# Coastal morphology of South Otago: Nugget Point to Chrystalls Beach

July 2014

## Executive summary

This report assesses changes in shoreline position between Nugget Point and Chrystalls Beach between 1946 and 2012. A survey of the offshore bathymetry and onshore surface profiles was completed in February and April 2013 to set a baseline for future coastal monitoring. An analysis of recent and historic changes in the onshore and offshore coastal environment between Nugget Point and Chrystalls Beach is provided.

The analysis contained in this report is based on terrestrial cross -section and bathymetric data collected in early 2013, LiDAR data collected in 2004 and 2009, and aerial photographs collected in 1946, 1972, 1997 and 2006. This report compares these data sources, where available, to allow comparisons of changes in the coastal zone to be quantified.

Between Kaka Point and the Koau Mouth of the Clutha River/Mata-Au, the vegetated foredune retreated at an average rate of 3.3m/yr between 1946 and 2012. The rate of retreat has increased during that period, and at the current rate (observed between 2006 and 2012), floodbanks, which form part of the Lower Clutha Flood Protection and Drainage Scheme, could be affected by coastal erosion in less than three decades. The average rate of erosion between the Koau and Matau mouths of the Clutha River/Mata-Au between 1946 and 2012 was 0.2m/yr, with net erosion occurring at the south-western end of this beach, and net accretion towards the northeast. At Measly and Chrystalls beaches (to the south and north of Toko Mouth), average rates of accretion between 1946 and 2006 were 2.3m/yr and 0.8m/yr, respectively.

Accretion of the foredune[1] (Figure 1) and an increase in sand volume occurred between Nugget Point and Kaka Point between 2004 and 2013, while a general retreat of the foredune occurred between Kaka Point and the Matau Mouth during the same period. Limited change in the dune profile has occurred between the Matau Mouth and Chrystalls Beach, with the exception of one profile (MBO7), which shows degradation across the whole transect.

The surface profile of the near-shore sand wedge[2] shows that the seafloor is generally smooth, with some areas of pockmarking and undulations, possibly rock outcrops.

This report has been prepared by the Otago Regional Council (ORC) and describes the changes that have occurred in the onshore coastal profile between Nugget Point and Chrystalls Beach. A baseline survey of the offshore profile has been completed. The information described in this report will allow future comparisons of the coastal environment (offshore and onshore) between Nugget Point and Chrystalls Beach to be made.

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[1] The first dune ridge forming at the back of the beach (Woodroffe, 2002)

[2] Located off the eastern Otago coastline, between Nugget Point and the Otago Peninsula, is a wedge of fine-grained silty sand that is commonly referred to as the 'near shore sand wedge' (see Appendix 1).

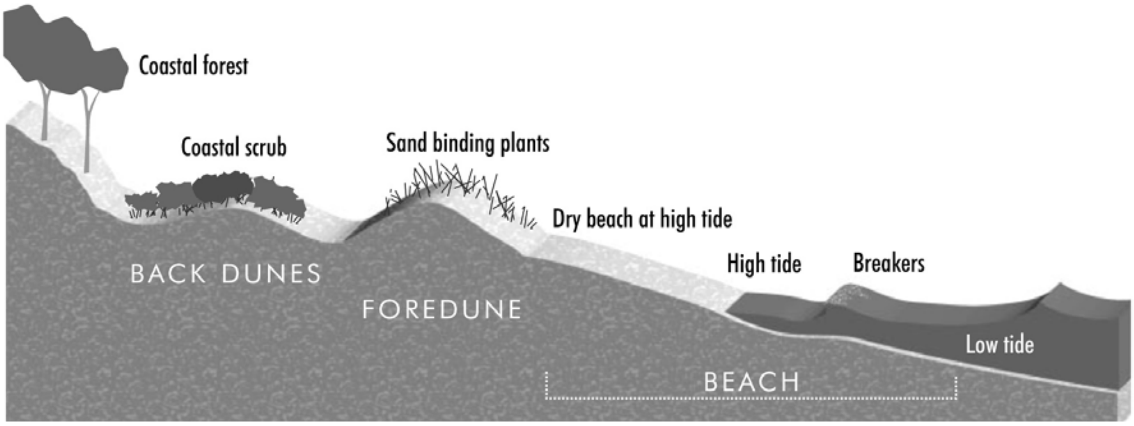


**Figure 1 Cross-sectional diagram of the coast (Environment Waikato)**

# 1. Introduction

The South Otago coastline is characterised by white sand beaches, interspersed by rocky cliffs and headlands, and extends for 140km from the mouth of the Taieri River to the Brothers Point on the boundary between Otago and Southland. A number of small settlements are located along this section of coast, including at the mouths of the Taieri and Tokomairiro rivers, Kaka Point, and Papatowai, Pounawea and Newhaven in the Catlins. The total population living in these settlements or elsewhere in close proximity to this section of coast is approximately 1,400 (Statistics New Zealand, 2013). The Lower Clutha Flood Protection and Drainage Scheme is located in the lower reaches of the Clutha River/Mata-Au, providing drainage and flood protection to the fertile farmland that makes up much of the Clutha Delta. Due to its proximity to the coast, assets associated with this scheme may be affected by shoreline erosion as well as other coastal hazards such as storm surge and tsunami (ORC, 2012).

