Ecological Issues and Management Options for the Avon-Heathcote Estuary/Ihutai









Wildlands

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Executive summary

The estuary of the Heathcote/Ōpāwaho and Avon/Ōtākaro Rivers/Ihutai - commonly referred to as the Avon-Heathcote Estuary/Ihutai (the Estuary) - is the largest estuary wetland of its type in Canterbury. The Estuary is an integral part of Christchurch City, where it is an important ecological and recreational resource, and has cultural significance to Ngāi Tahu. It contains significant biodiversity values, such as extensive areas of intertidal mudflats and saltmarsh around its margins. It is an internationally recognised wildlife habitat, with large populations of migratory wading birds, water birds, and swamp birds. It has three species of flowering plants that are classified as At Risk and two At Risk and culturally significant fish species.

The Avon-Heathcote Estuary Ihutai Trust (the Trust) commissioned Wildland Consultants Ltd to develop a report that describes the ecology of the Avon-Heathcote Estuary/Ihutai and identifies key management issues. This report will inform the development of an Ecological Management Plan for the Estuary by the Trust. This report is somewhat broad and conceptual and has the following purposes:

- Guide restoration, rehabilitation and maintenance of ecological health and key ecological processes.
- Influence the long-term protection, enhancement and maintenance of high quality habitats for indigenous plants, birds, fish and other biota.
- Promote resilience from coastal hazards, in particular coastal erosion, through 'natural engineering' where ecological habitats help mitiage adverse effects.
- Integrate projects and programmes being undertaken or planned by the Trust and other agencies.
- Contribute to evidence-based decision making.
- Provide an educational resource.

The report identifies the following as significant issues affecting the ecological, environmental and cultural values and integrity of the Estuary:

- Water contamination and sedimentation from the Avon River/Ōtākaro and Heathcote River/Ōpāwaho.
- Changed hydrodynamics and surface elevation due to the Canterbury Earthquake Sequence which has resulted in:
  - A decrease of the tidal prism.
  - An increase in salinity in the lower Avon River/Ōtākaro.
  - A decrease in salinity in the lower Heathcote River/Ōpāwaho.
- Significant declines in the dynamic and fragile saltmarsh herbfields and native musk herbfields.
- Loss of estuary margin vegetation and creation of hard edges, making the Estuary vulnerable to sea level rise, flooding events, and climate change.
- Loss of estuary margin from coastal erosion (also called shoreline retreat).
- Adverse effects of pest animals and pest plants on indigenous birds and vegetation.

The long-term ecological consequences of these effects need further evaluation.

To achieve improved ecosystem resilience, improved water quality, restoration of mahinga kai, and maintenance of recreational values, the following actions are proposed:

- The Trust should continue to be strong advocates for management of upstream water quality. In particular, they should advocate for:
  - Stormwater treatment in residential and industrial areas adjacent to the Avon River/Ōtākaro and Heathcote River/Ōpāwaho.
  - Sediment and erosion control, particularly in the catchment of the Heathcote River/Ōpāwaho, to prevent excessive sedimentation entering the Estuary.
  - Restoration of riparian areas, using species capable of processing and/or trapping contaminants.
- Halting development of riparian and floodplain areas around the Estuary, and planting these with vegetation communities that are more resilient to sea level change.
- Targeted waterway management and ecological restoration at the Linwood Paddocks, lower Avon River/Ōtākaro wetland areas and Southshore, to help maintain hydrological processes.
- Large-scale ecological restoration to:
  - Increase saltmarsh and salt meadow.
  - Increase brackish and freshwater vegetation.
  - Increase and enhance the quality of bird feeding, roosting and nesting habitat.
  - Enhance cultural, recreational, and landscape values.
  - Increase the resiliencw to the effects of coastal hazards.
- Increased pest control to protect bird populations.
- Prioritisation of wildlife when planning recreational activites and public access to the Estuary.
- Monitoring of bird populations before, during and after implementation of management actions.
- Monitoring of fish and shellfish populations before, during and after implementation of management actions.
- Development of an Avon Heathcote Estuary/Ihutai Pest Management Plan, to address terrestrial, freshwater and marine ecosystems.

If these actions are implemented, they will improve ecosystem health, provide significant steps towards restoring the cultural value of the Estuary for Ngāi Tahu, and strengthen connections between the Estuary and Christchurch residents.

Various research and monitoring projects are outlined. These are required to gauge the effectiveness of ecological restoration activities and address knowledge gaps which are vital for future ecological management of the Estuary, and include the following:

- Monitoring of sedimentation in the Estuary following the Canterbury Earthquake Sequence.
- Research into the causes of saltmarsh and salt meadow decline.
- Monitoring of the success of different restoration planting configurations, in relation to salinity levels.
- Monitoring of nocturnal predator activity and activity patterns of domestic cats.
- Research on minimum disturbance distances for nesting, roosting, and foraging birds.

Contents

1. Introduction

1.1 Purpose and scope

The Avon-Heathcote Estuary/Ihutai (the Estuary) is a large semi-enclosed estuarine system situated within the city limits of Christchurch/Ōtautahi, the third largest city in New Zealand. The Estuary covers an area of approximately eight square kilometres, making it Canterbury's largest estuary ecosystem. The Estuary lies within eastern Christchurch City. Figure 1 shows the project area, which is primarily within the Coastal Marine Area, and also includes the Christchurch wastewater treatment ponds.

The Avon-Heathcote Estuary Ihutai Trust (the Trust), in partnership with Environment Canterbury, Christchurch City Council, and Ngāi Tūāhuriri, share the following vision for the Estuary:

Communities working together for	
Clean water,	***Toitū te taonga ā iwi,***
Open space,	***Toitū te taonga ā Tāne,***
Safe recreation, and	***Toitū te taonga ā Tangaroa,***
Healthy ecosystems.	***Toitū te iwi***

To assist in achieving this vision, the Trust commissioned Wildland Consultants to prepare this report, to assist the Trust with development of an Ecological Management Plan for the Estuary. The purpose of this report is to provide information to assist the Trust and its partners to achieve the following outcomes:

- Guide restoration, rehabilitation and maintenance of the ecological health and key ecological processes of the Avon-Heathcote Estuary/Ihutai.
- Influence the long-term protection, enhancement and maintenance of high quality habitats for indigenous plants, birds, fish, and other biota.
- Integrate projects and programmes being undertaken or planned by the Trust and other agencies.
- Contribute to evidence-based decision making.
- Provide an educational resource.

This report also provides the following:

- An assessment of the Estuary's ecosystems, taking into account changes caused by the 2010-2011 Canterbury Earthquake Sequence.
- Priorities for improving the Estuary's ecosystems, including management activities and strategies for ensuring ecological integrity, and maintaining healthy viable ecosystems.
- An assessment of geomorphological and hydrodynamic effects of sea level rise on habitats within the Estuary.

- Support for the Mahaanui Iwi Management Plan objective that mahinga kai values are restored.

- A basis for preparation of an application to have the Estuary recognised as a wetland of international importance under the International Convention of Wetlands (Ramsar Convention 1971).

- A basis for the Trust to engage with their partners and stakeholders.

The report is presented at a level that is intended to be somewhat broad and conceptual. While important over-arching potential actions are identified, a more detailed Ecological Management Plan will be developed by the Trust.

1.2 Stakeholder consultation

The following stakeholder consultation was undertaken when preparing this report:

- Public meetings were held on 2 May 2017 at the New Brighton Club and on 4 May 2017 at the Mt Pleasant Community Centre.

- A meeting was held with Environment Canterbury and Christchurch City Council staff on 5 April 2017. The meeting discussed the progress and direction of the project. Agency staff present were generally supportive, but requested to review the draft output prior to it being finalised. Department of Conservation staff were invited to the meeting, but were unable to attend.

- Manawhenua consultation: A hui was held in July 2016 (prior to Wildlands' involvement) with the Trust and representatives of Te Ngāi Tūāhuriri Rūnanga, Te Hapū o Ngāti Wheke, and Te Ihutai Ahu Whenua Trust. Background to the Ecological Management Plan was presented, contacts were made, and questions answered. A draft of this report was forwarded to Te Rūnanga o Ngāi Tahu. Preliminary feedback indicated broad support for the report, which was then to be presented to Rūnanga meetings.

Figure 1: Avon-Heathcote Estuary/Ihutai project area and important sites.

2. Social and cultural environment

2.1 Human history

Māori settlement of the South Island began at least 600-700 years ago (Harris 1992a). The Christchurch area was settled by Waitaha, Ngāti Māmoe, and Ngāi Tahu. Māori had several settlements in the area, including at Southshore (Te Kai a Te Karoro), the Avon River/Ōtākaro near the Kilmore Street fire station (Ōtautahi), along the Heathcote River/Ōpāwaho, and along the southern edge of the Estuary (Raekura).

Tuawera (Cave Rock) was an urupā (burial site). The Estuary was extremely important for mahinga kai, and for the harvesting of harakeke (*Phormium tenax*) and plants used for traditional medicines (rongoā). The Estuary provided an important trade route and access point between Avon River/Ōtākaro, Heathcote River/Ōpāwaho, and the Sumner Beach area. The Heathcote River/Ōpāwaho also provided access between the Avon-Heathcote Estuary/Ihutai and Lake Ellesmere/Te Waihora.

Surrounded by wetlands and bush, and lacking roads, European settlers depended on the Estuary and the Avon River/Ōtākaro and Heathcote River/Ōpāwaho in a way that is now difficult to imagine. Trading ships used the deeper Heathcote River/Ōpāwaho channel, and travelled as far as Wilsons Bridge in St Martins (Harris 1992a). On the Avon River/Ōtākaro, schooners carried freight as far as Barbadoes Street. Even as late as 1880, a passenger ferry was running along the Avon River/Ōtākaro between Colombo Street and New Brighton.

By 1853, swamps around the lower reaches of the Avon River/Ōtākaro and Heathcote River/ Ōpāwaho had been drained and converted to dairy farms and orchards (Deely 1992). Several stormwater drains had been connected into each river and the City Outfall Drain emptied directly into the Estuary. In 1844, John Deans described the Avon River/Ōtākaro as "water clearer than crystal", but by the 1860s settlers were boiling the water, and a typhoid epidemic led to the establishment of the Drainage Board and a sewage farm at Bromley in 1883. By 1900, a quarter of New Zealand's manufacturing was based in Christchurch, and between 1880 and 1925 polluted runoff flooded into the Heathcote River/Ōpāwaho from woollen mills, metal works, glue works, tanneries, and gas works (Deely 1992). Pollutants included acids, alkalis, sulphur compounds, tars, oils and heavy metals such as lead, arsenic, chromium, copper, zinc, nickel, and iron. In sediment cores taken from the Estuary today, this industrial pollution is evident as a black layer rich in coal and heavy metals.

Land drainage around the Christchurch area also led to large quantities of loess soils being washed into the Avon River/Ōtākaro and Heathcote River/Ōpāwaho, where they became entrapped (Deely 1992). In 1925, a mechanical river sweeper began clearing the trapped sediments, and huge quantities entered the Estuary. This produced a thick layer of mud in the Estuary, with an average depth of 25 cm, and this was deepest in the channels. Silt coming from the Heathcote River/Ōpāwaho was contaminated with heavy metals, particularly chromium and lead.

The sewage treatment complex was expanded between 1958 and 1962, into the present day system, including treatment ponds (Deely 1992). In 1970, an industrial sewer was commissioned between Woolston and the sewage treatment complex, with

all industrial and domestic wastes now being diverted into the Christchurch wastewater treatment ponds. In 1974, managers of the Christchurch wastewater treatment ponds began discharging effluent into the Estuary only on the outgoing tide, helping to flush wastes out of the Estuary more effectively. In 1981, the gas works, which was the only remaining industry that was discharging effluent and stormwater runoff into the Heathcote River/Ōpāwaho, was closed. Today, tertiary treated wastewater from the treatment ponds is discharged directly to the ocean, through an outfall pipe that extends three kilometres off the coast of New Brighton (Christchurch City Council website). The outfall pipe was commissioned in 2010.

2.2 Cultural values

Prior to European settlement of Christchurch, the Avon-Heathcote Estuary/'Te Ihutai' was a highly valued source of mahinga kai for Ngāi Tahu (also see Section 2.1). A reserve was established for mahinga kai at Te Ihutai during the settlement of Christchurch, but in 1956 this was confiscated under the Public Works Act (1908), leading to the establishment of the Christchurch wastewater treatment works (Lobb 2009). Loss of this mahinga kai resource, and the ecological degradation of Te Ihutai, remains highly offensive to mana whenua, with Te Ihutai viewed as a lost resource (Lobb 2009).

In 2012, a cultural health assessment of the Estuary and its catchment was undertaken by Te Ngāi Tūāhuriri and Ngāti Wheke Rūnanga and Mahaanui Kurataiao Ltd (Lang *et al.* 2012), following an earlier assessment in 2007 (Pauling *et al.* 2007). Monitoring data from 31 sites throughout the Estuary, the Avon River/Ōtākaro catchment, and the Heathcote River/Ōpāwaho catchment were used to calculate a Cultural Health Index (Tipa and Tierney 2003), and assess values for stream health, indigenous vegetation, birds, and fish. The monitoring indicated that the Estuary and its catchment remain in poor cultural health. This was attributed to the presence of contaminants associated with stormwater and wastewater, sedimentation, and unnatural flow patterns. However, the assessment did acknowledge the positive contributions of various restoration and conservation initiatives. Restoration of cultural health is aligned with the Mahaanui Iwi Management Plan (2013).

2.3 Social, recreational, and economic values

The Estuary is an important recreational area for Christchurch residents and visitors to the city. It also has important aesthetic appeal for residents of Ferrymead, Mt Pleasant, Redcliffs, South New Brighton, and Southshore. Recreation commonly undertaken includes windsurfing and kite boarding, rowing, canoeing and kayaking, yachting, walking, running and mountain biking. Restoring and enhancing the ecology of the Estuary will be important in maintaining its attractiveness to recreationists in the long-term.

There is widespread concern about the health risks of consumption of seafood collected from the Estuary, particularly filter feeding shellfish, and the Estuary is not considered safe for swimming.

The Estuary is also an area of international interest for ornithologists, and in conjunction with Te Waihora, provides a reason for bird watchers to include Christchurch in their travels.

Location and ease of access also make it an important research and education resource for schools and tertiary institutions. Student field trips are often held at the Estuary, and a large number of research projects have been undertaken on the Estuary.

3. Physical character and land use

3.1 Geology and catchment setting

The Canterbury Plains abut and lie to the north and west of the Estuary and consist of stratified deposits of permeable fluvial gravels, and sand, silt, clay, and peat representing glacial and interglacial sea level fluctuations (Cameron 1992; Callander *et al.* 2005; Tonkin and Taylor 2013). Over the last 6,000 years, Holocene sea level rise has led to deposition of sand dunes, estuaries, lagoons, and intertidal swamps along the edge of the plains (Figure 2a) (Cameron 1992; Hicks 1993; Tonkin and Taylor 2013). Recent alluvial gravel deposits from the Waimakariri River link to the headwaters of the Avon River/Ōtākaro and Heathcote River/Ōpāwaho and it is possible that the Avon River/Ōtākaro could be a remnant flood channel of the Waimakariri River floodplain (Cameron 1992; Tonkin and Taylor 2013; Hughes *et al*. 2015). The Canterbury Plains rise no more than 20 metres above sea level at the headwaters of the Avon River/Ōtākaro and Heathcote River/Ōpāwaho (Quigley *et al*. 2016).

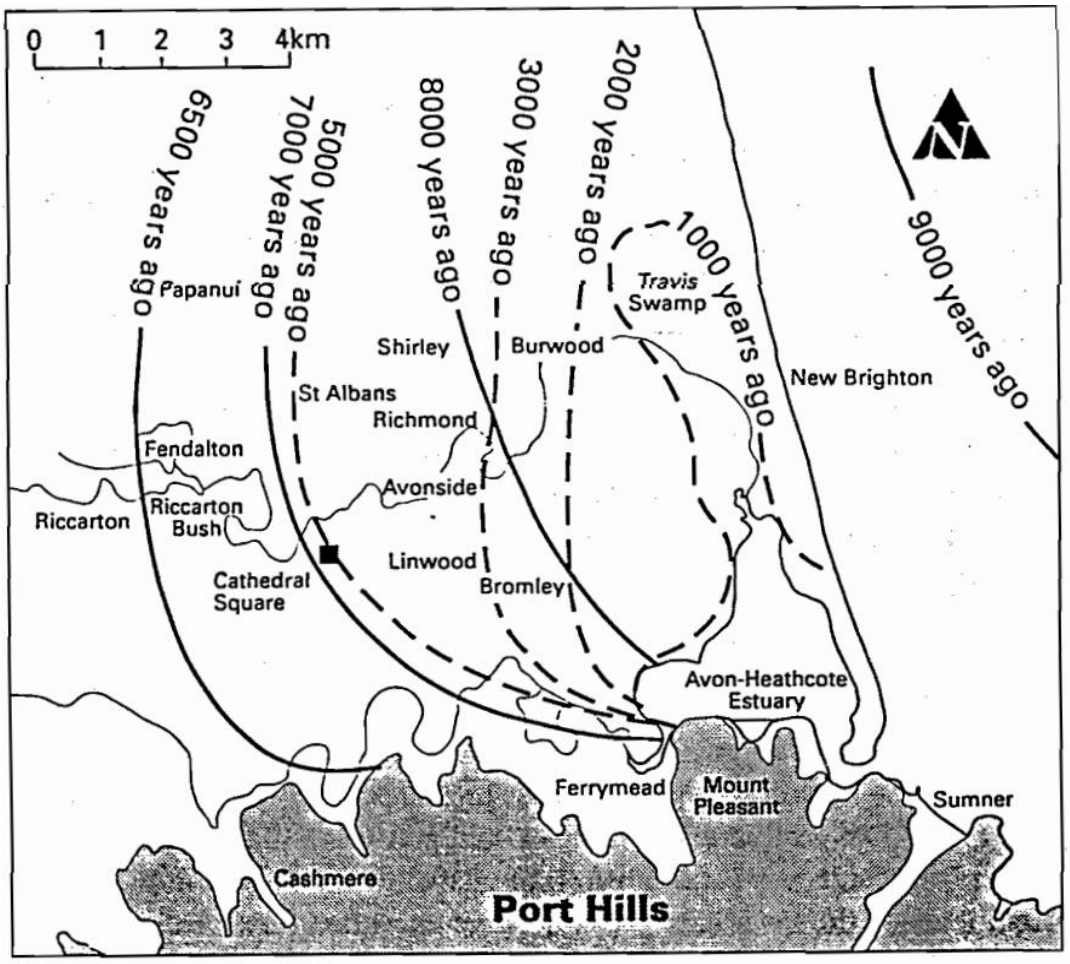

Figure 2a: Changes in shoreline position since the Holocene (from Hicks 1993).

The Estuary is the seaward extent of the spring-fed Avon River/Ōtākaro and Heathcote River/Ōpāwaho catchments. Aquifers which support ecological function within the Avon River/Ōtākaro and Heathcote River/Ōpāwaho catchments are associated with the alluvial gravel deposits, namely the Riccarton Gravels (70,000-

14,000 years ago), the Christchurch Formation (14,000 years ago), and the Springston Formation (contemporary) (Figure 2b). The Port Hills form the southern edge of the Heathcote River/Ōpāwaho catchment, within the Cashmere Stream sub-catchment (Hicks 1993), and are up to 500 metres above sea level. The Port Hills are eroded basalt and loess (Hicks 1993; Tonkin and Taylor 2013; Kaiser and Massey 2014; Quigley *et al*. 2016), and contribute up to 86 kilometres of streams to the Heathcote River/Ōpāwaho catchment (Opus 2016b).

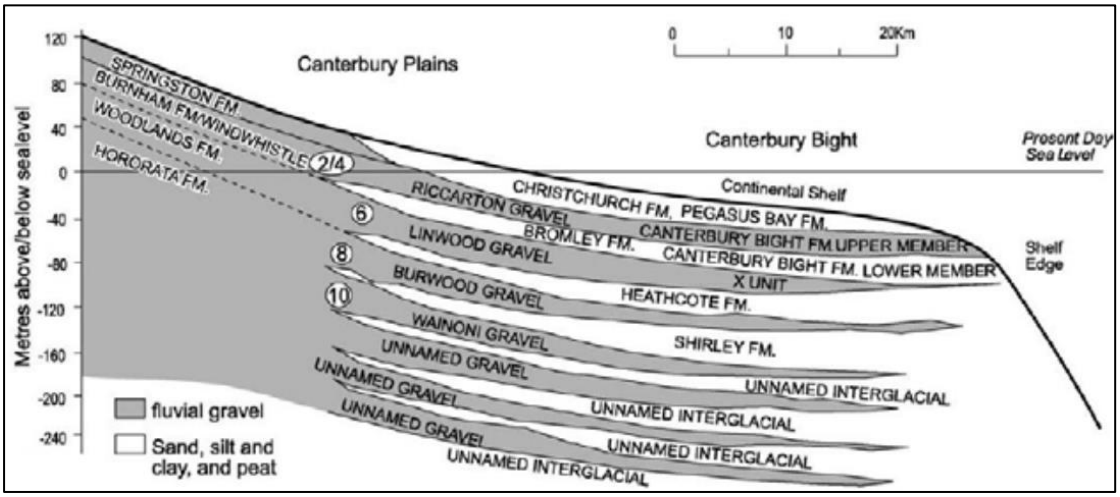

Figure 2b: Stratified glacial and interglacial deposits of the Canterbury Plains (after Brown and Naish 2003).

3.2 Estuary substrates and sedimentation 1920-2010

The Estuary is a shallow tidal lagoon (Findlay and Kirk 1988; Burge 2007; Tonkin and Taylor 2013; Hume *et al*. 2016; NIWA, https://www.niwa.co.nz) enclosed by a sand spit (New Brighton Spit). Maximum water depth at the mean high tide is only 1.4 metres (Burge 2007). A well-defined ebb-tide (outlet) channel runs parallel to Redcliffs and Moncks Bay, north of Shag Rock, and the geometry of this channel plays an important role in sedimentation processes and tidal compartment within the Estuary (Findlay and Kirk 1988; Hicks 1993; Measures and Bind 2013). Average maximum tidal inflow rate through the channel has been recorded as 1.14 m/s (Heath 1975 *in* Findlay and Kirk 1988), with the estimated tidal compartment likely to be close to 10.9×10^6 m^3 (Findlay and Kirk 1988). The Sumner Bar is at the tip of Southshore Reserve and long-term reduction of the Sumner Bar is believed to be reducing resilience of both the Southshore Scenic Reserve and Redcliffs area (Findlay and Kirk 1988).

Findlay and Kirk (1988) describe the morphodynamics of the Estuary mouth as a mixed bar and tidal bypassing regime, where coastally-derived sand is transported in and out of the Estuary during the tidal cycle. Recent sediment mapping has indicated that sand-dominated substrates within the Estuary are limited to the near the mouth and a small area between McCormacks Bay and the Southshore Reserve ('Middle Bars' in Hollever and Bolton-Ritchie 2016), indicating that some coastal sand is transported into the Estuary.

The Avon River/Ōtākaro and Heathcote River/Ōpāwaho contribute the most sediment to the Estuary, in the form of suspended solids (particles ≤0.063 mm), at the estimated rate of between 2,000-5,000 tonnes per year for the Avon River/Ōtākaro and 5,000-18,000 tonnes per year for the Heathcote River/Ōpāwaho (Hicks 1993; Burge 2007). This has led to the development of fine-grained deposition areas at the mouths of both rivers, which also have concentrations of heavy metals, organic matter, and nutrient contaminants (Burge 2007; Tonkin and Taylor 2013; Bolton-Ritchie 2014; Hollever and Bolton-Ritchie 2016). Sediment discharge into the Estuary increases during storm events, and the Heathcote River/Ōpāwaho has a variable sediment load due to both topography and land use in the Cashmere Stream catchment, which flows into the Heathcote River/Ōpāwaho (Hicks 1993; Burge 2007). Both rivers have been dredged since the early 1900s (Hicks 1993), resulting in a modified sediment regime.

3.3 Earthquake effects 2010-2011

The series of earthquakes between September 2010 and December 2011, known as the Canterbury Earthquake Sequence, caused significant changes to the Estuary and its contributing waterways (Measures *et al*. 2011; Tonkin and Taylor 2013; Measures and Bind 2013; Hughes *et al*. 2015; Quigley *et al.* 2016). Changes to topography included 0.3 to 0.5 metres of uplift on the southern margins of the Estuary, and up to 0.5 metres of subsidence at the northern end (Measures *et al*. 2011). This has led to changes in upstream salinity penetration, with a reduction in penetration of saltwater into the Heathcote River/Ōpāwaho, but minimal change in the Avon River/Ōtākaro (Orchard and Measures 2016; R. Measures, NIWA, pers. comm.). Water quality monitoring by Bolton-Ritchie (2014) has shown a similar trend, with post-earthquake low tide salinity levels lower in the lower Heathcote River/Ōpāwaho (at Ferrymead Bridge) and higher in the lower Avon River/Ōtākaro (at Bridge Street Bridge).

Uplift and liquefaction also caused changes to the bed level of the Estuary, with an 18 percent (50 hectares) increase in 'dry' surfaces following the Canterbury Earthquake Sequence (Measures *et al*. 2011, Figure 3). The greatest change was in McCormacks Bay, with a 50 percent reduction in tidal prism in this area (R. Measures, NIWA, pers. comm.), which will reduce wave energy within the Estuary, possibly altering substrate compositions by favouring fine-grained sediments such as muds and silts (Measures *et al.* 2011). There has also been a 14 percent reduction in the tidal prism for the whole Estuary (Measures *et al.* 2011).

The ebb-tide (outlet) channel has had a 15 percent reduction in capacity following the earthquakes. However, in the short term the channel appears to be returning to its pre-quake dimensions (R. Measures, NIWA, pers. comm.). In the longer term, there may be further changes to the outlet channel, Southshore Scenic Reserve, and the Sumner Bar, and these changes need to be monitored.

In addition, the lower Heathcote River/Ōpāwaho has been uplifted by up to 0.45 metres. This has changed the hydraulic gradient, and increased deposition within the upper reaches of the Heathcote River/Ōpāwaho (Tonkin and Taylor 2013). Lower reaches closest to the Estuary may show an erosion response, as the river lowers the bed level to match the sea level, and this may have already happened to some degree. There was also significant change to the Avon River/Ōtākaro, which experienced

lateral spreading when banks slipped into the river, reducing river width and depth (Hughes *et al.* 2015). This has increased the risk of the Avon River/Ōtākaro flooding its surrounding catchment, which has subsided by 0.5 metres (Figure 4). Also, both rivers have experienced a reduction in channel capacity due to a short-term pulse of liquefaction and sediment deposits in the river bed. These changes have impacted both the ecology and recreational use of the Estuary.

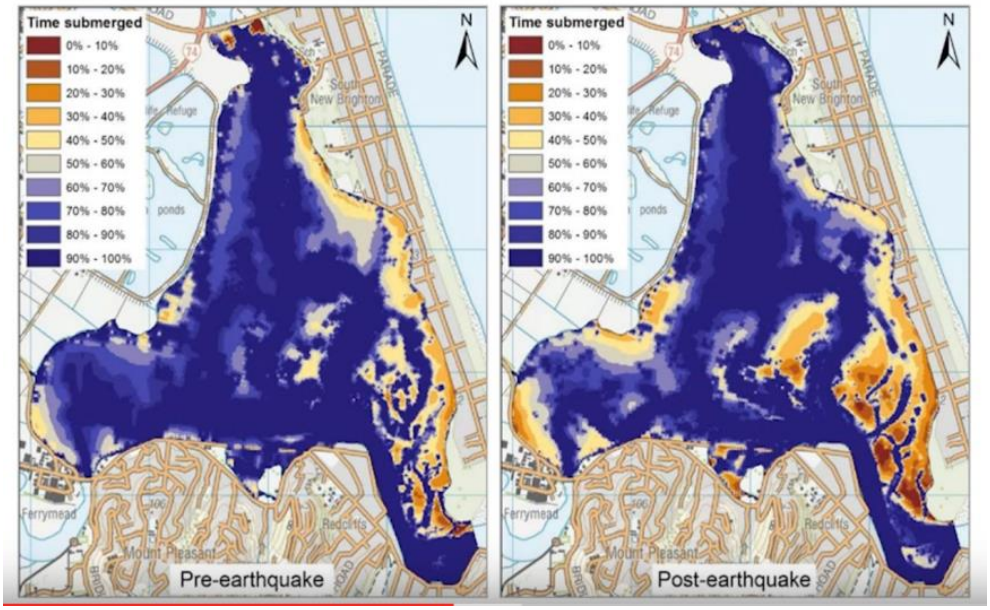

Figure 3: Changes in estuary surfaces submerged at high tide after the Canterbury Earthquake Sequence 2010-2011 (from Measures and Bind 2013).

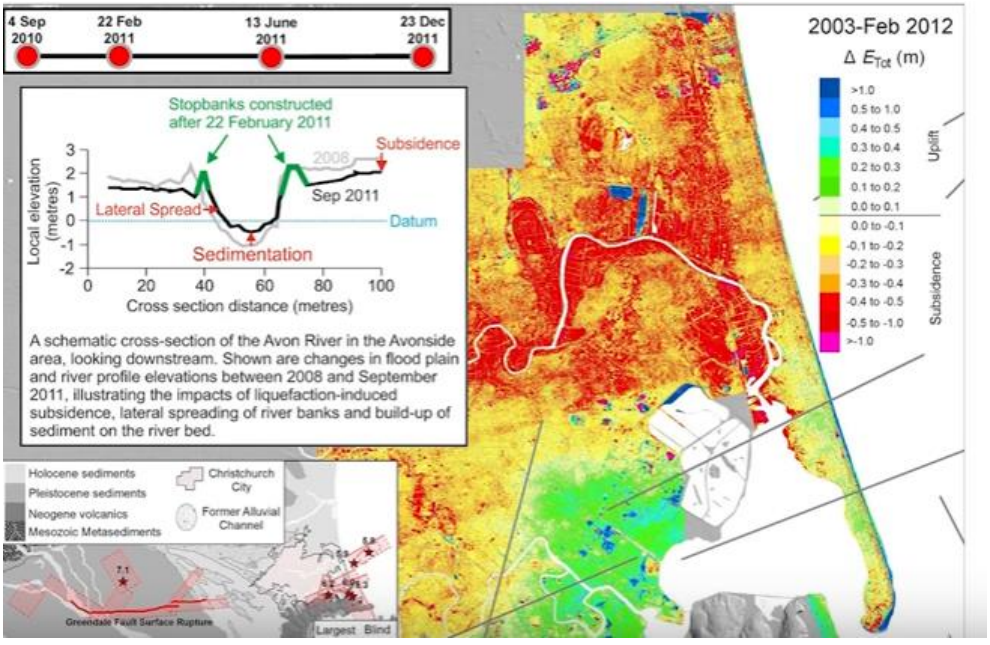

Figure 4: Degree of earthquake-induced topographical change across the Avon-Heathcote catchment, and typical cross-section of the Avon River/ Ōtākaro showing effects of lateral spread (Hughes *et al*. 2015).

3.4 Current land use

Land use around the Estuary, as shown in Figure 5, is a mixture of recreational, residential and industrial.

3.5 Water quality

Water quality within the Estuary is largely driven by the Avon River/Ōtākaro and Heathcote River/Ōpāwaho, which contribute both rural and urban-based contaminants. Sixty-seven stormwater outlets and four drains also contribute contaminants directly to the Estuary.

The Canterbury Earthquake Sequence resulted in severe infrastructure failure within the catchment, leading to untreated sewage being discharged directly into the rivers and Estuary. This resulted in a short-term decrease in dissolved oxygen, and elevated ammonium nitrogen, phosphorus and faecal coliform (Bolton-Ritchie 2014), but water quality is now improving with infrastructure repair.

