Habitat Mapping of the Kaikorai Stream Estuary

Otago Regional Council State of the Environment Report

Prepared by

Ryder Consulting

April 2008

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Cover photo: Spoonbills near the mouth of the Kaikorai Stream Estuary.

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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.

The Kaikorai Estuary is considered to be of regional, national, or international importance in terms of its ecological, scenic, spiritual and/or cultural values. As such it is designated as a Coastal Protection Area (CPA22) under the Otago Regional Council's Regional Plan: Coast. It is recognised that there is the potential for adverse effects on the intertidal ecosystem of this estuary from sediment 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 Kaikorai 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. i.e. 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
- Wind blown and deliberately dumped litter and other items
- Stock
- Erosion
- Reclamation
- Leachate from landfills

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 Kaikorai 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 80 mm diameter core was collected to a depth of at least 100 mm 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.

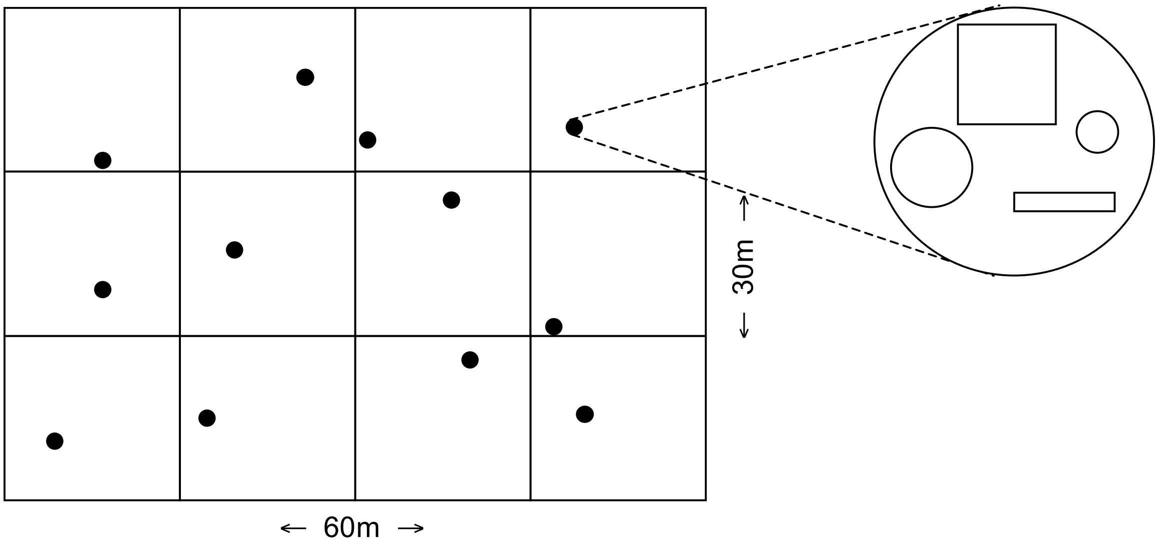

Figure 1. *Layout of sampling area. Squares are sub-areas; black dots are randomly located sampling plots. Circle on right is an enlargement of a sampling plot showing 0.25m² quadrat for epibiota analysis, small sediment core for RDL determination, large sediment core for infauna analysis, and small 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 125 mm diameter (area = 0.0039 m^2) corer.
- The corer was driven into the sediments to a depth of 150 mm, removed with core intact and the contents washed through 0.5 mm 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 20 mm 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 (2008) 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, 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 scattered and, where this happened, they were not recorded under broad scale mapping in this survey. However, where dense stands of gorse (*Ulex europaeus*) 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 Kaikorai Estuary modification is generally limited to reclamation, the formation of vehicle tracks, installation of fences, and the construction of bridges and sea walls/stop banks.

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

Pressure	Kaikorai Estuary
Flooding	B4
Introduced weeds	✓
Nutrient pollution	A3
Stormwater	B4
Vehicles	C3
Litter and dumped items	C1
Stock (grazing/trampling)	C3
Erosion	D3
Reclamation	D2
Degree of modification*	M
Leachate from Landfills	B1

* 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. Robertson *et al*. (2002) reports that approximately one third of the area of the Kaikorai Estuary was reclaimed in the 1800s for farming and there is little evidence of more recent reclamation in the estuary.

For the Kaikorai Estuary three red cells shows there is a need for some further investigation and/or action with respect to the estuary. Certainly the amount of wind blown and otherwise dumped items around the estuary was a cause of some concern (Figure 2). It is appreciated that mitigation measures and monitoring programmes are in place for leachate from the two landfills on either side of the estuary and it may be that leachate is not an issue.

Erosion does not appear to be a pressing issue at the Kaikorai Estuary. However, recent high southerly swells had eroded and/or disturbed a considerable area of the herbfields immediately beyond the dune line adjacent to the estuary mouth (Figure 3).

Figure 2. *An example of presumably wind blown debris, Kaikorai Estuary.*

Figure 3. *Heavily eroded herbfields near the mouth of the Kaikorai Stream Estuary.*

4.2 Broad Scale Mapping – Kaikorai Estuary

4.2.1 Ground-truthing and digitising habitat

The Kaikorai Estuary was visited for the purpose of broad scale mapping on 29 October 2007. 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 Kaikorai Stream has a long and relatively narrow estuary (Figures 4 and 5) covering slightly in excess of 140ha (Table 3), with a high percentage of the estuary area being exposed at low water. However, it should be noted that the bar at the estuary mouth is regularly blocked meaning that a large proportion of the estuary is often inundated for extended time periods. It is apparent some tracts of the estuary have been reclaimed over past years, notably for the golf course and the landfills with additional areas for farming. Some areas of the remaining estuary are still exposed to stock from time to time.

Much of the area that lies between mid tide and EHWS in the lower estuary is herbfield, with sea primrose (*Samolus repens*) being the major cover (Figure 5, Table 3). Although not a major component of the herbfields, bachelors button (*Cotula coronopifolia*) makes an occasional appearance. Grassland is also widespread, especially in areas that adjoin cultivated farmland, and comprises mostly exotic grasses

(Figure 5). Rushland is patchy but reasonably common, and generally confined to the edges of water channels. Both the jointed wire rush (*Apodasmia similis*) and the sea rush *Juncus kraussii* subsp. *Australiensis*) are present, with *Apodasmia* being the most common (Figure 5).

