Mapping of the Waikouaiti and Shag River Estuaries

Otago Regional Council State of the Environment Report

Prepared by

Ryder Consulting

March 2007

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Cover photo: Waikouaiti Estuary.

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1. Introduction

The Otago Regional Council 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 Waikouaiti River Estuary and the Shag River Estuary are areas considered to be of regional, national, or international importance in terms of their ecological, scenic, spiritual and cultural values. As such both are designated as Coastal Protection Areas 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 these estuaries from sediment runoff, discharges, stormwater, recreational use and alterations to the river 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 Otago Regional Council has engaged Ryder consulting to carry out the estuary mapping.

2. Objectives

To carry out broad and fine scale mapping of the Waikouaiti River Estuary and Shag 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

Broad scale mapping

Aerial photographs, supplied by the Otago Regional Council, were used to generate base maps of vegetation and substrata within the two estuaries. 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 filed 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 = 10cm 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 of =1%.
Boulder field: Land in which the area of unconsolidated bare boulders (> 200mm 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 each site 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.*

		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 at the different sites include:

- Flooding
- Introduced weeds
- Nutrient pollution
- Shellfish collection
- Stormwater (from parts of Karitane)
- Vehicles
- Stock
- Erosion
- Reclamation

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

Fine scale mapping

Neither the Waikouaiti River Estuary nor the Shag River Estuary is particularly large so two representative sites were selected at each 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, split lengthwise (vertically) into two halves, 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 0.25 m^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.

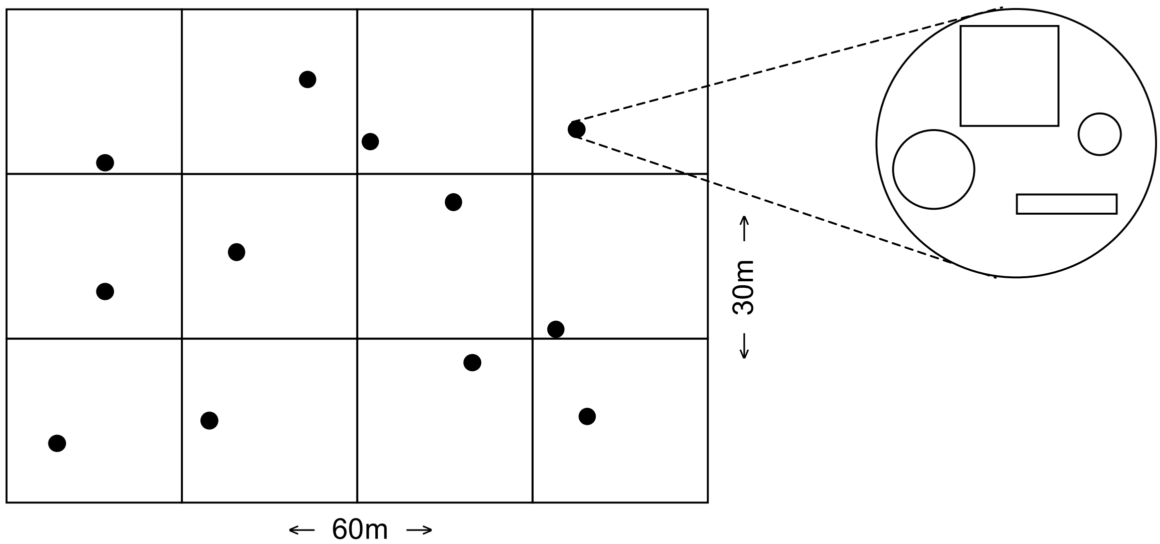

Figure 1. *Layout of sampling area. Squares are sub-areas; black dots are randomly located sampling plots. Circle on right is an enlargement of a sampling plot showing 0.25m^2 quadrat for epibiota analysis, small sediment core for RDL determination, large sediment core for infauna analysis, and small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

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 twelve samples were thoroughly mixed to provide one composite sample per site (i.e. a total of two samples for each estuary), as done by Stevens *et al*. (2004) for a similar exercise around Wellington. 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, 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.

A subjective assessment of the degree of modification to the estuary has also been included. In the case of both estuaries this is limited to reclamation, the formation of farm tracks, installation of fences, and the construction of wharves and sea walls.

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

Pressure	Waikouaiti Estuary	Shag Estuary
Flooding	A4	C4
Introduced weeds	✓	✓
Nutrient pollution	A3	B3
Shellfish collection	D4	?
Stormwater (from parts of Karitane for Waikouaiti)	D4	N/A
Vehicles	C3	D3
Stock (grazing/trampling)	B3	C3
Erosion	D1	D1
Reclamation	D2	D2
Degree of modification*	M	L

* 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 around each estuary, nutrient enrichment is likely, but is difficult to quantify without further investigation. Certainly there were areas of Waikouaiti estuary where backwaters and slow flowing side channels supported an abundance of algal growth, but to attempt to tie this to nutrient enrichment at this stage would be unwise. Likewise, a small area within the Shag Estuary featured a luxuriant growth of *Enteromorpha* spp. that may be associated with drainage from adjacent farmland, but at this point, such a link is purely speculative.

Reclamation has certainly occurred in past years in both estuaries, 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. It many instances it is not clear if the land was actively reclaimed or merely old flood plains that have been fenced off and broken in. There is little evidence of recent reclamation in either estuary.

Erosion does not appear to be a pressing issue at the Waikouaiti Estuary. At the Shag, however, there were many points around the edges of water channels that showed signs of relatively recent, and reasonably heavy, erosion (Figure 2). This may be due to the ANZAC Day 2006 floods as the erosion was generally confined to the larger water channels. Although scoring just a D1 in the level of concern matrix above (Table 2) due to the relatively small area affected, we believe this issue is of some concern.

Figure 2. *Evidence of relatively recent erosion along two of the main water channels, Shag River Estuary.*

Overall the presence of only one red cell suggests that the estuaries investigated are considered to be only slightly to moderately affected by the pressures identified at the present point in time. This reflects the relatively low urban density adjacent to the

Waikouaiti Estuary, the relative isolation of the Shag Estuary, and the generally low intensity farming around both estuaries.

4.2 Broad Scale Mapping – Waikouaiti River Estuary

4.2.1 Ground-truthing and digitising habitat

The Waikouaiti River Estuary was visited for the purpose of broad scale mapping on 8 November 2006. Six prominent landmarks were located using aerial photographs (Figure 3) 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® 6.0. 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 Waikouaiti River has a long and very irregularly shaped estuary (Figure 3) covering in excess of 200ha (Table 3), with a very high percentage of the estuary area being exposed at low water. It is apparent that large tracts of the estuary have been reclaimed over past years, and 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 is herbfield, with glasswort (*Sarcocornia quinqueflora*) being the major cover (Figure 4, Table 3). Although not a major component of the herbfields, sea primrose (*Samolus repens*) is common in places and 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 4). 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 4).