The coastal climate of this area is dominated by wind-generated sea waves from the southeast (ORC, 1992). The coastline is regularly subjected to severe storm conditions, either from waves generated to the west of New Zealand and refracted around the south of the South Island and up the east coast, or from waves generated by subtropical depressions drifting southward over New Zealand.

The Clutha River/Mata-Au enters the Pacific Ocean at Molyneux Bay, and large flood events have historically resulted in significant changes in the morphology of the Clutha delta, most noticeably in October 1878, when new mouths were forged for each of the Koau and Matau branches (ORC, 1992). The Clutha River/Mata-Au also provides sediment to the coastal system, particularly during high flow events.

Expert evidence presented at a resource consent hearing in 2001[3] was in disagreement as to the primary cause of coastal erosion observed at Molyneux Bay (ORC, 2010). However, it was generally accepted by the hearing panel that the operation of the Roxburgh Dam on the Clutha River/Mata-Au at least partly contributes to coastal erosion due to trapping of sediment

[3] Contact Energy Ltd Resource Consent Hearing 2002

behind the dam. This was recognised in Resource Consent 2001.394, condition 13, which states:

'The consent holder[4] shall contribute 50% of the costs of an Otago Regional Council coastal management programme specifically addressing:

*i) An analysis of historic shoreline positions using appropriate techniques at specific representative coastal sites that may be dependent on Clutha derived sediment.*

*ii) A comprehensive physical coastal monitoring programme at the representative sites, covering the near shore transport zone between the limits of the beach fore dune system and seaward limit of the near shore sand wedge between Nugget Point and Taieri Mouth.'*

This report describes the current and historical morphology of the South Otago coastline between Nugget Point and Chrystalls Beach (Figure 2). Measurements were not completed between Chrystalls Beach and Taieri Mouth due to the lack of long sandy beaches and the reduced importance of Clutha River/Mata-Au derived sediments in this area. It provides an accurate baseline description of this section of coastline (including the bathymetry of the offshore area), which can be used as a comparison against subsequent surveys. The information contained in this report, along with future survey work, can also be used to better understand the effects of the Roxburgh Dam on coastal morphology and the general state of the coast in Molyneux Bay and northwards to Chrystalls Beach.[5]

A range of information sources have been used to describe the shape of the shoreline and the morphology of the near-shore area. This includes charts and aerial photographs, survey data and LiDAR[6] collected in 2004 and 2009. The current morphology of this area has been primarily described using onshore and offshore (bathymetric) survey data collected in early 2013. The historical and recent information has been combined to describe changes in morphology at six lengths of coastline between Nugget Point and Chrystalls Beach (Figure 2). The following chapters present this information for each area.

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[4] The consent holder in this instance is Contact Energy Limited.

[5] Measurements were not completed past Chrystalls Beach due to a lack of sandy beaches and the limited effects of Clutha River/Mata-Au derived sediments to the north of Chrystalls Beach.

[6] **Li**ght **D**etection **a**nd **R**anging data is collected using a laser mounted on an aircraft that takes point measurements across the swath of the beam. The points record the height and location of the ground/objects.

