Extent of wetland vegetation in Maketu Estuary - 1939 to 2011

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Oblique aerial photo of Maketū Estuary by Shane Iremonger, May 2014.

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Executive summary

Maketū Estuary and the Kaituna River with its once extensive wetlands have experienced extensive changes since the early 1800's with most of the wetland drained for farming and the river diverted out of the estuary in 1957 to reduce flooding. Within the estuary itself, reports show extensive areas of wetland have disappeared since diversion of the river from the estuary. To assist in understanding the extent of change and driving factors, a small project was undertaken to accurately map historic wetland extent in Maketū Estuary. Mapping spanned the period from 1939 to 2011 using aerial photography readily available at the time.

Results from the spatial mapping show that seagrass in the estuary has been variable over time. Since 1939 seagrass had clearly increased from around 5 ha up to 13 ha in 1948. Then seagrass showed a long-term decline to just a few square meters in 2011. Wetland/saltmarsh shows a similar trend between 1939 and 1948 once the loss to farmland is taken into account with an increase of around 10 ha in the mid to upper estuary. As with sea grass, from 1948 to 1961 losses (around 35 ha) were apparent, particularly to the south of Papahikahawai Island. By 1977 much of the wetland in this area was gone and at 2011 only a few square meters exist where once there were tens of hectares.

As previously noted in earlier studies of Maketū Estuary, a large proportion of the estuary wetlands have been directly lost to farmland. In this study that was around 95 ha of the area mapped or about 46% of the 1939 wetland extent. Also as highlighted in previous studies (Murray 1978, KRTA 1986, Gillespie 1988, Richmond and Forbes 1990, Bergin 1994), much of the remaining wetland in the estuary has died back due to increased pore water salinity as a result of the drains and stop banks altering freshwater flows.

Analysis of the aerial photography shows that between 1939 and 1948 wetland vegetation (including seagrass) was increasing in extent, possibly in response to a previous earlier period (1907-1928) of high salinity when the Kaituna River was flowing to the sea at Te Tumu. Following the later 1957 diversion of the Kaituna River to the sea at Te Tumu, there is extensive loss of wetland in the area to the south of Papahikahawai Island that was not affected by drainage. In this case, it is likely to be the high increase of surface water salinity that has been the major factor for wetland loss. A review of saltmarsh plant salinity tolerances indicates that levels would have increased above the optimum growth preferences for many species. There are also a number of high salinity impacts on seagrass growth and reproduction that could account at least in part for the observed decline in extent following diversion of the Kaituna River.

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Tables and Figures

Part 1: Introduction

1.1 Overview

The objective of this study was to document historic changes in the extent of wetland vegetation in the lower Kaituna River and Maketū Estuary. This involved use of historic aerial photography and GIS tools to map vegetation and assess changes over time.

A key aim of this report is to accurately link quantitative changes in wetland extent to salinity changes associated with drainage and flood works in the lower Kaituna River and to provide as much definition as possible in terms of the wetland type. This information will be used to support the implementation of the Kaituna River and Ongatoro/Maketū Estuary Strategy.

1.2 Background of the Kaituna River and Maketū Estuary

1.2.1 Kaituna River

The Kaituna River is situated in the central Bay of Plenty and flows 53 km from the Okere Arm of Lake Rotoiti to the sea at Te Tumu. The first 25 km is fast flowing and drops some 260 m through a number of waterfalls and an incised gorge. The remaining 28 km is slower flowing dropping just 20 m in altitude to the sea. Total catchment area of the Kaituna River (including the lakes) is approximately 1,218 km^2. The Kaituna River has an average flow of 39 m^3/s with around half the flow sourced from Lake Rotoiti (at Okere).

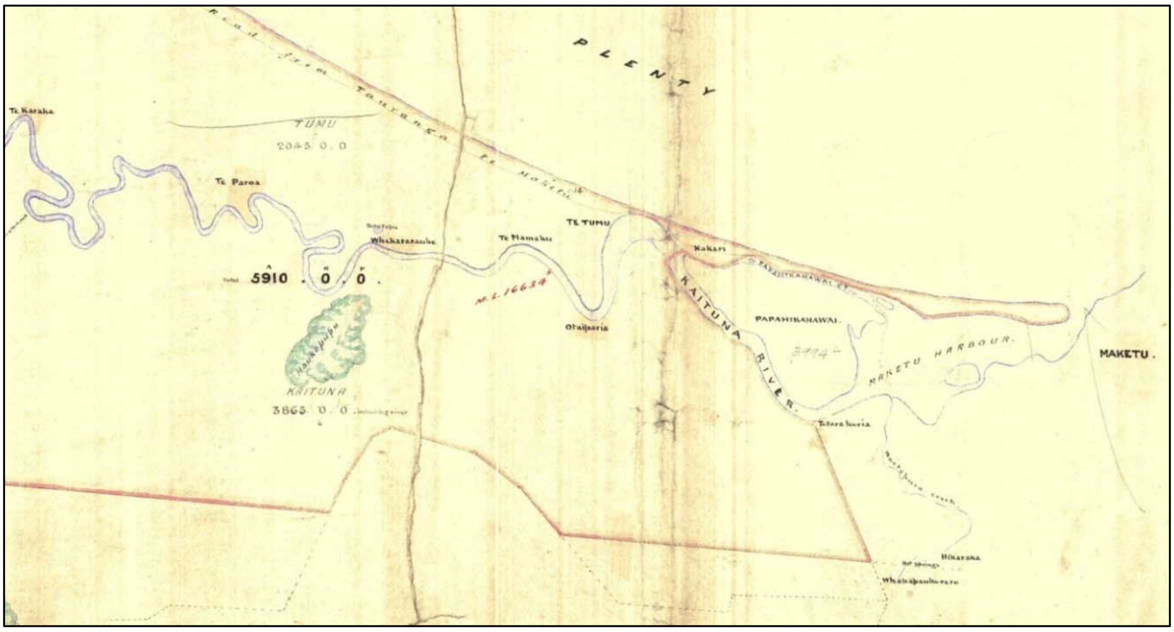

Figure 1 1877 survey of the Tumu Kaituna block showing the original course of the Kaituna River and vegetated areas within the Maketū Estuary.