Figure 4. *Kaikorai estuary with ground truthing sites marked as yellow bars.*

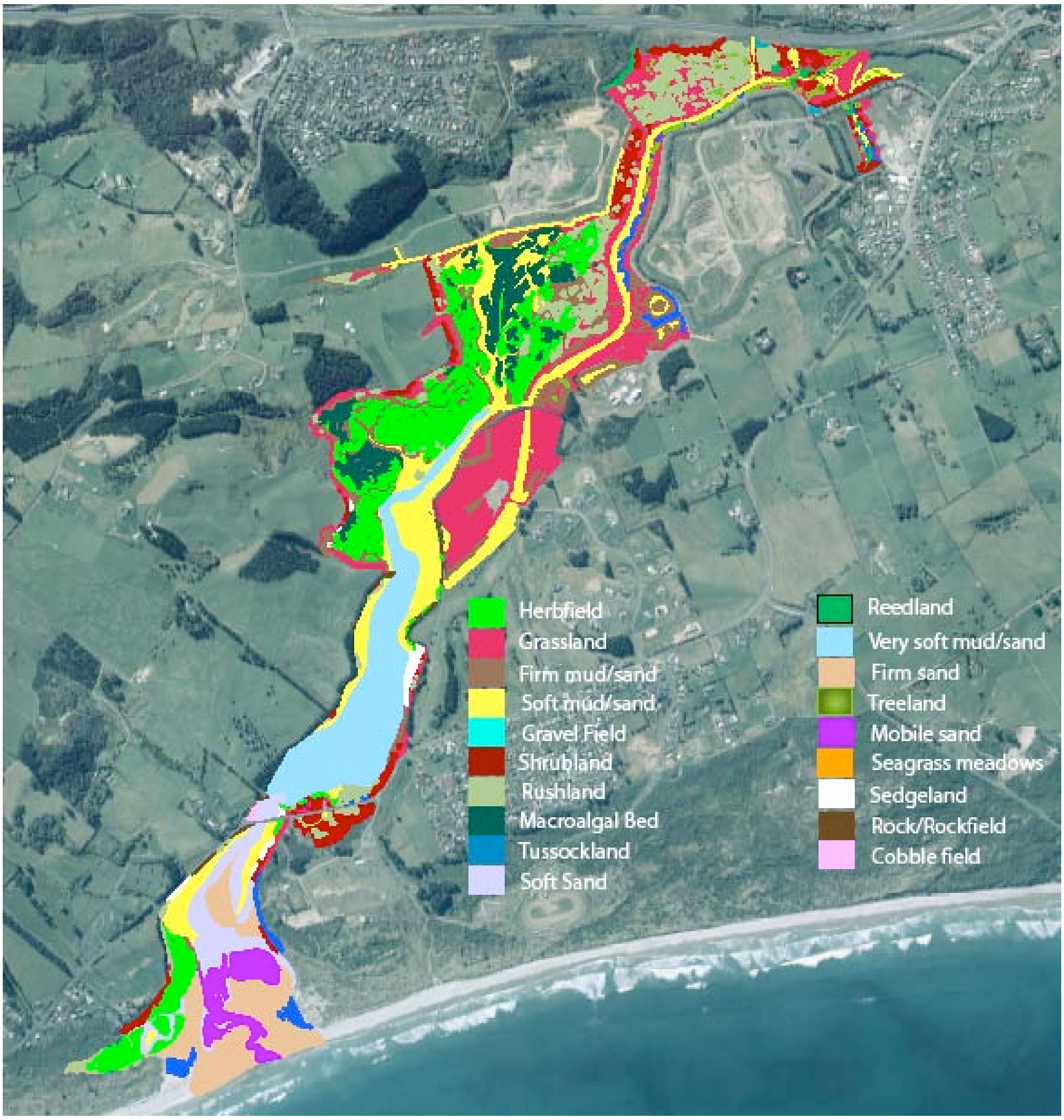

Figure 5. *Kaikorai Stream Estuary with different habitats mapped. More clarity and detail is available on GIS files lodged with the ORC.*

Associated with some of the rush beds are small clumps of shrubland comprising mainly saltmarsh ribbonwood (*Plagianthus divaricatus*).

On the mudflats on the true right bank (TRB) of the estuary near the mid section there are patches of periphyton comprising green filamentous algae, diatoms and cyanobacteria. Collectively these have been classified as macroalgal beds, although species more commonly described as estuarine macroalgae (e.g. *Gracilaria* spp., *Enteromorpha* spp., *Ulva* spp.) are notably absent.

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

Habitat type	Area (ha)	% of total area
Boulderfield	0.27	0.19
Firm mud/sand	11.47	8.09
Firm sand	11.65	8.21
Grassland	29.40	20.73
Gravel field	0.07	0.05
Herbfield	15.69	11.06
Macroalgae	5.06	3.57
Mobile sand	3.63	2.56
Reedland	0.70	0.50
Rushland	8.99	6.34
Scrubland	0.10	0.07
Sedgeland	0.63	0.45
Shrubland	5.53	3.90
Soft sand	6.18	4.36
Soft sand/mud	24.17	17.04
Treeland	1.05	0.74
Tussockland	1.91	1.34
Very soft sand/mud	15.29	10.78
Total	141.80	100.00

Tussockland and sedgeland are both quite rare and confined to generally small areas. Sedge and marram grass (*Ammophila arenaria*) are found near the mouth of the estuary and clumps of flax (*Phormium tenax*) are most prevalent adjacent to the Taieri Mouth Road and around an isolated backwater to the north of the Green Island landfill.

Substrate near the mouth of the estuary is generally firm sand with a soft sand/mud component becoming more pronounced as one moves upstream. Soft sand is largely confined to areas of standing water and two main channels just upstream of the mouth, although sand immediately east and west of the mouth can become soft once completely dry. Mobile sand is reasonably common over a wide area near the mouth and in the main channel when the mouth is open.

In side channels and backwaters the substrate is generally firm mud/sand but becoming soft mud/sand as one moves closer to the main channels. The centre portion of the main channel and parts of the lower estuary carrying very slow moving water is generally very soft mud/sand. Characteristic of these mud/sand beds is a lightly stained anoxic layer lying from 2-3mm to <60mm beneath the surface. On the true right bank and slightly upstream of the Taieri Road road bridge is the only area of gravel, although this does have a high proportion of coarse sand. The substrate underlying herbfields and grassfields appears to be mainly firm mud/sand.

4.3 Fine Scale mapping – Kaikorai Estuary

The Kaikorai Stream Estuary was visited on 30 October 2008. Two sites (Figure 6), selected during the broad scale mapping, were sampled according to the methodology described above. Both sites were located on low tidal sand/mud flats, representative of much of the greater estuarine area.

