# KENEPURU HEAD ESTUARY

**Broadscale Habitat Mapping 2018**

Prepared for: Marlborough District Council

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SLR

## PREPARED BY

SLR Consulting NZ Limited
Company Number 2443058
5 Duncan Street
Port Nelson 7010, Nelson New Zealand
T: +64 274 898 628
E: nelson@slrconsulting.com   www.slrconsulting.com

## BASIS OF REPORT

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# EXECUTIVE SUMMARY

## Introduction

SLR Consulting NZ Ltd (SLR) was engaged by Marlborough District Council (MDC) to undertake broad-scale mapping of the Kenepuru Head Estuary during the summer of 2017/2018. The aim of the monitoring was to provide baseline data regarding the estuary's habitats, vegetation and composition from which to assess the current condition of the estuary. This report presents and analyses the monitoring results and discusses management options and recommendations.

## Methodology

The sampling methodology applied, and the parameters sampled, were in accordance with the recommendations provided in the National Estuarine Monitoring Protocol (NEMP) and involved ground-truthing of aerial imagery supplied by MDC and digitisation of the data collected during the ground-truthing into detailed GIS maps. Further specific methodology is detailed within the report.

## Key findings

The intertidal area of Kenepuru Head Estuary (excluding water) covered 43.2 Ha and was dominated by soft/very soft mud (77%) and firm mud (10%). This high soft mud coverage gave the estuary a HIGH risk indicator ranking (ETI risk indicators- Robertson *et al.*, 2016) for this indicator. Macroalgae and seagrass were scarce in 2018 (0.74% and 0.05% cover respectively) and both occurred around the upper reaches of the estuary. Saltmarsh vegetation covered just 1.87 Ha (4.3%) of the intertidal area resulting in a HIGH ETI risk rating, with rushland (64%), comprised of sea rush and jointed wire rush, the dominant saltmarsh cover.

Patches of molluscs were observed from upper to lower intertidal areas (covering 20% of total intertidal area) and consisted of Pacific Oysters and cockles. Cockle beds in the mid-lower intertidal were found to be in/on soft mud sediments with a layer of fine silt/mud further covering the beds.

Over 94% of the 200 m terrestrial margin surrounding the estuary was vegetated by forest (largely regenerating), scrub/forest or grassland, giving a LOW ETI risk indicator rating. To the east of the estuary, the surrounding catchment contained significant areas of pastoral farming land.

## Conclusion and recommendations

Results from the 2018 broad-scale mapping of Kenepuru Head Estuary showed the main ecological risk was the high proportion of soft/very soft mud sediments. This was also likely to be influencing the low abundance of seagrass (almost absent), through smothering and reduction in light penetration for photosynthesis. The relatively small areas of saltmarsh vegetation compared to other Marlborough estuaries are likely influenced by the steeply sloping landforms surrounding many parts of the estuary but are still another area of concern as saltmarsh vegetation provides important transitional habitat between terrestrial and aquatic areas, trapping nutrients and sediment and providing food and shelter for numerous taxa. A lack of nuisance macroalgae in the estuary indicates that it is unlikely to be eutrophic and opportunistic measurements of oxidative status showed that surface sediments in most areas were not anoxic.

# EXECUTIVE SUMMARY

A previous lack of formal survey work on Kenepuru Head Estuary meant the ecological significance of this area had not been classified. Based on the findings of the 2018 survey it is recommended that MDC considers classifying this estuary as an ecologically significant marine site within the Marlborough Sounds Area.

It is recommended that broad-scale mapping in Kenepuru Head Estuary be repeated again within, at most, five years to track spatial and temporal changes in the estuary's condition, and that fine-scale monitoring also be undertaken at that time. In between times there may be scope for very simple opportunistic measures to be undertaken by MDC staff and/or with the help of citizen science, which might provide warning of any further degradation in estuary health.




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# 1 Introduction

Marlborough District Council (MDC) Coastal Strategy (2012) identified broad-scale mapping and fine-scale monitoring of benthic intertidal habitats as a priority. Consequently, a schedule has been developed as part of MDC's overall coastal monitoring programme to ensure that all estuaries in Marlborough will be subject to mapping and monitoring by 2023. As part of this programme, MDC commissioned SLR Consulting NZ Limited (SLR) to conduct broad-scale mapping of the Kenepuru Head Estuary during the summer of 2017/2018. This monitoring was done in accordance with the National Estuarine Monitoring Protocol (NEMP; Robertson *et al*., 2002) and involved an assessment of the ecological condition of the estuary and the development of management recommendations.

## 1.1 Estuaries

An estuary can be described as "a partially enclosed body of water that is either permanently or periodically open to the sea and within which there is a measurable variation of salinity due to the mixing of sea water with fresh water derived from land drainage" (Day, 1980). Estuarine ecosystems are critical transition zones where inputs of energy and matter from terrestrial, freshwater and marine environments are processed and transformed and can include habitats of rocky outcrops, sand dunes, seagrasses and salt marshes. Morphologically, estuaries are highly influenced by their location, wind, wave and tidal action, hydrology, sedimentation and erosion (Day, 1981).

Estuaries provide important feeding and nursery grounds for fish and bird species, and support a high diversity of flora and fauna including macro- and micro- algae, bacteria, seagrass, mangroves, phytoplankton, zooplankton, infauna, epifauna, fish and birds.

## 1.2 Threats to Estuaries

Human activities have placed significant pressures on estuarine habitats. Such activities include increased: eutrophication and sewage inputs, habitat loss and alteration through development, input of chemical contaminants, risk of introduced species, input of debris/litter, and an increased risk of sea level rise. These activities can have adverse effects on estuarine ecosystems which may include loss of habitats and diversity, algal blooms, increased primary production, increased organic matter and hypoxic/anoxic conditions. These not only have direct ecological effects, but can also have significant indirect effects on the recreational, aesthetic and commercial value of an estuary.

### 1.2.1 Sedimentation

Sedimentation is a natural process and sediment can enter estuaries indirectly via rivers, tidal creeks and eroding banks, or directly from coastal land and resuspended intertidal and subtidal deposits. However, the balance between sediment entering and exiting estuaries has been altered by human activities. Activities that result in increased sediment entering estuaries pose a threat to the physical, morphological, biological and ecological features of estuarine ecosystems. Habitat modification and development can increase erosion and change water-flow patterns and sediment movements, leading to the infilling of an estuary; although whether or not this occurs will depend on many factors including wave, tide and wind action, water inputs from rivers, and water depth.

Adverse effects of sedimentation include smothering of the estuarine surface (and associated biota), changes in sediment physical and chemical properties (e.g. grain size, permeability, flux and contaminant concentration), feeding impacts on biota (e.g. clogging of filtering mechanisms), increased water turbidity, the potential for transport of contaminants, and decreased pH. The effects of sedimentation are strongly dependent on the depth and spatial extent of the deposited sediment, the temporal frequency of sedimentation events, the concentration of suspended sediment, and the resilience of the existing community.

### 1.2.2 Eutrophication

Eutrophication occurs when excess nutrients from terrestrial sources enter the coastal zone (Cloern, 2001). Increased nutrient levels lead to the increased production of particulate and dissolved organic matter that becomes degraded and causes lowered oxygen concentrations (Diaz & Rosenberg, 1995).

Nitrogen and phosphorus are generally the nutrients of concern in contributing to eutrophication and most commonly enter the marine environment via groundwater, fluvial and atmospheric inputs. Although nitrogen and phosphorus are required for growth and production, large quantities of these elements can have detrimental impacts on the structure and functioning of ecosystems. They can cause excessive amounts of primary production and respiration, and the generation of particulate matter. These, in turn, can lead to severely degraded sediment chemistry, sub-oxic and anoxic water and sedimentary habitats for biota, blooms of nuisance macroalgae, toxic phytoplankton blooms, reductions in faunal diversity, and changes in food web structure. The extent of these impacts, and their consequences, depend both on the type and quantity of the input, as well as the characteristics of the environment to which it enters (Cloern, 2001).

Where an estuary has been exposed to nutrient inputs over a prolonged period, legacy effects of nutrients stored in the sediments can occur (often along with high levels of sediment organic content and anoxic cohesive sediments). Effects are exaggerated in areas where tidal flows and circulation are low.

### 1.2.3 Habitat Loss

There has been a rapid expansion of worldwide coastal populations in recent years and more than six billion people are expected to live in coastal areas by 2025 (Schwartz, 2005). As coastal populations have increased (and as they continue to increase), natural coastal ecosystems have been converted to urban developments. Areas which remain intact may still be affected by increased sediment runoff, and increased nutrient and sediment inputs from nearby developments. Diminished and degraded estuarine and margin habitats are less likely to support healthy and diverse biological communities and their aesthetic value may decline. These factors will adversely affect coastal populations who place value on these areas for their economic, aesthetic, environmental and cultural wellbeing.

### 1.2.4 Toxic Contamination/Disease

Toxic substances can cause serious illness or death and may be poisonous, carcinogenic or harmful in other ways to living things. Heavy metals, semi-organic volatile and organotin compounds, pesticides and hydrocarbon products are examples of toxic substances that can pollute estuaries. These substances can enter an estuary via industrial/commercial discharges, runoff, roads, agricultural activities and stormwater drains. They have the potential to accumulate in plant and animal tissue and can bioaccumulate through the food web, where they may ultimately be consumed by humans and thus pose a health risk.

#### 1.2.4.1 Heavy Metals

Although many heavy metals are essential to plant and animal life, high concentrations of some metals (such as lead, copper, cadmium and zinc) can inhibit essential life functions and be toxic to organisms (Bryan, 1971). In estuaries, contamination by heavy metals can be a complex process involving physical, chemical, biological and anthropogenic processes, as well as site-specific characteristics, legacy effects and recent inputs.

#### 1.2.4.2 Semi-volatile organic compounds and organotins

Organotin compounds were initially developed in the 1920s as moth-proofing agents but have since become more widely used as bactericides and fungicides, for the heat stabilisation of PVC, and in marine antifouling paints (Moore *et al*., 1991). Such compounds can contaminate estuaries and other waterways and can be toxic to marine organisms.

## 1.3 Objective and Aims

The overall objective of this work was to provide valuable insight and advancements in the scientific understanding of the ecological condition of the Kenepuru Head Estuary. This work comprised an important part of MDC's overall coastal monitoring programme.

Specific aims were to:

- Undertake broad-scale mapping of Kenepuru Head Estuary;
- Analyse and assess broad-scale results and provide management recommendations; and
- Provide a baseline dataset for Kenepuru Head Estuary from which to investigate future changes in the condition of the estuary.

## 1.4 Survey Area: Kenepuru Head Estuary

Kenepuru Head Estuary is located at the eastern end of Kenepuru Sound (**Figure 1**), and east of Havelock, Mahakipawa and Kaiuma estuaries. The estuary lies 22 km from the main channel of Pelorus Sound and therefore residence times of water in this area (~60 days – Broekhuizen *et al*., 2015) are relatively longer than in well flushed areas of the main Pelorus Sound. However, the shallow depth and unrestricted tidal opening of the estuary itself means it is flushed by each tidal cycle. At 43 Ha, Kenepuru Head Estuary is relatively small compared to Havelock Estuary, which covers around 800 Ha (Stevens and Robertson, 2014). One main creek system drains into the estuary, but the creek is split into two main streams in the estuary's north-eastern corner. A smaller creek with limited flow enters to the south of the main creek, and a further small freshwater inflow exists on the south-western edge of the estuary.