Figure 3. *Waikouaiti estuary with ground truthing sites marked as yellow bars.*

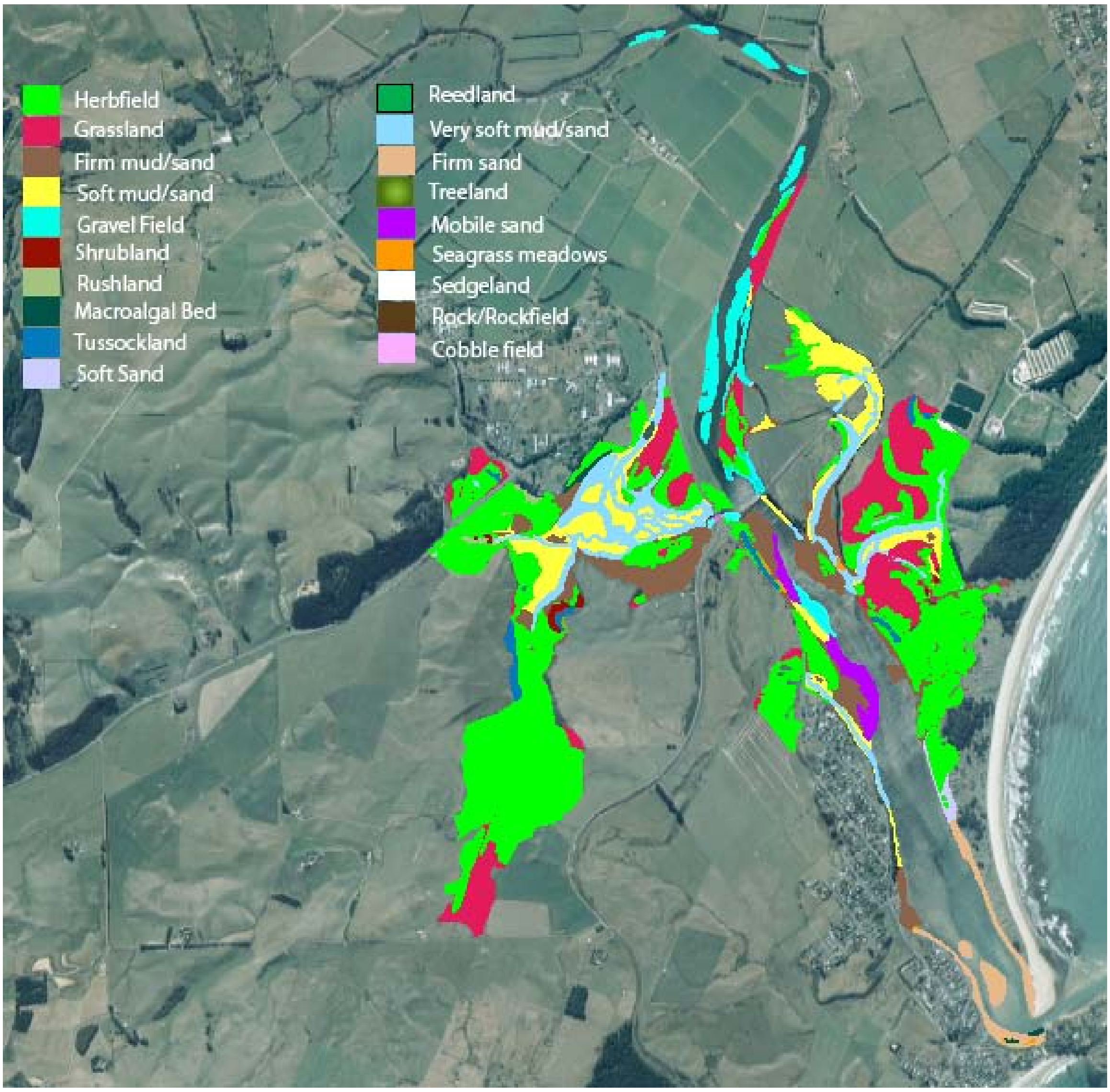

Figure 4. *Waikouaiti River Estuary with different habitats mapped. More detail is available on GIS files lodged with the ORC.*

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

On the sandflats of the true right bank (TRB) of the estuary near the mouth there are patches of seagrass (*Zostera novazelandica*) meadow with a further small patch in a backwater on the true left bank (TLB) between the rail bridge and the road bridge. Other macroalgal beds comprise *Enteromorpha* spp. adjacent to SH1 opposite the now defunct Cherry Farm hospital, and scattered beds of *Gracilaria chilensis* on the TRB sandflats downstream of the rail bridge. Many of the *Gracilaria* beds, however, lie below ELWS.

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

	Area (ha)	Percantage of total estuarty area (%)
Cobble	0.02	0.01
Firm mud/sand	31.25	15.73
Frim sand	4.47	2.25
Grass	32.33	16.27
Gravel	7.68	3.86
Herbfield	75.52	38.01
Macroalgae	0.60	0.30
Mobile sand	3.01	1.51
Rushes	1.01	0.51
Seagrass	0.18	0.09
Sedge	0.16	0.08
Shrub	0.46	0.23
Soft mud/sand	23.88	12.02
Soft sand	1.05	0.53
Trees	0.24	0.12
Tussock	1.70	0.86
Very soft mud/sand	15.21	7.65
Total area	198.76	100.00

Tussockland and sedgeland are both quite rare and confined to small areas at the head of the backwater that reaches toward the Waikouaiti sewage treatment plant oxidation ponds. Another small tussockland containing flax (*Phormium tenax*) lies at the eastern edge of the very extensive branch of the estuary reaching southward between SH1 and the railway.

A small portion of the estuary is separated from the estuary proper by SH1 south of Cherry Farm. This remnant is mainly herbfield with small patches of grassland and appears to be gradually infilling with sediment.

Substrate near the mouth of the estuary is generally firm sand with a gravel component becoming more pronounced as one moves upstream. Soft sand is largely confined to a short section of the TLB just upstream of the mouth. Mobile sand is reasonably common but confined to tongues extending downstream from the TRB below the rail bridge.

In side channels and backwaters the substrate is generally firm mud/sand but becoming soft mud/sand then very soft mud/sand as one moves away from the main channel. The centre portion of channels carrying very slow moving water and/or tributaries is also generally very soft mud/sand. Characteristic of these mud/sand beds is a darkly stained anoxic layer lying from 2-3mm to 50mm beneath the surface. Upstream of the SH1 road bridge the substrate is gravelfield, but with a high proportion of sand. The substrate underlying herbfields and grassfields appears to be mainly firm mud/sand, but in areas that have been vegetated for a considerable period of time, the mud (soil) layer can be up to 300mm deep.

4.3 Broad Scale Mapping – Shag River Estuary

4.3.1 Ground-truthing and digitising habitat

The Shag River Estuary was visited for the purpose of broad scale mapping on 23 November 2006. Six prominent landmarks were located using aerial photographs (Figure 5) 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® 6.0. 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). As for the Waikouaiti Estuary, the entire Shag River Estuary was walked, with notes being taken on substrate type, vegetation cover and type and any other distinguishing features. 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.

4.3.2 Habitat and Substrate Features

The Shag River has a long and irregularly shaped estuary, although less irregular than the Waikouaiti Estuary (Figure 5) and covers in excess of 130 hectares. As at Waikouaiti a high percentage of the estuary area is exposed at low water. It is apparent that large areas of what was once estuary or flood plain have been developed for farming at some time in the past, although such areas appear to have been developed for a considerable time. Some areas of the remaining estuary, however, are still exposed to stock from time to time and an abundance of rabbits was noted during the site visit.

Figure 5. *Shag River estuary with ground truthing sites shown as yellow bars. Note photograph has been turned 90° clockwise to fit on page.*

Table 4. *Proportions of the various habitat types at Shag River estuary shown as hectares and percentage.*

	Area (ha)	Percentage of total estuary area (%)
boulders	0.36	0.27
cobbles	0.42	0.31
firm mud/sand	20.27	15.21
firm sand	0.62	0.46
grass	38.28	28.73
gravel	13.17	9.88
herb	37.04	27.80
macroalgae	0.70	0.52
mobile sand	3.38	2.54
reed	0.57	0.43
rush	1.35	1.01
shrub	0.33	0.24
shrub	1.36	1.02
soft mud/sand	11.25	8.45
soft sand	2.18	1.64
tussock	0.95	0.72
very soft mud/sand	1.01	0.76
Total	133.24	100.00

As in the Waikouaiti Estuary, much of the area that lies between mid tide and EHWS is herbfield, with glasswort (*Sarcocornia quinqueflora*) once again being the major cover (Figure 6). Sea primrose (*Samolus repens*) is present, but not as common as at Waikouaiti. Grassland is widespread in areas that adjoin cultivated farmland and also as patches within areas of herbfield. Marram grass (*Ammophila arenaria*) and tree lupin (*Lupinus arboreus*) are features of the sand dunes of the spit enclosing the estuary, but lie above EHWS so are not strictly part of the estuary habitat.