Figure 6. *Location of fine scale sites at the Kaikorai Estuary in relation to Taieri Road bridge and Waldronville. Downstream site in blue, upstream site in red.*

4.3.1 Sediment Core Profiles

Photographs of sediment cores are presented in Appendix 1. The downstream site (Site 1) comprised predominantly firm sand. A redox discontinuity layer (RDL) appeared in many of the cores (Table 4) and varied in nature from quite diffuse to very intensely discoloured. In no instance was a smell of hydrogen sulphide detectable.

Table 4. *Brief description of sediment cores at downstream site (Site 1), Kaikorai 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	50	90	very diffuse	No
3	Fine sand	90	>150	diffuse	No
4	Fine sand	nil	nil	nil	No
5	Fine sand	130	>150	diffuse	No
6	Fine sand	120	>150	intense	No
7	Fine sand	90	>150	intense	No
8	Fine sand	90	>150	well defined	No
9	Fine sand	70	>150	well defined	No
10	Fine sand	45	>150	well defined	No
11	Fine sand	45	>150	patchy	No
12	Fine sand	40	>150	well defined	No

The upstream site (Site 2) showed a much higher component of mud intermixed with fine sand (Table 5, Appendix 1). A redox discontinuity layer was discernible but generally quite shallow and diffuse.

Table 5. *Brief description of sediment cores at upstream site (Site 2), Kaikorai Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine sand/mud	2	80	diffuse	No
2	Fine sand/mud	2	100	diffuse	No
3	Fine sand/mud	2	80	diffuse	No
4	Fine sand/mud	2	70	diffuse	No
5	Fine sand/mud	2	80	diffuse	No
6	Fine sand/mud	2	60	well defined	No
7	Fine sand/mud	2	70	diffuse	No
8	Fine sand/mud	2	50	very light	No
9	Fine sand/mud	nil	nil	nil	No
10	Fine sand/mud	2	60	very light	No
11	Fine sand/mud	2	60	very light	No
12	Fine sand/mud	2	40	well defined	No

4.3.2 Epifauna

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

Site 2 (upstream) also displayed a real paucity of epifauna with no animals seen within any of the quadrats. The surface of the substrate was, however, characterised by an almost uniform diatomaceous film with occasional wisps of filamentous green algae (Figure 7).

Figure 7. *Kaikorai Estuary. Diatomaceous film with wisps of green algae, Site 2.*

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 filamentous green algae were just noticeable at Site 2 with <1% cover in any quadrat. Beyond the quadrats at site one were sparsely scattered small clumps of green algae, probably *Enteromorpha* spp. A fine film of centric diatoms was evident in all quadrats at Site 2 (upstream).

4.3.4 Infauna

At each subsite 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 were characterised by a variety of burrowing polychaete worms and amphipods (Table 6).

Mean number of infaunal animals per square metre at Site 1 is 9200 with a mean of 5 taxa present for the site.

At Site 2 there are considerably more animals per square metre, due largely to the high number of amphipods. The infauna is dominated by amphipods, burrowing polychaete worms with a smattering of insects and molluscs (Table 7).

Mean number of infaunal animals per square metre at Site 2 is 13775 with a mean of 6 taxa present for the site.

Table 6. *Infauna at three sub sites sampled at downstream site (Site 1), Kaikorai Estuary.*

				Downstream site		
			GPS	E2307402	E2307381	E2307372
			co-ordinates	N5472416	N5472394	N5472377
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae		14	8	
		Maldanidae				1
		Nephtyidae		47	36	74
		Neriididae		6	6	
		Spionidae			2	2
Nemertea						
Crustacea						
	Amphipoda					
		Phoxocephalidae		41	63	67
		Haustoriidae				1
Number of Animals				108	115	145
Animals/m ^{2}				8100	8625	10875
Number of Taxa				4	5	5

Table 7. *Infauna at three sub sites sampled at upstream site (Site 2), Kaikorai Estuary.*

				Upstream site		
			GPS	E2307792	E2307814	E2307848
			co-ordinates	N5472696	N5472705	N5472720
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae				2
		Maldanidae			1	
		Nephtyidae		2	3	3
		Neriididae		1		2
		Spionidae				1
Nemertea						
Crustacea						
	Amphipoda					
		Phoxocephalidae		136	187	194
		Haustoriidae			6	4
	Branchiapoda					
		Daphniidae				
			Daphnia	1		
Insecta						
	Diptera					
		Ephydriidae				
			Shoreflies	1		
		Chironomidae				
			Midges	2	1	2
Mollusca						
	Gastropoda					
		Amphibolidae				
			Amphibola crenata	2		
Number of Animals				145	198	208
Animals/m^2				10875	14850	15600
Number of Taxa				7	5	7

4.3.5 Chemical Analysis

Replicate 250ml samples were scooped from the top 20mm of substrate at each of the 12 subsites 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 the downstream site (Table 8). At the upstream site contaminants were present in much higher concentrations with both lead and zinc levels exceeding the ANZECC-ISQG low trigger values (Table 8). Phosphorus levels too, were quite high but there are currently no guideline values for phosphorus in sediment.

Observations in the field with respect to the nature of the substrate at each site were confirmed by particle size analysis with the greatest proportion of the sediment being fine sand with a low percentage of mud at Site 1 (Table 8). As expected, the upstream site (Site 2) showed a significantly greater proportion of very fine material (<63μm)(Table 8).

Table 8. *Chemical analysis of sediments in Kaikorai Estuary.*

Parameter	ANZECC ISQG-Low Trigger Value	ANZECC ISQG-High Trigger Value	Downstream (Site 1)	Upstream (Site 2)
Dry Matter (g/100g)	-	-	83	37
Ash (g/100g)	-	-	99	93
Loss on Ignition (g/100g)	-	-	0.8	6.7
Total Nitrogen (g/100g)	-	-	<0.05	0.25
Total Phosphorus (mg/kg)	-	-	310	1100
Cadmium (mg/kg)	1.5	10	0.02	0.25
Chromium (mg/kg)	80	370	3.4	34.0
Copper (mg/kg)	65	270	2.0	22.0
Nickel (mg/kg)	21	52	2.3	16.0
Lead (mg/kg)	50	220	3.8	51.0
Zinc (mg/kg)	200	410	24	230.0
Dry matter sieved (g/100g)			83	37
>2mm fraction (g/100g)	-	-	<0.1	<0.1
63μm – 2mm fraction (g/100g)	-	-	92.3	42.0
<63μm fraction (g/100g)	-	-	7.7	57.9

5. Discussion and Recommendations

The Kaikorai Estuary is typical of moderately enriched southern South Island estuaries. There has been some reclamation for farmland, but the remaining estuarine area is largely intact with no further reclamation in progress. There are some environmental pressures at both sites, mainly from nutrient loadings, stock grazing and anthropogenic debris. While the Kaikorai Estuary is subject to flooding on occasion the large areal extent 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 at this location.