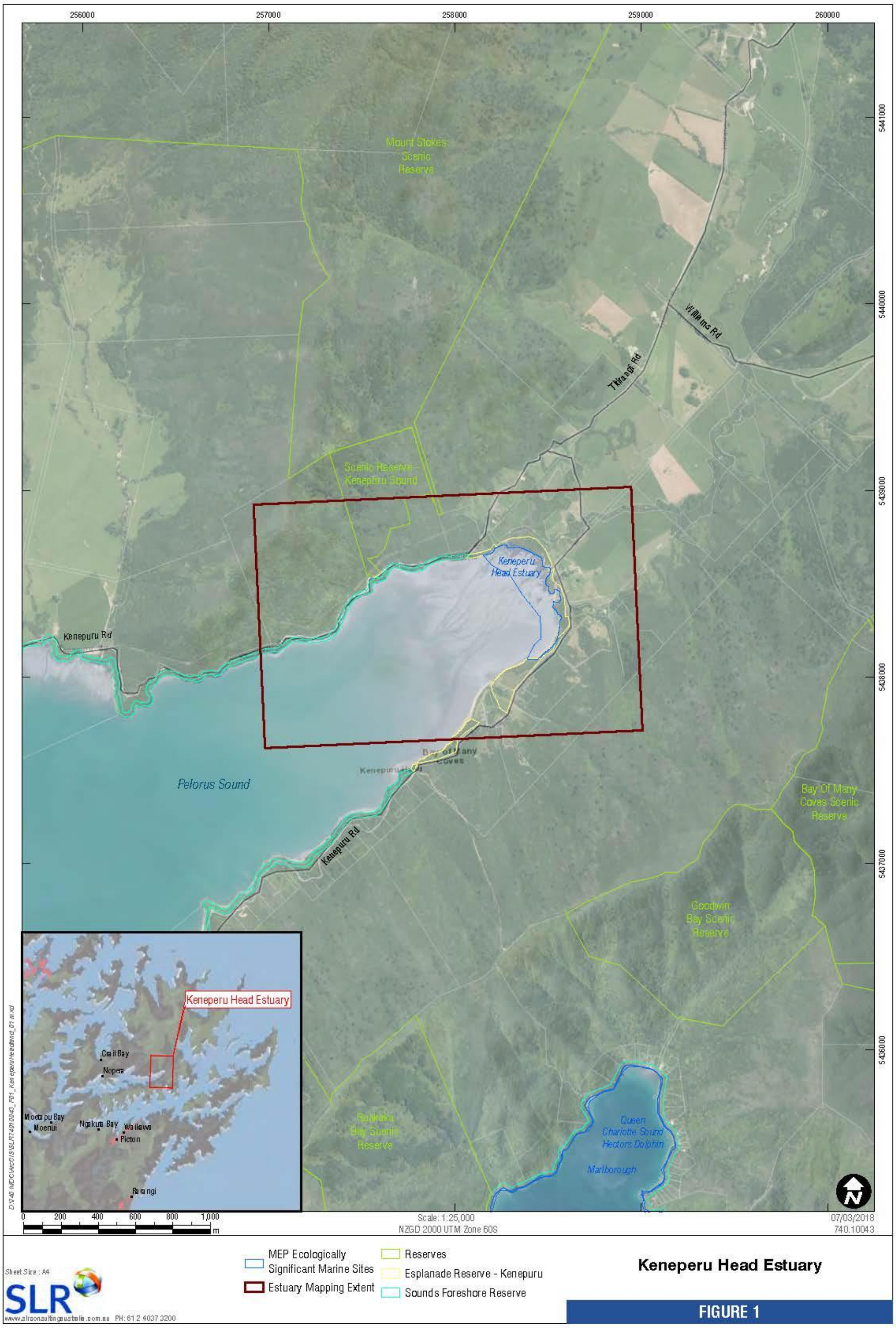
Kenepuru Road runs around the estuary, in most areas less than 100 m from the estuary edge. It provides road access for local residents and tourists from Queen Charlotte Drive to Kenepuru Sound and areas in the outer Pelorus Sounds and Port Gore. The catchment above the estuary is dominated by regenerating scrub/forest and grassland pasture, with small areas of native forest and some areas of exotic plantation forestry (*Pinus radiata*). The popular Queen Charlotte Track walkway runs along the ridgeline to the south of the estuary and several viewing locations along the track look out towards Kenepuru Sound and the estuary. A Department of Conversation (DOC) campground is located along the southern edge of the estuary which has 22 unpowered sites and is popular with New Zealand and overseas visitors to the area, particularly over the summer months. While there are several residential and farm properties located just back from the edge of the estuary, the area is less densely inhabited than nearby bays in Kenepuru Sound such as Waitaria, Sandy Bay and Portage.

Pacific oyster (*Crassostrea gigas*) beds in various parts of the Marlborough Sounds (e.g. the Mahakipawa Estuary) are an important kaimoana source for local iwi. However, little information exists as to whether Kenepuru Head Estuary has, or is, an important kaimoana gathering area. Ecologically, the hard structure of oysters also stabilises the sediment which helps to improve water quality.

The intertidal areas of the estuary are used by a variety of bird species including spoonbills, paradise ducks, black swans, weka and variable oystercatchers (personal observations – Reid Forrest) and occasionally the banded rail (Davidson *et al.*, 2011).

No previous quantitative habitat monitoring has been undertaken at the Kenepuru Head Estuary and as such this study represents a set of baseline measurements from which future changes can be measured.

### Figure 1 Location of the Kenepuru Head Estuary in the Marlborough Sounds



# 2 Methods: Broadscale Habitat Mapping

The monitoring approaches used followed the methods detailed in the NEMP (Robertson *et al*., 2002) and any advances made to this document since it was published. Methods/analyses applied in previous MDC commissioned estuarine monitoring reports were also followed for consistency.

Broad-scale habitat mapping aims to describe the habitat types of an estuary based upon the dominant features that are present, including;

- Substrate – boulder, cobble, gravel, sand, mud
- Vegetation – rushland, saltmarsh, macroalgae, seagrass, forest
- Water - open water extent, streams, creeks, rivers

## 2.1 Field Methods

High resolution Georeferenced Ortho colour aerial photos of Kenepuru Head Estuary were supplied by MDC from the SmartMaps system. These photos were taken from 2 December 2011 to 5 January 2012, and were rectified to 0.4 m with an accuracy of +/- 2 m. These ortho-rectified images were then printed onto A3 sheets (scale 1:1000) and laminated.

On 15 January 2018, SLR marine scientists ground-truthed these aerial images by walking the majority of the exposed area of the estuary following the receding tide and recording the spatial extent and boundaries of the dominant habitats and substrates directly onto the laminated A3 sheets. The 200 m terrestrial boundary of the estuary was also assessed to determine the type of habitat surrounding the estuary. Dominant habitats and surface substrates which were >2 m in diameter and which were generally visible on the aerial photos were classified and recorded. The substrate and habitat classifications used were consistent with those described in the NEMP (Robertson *et al*., 2002).

An iPad featuring the iGIS app was also used during ground-truthing and provided real-time position tracking against the aerial photos. A dual SkyPro GPS receiver was used which, via BlueTooth, works in conjunction with the iPAD to provide higher accuracy with regards to positioning.

Geo-tagged photographs from a representative selection of habitats within Kenepuru Head Estuary were taken using a Lumix MDC-FT6 digital camera, which allows for mapping of the location of the geo-tagged photos at a later date.

Stratigraphy of estuary sediments was assessed by excavating a series of small pits at haphazard locations throughout the estuary during the habitat mapping field work. Each small pit was photographed in order to record the colour of the sediment and any obvious layering or changes in colour with depth. A portable ORP probe was also used during the field survey to assess the oxidative/reductive potential (redox) of the upper 30 mm of the estuary sediments at opportunistic locations across the estuary.

## 2.2 Analysis and Reporting

Estuarine watercourses, substrates, vegetation, and habitat boundaries were manually digitised in ArcGIS 10.5. Boundaries were identified through combined interpretation of high resolution aerial photography and field observation data.

Maps and associated spatial datasets were produced indicating boundaries and coverage of intertidal substrates, macroalgae, seagrass, saltmarsh vegetation, mollusc patches and the land-use of the terrestrial margin.

Data outputs from the GIS analysis were examined to determine the percentage cover of each substrate/vegetation/habitat type within Kenepuru Head Estuary. These results were compared to Estuarine Trophic Index (ETI) risk indicator ratings as described by Robertson *et al*., (2016) and/or ratings applied in previously commissioned MDC estuary reports. Comparisons with other Marlborough estuaries were also made where possible.

## 2.3 Assessing Estuary Condition

### 2.3.1 Condition Ratings

Results were compared against ETI bands developed by Robertson *et al*., (2016) for a number of parameters. There are four ETI bands (A, B, C, D) which span a risk gradient of Low (A) to High (D). Each band has associated quantitative values for the classification of different biological, physical and chemical parameters. The statistical outputs from Kenepuru Head Estuary were compared with these bands to provide insight regarding estuarine condition and to indicate the risk of adverse ecological impacts.

# 3 Results and Discussion

The substrates and vegetation present in the 43.22 Ha of intertidal area surveyed within Kenepuru Head Estuary at low tide (excluding water), and the features present within the 76.69 Ha terrestrial margin (200 m wide boundary), were mapped during the 2018 survey.

Summary maps are provided in this section for the six key broadscale features of interest: intertidal substrates, saltmarsh, macroalgae, seagrass, mollusc patches and the terrestrial margin. High resolution versions of each map, showing greater detail, are provided in **Appendix B**.

A summary of the areas and percentage representations of the key habitat features in Kenepuru Head Estuary is presented in **Table 1**. Saltmarsh vegetation was present in 4.3% of the intertidal area surveyed in 2018, and both macroalgae (1.67%) and seagrass (0.04%) were scarce.

Representative images of some of the habitat types encountered during the field survey of Kenepuru Head Estuary are shown in **Figure 2**. Additional habitat photos are provided in **Appendix C** along with coordinates of the location of each image.

