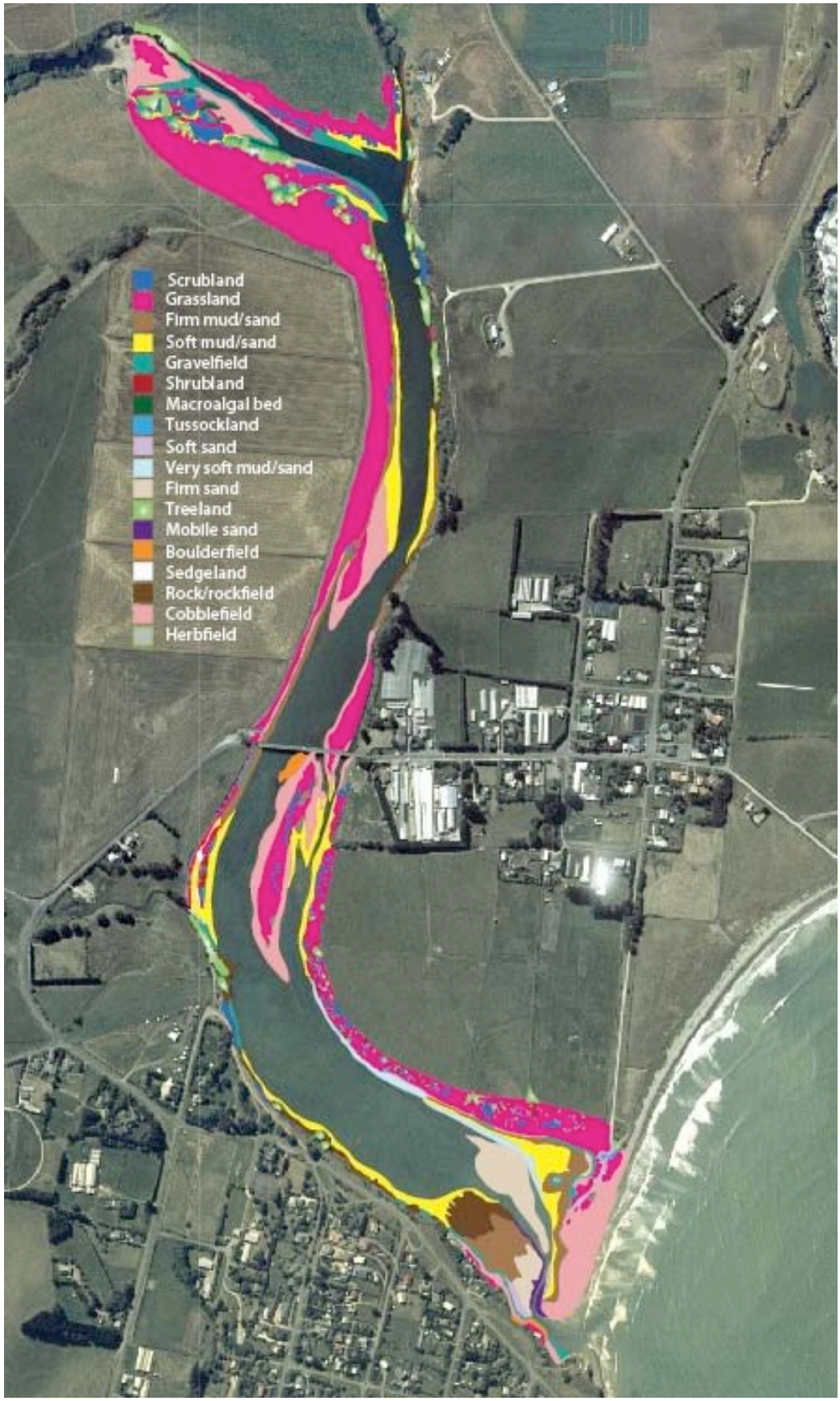


Figure 5. *Kakanui River Estuary showing habitat types.*

Figure 6. *Replanting being carried out along the true left bank, Kakanui River Estuary.*

Grassland is the dominant vegetation type surrounding the Kakanui River Estuary. Grasses are generally associated with flatter areas that adjoin cultivated farmland and dominate the upper estuary on the true right bank (TRB), mid estuary on the true left bank (TLB) and both sides of the estuary mouth (Figure 5). The predominant grass along the estuary edge is tall fescue (*Festuca arundinacea*), with other prevalent grass species including creeping bent (*Agrostis stolonifera*), cocksfoot (*Dactylis glomerata*), sweet vernal (*Anthoxanthum odoratum*) and Yorkshire fog (*Holcus lanatus*).