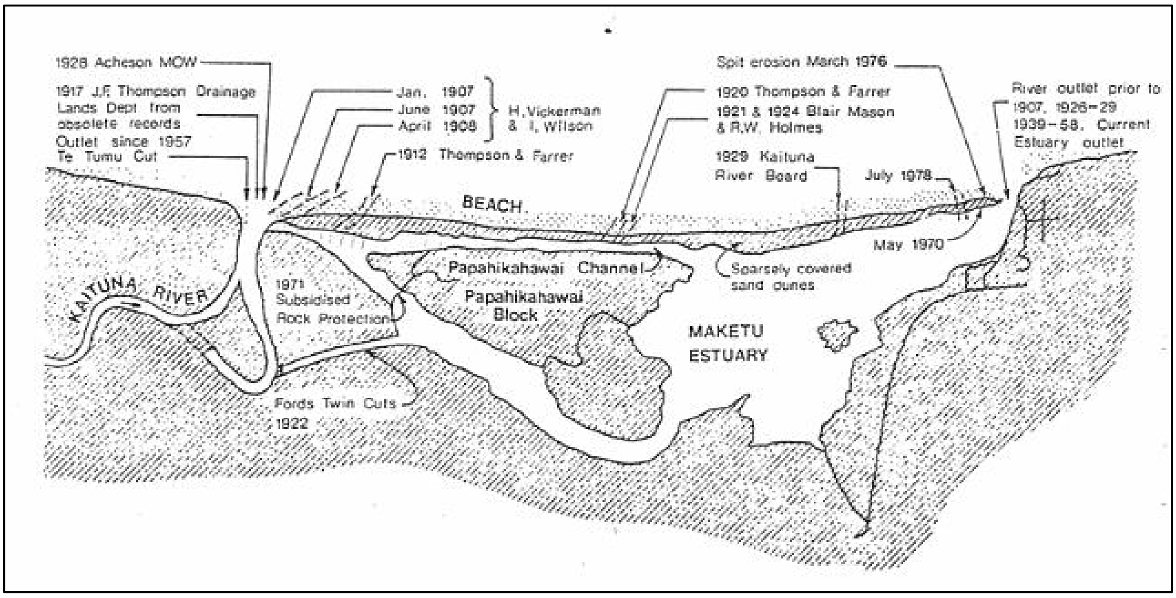

Figure 2 Location of historic river and estuary outlets to the sea (from BOPRC drawing No. K4254).

Figure 1 shows the lower river and estuary as surveyed in 1877. Historically the river has generally flowed through Maketū Estuary but has at times breached the spit between the estuary and the sea. Figure 2 shows the location of the river and estuary outlet at particular points in time back to the early 1900's. In 1919 the Kaituna River Board was formed for the purpose of reducing flooding and from the 1920's through to 1930's, a number of new channels were cut to take out bends and increase the river gradient. In February 1957 a new channel was opened to divert the river directly to the sea at Te Tumu. Re-diversion of restricted flows back to the estuary occurred in 1996 following the granting of consent to the Minister of Conservation.

The large flood plain of the lower Kaituna River formerly supported a very large area of wetland (around 14,000 ha). This was dominated by flaxes, reeds and rushes. A brief description of historic vegetation is provided by Murray (1978).

Water quality of the river is relatively good at the lake outlet and decreases in the lower reaches, particularly with respect to increases in nitrogen. Information reviewing water quality data is presented in Park (2007). Further information on water quality and land use in the catchment is available in Park (2010).

Lakes Rotorua and Rotoiti form the upper catchment of the Kaituna River and both have experienced long-term deterioration of water quality. This decline has been documented through a number of research projects and therefore there is good information on the source water quality of the Kaituna River. The water quality assessment prepared to support the diversion of the Ohau Channel directly into the top of the Kaituna River is particularly relevant (McIntosh 2005).

The upper regions of the lower Kaituna River catchment (downstream of the lakes) are dominated by pastoral and exotic forestry with some sub-catchments retaining extensive native forest cover. In recent years there has been some conversion of exotic forestry to dairy farms. Much of the mid-section of this catchment has had suitable land converted to horticulture with kiwifruit being dominant. The lower regions of the catchment are predominantly productive river-flat plains with extensive drainage schemes and the dominant land use is dairy farming.

Part 2: Methods

2.1 Mapping process and methods

A search was made for historic vertical aerial photography covering the lower Kaituna River and Maketū Estuary. Available photos were then scanned at a resolution high enough to match that of the photos and capture all the available detail. Not all aerial photograph coverage was obtained as KRTA (1986) lists 1939, 1948, 1959, 1963, 1970, 1977, 1980 and 1981 as having stereoscopic pairs while also mentioning additional photography from 1961, 1964, 1979 and 1983. Table 1 below sets out the details of the available aerial photographic coverage. The 1939 and 2011 aerial photography have the best resolution while the 1961 coverage has the lowest.

Table 1 Details of aerial photographs used for mapping.