**Table 1 Summary of the area covered by key habitat features in the intertidal area**

| | Area (Ha) | Percentage of Intertidal Area |
|---|---|---|
| **Intertidal area (not including water)** | **43.22** | **100** |
| Saltmarsh | 1.87 | 4.34 |
| Macroalgae | 0.72 | 1.67 |
| Seagrass | 0.02 | 0.04 |
| Mollusc Patches | 8.81 | 20.39 |
| Soft/Very Soft Mud | 33.32 | 77.10 |

**Figure 2 Representative habitats in different regions of Kenepuru Head Estuary. A: soft mud with cockle bed*;* B: wood debris, herbfield and muddy sand; C: herbfield and saltmarsh; D: soft mud, oysters and *Enteromorpha* sp.; E: Soft mud; F: gravel/cobbles, seagrass and *Enteromorpha* sp. at edge of estuary and bordered by soft muds.**

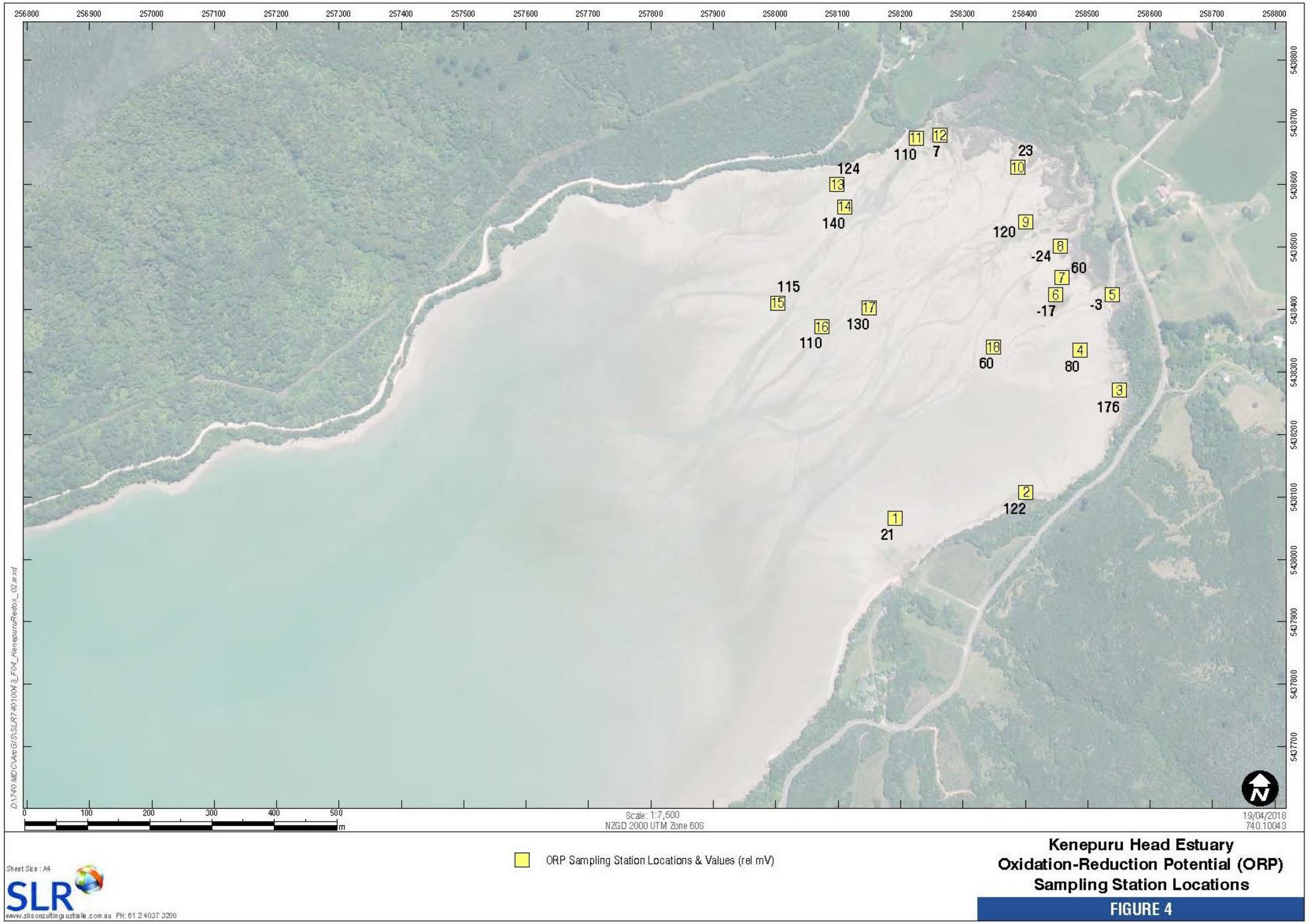
## 3.1 Sediment Oxygenation

Sediment oxygenation can be quantified by measuring the apparent Redox Potential Discontinuity depth (aRPD), a recognisable division zone sometimes occurring between the surface oxidised (aerobic) sediments and the underlying sediments that have reduced oxygen levels. There is often a distinct colour change at the aRPD. When the aRPD is at or near the surface, sediments are likely to be in a poor condition, supporting fewer taxa. This usually occurs in eutrophic or polluted areas, or where sediments have been smothered, for example, by dense macroalgal cover.

The redox potential of the upper 30 mm of sediment was tested using a portable ORP instrument at a series of locations within Kenepuru Head Estuary (**Figure 3** and **Figure 4**). Redox potential results ranged from -24 mV to 176 mV (Oxic B to Oxic A – Hargrave et al., 2008)(LOW to VERY LOW risk – Robertson (in prep)(as cited in Stevens and Robertson, 2017)), with the highest reading (176 mV) found in an area of firm muddy sand and gravel (station 3; **Figure 4**) and the lowest readings found in muddy sediments near the edges of the streams/creeks entering the estuary (stations 5, 6, 8 and 12; **Figure 4**).

**Figure 3 Sampling redox potential of surface sediments in Kenepuru Head Estuary in January 2018.**

**Figure 4 Redox potential values (Rel mV) of surface sediments measured at opportunistically sampled stations around the Kenepuru Head Estuary.**



## 3.2 Sediment Stratigraphy and Colour

While sediment cores are not normally collected during broadscale estuary surveys, SLR scientists excavated a number of shallow pits during the mapping work in order to make observations about the colouration of estuary sediments and the presence and/or depth of an aRPD (**Figure 5**, **Figure 6**). Images of the full set of shallow pits can be found in **Appendix A** with indicative images shown in **Figure 6**. The majority of sediments encountered in the estuary were light brown/tan to light grey coloured muds and sands, although at the edges of the estuary, gravel and cobble beaches were found. In the soft mud sediments that were the most commonly encountered, there was a notable but not visually distinct colour change beneath the surface from light brown to light grey, and then darker grey to almost black, in places. This absence of a distinct aRPD layer in high mud content sediments has been consistently observed in nearby estuaries with high soft mud levels such as Kaiuma Bay, Mahakipawa, and Havelock. Stations near the streams entering the estuary, such as 1, 7, 8 and 9 in **Appendix A**, showed the darkest sediments nearest the surface, and were found to have a moderate to strong sulphide odour. These results concur with the observations on sediment redox potential where the lowest values also occurred near the stream/creek inlets.

## Figure 5 Locations of shallow sediment observation pits dug during the Kenepuru Head Estuary habitat mapping in 2018

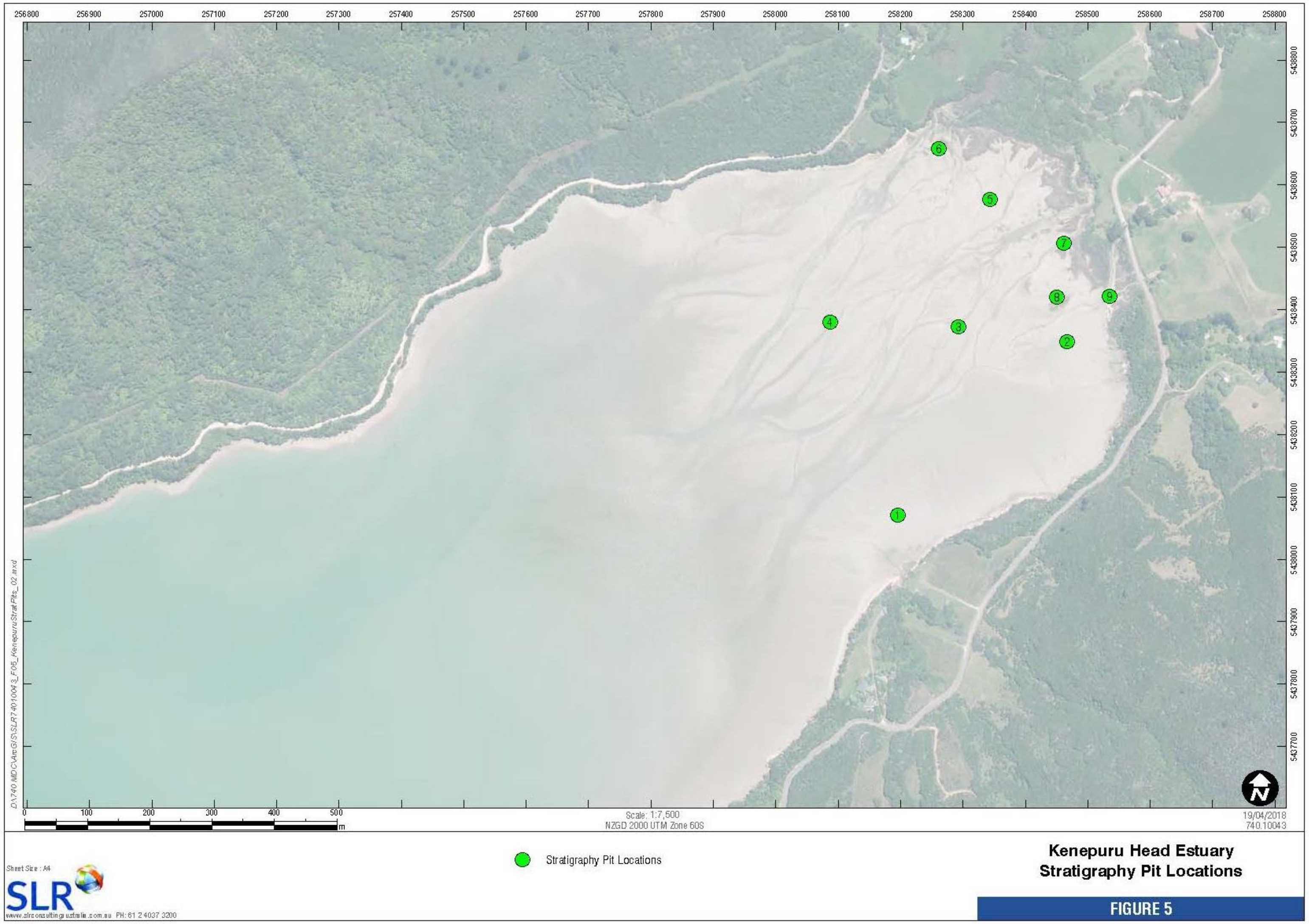


**Figure 6 Examples of subsurface sediments photographed in shallow pits at stations within Kenepuru Head Estuary showing the presence of aRPD layers.**

| Site 2 | Site 9 |
|---|---|
|  |  |

## 3.3 Intertidal Substrates

During the 2018 survey the intertidal area of the Kenepuru Head Estuary was found to be dominated by soft/very soft mud (77.1%), firm mud (9.3%), and soft mud and cobbles (4.6%) (**Figure 7**, **Table 2**). Firmer mud sediments generally occurred towards the upper parts of the intertidal zone around the edge of the estuary, often in areas where macroalgae and saltmarsh vegetation were present. Soft mud and cobbles was found largely towards the north-eastern corner of the estuary around the areas where the major creek system entered and around the edges of where the freshwater streams began to meander across the higher areas of the soft mud substrates. **Figure 8** shows two examples of the typical soft/very soft mud habitats encountered in Kenepuru Head Estuary in 2018.