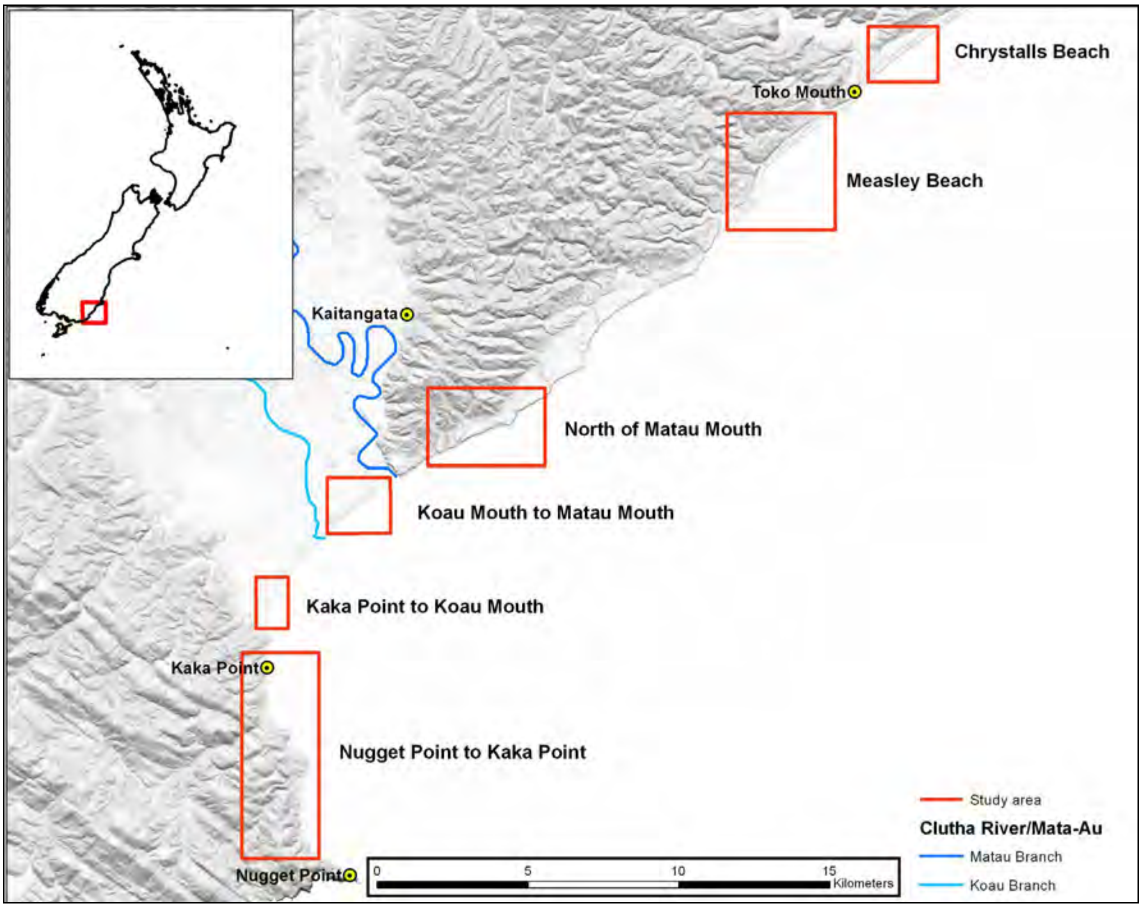


**Figure 2 Location of the six lengths of coastline for which changes in coastal morphology are described in this report**

A series of appendices provides the detailed information that has been used to inform this report. Appendix 1 lists the information held by ORC in regards to coastal processes in this area, and Appendix 2 provides a summary of the data and methods used to prepare this report, including any limitations associated with the collection and comparison of data.

# 2. Nugget Point to Kaka Point

This east-facing section of coast alternates between long stretches of white sand beaches, and a number of rocky headlands (Figure 3 and Figure 4). The settlement of Kaka Point is situated at the northern end of this section, and has a permanent population of approximately 220. Kaka Point is sufficiently elevated and set back from the coast as to not be affected by changes in the shoreline and storm action, although the dunes from the surf club south have incurred storm damage in the past (ORC, 1992).

**Figure 3 Looking north towards Kaka Point from Willsher Bay (August 2012)**

**Figure 4 Looking south towards Nugget Point from Willsher Bay (August 2012)**

A series of 12 beach transects was surveyed along this stretch of coast in April 2013 (Figure 5), extending from the low tide mark to the landward side of the adjacent road. The 2013 surveyed beach profiles are compared against topographic data (LiDAR) collected in 2004 in Figure 8 to Figure 17.[7] These figures show a general trend of accretion along the foreshore (the area where waves break) between 2004 and 2013. The four southernmost transects (KAK12 to KAK9) all experienced some accretion of the dune face over this period, although a small loss of sand did occur at the base of the dune face at KAK12 (Figure 6). No change in the shape of the beach profile was observed at transect KAK8 (Figure 13). At the northern end of this stretch of coastline, accretion of the dune face and beach was observed at transects KAK7 to

[7] A more detailed explanation of the methods used to generate these two sources of data is provided in Appendix 2.

KAK1 (Figure 12 to Figure 14). The combined onshore and bathymetric survey data for KAK12/MB10 and KAK7/MB9 are shown in Figure 18 and Figure 19.