Year/date	Type	Altitude	Scale	Pixel size
1939–14 Dec	B & W prints	9,000 ft	1:11,000	0.22 m
1948–10 Jun	B & W prints	11,000 ft	1:16,000	0.33 m
1961–6 Feb	B & W prints	16,500 ft	1:24,000	0.83 m
1977–4 Feb	B & W prints	-	1:8,000	0.33 m
2011	Colour/digital	13,700	-	0.25 m

Using GIS software (ArcMap 10.1), all digital copies of historic photography were geo referenced using the 2011 aerial photography to position them spatially. Most registration control points tended to be based around the drains with limited buildings or roads being of any use in the earlier photography. The overall registration accuracy of the photos tended to be within 1-2 m of the 2011 photography. Accuracy of the 2011 aerial photography is +/- 0.50 m for >90% of coverage.

Mapping of wetland extent was done at a scale of 1:600 and used the wetland classification system (Johnson & Gerbeaux 2004) to show the type of hydro-system and dominant type of plant structure. Hydro-systems used were palustrine (freshwater) and estuarine. Estuarine hydro-systems are areas influenced by saltwater down to a dilution of 5% of that of seawater (Clarkson et. al, 2003).

Classification of wetland area by hydro-system is indicative only and has accuracies of +/- tens of meters at best and possibly hundreds in some areas. Evaluation was made using information from river flows, channel morphology, reports, anecdotal evidence and examination of sediment cores to show mud types and shells etc.

Vegetation structural type/class is also indicative as the black and white photography and relatively low resolution for the 1948 to 1977 series is difficult to interpret, particularly for 1961, hence some of the historic wetland is classified as a mixed structural class. Vegetation structural type is also mapped at very low resolution (polygons are very large), hence many structural types may occur in that area and the class reflects that vegetation type that appeared to be dominant. For the 2011 photography a more detailed and accurate assessment was made. This was achieved by conducting ground truth surveys in summer 2013/2014 and mapping over the 2011 photography to provide extents. It is assumed that dominant plant structural form would not have changed significantly over that time.

In summary the historic photo geo-referencing has an error around 1-2 m for spatial placement. The mapping of wetland vegetation extents has an accuracy of around 1-2 m if the margin is easily discerned. Classification into historic hydro-system is only indicative and may have errors of up to 100 m or more in some areas. Historic vegetation structural form is based on very coarse polygons and only denotes what appears to be the dominant form. The 2011 has higher hydro-system and structural form accuracies due to higher resolution mapping with associated ground truth surveys.

Part 3: Vegetation extents 1939-2011

3.1 Seagrass

Extent of seagrass beds were mapped using available 1939, 1948, 1961 and 2011 aerial photography. The total area of seagrass beds in each of these years are provided in Table 2 below.

Table 2 Area of seagrass beds in Maketū Estuary in 1939, 1948, 1961 and 2011.

Year	Area (ha)
1939	4.784
1948	13.192
1961	2.173
2011	0.004

Mapping of seagrass beds in the 1939 and 1948 aerial photography was relatively easy with few issues in identifying areas clearly (Figures 3 and 4). The total area increased substantially from 1939 through to 1948. In the 1961 aerial photography (Figure 5) it was more difficult to identify areas of seagrass and hence it is possible that the mapping underestimates extent. The main reasons for this were the lower photo resolution, an abundance of drift algae within the area that the seagrass beds occur and the wetland areas were dying back leaving dead root stubble exposed. The total area of mapped seagrass in 1961 was less than the 1938 and 1948 period. In 2011 the total seagrass extent is limited two very small patches and although far less than present in the 1961 aerial photography, it is similar to that noted in the early 1990's during surveys by Bay of Plenty Regional Council.

3.2 Wetland vegetation

Areas of wetland vegetation within the mapped area of the lower Kaituna River/ Maketū Estuary based on aerial photography from 1939, 1948, 1961 and 2011 are provided in Table 3. Total wetland area includes seagrass bed extent which is given in Table 2 of section 3.1 above. The area mapped in 1939 sets the maximum inland extent mapped for all following years. The original Kaituna wetlands (some 14,000 ha) extended well beyond the area mapped in 1939 (Figure 3) which focuses on changes occurring with the lower river and estuary. In general the landward boundary for the 1939 mapping is areas of wetland that were contiguous with the estuary that had not been drained or stop-banked and farmed. Hence from 1939 onwards the last column in Table 3 shows how much wetland was lost directly to drainage/farming.

Table 3 Historic wetland extents (ha) in Maketū Estuary from 1939 to 2011 with breakdown into hydroclass and plant form. Also given is area lost by drainage.

Year	Total area	Rushland		Rush/reed/shrub	Drained
		Estuarine	Palustrine	Palustrine	
1939	205.304	60.519	124.128	15.8733	-
1948	196.645	61.099	105.785	16.569	24.205
1961	115.897	98.353	0.231	15.14	47.101
2011	16.288	7.219	0.368	3.593	95.223

Changes in wetland area from 1939 to 1948 show an increase within the estuary once the loss of wetland by draining is taken into account. Taking into account the area lost by drainage would have given a total area of 220.8 ha, which represent an increase of 15.5 ha. Around half of this increase was due to seagrass (8.4 ha) and the palustrine (freshwater) vegetation appears to have expanded by around 7 ha.

In 1961, four years after the diversion of the Kaituna River out to sea, The area of wetland has decreased from 1948, even taking into account the loss from further drainage (23 ha). A close look at the 1961 mapping shows that the greatest wetland loss in the estuary (58.6 ha) was in upper area where change in salinity conditions were highest. In particular, extensive areas of palustrine wetland have disappeared from the southwest margin of the wetland on Papahikahawai Island. In comparison the salt tolerant wetland present on the southeast margin of this Island shows less change.