The Heathcote River/Ōpāwaho may contribute sediment contaminated with high levels of zinc and polycyclic aromatic hydrocarbons (PAHs) to the Estuary, and the Avon River/Ōtākaro may contribute sediment with high levels of zinc, arsenic, lead and PAH to the Estuary (Opus 2016a). Re-suspension of Estuary sediments can occur with wind speeds greater than three metres per second (six knots) (Bolton-Ritchie 2014). Southwest, northwest and northeast winds have the highest likelihood of re-suspending contaminated sediments deposited around the mouths of the two rivers.

The main contaminants in the Avon River/Ōtākaro are nitrogen, phosphorus, copper, zinc and faecal coliform (Bolton-Ritchie 2014; Opus 2016a), and Riccarton Stream, Addington Brook, Horseshoe Lake and Dudley Creek are the sub-catchments that contribute the highest levels of these contaminants (Opus 2016a). The Heathcote River/Ōpāwaho has a similar contaminant load, with chromium, copper, and lead also present. The Heathcote River/Ōpāwaho sub-catchments contributing the highest contaminant loads are Haytons Stream and Curletts Road Stream (Opus 2016a). The City Outfall Drain contributes higher levels of ammonium nitrogen, total phosphorus and dissolved reactive phosphorus to the Estuary than the rivers. The other three drains are not monitored regularly, but have had high levels of ammonium and phosphorous in the past (Bolton-Ritchie 2014).

Since the cessation of wastewater discharge from the Christchurch wastewater treatment ponds into the Estuary in 2010, there has been a major improvement in water quality, with reduction in dissolved oxygen, ammonium nitrogen, and phosphorus. However, monitoring since 2011 suggests that the treatment ponds still contribute ammonium, nitrogen, dissolved reactive phosphorus, and faecal coliforms to the Estuary (Bolton-Ritchie 2014).

Figure 5: Land use around the Avon-Heathcote Estuary/Ihutai (figure supplied by Environment Canterbury).

4. Ecology

4.1 Ecological context

The Estuary margins are predominantly within the Low Plains Ecological District, within the Canterbury Plains Ecological Region (McEwen 1987). Near Moncks Bay, at the Estuary mouth, the Shag Rock/Clifton Hill side of the Estuary is in the Port Hills Ecological District, within Banks Ecological Region (McEwen 1987). Tidal parts of the Estuary are not included within the Canterbury Plains Ecological Region or Banks Ecological Region.

Estuary ecosystems are a naturally uncommon ecosystem type in New Zealand (Williams *et al.* 2007), and are classified as Threatened-Nationally Vulnerable (Holdaway *et al.* 2012). Estuary margins contain indigenous vegetation and habitat of indigenous fauna that at the national-level occur on 'Acutely Threatened' or 'Chronically Threatened' land environments which have <20% indigenous cover left at a national scale (Cieraad *et al.* 2015).

4.2 Wetland classification and vegetation types

The types of wetland class and broad vegetation types present in the Estuary are summarised in Appendix 1.

4.3 Vegetation surveys

Two comprehensive vegetation surveys of the Avon-Heathcote Estuary/Ihutai have been published:

- McCombs and Partridge (1992) provide a useful baseline for future studies.
- Jupp *et al*. (2007), resurveyed McCombs and Partridge's (1992) sites and created a vegetation map of the Estuary's margins.

Also, Campbell *et al*. (2013) surveyed the lower Avon River/Ōtākaro and Bexley wetlands, and Gibson and Marsden (2016) surveyed and mapped seagrass distribution. ECan have also surveyed the Avon-Heathcote Estuary, but at the time of preparing this report their work was not available as a completed report. However, data layers and a summary of their findings were provided to us for this report (Mark Parker and Philip Grove, ECan, pers. comm.).

Saltmarsh vegetation is diverse, with three broad vegetation zones and twelve vegetation types (Jupp *et al.* 2007):

- Lower zone: searush (*Juncus kraussii* subsp. *australiensis*), glasswort (*Sarcocornia quinqueflora*), and sea blite (*Suaeda novae-zelandiae*).
- Mid zone: Saltmarsh herbfields.
- Upper zone: Oioi (*Apodasmia similis*) rushland and saltmarsh ribbonwood (*Plagianthus divaricatus*) shrubland.

The 12 vegetation types have been defined and described in Appendix 2.

4.4 Indigenous vegetation

Saltmarsh vegetation is present at the following sites (Jupp *et al.* 2007):

Lower Avon River/Ōtākaro

- Avon River/Ōtākaro right bank: large areas of saltmarsh occur here above where the river enters the Estuary. The dominant vegetation is oioi rushland, with sea rush (*Juncus krausii* var. *australiensis*) rushland in some areas.
- Avon River/Ōtākaro left bank: This area is diverse saltmarsh vegetation with six vegetation types present. Oioi rushland is dominant, and has expanded at the expense of saltmarsh herbfield, couch (*Elytrigia repens*) grassland, and tall fescue (*Schedonorus phoenix*) and native musk (*Thyridia repens*) herbfield. Erosion from river flows has resulted in the loss of small herbaceous vegetation.
- Naughty Boys' Island: Oioi rushland is the dominant and is slowly displacing saltmarsh herbfield.
- Downstream of Bridge Street Bridge: six vegetation types occur in this area, with oioi rushland and three-square (*Schoenoplectus pungens*) sedgeland dominant. There are smaller areas of sea rush rushland, saltmarsh herbfield, couch grassland, and tall fescue and coastal ribbonwood. In the 1992 survey, ten vegetation types were present, with sedimentation increasing the elevation of sites and the 2007 survey recording the loss of native musk herbfield, native primrose (*Samolus repens*) herbfield, buck's horn plantain (*Plantago coronopus*) and rye grass (*Lolium perenne*) herbfield, seagrass mudflat, and *Coprosma propinqua* shrubland.

Southshore and South New Brighton

- South New Brighton near the South Brighton Motor Camp: sea rush rushland is the dominant vegetation type, with smaller areas of saltmarsh herbfield, couch grassland, tall fescue, and coastal ribbon wood.
- Penguin Street: sea rush rushland and saltmarsh herbfield are dominant.

Lower Heathcote River/Ōpāwaho and western Estuary

- Sandy Point: sea rush rushland and saltmarsh herbfield are the dominant vegetation types. There has been a loss of vegetation here, with sediment build up resulting in the loss of eight of 27 sites recorded in 1992.
- Charlesworth: this restored area is dominated by saltmarsh herbfield, and also includes coastal ribbonwood shrubland and sea rush rushland.
- Heathcote River/Ōpāwaho Ferrymead loop: sedimentation has resulted in loss of vegetation, with sea rush rushland the dominant vegetation type, and some smaller areas of saltmarsh herbfield.

- Calders Green: this area comprises sea rush rushland, saltmarsh herbfield, and couch grassland.

- Heathcote River/Ōpāwaho Devil's Elbow: Only sea rush rushland occurs in this area.

- Heathcote River/Ōpāwaho upstream of Ferrymead: sea rush rushland and saltmarsh herbfield are dominant, with oioi rushland occurs at one site. Localised sedimentation has caused the loss of saltmarsh vegetation and *Juncus* rushland.

- Heathcote River/Ōpāwaho near Ferrymead: saltmarsh herbfield is dominant, with sea rush rushland present. Saltmarsh herbfield has increased at this site.

4.5 Vegetation trends

Four detailed studies on the saltmarsh vegetation in the project area (McCombs and Partridge 1992; Jupp *et al.* 2007; 2008 unpublished study, P. Grove and M. Parker, Environment Canterbury, pers. comm.; 2015 unpublished study, P. Grove and M. Parker, Environment Canterbury, pers. comm.; Gibson and Marsden 2016) have enabled documentation of notable changes in vegetation between 1992 and 2016. These changes include:

- Native musk herbfield has virtually disappeared from the project area.

- Coastal ribbonwood shrubland was first recorded as a vegetation type between 1992 and 2007, but declined by 17.8 percent between 2008 and 2015.

- Sea rush rushland at Sandy Point has decreased.

- The system is dynamic, with a 37 percent change in vegetation types between 1992 and 2008.

- Saltmarsh herbfield declined by 35.8 percent between 2008 and 2015.

- Sea rush rushland declined 8.7 percent and oioi rushland increased by 3.8 percent between 2008 and 2015, although these are the most stable vegetation types.

- The cover of seagrass has increased from 0.29 km^2 in 2003 to 0.52 km^2 in 2015 (Gibson and Marsden 2016).

Some of the changes between 1992 and 2007 have been induced by sedimentation, which increases substrate elevation, resulting in the drying out of saltmarsh herbfield, with oioi rushland becoming the more dominant type. The larger plants of oioi and sea rush also smother the smaller herbaceous plants. Reclamation of part of the Bexley wetland also contributed to the loss of herbfield during this period. In addition, conversion of low elevation areas of the Bexley wetland into imponded water and bare mudflat also reduced vegetation cover after 2007. Uplift from the Canterbury Earthquake Sequence has also produced higher elevation substrates, creating drier habitats more suited to oioi rushland than saltmarsh herbfield.

Native musk and native primrose herbfields were never common in the Estuary and have declined substantially between the 1992 and 2008. Native musk herbfield has all

but disappeared, being replaced by oioi rushland. The 2015 survey documented native musk herbfield in only one area in the lower Heathcote River/Ōpāwaho. Native primrose herbfield has been reduced with other saltmarsh species, e.g. sea spurrey (*Spergularia media*) and New Zealand celery (*Apium prostratum*) now occurring within this vegetation type. Saltmarsh herbfield vegetation has declined a further 35.8 percent between 2008 and 2015.

At one site - South New Brighton, near the South Brighton Motor Camp - creation of new culverts in the 1980s to allow ingress of seawater has enhanced saltmarsh herbfield and sea rush (Jupp *et al*. 2007). There has also been a notable increase in herbfield at Charlesworth Reserve (A. Crossland pers. comm.). In contrast, Sandy Point is undergoing significant vegetation change. This site is dynamic and would appear to have several factors influencing the vegetation change and patterns, including erosion, sediment deposition from the Heathcote River/Ōpāwaho, and liquefaction.

It is important to note that the changes described here are based on the plot data and vegetation surveys of specific sites in 1992, 2007, 2008 and 2015, and there may be other types of vegetation changes occurring elsewhere in the Estuary.

4.6 Vegetation change post-earthquakes

An unpublished 2015 survey of saltmarsh vegetation provides more recent insights into post-earthquake vegetation changes (P. Grove and M. Parker, Environment Canterbury, pers. comm., 5 April 2017). Saltmarsh vegetation change continues to be dynamic and notable changes between the 2008 unpublished 2008 survey (P. Grove and M. Parker, Environment Canterbury, pers. comm.) and 2015 surveys include:

- 3.8 percent increase of oioi rushland.
- 8.7 percent decline of sea rush rushland.
- 17.8 percent decline of coastal ribbonwood shrubland.
- 35.8 percent decline of saltmarsh herbfield.

Other important observations (P. Grove and M. Parker, Environment Canterbury, pers. comm., 5 April 2017) include:

- Land subsidence in the lower Avon River/Ōtākaro area means that some freshwater vegetation is now connected to the Avon River/Ōtākaro at high tide and therefore has a saline influence.

- Freshwater vegetation has been lost in some places, e.g. coastal ribbonwood shrubland, raupo (*Typha orientalis*) and *Carex secta.*

- Presence of spartina/cordgrass (*Spartina anglica*) at Southshore, McCormacks Bay, and lower Heathcote River/Ōpāwaho, amongst sea rush rushland, saltmarsh herbfield and coastal ribbonwood shrubland.

- Loss of exotic pines (*Pinus* spp.) and alder (*Alnus glutinosa*) with subsidence and increased salinity on the terrestrial margin of the Estuary. Although not indigenous, these large trees are important roosts for a number of bird species.

Post-earthquake monitoring of glasswort vegetation in saltmarsh habitats confirmed the glasswort-dominated mid-saltmarsh vegetation increased when new surfaces with the appropriate tidal regime were available (Cochran *et al.* 2014). This included new surfaces created by both uplift and subsidence resulting from the Canterbury Earthquake Sequence. In areas where subsidence occurred, existing non-saline tolerant vegetation died out, including exotic species, e.g. grasses, ice plant (*Carpobrotus edulus*), and trees such as pines and macrocarpa (*Cupressus macrocarpa*). This vegetation was replaced by saline-tolerant indigenous (e.g. glasswort) and exotic vegetation (e.g. buck's horn plantain).

4.7 Flora

Overview

In total, 121 vascular plant species have been recorded in the Estuary (McCombs and Partridge 1992, Jupp *et al.* 2007). This includes 46 indigenous species and 75 introduced species (see Appendix 3). Three plant species are classified as At Risk: *Ruppia megacarpa* (At Risk-Naturally Uncommon), native musk (At Risk-Naturally Uncommon), and seagrass (At Risk-Declining) (de Lange *et al.* 2018).

Weeds

Six introduced species are listed as pest plants in the Canterbury Regional Pest Management Strategy 2011-2015 (Maw 2011), and pose a threat to indigenous ecological values of the area (Table 1). These species occur in terrestrial habitats, outside of the saline influence of the Estuary ecosystem. Notable saltmarsh pest plants are spartina/cordgrass (*Spartina ×townsendii* and *S. anglica*) which occur in a number of locations, and sea lavender (*Limonium companyonis*) which is present in the lower Heathcote River/Ōpāwaho. These species are being controlled, with the aim of eradication. Among the exotic grasses that occur in saltmarsh habitats, tall fescue and creeping bent (*Agrostis stolonifera*) are common and are relatively salt-tolerant (Partridge and Wilson 1987). Salt barley grass (*Hordeum marinum*) and sickle grass (*Parapholis incurva*) are distinctive, but are not detrimental to the ecology of the Estuary (Morland 2000). Other weeds, such as buck's horn plantain, are widespread and common, and grey willow (*Salix cinerea*) has been recorded in Bexley Wetland (Morland 2000).

Table 1: Pest plant species present in the Estuary area with a pest plant status in the Canterbury Regional Pest Management Strategy 2011-2015 (Maw 2011).

Common Name	Scientific Name	Pest Status (Maw 2011)
Blackberry	*Rubus fruticosus*	Restricted Pest
Bone seed	*Chrysanthemoides monilifera*	Restricted Pest
Boxthorn	*Lycium ferocissimum*	Biodiversity Pest
Gorse	*Ulex europaeus*	Containment Control Pest
Montpellier broom	*Genista monspessulana*	Containment Control Pest
Scotch Broom	*Cytisus scoparius*	Containment Control Pest

4.8 Birds

Factors that will limit the numbers of birds in the Estuary include: the availability of food, nesting habitat, and high tide roosts, the presence of predators, and levels of human disturbance.

Figure 6 shows sites where birds are known to nest and roost within the Estuary. High tide roosts in Figure 6 are derived from the Measures and Bind (2013) report on submergence of the Estuary bed post-earthquakes, and are parts of the Estuary that are submerged for only 0-10 percent of the time. Their use by shorebirds will depend on proximity to food sources, disturbance, aspect, and vegetative cover. These areas are almost entirely restricted to the inner side of Southshore Scenic Reserve. Other important high tide roosts include the Bexley Reserve paddocks, Lower Heathcote paddocks, and Linwood Paddocks. These paddocks are safe retreats during high spring tides and floods, when high tide roosts in the Estuary are not available. These pasture areas also provide important foraging for many water bird species, including gulls, oystercatchers, herons, and waders. Pied stilt (*Himantopus himantopus leucocephalus*) also nest at Linwood Paddocks. The Te Huingi Manu Wildlife Reserve within the Christchurch wastewater treatment pond complex also provides high tide roosting for many hundreds of birds, such as gulls. Sumner Beach, while outside of the Estuary boundary, is a site where oystercatcher's occaisonally roost when tides are very high. However, birds roosting at this site are subject to high levels of disturbance from people and dogs.

Birds will also roost in other locations around the Estuary margins, including Sandy Point, Raupō Bay off South New Brighton Park, and various locations with eucalypt and pine trees. Many pine trees used by shags and white-faced heron (*Egretta novaehollandiae*) have been removed from the eastern side of the Estuary, after earthquake subsidence resulted in mortality of the trees.

Most bird species use the Estuary during their non-breeding season, with a small overall nesting population in comparison to the non-breeding population. Nevertheless, nesting occurs in almost every terrestrial habitat around the Estuary. Artificial islands developed within the Te Huingi Manu Wildlife Reserve are very important for nesting. Many of the islands are planted with indigenous shrub and tree species, and others are maintained with minimal vegetation (Crossland 2005). Numerous species now nest in the ponds, including water bird species such as New Zealand scaup (*Aythya novaeseelandiae*) and four cormorant (shag) species. The ponds are also one of only five known locations in New Zealand where the New Zealand shoveler (*Anas rhynchotis*) forms large flocks during moulting (Crossland 2005).

Pied stilts nest in a number of locations around the Estuary, but particularly in the Lower Heathcote saltmarshes, Avon River/Ōtākaro wetlands, and Linwood Paddocks. If the three swamp bird species - Australasian bittern (*Botaurus poiciloptilus*), marsh crake (*Porzana pusilla affinis*), and spotless crake (*Porzana tabuensis plumbea*) - are nesting it is also likely to be in the saltmarshes and wetland vegetation around the Estuary margins. White-flippered penguins (*Eudyptula minor albosignata*) are known to nest amongst vegetation in Southshore Scenic Reserve. The Threatened-Nationally Critical black-billed gull (*Larus bulleri*) occasionally nests at the Estuary at locations

such as Bexley Wetland (prior to the earthquakes), and Charlesworth Wetland, where one colony was observed to abandon its nests due to black-backed gull (*Larus dominicanus dominicanus*) predation (Marsden and Soper 2009). Prior to the earthquakes, McCormacks Bay was not often used for nesting by birds, but major uplift has meant that the area may now be suitable for nesting by some species.

Birds forage for food throughout the Estuary. Of particular importance are the intertidal mudflats (Figure 6, no shading) which provide extensive beds of molluscs, crustaceans, and polychaete worms: important food sources for waders, water birds, herons, royal spoonbill (*Platalea regia*), gulls, and terns (Crossland 1993). Permanent water channels (Figure 6) provide small fish, which are taken by shags, terns, gulls, and herons. Emergent vegetation, such as eel/sea grass and sea lettuce, is grazed by water birds, and as for saltmarsh, support crustaceans, molluscs, and invertebrates which are taken by species such as bittern, spotless crake, and marsh crake. The waters of Te Huingi Manu Wildlife Reserve support a range of freshwater fauna, including aquatic insects, which are consumed by water birds and other species. Pasture grasslands, such as Linwood Paddocks, Bexley Reserve paddocks, and the Lower Heathcote paddocks provide terrestrial invertebrates such as earthworms and grass grubs which are consumed by gulls and also waders and pūkeko (*Porphyrio melanotus melanotus*). Pasture grasses are grazed by black swan (*Cygnus atratus*), paradise shelduck (*Tadorna variegata*), and Canada goose (*Branta canadensis*). Other terrestrial habitats around the Estuary support terrestrial bird populations, such as South Island fantail (*Rhipidura fuliginosa fuliginosa*) and grey warbler (*Gerygone igata*).

The Estuary supports a high diversity and abundance of bird species. A total of 129 bird species have been recorded in the Estuary including water birds and terrestrial species found in adjacent habitats (Crossland 2009). Of the 129 species (excluding extinct species), 105 are indigenous, and 24 introduced. Some of the species classified as indigenous are international migrants and do not actually breed in New Zealand, but use sites like the Estuary as over-wintering grounds. A full list of species, threat classifications, and local abundances is provided in Appendix 4. A further 10 species recorded previously are now locally extinct.

Numbers of water birds[1] regularly exceed 30,000 individuals (Crossland 1993; Crossland 2013), particularly during summer and autumn, the peak periods for post-breeding flocking, migration, and moulting. This means that the Estuary meets the Ramsar Convention Criterion 5 for the identification of wetlands of international importance: "A wetland should be considered internationally important if it regularly supports 20,000 or more water birds" (see Appendix 9).

The Estuary is one of 15 coastal wetlands in New Zealand of international importance for Artic-breeding waders, and one of 19 sites in New Zealand of international importance for endemic waders (Melville and Battley 2006). An 11-year study of waders at 263 sites around New Zealand found that the Estuary supports the sixth

[1] The definition of water birds used by the Ramsar Convention is "birds ecologically dependent on wetlands". See the Ramsar website for further explanation.

highest numbers of South Island pied oystercatchers (*Haematopus finschi*) in New Zealand (Sagar *et al.* 1999).

Appendix 4 lists water birds such as white heron/kōtuku (*Ardea modesta*) that, although scarce (e.g. only 1-2 birds observed per year), are observed annually in the Estuary. Twelve water bird taxa meet Criterion 6 of the Ramsar Convention: "A wetland should be considered internationally important if it regularly supports 1 percent of the individuals in a population of one species or subspecies of waterfowl" these are listed in Appendix 9. It is suspected that with more detailed monitoring, white heron and black shag (*Phalacrocorax carbo novaehollandiae*) could also be found to meet this threshold (see Appendix 9).

Thirteen species classified as having international threat rankings have been recorded in the Estuary (IUCN Red List Criteria; Birdlife International 2017; Appendix 4). Eight of these species are rare vagrants, including South Island kākā (*Nestor meridionalis meridionalis*), and four species of penguin. Five are present regularly: Australasian bittern (Nationally Critical; present in very low numbers), wrybill (*Anarhynchus frontalis*; Nationally Vulnerable; migrates to the Estuary from inland rivers), black-fronted tern (*Chlidonias albostriatus*; Nationally Endangered; migrates to the Estuary from inland rivers), black-billed gull (Nationally Critical; an abundant migrant from inland rivers, but also bred in the Estuary prior to the earthquakes), and far-eastern curlew (*Numenius madagascariensis*; Vagrant, an international migrant observed infrequently in the Estuary) (Crossland 1993, Crossland 2009, Crossland 2013).

Forty-one nationally Threatened or At Risk species have been recorded in the Estuary (Robertson *et al.* 2017; Appendix 4). Nineteen of these are vagrants, including the Threatened-Nationally Critical New Zealand fairy tern (*Sternula nereis davisae*), and the At Risk-Declining sooty shearwater (*Puffinus griseus*). Of the 22 species regularly present, only five are known to breed in the Estuary - white-flippered penguin, black shag, pied shag (*Phalacrocorax varius varius*), little black shag (*Phalacrocorax sulcirostris*), and black-billed gull - but a further three may breed in the Estuary: Australasian bittern, marsh crake, and New Zealand pipit (*Anthus novaeseelandiae novaeseelandiae*).

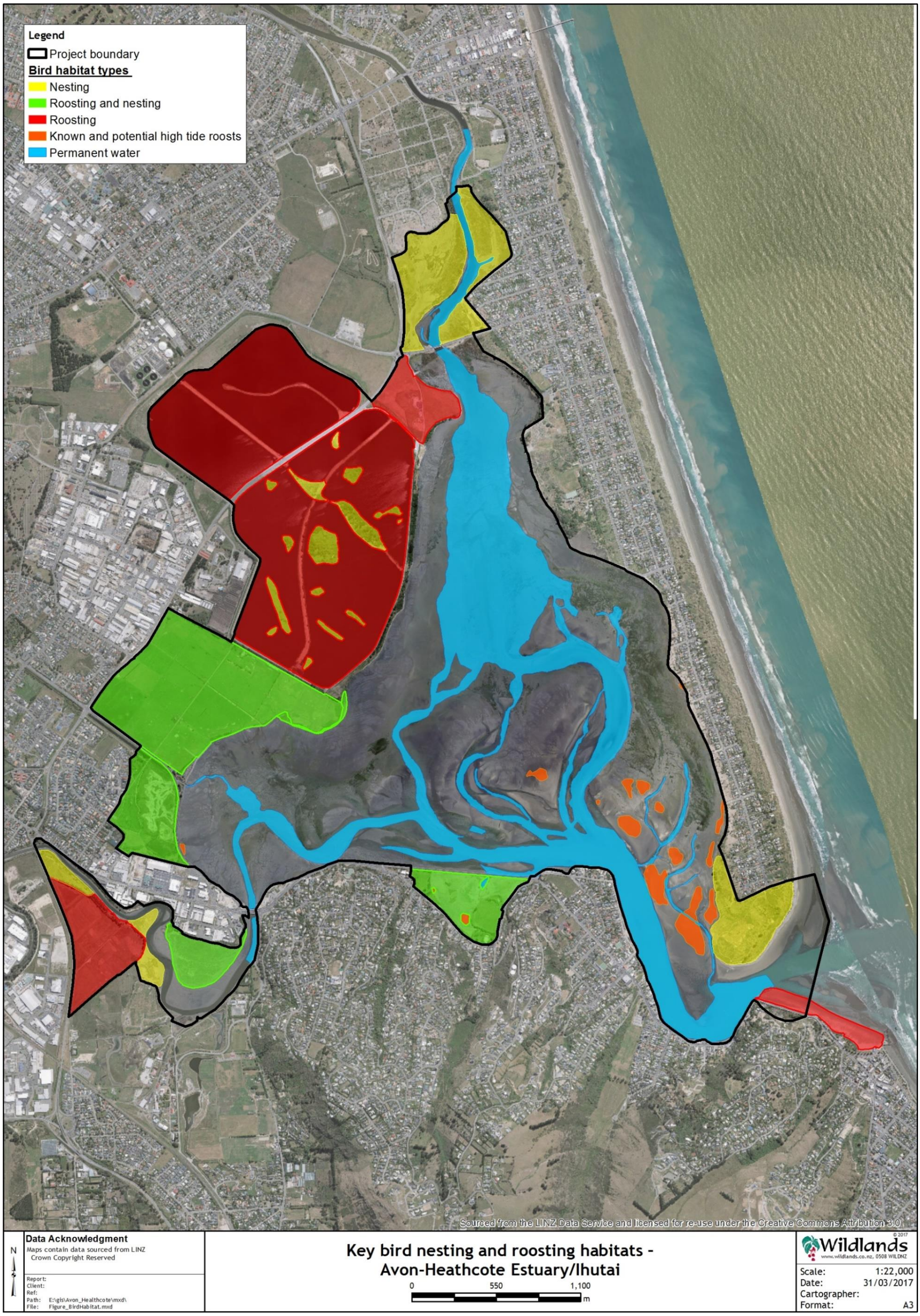

Figure 6: Key bird nesting and roosting habitat in the Avon-Heathcote Estuary/Ihutai.

4.9 Reptiles

The wider Avon River/Ōtākaro and Heathcote River/Ōpāwaho catchments are not known for high lizard diversity, with only four species recorded in the Department of Conservation herpetofauna database (Table 2) and only two of those possibly still present. There are also fossil records for tuatara (*Sphenodon punctatus*). Lizard habitat in the vicinity of the Estuary is generally scarce, highly modified, and restricted to non-aquatic habitats subject to little or no intermittent inundation, such as coastal dunes and areas of rank grassland. Further away from the immediate estuary environment, areas of rock tumble and rock outcropping can provide quality lizard habitat. The presence of lizards within any habitat type is highly dependent on local land use history. Fires, indigenous vegetation clearance, cultivation, and urbanisation can all negatively affect indigenous lizard populations, regardless of the presence of potentially suitable habitat.

Table 2: Reptiles of the Avon-Heathcote catchment from the Department of Conservation Herpetofauna database. Threat classifications follow Hitchmough *et al.* (2016).

Common Name	Scientific Name	Threat Classification
Southern grass skink	*Oligosoma* aff. *polychroma* Clade 5	At Risk-Declining
McCann's skink	*Oligosoma maccanni*	Not Threatened
Canterbury gecko	*Woodworthia* cf. *brunnea*	At Risk-Declining
Jewelled gecko	*Naultinus gemmeus*	At Risk-Declining
Tuatara	*Sphenodon punctatus*	Relict

Southern grass skink (*Oligosoma* aff. *polychroma* Clade 5) and McCann's skink (*Oligosoma maccanni)* are the species most likely to persist in and around the Estuary. There is an unverified record for McCann's skink at the southern end of the Southshore Scenic Reserve, but this species is extremely difficult to tell apart from the Southern grass skink which is more widespread across urban Christchurch, including wetland habitats such as Travis Wetland. However McCann's skink has been confirmed at Charlesworth Reserve (Andrew Crossland pers. comm). Southern grass skink could occur in any area of rank grass associated with the Estuary, but the nearest records of the species are from Sumner, and none of these are more recent than 1993 (Department of Conservation herpetofauna database). Herpetofauna database records for the Canterbury gecko (*Woodworthia* cf. *brunnea*) near the Estuary occur from the mid-1900s and are restricted to cliff/rocky areas at Redcliffs and New Brighton. This species, although widespread on Banks Peninsula, is unlikely to still be present around the Estuary, but may persist in the rocky habitat at Redcliffs.

The remaining two reptile species recorded are no longer present. According to the Department of Conservation herpetofauna database, there is a single record of jewelled gecko (*Naultinus gemeus*), dated 1940. This At Risk-Declining species has a stronghold on Banks Peninsula and although it is feasible that the species once also occurred around the Estuary, it is possible that the 1940 record was for a captive specimen that had escaped or was released into the urban settling of New Brighton. Tuatara historically occurred in the area, with bones having been found in sand dunes around the Estuary at Redcliffs, but they are now extinct in the wild on the New Zealand mainland. Tuatara are of great significance to tangata whenua, but were likely

to be extinct in and adjacent to the project area by the time Europeans arrived (A. Cree, University of Otago, pers. comm., 2017).

4.10 Terrestrial invertebrates

Estuary vegetation supports a distinctive array of indigenous invertebrates. This vegetation provides habitats that are rather isolated from each other, from the perspective of small flying insects (MacFarlane 2014). Four terrestrial invertebrate communities can be distinguished within the following habitats:

- Saltmarsh herbfield dominated by selliera (*Selliera radicans*), bucks horn plantain and glasswort.
- Rushland dominated by sea rush, oioi and three-square.
- Shrubland of coastal ribbonwood.
- Tall often exotic grassland with occasional pōhuehue (*Muehlenbeckia complexa*), *Carex secta*, harakeke (*Phormium* spp.), and tī kōuka/cabbage tree (*Cordyline australis*).

Each of these habitats supports a distinctive assemblage of invertebrates, particularly insects with larvae that feed exclusively on a particular plant species, but these estuarine plants and associated invertebrates are distributed nationally. Table 3 lists some of the specialist moths and butterflies associated with various indigenous plants found in the Estuary, illustrating the biodiversity, host specificity, and diversity of feeding strategies of the indigenous fauna of the Estuary habitats. Further information on other terrestrial invertebrates is provided in Appendix 5.

Table 3: Selected specialist moths and butterflies, and their host plants in various terrestrial habitats of the Estuary. None of the moth or butterfly species are classified as Threatened or At Risk.

Host Plant	Moth/Butterfly Species	Larval Feeding
Harakeke	*Tmetolophota steropastis*	Foliage
	Orthoclydon praefectata	Foliage
	Stathmopoda holochra	Flower head
Cabbage tree	*Epiphryne verriculata*	Foliage
Coastal ribbonwood	*Pseudocoremia lactiflua*	Foliage
	Stigmella aigialeia	Leaf miner
	Anisoplaca acrodactyla	Seeds
Pōhuehue	*Meterana stipata*	Foliage
	Meterana coeleno	Foliage
	Meterana alcyone	Foliage
	Bityla defigurata	Foliage
	Morova subfaciata	Stems
	Zapyrastra calliphanes	Leaf mining
	Chloroclystis sphragitis	Flowers
	Pseudocoremia indistincta	Foliage
	Lycaena feredayi (glade copper butterfly)	Foliage
	Lycaena new species (Canterbury common copper)	Foliage
Raupō	*Scieropepla typhicola*	Seed heads
Carex secta	*Diploseustis perieresalis*	?
	Megacraspedus calamogonus	Seed heads
	Tmetolophota semivittata	Foliage
	Protosynaema quaestuosa	Foliage

4.11 Fish

Twenty-seven marine, estuarine and freshwater fish species have been recorded in the Estuary (Appendix 6). Estuaries are where freshwater and marine species meet. It is an important place for migratory species - such as smelt (*Retropinna retropinna* and *Stokellia anisodon*), īnaka/īnanga (*Galaxias maculatus*), bullies (*Gobiomorphus* spp.), and eel/tuna (*Anguilla* spp.) - which travel between freshwater and seawater to complete their life cycles. For some migratory species, estuaries can be an important area for larval rearing, providing an environment where fish can spawn, develop, and grow during early life (McDowall 1976). Some of the species recorded in the Estuary have cultural significance as taonga species and are collected as traditional food e.g. giant bully (*Gobiomorphus gobioides*), eels, whitebait/inaka/inanga (*Galaxias maculatus*), and flounder/pātiki (*Rhombosolea retiaria*).