**Figure 5 Location of onshore cross-sections between Nugget Point and Kaka Point (aerial photograph date: March 2006)**

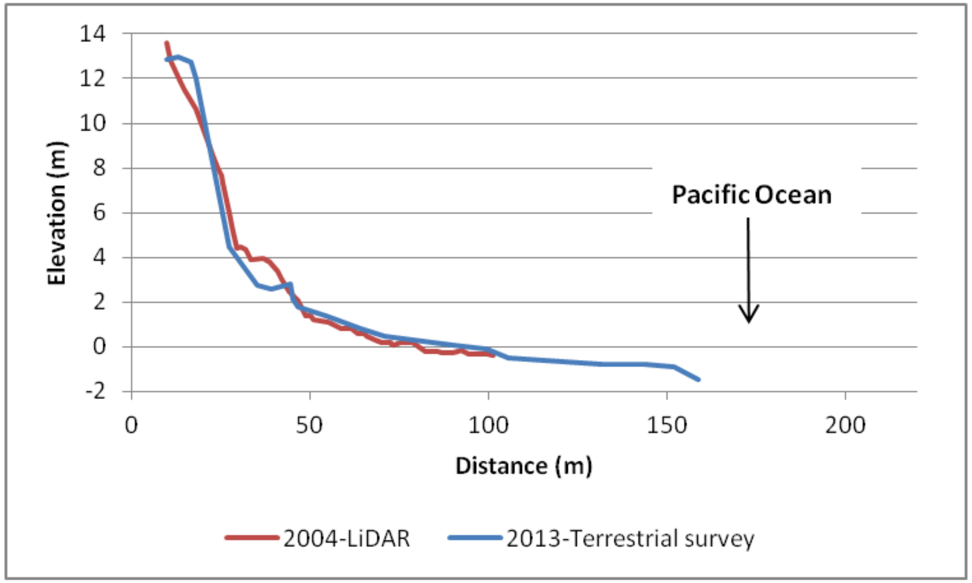


**Figure 6 Cross-section KAK12**

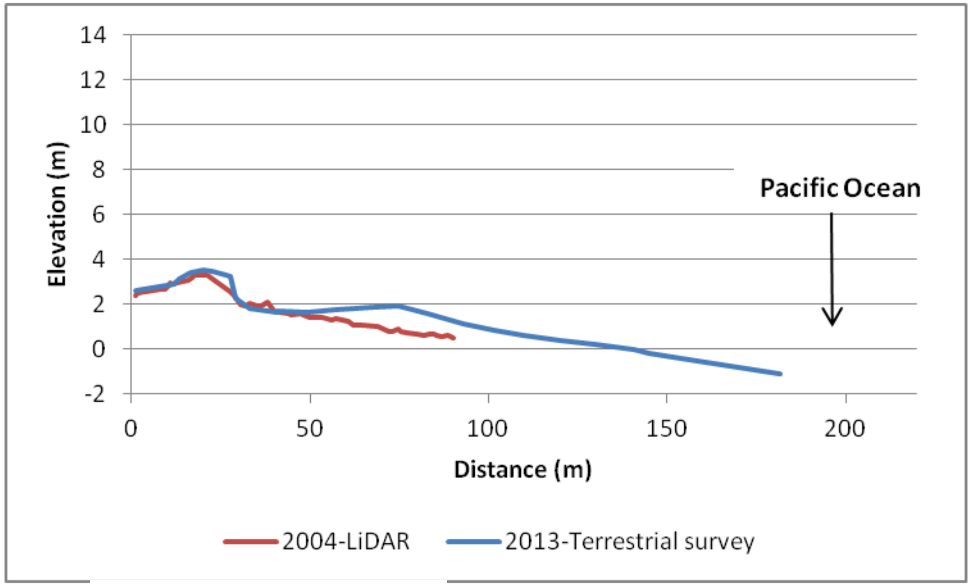