Rushland, bordered by a narrow band of sea primrose, is found lining either side of water channels crossing the large branch of the estuary that lies on the TLB adjacent to SH1. Rushes are also to be found in small pockets further upstream in the main channel. A reedland comprising a large bed of raupo (*Typha orientalis*) is located at the head of an intrusion into the forestry on the TLB approximately mid-way down the estuary (Figure 6).

Macroalgal beds are not extensive with just a few diffuse patches of *Gracilaria chilensis* present in the lower estuary. There is also an extremely dense bed of *Enteromorpha intestinalis* on the TLB just downstream of the confluence of the main channel and the tributary draining the large backwater between SH1 and the river.

An old river channel meanders through farmland to the south of the current riverbed. Although this contains water it appears to be largely stagnant. Pools in this channel are characterised by floating mats of green algae, probably *Enteromorpha* spp. and *Cladophora* spp.

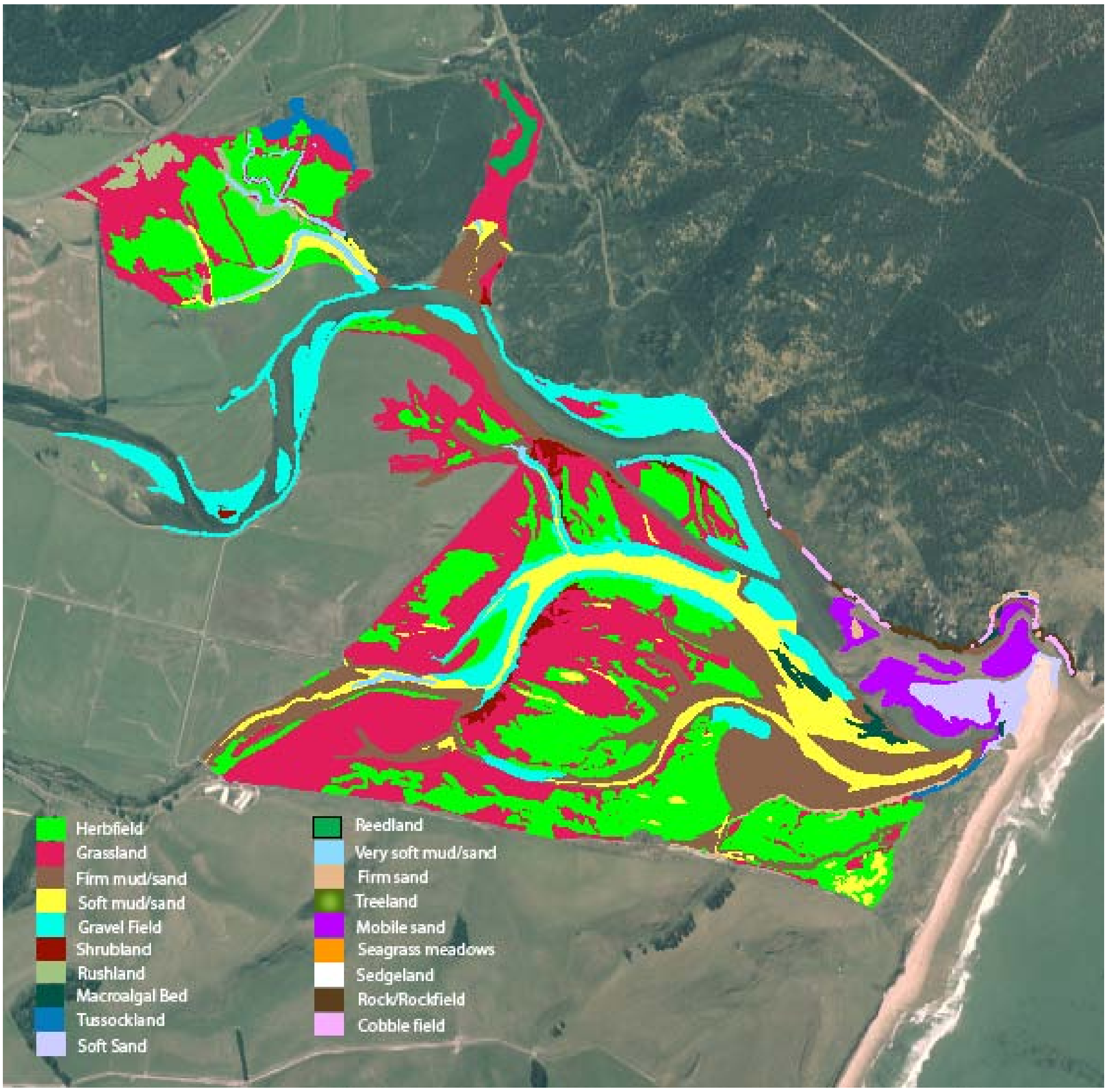

Figure 6. *Shag River Estuary with different habitats mapped. More detail is available on GIS files lodged with the ORC.*

Substrate within the Shag Estuary is characterised by firm mud/sand with soft mud/sand in water channels. As in the Waikouaiti Estuary the gravel component of the substrate becomes more pronounced as one moves further from the estuary mouth, but the gravel here is generally coarser. The middle of water channels comprises very soft mud/sand with a very darkly stained anoxic layer lying anything from 2-3mm to 50mm beneath the surface.

In many of the herbfields, especially in the south-east corner of the estuary, there are occasional pools of brackish water remaining, one assumes, from the last flood event. A layer of cyanobacteria coats the bottom of each pool. The substrate within such pools is generally soft to very soft mud/sand with a heavily stained anoxic layer just beneath the surface.

As one moves upstream the substratum becomes increasingly gravely along the main water course. Side branches and backwaters, however, remain largely soft mud/sand with very soft mud/sand nearer the centre of channels.

4.4 Fine Scale mapping – Waikouaiti River Estuary

The Waikouaiti River Estuary was visited on 9 November 2006. Two sites (Figure 7), selected during the broad scale mapping, were sampled according to the methodology described above. Both sites were located on low tidal sand flats, representative of much of the greater estuarine area.

4.4.1 Sediment Core Profiles

Photographs of sediment cores are presented in Appendix 1. The downstream site (Site 1) comprised predominantly firm sand, some of the sand being reasonably coarse. A redox discontinuity layer (RDL) appeared in many of the cores (Table 5) and varied in nature from quite diffuse to very intensely discoloured. In no instance was a smell of hydrogen sulphide detectable.

Figure 7. *Location of fine scale sites in relation to Karitane township. Downstream site in blue, upstream site in red.*

Table 5. *Brief description of sediment cores at downstream site (Site 1), Waikouaiti Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine/coarse sand	nil	nil	nil	No
2	Fine/coarse sand	130	>150	very diffuse	No
3	Fine/coarse sand	65	125	diffuse	No
4	Fine/coarse sand	90	>150	diffuse	No
5	Fine/coarse sand	50	>150	diffuse	No
6	Fine/coarse sand	20	>150	intense	No
7	Fine/coarse sand	40	>150	intense	No
8	Fine/coarse sand	70	>150	intense	No
9	Fine/coarse sand	80	>150	well defined	No
10	Fine/coarse sand	70	150	diffuse	No
11	Fine/coarse sand	110	>150	diffuse	No
12	Fine/coarse sand	60	130	well defined	No

The upstream site (site 2) showed a much higher component of fine gravel intermixed with fine and coarse sand (Appendix 1). Redox discontinuity layer was discernible at just core 7. Very fine gravel was a feature of most cores (Table 6, Appendix 1) with the gravel layer beginning between 30 and 70mm below the surface of the sand.