Although a quantitative assessment of change for the whole of the estuary from 1961 to 1977 is not possible because of the partial photographic cover, mapping of the limited coverage has been done (Figure 6) as it covers the area around Papahikahawai Island. Outside of the reclaimed (drained and stop banked) area on Papahikahawai Island (around 10.5 ha) there are only a few small wetland remnants left (1.9 ha) of an area that in 1948 measured around 71 ha in extent. Mapping of the 2011 photography shows that nearly all the extensive wetland area on the south side of Papahikahawai Island has gone with only around 0.3 ha remaining of the 71 ha present in 1948.

In the period from 1948 (highest wetland extent measured in the estuary) up to 2011, around 111 ha of wetland vegetation (excluding reclamation by drain and stop banks) has disappeared from Maketū Estuary. There is additional aerial photography between 1977 and 2011 to provide comparisons, but resolution and quality are not good for the pre 2000 runs and wetland extents post 2000 are very similar to 2011. For example the saltmarsh adjacent Maketū Road 150 m west of the wetland drain or last houses at Maketū has also shown considerable retreat. Between 1948 and 1961 it had retreated 90 m and then between 1961 and 1996 it had retreated a further 80 m, but between 1996 and 2011 it has only retreated at most 1-2 m.

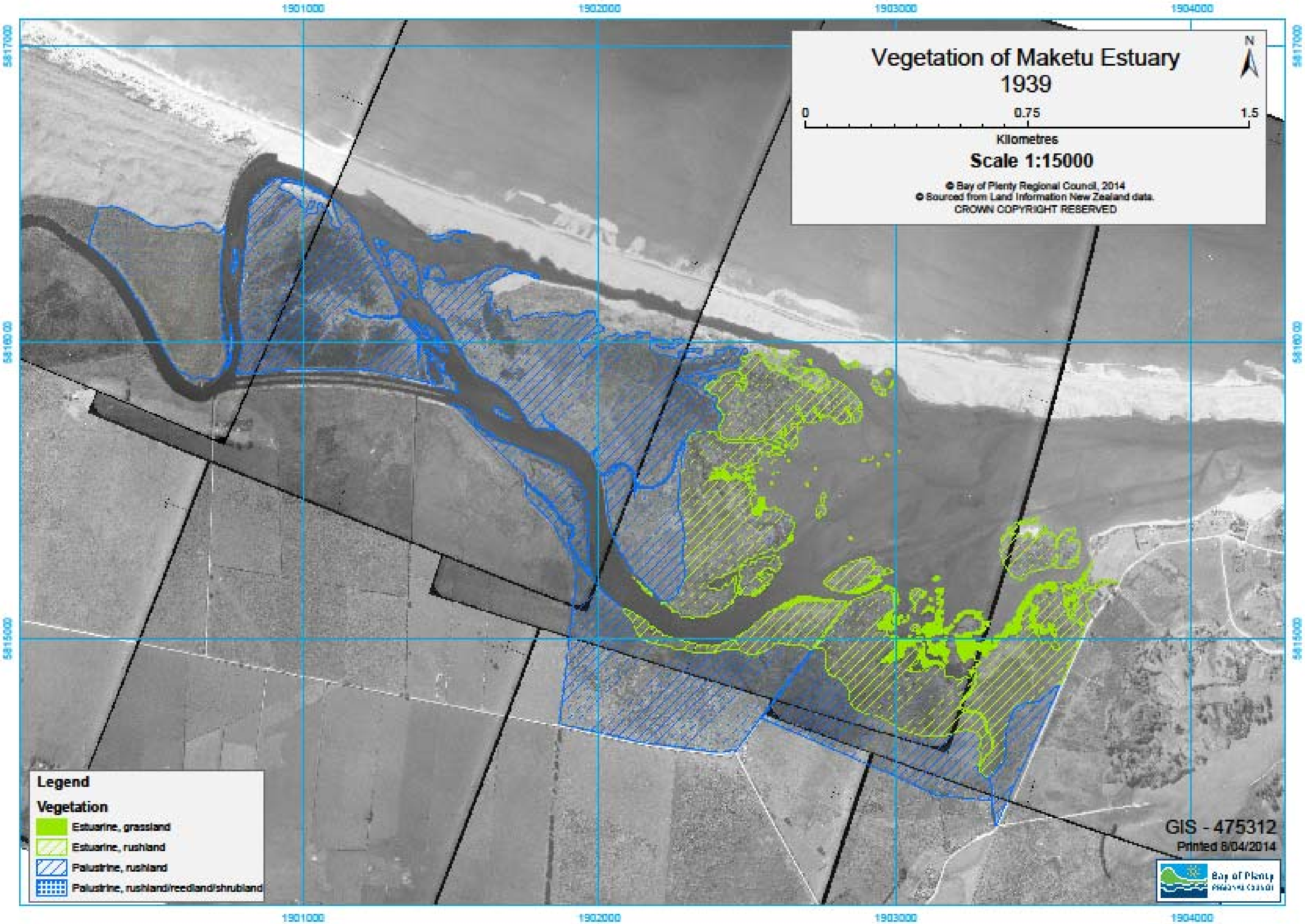

Figure 3 Extent of historic wetland vegetation (including seagrass) in 1939 within the lower Kaituna River and Maketū Estuary.