Fish species diversity in the Estuary is considered to be lower now than during the 1960s, with various species caught during 1972 (Webb 1972) and 1973 (Knox and Kilner 1973) not caught since. These species include redfin bully (*Gobiomorphus huttoni*), Stokells smelt (*Stokellia anisodon*), barracouta (*Thyrsites atun*), elephant fish (*Callorhinchus milii*), moki (*Latridopsis ciliaris*), pipefish (*Leptonotus* sp.), piper/garfish (*Hyporhamphus ihi*), red cod (*Pseudophycis bachus*), red gurnard (*Chelidonichthys kumu*), and rig (*Mustelus lenticulatus*). This apparent decline in species diversity may be due to changes in fish sampling methodologies between years or the infrequent catches of some species, but it may also be due to some species being targeted by commercial fishing operations (NIWA 2007). A marine cod species, ahuru (*Auchenoceros punctatus*), was first recorded in 2015 (NIWA 2016).

In 2005, Christchurch City Council commissioned NIWA to undertake a series of surveys to monitor changes in the Estuary's fish populations. Seven surveys were carried out, using consistent methodologies, with the final one completed in 2015. Results of these surveys suggest that there is no clear evidence of large scale changes in the fish community over the ten years of sampling (NIWA 2016).

4.12 Aquatic invertebrates

Overview

The aquatic invertebrate assemblage includes a variety of creatures that live both on and within the muddy substrate, and in the water column (see Appendix 7). These include sea anemones, polychaete worms, molluscs (shellfish, chitons, snails, and limpets), crustaceans, sea squirts, starfish, and insects (Jones and Marsden 2005). Dominant groups in the fauna are molluscs, polychaete worms, and crustaceans (Knox 1992; EOS 2005; EOS 2007a, Marsden and Knox 2008, EOS 2010). These invertebrates have important ecological roles such as processing of detritus; filtering of nutrients, pollutants, and plankton from the water; disturbing the substrate and incorporating materials; and providing food for other animals (Knox 1992; Jones and Marsden 2005; Marsden and Knox 2008).

The diversity of invertebrates is often low in estuaries, but their total biomass is often high, when compared to adjacent rocky shores, sea and inflowing rivers (Marsden and Knox 2008). Invertebrate distribution patterns, and sizes of individuals and

populations in an estuary, predominantly reflect their tolerance to salinity, modified by other factors such as substrate, food availability, tidal patterns, sedimentation and chemical pollutants (Knox 1992; Jones and Marsden 2005; EOS 2007b; Baharuddin 2010). Benthic fauna is made up of species that come from rivers and the sea, including some species that have evolved from marine forms and now exist only in estuaries (Knox 1992). The Estuary supports a diverse range of invertebrate fauna, having the largest number of species of any New Zealand estuary that had been studied before 1992 (Knox 1992).

There have been many studies of invertebrate communities in the Estuary. Some have been carried out to monitor human impacts (commissioned by the Christchurch City Council and Environment Canterbury) and others as part of student research studies. Taking into account differences in sampling methodologies, aquatic invertebrate communities of the Estuary appear to have changed little since studies by Marsden (1998 and 2000) and Robertson *et al.* (2002) (EOS 2005 and 2007). The sites sampled by EOS (2005) were a subset of those sampled by Marsden in 1998. There have been some more recent changes in macroinvertebrate communities, relating to the cessation of the sewerage outfall and the Canterbury Earthquake Sequence, but until long-term monitoring has been carried out it is difficult to tell whether there is overall improvement or deterioration in these communities (Bolton-Ritchie 2015).

Shellfish

Various shellfish species are present in the Estuary. Cockle (*Austrovenus stutchburyi*) is most prominent and occupies the mid to low tidal range (Dibley 2009). Cockle, pipi (*Paphies australis*), and greenshell mussel (*Perna canaliculus*) are important traditional food items.

Other Aquatic Invertebrates

More than 50 macroinvertebrate species have been recorded in the Estuary (Knox and Kilner 1973; Marsden 1998 and 2000; EOS 2007a and 2007b; Jones and Marsden 2005; Bolton-Ritchie 2015). The endemic mudsnail (*Amphibola crenata*) is one of the most abundant benthic invertebrates throughout the Estuary, which is typical of other estuaries elsewhere in New Zealand (Jones and Marsden 2005; EOS 2007).

Indicator Species

Some species are more sensitive to contaminants than others and these can be used as indicators of environmental deterioration. Cockles and mudsnails are possible indicator species, as well as the ribbed whelk and stalked-eye mudcrab (*Macrophthalmus hirtipes*) (Knox 1992, Marsden 1998).

4.13 Ecological significance

Appendix 8 of the Canterbury Regional Policy Statement sets out ten criteria for determining ecological significance under Section 6(c) of the Resource Management Act 1991 (ECan 2013). Interpretation of the criteria is provided by Wildland Consultants (2013), and a site is considered to be significant if it meets one or more of the criteria. The ecological significance of the Estuary was assessed using the criteria

in the Canterbury Regional Policy Statement. It meets nine of the ten criteria for ecological significance (see Appendix 8). Based on a previous assessment of ecological significance, using Appendix 3 of the Canterbury Regional Policy Statement, the Estuary and Environs are identified as a Site of Ecological Significance (SES/LP/14) in the Christchurch District Plan.

4.14 Ramsar assessments

The Department of Conservation (Cromarty and Scott 1996) considered that the Estuary met the Ramsar criteria for wetlands of international importance in 1996. Since then, the Estuary has been partially or fully assessed against the criteria on at least three more occasions (Williams 2005; Crossland 2009; Crossland 2013). The likely international importance of the Estuary has been confirmed by each assessment. A new Ramsar assessment is presented in Appendix 9. In this assessment the Estuary meets six of the eight Ramsar criteria.

4.15 Current ecological restoration projects

A number of ecological restoration projects have and are being undertaken around the Estuary. The Trust coordinates several ecological restoration projects. Once a particular project becomes successfully established it is usually handed over to local community groups for them to manage. The Trust's current projects are:

Charlesworth Reserve

Twenty hectares of land, bounded by Linwood Avenue and Humphreys Drive, was drained in the 1920s and used for grazing. In 1991, the Christchurch City Council cleared the paddocks and excavated shallow tidal pools, and in 2005 the reserve was officially opened. Since 2005 over 100,000 trees, shrubs, and saltmarsh plants have been planted. The area is now an important bird roosting and breeding area.

McCormacks Bay

In 2014, this largely neglected wetland was 'adopted' as a restoration project by the Trust. Christchurch City Council is the land owner and supervises the project. The project has been handed over to volunteers from the Ferrymead Rotary Club and Mt Pleasant Residents Association.

South New Brighton Park

This restoration project began in 2017 and is based at South New Brighton Park, which is Christchurch City Council land, between Ebbtide Street and Bridge Street. The Trust is working with the City Council Park Rangers and local residents to restore/enhance this earthquake-damaged area.

5. Issues, options, and desired outcomes

5.1 Human modification and disturbances

Urbanisation and modification of the greater Avon-Heathcote catchment has affected water quality and hydrology. Further to this, substantial changes in landforms and processes occurred following the Canterbury Earthquake Sequence. These changes have adversely affected water quality and hydrology by exacerbating existing problems such as sewage and stormwater contributions into the Avon River/Ōtākaro and Heathcote River/Ōpāwaho, and altered natural processes through the capping of freshwater springs by liquefaction and uplift or subsidence. Issues associated with human modification, disturbance, water quality, hydrology, and upstream effects are interconnected, and cannot be separated from catchment-scale processes.

5.1.1 Excessive sedimentation

Issues

Excessive sediment has a high potential of being permanently deposited within low energy environments. Sediment deposition will drive changes in vegetation types, with oioi becoming established in drier sites and where finer sediments are deposited, creating more extensive low energy environments, resulting in further deposition of sediment. Ultimately this will decrease the tidal prism, resulting in reduced habitat for saltmarsh vegetation and reduced habitat quality for aquatic organisms.

Excessive suspended sediment entering the Estuary can directly affect primary production with a reduction in phytoplankton, macrophytes, and sea grass, and can directly affect benthic organisms, such as shellfish, by smothering and decreasing habitat quality and food sources. In turn, this affects fauna that feed on benthic organisms, such as birds.

Outcomes

Reduced sediment inputs into the Estuary to restore and protect ecological processes.

Options

- Advocate for improved erosion and sediment control in the Avon River/Ōtākaro and Heathcote River/Ōpāwaho catchments.
- Catchment-scale stormwater management should occur, particularly in locations throughout the catchment where increased green field development or intensified urban development is occurring.
- Advocate for land use changes, or establishment of land use buffer zones, for high sediment source zones, such as Cashmere Stream and the Port Hills.
- The Water Zone Committee could prioritise the catchments directly above the Estuary for compliance with regard to sediment discharges. Although the Avon and Heathcote rivers contribute much of the sediment, some is also coming from

the hill slopes neighbouring the Estuary. The two councils could target this area for erosion and sediment control with the aim of significantly reducing sediment entering McCormicks Bay. The Committee could also prioritise sediment control in the Heathcote Catchment.

5.1.2 Water quality

Issues

Poor water quality can directly and/or indirectly affect estuary fauna, and in some cases contaminated water may remove or exclude aquatic and semi-aquatic vegetation. Common estuary contaminants are nutrients such as nitrogen, ammonium nitrogen, and phosphorus; metals, including copper, zinc, chromium, and lead; and bacteria (faecal coliforms).

Excessive nutrient loads cause algal blooms reduce levels of dissolved oxygen and which increases mortality in aquatic organisms. Metals, faecal coliforms and toxic algal blooms are also incompatible with human use of the Estuary, including contact recreation, passive recreation, and food harvesting. At present, only the seaward side of Southshore Scenic Reserve has water quality sufficient for shellfish harvesting.

Outcomes

Improved water quality entering the Estuary, ensuring safe recreation and food harvesting, and allowing more natural ecological function meeting the threshold levels for marine estuaries outlined in ANZECC guidelines (2000).

Options

- Water quality monitoring needs to continue on a regular basis at selected sites, for both ecosystem health and human health.
- Advocate for targeted catchment stormwater treatment for catchment-wide streams and rivers, the City Outfall drain, and the drains through Linwood Paddocks. Stormwater treatment should be incorporated into all land use development and restoration plans.
- Advocate for catchment-level riparian retirement and planting with species capable of processing or trapping contaminants.

5.1.3 Contaminated sediment

Issues

Contaminated sediment can have direct and indirect impacts on fauna, including the biomagnification of toxins. Toxins of greatest concern in the Estuary are zinc, Polycyclic Aromatic Hydrocarbons (PAHs), arsenic, copper and lead. The type and concentrations of contaminants may be incompatible with human use of the Estuary, including contact recreation, passive recreation and food harvesting, and may cause illness.

There is a high likelihood for continued re-suspension of contaminated sediments. Those sediments, already present in the Estuary will be difficult to treat, but may be buried or flushed over time. Some resuspension of these sediments occurred during the earthquakes as a result of liquefaction.

Outcomes

Reduction of contaminated sediment within the Estuary to levels that allow recreation, food harvesting, and natural ecological function, as per threshold levels for marine estuaries outlined in ANZECC guidelines (2000).

Options

- Advocate for sediment management in the Avon River/Ōtākaro and Heathcote River/Ōpāwaho catchments.
- Retirement of targeted riparian and floodplain areas and planting with species capable of trapping sediments. Areas include the lower Avon River/Ōtākaro wetlands, Linwood Paddocks, and Southshore.

5.1.4 Hard Engineered Estuary Edge

Hard engineered estuary edges result in loss of natural habitat, cultural values, and landscape values. There is an opportunity to restore a natural edge in some areas, e.g. South New Brighton Park, Southshore, that will enhance ecological, landscape, recreation, and cultural values, and be more resilient and reduce costs in the long term.

5.2 Environmental change and resilience

5.2.1 Sea level rise and climate change

Sea level rise will significantly affect ecological processes and services in the Estuary. If not able to expand into adjacent terrestrial habitats, intertidal mudflat habitat will be reduced, high tide bird roosts and bird nesting habitat will be lost, and sites such as Linwood Paddocks will be inundated.

Issues

Sea level rise could reduce the capacity of the Estuary to support estuarine vegetation and bird populations.

Outcomes

The estuary and its surrounds are resilient to sea level rise with space for saltmarsh and terrestrial vegetation to establish, providing continued bird roosting and nesting habitats, and sufficient intertidal mudflat habitats for foraging.

Options

- Identify locations where the Estuary can expand into adjacent habitats to allow for the natural mixing of saline and freshwater and persistence of associated habitats (see Section 6).
- Retirement of targeted riparian and floodplain areas, and planting with suitable species and communities that are resilient to sea level change (see Section 6).

5.3 Changes related to the Canterbury Earthquake Sequence

5.3.1 Changed hydrodynamics

Issues

There was a substantial decrease in the tidal prism following the Canterbury Earthquake Sequence, with substantial liquefaction and large areas of the Estuary uplifted (see Section 3.3). Subsidence in the Avon River/Ōtākaro catchment resulted in a slight increase in the upstream salt wedge penetration. Uplift may have caused a decrease in salinity in the lower Heathcote River/Ōpāwaho. These changes have implications for saltmarsh vegetation and habitat for aquatic organisms. At some locations, springs have been temporarily or permanently altered, causing changes to the freshwater vegetation types.

Outcomes

Ecological functions within the Estuary and catchment are restored to reflect changes in hydrology, using medium to large scale interventions to restore habitats which may have been lost, altered or reduced following the Canterbury Earthquake Sequence.

Options

- Targeted ecological restoration in the Linwood Paddocks, lower Avon River/Ōtākaro wetlands, and Southshore, to enhance ecological functions within the Estuary.

5.3.2 Changed surface elevations and hard edges

Issues

Uplift of the lower Heathcote River/Ōpāwaho means there is high risk of upstream erosion as the bed level adjusts to sea-level. This may have short, medium and long-term impacts on sediment budgets within the Estuary (including contaminated sediment), and any proposed or current restoration plans within the lower Heathcote River/Ōpāwaho. Also, changes to salt and freshwater inundation regimes have led to vegetation changes at McCormacks Bay and lower Avon River/Ōtākaro wetlands.

Hard surfaces also greatly limit habitat for aquatic species, which help to process organic matter and maintain ecological function.

Outcomes

Raised surfaces are recontoured and hard edges are reduced around the Estuary margin, to restore ecological function and recreate habitats that may have been lost through Canterbury Earthquake Sequence and urbanisation.

Options

- Recontour surfaces, where practical, to restore saltmarsh and freshwater vegetation at the Linwood Paddocks, lower Avon River/Ōtākaro wetlands, and Southshore.
- Recontour drains and waterways to maximise inundation, flushing, run-off (drainage away from urban areas), water and sediment treatment, and habitat availability, particularly at Linwood Paddocks, and also McCormacks Bay, which requires intervention to improve ecological and hydrological function.

5.4 Indigenous vegetation

5.4.1 Lack of continuous saltmarsh vegetation

There are very few places in the Estuary where there is a complete sequence of saltmarsh and associated vegetation zones, with the upper vegetation zones often absent or limited by hard edges and steep banks of the Estuary (Partridge *et al.*1999).

Issues

Lack of areas with a complete sequence of saltmarsh vegetation and associated zones limits the Estuary from functioning naturally as a dynamic and well-buffered estuarine ecosystem.

Outcomes

A continuous range of saltmarsh vegetation zones are present including saltmarsh herbfield, sea rush rushland, oioi rushland, and oioi/coastal ribbonwood, extending from brackish and freshwater ecosystems into coastal forest. This will provide a dynamic vegetation buffer, able to adjust to changing patterns of siltation, sea water currents and river flow, providing better protection against flooding and sea level rise.

Options

- Implement ecological restoration where it is possible to achieve a full sequence of vegetation zones and where there are hard edges that can be recontoured into upper zones of saltmarsh vegetation. Locations where this can be achieved are Linwood Paddocks, Avon River/Ōtākaro wetlands, and the Southshore estuary margin.

5.4.2 Decline of saltmarsh herbfield vegetation

The extent of saltmarsh herbfield vegetation in the Estuary has declined by 35.8 percent between 2007 and 2015.

Issues

Continued loss of saltmarsh herbfields will adversely affect the ecosystem functioning of saltmarsh vegetation in the Estuary. The decline may be associated with the Canterbury Earthquake Sequence, i.e. changing of habitat due to sediment build-up, increased elevation due to uplift, and incursion of seawater as a result of subsidence (e.g. in the lower Avon River/Ōtākaro wetlands area; Campbell *et al*. 2013).

Outcomes

Reverse the decline in saltmarsh herbfield, with increases in the distribution and diversity of saltmarsh species.

Options

- Undertake saltmarsh restoration, e.g. allowing seawater incursion on land of the appropriate elevation to allow saltmarsh herbfield to colonise the area. Lower Avon River/Ōtākaro wetlands would be a good site for this.

- Regular monitoring of salt marsh vegetation in the Estuary to detect changes and implement management before declines become irreversible.
  - Monitoring should consider the dynamic nature of the saltmarsh vegetation and the amount of change occurring.
  - Monitoring should be undertaken at least every four years, but possibly every one or two years for rapidly declining vegetation types such as native musk herbfield.

5.4.3 Native musk herbfield restoration

There has been a decline in the extent of native musk herbfield from 5.0 percent of the project area in 1992 to 0.5 percent in 2007. In 2015, only one small population was recorded within the project area, in the lower Heathcote River/Ōpāwaho.

Issues

Loss of native musk herbfield is significant because native musk is an At Risk-Declining species. Without active management this vegetation type will be lost from the Estuary. Increases in salinity may have resulted in changes in its distribution with it moving to new habitats that are less influenced by saline conditions and are more brackish.

Outcomes

Native musk herbfields are managed to become naturally regenerating and self-sustaining populations.

Options

- Identify reasons for the decline of native musk herbfield.
- Develop and implement a native musk restoration and management plan.

5.4.4 Coastal forest and indigenous trees for bird roosts

There are few areas of indigenous coastal forest adjacent to saltmarsh vegetation, and there are currently only a limited number of exotic trees available for tree roosting and nesting bird species. Some indigenous forest revegetation projects have been undertaken (e.g. Charlesworth Reserve and South New Brighton Park), and these plantings are a priority for future projects.

Issues

Several bird species use trees and shrubs for roosting and nesting, and their numbers may be limited by a lack of indigenous coastal forest.

Outcomes

Indigenouss, coastal forest is established, in order to provide suitable roosting and nesting habitat.

Options

- Include indigenous coastal forest tree and shrub species in ecological restoration plans, so that this habitat type becomes available for tree roosting and nesting birds. An example would be the inclusion of kahikatea (*Dacrycarpus dacrydioides*) swamp forest restoration plantings at Linwood Paddocks.

5.4.5 Sea lettuce

Sea lettuce (*Ulva lactuca*) is an indigenous marine alga that grows rapidly in summer with warm temperatures and high nutrient levels (especially nitrogen). It is abundant in shallow bays with higher water temperature than the deeper, more central, parts of the Estuary (Knox 1992).

Issues

After sea lettuce “blooms” it washes up on estuary margins and as it decomposes it produces hydrogen sulphide gas which is an unpleasant odour for local residents. Although indigenous, its odour affects residents and Estuary users.

Outcomes

Reduce the amount of sea lettuce that blooms and washes up on the Estuary margins.

Options

- Advocate for reductions in nutrient inputs from the Avon River/Ōtākaro and Heathcote River/Ōpāwaho.

5.5 Exotic pest plants and algae

5.5.1 Freshwater pest plants

The lower Avon River/Ōtākaro and Heathcote River/Ōpāwaho and their tributary streams have a range of freshwater weeds such as egeria (*Egeria densa*), Canadian pondweed (*Elodea canadensis*), and curly pondweed (*Potamogeton crispus*).

Issues

These species compete with indigenous species for light and nutrients, reducing the quality and quantity of habitat for indigenous flora and fauna and reducing the recreational value of waterways.

Outcomes

Protect the integrity of freshwater ecosystems by evaluating effects and, where necessary, controlling and eradicating freshwater pest plants.

Options

- Regular surveillance is required to detect pest plants in waterways.
- Current pest plant control programmes should continue, with new programmes and an incursion response for any new pest plants.
- Reviews should be undertaken to evaluate the success of existing control and surveillance programmes and to determine if further action is required. This should be addressed in an Avon-Heathcote Estuary/Ihutai Pest Management Plan.

5.5.2 Terrestrial pest plants

Pest plants can adversely affect saline and freshwater wetlands by competing with indigenous species for light, moisture and nutrients and transforming vegetation from indigenous to exotic or mixed vegetation. Many pest plants occur around the Estuary. They are introduced to the area by river flows, tidal flows, contamination of people's clothing and equipment, birds and other animals, or through dumping of rubbish. Pest plant species present include spartina/cordgrass, grey willow, crack willow (*Salix fragilis*), blackberry (*Rubus fruticosus*), bone seed (*Chrysanthemoides monilifera*), boxthorn (*Lycium ferocissimum*), gorse (*Ulex europaeus*), Montpellier broom (*Genista monspessulana*), and Scotch broom (*Cytisus scoparius*), all of which are in the Canterbury Regional Pest Management Strategy (Maw 2011). Other species present along waterways that flow into the Estuary include yellow flag iris (*Iris pseudoacoris*), pendulous sedge (*Carex pendula*), purple loosestrife (*Lythrum salicaria*), reed sweet grass (*Glyceria maxima*), and reed canary grass (*Phalaris*

arundinacea). The Christchurch Operational Pest Plan identified Sea Lavender (*Limonium campanyonis*) as a major pest plant and eradication initiatives for this have reduced its abundance at Ferrymead Loop.

Issues

Pest plants are adversely affect indigenous vegetation by displacement or smothering, and reducing habitat availability for indigenous fauna.

Outcomes

Protect the integrity of indigenous ecosystems from the adverse effects of pest plants.

Options

- Continue current pest plant control programmes (e.g. sea lavender and spartina) and establish new programmes as required.
- Undertake surveillance for pest plants not yet established in the Estuary, and develop an incursion response for new arrivals.
- Monitoring the success of these programmes to determine further actions.
- Pest plants should be included in an Avon-Heathcote Estuary/Ihutai Pest Management Plan.

5.5.3 Marine pest plants

Marine species such as undaria (*Undaria pinnatifida*) have the potential to enter the Estuary, especially as this species is already present in nearby marine areas around Banks Peninsula (Ministry of Primary Industries 2015).

Issues

Undaria could be brought into the Estuary on boats, and become established on solid structures. Once established it has the ability to replace or exclude indigenous seaweed species and associated marine flora and fauna.

Outcomes

Prevent undaria becoming established in the Estuary.

Options

- Surveillance should be undertaken for undaria by regularly examining solid substrates and structures.
- Include undaria in the Avon-Heathcote Estuary/Ihutai Pest Management Plan, with an incursion response.

5.6 Pest animals

5.6.1 Introduced mammalian predators

The following pest animal species are likely to be present in the project area: feral cats (*Felis catus*), ferrets (*Mustela furo*), stoats (*Mustela erminea*), weasels (*Mustela nivalis vulgaris*), brushtail possums (*Trichosurus vulpecula*), hedgehogs (*Erinaceus europaeus*), Norway rats (*Rattus norvegicus*), ship rats (*Rattus rattus*), and mice (*Mus musculus*). These species will prey on and disturb nesting and roosting birds, lizards, and invertebrates, and mice will eat fish eggs (e.g. inaka/inanga) that are laid in vegetation at the water's edge. In addition, domestic cats and dogs (*Canis lupus familiaris*) will prey on and disturb birds and lizards. The issue of dog management is addressed further in Section 7.9.2. Some indigenous birds, such as black-backed gulls, and swamp harrier/kāhu (*Circus approximans*) may also be active predators. Although this is often thought of as natural predation, these species have benefited from human occupation, increasing in abundance beyond natural levels. In particular, black-backed gulls can be a predator of shorebirds and seabirds.

Christchurch City Council rangers are currently undertaking control of pest mammals at four main sites:

- Charlesworth Wetland
- Christchurch wastewater treatment ponds
- Southshore Scenic Reserve
- Lower Avon River/Ōtākaro area

Pest control at the Christchurch wastewater treatment ponds is extensive and uses 50 DOC 200 trap boxes for controlling mustelids, 16 cage traps for feral cats, and 84 bait stations for controlling rodents. Pest control at Charlesworth Wetland has a network of 24 traps and 40 bait stations. There are 15 DOC 200 traps at Bexley, and five traps in Southshore Scenic Reserve (P. Borcherds, CCC, pers. comm.). The primary role of traps in Southshore Scenic Reserve is to protect white-flippered penguins.

Issues

Predation of shorebirds and wetland birds by introduced mammals is well documented (e.g. Dowding and Murphy 2001; O'Donnell *et al.* 2014). Some wetland and shorebird species that inhabit the Estuary - such as South Island pied oystercatcher and black-billed gull - are in decline nationally, with predation considered an important factor. Other species that breed in the Estuary may also be affected by predation, e.g. wetland species such as Australasian bittern and marsh crake. The latter two species are very rare in the Estuary and loss of nests, juveniles or adults to predation will increase the risk of local extinctions. Predation of roosting birds is less well documented, but may also occur.

Southern black-backed gull have recently established a colony in Charlesworth Reserve, and have been observed killing pied stilt chicks within the Estuary[1].

Predators will also prey on or disturb birds that are foraging or roosting at low tide. Such incursions on to intertidal mudflats will be more frequent at night, as this is when many predator species are most active. Domestic cats can have home ranges as large as 19 hectares on urban fringes (Metsers *et al.* 2010), meaning that domestic cats from adjacent suburbs will be active along the Estuary fringes at night. Predation and disturbance of birds at nocturnal nests, by predators such as cats and mustelids, has been observed elsewhere in New Zealand (Sanders and Maloney 2002). Disturbance may also affect the ability of migratory bird species to obtain sufficient fat reserves for return journeys to breeding grounds.

Terrestrial predators are known to affect lizard and terrestrial invertebrate populations elsewhere in New Zealand (e.g. Norbury 2001) and this is also likely to be happening around the Estuary.

Outcomes

Significantly reduce or eliminate predation and disturbance of indigenous birds by introduced mammals and other predators. In particular:

- Reduce the abundance of predators at important nesting and roosting sites.
- Prevent predator incursions into the Estuary.

Options

Figure 6 shows important bird nesting and roosting areas within the Estuary project area. Due to the large number of birds using the Estuary, these areas are extensive and widespread. Figure 7 shows where pest control is currently taking place. Figure 7 also shows terrestrial locations around the Estuary and within the project area where it would be possible to implement further pest control (note that this includes a long thin strip along the edge of Southshore). Pest control should be phased into these additional areas over time, with the aim of choking predators off the Estuary and protecting high tide roosting habitat. As with current operations being undertaken by CCC, pest control should use best practice methods e.g. traps to control mustelids and bait stations to control rodents and possums. Advice on best practice trapping methods can be sought from the Department of Conservation, or Environment Canterbury, or the National Pest Control Agency.

When phasing in pest control, the highest priority should be areas where bird nesting is occurring, e.g. the Avon River/Ōtākaro mouth - Bexley area, Linwood Paddocks, the lower Heathcote River/Ōpāwaho, and McCormacks Bay. The second priority should be to get spatial coverage around the full extent of the Estuary margin.

[1] http://www.stuff.co.nz/the-press/christchurch-life/summer-starter/74356873/Summer-Starter-diverts-for-breeding-birds. Downloaded 28 March 2017.

It would be valuable to undertake a nest predation study using camera-traps. The study could also include known high use roost areas. The study would identify which predator species are having the highest impact, and whether this varies between habitat types and bird species. The study would also identify:

- The extent of black-backed gull predation on birds and their nests.
- The extent of domestic cat predation on birds and their nests.
- Incidences of attacks on nests by uncontrolled dogs.

The study would inform predator control design and identify the need for further bylaws to protect birds from domestic dogs and cats. Also, if southern black-backed gulls were found to be a significant predator of nesting Threatened and At-Risk bird species, a culling programme should be introduced. Southern black-backed gulls are a natural part of the ecosystem, and some level of predation is expected, but this should not be occurring at levels that put other bird populations at risk. Control of black-backed gulls is commonly undertaken elsewhere.

Data on nesting success and bird counts should be used in population viability analyses (Beissinger and McCullough 2002), which determine the relative importance of predation versus other stressors on bird populations.

If domestic cats are found to be active nocturnal predators of estuary birds, then a public advocacy campaign should promote keeping cats confined overnight.

All pest mammal issues should be addressed in an Avon-Heathcote Estuary/Ihutai Pest Management Plan.

5.6.2 Browsing and grazing effects

Issue

Brushtail possums, rabbits (*Oryctolagus cuniculus cuniculus*), and possibly hares (*Lepus europaeus*) may browse indigenous vegetation around the Estuary. This is not currently considered a major issue, but could become more important as restoration plantings are establishing.

Outcome

Restoration plantings and restored vegetation communities are protected from introduced browsing mammals.

Options

- Monitoring of restoration plantings should be undertaken, and if significant browse damage by rabbits and hares is detected, then browsing mammals should be controlled.
- In the longer term, restored vegetation may require protection from possums.