**Figure 7 Cross-section KAK11**

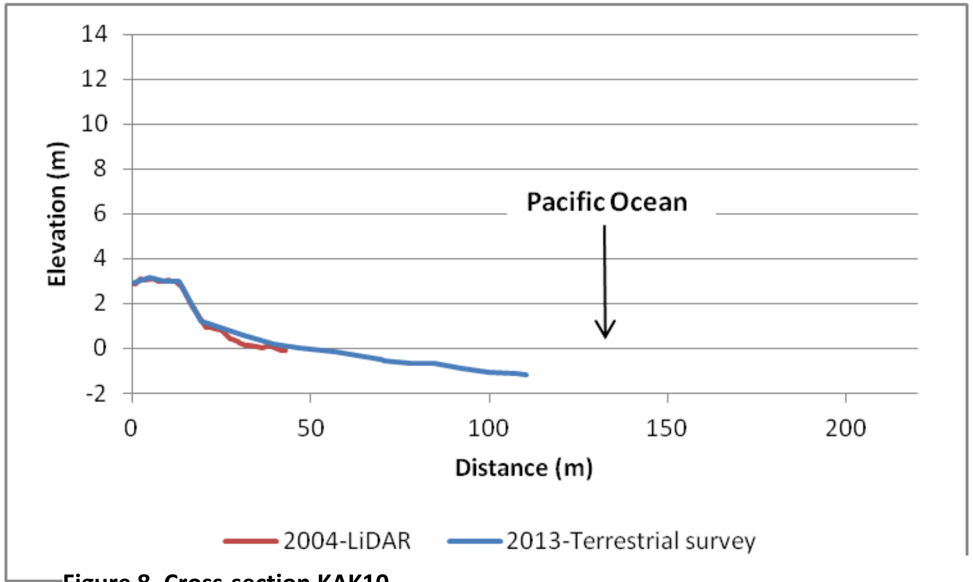


**Figure 8. Cross-section KAK10**

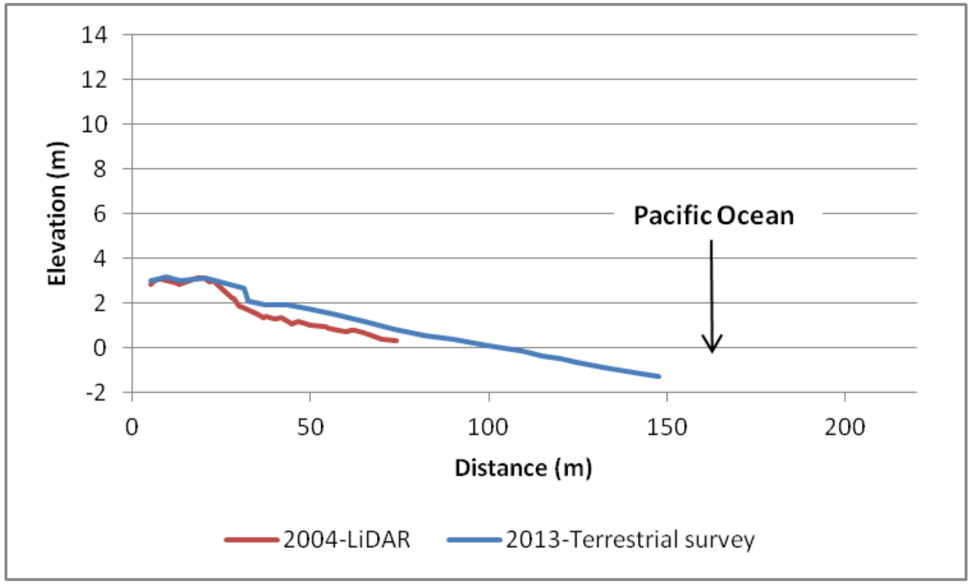


**Figure 9 Cross-section KAK9**

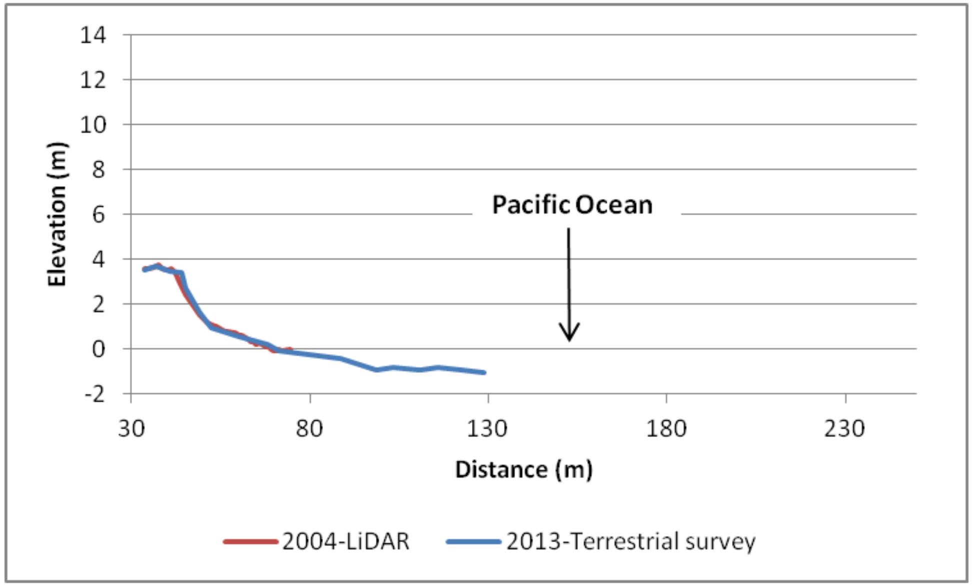