Isolated stands of treeland are present along both sides of the estuary (Figure 5). Crack willow (*Salix fragilis*) dominates the upper estuary true right bank and opposite true left bank, while Monterey pine (*Pinus radiata*) is found closer to the estuary mouth on the true right bank. Close to the bridge on the true left bank white poplar (*Populus alba*) is dominant, interspersed with patches of crack willow. Some planted cabbage trees (*Cordyline australis*) are scattered within the grassland (on the true left bank) close to the estuary mouth.

Scrubland and tussockland are scattered throughout the true right and true left estuary banks (Figure 5). Scrubland generally consists of gorse and lupin, with gorse slightly more abundant than lupin. Tussockland is patchily spread throughout the estuary, with individual flax bushes (*Phormium tenax*) scattered in the grassland on the lower true left bank and within the treeland on the upper true right bank. Areas of marram grass (*Ammophila arenaria*) are located at the true left bank near the estuary mouth.

Small clumps of shrubland, comprising of mainly saltmarsh ribbonwood (*Plagianthus divaricatus*), are most prevalent in the grassland on the upper true left bank.

Herbfield is quite rare and is generally confined to the islands under the Kakanui bridge between the mid tide and the extreme high water spring tide (EHWS) zones (Figure 5). A further patch is situated opposite the island on the true left bank. Herbfield is generally dominated by sea primrose (*Samolus repens*) and swampweed (*Selliera radicans*), with the occasional appearance of glasswort (*Salicornia australis*). The macroalgae *Entromorpha* sp. and *Chlodophera* sp. dominate the inlets between the islands in the upper estuary.

Sedgeland is located along the estuary at two areas. The first of these is found in the mid tide zone on the true right bank of the island under the bridge (Figure 5). The second patch is located slightly closer to the estuary mouth on the true right bank. Both of these patches are dominated by three-square (*Schoenoplectus pungens*).

Areas of exposed substrate are generally confined to cobblefields around the mouth of the estuary and on upstream islands (Figure 5). Firm sand is a feature of the lower estuary just upstream of the mouth with softer sand/mud substrates lining the shores as one moves upstream.

Table 3. *Proportions of the various habitat types at Kakanui River Estuary shown as hectares and percentage.*

Habitat type	Area (ha)	% of total area
Boulderfield	0.10	0.43
Cobblefield	7.19	29.19
Firm mud/sand	1.42	5.76
Firm Sand	0.95	3.86
Grassland	8.49	34.49
Gravelfield	0.78	3.18
Herbfield	0.06	0.24
Macroalgal Bed	0.04	0.15
Mobile Sand	0.07	0.29
Rockfield	0.74	3.02
Scrubland	0.66	2.69
Sedgeland	0.01	0.06
Shrubland	0.10	0.39
Soft mud/sand	2.41	9.79
Soft Sand	0.15	0.59
Treeland	1.06	4.29
Tussockland	0.08	0.31
Very soft mud/sand	0.31	1.26
Whole Estuary	24.62	100.00

4.3 Fine Scale mapping – Kakanui River Estuary

The Kakanui River Estuary was visited on 18th of November 2008. Two sites (Figure 7), selected during the broad scale mapping, were sampled according to the methodology described above. There was insufficient suitable substrate to assess an upstream and a downstream site, so sites were chosen on the true left bank (TLB) and true right bank (TRB) (Figure 7). Both sites were located on low tidal sand/mud flats, representative of much of the lower estuarine area.

Figure 7. *Location of fine scale sites at the Kakanui River Estuary. True left bank site in blue, true right bank site in red.*

4.3.1 Sediment Core Profiles

Photographs of sediment cores are presented in Appendix 1. The TLB site (Site 1) comprised predominantly soft sand with a mud, broken shell and coarse gravel component. A redox discontinuity layer (RDL) appeared in many of the cores (Table 4) and varied in nature from a separate shallow diffuse layer to a very intensely discoloured lower layer. In no instance was a smell of hydrogen sulphide detectable at Site 2, but there was a faint hint of H_2S detectable associated with most cores at Site 1.