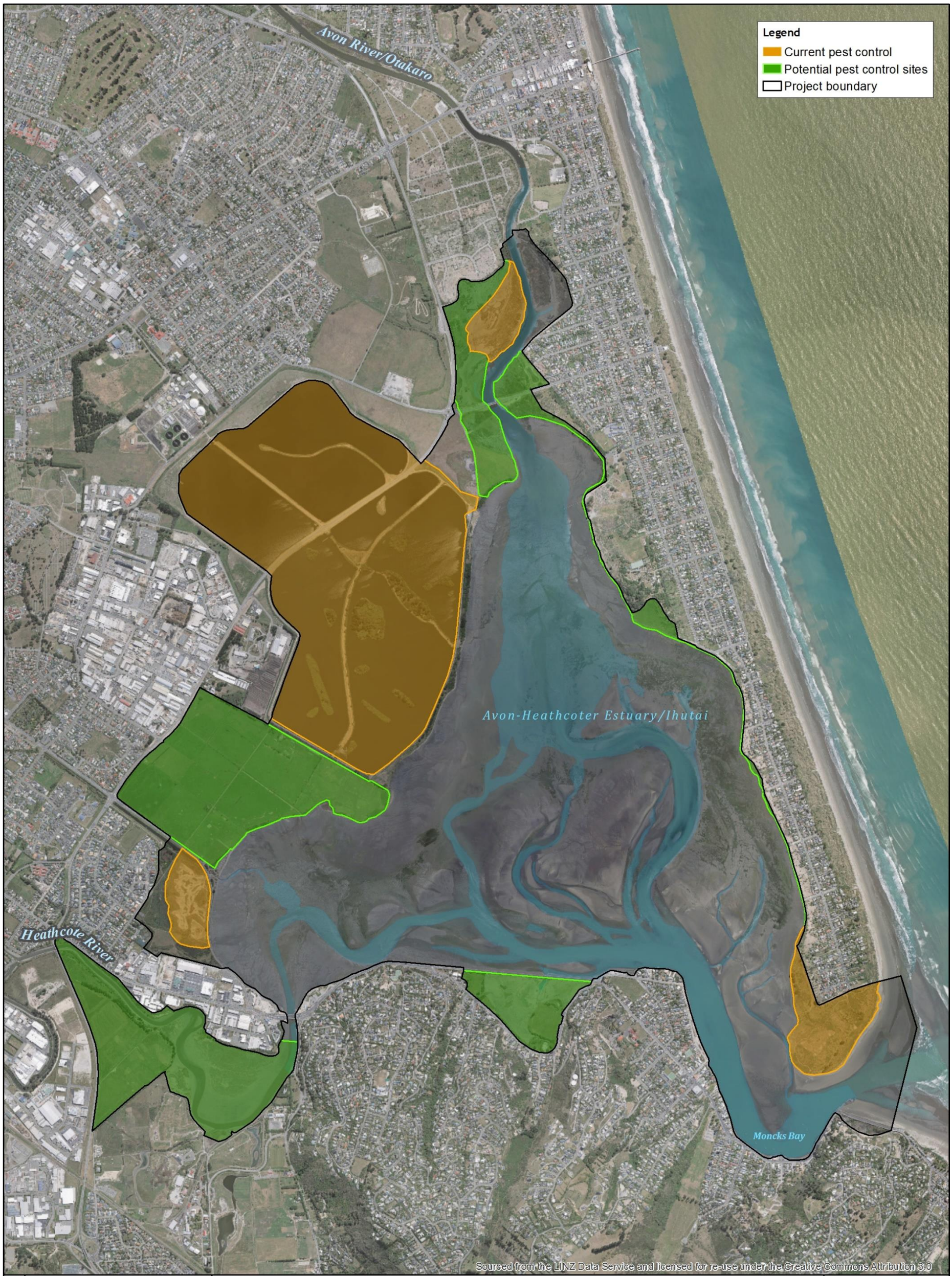

Figure 7: Current and potential pest control sites in the Avon-Heathcote Estuary/Ihutai.

5.6.3 Marine pest animals

Issues

There is a risk of introduction of marine pest animals. These can enter the Estuary through tidal flows, on humans and/or their equipment, or be dispersed by birds and other animals. There are already marine pests present in Canterbury, such as Mediterranean fanworm (*Sabella spallanzanii*) and leathery sea squirt (*Styela clava*), and these could become established in the Estuary (MPI 2015).

Outcomes

Steps should be undertaken to prevent the incursion and establishment of new marine pest animals into the Estuary.

Options

- Marine pests should be included in an Avon-Heathcote Estuary/Ihutai Pest Management Plan, with a surveillance plan and incursion response, which is an interagency collaboration between the Trust and organisations such as Environment Canterbury and the Ministry for Primary Industries.

5.7 Indigenous birds

5.7.1 Bird census data

A large amount of bird count data have been collected over the last 30 years by Christchurch City Council and the Ornithological Society of New Zealand. The North Canterbury Acclimatisation Society also undertook counts from the early 1950s (Crossland 1993). However, there has been little formal analysis of these data sets. Modelling of this data could be used to understand long-term population trends and the effects of factors such as predators, urbanisation, the cessation of effluent discharge, and the Canterbury Earthquake Sequence. Understanding bird population trends would allow for their better management, and could be linked with national and international research and management of these species.

Issue

Estimated trends in bird populations are largely anecdotal, and despite extensive data, no formal analysis or modelling has occurred.

Option

- Demographic modelling of bird count data should be undertaken so that evidence-based decisions can be made on the management of birds and their threats.

5.7.2 Improve bird nesting, feeding and roosting opportunities

Issues

Abundance and diversity of birds in the Estuary will be restricted by a range of factors, including:

- Food availability:
  - Restricted wetland and coastal shrubland foraging habitat.
  - Sediment encroachment on intertidal mudflats where birds forage.

- Availability of safe nesting habitats:
  - Areas of shrubland, wetland vegetation, and grassy areas where pests are controlled, allowing bird species such as white-flippered penguin, pied stilt, Australasian bittern, and banded dotterel to breed successfully.

- Availability of suitable high tide roosting habitat:
  - Areas that are dry during high tide and are safe from human and pest animal disturbance.

Sea level rise may further reduce habitat availability, if the Estuary cannot expand over time into surrounding terrestrial habitats.

Outcomes and Actions

Outcomes and actions to improve the availability of foraging, nesting, and roosting habitat in the Estuary are linked to other sections and include:

- Reducing sediment inputs (Section 5.1).

- Facilitating estuary expansion into adjacent areas (Section 5.2).

- Site-specific habitat restoration, including a full sequence of vegetation zones (Section 5.4).

- Development of full sequences of vegetation zones, from saltmarsh through to coastal shrublands and forest (Section 5.4).

- Implementation of pest control to protect nesting and roosting birds (Section 5.6).

- Management of recreational disturbance (Section 5.9).

5.8 Cultural

Loss of the mahinga kai resource and its continued ecological degradation remains highly offensive to tangata whenua, with Te Ihutai viewed as a lost resource (Lobb 2009).

In a report to the Avon-Heathcote Estuary Ihutai Trust, Andrea Lobb of Mahaanui Kurataiao Ltd identified the following concerns and priorities for the Estuary (Lobb

2009, Lang *et al.* 2012). These priorities are aligned with the ecological and environmental priorities identified throughout this plan.

5.8.1 Restoration of mauri through healthy water

Issue

The mauri (life force) of the Estuary can only restored by improved water quality (Lobb 2009).

Outcomes

Restoration of the mauri of the Estuary would be achieved through the progressive elimination of contaminants from the catchments and restoration of water quality to a level acceptable for mahinga kai (see Section 5.1).

Options

- Greater monitoring of water quality and identification of sources of water contamination, both within the Estuary and throughout the Avon River/Otākaro and Heathcote River/Opāwaho catchments (Lang *et al*. 2012). In particular, more monitoring of faecal coliform levels, as this is an important indicator of the safety of mahinga kai.
- Research into the source of human, agricultural and medical contaminants and the progressive elimination of contaminants from wastewater, stormwater and rural land uses associated with the Estuary and its catchment (Lang *et al*. 2012). And also further investigation of highly degraded sites, with possible remedial actions identified.
- All known springs should be protected and enhanced (Lang *et al*. 2012).

5.8.2 Restoration of mahinga kai resources

Issues

The two main issues associated with mahinga kai tikanga are:

- Food safety concerns around the collection of fish and shellfish.
- Lack of riparian indigenous habitat suitable for the harvest of harakeke and species suitable for rongoā (herbal medicine).

Outcomes

Ecological restoration of the Estuary margins and water quality restored to a level at which mahinga kai can be gathered and used safely (Lobb 2009).

Options

- Monitoring of faecal coliform levels and monitoring and assessment of shellfish contamination within the Estuary against the Ministry for the Environment, and Ministry of Health shellfish gathering standards (Lang *et al*. 2012).
- Ecological restoration, revegetation, habitat protection and advocacy for water quality improvement to help restore mahinga kai.

5.8.3 Enhancement and restoration of indigenous habitat

Issues

There should be enhancement and restoration of indigenous vegetation around the Estuary, for the following reasons (Lobb 2009):

- Riparian margins are degraded, often lacking indigenous vegetation.
- To prevent further erosion of various sites around the Estuary.

Enhancement and restoration would require pest plant and pest animal species to be controlled.

Outcomes

Restoration of riparian and marginal areas of the Estuary to a state representative of the vegetation types present when Christchurch was settled.

Options

- Implementation of habitat restoration actions in Section 5.4, and management of pest plants and pest animals, as described in Sections 5.5 and 5.6.
- Development of policies that prevent urban development from further encroaching on waterways, and oblige future developments to complement riparian restoration activities (Lobb 2009).

5.9 Recreation, commercial use, and public access

The estuary is an important recreational resource for Christchurch City. The public use the Estuary for activities such as wind surfing, running, walking, cycling, bird watching, fishing, and shellfish harvesting. Recreational use of the Estuary needs to take account of and protect its ecological values.

5.9.1 Public disturbance of bird life

Issues

Repetitive disturbance of nesting birds by recreational users may lead to the abandonment of nests. This could affect the productivity of rare and threatened bird species. Nests of ground-nesting birds may also be at risk from accidental trampling.

Repetitive disturbance of roosting and foraging birds may reduce their body condition. This may be an important factor for migratory species, such as the eastern bar-tailed godwit (*Limosa lapponica baueri*), which must gain body weight before migrating to the Arctic.

Outcome

Human disturbance of indigenous birds is minimised through the careful management of recreational activities within and around the Estuary.

Options

Reduce recreational disturbance to birds using the following methods:

- Assess proposed new developments (e.g. tracks, carparks, picnic areas) to determine the risk of disturbance to nesting, foraging, or roosting birds. If the risk is high, then identify options to avoid adverse effects.
- Ensure that sufficient signage is available to alert human users of the need to minimise disturbance to birds. This could include requirements to keep to public tracks in some locations.
- Restoration planting plans described in Sections 5.1, 5.0 and 5.4 should be designed to buffer nesting, roosting, and foraging birds from human users.
- Public event planning and maintenance activities should consider timing of bird nesting and parts of the Estuary where birds may be nesting or congregating.
- Development of guidelines on minimum distances that need to be maintained between human activities and birds in order to prevent or minimise disturbance.

5.9.2 Disturbance of birds by domestic dogs

Issues

The Estuary is popular for dog walking, and adjoins residential properties with dogs. Roaming or uncontrolled dogs can kill birds, and dog attacks on white-flippered penguins are well-documented in the Christchurch area. Disturbance by dogs is also an issue, for example research elsewhere in New Zealand found that nesting New Zealand dotterel (*Charadrius obscurus aquilonius*) were disturbed by dogs even when they were on a leash (Lord *et al.* 2001).

Outcomes

Protect bird populations in the Estuary from predation and disturbance by domestic dogs.

Actions

- The Christchurch City Council Dog Control Bylaw and Policy (2016) provide extensive controls (Figure 8 and Appendix 10), with dogs prohibited or required to be on a leash around most of the Estuary. Given these restrictions, if problems continue to occur, the focus should be on enforcement, with owners of uncontrolled dogs fined and roaming dogs removed by City Council dog control officers.

- Signage should be installed to educate dog owners about the threat that uncontrolled dogs pose to birdlife.

Figure 8: Dog Control Locations within the Estuary boundary; Christchurch City Council Dog Control Bylaw and Policy 2016[1].

[1] https://www.ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/bylaws/dog-control-policy-and-bylaw-2016/ Downloaded 31 March 2017.

5.9.3 Harvesting of fish and shellfish

Issues

Harvesting of fish and shellfish occurs in the Estuary, particularly on the seaward side, but health warnings regarding contaminants constrain collection in other parts of the Estuary. If the Estuary becomes cleaner, shellfish harvesting may increase and it will be important that it is managed sustainably.

Outcomes

- Fish and shellfish populations are maintained at levels that provide sufficient food resources for bird populations.
- Fish and shellfish resources are available for future generations.

Options

- Active compliance and monitoring, and interpretation and signage about fishing regulations should be established and maintained at locations where fish and shellfish harvesting occur. The following regulations are relevant to the Estuary and have been developed to guide the sustainable management of fish and shellfish harvesting in New Zealand:
  - Whitebait Fishing Regulations 1994 (Department of Conservation) - inaka/inanga.
  - Fisheries (Amateur Fishing) Regulations 2013 (Ministry for Primary Industries) - fish and shellfish.
  - Fisheries (Commercial Fishing) Regulations 2001 (Ministry for Primary Industries) - fish and shellfish.
- Monitoring of changes in fish and shellfish populations over time should be used to guide decision-making. Monitoring regimes should be able to detect changes in fish and shellfish abundance at the local scale. If populations are found to be declining then specific, localised rules should be created to ensure the protection of fish and shellfish throughout the Estuary.

5.10 Summary of issues, actions, and outcomes

Various environmental and ecological issues have compromised the integrity of the Estuary, the most notable being sedimentation, contamination (water and sediment), elevated nutrient levels, decline in saltmarsh vegetation, loss of indigenous estuary margin vegetation types, pest plants and animals, and limited high tide roosting and nesting sites for birds. Changes in hydrology and substrate elevations resulting from the Christchurch Earthquake Sequence have further modified ecological processes.

Management outcomes and options to address these issues are summarised in Table 4. If implemented, these will greatly improve the environmental and ecological

condition of the Estuary. They will also improve cultural values enabling the collection of mahinga kai and the reconnection of Canterbury citizens to the Estuary.

Most of the water management actions cannot be addressed within the Estuary alone and require a catchment-wide focus. Although the upstream catchments are beyond the project area boundary, appropriate actions are included in Table 4 because the Trust needs to be a strong advocate for management of upstream catchment issues. Implementation of all of the actions described requires significant engagement between the Trust and other stakeholders.

Table 4: Summary of the issues, actions, and outcomes, along with key agency partners, timeframes in which these actions should be undertaken, and indicative project costing: low ≤$100,000; medium $100,001 - $400,000; high >$400,000.

Section	Issue	Action	Key Partners	Indicative Costing	Urgency and Duration
5.1.1	Excessive sedimentation	• Implement sediment management in lower Avon River/Ōtākaro and Heathcote River/Ōpāwaho. • Support catchment scale stormwater treatment. • Establish land use buffers or land use changes for high sediment source zones.	CCC, ECan	High	• Immediate start • Long-term, ongoing
5.1.2	Poor quality water	• Regular water quality monitoring. • Site-targeted catchment stormwater treatment, including incorporation into site restoration plans. • Catchment riparian planting and retirement from development.	CCC, ECan	Medium	• Immediate start • Long-term, ongoing
5.1.3	Contaminated sediment	• Implement sediment management in the Avon River/Ōtākaro and Heathcote River/Ōpāwaho. • Targeted retirement of riparian areas and restoration of floodplain areas.	CCC, ECan	Medium-High	• Immediate start • Long-term, ongoing
5.2.1	Sea level rise and climate change	• Identify locations for restoration where estuary expansion can enable interaction between seawater and freshwater. • Retirement and restoration of targeted riparian and floodplain areas.	CCC, ECan	Low	• Immediate start • Long-term, ongoing
5.3.1	Changed hydrology	• Targeted ecological restoration of ecological function within the Estuary, to manage resilience in response to changes in freshwater springs and penetration of the salt wedge.	CCC, ECan	High	• Immediate start • Ongoing, until established
5.3.2	Changed surface elevations and hard edges	• Recontour surfaces to establish saltmarsh and freshwater vegetation types. • Realign or recontour drains/waterways to maximise inundation, flushing, run-off, sediment treatment and habitat availability. • Investigate erosion potential in lower Heathcote River/Ōpāwaho with cross-sectional surveys.	CCC, ECan	High	• Immediate start • Short to medium-term, some ongoing maintenance
5.4.1	Lack of continuous saltmarsh vegetation	• Site-targeted ecological restoration and management to achieve a full sequence of vegetation zones.	CCC, ECan	Medium-High	• Start within one-two years • Short to medium-term
5.4.2	Decline of saltmarsh herbfield vegetation	• Investigate and implement appropriate management actions to encourage natural recolonisation of saltmarsh vegetation. • Saltmarsh vegetation monitoring to be undertaken at more frequent and regular intervals.	CCC, ECan, DOC	Low	• Immediate start • Short to medium-term, ongoing
5.4.3	Native musk herbfield restoration	• Investigate the decline of native musk herbfield. • Implement a native musk restoration and management plan.	CCC, ECan, DOC	Low	• Immediate start • Short to medium-term

Section	Issue	Action	Key Partners	Indicative Costing	Urgency and Duration
5.4.4	Coastal forest and indigenous trees for bird roosts	• Include appropriate indigenous coastal forest tree and shrub species in restoration plans, to provide bird roosting and nesting. • Kahikatea swamp forest to be included in restoration plantings at Linwood Paddocks.	CCC	Low	• Start within two years • Short to medium-term
5.4.5	Sea lettuce	• Reduce high nutrient inflows from the Avon River/Ōtākaro and Heathcote River/Ōpāwaho.	CCC, ECan	Medium-High	• Start within two years • Short to medium-term
5.5.1	Freshwater pest plants	• Continue existing control programmes. • Implement surveillance for pest plants not yet established but with potential to establish in the Estuary. • Develop an incursion response plan. • Monitor control programmes to evaluate success. • Include in an Avon-Heathcote Estuary/Ihutai Pest Management Plan.	CCC, ECan	Low	• Immediate start • Long-term, ongoing
5.5.2	Terrestrial pest plants	• Continue existing control programmes. • Implement surveillance for pest plants not yet established but with potential to establish in the Estuary. • Develop an incursion response plan. • Monitor control programmes to evaluate success. • Include in an Avon-Heathcote Estuary/Ihutai Pest Management Plan.	CCC, ECan	Low	• Immediate start • Long-term, ongoing
5.5.3	Marine pest plants	• Implement surveillance for undaria. • Include an undaria incursion response plan in the Avon-Heathcote Estuary/Ihutai Pest Management Plan.	ECan, MPI	Low	• Start within one-two years • Long-term, ongoing
5.6.1	Introduced mammalian predators	• Phase in predator control around the full margin of the Estuary. • Undertake predation research. • Incorporate into an Avon-Heathcote Estuary/Ihutai Pest Management Plan.	CCC, DOC, ECan	Medium	• Start within one-two years • Long-term, ongoing
5.6.2	Browsing and grazing impacts	• Monitoring for browse damage of restoration plantings. If browse damage occurs, instigate control. • Include in an Avon-Heathcote Estuary/Ihutai Pest Management Plan.	CCC, DOC, ECan	Low	• Start within eight years • Long-term, ongoing
5.6.3	Marine pest animals	• Implement surveillance for potential pest animals not yet established in the Estuary. • Include incursion response for marine pest animals in an Avon-Heathcote Estuary/Ihutai Pest Management Plan.	MPI, DOC, ECan	Low	• Start within one-two years • Long-term, ongoing

Section	Issue	Action	Key Partners	Indicative Costing	Urgency and Duration
5.7.1	Bird census data	• Undertake a detailed demographic analysis of Estuary bird count data.	CCC	Low	• Short-term, but repeated at intervals for new data
5.7.2	Improve bird nesting, feeding and roosting opportunities	• Reduce sediment inputs through targeted stormwater treatment and catchment riparian planting. • Allow progressive estuary movement into adjacent habitats. • Targeted restoration of specific sites including recontouring of surfaces. • Implementing pest control (Section 7.6 Pest animals). • Manage recreational disturbance.	CCC, DOC, ECan	Medium-High	• Immediate start • Long-term, ongoing
5.8.1	Restoring mauri through healthy water	• Continue to monitor water quality, within the Estuary and catchments, focussing on contaminants such as faecal coliforms. • Research the source of human, agricultural and medical contaminants, and their progressive elimination from wastewater and stormwater. • Assess highly degraded sites. • Protect and enhance all known springs in the catchment.	CCC, DOC, ECan	Low	• Start within one-two years • Long-term, ongoing
5.8.2	Restoration of mahinga kai resources	• Monitor faecal coliforms and other contaminants of shellfish.	CCC, DOC, ECan	Low	• Start within eight years • Long-term, ongoing
5.8.3	Enhancement and restoration of indigenous habitat	• Advocate for policies to ensure urban development does not further encroach on catchment waterways.	MPI, DOC, ECan	Low	• Immediate start • Long-term, ongoing
5.9.1	Public disturbance of bird life	• Assess proposed new recreational developments to determine their effects on birds. If there are impacts find alternatives. • Provide signage that educates the public on the importance of minimising disturbance to birds.	CCC, DOC, ECan	Low	• Start within one-two years • Long-term, ongoing
5.9.2	Disturbance of bird life by domestic dogs	• Enforcement of the Christchurch City Council Dog Control Policy and Bylaw (2016). • Install signage to educate dog owners on the risks that uncontrolled dogs pose to birdlife.	CCC	Low	• Immediate start • Long-term, ongoing
5.9.3	Harvest of fish and shellfish	• Active compliance and monitoring of fishing activities (finfish and shellfish).	MPI	Low	• Immediate start • Long-term, ongoing

6. Ecological restoration opportunities and priorities

This section focusses on actions that can be implemented within project boundaries. Catchment-level actions, such as upstream water and sediment management, will need to be addressed via ongoing advocacy by the Trust.

6.1 Opportunities

6.1.1 Collaboration with Regenerate Christchurch

The Canterbury Earthquake Sequence has resulted in 600 hectares of land becoming available in the residential Red Zone in the lower Avon River/Ōtākaro. Land has also become available in Southshore and South New Brighton. Regenerate Christchurch is engaging with the community and its partners to determine future uses for this land. There is a significant opportunity to use residential Red Zone land adjacent to the Estuary to undertake ecological restoration and develop the saltmarsh vegetation sequences described in Section 7.4. Residential Red Zone land can also be developed into buffers that allow for fluctuating vegetation zones that respond to sea level rise and changes caused by earthquakes. Restoration of coastal forest in these areas will also provide breeding and roosting habitat for some estuary birds, and improve Ngāi Tahu's cultural connection to the area.

6.1.2 Estuary edge projects

Various proposals to improve the ecological connection between the Estuary and the adjacent land have been promoted, including the creation of an Estuary Green Edge in the 1990s. In 2005, a more detailed plan including a concept for the Linwood Paddocks was developed (Lewthwaite 2005) and this should be implemented. Further discussion is provided, in Section 6.2.1, of a concept for Linwood Paddocks that builds on these previous ideas.

6.2 Priority areas for ecological restoration

6.2.1 Linwood Paddocks

Various vegetation zones could be restored at Linwood Paddocks. On the Estuary edge, saltmarsh can be restored, including herbfield, searush rushland, oioi rushland, and coastal ribbonwood, resulting in an intact saltmarsh vegetation sequence. Realignment of the current drainage channels in Linwood Paddocks into more natural freshwater streams with a single outlet into the Estuary, accompanied by plantings of wetland species such as harakeke and kahikatea, will provide better habitat for freshwater fauna and plant species.

Higher ground near Sandy Point and the margins of Linwood Paddocks could be restored to coastal forest, providing important nesting and roosting habitat for bird species such as the shags, white-faced heron, and royal spoonbill.

A tidal wetland area close to Linwood Avenue would result in freshwater streams flowing into the Estuary through an area which will have lower sediment deposition rates and higher erosion potential. The single outlet into the Estuary will allow

flushing of sediment from the saltmarsh vegetation zone and the Estuary margin. The success of restoration at Charlesworth Reserve shows that saltmarsh vegetation can be restored successfully.

Restoration at Linwood Paddocks would involve:

- Civil works to construct open areas that allow tidal flow to and from the Estuary, while protecting adjacent urban areas from tidal surges or flooding.
- Land recontoured to ensure a range of topography and moisture regimes, for the different habitats.
- Drainage ditches realigned into more natural channels.
- Creation of a diversity of vegetation types including oioi rushland, sea rush rushland, saltmarsh herbfield, three-square sedgeland, primrose herbfield, native musk herbfield, coastal ribbonwood shrubland, mikimiki shrubland, kahikatea swamp forest, and coastal forest.
- Creation of sand and shingle banks for bird roosting and open areas for nesting and feeding.
- Management of public access to minimise disturbance to birds.

Intervention Options

The following physical intervention options have been identified for Linwood Paddocks:

- No intervention (Figure 9).
- Medium scale intervention (Figure 10).
- Large scale intervention (Figure 11).

Each of these options is described further below.

No Intervention

Leave all surfaces and processes untouched and work with existing conditions to restore indigenous vegetation types where possible. This is likely to result in Charlesworth Wetland receiving less flushing flows as the bay at the outlet fills with sediment from the Heathcote River/Ōpāwaho. Hydrological regimes and landforms may not be suitable for restoration of oioi rushland, searush rushland and saltmarsh herbfield. Freshwater flows through the paddocks will have a short duration, due to the short, straight channels, resulting in little removal of catchment contaminants before discharging into the Estuary.

Medium Scale Intervention

Establish sediment management in the Heathcote River/Ōpāwaho and the City Outfall Drain to lower sedimentation rates within the basin adjacent to Charlesworth Wetland and the Linwood Paddocks. Design more natural channel forms for Lovett's Drain, Charlesworth Drain, and the City Outfall Drain, working with the existing landform

and surface elevations to allow for a central area of the paddocks to flood allowing for greater habitat diversity and longer residence times for freshwater entering from urban areas. This will filter nutrients and contaminants before they reach the Estuary. A single long outlet channel should flush the system, preventing rapid sediment infilling.

Large Scale Intervention

This requires large scale earthworks to recontour existing surfaces to create wetlands that provide specific habitat requirements. The elevated north-western margin of the Linwood Paddocks could be infilled to provide greater protection from coastal flood risk and sea-level rise. Redesigning of the City Outfall Drain so that it matches the area estimated to have the least sediment deposition will keep the outlet into the Linwood Paddocks clear of sediment, and flush the system. A wider mouth for the City Outfall Drain and a deeper channel into the Paddocks may increase wetland salinity, promoting establishment of saltmarsh vegetation types, and allowing faster conveyance of freshwater flood flows. However, this scale of intervention requires hydraulic modelling to ensure that design dimensions would allow these processes to operate. A gravel ridge could be created where the paddock margins are already elevated. This would provide habitat for birds during high tides and would be free from muddy sediment.

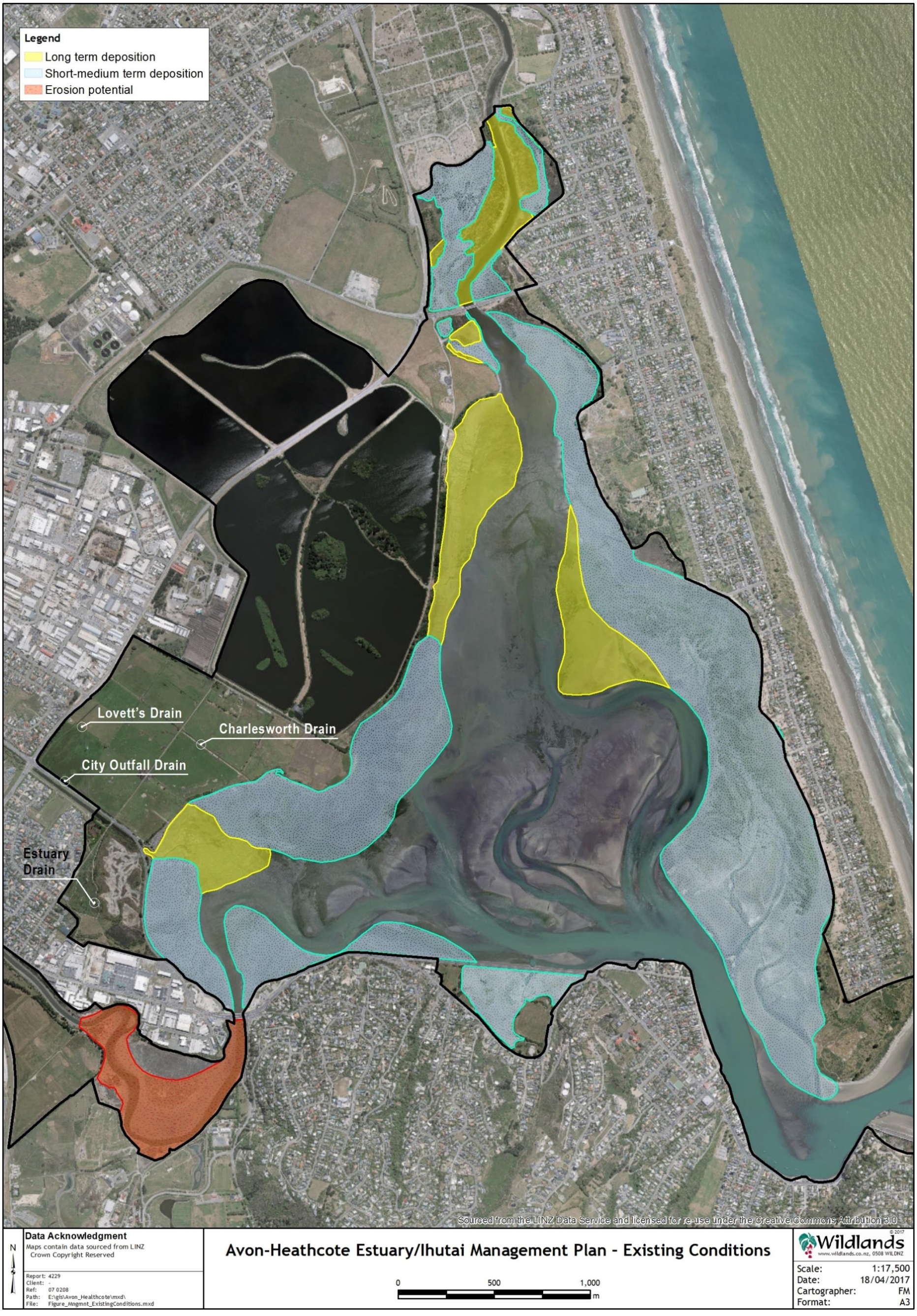

Figure 9: Expected sediment deposition in the Avon-Heathcote Estuary/Ihutai, with no intervention.

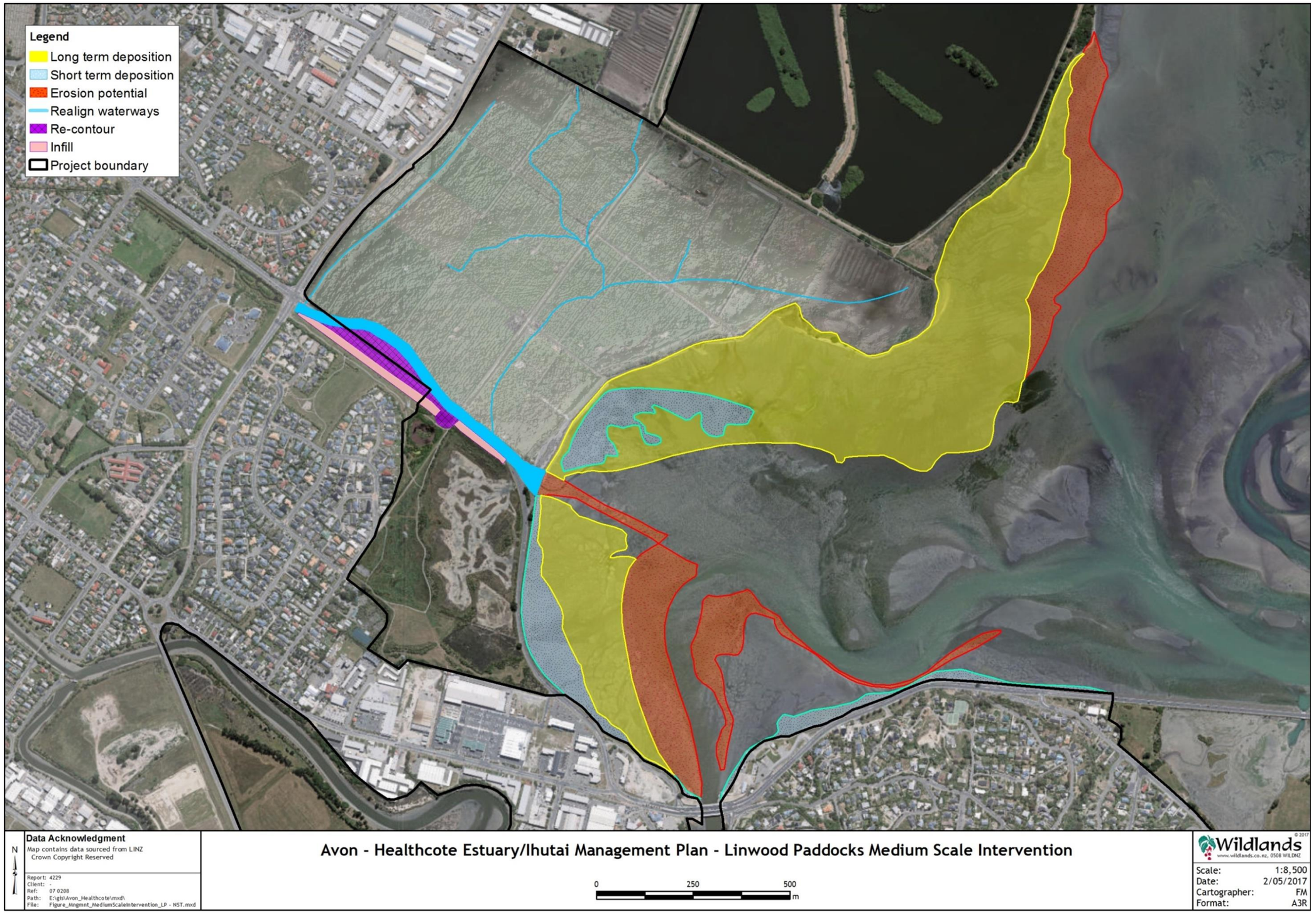

Figure 10: Predicted outcomes and deposition rates of medium scale intervention at Linwood Paddocks.