Fauna too, are representative of typical estuarine animals found in healthy environments (Morton and Miller 1973). Mud crabs, mud snails, polychaete worms and amphipods are a feature of all estuaries in the Otago region and densities of these animals are as one would expect. Shellfish, such as cockles, are scarce in the inlet and there is consequently little pressure from recreational harvesting.

There is some evidence of contamination of the sediments within the Kaikorai Stream Estuary. The estuary has relatively high levels of heavy metals, with both lead and zinc slightly exceeding the ANZECC (2000) ISQG - low trigger levels at the upstream site.

The sediments within the estuary reflect the geology of the Kaikorai Stream catchment, with there being a high proportion of very fine sediment, especially upstream of the Tairei Mouth Road bridge. There are patches of anoxic sediment within the estuary, but nothing that would not be expected in moderately enriched estuaries.

In conclusion the Kaikorai Estuary appears to be in moderate to good health. Areas of concern that may require further investigation are nutrient and heavy metal enrichment and also the presence of quantities of rubbish and litter along much of the shore of the estuary. These pressure may require monitoring over the coming years.

6. References

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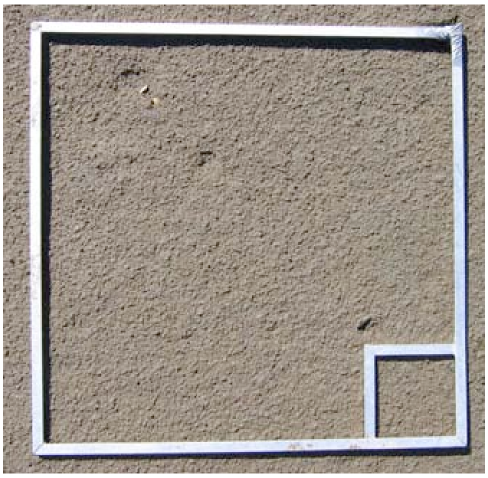
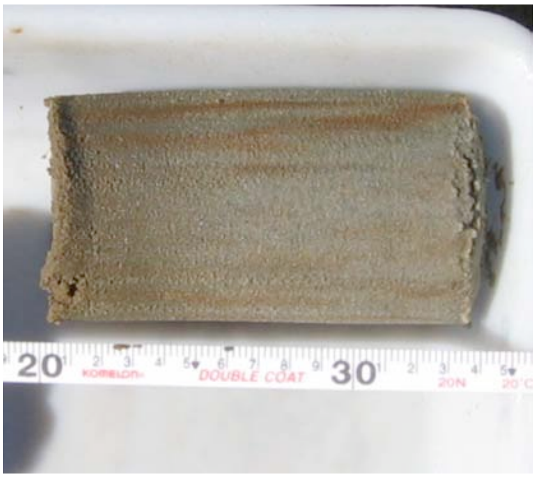
APPENDIX 1

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

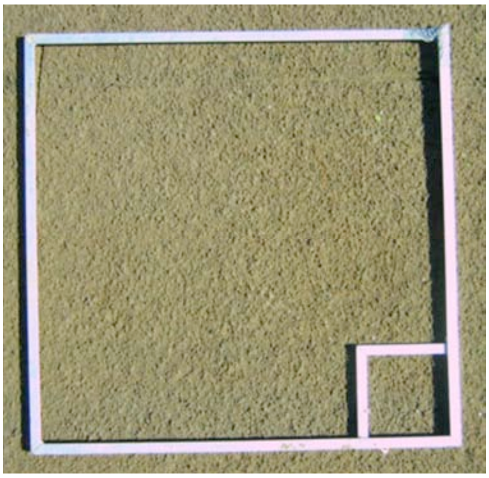
Kaikorai Estuary
Site 1 (Downstream)