**Figure 13 Cross-section KAK8**

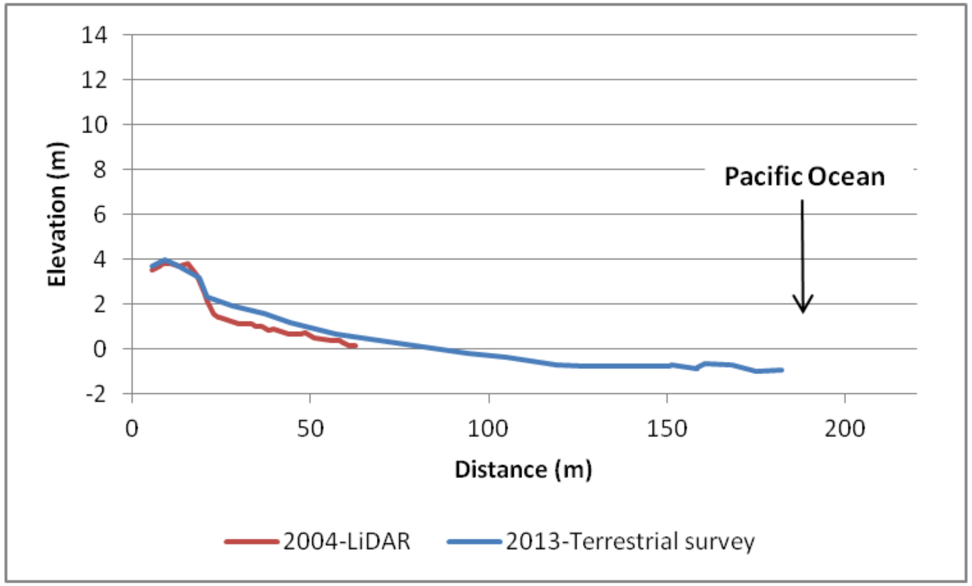


**Figure 12 Cross-section KAK7**

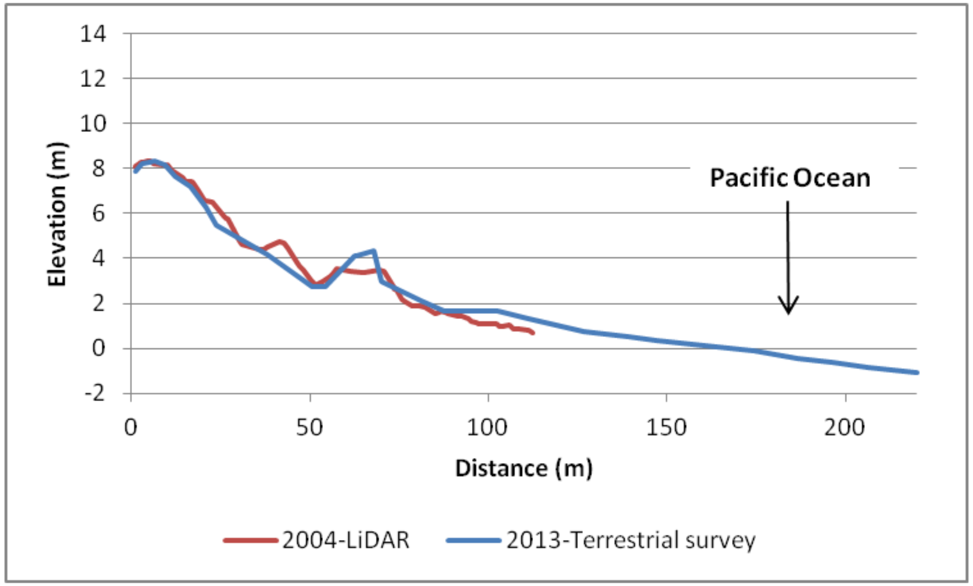


**Figure 11 Cross-section KAK6**

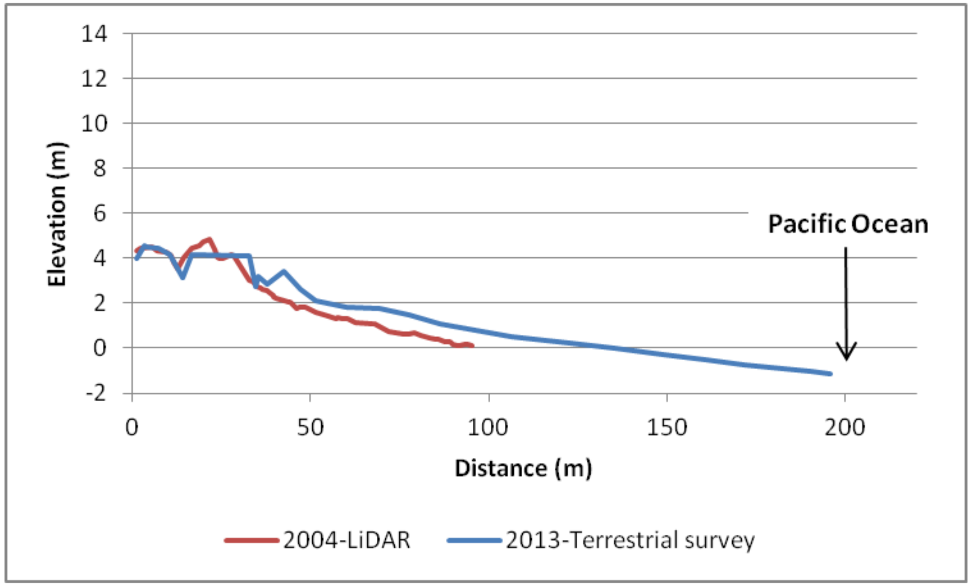