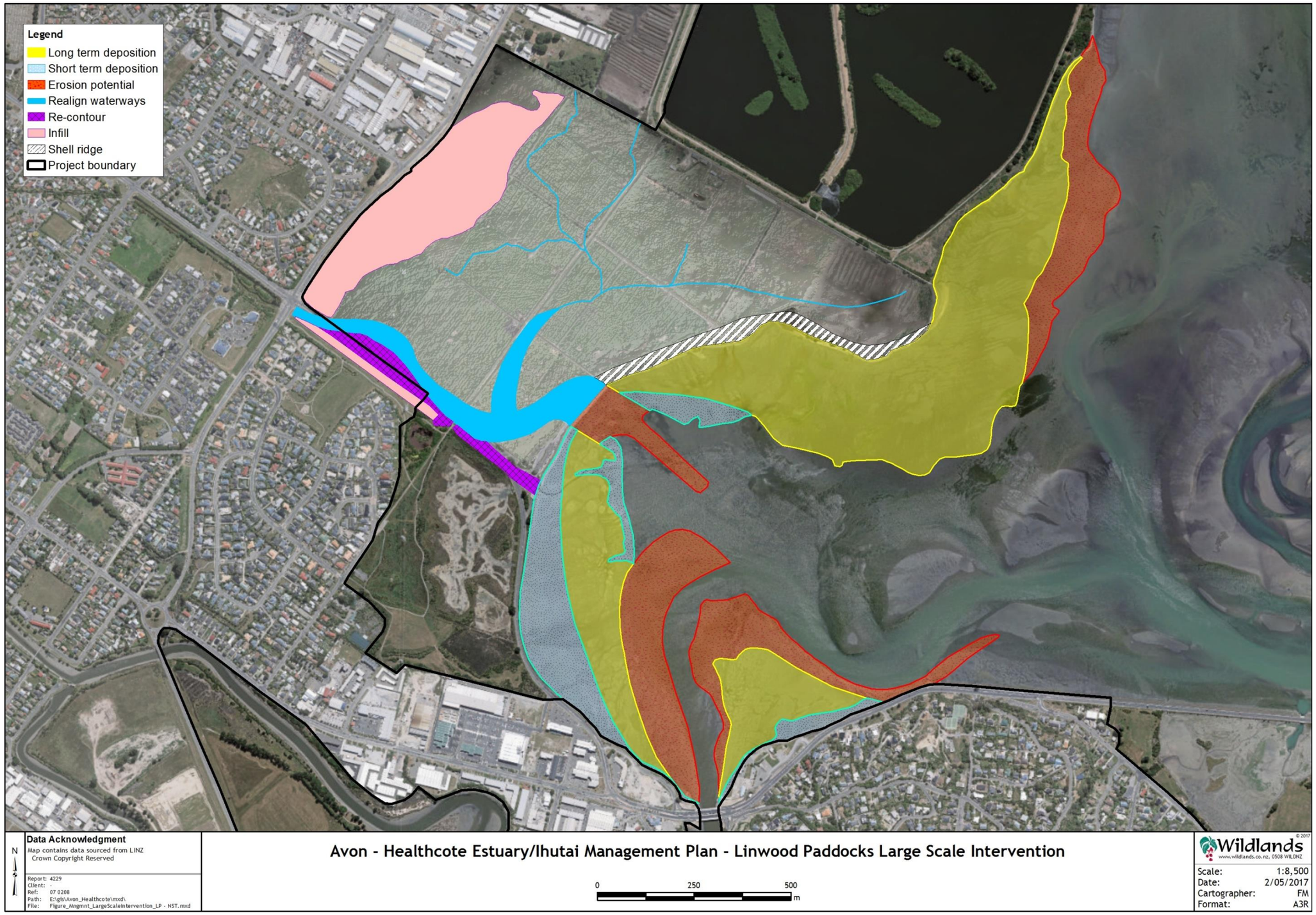

Figure 11: Predicted outcomes and deposition rates of large scale intervention at Linwood Paddocks.

6.2.2 Bexley Reserve southern paddocks

The Bexley Reserve southern paddocks should be retained as open grassland for bird foraging and roosting, and patches of coastal forest could be established around the margin to provide nesting and roosting habitat for bird species, as was suggested in the Green Edge Proposal (Lewthwaite 2005).

6.2.3 Lower Avon River/Ōtākaro wetlands

Prior to the Canterbury Earthquake Sequence, Bexley Wetland was a mixed freshwater/brackish wetland. However, with land subsidence, it has reverted to an estuarine habitat with tidal coverage, increased salinity, and saltmarsh vegetation (Campbell *et al.* 2013) and should be managed accordingly. Opportunities for ecological restoration exist within adjacent residential Red Zone land. The current stopbank should be partially removed to allow tidal flow and saline conditions to extend toward Anzac Drive, across remnant areas of saltmarsh. This will prevent further establishment and proliferation of introduced broadleaved weeds and grasses. A new stopbank should be constructed along Anzac Drive, and remnants of the existing stopbank converted to islands suitable for bird roosts. Increased tidal flow will allow restoration of the full sequence of saltmarsh vegetation. The extent to which saltmarsh restoration is successful will be subject to the scale of intervention.

A development plan for Bexley Wetland (Morland 2000) identified that natural freshwater springs in the area contribute to the presence of brackish water. Where possible, these springs should be incorporated into restoration plans due to their influence on local vegetation, particularly raupō, harakeke, and *Carex secta*.

The Black Maps (1856) indicate that harakeke swamp and rushes were once common in the area, and mānuka (*Leptospermum scoparium*) scrub was also present. Restoration planting should also give consideration to these vegetation types.

Intervention Options

There are three scenarios for potential levels of intervention in the Lower Avon River/Ōtākaro wetlands:

- No intervention (Figure 9).
- Medium scale intervention (Figure 12).
- Large scale intervention (Figure 13).

These options are discussed further below:

No Intervention

Leave all surfaces and processes untouched, working with existing conditions to restore indigenous vegetation types where possible. Under this approach, the lower Avon River/Ōtākaro wetlands will be slow to recover from changing hydrological conditions i.e. increased tidal inputs submerging the area at high tide, and sustained sediment inputs from the Avon River/Ōtākaro. Stopbanks lining the Avon

River/Ōtākaro mean will prevent water quality improvement through biofiltration, and reduce filtration and processing of sediment, nutrients, and organic materials.

Medium Scale Intervention

Establish sediment management in the Avon River/Ōtākaro to lower sedimentation rates within the Avon River/Ōtākaro Wetland. This will also help to reduce the amount of sedimentation occurring in the Estuary. Remove two small sections of the stopbank at the northern end of Bexley Road and the eastern end of Morganwood Street, and excavate small-scale flood channels. This will allow this area to flood and create areas suitable for wetland establishment. This would result in freshwater wetland in the north and saline/brackish wetlands in the south. These systems would be separated by Pages Road which would act as a raised bund, with culverts installed near Waitaki Street to prevent flooding. Woody vegetation and small areas of infill would prevent erosion and meandering from the Avon River/Ōtākaro. The elevated southern end of the residential Red Zone should be restored to suitable bird habitat (indigenous grass and coastal forest).

Large Scale Intervention

Implementation of sediment management in the Avon River/Ōtākaro would reduce sedimentation within the Avon River/Ōtākaro wetlands. It would also reduce the amount of sedimentation occurring in the Estuary. Remove two small sections of the stopbank at the northern end of Bexley Road and the eastern end of Morganwood Street. Small scale excavation of flood channels will flood the area, allowing for wetland creation. Major earthworks to recontour landforms will be required to establish distinct wetland areas that incorporate saline, freshwater, and brackish habitats. Pages Road should become a bridge over the wetland, to limit scour and deposition within the wetlands, and to prevent the road flooding. Woody vegetation and small areas of infill would prevent erosion and meandering from the Avon River/Ōtākaro. The elevated southern end of the residential Red Zone should be restored to suitable bird habitat (indigenous grass and coastal forest).

The creation of wetlands would help to retain floodwaters and to trap and process stormwater and contaminated sediment. The large scale intervention will provide an area where vegetation zones can fluctuate and buffer sea level rise.

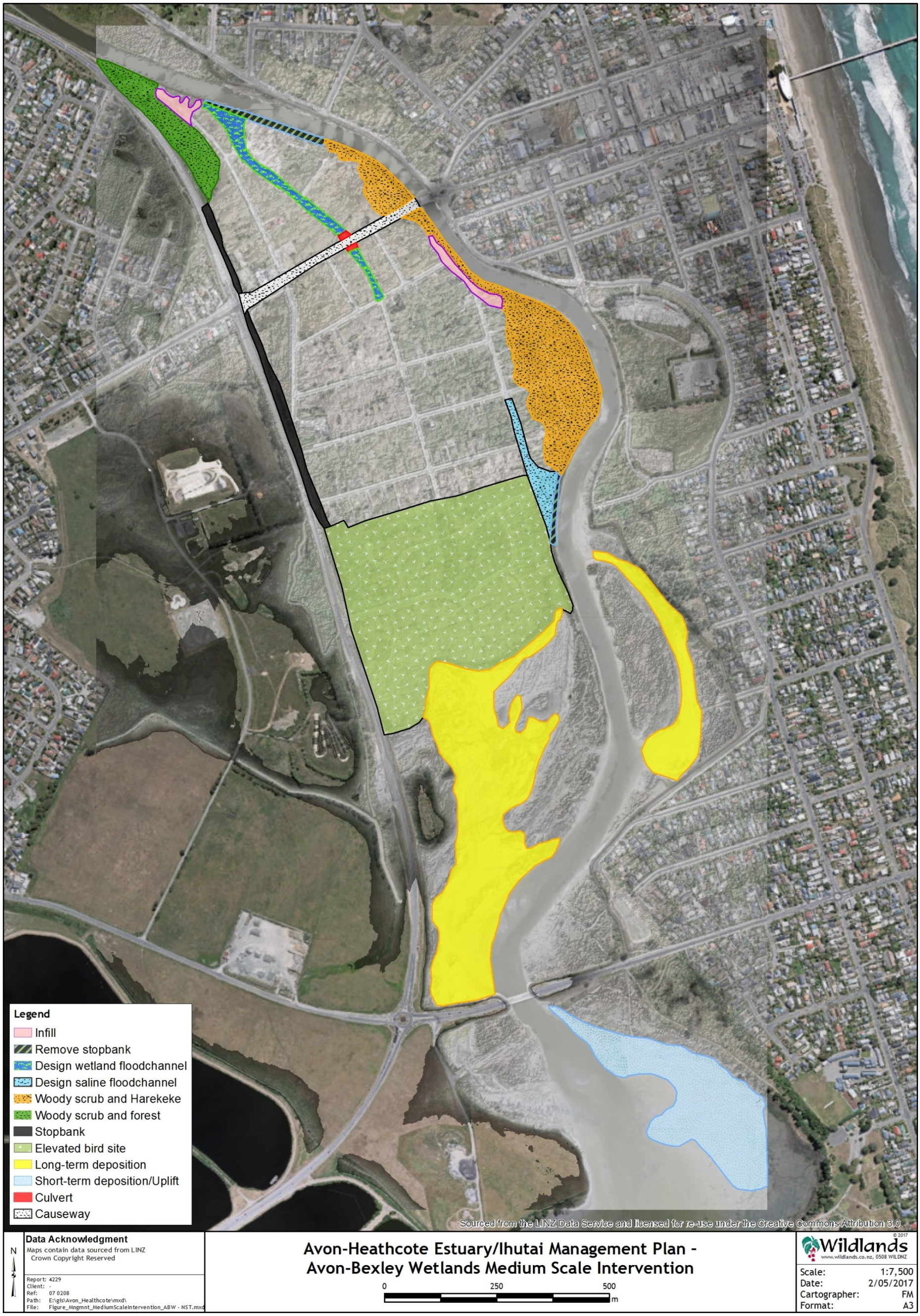

Figure 12: Predicted outcomes and deposition rates of medium scale intervention in the lower Avon River/Ōtākaro wetlands.

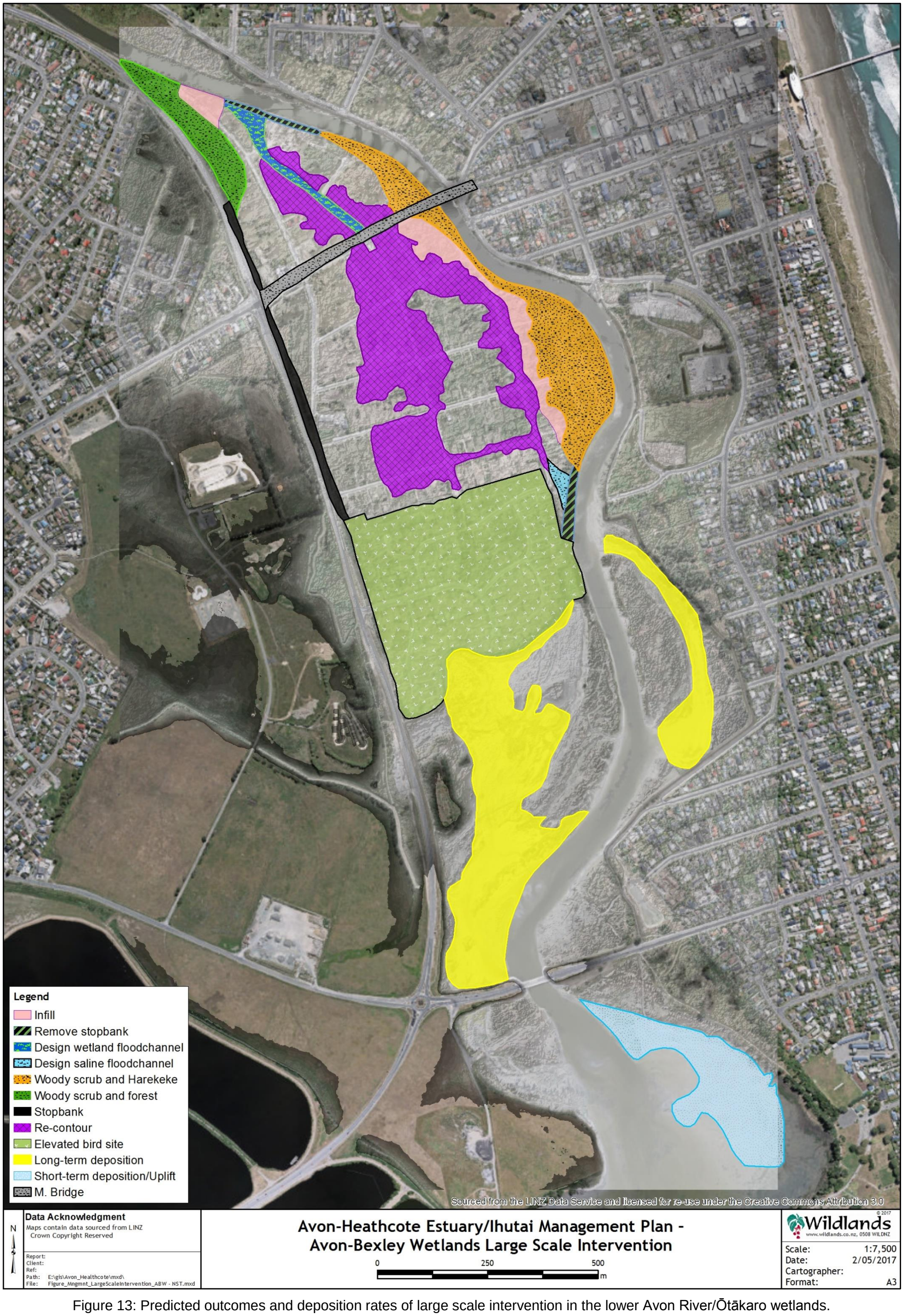

Figure 13: Predicted outcomes and deposition rates of large scale intervention in the lower Avon River/Ōtākaro wetlands.

6.2.4 Southshore and South New Brighton Estuary margin

Opportunities exist for ecological restoration on residential Red Zone land between Southshore and the Estuary margin. Land should be recontoured to obtain suitable gradients between the intertidal mudflats and dryer terrestrial habitats, to establish a sequence of vegetation types from saltmarsh to coastal forest. If suitable tidal flow and saline conditions are created, saltmarsh vegetation will regenerate naturally. Above the saltmarsh zone, on terrestrial sites, restoration plantings will be necessary to establish coastal forest. Engineering solutions may be required at some locations to protect land vulnerable to wave action and erosion.

A significant area of saltmarsh is already present near the South Brighton Motor Camp (Jellico Saltmarsh). This saltmarsh vegetation can be enhanced by undertaking two actions:

- Replace the existing boardwalk with a new boardwalk that allows tidal flows through it, allowing the existing sea rush and saltmarsh herbfield to respond to natural saline conditions.
- Eradicate pest plants from the site to minimise competition with saltmarsh vegetation.

Raupō Bay (Figure 1) has a natural stand of raupō and harakeke, because freshwater springs are present there. The condition of the raupō and harakeke has deteriorated since the earthquakes, due to subsidence reducing freshwater at the site. Raupō and harakeke could be enhanced at this site by ensuring a reliable freshwater supply.

6.2.5 Lower Heathcote River/Ōpāwaho

Ecological management and restoration of the Lower-Heathcote River/Ōpāwaho area should address the following:

- Develop and implement a restoration plan for native musk that will ensure the survival of the existing native musk herbfield and the establishment of new sites.
- Protect existing saltmarsh vegetation from weed incursion. For example, continue the programme to eradicate sea lavender from this area.

6.2.6 McCormacks Bay

This area has been heavily affected by uplift and reduction of the tidal prism, and the small stream has become filled with liquefaction material. The best option for McCormacks Bay is to leave natural ecological processes to run their course; otherwise restoration would require major earthworks and these may not be sustainable. Vegetation change is naturally occurring in the area, with for example seagrass (*Zostera muelleri* subsp. *novozelandica*) becoming established.

6.3 Indigenous revegetation

Ecological restoration plantings should mimic indigenous plant communities that would have been found in the Estuary prior to human disturbance, and plant stock

should be grown from seed that is sourced locally (Appendices 1, 2 and 3). When strongly saline tidal conditions are present, and substrate levels are suitable, saltmarsh vegetation will regenerate naturally (Partridge *et al.* 1999), but other vegetation types will need site-specific detailed restoration plans. Major vegetation types that can be restored are:

- Saltmarsh herbfield

  When conditions are suitable, saltmarsh vegetation will replace introduced broad-leaved weeds and grasses intolerant of saline conditions (Partridge and Wilson 1987). However, saltmarsh declines in the Estuary may be related to increases in sediment from the rivers and reduced wave energy (see Sections 5.2 and 5.3). Research is therefore required to better understand how to appropriately restore saltmarsh habitat under these sedimentation scenarios. Glasswort is known to readily colonise new substrate and to have good dispersal mechanisms (Cochran *et al.* 2014), so it may not necessarily be a good indicator of healthy and diverse saltmarsh vegetation.

- Native musk herbfield

  Native musk is a mat-forming succulent perennial herb that is found in wet brackish depressions behind saltmarshes, in permanently damp or soggy, saline mud or silt soils that are flooded periodically during spring or tides. Native musk cannot compete with more salt-tolerant herbs, taller plants, or other mat-forming species. Restoration of native musk herbfield requires:

  - Suitable brackish wetland habitats.
  - Control of competing vegetation, including indigenous species if necessary.
  - Establishment of saturated soils.

- Three-square, sea rush, and oioi rushland

  These species can establish naturally where there is sufficient tidal flow and, if necessary, populations can be enhanced through restoration plantings. Sea rush should be planted where regular inundation occurs, and oioi higher on the bank where it will only occasionally be inundated. Three-square is a difficult species to establish using restoration plantings (Partridge *et al.* 1999).

- Harakeke swamp

  Restoration plantings to accompany harakeke should include a range of sedges (e.g. *Carex secta* and *C. virgata*) and rushes (e.g. *Juncus edgariae, J. pallidus*), along with ferns (e.g. *Blechnum minus*), creeping herbs (e.g. *Ranunculus* and *Hydrocotyle* species), climbing nettle species (e.g. *Urtica perconfusa*; At Risk-Declining, de Lange *et al.* 2018).

- Coastal ribbonwood shrubland

  Brackish conditions support coastal ribbonwood, which is increasing naturally as saltmarsh herbfield is drying out due to sedimentation and uplift from the

Canterbury Earthquake Sequence. Coastal ribbonwood is a poor competitor when growing in association with introduced grasses and other weeds, and requires active management to become established as part of restoration plantings (Partridge *et al.* 1999).

- Coastal forest

  Coastal forest was not present around the Estuary in the 1800s, based on the Black Maps of 1856. However, establishment of some coastal forest would provide high tide roosts for bird species, particularly as sea level rises and vegetation changes to reflect that. Suitable species would include five finger (*Pseudopanax arboreus*), akeake (*Dodonea viscosa*), ngaio (*Myoporum laetum*), kāpuka/broadleaf (*Griselinia littoralis*), karamū (*Coprosma robusta*), koromiko (*Hebe salicifolia*), mikimiki (*Coprosma propinqua*, *C. rubra*, and *C. areolata*), and kōhūhū (*Pittosporum tenuifolium*).

- Mānuka scrub

  Mānuka was present in the Black Maps of 1856, and should be considered for restoration plantings in elevated terrestrial areas. Mānuka stands can collapse after 10-15 years, so other species will also need to be planted. Mānuka could also be planted in the coastal forest mix described above.

- Kahikatea swamp forest

  Restoration of kahikatea swamp forest in suitable habitat on the Estuary margin is an aspiration of Te Ngāi Tūāhuriri Rūnunga (Lobb 2009). Linwood Paddocks would be an ideal site, in association with the interventions described in Section 6.2.1.

7. Further investigation and education

The following research and education priorities will assist with ecological management of the Estuary:

7.1 Sea level change and resilience

Predictive modelling of sea level change and sedimentation processes should be undertaken, to understand how restored ecosystems will interact with these changes.

7.2 Decline of saltmarsh herbfield

Investigate reasons for the decline of saltmarsh herbfield, native musk herbfield and native primrose herbfield, and establish best practice guidelines for their restoration.

7.3 Success of ecological restoration plantings

Undertake a review of the success and failure of ecological restoration plantings at saline locations within the Estuary, to inform best practice.

7.4 Review of ecological restoration in Charlesworth Reserve

Review the Charlesworth Reserve restoration project. This is a significant project and key learnings could be applied here and to other restoration projects within the Estuary and elsewhere.

7.5 Population viability analyses of At Risk bird species

Population viability analyses should be undertaken for At Risk bird species to predict the probability of their populations surviving in the Estuary and which factors are most important for their survival.

7.6 Research into avian disease

Research the threat and management of diseases such as avian botulism to birds inhabiting the Estuary.

7.7 Minimum disturbance distances for nesting and roosting birds

Research is needed into the distances that need to be maintained between public activity and nesting and roosting birds, to avoid disturbance. This will help to inform the design of pathways and other public facilities.

7.8 Predation of nesting, roosting and foraging birds

Carefully designed camera-trap studies should be used to establish which predators are having the greatest effects on resident bird populations. This research would be used to design more effective pest control.

7.9 Nocturnal predator activity at low tide

It is possible that predators hunt birds roosting or feeding on intertidal mudflats at night, when the tide is low. Camera-trap surveillance could be used to evaluate this.

7.10 Activity patterns of domestic cats

Given the substantial number of domestic cats living in close proximity, research similar to Morgan (2002) and Metsers *et al.* (2010) should be undertaken, to understand their spatial ecology and role as predators of estuary birds.

7.11 Involvement of tertiary education institutions

The longstanding and strong research connection between the University of Canterbury, Lincoln University, and Ara (formerly CPIT) should be maintained and fostered.

7.12 Involvement of schools in Estuary projects

As part of the Trust's wider public engagement strategy, opportunities for involving schools in the Estuary conservation and restoration should be sought, e.g. classroom participation in planting days, bird counts, rubbish collection. Perhaps a children's 'Avon-Heathcote Estuary/Ihutai Conservation Club' could be established, or patches/areas of interest could be allocated to nearby schools for them to care for and restore.

8. Monitoring and surveillance

The following monitoring and surveillance is necessary for ongoing ecological management of the Estuary:

8.1 Long-term changes resulting from the Canterbury Earthquake Sequence

Sedimentation within the Estuary should be monitored to provide better understanding of the long-term accumulation patterns following the Christchurch Earthquake Sequence.

8.2 Indigenous vegetation

Previous monitoring has provided important information on changes in indigenous plant communities. However, vegetation monitoring should be ongoing, and undertaken at more regular 4-5 year intervals, given the dynamic changes happening to the saltmarsh ecosystem. It should use a repeatable methodology, and include all of the sites in previous monitoring as well as new areas where saltmarsh has established, and should address all vegetation types present.

Declining species, such as native musk, should be monitored annually to ensure that conservation status and management are aligned.

8.3 Pest plant control and monitoring

Annual surveillance for pest plants should be undertaken throughout the entire project area, and an incursion response developed. Targeted monitoring should also occur at sites where pest plant control has occurred previously, to check for reinfestations.

8.4 Pest animals

Pest animal monitoring using methods which provide indices of abundance - such as tracking tunnels, WaxTags, and chew cards - should be used to determine whether predator control is reducing predator abundance within the project area. Monitoring of the breeding productivity of birds should also be undertaken, to determine whether levels of predator control are benefiting birds.

A surveillance and incursion response plan needs to be developed for marine pest animals that are already in Canterbury, such as Mediterranean fanworm (*Sabella spallanzanii*) and leathery sea squirt (*Styela clava*), which have the potential to establish in the Estuary.

8.5 Water quality monitoring

Water quality should continue to be monitored on a regular basis, to inform understanding of ecosystem health and human health. This data should continue to be publicly-available, so that people can understand where it is safe to carry out recreational activities. Monitoring data could be used to identify areas of poor water quality that require specific management.

8.6 Fish and shellfish monitoring

Monitoring of fish populations should be ongoing and undertaken every two to three years. Methodologies should be consistent with previous studies, to allow long-term comparison of data.

Monitoring of shellfish contamination should continue, so that toxin levels can be assessed to determine whether or not they are suitable for food harvesting. Population monitoring should also be undertaken every two to three years. The methodology used should be consistent with previous population monitoring, allowing for the adaptive management of local harvest restrictions.

8.7 Monitoring of cultural health

Cultural monitoring and reporting should be undertaken every five years, to provide information on the extent of progress towards overcoming the issues and achieving the outcomes identified in Section 5.8. For consistency, and to generate comparable longitudinal data, cultural monitoring should be undertaken at the same 31 sites as Lang *et al.* (2012), using the same methods.

8.8 Annual bird counts

Annual bird counts should be undertaken in a consistent manner, at a time of year when most migratory species are present, e.g. February. An annual census, similar to that used by the Waihora Ellesmere Trust, could be adopted. This would involve groups of volunteers, with a skilled team leader, covering off separate sections of the Estuary within a single day. Organisations like the Ornithological Society of New Zealand may be able to help, along with the Christchurch City Council and Department of Conservation.

8.9 Pest Management Plan

Animal and plant pest control, monitoring, surveillance and incursion response should be part of an overall Avon-Heathcote Estuary/Ihutai Pest Management Plan. This would be a multiagency collaboration between the Trust and partners such as Christchurch City Council, Environment Canterbury, Department of Conservation and the Ministry for Primary Industries. The Plan should cover terrestrial, freshwater and marine ecosystems.

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Appendix 1: Wetland classification and broad vegetation types

A semi-hierarchical wetland classification system was developed by Johnson and Gerbeaux (2004). Applying these criteria, wetland vegetation associated with the Estuary is defined as follows:

- Level I Hydrosystem

  The Estuary is defined as an estuarine hydrosystem, encompassing areas partly enclosed by land but open to the sea, tidal effects and tidal reaches where soil water is affected by sea salts, and salinity is 5-35 parts per thousand. Dominant functions are the mixing of freshwater and seawater and tidal fluctuation. The inland limit of estuarine hydrosystems occurs where salinity reaches a dilution of five parts per thousand marine salt concentration (Clarkson *et al.* 2003). An estuarine hydrosystem includes all areas of subtidal and intertidal zones in estuaries and wet ground in supratidal zones where surface water and ground water receive saline concentrations from wave splash or sea spray.

- Level II Wetland Class

  Saltmarsh vegetation is present on margins, as defined by substrate, water regime, and nutrients. The prevalence of tidal fluctuation is a predominant factor, but other defining features include the influence of tidal water, surface water being slight or tidal and persisting above or near ground level for most of the year, and there is no peat accumulation although layers of organic material and a mix of mineral and organic material may be present. This wetland class includes a range of vegetation types typical of the intertidal zone such as non-vegetated mudflats, saltmarsh herbfield, rushland, and scrub, all of these occur in the Estuary.

  Other features of the saltmarsh vegetation class include moderate to slow water flow, good drainage, water table closely below surface, tidal water fluctuation, a mainly mineral substrate, moderate nutrient status, and pH ranging from 4.9-8.0.

- Level III Structural Class

  This includes seagrass meadow, turf, herbfield, rushland, and scrub.

- Level IV Dominant Vegetation and Key Indicator Plants

  Dominant plant species and vegetation types are seagrass in seagrass meadows, glasswort and native primrose in saltmarsh herbfield, oioi, and sea rush in rushlands, and coastal ribbonwood in coastal shrubland.

Hydrosystem types in New Zealand have also been defined by Hume *et al*. (2016) who provide a key and description. The classes and their subclasses of Hume *et al*. (2016) are discriminated by their landscape and waterscape characteristics, such as geology, geomorphology and hydrodynamic characteristics arising from river and oceanic forcing and basin morphometry. Based on Hume *et al*. (2016) the Estuary can be defined as:

- Level 1 Global: Temperate Australasian Realm.
- Level 2 Hydrosystem: Estuarine.

- Level 3 Geomorphic class: 7A, Tidal lagoon, permanently open.
- Level 4 Tidal Regime: mostly intertidal.

Features of a permanently open tidal lagoon (Geomorphic class 7A) include: shallow (mean depth 1-3 metres), circular to elongate basins with simple (not dendritic) shorelines and extensive intertidal area; a narrow entrance to the sea, constricted by a spit or sand barrier; ebb and flood tidal delta sand bodies form in the sea and bay sides of the entrance; strong reversing tidal currents flow through the entrance; and the tidal prism makes up a large proportion of the total basin volume.

Appendix 2: Vegetation type descriptions

Type 1: Oioi rushland

Predominantly oioi, but often associated with sea rush and/or coastal ribbonwood.

Type 2: Sea rush rushland

Predominantly sea rush, but coastal ribbonwood is present at some sites.