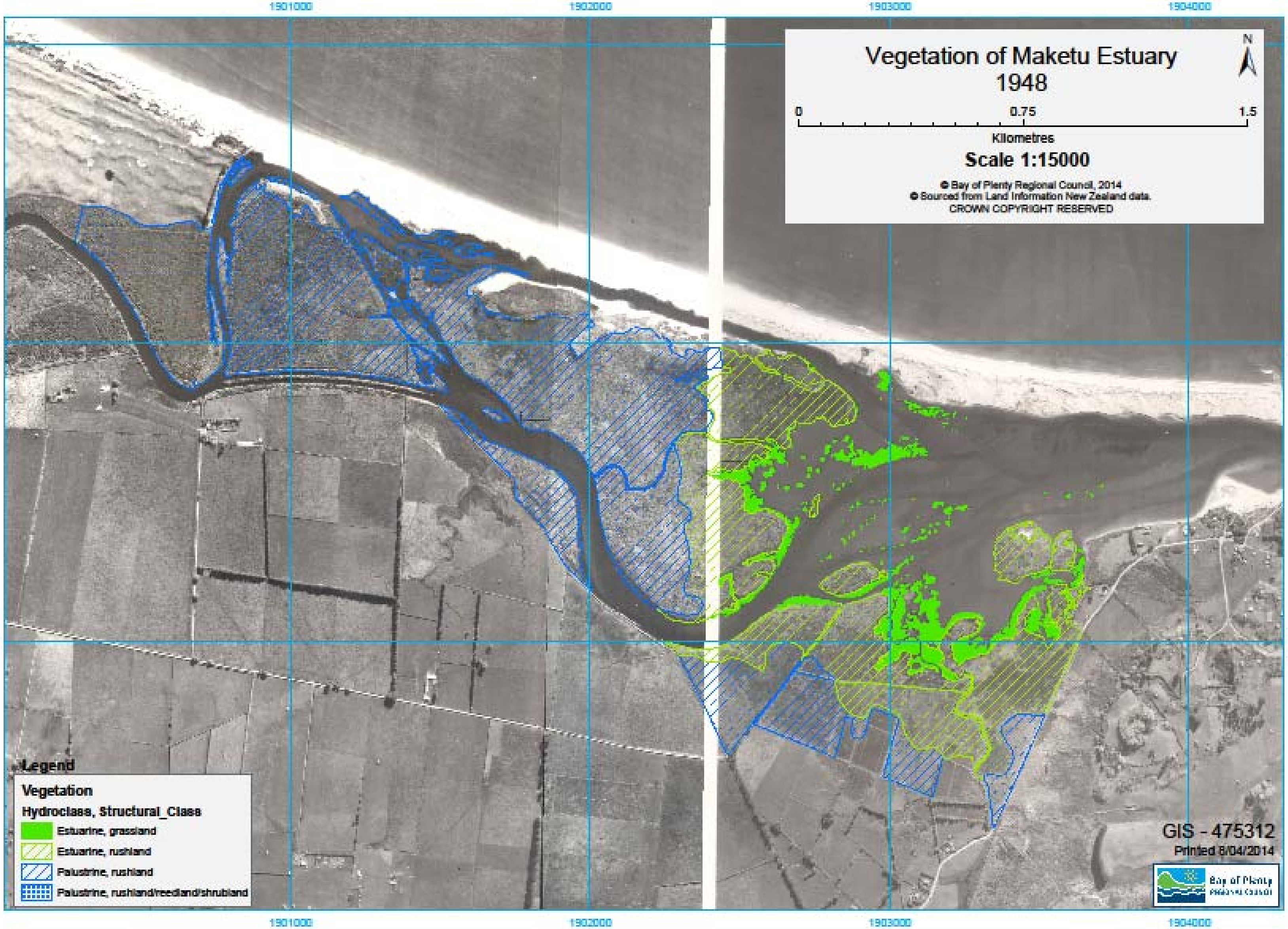

Figure 4 Extent of historic wetland vegetation (including seagrass) in 1948 within the lower Kaituna River and Maketū Estuary.