Table 6. *Brief description of sediment cores at upstream site (Site 2), Waikouaiti Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Coarse sand/fine sand/fine gravel	nil	nil	nil	No
2	Coarse sand/fine sand/fine gravel	nil	nil	nil	No
3	Coarse sand/fine sand/fine gravel	nil	nil	nil	No
4	Coarse sand/fine gravel	nil	nil	nil	No
5	Coarse sand/fine sand/fine gravel	nil	nil	nil	No
6	Fine/coarse sand	nil	nil	nil	No
7	Coarse sand/fine sand/fine gravel	110	>150	intense	No
8	Coarse sand/fine gravel	nil	nil	nil	No
9	Fine/coarse sand	nil	nil	nil	No
10	Coarse sand/fine sand/fine gravel	nil	nil	nil	No
11	Coarse sand/fine sand/fine gravel	nil	nil	nil	No
12	Coarse sand/fine sand/fine gravel	nil	nil	nil	No

4.4.2 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 downstream site (Site 1) all sub sites were largely devoid of macroalgae (see section 4.3.3) and were characterised by fine sand with scattered fine gravel. Epifauna comprised some unburied cockles (*Austrovenus stutchburyi*), mud whelks (*Cominella glandiformis*), burrowing crabs (*Helice crassa*), and mudflat topshells (*Diloma subrostrata*) (Table

7). Overall abundance of epifauna per square metre for Site 1 is cockles: 6, whelks: 1, crabs: 0.33, and topshells: 13, although crabs burrows were much more densely grouped (>80 m^{-2}) at higher tide levels within a few metres of the study site (Figure 8). In some of the more brackish backwaters the small estuarine snail *Potamopyrgus estuarinus* was common and could be found in densities approaching 2000m^{-2}.

Figure 8. *Burrowing crab,* Helice crassa*, burrows in muddy substrate near Site 1.*

Table 7. *Epifauna (individuals per square metre) at downstream site (Site 1), Waikouaiti River Estuary.*

Quadrat #	Substrate surface	Cockles (m^{-2})	Whelks (m^{-2})	Topshells (m^{-2})	Crabs (m^{-2})
1	Fine sand/scattered fine gravel	4	-	4	-
2	Fine sand/scattered fine gravel	-	4	24	-
3	Coarse sand/fine sand/fine gravel	12	-	4	-
4	Fine sand/scattered fine gravel	12	-	16	-
5	Fine sand/scattered fine gravel	-	-	8	-
6	Fine sand	8	-	12	-
7	Fine sand/scattered fine gravel	12	-	32	-
8	Fine sand/scattered fine gravel	4	-	20	-
9	Fine sand/scattered fine gravel	8	-	4	4
10	Fine sand/scattered fine gravel	8	8	4	-
11	Fine sand/scattered fine gravel	4	-	4	-
12	Fine sand/scattered fine gravel	-	-	24	-

Site 2 (upstream) displayed a real paucity of epifauna with just single individuals seen within most 0.25m^2 quadrats (Table 8). As with Site 1, crab burrows were much more densely grouped (up to 104 m^{-2}) in muddy areas along channels (Figure 9). The mud snail, *Amphibola crenata*, was also very common on muddy substrata near Site 2 with densities up to 100 m^{-2} being observed (Figure 10).

Figure 9. *Burrowing crab,* Helice crassa*, burrows in muddy substrate near Site 2.*

Figure 10. *Mud snails,* Amphibola crenata*, on muddy substrate near Site 2.*

Table 8. *Epifauna (individuals per square metre) at upstream site (Site 2), Waikouaiti River Estuary.*

Quadrat #	Substrate surface	Whelks (m^{-2})	Topshells (m^{-2})	Crabs (m^{-2})
1	Muddy sandy gravel	-	4	-
2	Sandy gravel	-	-	12
3	Sandy gravel	-	-	-
4	Muddy sandy gravel	4	-	-
5	Muddy coarse sand/gravel	-	-	-
6	Muddy sandy gravel	-	-	-
7	Coarse sand/fine sand/fine gravel	4	-	-
8	Coarse sand/fine sand	-	-	-
9	Coarse sand/fine sand/fine gravel	-	-	-
10	Muddy sandy gravel	-	4	-
11	Muddy sandy gravel	-	-	-
12	Muddy sandy gravel	-	-	-

4.4.3 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 scarce. *Enteromorpha intestinalis* was just noticeable at Site 1 with 0.9% cover at quadrat three, 1.9% cover at quadrat four, 2.5% cover at quadrat five, 0.9% cover at quadrat eight and 1.2% cover at quadrat twelve. Beyond the quadrats were sparsely scattered small clumps of brown algae, probably *Ectocarpus* spp. An extremely fine film of centric diatoms was evident at quadrats 7, 8 10 and 11.

At Site 2 *Ectocarpus* spp. was evident at quadrats 5 (1.2% cover), 11 (5.2% cover) and 12 (4.3%cover). A fine film of microalgae comprising centric diatoms, *Cladophora* and *Bostrychia* was present at quadrats 1, 4, 5, 9, 11 and 12.

4.4.4 Infauna

At each subsite the contents from a 125mm diameter corer, driven into the substrate to a depth of 150mm at three randomly located subsites, 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 cockles (*Austrovenus stutchburyi*) and a variety of burrowing polychaete worms and amphipods (Table 9).

Mean number of infaunal animals per square metre at Site 1 is 6475 with a mean of 9.3 taxa present for the site.

At Site 2 there are considerably fewer animals per square metre, likely due to the coarser substrate. The infauna is dominated by burrowing polychaete worms with a smattering of molluscs (Table 10).

Mean number of infaunal animals per square metre at Site 2 is 2075 with a mean of 6.3 taxa present for the site.

Table 9. *Infauna at three sub sites sampled at downstream site (Site 1), Waikouaiti Estuary.*

			GPS	E2327154	E2327154	E2327165
			co-ordinates	N5505306	N5505320	N5505319
			Sample	4	5	6
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Eunicidae				
		Glyceridae		16	10	12
		Nephtyidae		8	11	4
		Neriididae			4	1
		Spionidae				
		Syllidae		3	2	
Nemertea						
Crustacea						
	Amphipoda					
		Phoxocephalidae		5	4	1
		Oedicerotidae		3	2	
		Haustoriidae		5	9	7
	Cumacea					
		Dyastylidae		8	7	12
	Stomatopoda					
		Squillidae				
	Copepoda			21		
	Decapoda					
		Grapsidae				
			Helice crassa			1
Insecta						
	Diptera			2		
Mollusca						
	Gastropoda					
		Buccinidae				
			Cominella glandiformis			1
		Amphibolidae				
			Amphibola crenata			
	Bivalvia					
		Veneridae				
			Austrovenus stutchburyi	26	44	30
Number of Animals				97	93	69
Animals/m ^{2}				7275	6975	5175
Number of Taxa				10	9	9

4.4.5 Chemical Analysis

Replicate 250ml samples were scooped from the top 20mm of substrate at each of the twelve subsite 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 (Table 11). In the case of heavy metals contamination was present but at levels well below the ANZECC interim sediment quality guideline (ISQG) – Low Trigger values (Table 11).

Table 10. *Infauna at three sub sites sampled at upstream site (Site 2), Waikouaiti Estuary.*

			GPS	E2326882	E2326889	E2326897
			co-ordinates	N5506235	N5506233	N5506244
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Eunicidae		6	17	10
		Glyceridae		2	2	2
		Nephtyidae		2	4	3
		Neriididae		4		2
		Spionidae			13	9
		Syllidae				1
Nemertea						1
Crustacea						
	Amphipoda					
		Phoxocephalidae				
		Oedicerotidae				
		Haustoriidae				
	Cumacea					
		Dyastylidae				
	Stomatopoda					
		Squillidae			1	
	Copepoda					
	Decapoda					
		Grapsidae				
			Helice crassa			
Insecta						
	Diptera					
Mollusca						
	Gastropoda					
		Buccinidae				
			Cominella glandiformis	1		
		Amphibolidae				
			Amphibola crenata			1
	Bivalvia					
		Veneridae				
			Austrovenus stutchburyi			2
Number of Animals				15	37	31
Animals/m ^{2}				1125	2775	2325
Number of Taxa				5	5	9

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 (Table 11). As expected, the upstream site (Site 2) showed a slightly greater proportion of coarse material (>2mm)(Table 11).