Type 3: Saltmarsh herbfield

Comprising a diversity of saltmarsh herbs and some larger plants, glasswort is the most common species, along with buck's horn plantain, orache (*Atriplex prostrata*), native primrose, salt grass (*Puccinellia stricta*) and selliera. Taller plants of oioi, coastal ribbonwood and sea rush are also sometimes found.

Type 4: Couch grassland

This vegetation type occurs in the upper marsh zone and comprises thick swards of couch. Remnant sea rush is sometimes found and creeping bent is also common.

Type 5: Tall fescue and coastal ribbonwood

Upper marsh vegetation comprising a mix of exotic tall fescue and coastal ribbonwood, with harakeke, couch and taupata (*Coprosma repens*).

Type 6: Three-square sedgeland

Three-square dominates this vegetation type. Raupō and tall fescue also occur at Raupō Bay in a palustrine spring fed freshwater wetland on the Estuary margin.

Type 7: Coastal ribbonwood shrubland

Coastal ribbonwood occurs with few associated saltmarsh species. However, the exotic pest plant reed canary grass has often colonised these sites. This vegetation type was not recorded by McCombs and Partridge (1992), and has appeared as a novel type.

Type 8: Native musk herbfield

This vegetation type is similar to the saltmarsh herbfield (Type 3) but native musk is present instead of other more salt tolerant herbs such as glasswort sea blite and Bachelors button (*Cotula coronopifolia*). Native musk indicates brackish conditions. Native musk herbfield has almost disappeared from the Estuary, with its distribution declining from 5 percent of the sites recorded by McCombs and Partridge (1992) to a mere 0.5 percent of the 2007 sites. It has been replaced by oioi rushland (Type 1).

Native musk was recorded in low numbers (1-5 percent) at a number of sites in the Avon River/Ōtākaro and Bexley wetlands by Campbell *et al*. (2013). In a saltmarsh vegetation survey undertaken in 2015 (P. Grove and M. Parker, Environment Canterbury, pers. comm., 5 April 2017), native musk was recorded at 14 sites in the lower Heathcote River/Ōpāwaho. Only one of

these sites occurs in the project area, on a sparsely vegetated mudflat. The other 13 sites are just outside the project boundary, and only two of these sites are defined as native musk herbfield. The vegetation at these sites are categorised as:

- Mudflat, sparsely vegetated with saltmarsh species (one site).
- *Bolboschoenus caldwellii* with exotic grasses (one site).
- Native musk herbfield (two sites).
- Oioi and saltmarsh herbfield (two sites).
- Glasswort and native musk herbfield (four sites).
- Coastal ribbonwood with exotic grasses (five sites).

Type 9: Native primrose herbfield

This rather depauperate and rare vegetation type is characterised by the presence of native primrose, without its normal saltmarsh associates. It was present during the 1992 survey, but in 2007 most of these sites were found to have other saltmarsh species such as sea spurrey and New Zealand celery.

Type 10: Plantain and rye grass herbfield

The presence of buck's horn plantain and ryegrass indicates disturbed sites, often where soil has been dumped onto the saltmarsh.

Type 11: Seagrass mudflat

Seagrass is a marine species found in the Estuary as a sward below, but sometimes within, the saltmarsh zone. Three sites recorded in McCombs and Partridge (1992) no longer have seagrass present, with two sites colonised by other saltmarsh vegetation e.g. rush or three-square.

Seagrass was abundant in the early 20th century, but declined over the next four or five decades. In the 1970s to 1990s populations increased irregularly, and declined between 2002 and 2005 (Marsden & Knox 2008). December 2015 mapping of seagrass within the Estuary showed seagrass mainly occurring on the eastern side of the Estuary (Gibson and Marsden 2016). Since the last seagrass survey in 2003, the main seagrass bed has increased from 0.29 km^2 to 0.52 km^2 expanding in the eastern and northern Estuary. A new seagrass area was located within McCormack's Bay. This consisted of small isolated patches on the north-eastern edge of the Bay near the causeway.

Type 12: *Coprosma propinqua* shrubland

This is a freshwater wetland with the shrub mikimiki (*Coprosma propinqua)*, raupō, and the sedge *Schoenoplectus vallidus*. Sites present in the 1992 survey were no longer present in 2007 and have been replaced by three-square sedgeland (Type 6), suggesting that the area has been eroded with new vegetation establishing on the resultant mudflats.

Appendix 3: Indigenous and exotic plant species recorded in the Estuary

Conservation status follows de Lange *et al.* (2018).

Common Name	Scientific Name	Conservation Status	Citation Source
Indigenous			
Arrow grass	*Triglochin striata*	Not Threatened	McCombs & Partridge 1992
Bachelors button	*Cotula coronopifolia*	Not Threatened	McCombs & Partridge 1992
Bracken	*Pteridium esculentum*	Not Threatened	McCombs & Partridge 1992
Cabbage tree	*Cordyline australis*	Not Threatened	McCombs & Partridge 1992
Coastal ribbonwood	*Plagianthus divaricatus*	Not Threatened	McCombs & Partridge 1992
Danthonia	*Rytidosperma* sp.	Not Threatened	McCombs & Partridge 1992
Duckweed	*Lemna minor*	Not Threatened	McCombs & Partridge 1992
Five finger	*Pseudopanax arboreus*	Not Threatened	McCombs & Partridge 1992
Glasswort	*Sarcocornia quinqueflora*	Not Threatened	McCombs & Partridge 1992
Glossy karamū	*Coprosma lucida*	Not Threatened	McCombs & Partridge 1992
Harakeke	*Phormium tenax*	Not Threatened	McCombs & Partridge 1992
Horse's mane weed	*Ruppia megacarpa*	At Risk-Naturally Uncommon	McCombs & Partridge 1992
Horse's mane weed	*Ruppia polycarpa*	Not Threatened	McCombs & Partridge 1992
Hounds tongue fern	*Microsorum pustulatum*	Not Threatened	McCombs & Partridge 1992
Knobby clubrush	*Ficinia nodosa*	Not Threatened	McCombs & Partridge 1992
Kiokio	*Blechnum* sp.	Not Threatened	McCombs & Partridge 1992
Lake club rush	*Schoenoplectus tabernaemontani*	Not Threatened	McCombs & Partridge 1992
Leptinella	*Leptinella dioca*	Not Threatened	McCombs & Partridge 1992
Lilaeopsis	*Lilaeopsis novae-zelandiae*	Not Threatened	McCombs & Partridge 1992
Māakoako, sea primrose	*Samolus repens*	Not Threatened	McCombs & Partridge 1992
Mingimingi	*Coprosma propinqua* subsp. *propinqua*	Not Threatened	Jupp *et al.* 2007
Mukura	*Carex secta*	Not Threatened	McCombs & Partridge 1992
Native musk	*Thyridia repens*	At Risk-Naturally Uncommon	McCombs & Partridge 1992
Ngaio	*Myoporum laetum*	Not Threatened	McCombs & Partridge 1992
Oioi	*Apodasmia similis*	Not Threatened	McCombs & Partridge 1992
Oranche	*Atriplex prostrata*	Not Threatened	McCombs & Partridge 1992
Pōhuehue	*Muehlenbeckia complexa*	Not Threatened	McCombs & Partridge 1992
Purua grass	*Bolboschoenus caldwellii*	Not Threatened	McCombs & Partridge 1992
Raupō	*Typha orientalis*	Not Threatened	McCombs & Partridge 1992
Remuremu, selliera	*Selliera radicans*	Not Threatened	McCombs & Partridge 1992
Retoreto	*Azolla rubra*	Not Threatened	McCombs & Partridge 1992
Rush	*Juncus pallidus*	Not Threatened	McCombs & Partridge 1992
Salt grass	*Puccinellia stricta*	Not Threatened	McCombs & Partridge 1992
Sea blite	*Suaeda novae-zelandiae*	Not Threatened	McCombs & Partridge 1992
Sea grass	*Zostera muelleri* subsp. *novazelandica*	At Risk-Declining	McCombs & Partridge 1992
Sea rush	*Juncus kraussii* var. *australiensis*	Not Threatened	McCombs & Partridge 1992
Sea spurrey	*Spergularia media*	Not Threatened	McCombs & Partridge 1992
Sedge	*Carex maorica*	Not Threatened	McCombs & Partridge 1992
Shore convolvulus	*Calystegia soldanella*	Not Threatened	McCombs & Partridge 1992
Shore parsley	*Apium prostratum*	Not Threatened	McCombs & Partridge 1992
Silver tussock	*Poa cita*	Not Threatened	McCombs & Partridge 1992
Slender club rush	*Isolepis cernua*	Not Threatened	McCombs & Partridge 1992
Spike sedge	*Eleocharis acuta*	Not Threatened	McCombs & Partridge 1992
Taupata	*Coprosma repens*	Not Threatened	McCombs & Partridge 1992
Three-square	*Schoenoplectus pungens*	Not Threatened	McCombs & Partridge 1992
Toetoe	*Austroderia richardii*	Not Threatened	McCombs & Partridge 1992

Common Name	Scientific Name	Conservation Status	Citation Source
Exotic			
Annual poa	*Poa annua*	Introduced and Naturalised	McCombs & Partridge 1992
Australian ngaio	*Myoporum insulare*	Introduced and Naturalised	McCombs & Partridge 1992
Barley grass	*Hordeum murinum*	Introduced and Naturalised	McCombs & Partridge 1992
Blackberry	*Rubus fruticosus*	Introduced and Naturalised	McCombs & Partridge 1992
Bone seed	*Chrysanthemoides monilifera*	Introduced and Naturalised	McCombs & Partridge 1992
Box thorn	*Lycium ferocissimum*	Introduced and Naturalised	McCombs & Partridge 1992
Broad-leaved dock	*Rumex obtusifolius*	Introduced and Naturalised	McCombs & Partridge 1992
Broom	*Cytisus scoparius*	Introduced and Naturalised	McCombs & Partridge 1992
Browntop	*Agrostis capillaris*	Introduced and Naturalised	McCombs & Partridge 1992
Bucks horn plantain	*Plantago coronopus*	Introduced and Naturalised	McCombs & Partridge 1992
Cape weed	*Arctotis calendula*	Introduced and Naturalised	McCombs & Partridge 1992
Catsear	*Hypochaeris radicata*	Introduced and Naturalised	McCombs & Partridge 1992
Celery leaved buttercup	*Ranunculus sceleratus*	Introduced and Naturalised	McCombs & Partridge 1992
Chewings fescue	*Festuca rubra*	Introduced and Naturalised	McCombs & Partridge 1992
Chickweed	*Stellaria media*	Introduced and Naturalised	McCombs & Partridge 1992
Cleavers	*Galium aparine*	Introduced and Naturalised	McCombs & Partridge 1992
Cocksfoot	*Dactylis glomerata*	Introduced and Naturalised	McCombs & Partridge 1992
Cord grass	*Spartina anglica*	Introduced and Naturalised	McCombs & Partridge 1992
Couch	*Elytrigia repens*	Introduced and Naturalised	McCombs & Partridge 1992
Creeping bent	*Agrostis stolonifera*	Introduced and Naturalised	McCombs & Partridge 1992
Creeping buttercup	*Ranunculus repens*	Introduced and Naturalised	McCombs & Partridge 1992
Curled dock	*Rumex crispus*	Introduced and Naturalised	McCombs & Partridge 1992
Drooping brome	*Bromus tectorum*	Introduced and Naturalised	McCombs & Partridge 1992
Dwarf mallow	*Malva neglecta*	Introduced and Naturalised	McCombs & Partridge 1992
Dwarf mellow	*Malva sylvestris*	Introduced and Naturalised	Jupp *et al.* 2007
Elder	*Sambucus nigra*	Introduced and Naturalised	McCombs & Partridge 1992
Goose grass	*Bromus hordeaceus*	Introduced and Naturalised	McCombs & Partridge 1992
Gorse	*Ulex europaeus*	Introduced and Naturalised	McCombs & Partridge 1992
Grey willow	*Salix cinerea*	Introduced and Naturalised	McCombs & Partridge 1992
Groundsel	*Senecio vulgaris*	Introduced and Naturalised	McCombs & Partridge 1992

Common Name	Scientific Name	Conservation Status	Citation Source
Haresfoot trefoil	*Trifolium arvense*	Introduced and Naturalised	McCombs & Partridge 1992
Hawksbeard	*Crepis capillaris*	Introduced and Naturalised	McCombs & Partridge 1992
Hedge mustard	*Sisymbrium officinale*	Introduced and Naturalised	McCombs & Partridge 1992
Ice plant	*Carpobrotus aequilaterus*	Introduced and Naturalised	McCombs & Partridge 1992
Ice plant	*Carpobrotus edulis*	Introduced and Naturalised	McCombs & Partridge 1992
Ivy	*Hedera helix*	Introduced and Naturalised	McCombs & Partridge 1992
Jointed rush	*Juncus articulatus*	Introduced and Naturalised	McCombs & Partridge 1992
Meadow grass	*Poa pratensis*	Introduced and Naturalised	McCombs & Partridge 1992
Monkey musk	*Erythranthe guttata*	Introduced and Naturalised	McCombs & Partridge 1992
Monterey pine	*Pinus radiata*	Introduced and Naturalised	McCombs & Partridge 1992
Montpellier broom	*Genista monspessulana*	Introduced and Naturalised	McCombs & Partridge 1992
Mudwort	*Callitriche stagnalis*	Introduced and Naturalised	McCombs & Partridge 1992
Narrow leaved plantain	*Plantago lanceolata*	Introduced and Naturalised	McCombs & Partridge 1992
Oriental mustard	*Sisymbrium orientale*	Introduced and Naturalised	McCombs & Partridge 1992
Peppercress	*Lepidium africanum*	Introduced and Naturalised	McCombs & Partridge 1992
Prairie grass	*Bromus willdenowii*	Introduced and Naturalised	McCombs & Partridge 1992
Rayless chamomile	*Matricaria matricarioides*	Introduced and Naturalised	McCombs & Partridge 1992
Red clover	*Trifolium pratense*	Introduced and Naturalised	McCombs & Partridge 1992
Reed canary grass	*Phalaris arundinacea*	Introduced and Naturalised	Jupp *et al.* 2007
Rye grass	*Lolium perenne*	Introduced and Naturalised	McCombs & Partridge 1992
Salt barley grass	*Hordeum marinum*	Introduced and Naturalised	McCombs & Partridge 1992
Sea lavender	*Limonium companyonis*	Introduced and Naturalised	Heenan *et al.* (1999)
Sheeps sorrel	*Rumex acetosella*	Introduced and Naturalised	McCombs & Partridge 1992
Sickle grass	*Parapholis incurva*	Introduced and Naturalised	McCombs & Partridge 1992
Silverbeet	*Beta vulgaris*	Introduced and Naturalised	McCombs & Partridge 1992
Soft rush	*Juncus effusus*	Introduced and Naturalised	McCombs & Partridge 1992
Sour thistle, puha	*Sonchus oleraceus*	Introduced and Naturalised	McCombs & Partridge 1992
Speedwell	*Veronica sp.*	Introduced and Naturalised	McCombs & Partridge 1992
Stinking iris	*Iris foetidissima*	Introduced and Naturalised	Jupp *et al.* 2007
Strawberry clover	*Trifolium fragiferum*	Introduced and Naturalised	McCombs & Partridge 1992
Suckling clover	*Trifolium dubium*	Introduced and Naturalised	McCombs & Partridge 1992

Common Name	Scientific Name	Conservation Status	Citation Source
Tagasaste	*Chamaecytisus palmensis*	Introduced and Naturalised	McCombs & Partridge 1992
Tall fescue	*Festuca arundinacea*	Introduced and Naturalised	McCombs & Partridge 1992
Tarweed	*Parentucellia viscosa*	Introduced and Naturalised	McCombs & Partridge 1992
Timothy	*Phleum pratense*	Introduced and Naturalised	McCombs & Partridge 1992
Toad rush	*Juncus bufonius*	Introduced and Naturalised	McCombs & Partridge 1992
Tree lupin	*Lupinus arboreus*	Introduced and Naturalised	McCombs & Partridge 1992
Tree mallow	*Lavatera arborea*	Introduced and Naturalised	McCombs & Partridge 1992
Twin cress	*Lepidium didymus*	Introduced and Naturalised	McCombs & Partridge 1992
Vetch	*Vicia sativa*	Introduced and Naturalised	McCombs & Partridge 1992
Watercress	*Rorippa microphyllum*	Introduced and Naturalised	McCombs & Partridge 1992
White clover	*Trifolium repens*	Introduced and Naturalised	McCombs & Partridge 1992
Willowherb	*Epilobium* sp.	Introduced and Naturalised	McCombs & Partridge 1992
Yarrow	*Achillea millefolium*	Introduced and Naturalised	McCombs & Partridge 1992
Yellow flag	*Iris pseudacorus*	Introduced and Naturalised	McCombs & Partridge 1992
Yorkshire fog	*Holcus lanatus*	Introduced and Naturalised	McCombs & Partridge 1992

Appendix 4: Bird species recorded in the Estuary

Table A: Bird species recorded in the Estuary (Crossland 1993, 2013). Conservation status and common and scientific names follow Robertson *et al*. (2017).

Common Name	Species Name	Māori Name	National Conservation Status	IUCN Red List Classification	Status at Avon-Heathcote
Northern giant petrel	*Macronectes halli*	Pāngurunguru	At Risk-Recovering	Least Concern	Vagrant
Sooty shearwater	*Puffinus griseus*	Tītī	At Risk-Declining	Near Threatened	Vagrant
Hutton's shearwater	*Puffinus huttoni*		Threatened-Nationally Vulnerable	Endangered	Vagrant
Common diving petrel	*Pelecanoides urinatrix*	Kuaka	At Risk-Relict	Least Concern	Vagrant
Fairy prion	*Pachyptila turtur*	Tītī wainui	At Risk-Relict	Least Concern	Vagrant
Australasian gannet	*Morus serrator*	Tākapu	Not Threatened	Least Concern	Seasonal
Black swan	*Cygnus atratus*	Kakīānau	Not Threatened	Least Concern	Breeding, seasonal
Mute swan	*Cygnus olor*		Introduced and Naturalised	Least Concern	Vagrant
Canada goose	*Branta canadensis*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Grey duck	*Anas superciliosa superciliosa*	Pārera	Threatened-Nationally Critical	Least Concern	Seasonal
Feral (greylag) goose	*Anser anser*		Introduced and Naturalised	Least Concern	Breeding
Cape Barren goose	*Cereopsis novaehollandiae*		Introduced and Naturalised	Least Concern	Vagrant
Paradise shelduck	*Tadorna variegata*		Not Threatened	Least Concern	Breeding, seasonal
Mallard or hybrid mallard/grey duck	*Anas platyrhynchos*		Introduced and Naturalised	Least Concern	Breeding, seasonal
New Zealand shoveler	*Anas rhynchotis*		Not Threatened	Least Concern	Breeding, seasonal
Chestnut teal	*Anas castanea*		Vagrant	Least Concern	Vagrant
Grey teal	*Anas gracilis*		Not Threatened	Least Concern	Breeding, seasonal
New Zealand scaup/pāpango	*Aythya novaeseelandiae*	Pāpango	Not Threatened	Least Concern	Breeding, seasonal
Chestnut-breasted shelduck	*Tadorna tadornoides*		Vagrant	Least Concern	Vagrant
Australian wood duck	*Chenonetta jubata*		Coloniser	Least Concern	Vagrant
Chestnut teal	*Anas castanea*		Vagrant	Least Concern	Vagrant
Brown teal	*Anas chlorotis*		At Risk-Recovering	Near Threatened	Vagrant
Australian white-eyed duck	*Aythya australis*		Vagrant	Least Concern	Vagrant
Southern crested grebe	*Podiceps cristatus australis*		Threatened-Nationally Vulnerable	Least Concern	Vagrant
Hoary-headed grebe	*Poliocephalus poliocephalus*		Vagrant	Least Concern	Vagrant
Australasian little grebe	*Tachybaptus novaehollandiae novaehollandiae*		Coloniser	Least Concern	Vagrant

Common Name	Species Name	Māori Name	National Conservation Status	IUCN Red List Classification	Status at Avon-Heathcote
White-flippered penguin	*Eudyptula minor albosignata*		At Risk-Declining	Least Concern	Breeding
Yellow-eyed penguin	*Megadyptes antipodes*		Threatened-Nationally Endangered	Endangered	Vagrant
Southern blue penguin	*Eudyptula minor minor*		At Risk-Declining	Least Concern	Vagrant
Eastern rockhopper penguin	*Eudyptes filholi*		Threatened-Nationally Vulnerable	Vulnerable	Vagrant
Fiordland crested penguin	*Eudyptes pachyrhynchus*		Threatened-Nationally Vulnerable	Vulnerable	Vagrant
Erect-crested penguin	*Eudyptes sclateri*		At Risk-Declining	Endangered	Vagrant
Black shag	*Phalacrocorax carbo novaehollandiae*		At Risk-Naturally Uncommon	Least Concern	Breeding
Pied shag	*Phalacrocorax varius varius*		At Risk-Recovering	Least Concern	Breeding
Little shag	*Phalacrocorax melanoleucos brevirostris*		Not Threatened	Least Concern	Breeding
Little black shag	*Phalacrocorax sulcirostris*		At Risk-Naturally Uncommon	Least Concern	Breeding
Spotted shag	*Stictocarbo punctatus punctatus*		Not Threatened	Least Concern	Breeding
White-faced heron	*Egretta novaehollandiae*		Not Threatened	Least Concern	Breeding, seasonal
White heron/kōtuku	*Ardea modesta*	Kōtuku	Threatened-Nationally Critical	Least Concern	Seasonal
Little egret	*Egretta garzetta immaculata*		Vagrant	Least Concern	Seasonal
Eastern cattle egret	*Ardea ibis coromanda*		Migrant	Least Concern	Seasonal
Intermediate egret	*Ardea intermedia plumifera*		Vagrant	Least Concern	Vagrant
Reef heron	*Egretta sacra sacra*		Threatened-Nationally Endangered	Least Concern	Vagrant
Australasian bittern	*Botaurus poiciloptilus*		Threatened-Nationally Critical	Endangered	Resident
Royal spoonbill	*Platalea regia*		At Risk-Naturally Uncommon	Least Concern	Resident, seasonal
Glossy ibis	*Plegadis falcinellus*		Coloniser	Least Concern	Vagrant
Swamp harrier/kāhu	*Circus approximans*		Not Threatened	Least Concern	Breeding, seasonal
Nankeen kestrel	*Falco cenchroides cenchroides*		Vagrant	Least Concern	Vagrant
Eastern falcon	*Falco novaeseelandiae novaeseelandiae*	Karearea	At Risk-Recovering	Near Threatened	Vagrant
California quail	*Callipepla californica*		Introduced and Naturalised	Least Concern	Breeding
Common pheasant	*Phasianus colchicus*		Introduced and Naturalised	Least Concern	Breeding
New Zealand quail	*Coturnix novaezelandiae*		Extinct	Extinct	Extinct
Pūkeko	*Porphyrio melanotus melanotus*	Pūkeko	Not Threatened	Least Concern	Breeding, seasonal
Australian coot	*Fulica atra australis*		At Risk-Naturally Uncommon	Least Concern	Seasonal
Marsh crake	*Porzana pusilla affinis*		At Risk-Declining	Least Concern	Breeding, seasonal
Spotless crake	*Porzana tabuensis plumbea*		At Risk-Declining	Least Concern	Breeding, seasonal

Common Name	Species Name	Māori Name	National Conservation Status	IUCN Red List Classification	Status at Avon-Heathcote
Buff weka	*Gallirallus australis hectori*		At Risk-Relict	Vulnerable	Extinct
Red-necked stint	*Calidris ruficollis*		Migrant	Near Threatened	Vagrant
Curlew sandpiper	*Calidris ferruginea*		Vagrant	Near Threatened	Vagrant
Sharp-tailed sandpiper	*Calidris acuminata*		Migrant	Least Concern	Vagrant
Pectoral sandpiper	*Calidris melanotos*		Vagrant	Least Concern	Vagrant
Lesser knot	*Calidris canutus rogersi*		Threatened-Nationally Vulnerable	Near Threatened	Seasonal
Sanderling	*Calidris alba*		Vagrant	Least Concern	Vagrant
Far-eastern curlew	*Numenius madagascariensis*		Vagrant	Endangered	Seasonal
Asiatic whimbrel	*Numenius phaeopus variegatus*		Migrant	Least Concern	Seasonal
American whimbrel	*Numenius phaeopus hudsonicus*		Vagrant	Least Concern	Vagrant
Asiatic dowitcher	*Limnodromus semipalmatus*		Vagrant	Near Threatened	Vagrant
Eastern bar-tailed godwit	*Limosa lapponica baueri*		At Risk-Declining	Near Threatened	Seasonal
Hudsonian godwit	*Limosa haemastica*		Vagrant	Least Concern	Seasonal
Asiatic black-tailed godwit	*Limosa limosa melanuroides*		Vagrant	Near Threatened	Seasonal
Turnstone	*Arenaria interpres*		Migrant	Least Concern	Seasonal
Wandering tattler	*Tringa incana*		Vagrant	Least Concern	Vagrant
Siberian tattler	*Tringa brevipes*		Vagrant	Near Threatened	Seasonal
Lesser yellowlegs	*Tringa flavipes*		Vagrant	Least Concern	Vagrant
Variable oystercatcher	*Haematopus unicolor*		At Risk-Recovering	Least Concern	Resident, seasonal
South Island pied oystercatcher	*Haematopus finschi*		At Risk-Declining	Least Concern	Resident, seasonal
Pied stilt	*Himantopus himantopus leucocephalus*		Not Threatened	Least Concern	Breeding, seasonal
Black stilt	*Himantopus novaezelandiae*		Threatened-Nationally Critical	Critically Endangered	Vagrant
Red-necked avocet	*Recurvirostra novaehollandiae*		Vagrant	Least Concern	Vagrant
Spur-winged plover	*Vanellus miles novaehollandiae*		Not Threatened	Least Concern	Breeding, seasonal
New Zealand shore plover	*Thinornis novaeseelandiae*		Threatened-Nationally Critical	Endangered	Extinct
Northern New Zealand dotterel	*Charadrius obscurus aquilonius*		At Risk-Recovering	Near Threatened	Vagrant
Banded dotterel	*Charadrius bicinctus bicinctus*		Threatened-Nationally Vulnerable	Least Concern	Resident, seasonal
Black-fronted dotterel	*Elseyornis melanops*		At Risk-Naturally Uncommon	Least Concern	Vagrant
Wrybill	*Anarhynchus frontalis*		Threatened-Nationally Vulnerable	Vulnerable	Seasonal
Red-capped plover	*Charadrius ruficapillus*		Vagrant	Least Concern	Vagrant

Common Name	Species Name	Māori Name	National Conservation Status	IUCN Red List Classification	Status at Avon-Heathcote
Pacific golden plover	*Pluvialis fulva*		Migrant	Least Concern	Vagrant
Grey plover	*Pluvialis squatarola*		Vagrant	Least Concern	Vagrant
Brown skua	*Catharacta antarctica lonnbergi*		At Risk-Naturally Uncommon	Least Concern	Vagrant
Pomarine skua	*Coprotheres pomarinus*		Migrant	Least Concern	Vagrant
Arctic skua	*Stercorarius parasiticus*		Migrant	Least Concern	Seasonal
Southern black-backed gull	*Larus dominicanus dominicanus*		Not Threatened	Least Concern	Breeding, seasonal
Red-billed gull	*Larus novaehollandiae scopulinus*		At Risk-Declining	Least Concern	Resident, seasonal
Black-billed gull	*Larus bulleri*		Threatened-Nationally Critical	Endangered	Breeding, seasonal
Black-fronted tern	*Chlidonias albostriatus*		Threatened-Nationally Endangered	Endangered	Seasonal
Caspian tern	*Hydroprogne caspia*		Threatened-Nationally Vulnerable	Least Concern	Resident, seasonal
White-fronted tern	*Sterna striata striata*		At Risk-Declining	Least Concern	Seasonal
New Zealand fairy tern	*Sternula nereis davisae*		Threatened-Nationally Critical	Vulnerable	Vagrant
Whiskered tern	*Chlidonias hybridus javanicus*		Vagrant	Least Concern	Vagrant
Gull-billed tern	*Gelochelidon nilotica*		Vagrant	Least Concern	Vagrant
Eastern little tern	*Sternula albifrons sinensis*		Migrant	Least Concern	Vagrant
White-winged black tern	*Chlidonias leucopterus*		Migrant	Least Concern	Vagrant
Rock pigeon	*Columba livia*		Introduced and Naturalised	Least Concern	Resident
New Zealand pigeon	*Hemiphaga novaeseelandiae*		Not Threatened	Near Threatened	Seasonal
Barbary dove	*Streptopelia risoria*		Introduced and Naturalised	Least Concern	Vagrant
Sulphur-crested cockatoo	*Cacatua galerita*		Introduced and Naturalised	Least Concern	Vagrant
South Island kaka	*Nestor meridionalis meridionalis*		Threatened-Nationally Vulnerable	Endangered	Vagrant
Oriental cuckoo	*Cuculus optatus*		Vagrant	Least Concern	Vagrant
Shining cuckoo	*Chrysococcyx lucidus*		Not Threatened	Least Concern	Breeding, seasonal
Morepork	*Ninox novaeseelandiae novaeseelandiae*		Not Threatened	Least Concern	Extinct
Little owl	*Athene noctua*		Introduced and Naturalised	Least Concern	Breeding
Fork-tailed swift	*Apus pacificus pacificus*		Vagrant	Least Concern	Vagrant
New Zealand kingfisher	*Todiramphus sanctus vagans*		Not Threatened	Least Concern	Breeding, seasonal
Welcome swallow	*Hirundo neoxena neoxena*		Not Threatened	Least Concern	Breeding, seasonal
Skylark	*Alauda arvensis*		Introduced and Naturalised	Least Concern	Breeding, seasonal
New Zealand pipit	*Anthus novaeseelandiae novaeseelandiae*		At Risk-Declining	Least Concern	Breeding, seasonal
Dunnock	*Prunella modularis*		Introduced and Naturalised	Least Concern	Breeding, seasonal

Common Name	Species Name	Māori Name	National Conservation Status	IUCN Red List Classification	Status at Avon-Heathcote
Blackbird	*Turdus merula*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Song thrush	*Turdus philomelos*		Introduced and Naturalised	Least Concern	Breeding, seasonal
South Island fernbird	*Bowdleria punctata punctata*		At Risk-Declining	Least Concern	Extinct
Brown creeper	*Mohoua novaeseelandiae*		Not Threatened	Least Concern	Extinct
Grey warbler	*Gerygone igata*		Not Threatened	Least Concern	Breeding, seasonal
South Island fantail	*Rhipidura fuliginosa fuliginosa*		Not Threatened	Least Concern	Breeding, seasonal
Yellow-breasted tomtit	*Petroica macrocephala macrocephala*		Not Threatened	Least Concern	Extinct
South Island robin	*Petroica australis australis*		At Risk-Declining	Least Concern	Extinct
Silvereye	*Zosterops lateralis*		Not Threatened	Least Concern	Breeding, seasonal
Bellbird	*Anthornis melanura*		Not Threatened	Least Concern	Breeding, seasonal
Tūī	*Prosthemadera novaeseelandiaec novaeseelandiae*		Not Threatened	Least Concern	Vagrant
Yellowhammer	*Emberiza citrinella*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Cirl bunting	*Emberiza cirlus*		Introduced and Naturalised	Least Concern	Seasonal
Chaffinch	*Fringilla coelebs*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Greenfinch	*Carduelis chloris*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Goldfinch	*Carduelis carduelis*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Redpoll	*Carduelis flammea*		Introduced and Naturalised	Least Concern	Breeding, seasonal
House sparrow	*Passer domesticus*		Introduced and Naturalised	Least Concern	Breeding, seasonal
South Island saddleback	*Philesturnus carunculatus*		At Risk-Recovering	Near Threatened	Extinct
Starling	*Sturnus vulgaris*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Australian magpie	*Gymnorhina tibicen*		Introduced and Naturalised	Least Concern	Breeding, seasonal
Rook	*Corvus frugilegus*		Introduced and Naturalised	Least Concern	Extinct

Table B: Water birds observed regularly in the Estuary (abundant, common and uncommon). Conservation status, common and scientific names, follow Robertson *et al*. (2017).