Table 4. *Brief description of sediment cores at the true left bank site (Site 1), Kakanui River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine sand/mud	50	>150	Diffuse, becoming intense	No
2	Fine sand/mud	50	>150	Well defined	No
3	Fine sand/mud	90	>150	Well defined/intense	No
4	Fine sand/mud	Nil	>150	Well defined/intense	No
5	Fine sand/mud	130	>150	Well defined/intense	No
6	Fine sand/mud	120	>150	Well defined/intense	No
7	Fine sand/mud	90	>150	Well defined/intense	No
8	Fine sand/mud	90	>150	Intense	No
9	Fine sand	Nil	Nil	Nil	No
10	Fine sand	Nil	Nil	Nil	No
11	Fine sand	Nil	Nil	Nil	No
12	Fine sand	Nil	Nil	Nil	No

The TRB site (Site 2) comprised mobile fine sand only (Table 5, Appendix 1). No redox discontinuity layer was discernible in any of the cores from the TRB site.

Table 5. *Brief description of sediment cores at the true right bank site (Site 2), Kakanui River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine sand	Nil	Nil	Nil	No
2	Fine sand	Nil	Nil	Nil	No
3	Fine sand	Nil	Nil	Nil	No
4	Fine sand	Nil	Nil	Nil	No
5	Fine sand	Nil	Nil	Nil	No
6	Fine sand	Nil	Nil	Nil	No
7	Fine sand	Nil	Nil	Nil	No
8	Fine sand	Nil	Nil	Nil	No
9	Fine sand	Nil	Nil	Nil	No
10	Fine sand	Nil	Nil	Nil	No
11	Fine sand	Nil	Nil	Nil	No
12	Fine sand	Nil	Nil	Nil	No

4.3.2 Epifauna

At each sub-site a randomly placed 0.25m^2 quadrat was photographed to assess epifauna. The photographs are presented in Appendix 1. At the true left bank site (Site 1) all sub-sites were largely devoid of macroalgae (see Section 4.3.3) with the substrate surface characterised by fine sand and occasional pebbles. Epifauna were not evident in any of the quadrats.

Site 2 (true right bank) also displayed a real paucity of epifauna with no animals seen within any of the quadrats. Amphipod burrows, however, were common. The surface of the substrate was characterised by uniform fine sand with undulations characteristic of mobile substrata (Figure 8).

Figure 8. *Rippled sand at Site 2, Kakanui River Estuary.*

4.3.3 Macroalgae

At each subsite the randomly placed 0.25m^2 quadrat photographed to assess epifauna was used to assess macroalgal cover at the fine scale, in addition to the broad scale mapping of macroalgae already discussed. At both Sites 1 and 2 macroalgae was almost totally absent. Very sparse wisps of the red alga, *Porphyra*, were just noticeable at quadrat 9, Site 1, with <2% cover.

4.3.4 Infauna

At each sub-site the contents from a 125mm diameter corer, driven into the substrate to a depth of 150mm at three randomly located sites, were sieved through a 0.5mm mesh Endicott® sieve. Retained material was examined in the laboratory using a 10X power dissecting microscope to assess infauna. Infauna at Site 1 was relatively depauperate but was characterised by burrowing polychaete worms and amphipods (Table 6). Mean number of infaunal animals per square metre at Site 1 is 625 with a mean of 5 taxa present for the site (Table 6).

At Site 2 there are considerably more animals per square metre, due largely to the very high number of gammarid amphipods. The infauna is dominated by amphipods, with a diversity of burrowing polychaete worms somewhat rare. There is, however, a smattering of small molluscs (Table 7). Mean number of infaunal animals per square metre at Site 2 is 27,150 with a mean of 4 taxa present for the site (Table 7).

Table 6. *Infauna at three sub sites sampled at the true left bank site (Site 1), Kakanui River Estuary.*

			GPS co-ordinates	E2344842 N5555811	E2344775 N5555802	E2344770 N5555795
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae		2	4	2
		Spionidae		3	2	2
Nemertea						
Crustacea						
	Amphipoda					
		Phoxocephalidae		1	1	1
		Lysianassidae				1
		Gammaridae			1	2
Mollusca						
	Gastropoda					
		Hydrobiidae				
			Potanopyrgus estuarinum	1		
		Veneridae				
			Austrovenus stutchburyi		1	
Nematoda						1
Number of Animals				7	9	9
Animals/m^2				525	675	675
Number of Taxa				4	5	6

Table 7. *Infauna at three sub sites sampled at the true right bank site (Site 2), Kakanui River Estuary.*