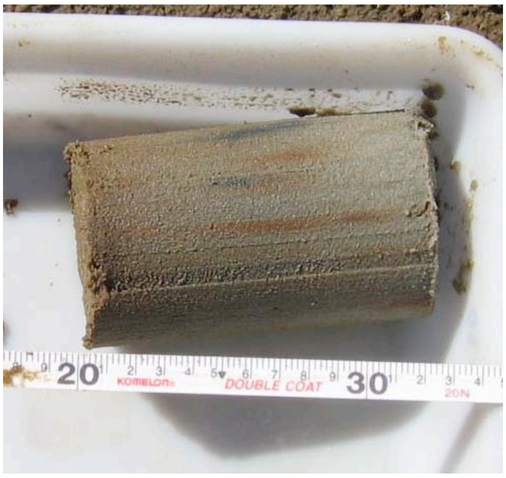
Quadrat 1



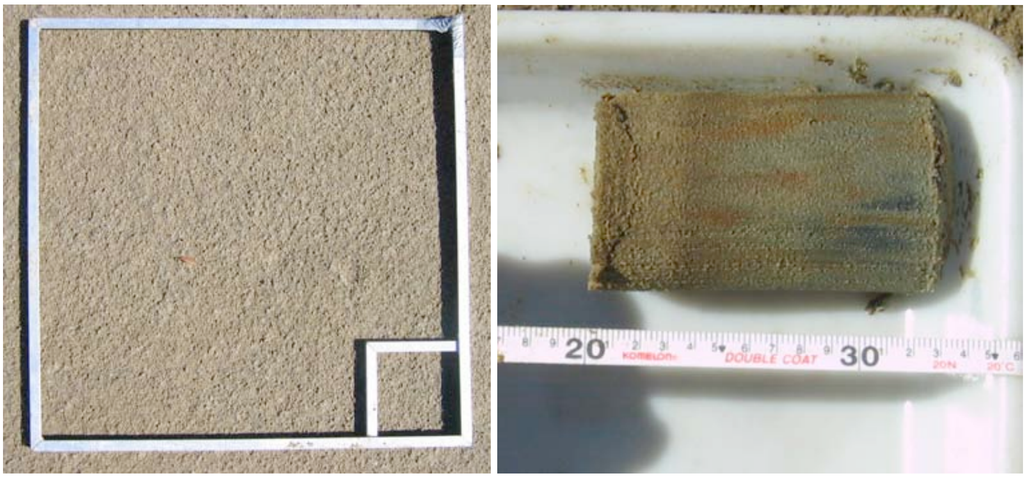


Quadrat 2





Quadrat 3



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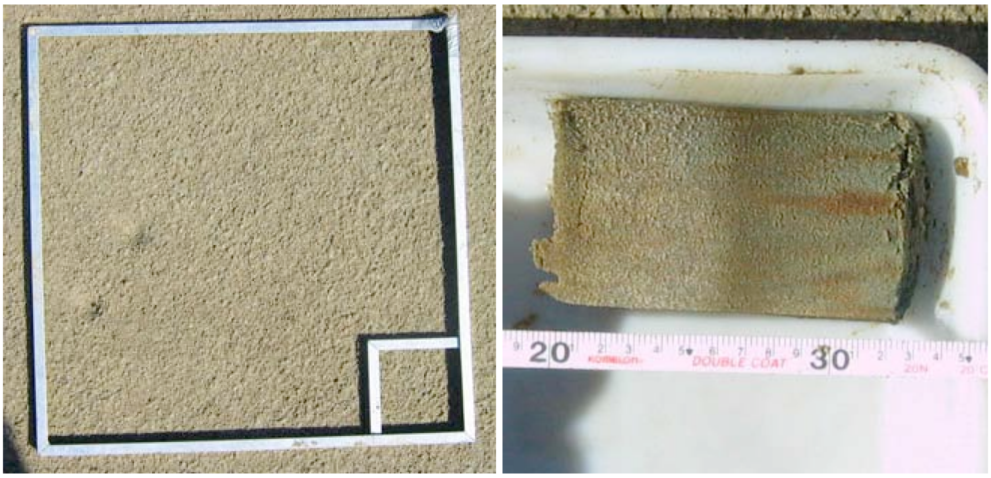

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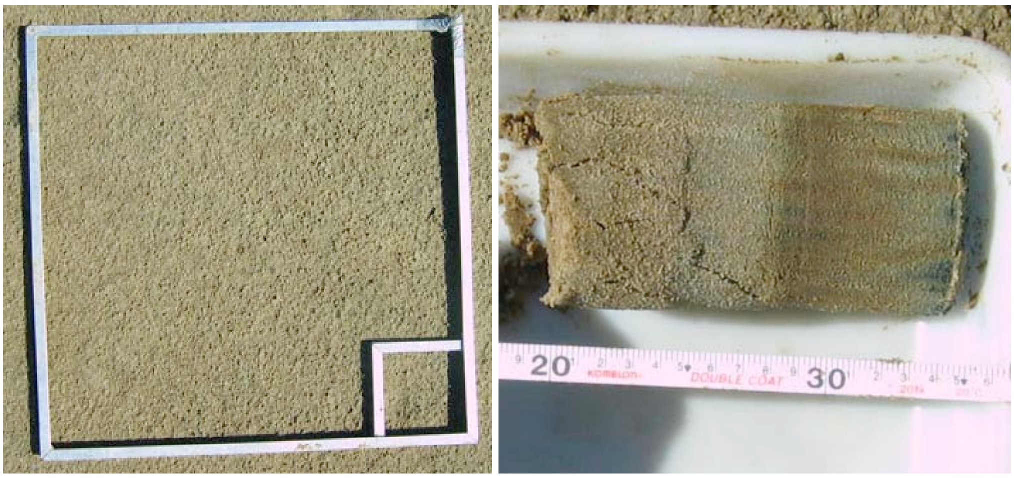

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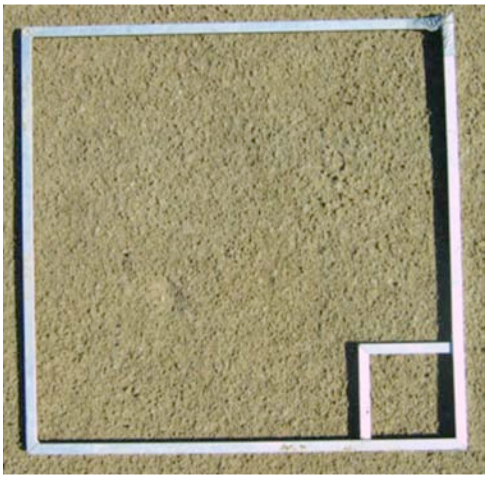
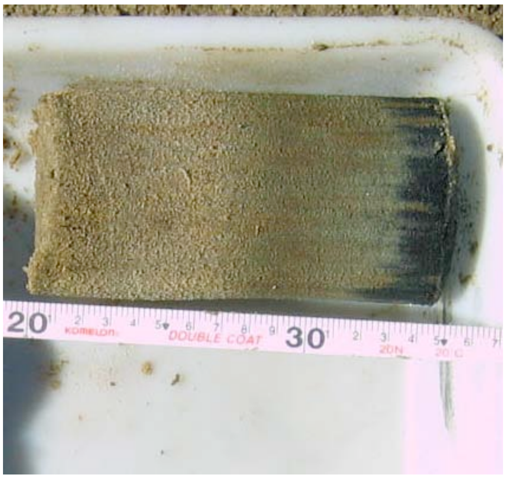

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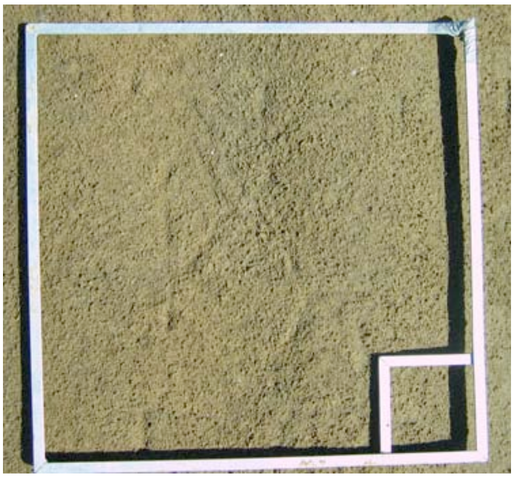