Common Name	Scientific Name	National Conservation Status	Abundance (Abundant >1,000; Common 100-999; Uncommon <100)
Black swan	*Cygnus atratus*	Not Threatened	Abundant
Paradise shelduck	*Tadorna variegata*	Not Threatened	Abundant
New Zealand shoveler	*Anas rhynchotis*	Not Threatened	Abundant
Grey teal	*Anas gracilis*	Not Threatened	Abundant
New Zealand scaup	*Aythya novaeseelandiae*	Not Threatened	Abundant
Canada goose	*Branta canadensis*	Introduced and Naturalised	Abundant
Mallard or mallard/grey duck hybrid	*Anas platyrhynchos*	Introduced and Naturalised	Abundant
Feral (greylag) goose	*Anser anser*	Introduced and Naturalised	Uncommon
Black shag	*P. carbo novaehollandiae*	At Risk-Naturally Uncommon	Uncommon
Pied shag	*Phalacrocorax varius varius*	At Risk-Recovering	Common
Little black shag	*Phalacrocorax sulcirostris*	At Risk-Naturally Uncommon	Uncommon
Little shag	*Phalacrocorax melanoleucos brevirostris*	Not Threatened	Common
Spotted shag	*Stictocarbo punctatus punctatus*	Not Threatened	Uncommon
White heron	*Ardea modesta*	Threatened-Nationally Critical	Uncommon
Australasian bittern	*Botaurus poiciloptilus*	Threatened-Nationally Critical	Uncommon
Royal spoonbill	*Platalea regia*	At Risk-Naturally Uncommon	Common
White-faced heron	*Egretta novaehollandiae*	Not Threatened	Uncommon
Eastern cattle egret	*Ardea ibis coromanda*	Migrant	Uncommon
Pūkeko	*Porphyrio melanotus melanotus*	Not Threatened	Common
Australian coot	*Fulica atra australis*	At Risk-Naturally Uncommon	Uncommon
Spotless crake	*Porzana tabuensis plumbea*	At Risk-Declining	Uncommon
Marsh crake	Porzana pusilla affinis	At Risk-Declining	Uncommon
Lesser knot	*Calidris canutus rogersi*	Threatened-Nationally Vulnerable	Uncommon
Far-eastern curlew	*Numenius madagascariensis*	Vagrant	Uncommon
Asiatic whimbrel	*Numenius phaeopus variegatus*	Migrant	Uncommon
Eastern bar-tailed godwit	*Limosa lapponica baueri*	At Risk-Declining	Abundant
Hudsonian godwit	*Limosa haemastica*	Vagrant	Uncommon
Asiatic black-tailed godwit	*Limosa limosa melanuroides*	Vagrant	Uncommon
Turnstone	*Arenaria interpres*	Migrant	Uncommon
Siberian tattler	*Tringa brevipes*	Vagrant	Uncommon
Variable oystercatcher	*Haematopus unicolor*	At Risk-Recovering	Common
South Island pied oystercatcher	*Haematopus finschi*	At Risk-Declining	Abundant
Pied stilt	*Himantopus himantopus leucocephalus*	Not Threatened	Common
Spur-winged plover	*Vanellus miles novaehollandiae*	Not Threatened	Common
Banded dotterel	*Charadrius bicinctus bicinctus*	Threatened-Nationally Vulnerable	Uncommon
Wrybill	*Anarhynchus frontalis*	Threatened-Nationally Vulnerable	Uncommon
Southern black-backed gull	*Larus dominicanus dominicanus*	Not Threatened	Abundant
Red-billed gull	*Larus novaehollandiae scopulinus*	At Risk-Declining	Abundant
Black-billed gull	*Larus bulleri*	Threatened-Nationally Critical	Abundant
Black-fronted tern	*Chlidonias albostriatus*	Threatened-Nationally Endangered	Uncommon
Caspian tern	*Hydroprogne caspia*	Threatened-Nationally Vulnerable	Uncommon
White-fronted tern	*Sterna striata striata*	At Risk-Declining	Common

Appendix 5: Terrestrial invertebrates

Saltmarsh herbfield habitat supports a distinctive array of invertebrates. For example selliera supports several insect species, including the specialist leaf mining moth *Eutorna symmorpha*, while bucks horn plantain supports the indigenous day-flying geometrid moth *Leptomeris rubraria* on its foliage, and the indigenous plumemoth *Platyptilia repletatlis* on its seed heads. MacFarlane (2014) found the bug *Anchodelphus olearus* was a characteristic herbivore in this habitat. He also caught high numbers of transient midge species in the open saltmarsh meadows; these will often arrive in pulses, with adults emerging from the adjacent estuarine water.

Rushland dominated by oioi, three-square, and sea rush supports a distinctive invertebrate fauna, although less diverse than the other communities present. The small moth *Batrachedra tristicta* is numerous here and has its larvae feeding in the seed heads of the introduced *Juncus effusus*. The geometrid moth *Microdes epicryptis* is also a resident of this community, where its larvae feed on the flowers of *Juncus effusus*. Additionally, several day-flying glyphipterid moths have larvae that bore in the stems of oioi and *Juncus* species, such as *Glyphipterix iocheaera.* Other insects recorded in this habitat by MacFarlane (2014) include a bug (*Anchodelphus olearus*; a previously unknown species host of *Elenchus maoricus*), a scale insect (*Poliaspoides leptocarpi*), a miridae bug (*Josemiris corvalhoi*), a root mealy bug (*Balanococus*s sp.), and a new moth herbivore (*Megacraspedus* sp.) that is possibly an undescribed introduced species. The presence of adults and nymphs of *Josemiris corvalhoi* amongst the vegetation indicates that the bug is reliant on the introduced jointed rush (*Juncus articulatus*) (MacFarlane 2014).

Coastal ribbonwood is rich in specialist insects, particularly moths (Table 3). It supports the large omnivorous casemoth *Liothula omnivora* and a variety of beetles (Coleoptera), bugs (Hemiptera), and the praying mantis (*Orthodera novaezelandiae*) (Mantodea). MacFarlane (2014) found this habitat type had the highest invertebrate diversity compared to other vegetation types in nearby saltmarshes, with approximately 100 species of insect and 20 species of spider. These included leaf hoppers (*Arawa* sp.), a small mining weevil (*Peristoresus durus*), a mirid bug (*Halormus velifer*), scale insects (including *Coccus hesperidum*), beetles (*Dasytes* sp.), thrips, a chalcid wasp, and species in the litter such as mildew beetles (Cortacariidae), fungus gnats (Diptera) and high numbers of bark lice (*Philotarsopsis guttatus*). Also present were some little known and possibly udescribed parasite species, from three insect families. MacFarlane (2014) also noted that there was a considerable influx of temporary invertebrate visitiors, e.g. midges and muscid flies, to the shrubland. These species breed within the Estuary and move into the surrounding shrubland, perhaps for shelter and rest, and their presence in the shrubland can provide predators with increased prey items.

Taller, often exotic-grass dominated areas, with occasional harakeke and tī kōuka/cabbage tree support other conspicuous insects including katydid (*Conocephalus bilineatus*), the small grasshopper *Phaulacridium marginale*, and field cricket (*Pteronemobius* species), all in the Orthoptera. Additionally, the predatory lacewings *Micromus tasmaniae* and *Drepanacra binocula* (Neuroptera), praying mantis, and the shield bug *Oncacontias vittatus* (Hemiptera) are numerous here. Grass moths in the genus *Orocrambus* are diverse here, with *Orocrambus ramosellus, O. vittellus* and *O. vulgaris* common during different seasons in this habitat. The magpie moth *Nyctemera annulata* is also common here, with its larvae specialist on various *Senecio* species. Small day-flying moths also reside here, with the larvae of *Glyphipterix cionophora* boring into the stems of indigenous grasses.

Freshwater wetlands which support the sedges *Carex secta* and *Carex virgata* provide habitat for a rich community of indigenous insects. These include many moths which bore into the stems and flower heads, and various insects amongst the abundant and persistent leaf litter.

Appendix 6: Fish species recorded in the Estuary 1965 to 2015

Common Name	Scientific Name	Conservation Status	Citation Source
Ahuru	*Auchenoceros punctatus*	Not Evaluated[2]	NIWA 2016
Black flounder	*Rhombosolea retiaria*	Not Threatened[1]	NIWA 2016; Lang *et al.* 2012
Chinook salmon	*Oncorhynchus tshawytscha*	Introduced and Naturalised[1]	NIWA 2016
Clingfish	Gobiesociadae	n/a	NIWA 2016
Cockabully/estuarine Triplefin	*Fosterygion nigripenne* syn *Tripterygion nigripenne*	Not Threatened[1]	Jones and Marsden 2005; Webb 1972
Common bully	*Gobiomorphus cotidianus*	Not Threatened[1]	NIWA 2016; EOS 2012b; Lang *et al.* 2012; Jones and Marsden 2005; Webb 1972
Common smelt	*Retropinna retropinna*	Not Threatened[1]	NIWA 2016; EOS 2012b
Common sole	*Peltorhamphus novaezeelandiae*	Not Evaluated[2]	NIWA 2016; Jones and Marsden 2005; Webb 1972
Estuary stargazer	*Leptoscopus macropygus*	Not Evaluated[2]	NIWA 2016
Giant bully	*Gobiomorphus gobioides*	Not Threatened[1]	NIWA 2016; Lang *et al.* 2012
Globefish	*Contusus richiei* syn *Spheroides richei*	Not Evaluated[2]	NIWA 2016; Webb 1972
Herring	Clupeidae	n/a	Lang *et al.* 2012
Inaka/Inanga	*Galaxias maculatus*	At Risk-Declining[1]	NIWA 2016; EOS 2008, 2012a,b; Jones and Marsden 2005; Lang *et al.* 2012
Kahawai	*Arripis trutta*	Not Evaluated[2]	NIWA 2016; Jones and Marsden 2005; Webb 1972
Longfin eel/tuna	*Anguilla dieffenbachii*	At Risk-Declining[1]	NIWA 2016; EOS 2008, 2012; Jones and Marsden 2005
Olive rockfish	*Acanthoclinus fuscus*	Not Evaluated[2]	Jones and Marsden 2005
Red cod/hoka	*Pseudophycis bachus*	Not Evaluated[2]	Jones and Marsden 2005
Sand flounder/pātiki	*Rhombosolea plebeia*	Not Threatened[2]	NIWA 2016: EOS 2008, 2012a; Jones and Marsden 2005; Webb 1972
Shortfin eel/tuna	*Anguilla australis*	Not Threatened[1]	NIWA 2016; EOS 2008, 2012a; Lang *et al.* 2012; Jones and Marsden 2005
Slender sprat	*Sprattus antipodum*	Not Evaluated[2]	NIWA 2016
Speckled sole	*Peltorhamphus latus*	Not Evaluated[2]	NIWA 2016
Spotted stargazer	*Genyagnus monopterygius*	Not Evaluated[2]	NIWA 2016
Spotty/paketi/pākirikiri	*Notolabrus celidotus* syn *Pseudolabrus celidotus*	Not Threatened[2]	NIWA 2016; Jones and Marsden 2005; Webb 1972
Sprat	*Sprattus muelleri*	Not Evaluated[2]	NIWA 2016
Triplefin	Tripterygiidae	n/a	NIWA 2016; Jones and Marsden 2005; Webb 1972
Yellowbelly flounder/pātiki tōtara	*Rhombosolea leporina*	Not Evaluated[2]	NIWA 2016; Jones and Marsden 2005; Webb 1972
Yelloweye mullet	*Aldrichetta forsteri*	Not Threatened[1]	NIWA 2016; EOS 2008, 2012a,b; Lang *et al.* 2012; Jones and Marsden 2005; Webb 1972

[1] Source: Goodman *et al*. (2014).
[2] Source: Helen Kettles, Department of Conservation, pers. comm.

Appendix 7: Shellfish and other marine invertebrate species recorded in the Estuary 1965 to 2013; foraminifera recorded in the Estuary 2008 to 2009

Common Name	Scientific Name	Conservation Status	Citation Source
Shellfish			
Bivalve	*Protothaca crassicosta*	Not Evaluated[1]	Jones and Marsden 2005
Bivalve	*Ruditapes largillierti*	Not Evaluated[1]	Jones and Marsden 2005
Blue mussel	*Mytilus edulis galloprovincialis*	Not Evaluated[1]	Jones and Marsden 2005
Coarse Venus shell	*Dosinia anus*	Not Evaluated[1]	Jones and Marsden 2005
Cockle/ tuaki	*Austrovenus stutchburyi* syn *Chione stutchburyi*	Not Threatened[1]	Bolton-Ritchie 2015; Skilton 2013; Zeldis *et al.* 2011; EOS 2005, 2007a,b, 2012a; Jones and Marsden 2005; Marsden 1998; Webb 1972
Common mussel	*Mytilus edulis aoteanus*	Not Evaluated[1]	Webb 1972
Common paua	*Haliotis iris*	Not Evaluated[1]	Jones and Marsden 2005
Greenshell/green-lipped mussel	*Perna canaliculus*	Not Threatened[1]	Bolton-Ritchie 2015; Jones and Marsden 2005
Large trough shell	*Mactra murchisoni*	Not Evaluated[1]	Jones and Marsden 2005
Little black/blue mussel	*Xenostrobus pulex*	Not Evaluated[1]	Bolton-Ritchie 2015; Jones and Marsden 2005; Webb 1972
Nesting mussel	*Modiolarca impacta*	Not Evaluated[1]	Jones and Marsden 2005
Pipi	*Paphies australis*	Not Threatened[1]	Bolton-Ritchie 2015; EOS 2007a, 2012a; Jones and Marsden 2005; Marsden 1998; Webb 1972
Ribbed mussel	*Aulacomya ater maoriana*	Not Evaluated[1]	Jones and Marsden 2005
Rock oyster	*Tiostrea chilensis lutaria*	Not Evaluated[1]	Jones and Marsden 2005
Triangle shell	*Spisula aequilatera*	Not Evaluated[1]	Jones and Marsden 2005
Trough sell	*Mactra ovata* syn *Cyclomactra ovata*	Not Threatened[1]	Bolton-Ritchie 2015; EOS 2005, 2007a,b; Jones and Marsden 2005; Marsden 1998
Tuatua	*Paphies donacina*	Not Evaluated[1]	Jones and Marsden 2005
Wedge shell	*Tellina liliana* syn *Macomona liliana*	Not Threatened[1]	Bolton-Ritchie 2015; EOS 2005, 2007a; Jones and Marsden 2005; Marsden 1998; Webb 1972
Other Aquatic Invertebrates			
Amphipod	*Paracalliope fluviatilis*	Not Evaluated[1]	Jones and Marsden 2005
Amphipod	*Paracorophium excavatum*	Not Evaluated[1]	Jones and Marsden 2005
Amphipod	Caprellidae	n/a	Bolton-Ritchie 2015
Amphipod	Amphipoda	n/a	Bolton-Ritchie 2015; EOS 2007a,b, 2010; Jones and Marsden 2005; Webb 1972
Banded periwinkle	*Nodilittorina antipodum*	Not Evaluated[1]	Jones and Marsden 2005
Barnacle	*Balanus decorus*	Not Evaluated[1]	Jones and Marsden 2005
Barnacle	*Chamaesipho columna*	Not Evaluated[1]	Jones and Marsden 2005
Barnacle	*Epopella plicata*	Not Evaluated[1]	Jones and Marsden 2005
Barnacle	*Tetraclitella purpurascens*	Not Evaluated[1]	Jones and Marsden 2005
Beach flea	*Transorchestia chiliensis*	Not Evaluated[1]	Jones and Marsden 2005

[1] Source: Helen Kettles, Department of Conservation, pers. comm.

Common Name	Scientific Name	Conservation Status	Citation Source
Beetle	Staphylinidae	n/a	Jones and Marsden 2005
Bivalve	*Arthritica* sp.	Not Threatened[1]	Bolton-Ritchie 2015; EOS 2007a
Bivalve	Mytilidae	n/a	Bolton-Ritchie 2015
Black-edged limpet	*Notoacmea parviconoidea*	Not Evaluated[1]	Jones and Marsden 2005; Webb 1972
Brine fly	*Ephydrella novaezealandiae*	Not Evaluated[1]	Jones and Marsden 2005
Brine fly	*Neoscatella vittithorax*	Not Evaluated[1]	Jones and Marsden 2005
Brown periwinkle	*Nodilittorina cincta*	Not Evaluated[1]	Jones and Marsden 2005
Butterfly chiton	*Cryptoconchus porosus*	Not Evaluated[1]	Jones and Marsden 2005
Cancer crab	*Cancer novaezelandiae*	Not Evaluated[1]	Jones and Marsden 2005
Cat's eye	*Turbo smaragdus*	Not Evaluated[1]	Jones and Marsden 2005
Chiton	*Guildingia obtecta*	Not Evaluated[1]	Jones and Marsden 2005
Chiton	*Maorichiton caelatus*	Not Evaluated[1]	Jones and Marsden 2005
Copepod	Harpacticoida	n/a	Jones and Marsden 2005
Crab	*Halicarcinus* sp.	n/a	Bolton-Ritchie 2015; EOS 2007a,b; Jones and Marsden 2005
Cranefly	*Erioptera confluens*	Not Evaluated[1]	Jones and Marsden 2005
Crevice snail	*Risellopsis varia*	Not Evaluated[1]	Jones and Marsden 2005
Cushion star	*Patiriella regularis*	Not Evaluated[1]	Jones and Marsden 2005
Dark rock shell	*Haustrum haustorium*	Not Evaluated[1]	Jones and Marsden 2005
Ducksbill limpet/shield shell	*Scutus breviculus*	Not Evaluated[1]	Jones and Marsden 2005
Ellobiid snail	*Marinula filholi*	Not Evaluated[1]	Jones and Marsden 2005
Encrusted limpet	*Patelloida corticata*	Not Evaluated[1]	Jones and Marsden 2005
Estuarine barnacle	*Elminius modestus*	Not Evaluated[1]	Jones and Marsden 2005; Webb 1972
Estuarine limpet	*Notoacmea helmsi*	Not Threatened[1]	EOS 2007b, 2010; Jones and Marsden 2005; Marsden 1998
Estuarine/tunnelling mudcrab	*Helice crassa* syn *Austrohelice crassa*	Not Threatened[1]	Bolton-Ritchie 2015; Skilton 2013; EOS 2007a,b; Jones and Marsden *2005;* Webb 1972
Estuarine prawn	*Palaemon affinis*	Not Evaluated[1]	Jones and Marsden 2005
Even-handed shrimp	*Betaeopsis aequimanus*	Not Evaluated[1]	Jones and Marsden 2005
Fanworm	*Janua pseudocorrugata*	Not Evaluated[1]	Jones and Marsden 2005
Fanworm	*Manayunkia* sp.	n/a	Jones and Marsden 2005
Fanworm	*Paralaeospira levinseni*	Not Evaluated[1]	Jones and Marsden 2005
Fanworm	*Pileolaria pocillator*	Not Evaluated[1]	Jones and Marsden 2005
Fanworm	*Protolaeospira lebruni*	Not Evaluated[1]	Jones and Marsden 2005
Fanworm	*Spirobranchus caeruleus*	Not Evaluated[1]	Jones and Marsden 2005
Fly	Dolichopodidae	n/a	Jones and Marsden 2005
Fly	Ephydridae	n/a	Bolton-Ritchie 2015
Fragile limpet	*Atalacmea fragilis*	Not Evaluated[1]	Jones and Marsden 2005
Ghost shrimp	*Callianassa filholi*	Not Evaluated[1]	Jones and Marsden 2005
Green chiton	*Amaurochiton glaucus*	Not Evaluated[1]	Jones and Marsden 2005; Webb 1972
Half crab	*Petrolithes elongates*	Not Evaluated[1]	Webb 1972
Hairy-handed crab	*Hemigrapsus crenulatus*	Not Threatened[1]	Bolton-Ritchie 2015; Skilton 2013; EOS 2007a,b; Jones and Marsden 2005; Marsden 1998; Webb 1972
Hermit crab	*Pagurus novizealandiae*	Not Evaluated[1]	Jones and Marsden 2005
Hermit crab	*Pagurus traversi*	Not Evaluated[1]	Jones and Marsden 2005

Common Name	Scientific Name	Conservation Status	Citation Source
Isopod	*Exosphaeroma planulum*	Not Evaluated[1]	Jones and Marsden 2005
Isopod	*Isocladus armatus*	Not Evaluated[1]	Jones and Marsden 2005
Isopod	*Ligia novaezealandiae*	Not Evaluated[1]	Jones and Marsden 2005
Isopod	*Munna neozelanica*	Not Evaluated[1]	Jones and Marsden 2005
Isopod	*Pseudosphaeroma campbellensis*	Not Evaluated[1]	Jones and Marsden 2005
Isopod	*Sphaeroma quoyannum*	Not Evaluated[1]	Jones and Marsden 2005
Isopod	Flabellifera	n/a	Bolton-Ritchie 2015
Isopod	Munnidae	n/a	Bolton-Ritchie 2015
Isopod	Isopoda	n/a	EOS 2007b; Jones and Marsden 2005; Webb 1972
Kelp fly	Coelopidae	Not Evaluated[1]	Jones and Marsden 2005
Limpet	*Siphonaria australis*	Not Evaluated[1]	Jones and Marsden 2005
Limpet	*Benhamina obliquata*	Not Evaluated[1]	Jones and Marsden 2005
Limpet	*Notoacmea elongata*	Not Evaluated[1]	Bolton-Ritchie 2015
Lined whelk	*Buccinulum vittatum*	Not Evaluated[1]	Jones and Marsden 2005
Lugworm	*Abarenicola assimilis*	Not Evaluated[1]	Jones and Marsden 2005
Lumbricid worms	Lumbricidae	n/a	Webb 1972
Midge	*Chironomus zealandicus*	Not Evaluated[1]	Jones and Marsden 2005
Midge	*Chironomus* sp.	n/a	Bolton-Ritchie 2015
Mud shrimp	*Upogebia danai*	Not Evaluated[1]	Jones and Marsden 2005
Mudflat anemone	*Anthopleura aureoradiata*	Not Evaluated[1]	Bolton-Ritchie 2015; Zeldis *et al.* 2011; EOS 2005, 2007b; Jones and Marsden 2005; Marsden 1998
Mudflat top shell	*Zediloma corrosa*	Not Evaluated[1]	Webb 1972
Mudflat whelk	*Cominella glandiformis*	Not Threatened[1]	Bolton-Ritchie 2015; EOS 2005, 2007a,b; Jones and Marsden 2005; Marsden 1998
Mudsnail/Waikaka/ Pūpū	*Amphibola crenata*	Not Threatened[1]	Bolton-Ritchie 2015; Skilton 2013; Zeldis *et al.* 2011; EOS 2005, 2007a,b; Jones and Marsden 2005; Marsden 1998; Webb 1972
Muscid fly	Muscidae	n/a	Jones and Marsden 2005
Nemertine worms	Nemertinea	n/a	Jones and Marsden 2005
Oligochaete worm	Oligochaeta	n/a	Bolton-Ritchie 2015; EOS 2005, 2007a
Opheliid worm	*Armandia maculata*	Not Evaluated[1]	Bolton-Ritchie 2015; Jones and Marsden 2005
Ornate limpet	*Cellana ornata*	Not Evaluated[1]	Jones and Marsden 2005
Ostracod	*Leptocythere* sp.	n/a	Jones and Marsden 2005
Ostracod	*Propontocypris* sp.	n/a	Jones and Marsden 2005
Ostracod	Ostracoda	n/a	Bolton-Ritchie 2015
Oyster borer/barnacle drill whelk	*Lepsiella scobina*	Not Evaluated[1]	Jones and Marsden 2005
Paddle/swimming crab - syn?? See swimming crab below	*Ovalipes catharus* syn *Ovalipes bipustulatus*	Not Threatened[1]	Jones and Marsden 2005; Webb 1972
Paddle worm	*Eulalia microphylla*	Not Evaluated[1]	Jones and Marsden 2005
Pea/mussel crab	*Pinnotheres novaezelandiae*	Not Evaluated[1]	Jones and Marsden 2005
Peanut worm	*Dendrostomum huttoni*	Not Evaluated[1]	Jones and Marsden 2005
Peanut worm	*Golfingia cantabriensis*	Not Evaluated[1]	Jones and Marsden 2005
Piddock/rock borer	*Anchomasa similis*	Not Evaluated[1]	Jones and Marsden 2005

Common Name	Scientific Name	Conservation Status	Citation Source
Pillbox crab	*Halicarcinus whitei*	Not Threatened[1]	Jones and Marsden 2005
Polychaete	*Aglaophamus macroura* syn *Nephtys macroura*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005; Jones and Marsden 2005
Polychaete	*Aonides trifidus*	Not Evaluated[1]	Jones and Marsden 2005
Polychaete	*Aonides* sp.	n/a	Bolton-Ritchie 2015; EOS 2005, 2007a, 2010
Polychaete	*Aquilospio* sp.	n/a	Bolton-Ritchie 2015; EOS 2007a
Polychaete	*Boccardia polybranchia*	Not Evaluated[1]	EOS 2005, 2007a; Jones and Marsden 2005
Polychaete	*Boccardia* spp.	n/a	Bolton-Ritchie 2015;
Polychaete	*Capitella capitata*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005, 2007a, 2010; Jones and Marsden 2005
Polychaete	*Capitella capitella*	Not Evaluated[1]	EOS 2007a
Polychaete	Capitellidea	n/a	Bolton-Ritchie 2015; EOS 2007a; Jones and Marsden 2005
Polychaete	*Edwarsia leucomelos*	Not Evaluated[1]	EOS 2007a
Polychaete	*Euchone pallida*	Not Evaluated[1]	Bolton-Ritchie 2015
Polychaete	*Eumenia* sp.	n/a	Webb 1972
Polychaete	*Glycera americana*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2007a; Jones and Marsden 2005; Webb 1972
Polychaete	*Glycera* sp.	n/a	Bolton-Ritchie 2015
Polychaete	*Haploscoloplos cylindrifer* syn *Scoloplos cylindrifer*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005, 2007a; Jones and Marsden 2005
Polychaete	*Hemipodus simplex*	Not Evaluated[1]	Jones and Marsden 2005
Polychaete	*Heteromastus filiformis*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005, 2007a; Jones and Marsden 2005
Polychaete	*Lumbrineris coccinea*	Not Evaluated[1]	Jones and Marsden 2005
Polychaete	Manayunkia *sp.*	n/a	Bolton-Ritchie 2015
Polychaete	Nereidae	n/a	Bolton-Ritchie 2015; EOS 2005, 2007a; Jones and Marsden 2005; Webb 1972
Polychaete	*Orbinia papillosa*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005, 2007a; Jones and Marsden 2005
Polychaete	*Perinereis brevicirrus*	Not Evaluated[1]	Bolton-Ritchie 2015
Polychaete	*Perinereis vallata*	Not Evaluated[1]	Bolton-Ritchie 2015
Polychaete	*Pisione* sp.	n/a	Webb 1972
Polychaete	*Prionospio aucklandica*	Not Evaluated[1]	Bolton-Ritchie 2015
Polychaete	*Prionospio* sp.	n/a	Bolton-Ritchie 2015
Polychaete	Sabellidae	n/a	Bolton-Ritchie 2015
Polychaete	*Scolecolepides benhami*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005, 2007; Jones and Marsden 2005
Polychaete	*Scolelepis* sp.	n/a	Bolton-Ritchie 2015; EOS 2005
Polychaete	*Syllidae* sp.	n/a	EOS 2005
Polychaete	*Trochodota* sp.	n/a	EOS 2005
Polychaete	*Glycera americana*	Not Evaluated[1]	Webb 1972
Porcelain/false/half/bluestone crab	*Petrolisthes elongatus*	Not Evaluated[1]	Jones and Marsden 2005
Purple rock crab	*Hemigrapsus sextdentatus*	Not Evaluated[1]	Jones and Marsden 2005
Radiate limpet	*Cellana radians*	Not Evaluated[1]	Jones and Marsden 2005
Rag worm	*Nereis cricognatha*	Not Evaluated[1]	EOS 2007a; Jones and Marsden 2005
Rag worm	*Nicon aestuariensis*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005, 2007a; Jones and Marsden 2005; Webb 1972
Rag worm	*Perinereis nuntia*	Not Evaluated[1]	EOS 2007a; Jones and Marsden 2005

Common Name	Scientific Name	Conservation Status	Citation Source
Rag worm	*Perinereis novaehollandiae*	Not Evaluated[1]	Jones and Marsden 2005
Rag worm	*Platynereis australis*	Not Evaluated[1]	Bolton-Ritchie 2015; Jones and Marsden 2005
Ribbon worm	Nemertea	n/a	EOS 2005, 2007a; Jones and Marsden 2005
Roundworm	Nematoda	n/a	Jones and Marsden 2005
Sand mason worm	*Pectinaria australis*	Not Evaluated[1]	Bolton-Ritchie 2015; Jones and Marsden 2005
Sandhopper	*Talorchestia quoyana*	Not Evaluated[1]	Jones and Marsden 2005
Scale worm	*Lepidonotus polychromus*	Not Evaluated[1]	Jones and Marsden 2005
Scale worm	*Lepidasthenia accolus*	Not Evaluated[1]	Jones and Marsden 2005
Sea anemone	*Actinia tenebrosa*	Not Evaluated[1]	Jones and Marsden 2005
Sea anemone	*Diadumene neozelandica*	Not Evaluated[1]	Jones and Marsden 2005
Sea anemone	*Edwardsia leucomelos*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2005, 2007a; Jones and Marsden 2005; Marsden 1998
Sea anemone	*Isocradactis magna*	Not Evaluated[1]	Jones and Marsden 2005
Sea slug	*Onchidella nigricans*	Not Evaluated[1]	Jones and Marsden 2005
Sea tulip/kaeo	*Pyura pachydermata*	Not Evaluated[1]	Jones and Marsden 2005
Serpulid worm	*Pomatoceros cariniferus*	Not Evaluated[1]	Webb 1972
Shield slug	*Scutus breviculus*	Not Evaluated[1]	Webb 972
Shrimp	*Palaemon affinis*	Not Evaluated[1]	Davey 2010; EOS 2012a; Lang *et al.* 2012
Shrimp	*Gastrosaccus australis*	Not Evaluated[1]	Jones and Marsden 2005
Shrimp	*Tenagomysis chiltoni*	Not Evaluated[1]	Jones and Marsden 2005
Shrimp	*Tenagomysis macropsis*	Not Evaluated[1]	Jones and Marsden 2005
Shrimp	*Tenagomysis novaezealandiae*	Not Evaluated[1]	Jones and Marsden 2005
Shrimp	Mysidacea	n/a	EOS 2005; Jones and Marsden 2005; Webb 1972
Small bivalve	*Arthritica bifurca*	Not Evaluated[1]	EOS 2005, 2007b
Small mud snail	*Zeacumantus subcarinatus*	Not Evaluated[1]	EOS 2010; Jones and Marsden 2005
Smooth shore crab	*Cyclograpsus lavauxi*	Not Evaluated[1]	Bolton-Ritchie 2015; EOS 2007a; Jones and Marsden 2005
Snail (dark/black top shell)	*Diloma nigerrima*	Not Evaluated[1]	EOS 2005, 2007a,b; Jones and Marsden 2005; Marsden 1998
Snail (mudflat top shell)	*Diloma subrostrata*	Not Threatened[1]	Bolton-Ritchie 2015; EOS 2005, 2007a,b; Jones and Marsden 2005; Marsden 1998
Snail	*Diloma zealandica*	Not Evaluated[1]	EOS 2005, 2007,b
Snail	*Diloma* sp.	n/a	Zeldis *et al.* 2011
Snail	*Micrelenchus tenebrosus*	Not Evaluated[1]	Bolton-Ritchie 2015; Zeldis *et al.* 2011; EOS 2007a, 2010; Jones and Marsden 2005; Marsden 1998
Snail	*Potamopyrgus estuarinus*	Not Threatened[1]	EOS 2007b; Jones and Marsden 2005
Snail	*Potamopyrgus* sp.	n/a	Bolton-Ritchie 2015
Snake-skin chiton	*Chiton pelliserpentis* syn *Sypharochiton pelliserpentis*	Not Evaluated[1]	Jones and Marsden 2005; Webb 1972

Common Name	Scientific Name	Conservation Status	Citation Source
Spider crab	*Hombronia depressa*	Not Evaluated[1]	Webb 1972
Spiral worm	*Spirorbis* sp.	n/a	Webb 1972
Speckled whelk	*Cominella lurida*	Not Evaluated[1]	Webb 1972
Spotted/dark top shell	*Melagraphia aethiops*	Not Evaluated[1]	EOS 2007b; Jones and Marsden 2005; Marsden 1998; Webb 1972
Spotted whelk	*Cominella maculosa*	Not Evaluated[1]	Zeldis *et al.* 2011; Jones and Marsden 2005
Stalk eyed mudcrab	*Macrophthalmus hirtipes* syn *Hemiplax hirtipes*	Not Threatened[1]	Bolton-Ritchie 2015; Skilton 2013; Zeldis *et al.* 2011; EOS 2005, 2007a,b; Jones and Marsden 2005; Marsden 1998
Starfish	*Astrostrole scabra*	Not Evaluated[1]	Jones and Marsden 2005
Tubicolous worm	*Thelepus plagiostoma*	Not Evaluated[1]	Jones and Marsden 2005
Tufted chiton/bristle chiton	*Acanthochitona zelandica*	Not Evaluated[1]	Jones and Marsden 2005
Variable/active chiton	*Ischnochiton maorianus*	Not Evaluated[1]	Jones and Marsden 2005
Worm (Platyhelminthes)	*Notoplana australis*	Not Evaluated[1]	Jones and Marsden 2005
Foraminifera			
Foraminifera	*Ammonia parkinsoniana f. aoteana*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Elphidium excavatum*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Elphidium advenum*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Haplophragmoides wilberti*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Haynesina depressula*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Milliammina fusca*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Milliammina obliqua*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Nonionellina flemingi*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Trochammina inflata*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Trochamminata salsa*	Not Evaluated[1]	Pearson 2009
Foraminifera	*Zeaflorilus parri*	Not Evaluated[1]	Pearson 2009

Appendix 8: Ecological significance assessment

Ecological significance assessment for Avon-Heathcote Estuary/Ihutai using the criteria in Appendix 3 of the Canterbury Regional Policy Statement (ECan 2013). (Veg = vegetation; Inv = aquatic invertebrates).