The high proportion of Kenepuru Head Estuary intertidal area covered with soft/very-soft mud was similar to that found in Havelock (75%; Stevens & Robertson, 2014) and Kaiuma estuaries (72%; Stevens and Robertson, 2017), and somewhat higher than Mahakipawa Estuary (61.5%; SLR, 2017). However, this high proportion was considerably greater than that in several other estuaries in the wider Marlborough region; for example, Shakespeare Bay (6% soft mud/sand; Berthelsen *et al*., 2016), Whangarae Estuary (9.5% soft/very soft mud; Robertson & Stevens, 2016a) and Waikawa Estuary (7.7% soft/very soft mud; Stevens & Robertson, 2016).

The high levels of soft/very-soft mud in Kenepuru Head Estuary are likely linked to the low flushing rates known to exist in the Kenepuru Sound (Broekhuizen *et al*., (2015) estimate a 60 day residence time for water in Kenepuru Sound). Additionally, historical land uses such as clear-felling and burning native forests to plant pastoral land in the surrounding catchments, and current land uses such as plantation forestry which occurs in several locations in the catchment drains into the north-eastern corner of the estuary, are likely to have resulted in considerable fine sediment deposition. The relatively quiescent, sheltered nature of the area, and the high sediment loads carried into Kenepuru Sound during flood events in the Pelorus and Kaituna Catchments, also mean fine sediments tend to settle more readily in the upper parts of the Sound rather than be resuspended and moved elsewhere. Ecologically, excessive fine sediment composition will influence the infaunal, epifaunal, and macroalgal/seagrass community composition in an estuary, often resulting in the smothering of sessile organisms, choking of organisms with fine filtering or breathing appendages (gills), and reduction in light levels reaching macroalgae/seagrass during periods when water covers them.

In accordance with Robertson *et al*., (2016), when the percentage of the intertidal area covered in soft mud exceeds 15%, the estuary is classified as being ***high risk*** (BAND D). There is likely to be significant persistent stress on a range of aquatic organisms as well as local extinctions of keystone species and loss of ecological integrity (Robertson *et al*., 2016). Thus in 2018 Kenepuru Head Estuary would be classified as having a **HIGH** risk rating.

## Figure 7 Substrates present within the intertidal area of Kenepuru Head Estuary

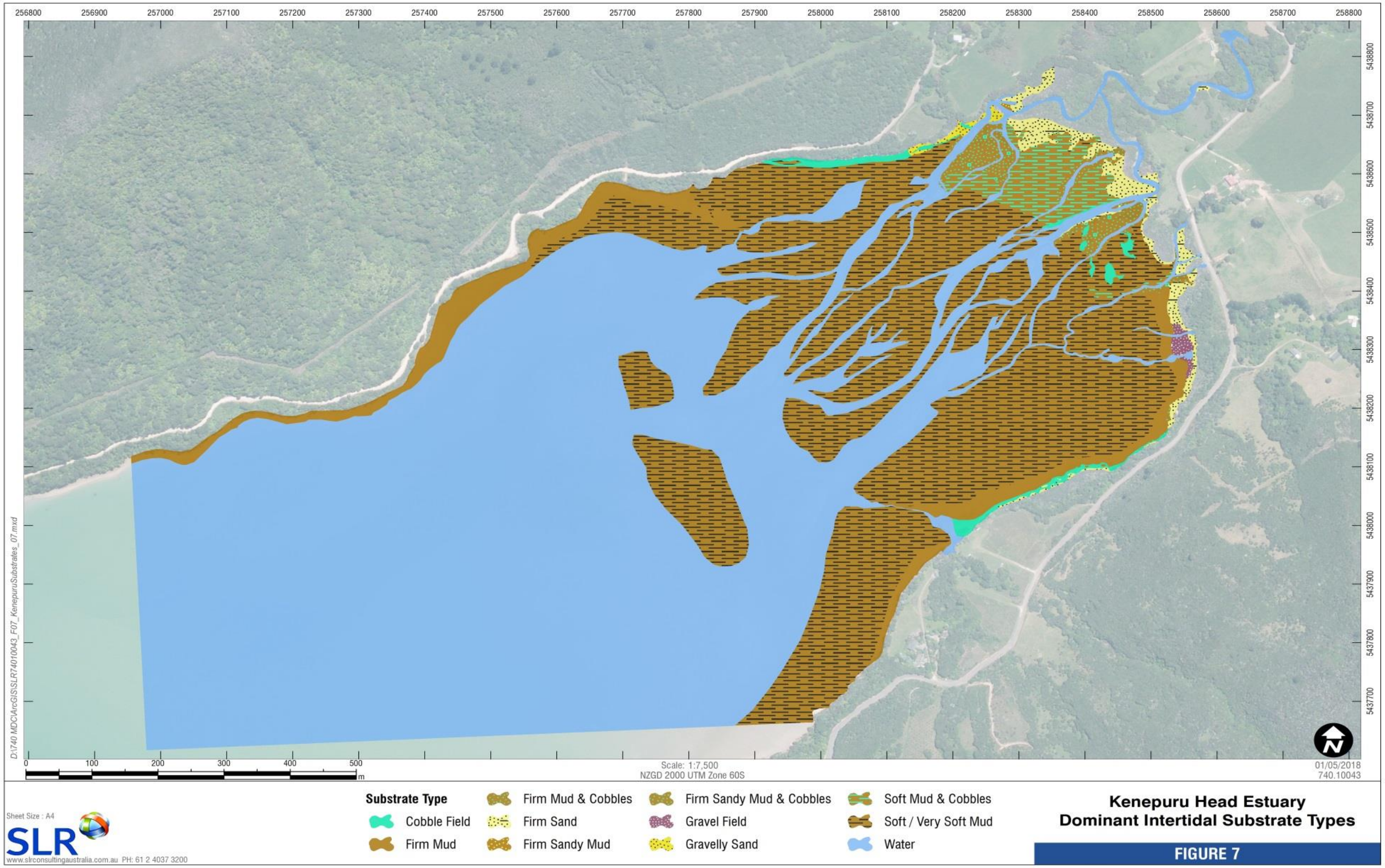


**Figure 8 Soft mud habitats in Kenepuru Head Estuary**

**Table 2 Areas and percentage cover of substrates present within the intertidal area of Kenepuru Head Estuary**

| Substrate | Total area (Ha) | Percentage Cover |
|---|---|---|
| Soft/Very Soft Mud | 33.32 | 77.10 |
| Soft Mud and Cobbles | 1.99 | 4.59 |
| Firm Mud | 4.03 | 9.32 |
| Firm Mud and Cobbles | 0.27 | 0.62 |
| Firm Sandy Mud | 0.01 | 0.03 |
| Firm Sandy Mud and Cobbles | 1.09 | 2.52 |
| Firm Sand | 1.47 | 3.02 |
| Gravel | 0.16 | 0.36 |
| Cobbles | 0.74 | 1.72 |
| Gravelly Sand | 0.14 | 0.33 |
| **Total** | **43.22** | **100** |

### 3.3.1 Molluscs

Several distinct areas of mollusc beds were observed during the 2018 survey, including oyster and cockle beds (**Figure 9**). In total, mollusc beds were found to cover 20.39% of the intertidal area of Kenepuru Head Estuary. While mapping the location and extent of the cockle beds a sample of the cockles living within these beds were collected, washed and photographed (**Figure 10**). Average sizes of the cockles appeared to be relatively small (10-20 mm) and many of the cockles had barnacles attached to their shells. The cockle beds observed in 2018 were situated in/on very soft mud substrate. While cockle beds are found on intertidal flats of mud and fine to coarse sand (Morton and Miller, 1968), and can tolerate sediment mud contents up to 85%, their optimum range is usually sandier sediments (0-10% mud)(WRC, 2018). Sediments within and around the cockle beds observed in 2018 were soft/very-soft muds with a layer of this fine mud observed to be covering the beds, High levels of fine sediments can impact the delicate breathing and feeding apparatus possessed by filer feeding organisms such as cockles. In healthy estuary systems where cockle beds exist in firmer sandy sediments, there are often large areas where dead cockle shells are present on the sediment surface. During this survey there were no obvious large areas of empty shells; all cockles, living and dead, were covered by a fine layer of soft mud. In a recent study prepared for MDC (Barrett *et al.*, 2017) showed that cockles were able to resurface relatively quickly from under significant amounts of deposition (up to 25 cm) and were resilient to low levels of repeated deposition such as light daily re-burial. Thus although there is a high proportion of soft mud sediments in Kenepuru Head estuary the existing cockle beds appear to be surviving and unless large increases in fine sediment deposition occur in the future these beds should hopefully be able to continue to survive.

Scattered areas of Pacific Oysters were common in the upper parts of the north-eastern corner of the estuary near where the freshwater streams and creeks entered. At the lower end of the estuary near the intertidal/subtidal boundary, large beds of Pacific Oysters were present on the soft/very soft mud substrates. This invasive species tends to favour soft mud habitats and in certain areas has been an important recreational food source for local iwi, although it is unknown whether Kenepuru Head Estuary is/was an important kaimoana area for local Maori.

The very soft nature of the mud surrounding these beds made it difficult and unsafe to approach close to the beds on foot. The extent of oyster beds at the lower edge of the estuary in the aerial imagery provided by MDC appeared to be significantly less than what was observed during the field survey. Therefore the size of the beds in the GIS data, and in **Figure 9,** reflect as accurately as possible what was observed on the day of the field survey. A recent report investigating the history of seabed change in the Pelorus Sound (Handley *et al*., 2017) states "*Pacific oysters became abundant in Kenepuru Sound during the 1970-'80s on stony beaches and rock outcrops, but recently have declined and appear restricted to soft sediment intertidal habitat where they likely cannot be easily predated by oyster borers (Haustrum sp.) (J. Jenkins, pers. comm., Handley, pers. observ.)*". These comments and observations are consistent with what appears to be an increasing bed of Pacific Oysters at Kenepuru Head Estuary as seen in the current survey, and similar observations of growing Pacific Oyster beds in Mahakipawa Estuary (SLR, 2017).