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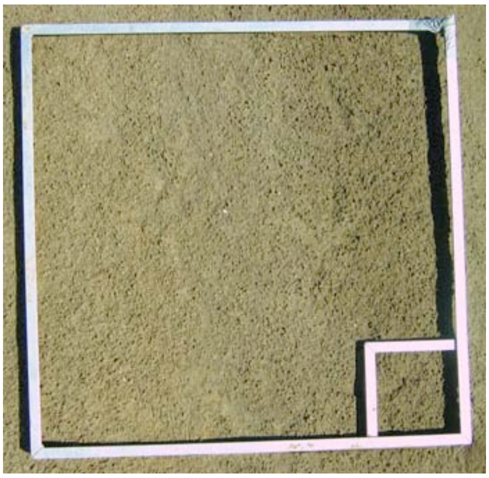


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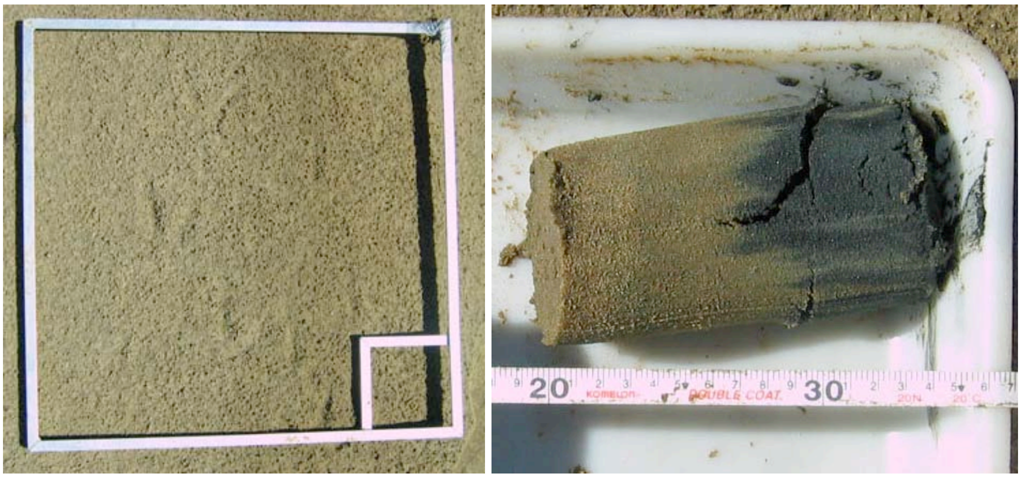

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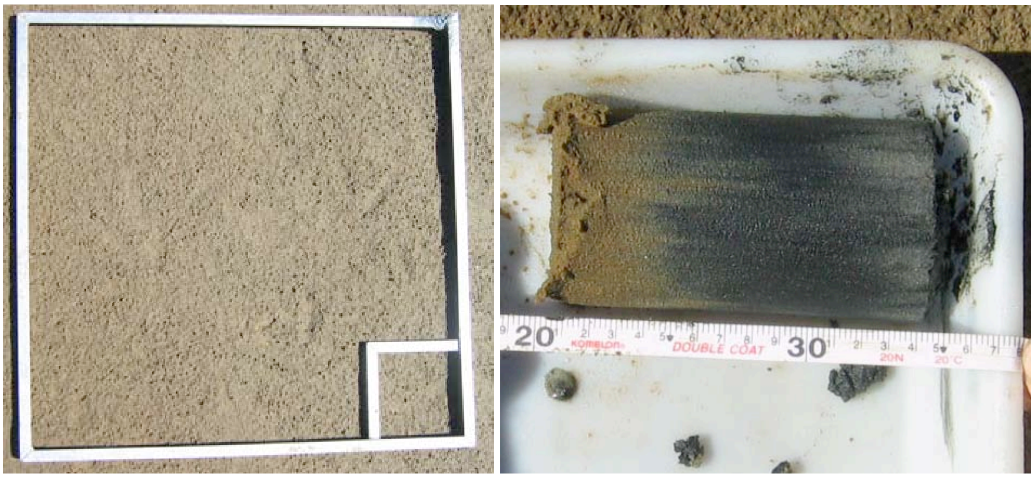

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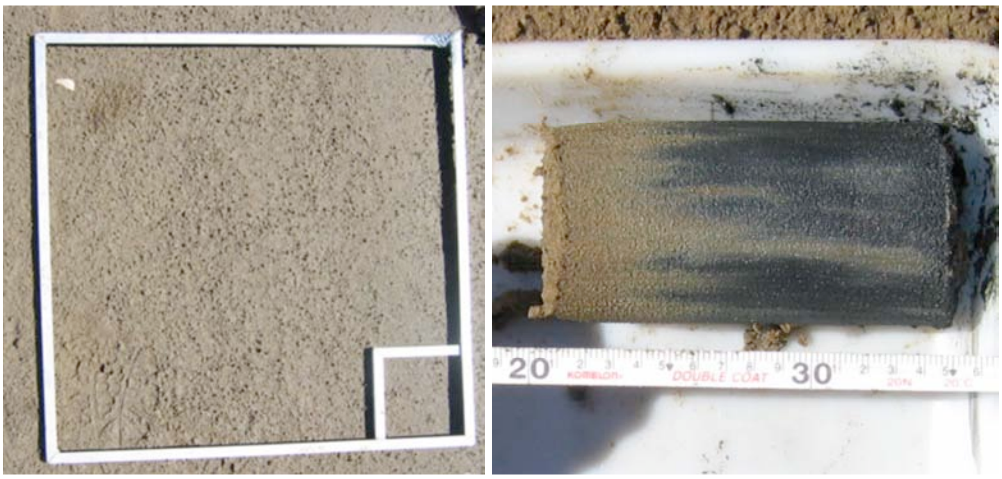