Table 11. *Chemical analysis of sediments in Waikouaiti River Estuary.*

Parameter	ANZECC ISQG-Low Trigger Value	ANZECC ISQG-High Trigger Value	Downstream (Site 1)	Upstream (Site 2)
Dry Matter (g/100g)	-	-	78.2	77.1
Ash (g/100g)	-	-	98.0	98.1
Loss on Ignition (g/100g)	-	-	2.03	1.89
Total Nitrogen (g/100g)	-	-	0.07	0.06
Total Phosphorus (mg/kg)	-	-	466	417
Arsenic (mg/kg)	20	70	6.2	6.7
Cadmium (mg/kg)	1.5	10	0.02	0.01
Chromium (mg/kg)	80	370	6.4	5.1
Copper (mg/kg)	65	270	4.6	4.8
Nickel (mg/kg)	21	52	6.0	5.9
Lead (mg/kg)	50	220	4.21	4.28
Zinc (mg/kg)	200	410	26.3	26.3
Dry matter sieved (g/100g)	-	-	79.3	77.2
>2mm fraction (g/100g)	-	-	13.7	17.9
63μm – 2mm fraction (g/100g)	-	-	75.5	73.4
<63μm fraction (g/100g)	-	-	10.7	8.7

4.5 Fine Scale mapping – Shag River Estuary

The Shag River Estuary was visited on 23 November 2006. Two sites (Figure 11), selected during the broad scale mapping, were sampled according to the methodology described above. Both sites were located on low tidal sand flats, representative of much of the greater estuarine area.

4.5.1 Sediment Core Profiles

Photographs of sediment cores are presented in Appendix 2. The downstream site (Site 1) comprised predominantly firm sand, some of the sand with a minor component of silt. A redox discontinuity layer (RDL) appeared in all of the cores (Table 12) and varied in nature from diffuse to very intensely discoloured. In no instance was a smell of hydrogen sulphide detectable.

Figure 11. *Shag River Estuary with locations of Downstream (blue) and Upstream (red) fine scale mapping sites shown.*

Table 12. *Brief description of sediment cores at downstream site (Site 1), Shag River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Fine sand	20	>150	intense	No
2	Fine sand	30	>150	well defined	No
3	Fine/coarse sand	30	>150	well defined in patches	No
4	Fine sand	25	~140	well defined	No
5	Fine/coarse sand	30	~150	diffuse	No
6	Fine sand	20	>150	reasonably diffuse	No
7	Fine sand	50	>150	diffuse	No
8	Fine/coarse sand	25	120	Well defined	No
9	Fine sand	20	110	diffuse	No
10	Fine/coarse sand	30	150	reasonably diffuse	No
11	Fine/coarse sand	40	>150	well defined	No
12	Fine sand	30	>150	well defined	No

The upstream site (site 2) showed a high component of coarse gravel overlain by a mixed layer of fine and coarse sand containing a small proportion of silt (Appendix 2). A redox discontinuity layer was discernible in all cores (Table 13). The very coarse nature of the gravel made obtaining cores difficult, with most cores being no more than 120mm deep.

Table 13. *Brief description of sediment cores at upstream site (Site 2), Shag River Estuary.*

Core #	Substrate	RDL begins (mm depth)	RDL ends (mm depth)	Nature of RDL	H_2S detected
1	Silt/fine sand/coarse sand/coarse gravel	20	~100	well defined	No
2	Silt/fine sand/coarse sand/coarse gravel	5	>125	intense	No
3	Silt/fine sand/coarse sand/coarse gravel	5	>120	well defined	No
4	Silt/fine sand/coarse sand/coarse gravel	15	>120	diffuse	No
5	Silt/fine sand/coarse sand/coarse gravel	5	>120	diffuse	No
6	Silt/fine sand/coarse sand/coarse gravel	30	>100	well defined	No
7	Silt/fine sand/coarse sand/coarse gravel	10	>90	well defined	No
8	Silt/fine sand/coarse sand/coarse gravel	5	>140	diffuse	No
9	Silt/fine sand/coarse sand/coarse gravel	10	>130	intense	No
10	Silt/fine sand/coarse sand/coarse gravel	5	>130	well defined	No
11	Silt/fine sand/coarse sand/coarse gravel	20	>120	diffuse	No
12	Silt/fine sand/coarse sand/coarse gravel	15	>120	well defined	No

4.5.2 Epifauna

At each subsite a randomly placed 0.25m^2 quadrat was photographed to assess epifauna. The photographs are presented in Appendix 2. At the downstream site (Site 1) all sub sites were largely devoid of macroalgae (see section 4.5.3) and were characterised by fine sand with little epifauna in evidence. Epifauna at the downstream site comprised one unburied cockle (*Austrovenus stutchburyi*), one mudflat topshell (*Diloma subrostrata*), and a few burrows showing the presence of burrowing crabs (*Helice crassa*) (Table 14). Overall abundance of epifauna per square metre for Site 1 was cockles: 0.13, crabs: 0.87, and topshells: 0.07.

Table 14. *Epifauna (individuals per square metre) at downstream site (Site 1), Shag River Estuary.*

Quadrat #	Substrate surface	Cockles (m^{-2})	Topshells (m^{-2})	Crabs (m^{-2})
1	Fine sand	4	-	-
2	Fine sand	4	-	-
3	Fine sand	-	8	-
4	Fine sand	-	8	-
5	Fine sand	-	-	-
6	Fine sand	-	4	-
7	Fine sand/scattered fine gravel	-	8	-
8	Fine sand/scattered fine gravel	-	8	-
9	Fine sand/scattered fine gravel	-	4	-
10	Fine sand	-	-	-
11	Fine sand	-	8	-
12	Fine sand	-	4	-

As with Site 1 (downstream), Site 2 (upstream) displayed a real paucity of epifauna with just occasional crab burrows seen within most 0.25m^2 quadrats (Table 15). Overall density of crab burrows at Site 2 was 0.8 per square metre. Like Waikouaiti

Estuary, there were areas of the Shag River Estuary away from the fine scale sites where much higher densities off epifauna, particularly crabs and mud snails (*Amphibola crenata*) were evident (Figure 12a,b). Densities for each ranged as high as 63m^{-2} and 43m^{-2} respectively.

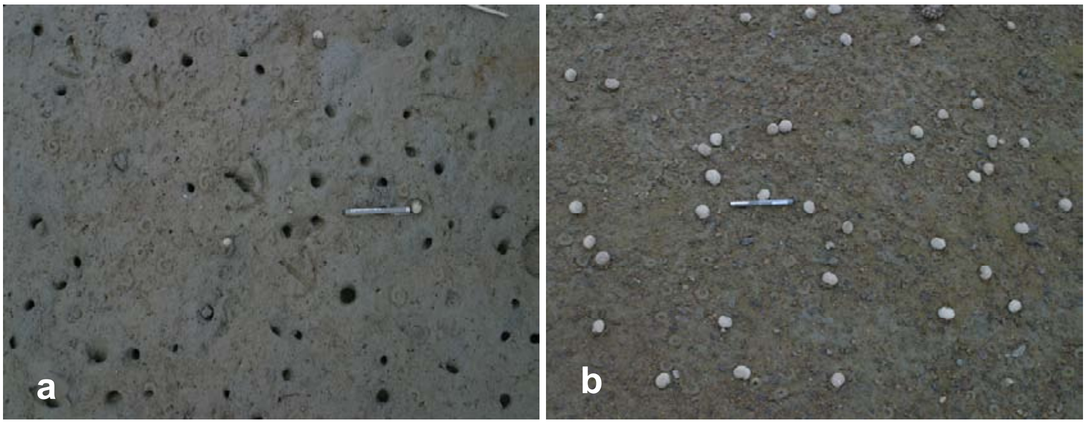

Figure 12. ***(a)*** Helice crass*a burrows and* ***(b)*** *mud snails (*Amphibola crenata*) at Site 2, Shag River Estuary. Pen is 140mm long.*

Table 15. *Epifauna (individuals per square metre) at upstream site (Site 2), Shag River Estuary.*

Quadrat #	Substrate surface	Crabs (m^{-2})
1	Muddy gravelly sand	-
2	Muddy gravelly sand	-
3	Muddy gravelly sand	8
4	Muddy gravelly sand	-
5	Gravelly sand	20
6	Muddy gravelly sand	8
7	Muddy sand	-
8	Coarse sand/fine sand	4
9	Muddy gravelly sand	-
10	Gravelly sand	8
11	Muddy gravelly sand	-
12	Muddy gravelly sand	-

4.5.3 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 very scarce. *Gracilaria chilensis* was barely noticeable at Site 1 with 1.2% cover at quadrat ten. Beyond the quadrats in deeper channels sparsely scattered small clumps of *Gracilaria chilensis* were more common. An extremely fine film of centric diatoms was evident at quadrats 3, 5 and 6.