Criterion	Met	Explanation
Representativeness		
1. Indigenous vegetation or habitat of indigenous fauna that is representative, typical or characteristic of the natural diversity of the relevant ecological district. This can include degraded examples where they are some of the best remaining examples of their type, or represent all that remains of indigenous biodiversity in some areas.	**Yes** Veg Fish Inv Bird	• The Estuary contains a range of indigenous saltmarsh vegetation types that are representative for Low Plains Ecological District. • The Estuary contains characteristic indigenous fish, invertebrate and bird habitats for Low Plains Ecological District..
2. Indigenous vegetation or habitat of indigenous fauna that is a relatively large example of its type within the relevant ecological district.	**Yes** Veg Fish Inv Bird	• The Estuary contains extensive areas of saltmarsh vegetation around large parts of the Estuary margin. • The Estuary provides habitat for several species of indigenous plant, fish, invertebrate and bird species.The Estuary is the largest example of its type within the Low Plains Ecological District.,
Rarity/Distinctiveness		
3. Indigenous vegetation or habitat of indigenous fauna that has been reduced to less than 20 percent of its former extent in the Region, or relevant land environment, ecological district, or freshwater environment.	**Yes** Veg Bird	• The Estuary contains indigenous vegetation and habitat of indigenous fauna that occur on 'Acutely Threatened' or 'Chronically Threatened' land environments wuth <20% indigenous cover left (Cierad *et al.* 2014).
4. Indigenous vegetation or habitat of indigenous fauna that supports an indigenous species that is threatened, at risk, or uncommon, nationally or within the relevant ecological district.	**Yes** Veg Fish Bird	• The Estuary contains three plant species that are At Risk Naturally Uncommon or Declining: - *Ruppia megacarpa* (At Risk-Naturally Uncommon) - *Thyridia repens* (At Risk-Naturally Uncommon) - *Zostera muelleri* subsp. *novazelandica* (At Risk-Declining • The Estuary has records of two At-Risk Declining fish species - short fin eel/tuna and inaka/inanga. • The Estuary has records for 19 Threatened and 29 At Risk bird species. A further 10 bird species are migrants and three are colonisers. Twenty-two of the nationally Threatened or At Risk bird species are regularly present: - Grey duck: Threatened-Nationally Critical - Black-billed gull: Threatened-Nationally Critical - White heron/kōtuku: Threatened-Nationally Critical - Australasian bittern: Threatened-Nationally Critical - Black-fronted tern: Threatened-Nationally Endangered - White-flippered penguin: At Risk-Declining - Red-billed gull: At Risk-Declining - Pied shag: At Risk-Recovering - Banded dotterel: Threatened-Nationally Vulnerable - Wrybill: Threatened-Nationally Vulnerable - Caspian tern: Threatened-Nationally Vulnerable - Lesser knot: Threatened-Nationally Vulnerable - South Island pied oystercatcher: At Risk-Declining - White-fronted tern: At Risk-Declining - New Zealand pipit: At Risk-Declining - Eastern bar-tailed godwit: At Risk-Declining - Black shag: At Risk-Naturally Uncommon

Criterion	Met	Explanation
		- Little black shag: At Risk-Naturally Uncommon - Royal spoonbill: At Risk-Naturally Uncommon - Marsh crake: At Risk-Declining - Spotless crake: At Risk-Declining - Variable oystercatcher: At Risk-Recovering
5. The site contains indigenous vegetation or an indigenous species at its distribution limit within Canterbury Region or nationally.	**Yes**	• The Estuary is the southernmost (national) and south-easternmost (global) distritubitonal limit for little black cormorant (shags) and it is the only breeding population in the South Island.
6. Indigenous vegetation or an association of indigenous species that is distinctive, of restricted occurrence, occurs within an originally rare ecosystem, or has developed as a result of an unusual environmental factor or combinations of factors.	**Yes** Veg Bird	• Estuary ecosystems are a naturally uncommon ecosystem type (Williams *et al.* 2007), and are classified as Vulnerable (Holdaway *et al.* 2012). • Coastal saltmarsh is a distinctive ecosystem type, with a characteristic and specialist indigenous flora. • The assemblage of 129 bird species demonstrates extremely high species richness, and occurs in few other locations in the South Island.
<u>Diversity and Pattern</u>		
7. Indigenous vegetation or habitat of indigenous fauna that contains a high diversity of indigenous ecosystem or habitat types, indigenous taxa, or has changes in species composition reflecting the existence of diverse natural features or ecological gradients.	**Yes** Veg Fish Inv Bird	• The Estuary contains a moderate-high diversity of indigenous plant species and vegetation/habitat types. • The distinctive vegetation types include oioi rushland, sea rush rushland, saltmarsh herbfield, coastal ribbonwood shrubland, *Coprosma propinqua* shrubland, native musk herbfield, native primrose herbfield, and seagrass mudflat. • The Estuary contains a wide variety of species of freshwater, estuarine and marine fish and invertebrates. Some species are permanent residents, but many migrate into and through the Estuary on a daily or seasonal basis. • The Estuary has extremely high bird species richness, with 129 species recorded in recent decades.
<u>Ecological Context</u>		
8. Vegetation or habitat of indigenous fauna that provides or contributes to an important ecological linkage or network, or provides an important buffering function.	**Yes** Veg Fish Bird	• The Estuary provides important linkages to the catchments of the Avon River/Ōtākaro and Heathcote River/Ōpāwaho that are essential for migratory fish species and bird species, particularly water birds.
9. A wetland which plays an important hydrological, biological or ecological role in the natural functioning of a river or coastal system.	**Yes** Veg Fish Inv	• The vegetation types are predominantly saltmarsh wetlands and are highly important for the functioning of the Avon and Heathcote River/Ōpāwaho and the coastal ecosystem. • The Estuary has an important role in the functioning of fish and invertebrate communities, including marine/estuarine species and freshwater species that are transitioning to the marine or freshwater environment during migration.
10. Indigenous vegetation or habitat of indigenous fauna that provides important habitat (including refuges from predation, or key habitat for feeding, breeding, or resting) for indigenous species, either seasonally or permanently.	**Yes** Fish Inv Bird	• The site provides important feeding, spawning and nursery habitats for many fish, shellfish and birds. • The Estuary is a nationally and internationally important habitat for wetland and migratory birds.

Appendix 9: Ramsar assessment

Table A summarises the assessment of the Avon-Heathcote Estuary/Ihutai against the eight Ramsar criteria and is based on the most up-to-date information available. The Estuary meets six of the eight criteria. For birds, the assessment is based on numbers from the 2009-2010 year (Crossland 2013), which does not consider data from after the Canterbury earthquake sequence (not available for this plan). When available, data from 2011 onwards should be used to reassess the Estuary's birdlife against the criteria. Further notes on the assessment follow the table.

Table A: Summary of assessment of the Avon-Heathcote Estuary/Ihutai against the eight Ramsar criteria for identifying Wetlands of International Importance.

Group A of the Criteria. Sites containing representative, rare or unique wetland types	**Criterion 1:** A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.	The Avon-Heathcote Estuary/Ihutai is the largest estuary in the Canterbury Region, and is one of the most important saltmarsh wetlands in New Zealand. The Avon-Heathcote Estuary/Ihutai saltmarsh wetlands occur on 'Acutely Threatened' or 'Chronically Threatened' land environments (Cieraad *et al.* 2014). In New Zealand, estuary ecosystems are a naturally uncommon ecosystem type (Williams *et al.* 2007), and are classified as Vulnerable (Holdaway *et al.* 2012). The Avon-Heathcote Estuary/Ihutai is representative of saltmarsh wetlands as it contains seagrass meadow, several types of indigenous herbfield, two types of rushland, and coastal scrub.
Group B of the Criteria. Sites of international importance for conserving biological diversity **Criteria based on species and ecological communities**	**Criterion 2:** A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	The Avon-Heathcote Estuary/Ihutai supports regular populations of the following globally threatened species, as recognised by IUCN/BirdLife International: • **Endangered:** Australasian bittern, far eastern curlew, black-billed gull, black-fronted tern • **Vulnerable**: wrybill The estuary supports three At Risk plant species: • **Naturally uncommon:** *Thyridia repens*, *Ruppia megacarpa* are • **Declining:** *Zostera muelleri* subsp. *novazelandica*
	Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.	The estuary is of special value in maintaining the genetic and ecological diversity of both Canterbury and the New Zealand region because of its relatively large size, diversity of habitats types, and species richness. It includes: 46 indigenous plant species, 34 species of fish representative of both marine and freshwater habitats, regular populations of 73 bird species of which 53 are indigenous (a further 51 bird species have been recorded as vagrants), and a diverse invertebrate fauna.

	Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.	The estuary is of special value as the habitat for wading and migratory bird species at critical stages in their biological cycles. It supports the largest concentrations of international and internal migratory shorebirds on the east coast of South Island (Cromarty and Scott 1996). The mudflats in the Estuary provide a haven for hairy-handed crabs, mud snails, wedge shells, whelks and microscopic creatures, which provide food for young fish and wading birds. Populations of small marine worms can exceed 20,000 per square metre.
Specific criteria based on water birds	**Criterion 5:** A wetland should be considered internationally important if it regularly supports 20,000 or more water birds.	Counts in August 2009 - July 2010 (Crossland 2013) indicated that when all water bird species were counted, numbers in the Estuary exceeded 30,000 individuals. Previous counts have also shown water birds to exceed 20,000 individuals (e.g. Crossland 1993).
	Criterion 6: A wetland should be considered internationally important if it regularly supports 1 percent of the individuals in a population of one species or subspecies of water bird.	Bird taxa present in the Estuary that exceed the 1 percent population threshold are (Table B): • Black swan (NZ population) • New Zealand shoveler (species) • Grey teal (species) • New Zealand scaup (species) • Pied shag (subspecies) • Eastern bar-tailed godwit (subspecies) • Variable oystercatcher (species) • South Island pied oystercatcher (species) • Pied stilt (subspecies) • Red-billed gull (subspecies) • Black-billed gull (species) • Caspian tern (species) The following species that may meet the 1 percent population threshold are: • Paradise shelduck (species) • Black shag (subspecies) • White heron/kōtuku (NZ population)
Specific criteria based on fish	**Criterion 7:** A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity	The Avon-Heathcote Estuary/Ihutai supports a number of indigenous fish species, but many of these are freshwater fish that are passing through (to migrate out to sea to spawn or upstream to mature), or marine wanderers that are short-term residents. Most species recorded in the Estuary are widely distributed around New Zealand. The Estuary supports two At Risk-Declining freshwater fish species: • longfin eel/tuna • inaka/inanga

	Criterion 8: A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.	Flounder (pātiki) and other flatfish enter the Estuary to feed and breed, triplefins live along the shoreline, and eels/tuna, adult whitebait (inaka/inanga) and many small fish are daily or seasonal visitors, feeding on plankton and other marine species. (CCC Avon Heathcote Estuary Fact Sheet). However, it is unlikely that these species are solely or primarily dependent on such a large estuary for one or more of their life stages. The most important factor for these species is that freshwater and saltwater interact at the river mouths, and there is open access to the sea at key times, to facilitate migration and provide food resources.

Criterion 2

Australasian bittern are rarely observed within the Estuary, but in 1992 tracks of at least two adults, and possibly two young, were noted on the Lower Heathcote saltmarshes (Calder-Green Reserve, Crossland 1993). Andrew Crossland stated in a Radio New Zealand report in 2015 that 15 bittern had been seen around Christchurch wetlands within the last year and that changes resulting from the earthquakes have made some areas more attractive to bittern[1].

Although wrybill were not recorded during the 2009-2010 year, small numbers of this species overwinter in most years (Crossland 2013), so they have been included in Criterion 2.

Criterion 6

This criterion was assessed using the Water bird Population Estimates online database (WPE 2017). This database has been developed by Wetlands International with the support of Environment Canada and the Ramsar Convention on Wetlands. The database provides 1 percent thresholds for over 800 water bird species and subspecies, and includes estimates for most of the New Zealand taxa assessed. Delaney and Scott (2006) provided the first publication of formal 1 percent estimates.

Table B lists the water bird species regularly observed in the Avon-Heathcote Estuary/Ihutai and the data used to assist with the assessments. The following species require further explanation:

- Black swan: Formally recognised as an indigenous species in 2001 (Holdaway *et al.* 2001). Estimated to number 50,000 birds in 2011 (Williams 2013). Therefore their 1 percent level is 500.
- New Zealand shoveler: WPE (2017) population estimate for subspecies *variegata* is 120,000. However, Williams (2013) estimates 15,000-20,000 birds, with 6,500 shot annually. In both cases the species meets the 1 percent level.
- New Zealand scaup: The species was estimated to number *c.*20,000 individuals in the 1990s; however, it may now number considerably more due to predator control and habitat development at the Te Huingi Manu Wildlife Reserve (Adams 2013). WPE still use a

[1] http://www.radionz/news/regional/266792/rare-birds-return-to-christchurch

very low 1 percent level, similar to that of Delaney and Scott (2006). In either case, the species meets the 1 percent level.

- Pied shag: WPE (2017) level indicates an estimated population of 25,000 birds. However, the species' national threat classification is based on an estimated population of 1,000-5,000 birds, suggested a 1 percent level of ≤50 birds.
- Red-billed gull: the WPE estimate assumes a population of one million birds for subspecies *scopulinus*. However, a recent New Zealand survey indicates a population of at least 26,906 breeding pairs (Frost and Taylor 2016). This suggests a 1 percent level of 600 would be appropriate, in which case the threshold appears to be met.
- Black-billed gull: counts for red-billed gull and black-billed gull have been combined as per Crossland (2013). This is because the two species can be difficult to distinguish reliably from a distance. However, the annual numbers of black-billed gulls on the Estuary exceeds 1,000 birds (Crossland 2009, 2013).
- Paradise shelduck: WPE (2017) uses a population estimate of 160,000. Williams (2013) estimates the population at 600,000-700,000 individuals, with 200,000 shot annually. The WPE 1 percent level may be an underestimate and the Estuary may not be significant for this species.
- Black shag: WPE (2017) uses a population estimate of 25,000 birds. However, the species' national threat classification is based on an estimated population of 5,000-10,000 birds, suggesting a maximum 1 percent level of 100 birds. The 2010 count was extremely close to this threshold at 93 birds. In 2009, the number of black shags on the Estuary was greater than 250 (Crossland 2009); provision of further estuary bird count data will clarify whether the species still meets the 1 percent level.
- White heron/kōtuku: white herons are extremely rare, and can easily be missed in a one-off survey. The Estuary supports 1-2 birds annually which meets the 1 percent level (Crossland 2009); provision of further Estuary bird count data will clarify whether white heron still meet the 1 percent level.

Table B: Water bird species present in the Estuary assessed against the Ramsar 1 percent population threshold criterion. Yellow = significant at the 1 percent level; orange = may be significant at the 1 percent level (see text for explanation). Conservation status and common and scientific names follow Robertson *et al*. (2017).

Common Name	National Threat Classification	International Threat Classification	Maximum Estuary Count (2009-2010) (Crossland 2013)	1 percent Significance Level	Significant	Basis for Significance: Water bird Population Estimates (WPE) or Other (see text)
Black swan	Not Threatened	Least Concern	1104	500	Yes	Other
Paradise shelduck	Not Threatened	Least Concern	3092	1600	Yes?	WPE/Other
New Zealand shoveler	Not Threatened	Least Concern	7046	1200	Yes	WPE
Grey teal	Not Threatened	Least Concern	5881	1,200	Yes	WPE
New Zealand scaup	Not Threatened	Least Concern	5739	70	Yes	WPE/Other
Black shag	At Risk-Naturally Uncommon	Least Concern	93	250	Yes?	Other
Pied shag	At Risk-Recovering	Least Concern	427	250	Yes	Other
Little shag	Not Threatened	Least Concern	142	1,000	No	WPE
Little black shag	At Risk-Naturally Uncommon	Least Concern	10	10,000	No	WPE
Spotted shag	Not Threatened	Least Concern	16	1,000	No	WPE
White-faced heron	Not Threatened	Least Concern	85	1,000	No	WPE
White heron	Threatened-Nationally Critical	Least Concern	0	1	Yes?	WPE/Other
Eastern cattle egret	Migrant	Least Concern	0	10,000	No	WPE
Australasian bittern	Threatened-Nationally Critical	Endangered	N/A	10	No	WPE
Royal spoonbill	At Risk-Naturally Uncommon	Least Concern	102	1000	No	WPE
Pūkeko	Not Threatened	Least Concern	881	6,000	No	WPE
Australian coot	At Risk-Naturally Uncommon	Least Concern	23	10,000	No	WPE
Marsh crake	At Risk-Declining	Least Concern	N/A	Unknown	?	WPE
Spotless crake	At Risk-Declining	Least Concern	N/A	Unknown	?	WPE

Common Name	National Threat Classification	International Threat Classification	Maximum Estuary Count (2009-2010) (Crossland 2013)	1 percent Significance Level	Significant	Basis for Significance: Water bird Population Estimates (WPE) or Other (see text)
Lesser knot	Threatened-Nationally Vulnerable	Near Threatened	2		No	WPE
Far-eastern curlew	Vagrant	Endangered	0		No	WPE
Asiatic whimbrel	Migrant	Least Concern	1		No	WPE
Eastern bar-tailed godwit	At Risk-Declining	Near Threatened	2110	1300	Yes	WPE
Hudsonian godwit	Vagrant	Least Concern	0		No	WPE
Asiatic black-tailed godwit	Vagrant	Near Threatened	0		No	WPE
Turnstone	Migrant	Least Concern	1		No	WPE
Siberian tattler	Vagrant	Near Threatened	0		No	WPE
Variable oystercatcher	At Risk-Recovering	Least Concern	109	45	Yes	WPE
South Island pied oystercatcher	At Risk-Declining	Least Concern	4,844	1,000	Yes	WPE
Pied stilt	Not Threatened	Least Concern	312	300	Yes	WPE
Spur-winged plover	Not Threatened	Least Concern	116	10,000	No	WPE
Banded dotterel	Threatened-Nationally Vulnerable	Least Concern	86	500	No	WPE
Wrybill	Threatened-Nationally Vulnerable	Vulnerable	0	45	No	WPE
Southern black-backed gull	Not Threatened	Least Concern	2,344	30,000	No	WPE
Red-billed gull	At Risk-Declining	Least Concern	6,214*	10,000	Yes	Other
Black-billed gull	Threatened-Nationally Critical	Endangered	6,214*	960	Yes	WPE/Other
Black-fronted tern	Threatened-Nationally Endangered	Endangered	21	45	No	WPE
Caspian tern	Threatened-Nationally Vulnerable	Least Concern	62	40	Yes	WPE
White-fronted tern	At Risk-Declining	Least Concern	319	15,000	No	WPE

Appendix 10: Christchurch City Council Dog Control Bylaw and Policy 2016, as they apply to locations within the Estuary boundary

Location	Restriction	Details
Lower Avon River/Ōtākaro saltmarshes	Prohibited	Lower Avon saltmarshes, including Naughty Boys' Island and Bligh's Garden. Dogs are prohibited to protect wildlife values (particularly estuarine birds).
Bexley Wetland	Prohibited/ Leashed	Dogs are prohibited to protect wildlife values in the wetland area (except on walkways). Dogs must be on a leash on walkways.
Raupō Bay saltmarsh	Prohibited	Lower Avon River/Ōtākaro saltmarshes Raupō Bay saltmarsh, Rat Island Reserve, and the Estuary and margins. Dogs are prohibited, in order to protect wildlife values (particularly estuarine birds).
Te Huingi Manu Wildlife Reserve (Christchurch wastewater treatment ponds)	Prohibited	Wildlife Reserve - dogs are prohibited, in order to protect wildlife and wildlife values (particularly up to 15,000 wetland birds including many threatened species).
Linwood Paddocks	Prohibited	Dogs are prohibited; in order to protect wildlife values (particularly indigenous and migrating birds, including threatened species).
Charlesworth Reserve	Prohibited/ Leashed	Dogs are prohibited in the wildlife habitat and regenerating bush areas. On the grass area with no wildlife values, dogs are allowed, under effective control.
Lower Heathcote saltmarshes	Prohibited	Lower Heathcote saltmarshes: Devil's Elbow saltmarsh, Ferry Esplanade Reserve, Ferrymead Esplanade saltmarsh, Settlers Reserve and saltmarsh, and Stilt Island saltmarsh, including Avoca Valley Stream. Dogs are prohibited, in order to protect wildlife values, except on walking tracks, where dogs must be on a leash.
McCormacks Bay islands, mudflat and saltmarsh	Prohibited	Dogs are prohibited on roosting/nesting islands and in the wet areas. Dogs are permitted in other areas as long as they are under effective control at all times.
Southshore Scenic Reserve and foreshore	Prohibited/ Leashed	Dogs are prohibited from the foreshore and sand dunes area, in order to protect wildlife (particularly godwits and oyster catchers). Dogs are allowed, on a leash, when walking around the boundary between the vegetated reserve area and the foreshore and sand dunes area. Dogs are allowed under effective control on the vegetated reserve area.
Sumner Beach	Summer Beach Prohibition: 1 November-31 March. Effective between 9:00 and 19:00	Sumner Beach, 100 metres north of the Sumner Surf Life Saving Club's pavilion to Cave Rock in the south. Swimming and recreation area - dogs are prohibited during summer (from 1 November to 31 March between 9am-7pm), except for the purposes of passing through on a short leash. Outside of these times dogs are permitted, under effective control.

Appendix 11: Legislative and policy framework

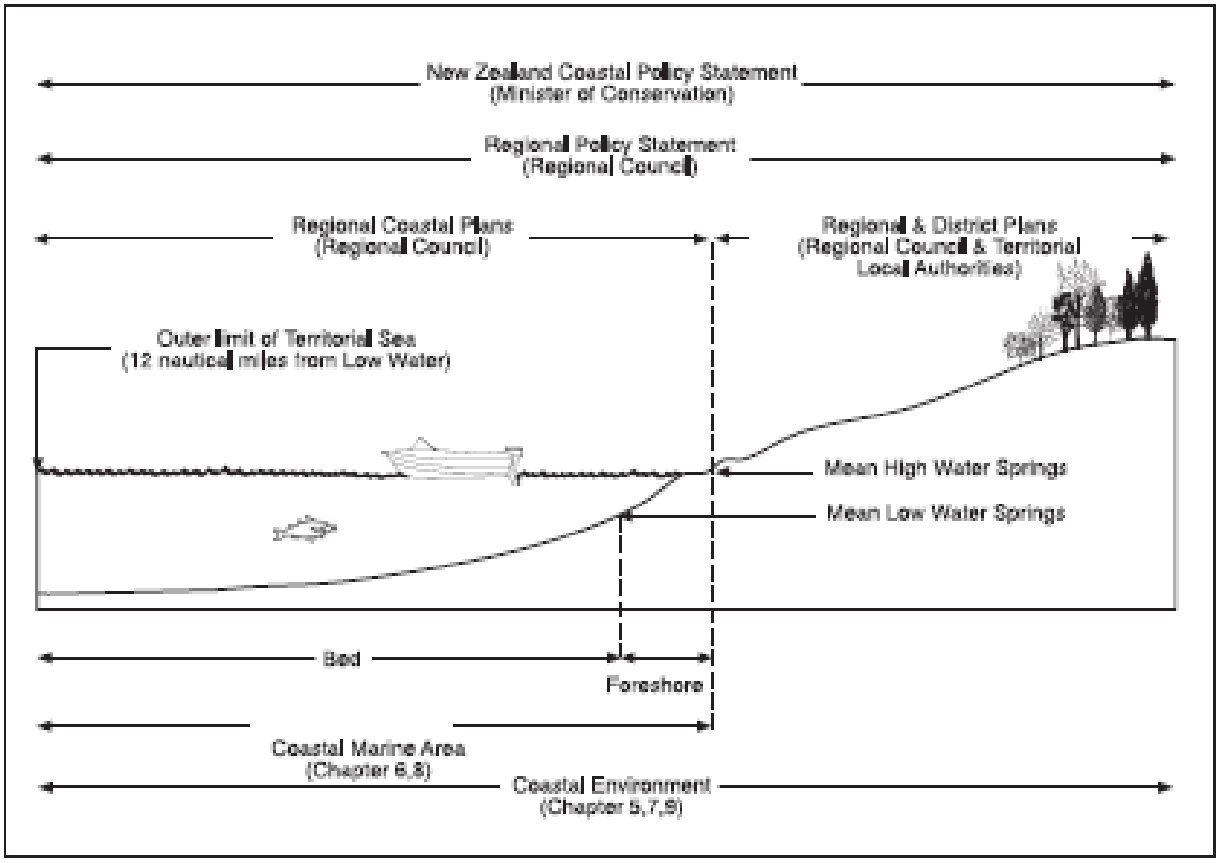

Figure 14: Areas of jurisdiction of coastal plans (from Environment Canterbury Regional Coastal Environment Plan 2005).

Document	Scope
Greater Christchurch Regeneration Act 2016 (the GCRA) – April 2016	Provides the overall framework and context for the regeneration of Greater Christchurch, including the consideration of future uses of residential red zone land
The Christchurch District Plan – 2016	Sets out the regulatory provisions for land use in Christchurch. The CCC has responsibilities for resource management landward of the line of MHWS, including land use control. The City Plan must not be inconsistent with the New Zealand Coastal Policy Statement or the Regional Policy Statement
NZ Coastal Policy Statement	Represents the national policy towards the whole coast of New Zealand. It also deals, in its objectives and policies, with the coastal environment
Canterbury Regional Policy Statement	Is the overarching resource management policy document for the Canterbury region. It must not be inconsistent with the NZCPS or any national policy statements. District plans or regional plans must give effect to the CRPS
Canterbury Regional Coastal Environment Plan	Chapter 6 sets out a range of objectives, policies and methods which recognise and provide for the preservation of the natural character of the coastal environment as a matter of national importance. Chapter 6 seeks to protect, and where appropriate enhance: • Areas of Significant Natural Value (ASNV); • areas of high natural, physical, heritage or cultural value; and • identified areas of value to Tangata Whenua Chapter 6 also has Objectives and Policies to enable people to undertake

Document	Scope
	commercial and recreational activities in the coastal environment while avoiding conflicts between those activities; avoiding, remedying or mitigating adverse effects on the natural character of the coastal environment; and maintaining and enhancing public access to and along the CMA. Chapter 7 identifies issues in relation to water quality. It provides water quality standards to prevent further degradation of coastal water while improving existing degraded areas. It sets water quality standards for the Estuary and provides objectives, polices and methods for controlling discharges into the Estuary, with the aim to improve the quality of water where it is currently degraded by point and non-point source discharges. Chapter 8 focuses on activities and structures in the CMA to ensure there are no adverse impacts on the environment. Chapter 9 identifies the issues in relation to coastal hazards in the coastal environment and provides solutions for minimising the costs of damage. The RCEP contains a schedule of Areas of Significant Natural Value (ASNV) which includes the Avon-Heathcote Estuary/Ihutai. The RCEP contains rules that apply to the CMA generally, and others that apply to ASNVs specifically.
Land and Water Regional Plan	The LWRP applies to areas outside the CMA and addresses water quality, water quantity and wetlands
Mahaanui Iwi Management Plan 2013	
Christchurch City Council Long Term Plan 2015-2025	Sets out the Council's budgets and programme of work over a ten-year period.
Greater Christchurch Urban Development Strategy (UDS) 2007, and 2016 Update	Provides coordinated and integrated planning of the urban areas of Greater Christchurch with the aim of providing well-being for the people and communities who live there.
Resilient Greater Christchurch Plan 2016	The Plan develops a locally specific framework to embed resilience into community through goals, programmes and actions. This includes consideration of the effects of climate changes and sea level rise
Canterbury Water Management Strategy	The strategy provides a long-term direction for the management of all water in Canterbury, combining current and contemplated projects and activities. It outlines fundamental water use principles and includes targets related to the environment, water quantity and quality, customary uses, recreation, tourism and amenity.
Bylaws under the Local Government Act 2002 and 1974	The control of navigation safety bylaw 2016 regulates the movement of commercial shipping; regulate the speed of vessels and reserves specified areas for particular activities. The bylaw can only control water activities for safety or navigation purposes, or for regulating nuisances to people arising from the use of vessels or seaplanes, (including noise nuisance). It cannot be used as a means of avoiding, remedying or mitigating other adverse effects on the environment such as effects on wildlife. Specifically the bylaw restricts powered craft to 5 knots for the Avon Heathcote Estuary /Ihutai; reserves the area on the west side of the Estuary near Ferrymead Bridge for the use of windsurfers, kite surfing, sailboards and non-powered craft; and allocates Moncks Bay as an area for swing moorings Christchurch City Council Dog Control Bylaw 2016. Christchurch City Council Dog Control Policy 2016.

Document	Scope
Other legislation • Reserves Act 1977 • Conservation Act 1987 • Wildlife Act 1953 • Fisheries Act 1996	
Non-Statutory Plans • Ihutai Management Plan 2013 • Southshore Spit Development Plan 2000	

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