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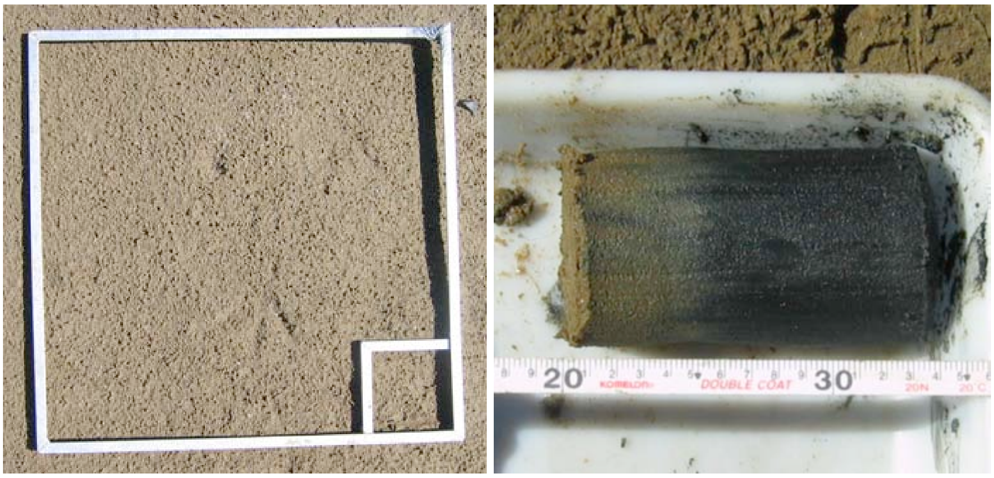
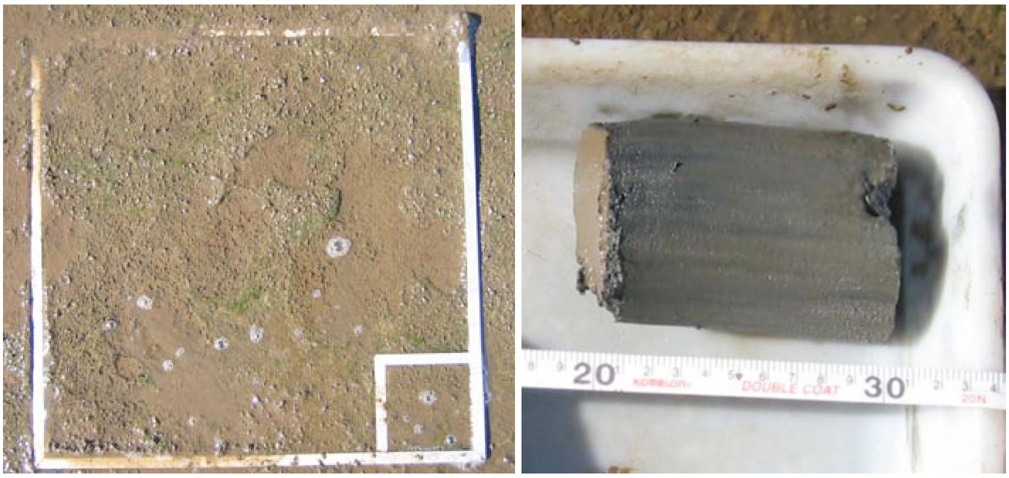


Kaikorai Estuary
Site 2 (Upstream)
Quadrat 1



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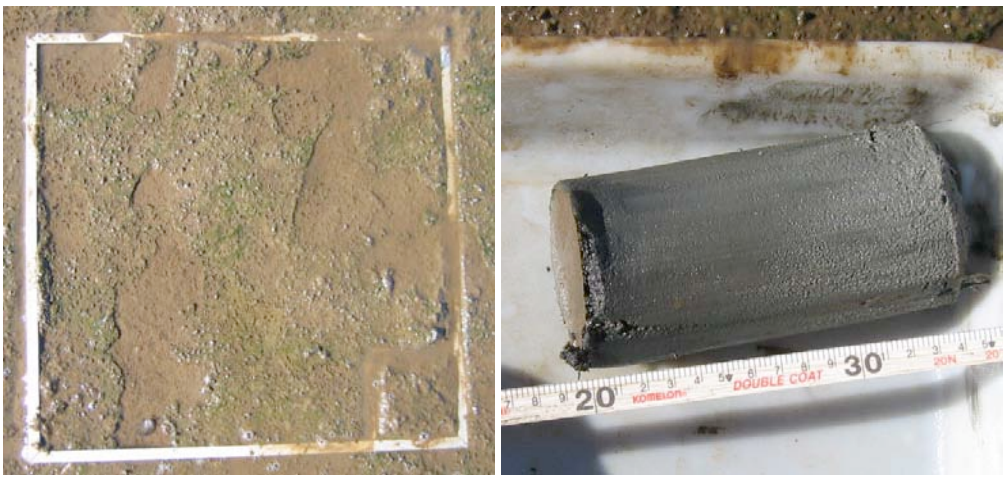

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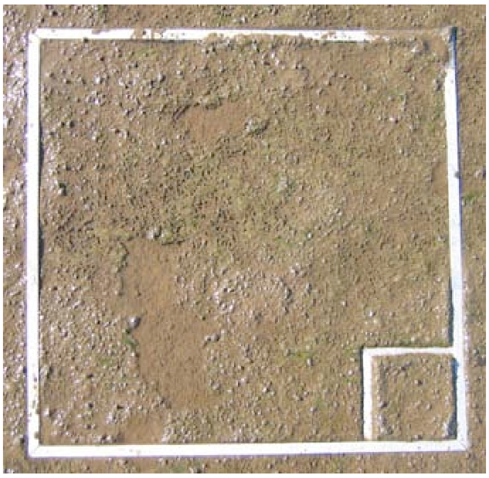
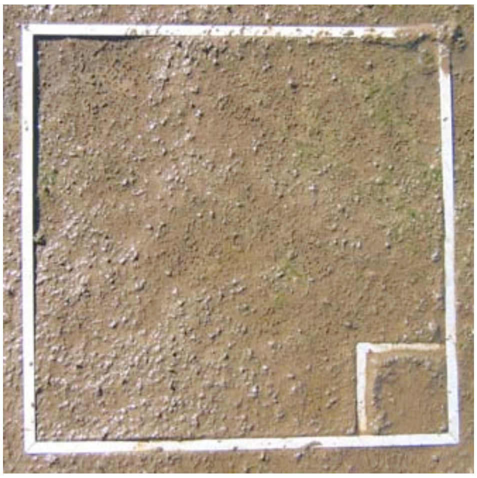



Quadrat 4


Quadrat 5

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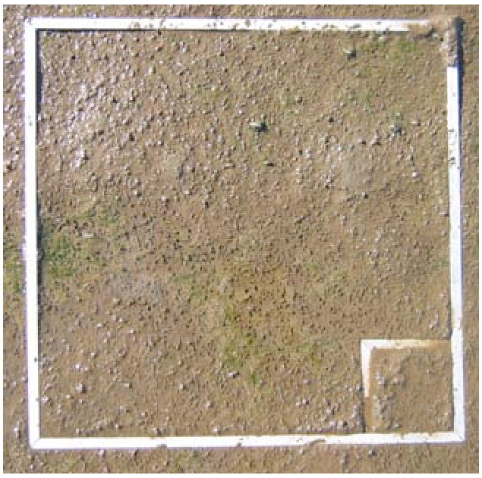