**Figure 10 Cross-section KAK5**

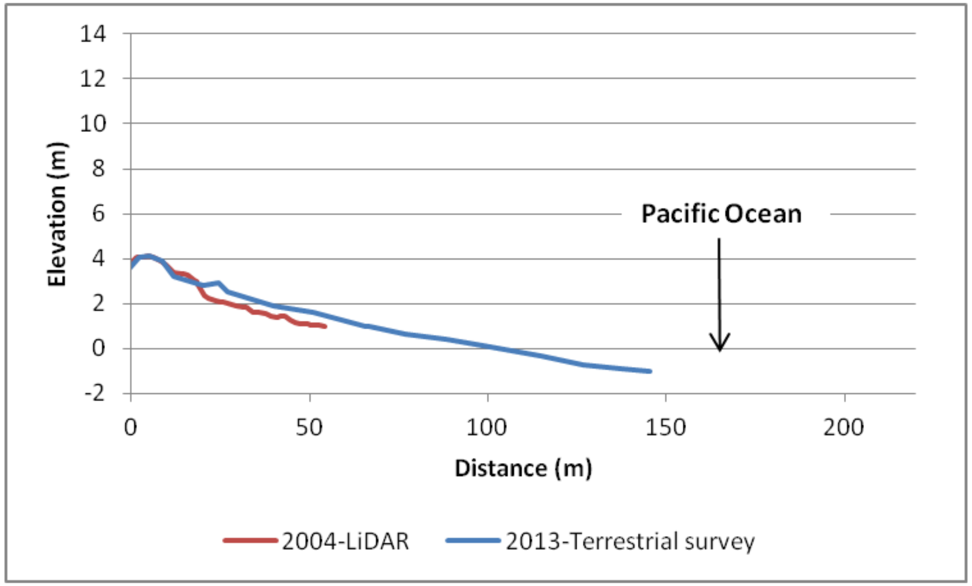


**Figure 17 Cross-section KAK4**

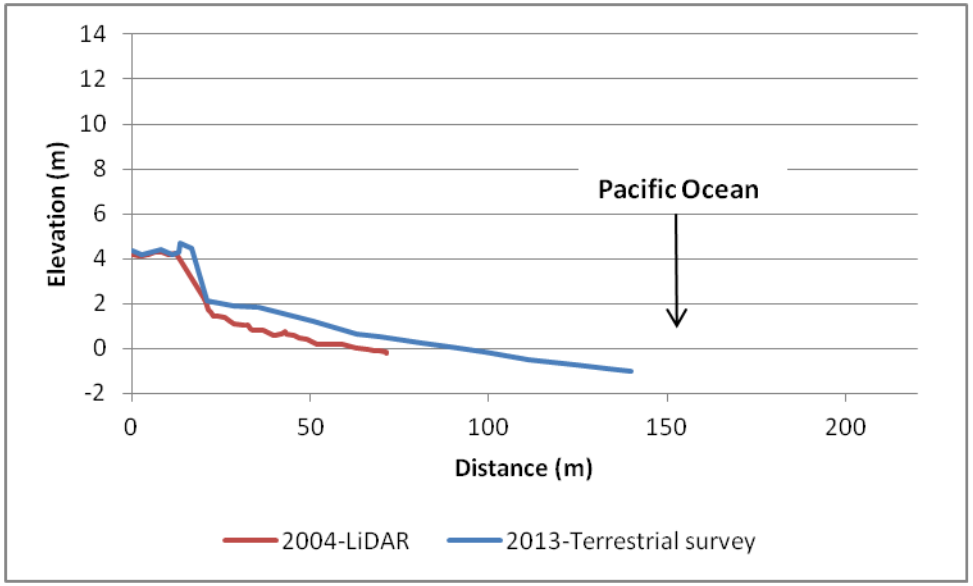


**Figure 16 Cross-section KAK3**

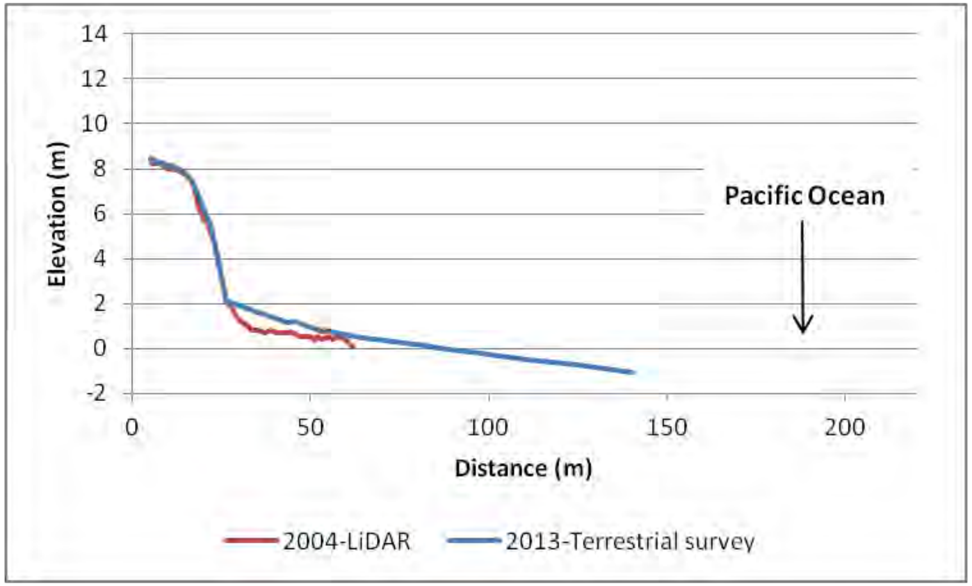