At Site 2 *Gracilaria chilensis* was evident at quadrat one (8% cover), while a fine film of microalgae comprising centric diatoms was present at quadrats 7, 8 and 9. Lying about midway between each of the fine scale sites, however, was a bed of *Enteromorpha* spp. covering some 80m^2.

4.5.4 Infauna

Infauna at Site 1 were characterised by a variety of burrowing polychaete worms and amphipods (Table 16).

Table 16. *Infauna at three sub sites sampled at downstream site (Site 1), Shag Estuary.*

				Downstream site		
			GPS	E2339012	E2339000	E2338979
			co-ordinates	N5522919	N5522932	N5522929
			Sample	4	5	6
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae		4	1	
		Maldanidae		2	3	
		Nephtyidae		3	2	1
		Neriididae				
		Spionidae		24		18
Enteropneusta						1
Sipuncula				1		1
Crustacea						
	Amphipoda					
		Phoxocephalida		10	6	7
		Oedicerotidae		1	2	
		Haustoriidae				
	Cumacea					
		Dyastylidae		1		
	Decapoda					
		Grapsidae				
			Helice crassa		1	
Mollusca						
	Bivalvia					
		Tellinidae				
			Macomona liliana			1
		Veneridae				
			Austrovenus stutchburyi	5		12
Number of Animals				51	15	41
Animals/m^2				3825	1125	3075
Number of Taxa				9	6	7

Mean number of infaunal animals per square metre at Site 1 is 2675 with a mean of 7.3 taxa present for the site.

At Site 2 the infauna was dominated by burrowing polychaete worms and amphipods with a small number of molluscs (Table 17).

Table 17. *Infauna at three sub sites sampled at upstream site (Site 2), Shag Estuary.*

				Upstream site		
			GPS co-ordinates	E2338751 N5523163	E2338771 N5523139	E2338789 N5523127
			Sample	1	2	3
Phylum		Family	Genus/species			
Annelida						
	Polychaeta					
		Glyceridae		6	9	2
		Nephtyidae		7	2	2
		Neriididae		10	3	3
		Spionidae			19	8
Nemertea						
Crustacea						
	Amphipoda					
		Phoxocephalidae		11	33	48
		Oedicerotidae				2
		Haustoriidae		6	7	13
Mollusca						
	Bivalvia					
		Tellinidae				
			Macomona liliana		1	
		Veneridae				
			Austrovenus stutchburyi	1	1	1
Number of Animals				41	75	79
Animals/m^2				3075	5625	5925
Number of Taxa				6	8	8

Mean number of infaunal animals per square metre at Site 2 is 4875 with a mean of 7.3 taxa present for the site.

4.5.5 Chemical Analysis

As for the Waikouaiti River Estuary, replicate 250ml samples were scooped from the top 20mm of substrate at each of the twelve subsite 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 (Table 18), but values were slightly higher than for the Waikouaiti Estuary. However, as with Waikouaiti, contamination by heavy metals was still at levels well below the ANZECC ISQG – Low Trigger values (Table 18).

Observations in the field that the substrate at the upstream site was more muddy and gravelly were confirmed with a considerably higher proportion of these fractions present at Site 2 that at Site 1 (Table 18).

Table 18. *Physico-chemical analysis of sediments in Shag River Estuary.*

Parameter	ANZECC ISQG-Low Trigger Value	ANZECC ISQG-High Trigger Value	Downstream (Site 1)	Upstream (Site 2)
Dry Matter (g/100g)	-	-	75.3	81.8
Ash (g/100g)	-	-	97.2	98.0
Loss on Ignition (g/100g)	-	-	2.85	2.05
Total Nitrogen (g/100g)	-	-	0.09	0.05
Total Phosphorus (mg/kg)	-	-	544	503
Arsenic (mg/kg)	20	70	9.2	11.0
Cadmium (mg/kg)	1.5	10	0.04	0.02
Chromium (mg/kg)	80	370	10.2	10.5
Copper (mg/kg)	65	270	5.0	3.9
Nickel (mg/kg)	21	52	6.7	7.1
Lead (mg/kg)	50	220	5.61	4.69
Zinc (mg/kg)	200	410	33.6	30.2
Dry matter sieved (g/100g)	-	-	76.2	80.4
>2mm fraction (g/100g)	-	-	18.7	5.5
63μm – 2mm fraction (g/100g)	-	-	51.9	76.1
<63μm fraction (g/100g)	-	-	29.4	18.3

5. Discussion and Recommendations

Both the Waikouaiti and Shag River estuaries are typical of moderately enriched southern South Island estuaries. In both cases 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 vehicle access (Waikouaiti Estuary), and erosion, nutrient loadings, and stock grazing at the Shag Estuary. While each estuary is subject to flooding on occasion their large areal extent generally limits impacts. Erosion, which is of some concern at the Shag Estuary, is largely confined to the edges of major channels.

Both estuaries show a healthy suite of estuarine flora dominated by herbfields, with grassland generally bordering farmland. Macroalgae are relatively scarce and nuisance growths that could be attributed to enrichment are relatively minor and generally confined to back waters. More recent trips past both estuaries reveal that cover of *Enteromorpha* and *Cladophora* have grown, likely due to the warmer weather and longer sunshine hours over summer. It is expected hat these patches will decrease in size once more over winter.

Fauna too, are representative of typical estuarine animals found in healthy environments. 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 present in both inlets but there appears to be little pressure from recreational harvesting.

There is little evidence of contamination of the sediments within either estuary. The Shag Estuary has very slightly higher levels of metals than the Waikouaiti Estuary, but none of the parameters examined exceed the ANZECC (2000) ISQG - low trigger levels. As can be expected, levels of heavy metals usually associated with urban and road runoff (Zn, Cu, Fe) are low.

The sediments within each estuary reflect the geology of their respective catchments, with the Shag Estuary having a higher proportion of very fine sediment. There are extensive patches of anoxic sediment in both inlets, but nothing that would not be expected in moderately enriched estuaries.

In conclusion, both estuaries appear to be in good health. Areas of concern that may require further investigation are nutrient enrichment and vehicle access in Waikouaiti Estuary, and erosion in the Shag River Estuary. We would recommend that vehicle access to the north side of the Waikouaiti Estuary and damage resulting from this be monitored. Nutrient loadings to Waikouaiti Estuary, particularly backwaters on the north side of the estuary also may be worthwhile monitoring.

While erosion in the Shag Estuary is seen as a concern, it may be that the very heavy rains around ANZAC Day 2006 have caused more than usual damage. Monitoring of the rate of erosion along the main channels in the Shag Estuary over the course of 1-2 years may be of benefit.