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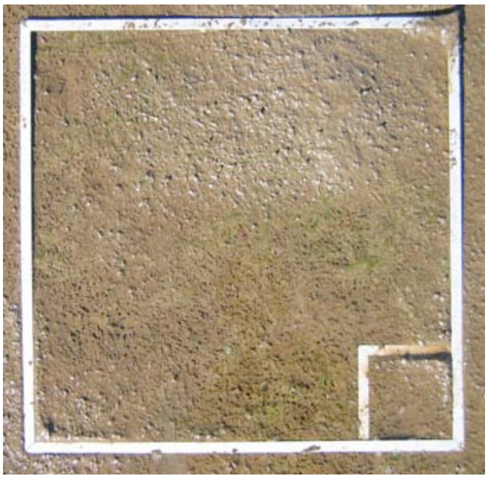

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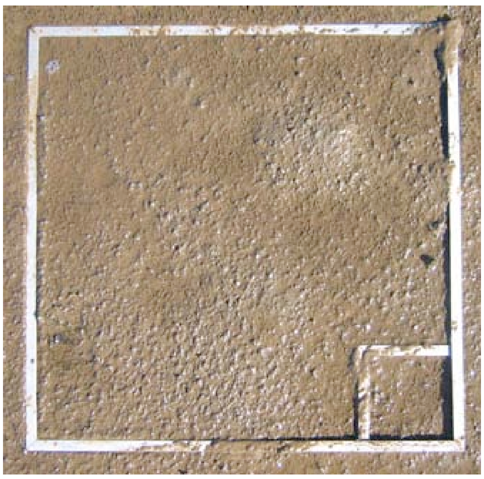

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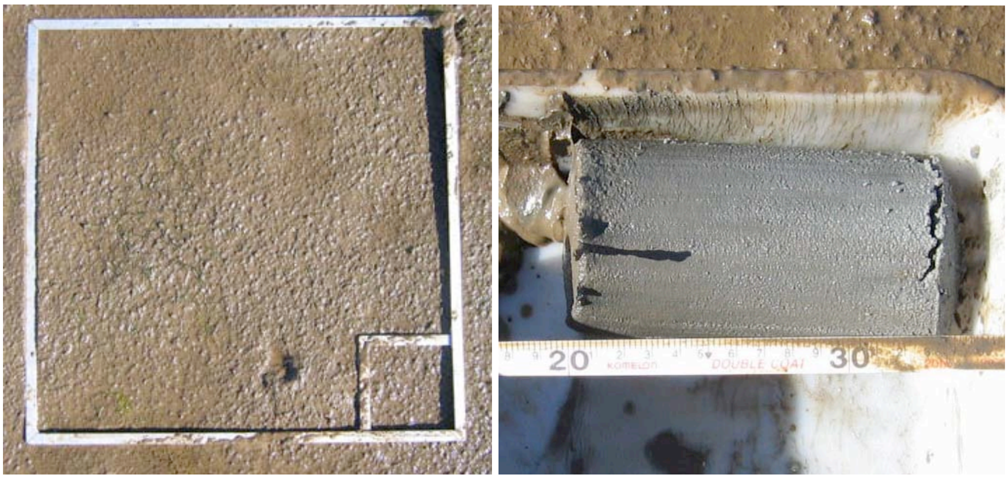

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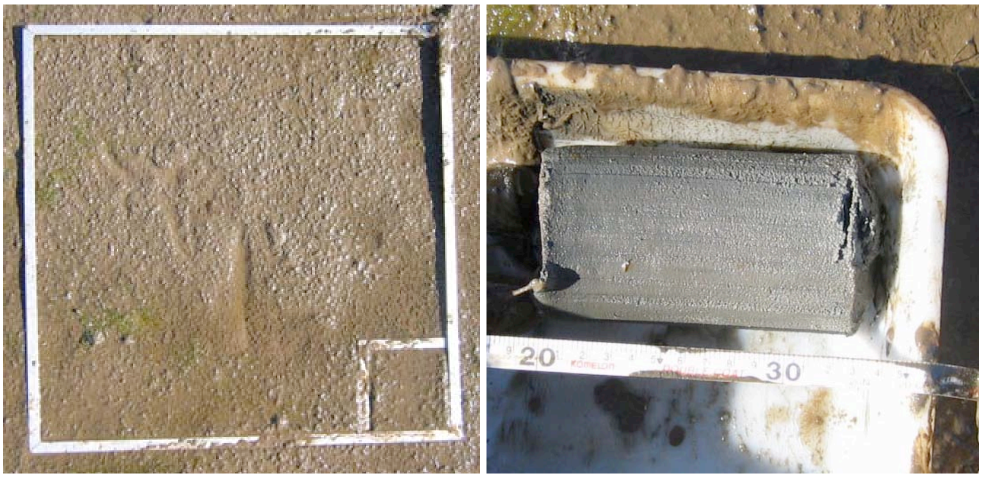

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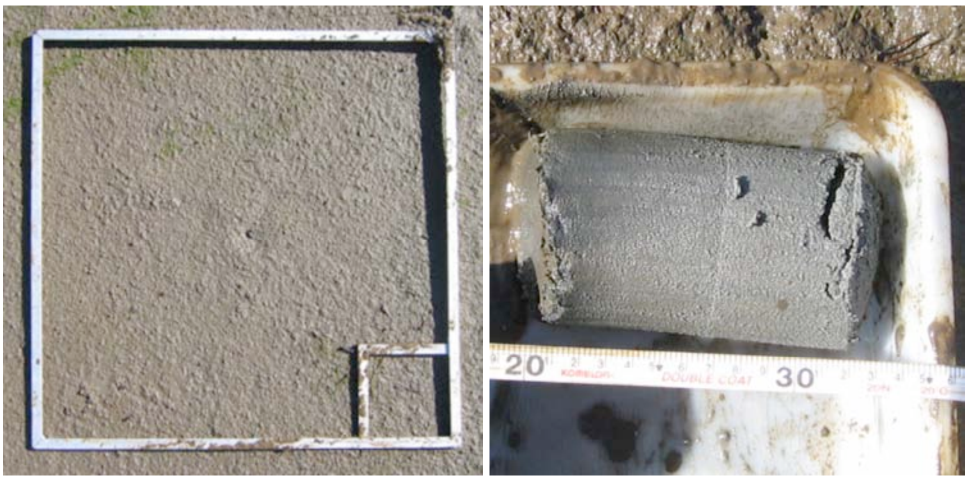

Quadrat 12