			GPS	E2344719	E2344810	E2344825
			co-ordinates	N5555669	N5555755	N5555750
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Maldanidae			1	
Nemertea						
Crustacea						
	Amphipoda					
		Gammaridae		356	243	463
		Phoxocephalidae		3	8	2
		Lysianassidae		4	3	
	Isopoda					
			Isocladus armatus	1	1	1
Number of Animals				364	256	466
Animals/m^2				27300	19200	34950
Number of Taxa				4	5	3

4.3.5 Chemical Analysis

Replicate 250ml samples were scooped from the top 20mm of substrate at each of the 12 sub-sites at Sites 1 and 2. The replicate samples were thoroughly combined in a plastic bucket and a 500ml composite sample taken for each site. The composite samples were returned to the laboratory and frozen before being sent to Hill Laboratories in Hamilton for analysis.

All measured parameters were found at low levels at both the true left bank site and the true right bank site (Table 8). At the true left bank site contaminants were generally present in slightly higher concentrations (Table 8).

Observations in the field with respect to the nature of the substrate at each site were confirmed by particle size analysis with the higher proportion of finer sediments being found at the true left bank site (Table 8). This result and the slightly higher concentration of metals at this site likely reflects the more sheltered and less well flushed nature of the true left bank site (Figure 6).

Table 8. *Chemical analysis of sediments in Kakanui River Estuary.*

Parameter	ANZECC ISQG-Low Trigger Value	ANZECC ISQG-High Trigger Value	True Left Bank	True Right Bank
Dry Matter (g/100g)	-	-	79	81
Ash (g/100g)	-	-	98	99
Loss on Ignition (g/100g)	-	-	1.8	0.8
Total Nitrogen (g/100g)	-	-	<0.05	0.065
Total Phosphorus (mg/kg)	-	-	320	190
Cadmium (mg/kg)	1.5	10	0.032	0.017
Chromium (mg/kg)	80	370	5.6	3.2
Copper (mg/kg)	65	270	2.3	1.4
Nickel (mg/kg)	21	52	5.1	4.0
Lead (mg/kg)	50	220	10.0	1.7
Zinc (mg/kg)	200	410	20	8.8
Dry matter sieved (g/100g)			79	81
>2mm fraction (g/100g)	-	-	2.2	<0.1
63μm – 2mm fraction (g/100g)	-	-	92.9	98.1
<63μm fraction (g/100g)	-	-	4.9	1.9

5. Discussion and Recommendations

The Kakanui River Estuary is typical of moderately enriched southern South Island estuaries. There has been a small amount of reclamation for farmland, with the remaining estuarine area being largely intact and no further reclamation in progress. There are some environmental pressures within the estuary, mainly from nutrient loadings and stock grazing. Direct human impacts are limited to some littering and dumping of anthropogenic debris plus a small amount of damage by vehicular movements. While the Kakanui River Estuary is subject to flooding on occasion the relatively narrow nature of the estuary generally limits impacts.

The estuary shows a healthy suite of estuarine flora dominated by grassland generally bordering farmland with the addition of extensive areas of herbfield. Macroalgae are relatively scarce and nuisance growths that could be attributed to enrichment are not evident anywhere within the estuary.

Fauna, although relatively depauperate, are representative of typical estuarine animals found in healthy environments (Morton and Miller 1973). Polychaete worms and amphipods are a feature of all estuaries in the Otago region but densities of these animals are slightly lower than one would expect. Shellfish, such as cockles, are scarce in the inlet and there is consequently little pressure from recreational harvesting. Mud crabs, mud snails are notably absent from the lower estuary, likely due to the absence of

suitable habitat. Mud crab burrows are, however, evident in mud banks along the margins of the upper estuary

There is some evidence of very slight contamination of the sediments within the Kakanui River Estuary. However, levels are very low and are most likely stem from stormwater runoff.

The sediments within the estuary reflect the geology of the Kakanui River catchment and the well flushed nature of the estuary, with there being a high proportion of moderately fine sediment but very little silt or mud. There are patches of anoxic sediment within the estuary, but nothing that would not be expected in moderately enriched estuaries.

In conclusion the Kakanui River Estuary appears to be in good health. Areas of concern that may require further investigation are nutrient enrichment and also the direct impacts of humans (vehicles/dumping) along portions of the shore of the estuary. These pressures are not significant but may require monitoring over the coming years.

6. References

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

Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 2, Aquatic Ecosystems.

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.

Morton, J. and Miller M. (1973). The New Zealand Sea Shore. Collins, Auckland. 653 pp.