**Figure 9 Location and extent of mollusc beds identified during the 2018 Kenepuru Head Estuary survey.**

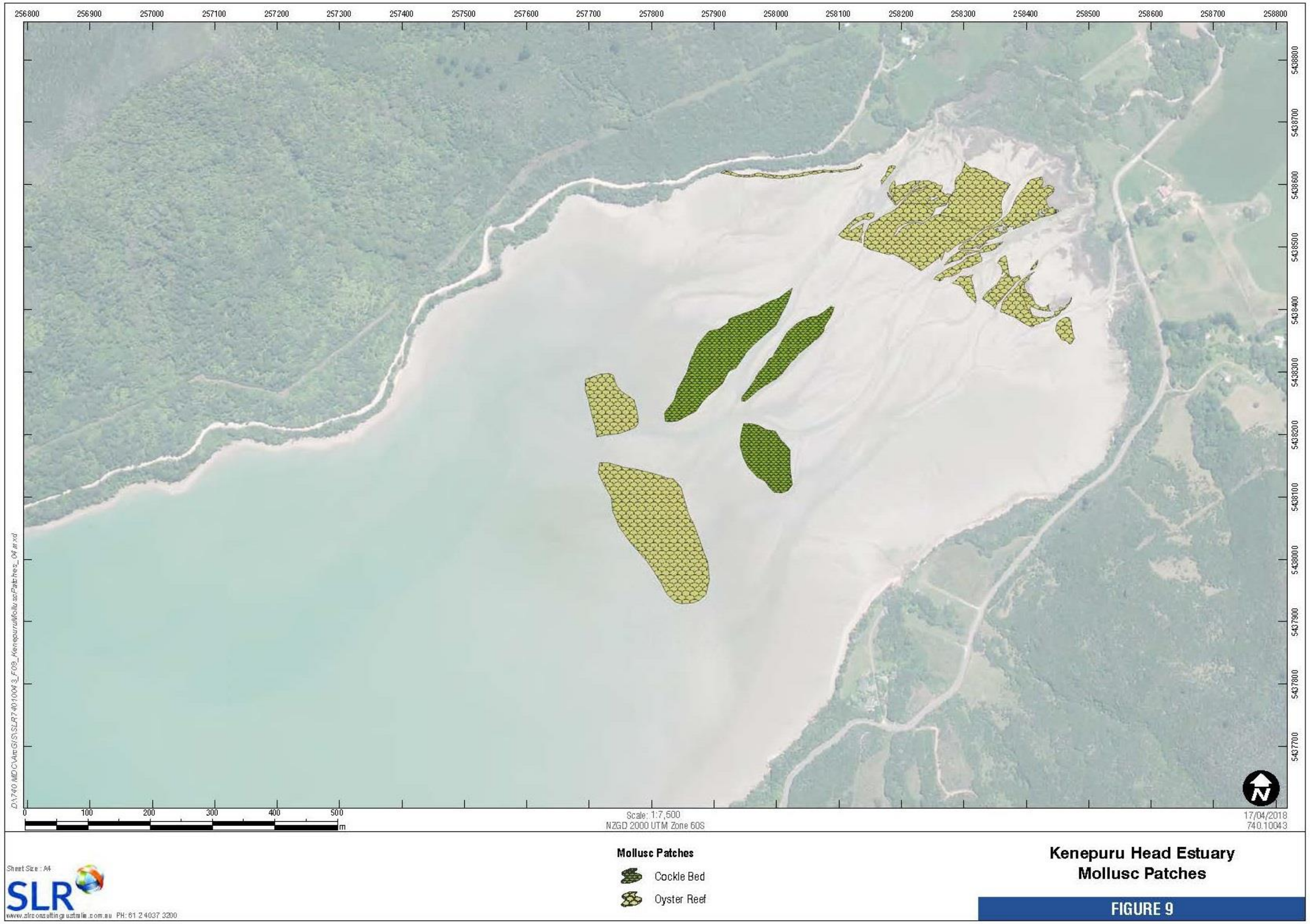


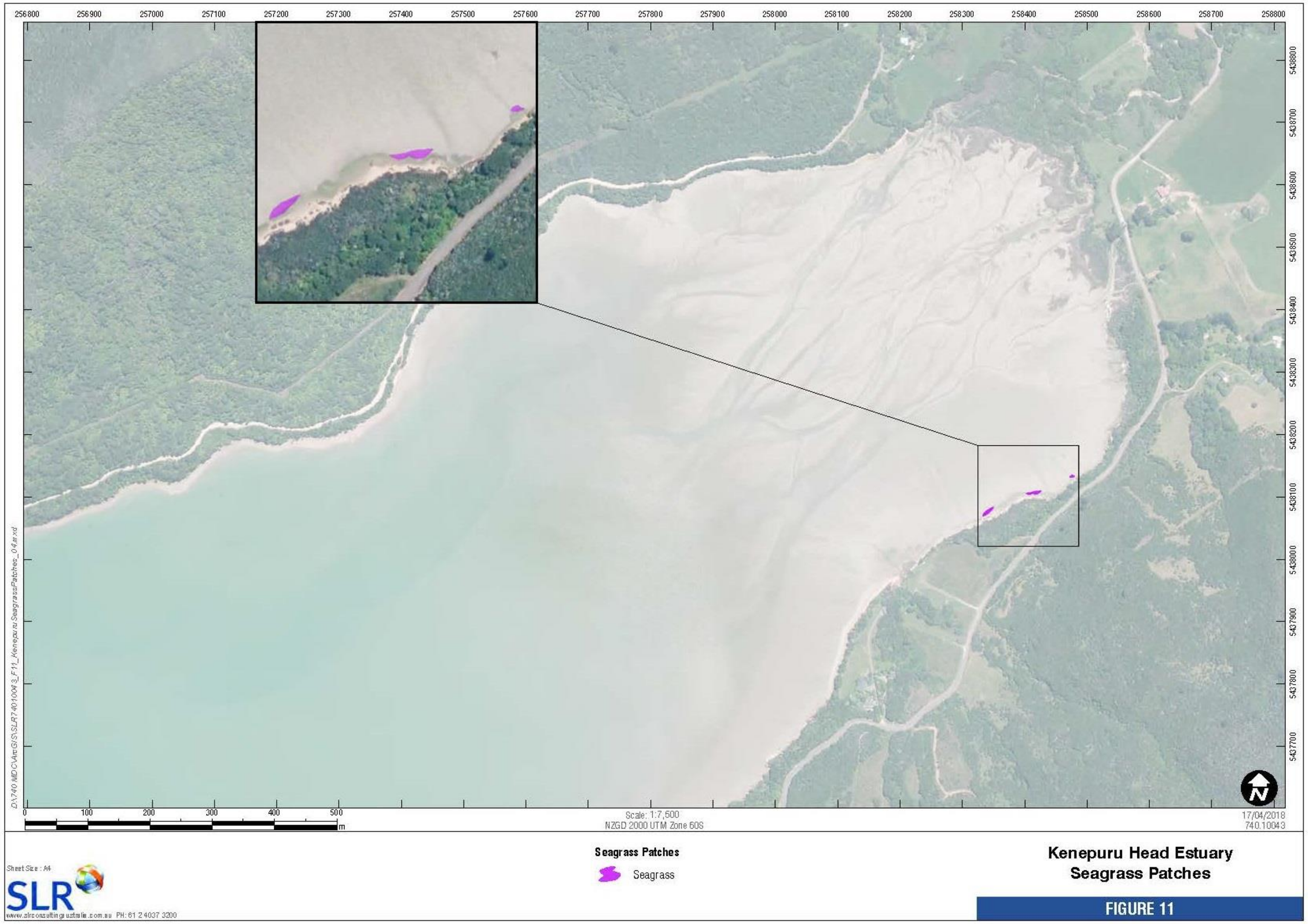
**Figure 10 Cockle beds observed in Kenepuru Head Estuary during the 2018 survey. Note that the small number of cockles in the middle of the image have been removed and washed of the soft mud covering the bed to more clearly show average sizes.**

### 3.3.2 Seagrass

Seagrass plays an important role in stabilising sediments, reducing water movement, providing habitat for invertebrates, structuring benthic communities and influencing ecosystem functioning due to its high productivity. It is, however, sensitive to fine sediments, pollution, eutrophication, disturbance, poor oxygenation, high organic content of sediments and other changes in the physical environment (Waycotta *et al*., 2009).

During the 2018 survey, seagrass (*Zostera* sp.) was observed to occur in only three small patches along the south-eastern edge of the upper estuary, just below a coarse sand and gravel beach (e.g. image F in **Figure 2**). In total these three small patches covered only an area of 164 $m^2$ (0.04% of the total intertidal area), with percentage cover ranging between 80-100% at two of the patches and 30-50% at the other. Such low levels of seagrass within the estuary are a concern for the future and further indicate that there are significant ecological issues occurring, most likely related to the high proportions of soft/very-soft mud substrates found to be present in the estuary. The 2018 survey provides a high resolution baseline from which future changes to seagrass extent can be compared.

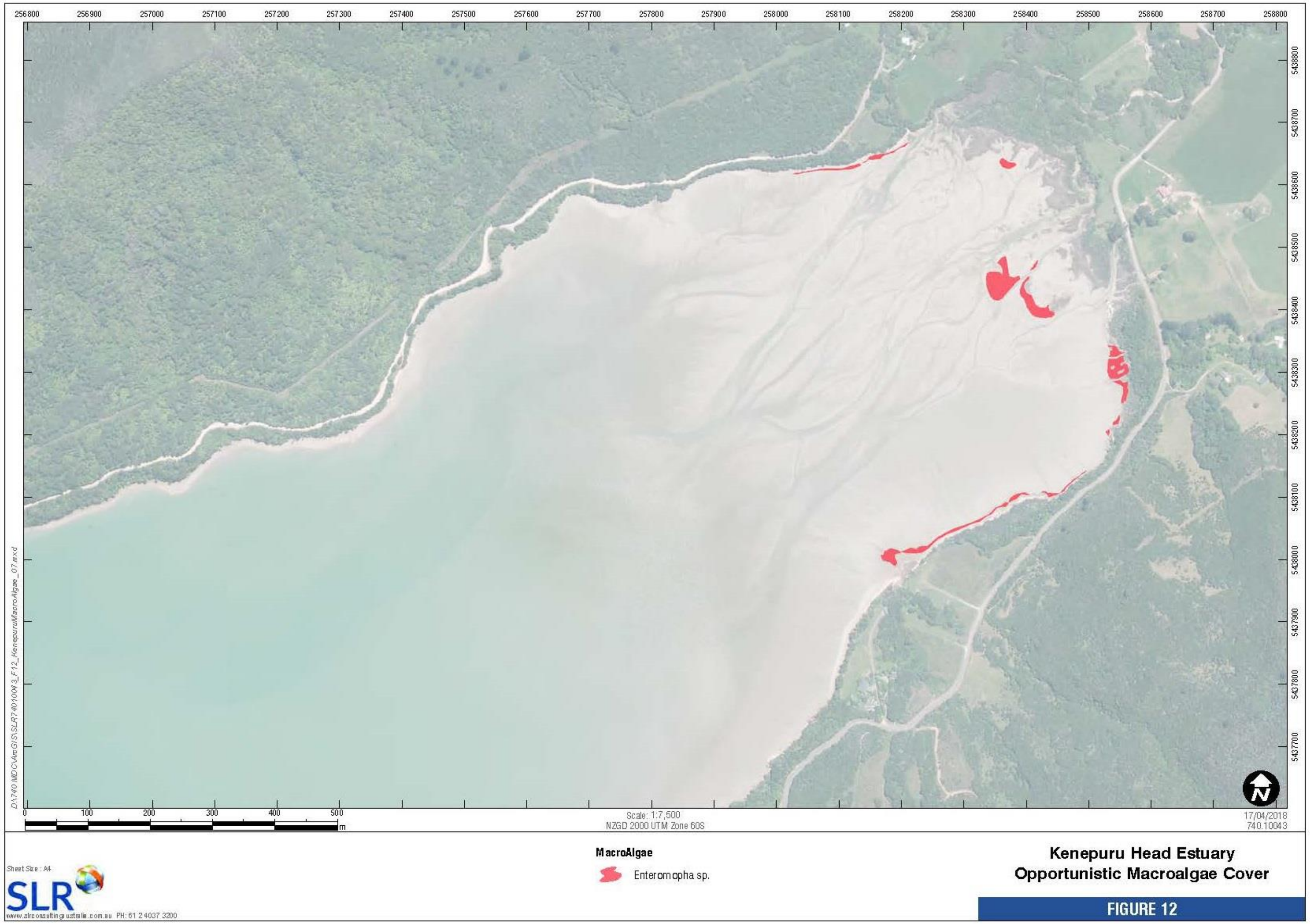
## Figure 11 Seagrass areas present within Kenepuru Head Estuary in 2018



### 3.3.3 Macroalgae

Narrow bands of macroalgae (*Enteromorpha* sp.) were found around the northern and south-eastern edges of Kenepuru Head Estuary in 2018, as well as around the stream that entered at the eastern side of the estuary. Macroalgae comprised only 1.67% of the total intertidal area and as such it does not appear that Kenepuru Head Estuary is receiving high levels of nutrient input. Furthermore, there was no indication of eutrophic conditions. The densest patch of macroalgae was observed near the south-eastern corner of the estuary where a small stream, which flowed past several residential houses and sheds, entered the estuary through a small stand of regenerating bush. It is possible that there may be a nutrient source associated with these residences which is causing increased algal growth in this one small area of the estuary. The macroalgae observed during the 2018 survey was confined to the upper, shallow edges of the estuary. It is likely that this distribution has been influenced by the significant proportions of soft mud in the Kenepuru Head Estuary which provides poor attachment surfaces for macroalgae, and also reduces sunlight penetration through the water, confining algae to shallow depths where sufficient light exists for photosynthesis.