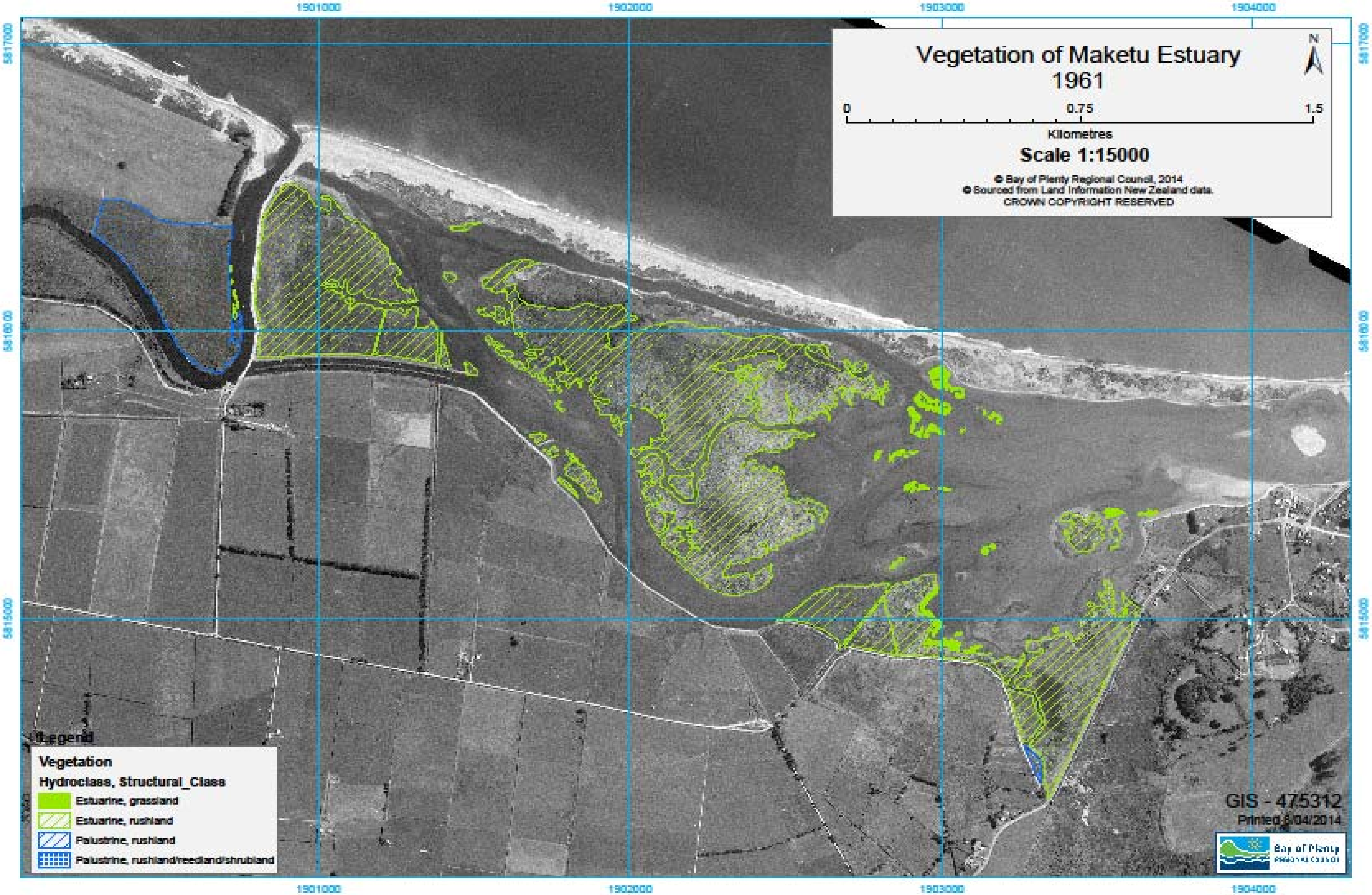

Figure 5 Extent of historic wetland vegetation (including seagrass) in 1961 within the lower Kaituna River and Maketū Estuary.

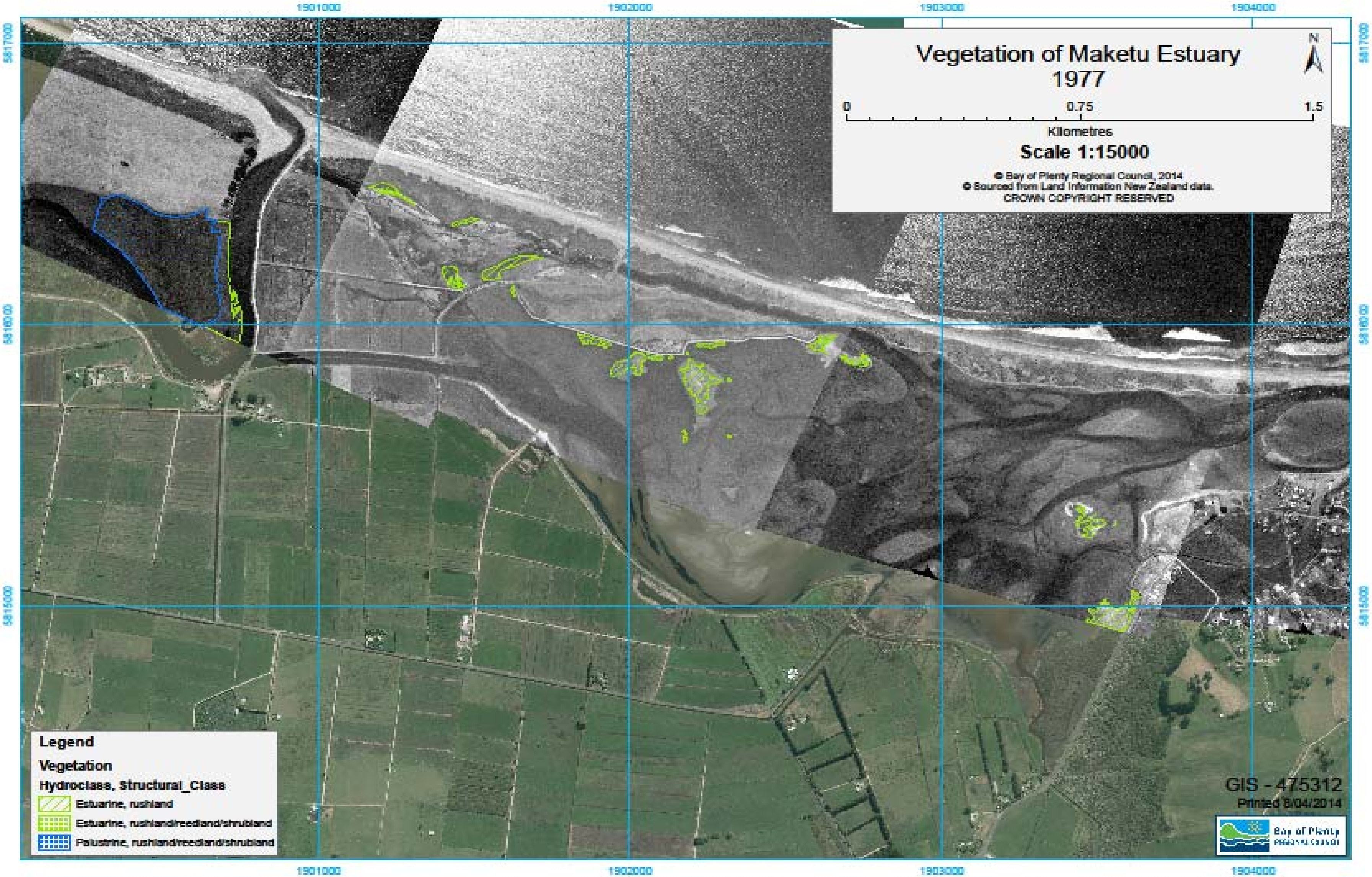

Figure 6 Extent of historic wetland vegetation (including seagrass) in 1977 within the lower Kaituna River and Maketū Estuary.