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APPENDIX 1

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

Waikouaiti Estuary
Site 1 (Downstream)
Quadrat 1


Quadrat 2


Quadrat 3


Quadrat 4


Quadrat 5


Quadrat 6


Quadrat 7


Quadrat 8


Quadrat 9

Quadrat 10

Quadrat 11

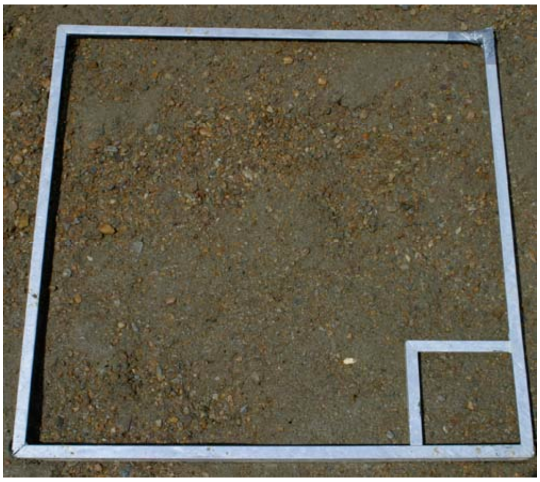
Quadrat 12


Waikouaiti Estuary
Site 2 (Upstream)

Quadrat 1


Quadrat 2


Quadrat 3




Quadrat 4


Quadrat 5

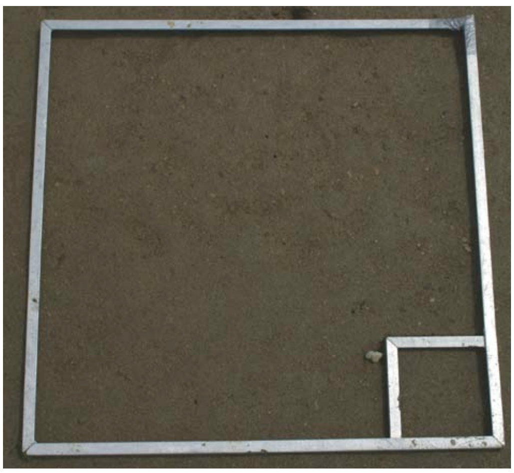

Quadrat 6

Quadrat 7

Quadrat 8

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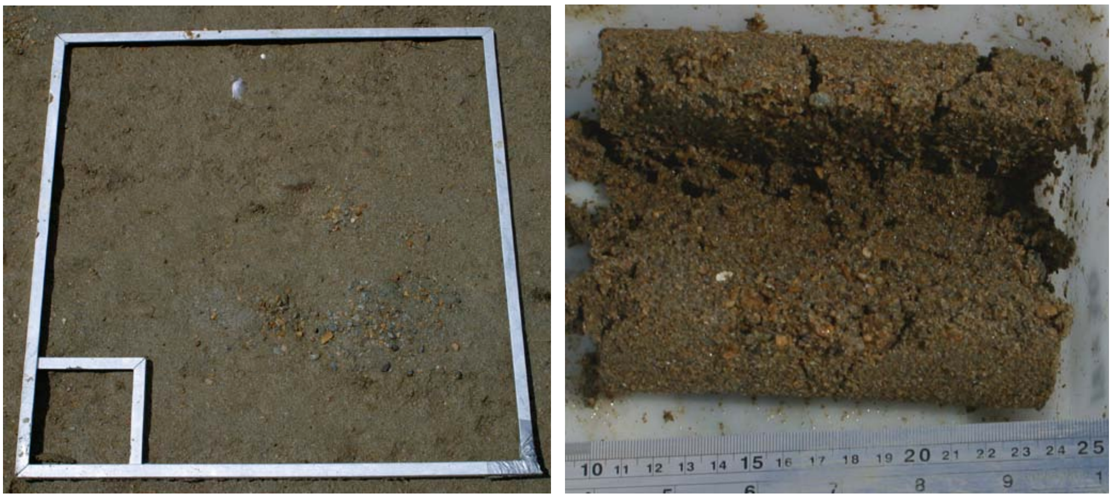

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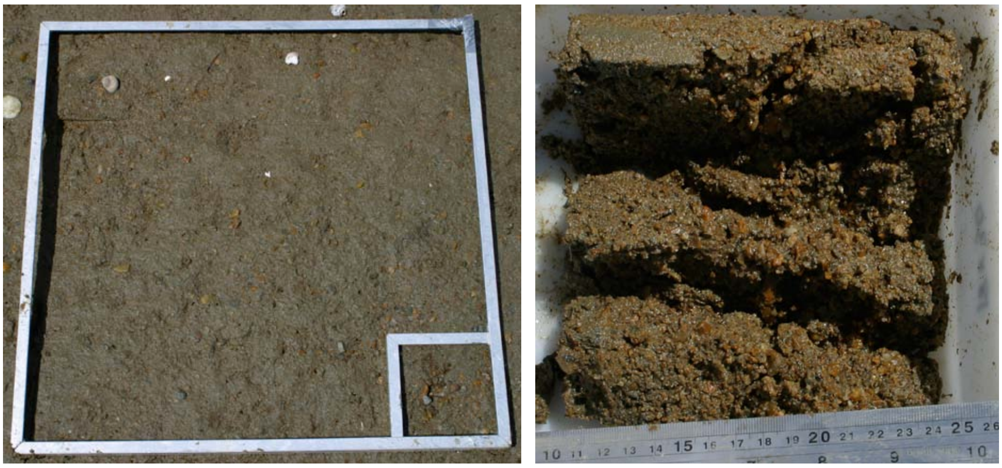

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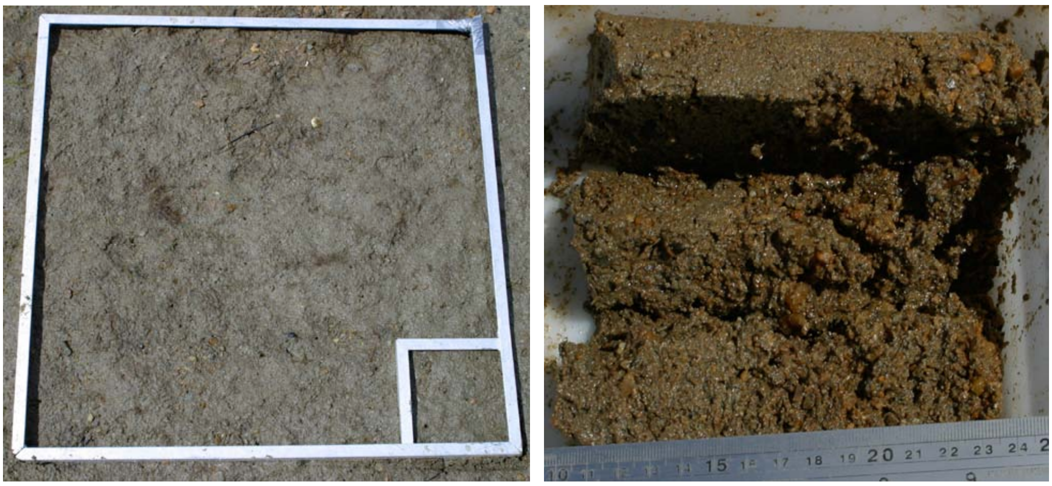


Quadrat 12

APPENDIX 2

Shag River Estuary
Site 1 (Downstream)