## Figure 12 Areas of macroalgae observed in Kenepuru Head Estuary in 2018



### 3.3.4 Saltmarsh

Saltmarsh vegetation provides important transitional habitat between the intertidal zone and the terrestrial zone surrounding an estuary. Plants in this area are adapted to tolerate fluctuations in salinity and water level. Like seagrass habitats, saltmarsh areas are highly productive and provide food and habitat for a range of organisms, particularly juvenile fish and crustaceans. Saltmarshes also trap nutrients and sediments and consequently healthy saltmarsh vegetation can help to protect the estuary from eutrophication, sedimentation and erosion.

In 2018, saltmarsh vegetation covered 1.87 Ha (4.34%) of the intertidal area of Kenepuru Head Estuary, which was notably lower than other estuaries in the Marlborough region including Mahakipawa and Havelock (25%) (SLR, 2017; Stevens & Robertson, 2014), and Kaiuma Estuary (22%) (Stevens & Robertson, 2017). This coverage was however closer to that of Whangarae Estuary (8.8%) (Stevens & Robertson, 2016a), and greater than the 0.4% recorded in Waikawa Estuary (Stevens & Robertson, 2016b). Consistent with the estuary condition risk indicator ratings used in Stevens and Robertson 2014, the low percentage of saltmarsh vegetation occurring in the intertidal area in Kenepuru Head Estuary classifies the estuary as having a **HIGH** estuary condition risk indicator rating for saltmarsh extent.

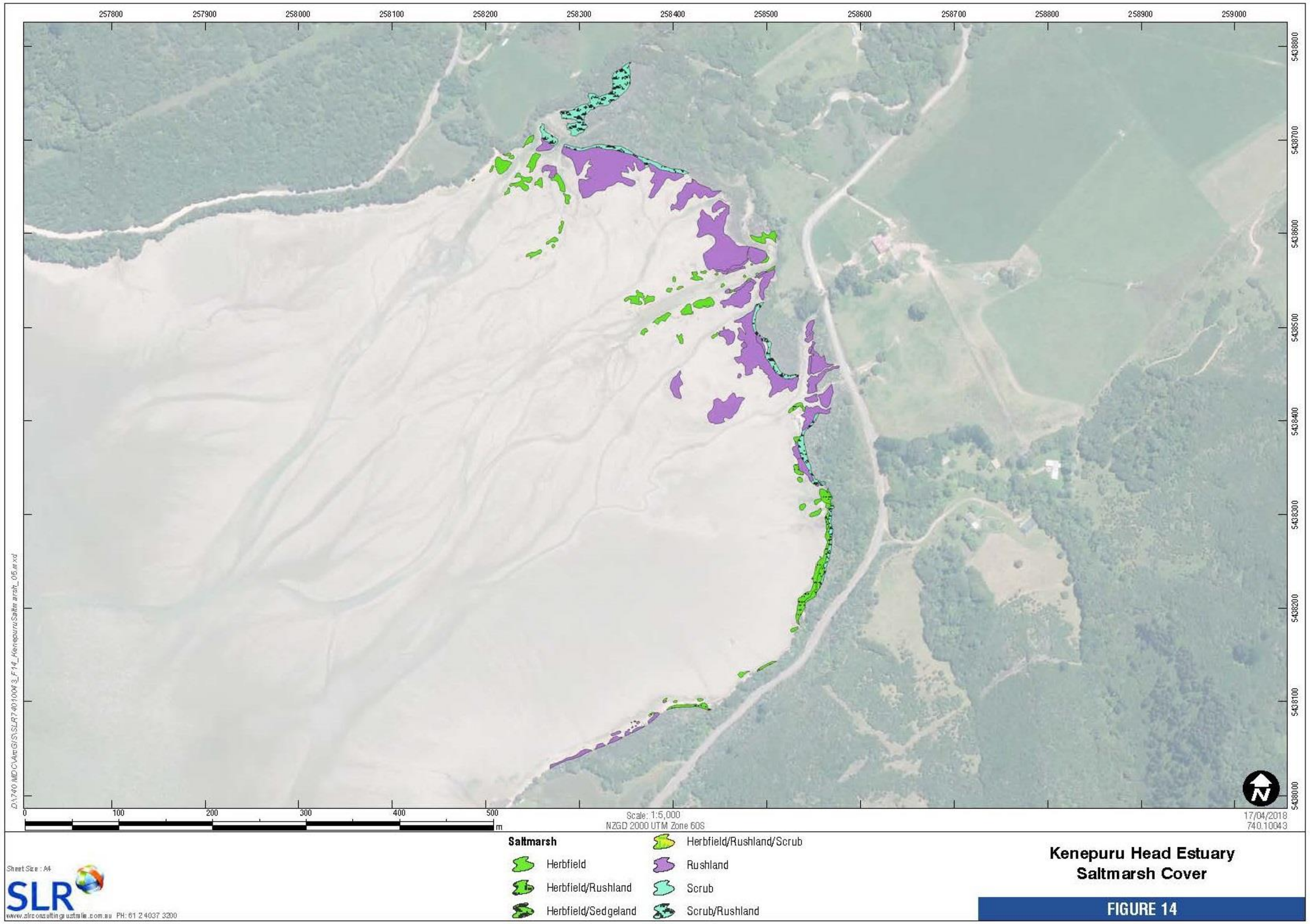
Similar to other estuaries in the Marlborough region, saltmarsh habitat was concentrated in the upper reaches. Saltmarsh vegetation in Kenepuru Head Estuary consisted of rushland, herbfield, sedgeland, and scrub (**Figure 13**). The largest areas of saltmarsh vegetation occurred along the eastern edges of the estuary, while the northern and southern parts of the estuary had more steeply sloping edges and surrounding lands which limited the extent of suitable substrate for saltmarsh to occur. The contribution of each saltmarsh habitat type to the total area covered by saltmarsh is shown in **Table 3**, with **Table 4** providing a comprehensive list of the saltmarsh species comprising each of these categories, and the area covered by, and percentage cover of, specific saltmarsh species.

The dominant saltmarsh vegetation in 2018 was rushland, contributing over 64% of the total saltmarsh cover. Within the rushland areas, the searush *Juncus krausii* constituted 49.6% of the total, followed by areas where both *J. krausii* and *Leptocarpus similis* (jointed wirerush) occurred (47.8%).

**Table 3 The area and percentage cover of the different saltmarsh habitats within the Kenepuru Head Estuary in 2018**

| Saltmarsh Habitat Type | Area (Ha) | Percentage Cover |
|---|---|---|
| Rushland | 1.21 | 64.21 |
| Herbfield/Rushland | 0.12 | 6.29 |
| Herbfield | 0.23 | 12.50 |
| Herbfield/Rushland/Scrub | 0.005 | 0.25 |
| Herbfield/Sedgeland | 0.0004 | 0.02 |
| Scrub/Rushland | 0.31 | 16.73 |
| **Total** | **1.88** | **100** |

## Figure 13 Saltmarsh vegetation types observed within Kenepuru Head Estuary in 2018.



## Table 4 Area and percentage cover of individual saltmarsh species in Kenepuru Head Estuary in 2018

| Saltmarsh type | Taxa | Common name | Area (Ha) | Total area covered by saltmarsh type (Ha) | Contribution to total saltmarsh area (%) | Contribution to Saltmarsh type (%) |
|---|---|---|---|---|---|---|
| **Herbfield** | *Samolus repens* | Primrose | 0.2302 | 0.2348 | 12.53 | 98.04 |
| | *Selliera radicans* | Remuremu | 0.0030 | | | 1.29 |
| | *Samolus repens/Plantain* sp./*Gunnera* sp. | Primrose/Plantain/Gunnera | 0.0016 | | | 0.67 |
| **Herbfield/Rushland** | *Samolus repens/Juncus kraussii/Leptocarpus similis* | Primrose/Searush/Jointed Wirerush | 0.0161 | 0.1134 | 6.05 | 14.19 |
| | *Samolus repens/Juncus kraussii* | Primrose/Searush | 0.0781 | | | 68.86 |
| | *Samolus repens/Selliera radicans/Juncus kraussii* | Primrose/Remuremu/Searush | 0.0127 | | | 11.16 |
| | *Samolus repens/Selliera radicans/Juncus kraussii/Leptocarpus similis* | Primrose/Remuremu/Searush/Jointed Wirerush | 0.0066 | | | 5.79 |
| **Herbfield/Rushland/Scrub** | *Samolus repens/Selliera radicans/Juncus kraussii/Leptospermum scoparium* | Primrose/Remuremu/Searush/Manuka | 0.0047 | 0.0047 | 0.25 | 100.00 |
| **Herbfield/Sedgeland** | *Samolus repens/Isolepis cernua* | Primrose/Slender clubrush | 0.0005 | 0.0005 | 0.02 | 100.00 |
| **Rushland** | *Juncus kraussii* | Searush | 0.5983 | 1.2064 | 64.37 | 49.59 |
| | *Juncus kraussii/Leptocarpus similis* | Searush/Jointed Wirerush | 0.5761 | | | 47.76 |
| | *Leptocarpus similis* | Jointed Wirerush | 0.0320 | | | 2.65 |
| **Rushland/Scrub** | *Juncus kraussii/Leptocarpus similis/Plagianthus divaricatus* | Searush/Jointed Wirerush/Saltmarsh Ribbonwood | 0.1668 | 0.3143 | 16.77 | 53.05 |
| | *Juncus kraussii/Plagianthus divaricatus* | Searush/Saltmarsh Ribbonwood | 0.1110 | | | 35.31 |
| | *Juncus kraussii/Plagianthus divaricatus/Leptospermum scoparium/Kunzea ericoides* | Searush/Saltmarsh Ribbonwood/Mauka/Kanuka | 0.0366 | | | 11.64 |

### 3.3.5 Terrestrial Margin

The 200 m terrestrial margin around the Kenepuru Head Estuary was dominated by forest and grassland cover (51.6% and 28.6% respectively), with vegetated habitat covering 94.8% of this margin (**Table 5, Figure 14**). The majority of forest land was composed of regenerating native forest, with smaller patches of more established native forest, as well as small areas of exotic/introduced species (particularly as shelter belts around the grassland/pasture). Grassland areas occurred from the north-eastern to southern side of the estuary although grassland areas to the east of the estuary opened out into larger areas of pastureland. These areas continued well up into the valleys to the east, while those to the southeast and south were smaller grassland areas surrounded by regenerating forest and forest/scrub.