Stevens, L,, Robertson, B.M., and Robertson B. (2004). Broad Scale Habitat Mapping of Sandy Beaches and River Estuaries – Wellington Harbour and South Coast. Report prepared for the Greater Wellington Regional Council. pp.74.

Stewart B. (2007). Mapping of the Waikouaiti and Shag River Estuaries: Otago Regional Council State of the Environment Report. Prepared for the ORC by Ryder Consulting Ltd. pp. 55.

Stewart B. (2008a). Habitat Mapping of the Taieri River Estuary; Otago Regional Council State of the Environment Report. Prepared for the ORC by Ryder Consulting Ltd. pp. 34.

Stewart B. (2008b). Habitat Mapping of the Kaikorai Estuary; Otago Regional Council State of the Environment Report. Prepared for the ORC by Ryder Consulting Ltd. pp. 34.

APPENDIX 1

Quadrats and a representative core from each quadrat for fine-scale mapping.

Kakanui River Estuary
Site 1 (TLB)
Quadrat 1

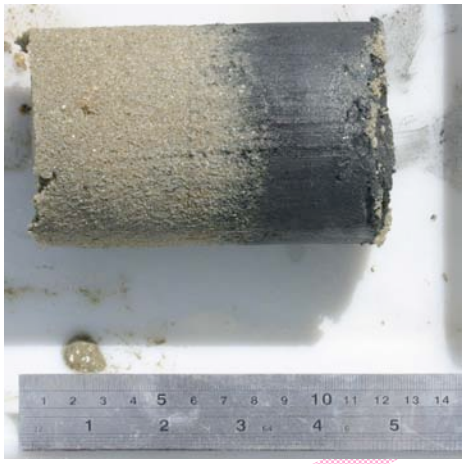
Quadrat 2

Quadrat 3


Quadrat 4

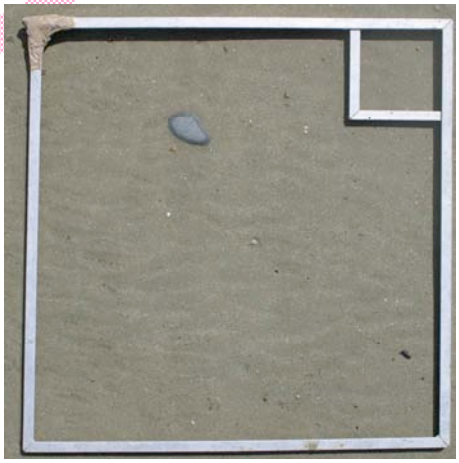

Quadrat 5


Quadrat 6



Quadrat 7

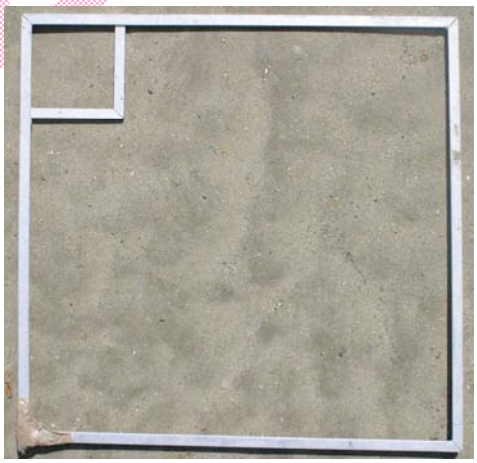
Quadrat 8



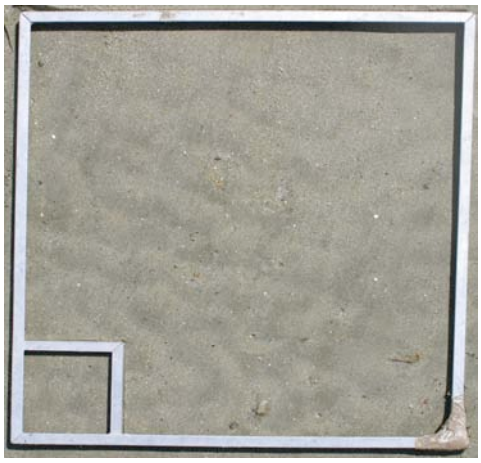
Quadrat 9


Quadrat 10


Quadrat 11




Quadrat 12



Kakanui River Estuary
Site 2 (TRB)

Quadrat 1

Quadrat 2

Quadrat 3

Quadrat 4

Quadrat 5

Quadrat 6

Quadrat 7

Quadrat 8

Quadrat 9

Quadrat 10

Quadrat 11

Quadrat 12