Quadrat 1


Quadrat 2


Quadrat 3

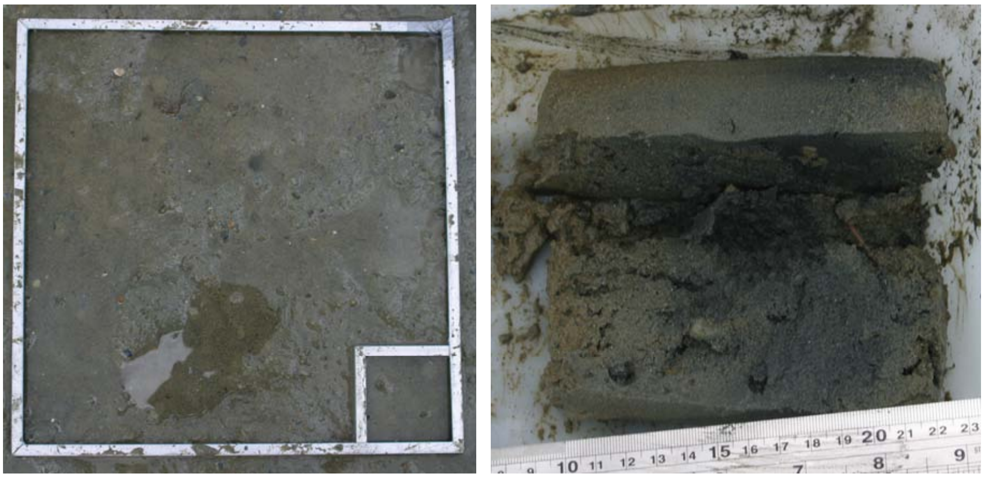

Quadrat 4


Quadrat 5


Quadrat 6


Quadrat 7

Quadrat 8



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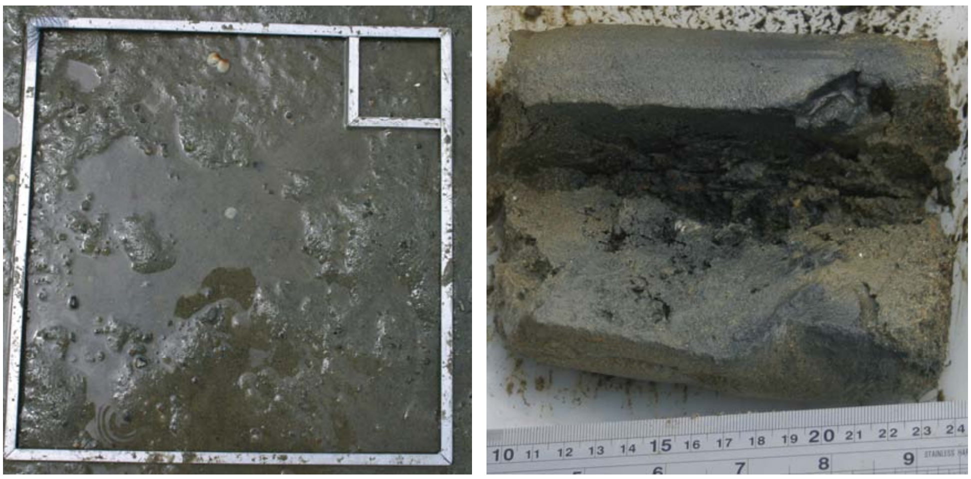

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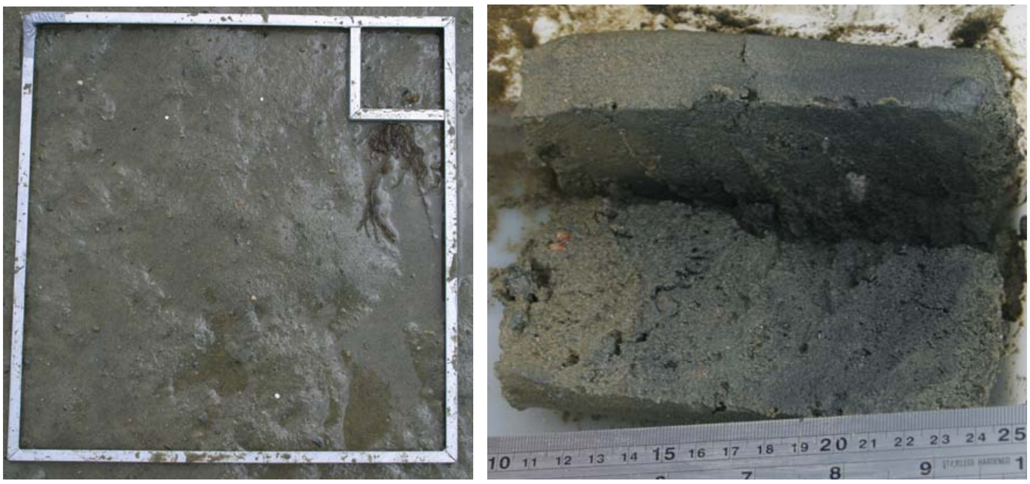


Quadrat 11

Quadrat 12

Shag River Estuary
Site 2 (Upstream)

Quadrat 1

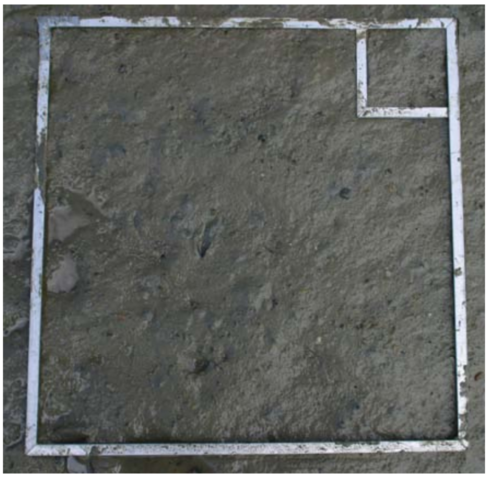
Quadrat 2

Quadrat 3

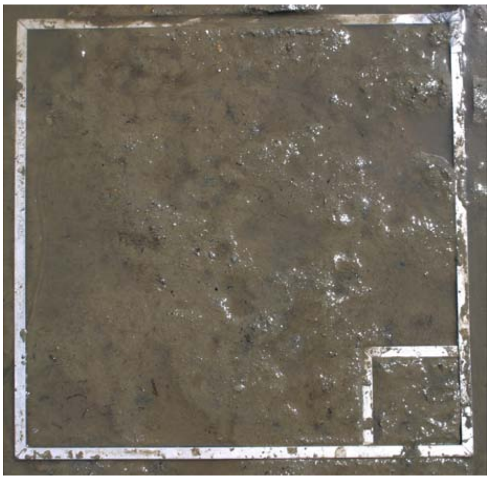
Quadrat 4




Quadrat 5


Quadrat 6


Quadrat 7

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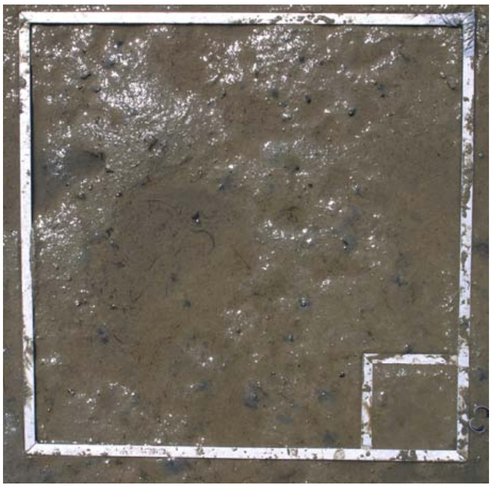


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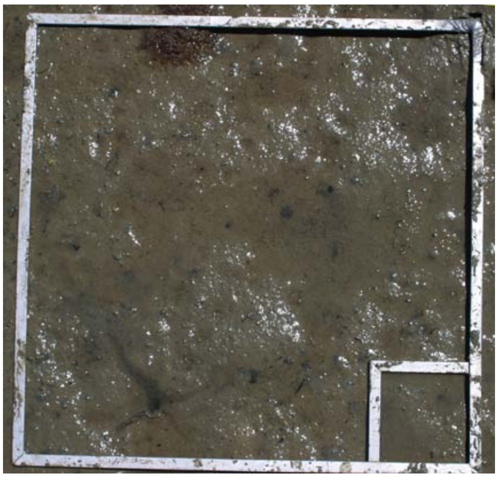
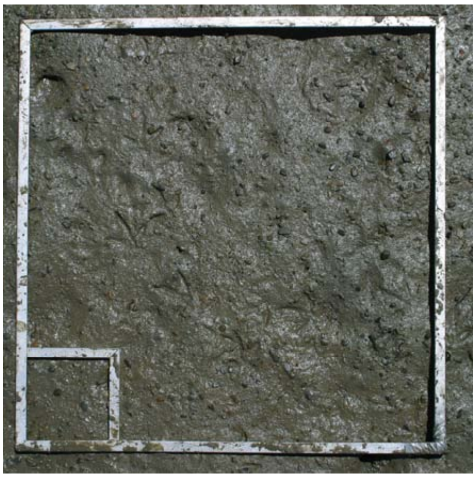



Quadrat 10

Quadrat 11



Quadrat 12