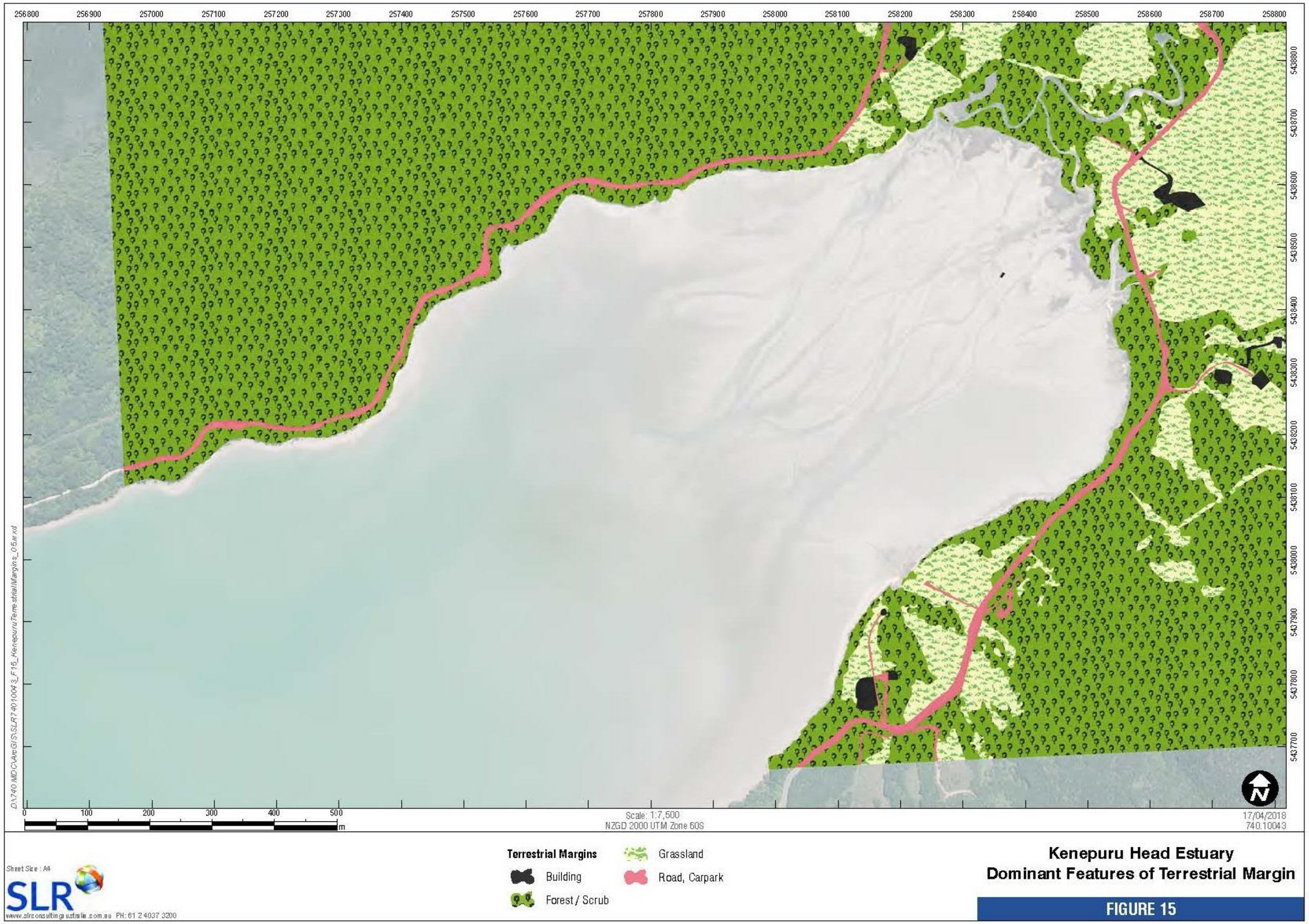
Within **Figure 14** a small area in the middle of the estuary has been shown classed as 'building'. During the ground-truthing fieldwork SLR staff came across a large steel boiler at this location which appeared to have been resting at this location for some time. Reviewing satellite imagery on GoogleEarth™ extending back to 2009 shows the boiler was present as far back as at least that time and likely much longer. No further evidence of a historical wrecked/scrapped vessel was seen around the area where the boiler was found, or in the wider estuary, so it is unknown whether the boiler was from a vessel, or from some large machinery that operated on nearby land.

Vegetated margin habitats are important as they help to protect estuaries, particularly with regards to assimilating sediments and consequently reducing the amount of fine particles entering the estuary. With 94% of the terrestrial margin vegetated in 2018, the Kenepuru Head Estuary is classified as **LOW** risk by this indicator (Stevens & Robertson, 2014). However, it should be acknowledged that there are distinct differences in the functional importance of densely vegetated scrub/forest (such as that on the northern side of the estuary) versus grassland/pasture areas (such as those to the east). A large proportion of the inputs (nutrient and sediments) entering Kenepuru Head Estuary will likely come from the streams draining the catchments to the east, where grassland/pasture is prevalent. Grassland/pasture such as these are less effective in filtering sediments/nutrients from runoff, and thus preventing them from entering the estuary, particularly from pasture where riparian strips do not border the streams.

**Table 5 Area and percentage cover of the habitats/features occurring within the 200 m terrestrial margin surrounding Kenepuru Head Estuary in 2018.**

| Terrestrial Margin feature/habitat | Area (Ha) | Percentage Cover |
|---|---|---|
| Grassland | 21.91 | 28.56 |
| Forest / Scrub | 7.77 | 10.13 |
| Forest | 39.56 | 51.58 |
| Scrub | 3.45 | 4.50 |
| Building | 0.60 | 0.78 |
| Road | 3.41 | 4.44 |
| **Total** | **76.70** | **100.00** |

## Figure 14 Terrestrial margin features/habitats surrounding Kenepuru Head Estuary in 2018



# 4 Summary and Recommendations

Broad-scale habitat mapping of Kenepuru Head Estuary identified that the key ecological risk was the large proportion of the estuary comprised of soft mud habitat (77% - HIGH risk rating, ETI risk indicators- Robertson *et al.*, 2016). The relatively low proportion of the intertidal area where saltmarsh vegetation was present also showed HIGH risk indicator ratings, while indicators such as the vegetated terrestrial margin were LOW risk (ETI rating)(**Table 6**).

While some areas of healthy seagrass were observed on the southern edge of the estuary, these areas comprised a tiny fraction of the total estuary area and further indicate that the estuary health is relatively low. It is likely that the high proportion of soft mud substrate in the estuary has contributed to the decline of the seagrass beds through reduction of light penetrating the water column and by smothering effects. Measurements of seagrass location and extent determined in 2018 provide a baseline for future assessments of any changes in seagrass.

The quiescent location of Kenepuru Head Estuary at the end of a long, relatively shallow sound, well away from the main flushing flows of Pelorus Sound, mean that sediments that are pushed up into this area by tidal and wind driven currents (from the predominant west/northwest winds), are likely to settle out to the seabed. While some significant erosion of saltmarsh areas, along with stream banks and shoreline was noted in places during the survey, these sources do not appear to account for all the soft sediment present in the Kenepuru Head Estuary. Visual observations of the surrounding catchments at the time of the survey did not reveal any areas of recent plantation forestry harvesting, or significant landslide events, which may have released finer sediments into the waterways draining into the estuary, although significant erosion of the leading edges of the saltmarsh areas was observed in places along the north-eastern parts of the estuary. Significant flood events that occurred in the Kaituna and Pelorus catchments in 2016 have been linked with the high proportions of fine sediment found in the Mahakipawa (SLR, 2017) and Kaiuma Bay estuaries during surveys in 2017, and it is likely that significant amounts of fine silt from this same flood event could have carried with floodwaters up into Kenepuru Sound. In a recent study investigating the history of seabed change in Pelorus Sound, Handley *et al*. (2017), classified the inflow of sediment from the Havelock and Kaituna River systems as the ‘Havelock inflow’. The study showed that post European settlement, sediment accumulations increased markedly in areas such as Kenepuru Sound, with the contribution of the Havelock inflow to total sediment volumes also greatly increasing, reflecting the clearing of land for pastoral farming and ongoing pasture maintenance. Thus it is likely that the build-up of soft mud sediment in the Kenepuru Head Estuary has been increasing for a long period, and recent flood events are likely to have resulted in further significant pulses of sediment occurring. But without previous scientific surveys, or historical images of the estuary, we are unable to know whether it has been a slow, gradual build-up of soft sediment through time, or due to more recent large scale events.

The low levels of macroalgae, and particularly nuisance algae, within the estuary in 2018 suggest that it is not subject to widespread eutrophication. However, the small area where the densest beds of *Enteromorpha* sp. were observed was located near the mouth of a small stream which drained past several residences. Consequently there may be some evidence of nutrient input at this point and future monitoring should be mindful of this.

Mollusc patches composed of oyster and cockle beds covered over 20% of the intertidal area of the estuary and similar to other soft mud dominated estuaries in Pelorus Sound, Pacific Oysters appear to be surviving and growing widely in the lower reaches of the estuary. However, the cockle beds observed in 2018 occurred in soft mud substrate, covered by a thin layer of fine mud (both the shellfish and the bed itself), which is unusual for healthy cockle beds.

While the high level of vegetated land surrounding the estuary (94%) classifies it as having a VERY LOW risk indicator rating, land use to the east of the estuary beyond the 200 m strip (used to calculate this rating), has considerable areas of pastoral land and also areas of plantation forestry. The largest freshwater input to the estuary drains from this eastern catchment and as a result, nutrients and sediments lost from these areas could end up directly deposited into the Kenepuru Head Estuary.

**Table 6 Summary of the broad-scale mapping results. Results of concern are shown in bold.**

| | % Coverage | Ecological Assessment |
|---|---|---|
| Dominant Substrate: Soft/Very Soft Mud | 77.10 | **HIGH Risk** |
| Mollusc patches | 20.39 | LOW Risk |
| Seagrass | 0.04 | Baseline established |
| Macroalgae | 1.67 | LOW Risk |
| Saltmarsh | 4.34 | **HIGH Risk** |
| Terrestrial Margin Vegetation | 94.80% | VERY LOW Risk |

Although small, the Kenepuru Head Estuary provides important ecological, and aesthetic ecosystem services for the animals, plants, algae, iwi, locals and visitors which use, visit and/or rely on its habitat. The results from the 2018 survey provide a snapshot of the current condition of the estuary, a baseline to compare against future surveys/monitoring, and give MDC information from which to discuss and establish management goals. Here, suitable management targets may be to aim for a desired set of ecosystem characteristics, such as:

- improved estuary health with respect to decreased soft/very soft mud substrate (including examining sediment inputs);
- growth and spread of seagrass;
- removal of anthropogenic debris (e.g. large steel boiler); and
- more attractive conditions for increased recreational usage, such as camping, swimming, kiteboarding, fishing, shell-fish gathering and/or picnicking.