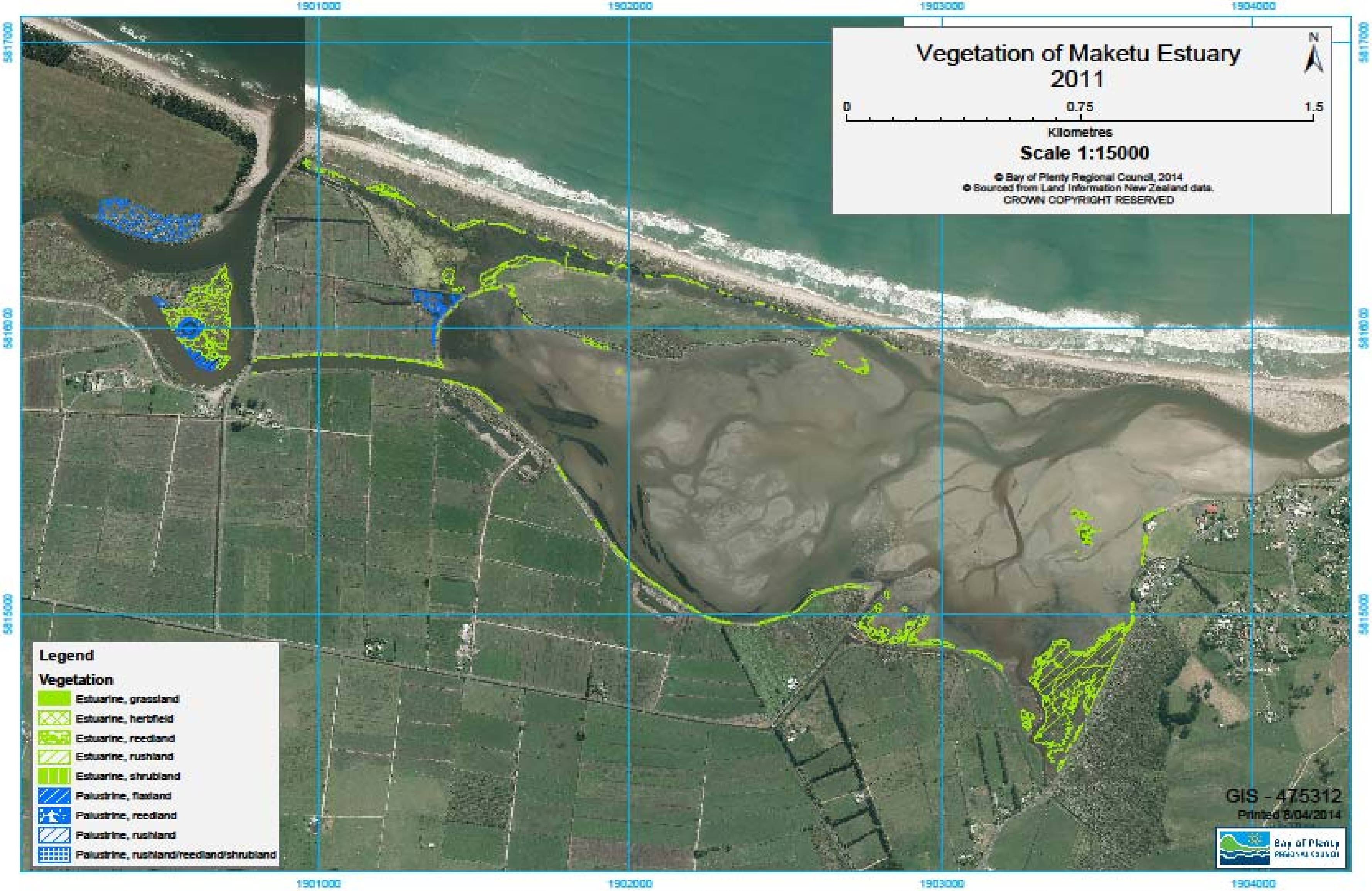

Figure 7 Extent of historic wetland vegetation (including seagrass) in 2011 within the lower Kaituna River and Maketū Estuary.

Part 4: Discussion

4.1 Maketū Estuary seagrass extent

Seagrass is a euryhaline species (able to live in a wide range of salinities) that is capable of living near stream mouths or other areas where the water is fresh at low tide but requires periodic immersion in water of higher salinity. The ideal salinity range for optimum growth is around 10 to 30 practical salinity units (psu). Sea water has a salinity of 35 psu. The species of seagrass in New Zealand is generally referred to as *Zostera muelleri*. A phylogenetic analysis of genetic and morphological characteristics of the Australian and New Zealand species of *Zostera* by Les et al. (2002) determined that *Zostera capricorni*, *muelleri*, *mucronata* and *novaezelandica* were the same species and recommended that *Z. capricorni* be used. However, since *Z. muelleri* has priority, it should have been the accepted name and is commonly used to refer to this seagrass.

In Maketū Estuary there have been major changes in the salinity regime and in the seagrass extent over time. Mapping of seagrass extents from 1939 to 1948 shows a marked increase and from 1961 through to 2011 a major decline. The decline fits with anecdotal and reported observations (Bioresearches, 1976 and Murray, 1978) noting the presence of seagrass in the central area of the estuary. It also coincides with major salinity changes, although a range of other factors can affect seagrass productivity including disease, contaminants, nutrients and sedimentation. Within New Zealand there has been a clear decrease in many estuaries, potentially for a variety of reasons. See Turner & Schwarz (2006) for a general review of New Zealand seagrass.

Prior to the period in which seagrass markedly increased (1939-1948) the Kaituna River had for the period 1907 to 1928, been flowing to the sea near or at Te Tumu. During this period the salinity may have been more similar to what it is now (high) with only small areas in the upper estuary having values of less than 30 psu (McIntosh & Park 1997). From 1928 up until 1957 the Kaituna River was flowing through the estuary and lowering the salinity markedly. This coincides with the 1939-1948 period of seagrass increase. The 1961-2011 decline of seagrass coincides with the 1957 diversion of the Kaituna River back out of the estuary and the associated increase back to high salinity, hence it could be a key factor for the change.

Seagrass (*Zostera spp.*) is known to flower more frequently, increase seed production and have higher germination rates in lower salinity (Philips et al. 1983, Conacher et al. 1994, Tanner & Parham 2010, Ramage & Schiel 1998). *Z. muelleri* also has wide salinity tolerance and has been shown to produce the highest shoot density at 12 psu after ten weeks (Collier et al. 2014) compared to higher or lower salinities. In addition estuarine seagrass has been shown to have lower vitality at higher salinities in the presence of high nutrient loads (Katwijk et al., 1999). These traits may be linked to the initial increases of seagrass in Maketū Estuary from 1939 to 1948 (more favourable low salinity period) and then to the decline seen from 1961 to 2011. However, as stated above there are many potential factors that can influence seagrass productivity and extent, so without extensive historic monitoring it is not possible to prove that salinity alone was the main driver of change.

4.2 Wetland vegetation extent in Maketū Estuary

The focus of this study was to document the changes in wetland extent the lower Kaituna River and Maketū Estuary with a high degree of accuracy and compare to current extents. Results generally line up with the analysis made by KRTA (1986) which is the most quantitative of previous studies. KRTA (1986) also noted the slight increase of marsh area in the middle of the estuary to the south of Papahikahawai Island between 1939 and 1948, and then noted some degeneration of maritime marsh in the early 1960's following the 1957 diversion of the Kaituna River out of the estuary. KRTA (1986) also note the loss of marsh in the estuary was essentially complete by 1979.

The increase of marsh area in the mid estuary from 1939 to 1948 is possibly a response to the period 1907 to 1928 in which the river had been flowing out to sea at Te Tumu. During this period less fresh water would have been entering the estuary and salt intolerant marsh species would have died back. Then from 1928 onwards the fresh water dominated area would have extended much further down the estuary and prompted freshwater species to re-establish and would have also been more favourable for the salt tolerant species.

Taking into account the direct loss of marsh around Maketū Estuary as a result of reclamation for farming, the biggest decline recorded in the early 1960's through to the 1970's coincides with the diversion of the Kaituna River out of the estuary in 1957. The removal of the river flow resulted in a salinity regime strongly dominated by sea water throughout the estuary except for a small area where the Waitipuia Stream and drains enter to the south. Typical salinities in the early 1990's (McIntosh & Park 1997) of the central and lower estuary were above 30 psu and around 25 psu at the top of Fords Cut. This salinity regime is less favourable for saltmarsh as indicated by a study of salt tolerance in New Zealand 31 saltmarsh plants (Partridge & Wilson 1987) which showed most could not grow in sea water (35 psu). Of those species that had a salt requirement for maximum growth, the highest was 15 psu (Partridge & Wilson 1987). *Juncus kraussii* (previously referred to as *J. maritimus*) is one of the most salt tolerant species formerly dominant in central areas of Maketū Estuary (Murray 1978, KRTA 1986) and has a preferred salinity range of 5-31 psu.

Another important aspect of salt tolerance affecting the viability of saltmarsh is the salinity of pore water or shallow ground water to which plant roots are exposed. A number of the previous studies in Maketū (Murray 1978, KRTA 1986, Gillespie 1988, Richmond and Forbes 1990, Bergin 1994) have all highlighted the building of stop banks and drains as a factor that will have contributed to an increase in pore water salinity in areas of the estuary outside of the reclaimed areas. However, the drainage and stop banking was clearly not an initial factor in the loss of the extensive marsh area adjacent the south side of Papahikahawai Island where extensive marsh loss had already occurred. This indicates that the change in the salinity of the overlaying water was the primary factor in this area. This conclusion was also postulated by KRTA (1986) in their analysis of marsh loss. Loss of Papahikahawai Island marsh was most rapid and pronounced towards the western end of the island. It is likely that more salt intolerant species were present in this area, hence most affected by the huge change in salinity.

Bergin (1994) had noted 1.5 m of saltmarsh retreat in the southern area of the estuary over a four year period due to substrate erosion. As part of this study it has been noted that from 1948-61 saltmarsh retreated around 90 m and from 1961-1996 around 80 and from 1996-2011 around 1-2 m in this area. It would appear that the substrate erosion is probably more a response to the salinity changes and subsequent loss of marsh plants, rather than being the primary driver of marsh loss in this area of the estuary.

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