Management decisions and goals must take into account the priorities of different stakeholders and user groups, as well as the resources available. This may require managers to consider difficult questions such as 'what components of the ecosystem should we be most concerned about.' Clearly, the answers to such a question will be subjective and may differ considerably among different stakeholder groups. The success of ecosystem-based management then becomes an issue of setting and achieving the best set of outcomes for all parties involved. To achieve this, a holistic approach that considers habitats, communities and processes over a wide range of spatial and temporal scales and that incorporates research carried out over all levels of ecological organisation is required.

The 2018 monitoring was undertaken using high resolution aerial imagery collected in 2011/2012. As such, the field ground-truthing found that features on the imagery, and those in reality were often somewhat different. The outlines of some features (such as saltmarsh areas, herbfields, oyster beds etc.) had to be plotted to the best available estimates onto the older imagery, adding additional time and complexity. Future surveys would benefit greatly from having aerial imagery collected as close as possible to the time the ground-truthing surveys were planned/undertaken to ensure the quickest, and most up-to-date and accurate mapping.

In the assessment of ecologically significant sites in the Marlborough Sounds, Davidson et al. (2011) stated that the Kenepuru Head Estuary required further investigation to determine the ecological significance of this area as it "*has not been formally surveyed*". Based on the findings of the 2018 survey it is recommended that MDC considers classifying this estuary as an ecologically significant marine site within the Marlborough Sounds Area.

It is recommended that broad-scale monitoring of Kenepuru Head Estuary be repeated within five years and, if funding allows, fine scale monitoring be undertaken at that time also. However, it is recommended that where possible, opportunistic and very broad scale monitoring of certain factors be undertaken by MDC or harbourmaster staff when they are working in or passing through this area. For example, the small areas of seagrass that remain in the estuary are at the southern edge near the camping area and can be easily accessed from this point to check their ongoing survival and/or any obvious changes in size of the patches. During fieldwork at this site, SLR staff met and discussed the estuary survey with the Department of Conservation voluntary campground supervisor. Another recommendation for a simple, low cost method for a basic ongoing assessment tool may be to discuss with the Department of Conservation whether the campground supervisor could take several high resolution images across the estuary at low tide from the campground each summer, and these be passed onto MDC. From these images very basic details such as the presence/extent of nuisance algae, spread of oyster beds and extent of soft mud, might be able to be estimated, or at least compared to previous years.

# 5 Acknowledgements

Thank you to Steve Urlich (MDC) for his assistance with, and support of, this work, as well as for providing valuable feedback during his review of the report. SLR marine scientists involved in the fieldwork were Reid Forrest and Nicole Pannell, and Nathan Thompson (SLR Spatial Information Systems Technical Discipline Manager) produced the GIS and mapping outputs.

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# APPENDIX A

Images of shallow pits dug across estuary to investigate sediment stratigraphy.

# APPENDIX B

**High resolution PDF versions of habitat maps for substrates, saltmarsh, macroalgae, seagrass, mollusc patches and the terrestrial margin are provided on the DVD-ROM inside the back over of this report, in the folder titled: *Appendix B*. These provide greater detail than the summary graphs presented in the body of this report**

# APPENDIX C

**Georeferenced habitat photos (in addition to those presented in the body of this report) are provided on the DVD-ROM inside the back cover of this report in the folder titled: *Appendix C*.**

| Photo Number | Latitude | Longitude | | Photo Number | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | 41° 10' 20.760" | 174° 07' 13.430" | | 32 | 41° 10' 02.800" | 174° 07' 03.990" |
| 2 | 41° 10' 20.760" | 174° 07' 13.430" | | 33 | 41° 10' 01.970" | 174° 07' 05.520" |
| 3 | 41° 10' 20.640" | 174° 07' 13.479" | | 34 | 41° 10' 01.970" | 174° 07' 05.520" |
| 4 | 41° 10' 21.040" | 174° 07' 13.900" | | 35 | 41° 10' 00.740" | 174° 07' 10.810" |
| 5 | 41° 10' 20.820" | 174° 07' 14.340" | | 36 | 41° 10' 00.640" | 174° 07 10.500" |
| 6 | 41° 10' 19.840" | 174° 07' 14.760" | | 37 | 41° 10' 00.500" | 174° 07' 09.650" |
| 7 | 41° 10' 14.170" | 174° 07' 18.270" | | 38 | 41° 10' 00.760" | 174° 07' 09.670" |
| 8 | 41° 10' 14.170" | 174° 07' 18.270" | | 39 | 41° 10' 00.590" | 174° 07' 07.280" |
| 9 | 41° 10' 14.160" | 174° 07' 18.250" | | 40 | 41° 10' 01.560" | 174° 07' 06.360" |
| 10 | 41° 10' 12.260" | 174° 07' 11.950" | | 41 | 41° 10' 02.190" | 174° 07' 06.460" |
| 11 | 41° 10' 12.260" | 174° 07' 11.950" | | 42 | 41° 10' 02.190" | 174° 07' 06.460" |
| 12 | 41° 10' 12.260" | 174° 07' 11.950" | | 43 | 41° 10' 02.580" | 174° 07' 06.580" |
| 13 | 41° 10' 12.320" | 174° 07' 12.070" | | 44 | 41° 10' 02.650" | 174° 07' 06.540" |
| 14 | 41° 10' 11.210" | 174° 07' 09.550" | | 45 | 41° 10' 05.010" | 174° 07' 16.350" |
| 15 | 41° 10' 11.090" | 174° 07' 09.450" | | 46 | 41° 10' 04.970" | 174° 07' 16.510" |
| 16 | 41° 10' 11.090" | 174° 07' 09.450" | | 47 | 41° 10' 06.990" | 174° 07' 13.660" |
| 17 | 41° 10' 11.090" | 174° 07' 09.450" | | 48 | 41° 10' 07.370" | 174° 07' 11.660" |
| 18 | 41° 10' 11.140" | 174° 07' 08.670" | | 49 | 41° 10' 07.370" | 174° 07' 11.660" |
| 19 | 41° 10' 11.190" | 174° 07' 08.650" | | 50 | 41° 10' 08.510" | 174° 07' 10.940" |
| 20 | 41° 10' 10.980" | 174° 07' 07.320" | | 51 | 41° 10' 08.100" | 174° 07' 12.800" |
| 21 | 41° 10' 10.830" | 174° 07' 01.630" | | 52 | 41° 10' 10.670" | 174° 07' 14.250" |
| 22 | 41° 10' 10.830" | 174° 07' 01.630" | | 53 | 41° 10' 10.670" | 174° 07' 14.250" |
| 23 | 41° 10' 10.810" | 174° 07' 01.710" | | 54 | 41° 10' 10.690" | 174° 07' 14.220" |
| 24 | 41° 10' 11.750" | 174° 06' 56.770" | | 55 | 41° 10' 22.190" | 174° 07' 08.930" |
| 25 | 41° 10' 10.490" | 174° 06' 55.350" | | 56 | 41° 10' 22.630" | 174° 07' 07.280" |
| 26 | 41° 10' 10.490" | 174° 06' 55.350" | | 57 | 41° 10' 22.180" | 174° 07' 07.190" |
| 27 | 41° 10' 10.490" | 174° 06' 55.350" | | 58 | 41° 10' 22.140" | 174° 07' 07.130" |
| 28 | 41° 10' 10.650" | 174° 06' 55.280" | | 59 | 41° 10' 23.270" | 174° 07' 04.750" |
| 29 | 41° 10' 05.580" | 174° 07' 00.220" | | 60 | 41° 10' 23.320" | 174° 07' 04.720" |
| 30 | 41° 10' 04.200" | 174° 06' 59.670" | | 61 | 41° 10' 14.350" | 174° 07' 19.030" |
| 31 | 41° 10' 03.430" | 174° 06' 59.480" | | 62 | 41° 10' 14.310" | 174° 07' 19.030" |

| Photo Number | Latitude | Longitude | | Photo Number | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 63 | 41° 10' 13.980" | 174° 07' 19.220" | | 68 | 41° 10' 21.160" | 174° 07' 12.680" |
| 64 | 41° 10' 14.990" | 174° 07' 18.860" | | 69 | 41° 10' 20.820" | 174° 07' 12.490" |
| 65 | 41° 10' 16.010" | 174° 07' 19.200" | | 70 | 41° 10' 20.820" | 174° 07' 12.370" |
| 66 | 41° 10' 17.400" | 174° 07' 17.790" | | 71 | 41° 10' 20.920" | 174° 07' 11.980" |
| 67 | 41° 10' 21.160" | 174° 07' 12.680" | | 72 | 41° 10' 21.020" | 174° 07' 11.140" |

## ASIA PACIFIC OFFICES

**BRISBANE**
Level 2, 15 Astor Terrace
Spring Hill QLD 4000
Australia
T: +61 7 3858 4800
F: +61 7 3858 4801

**CANBERRA**
GPO 410
Canberra ACT 2600
Australia
T: +61 2 6287 0800
F: +61 2 9427 8200

**DARWIN**
5 Foelsche Street
Darwin NT 0800
Australia
T: +61 8 8998 0100
F: +61 2 9427 8200

**MACKAY**
21 River Street
Mackay QLD 4740
Australia
T: +61 7 3181 3300

**MELBOURNE**
Suite 2, 2 Domville Avenue
Hawthorn VIC 3122
Australia
T: +61 3 9249 9400
F: +61 3 9249 9499

**NEWCASTLE**
10 Kings Road
New Lambton NSW 2305
Australia
T: +61 2 4037 3200
F: +61 2 4037 3201

**PERTH**
Ground Floor, 503 Murray Street
Perth WA 6000
Australia
T: +61 8 9422 5900
F: +61 8 9422 5901

**ROCKHAMPTON**
rockhampton@slrconsulting.com
M: +61 407 810 417

**SYDNEY**
2 Lincoln Street
Lane Cove NSW 2066
Australia
T: +61 2 9427 8100
F: +61 2 9427 8200

**TAMWORTH**
PO Box 11034
Tamworth NSW 2340
Australia
M: +61 408 474 248
F: +61 2 9427 8200

**TOWNSVILLE**
Level 1, 514 Sturt Street
Townsville QLD 4810
Australia
T: +61 7 4722 8000
F: +61 7 4722 8001

**AUCKLAND**
68 Beach Road
Auckland 1010
New Zealand
T: +64 27 441 7849

**NELSON**
5 Duncan Street
Port Nelson 7010
New Zealand
T: +64 274 898 628

**NEW PLYMOUTH**
Level 2, 10 Devon Street East
New Plymouth 4310
New Zealand
T: +64 0800 757 695