**Figure 15 Cross-section KAK2**

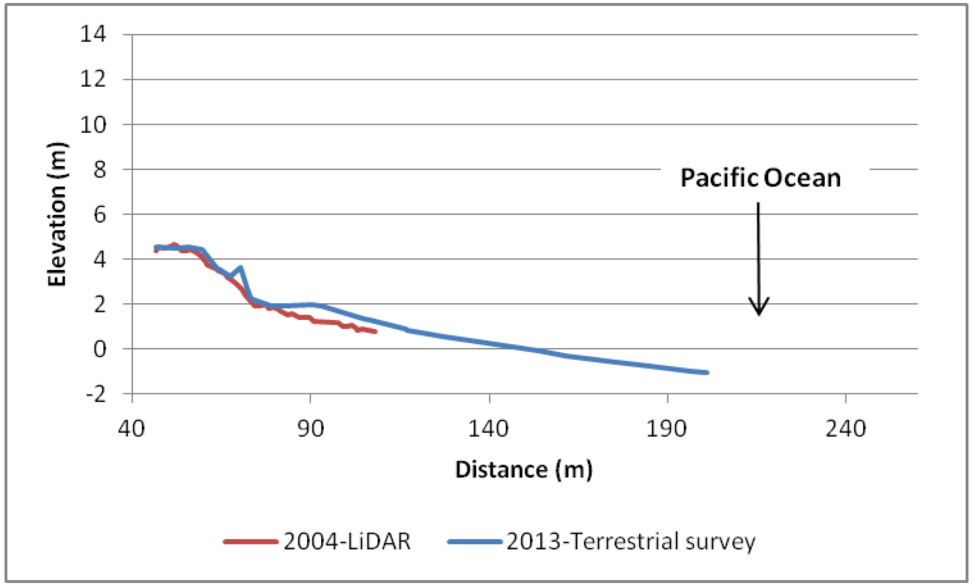


**Figure 14 Cross-section KAK1**

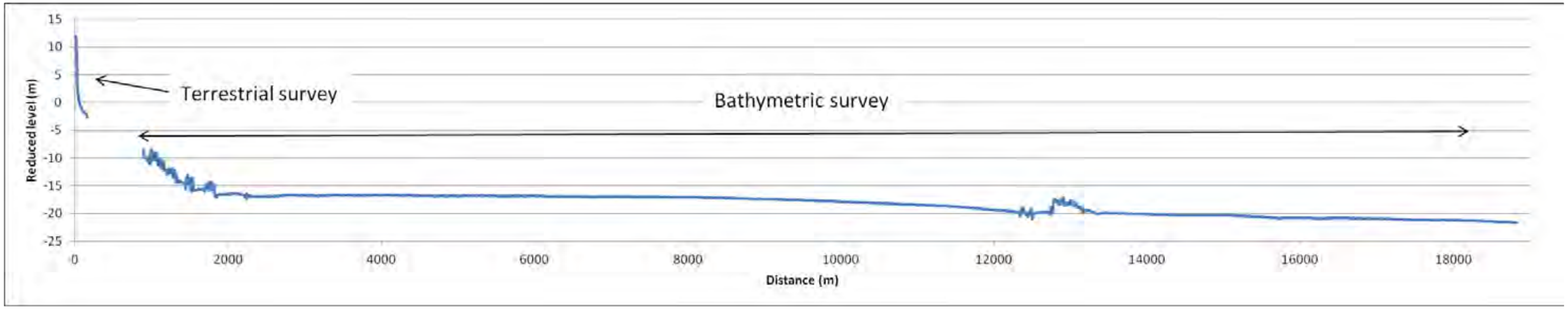


**Figure 18 Combined terrestrial and bathymetric profile of MB10 and KAK12**

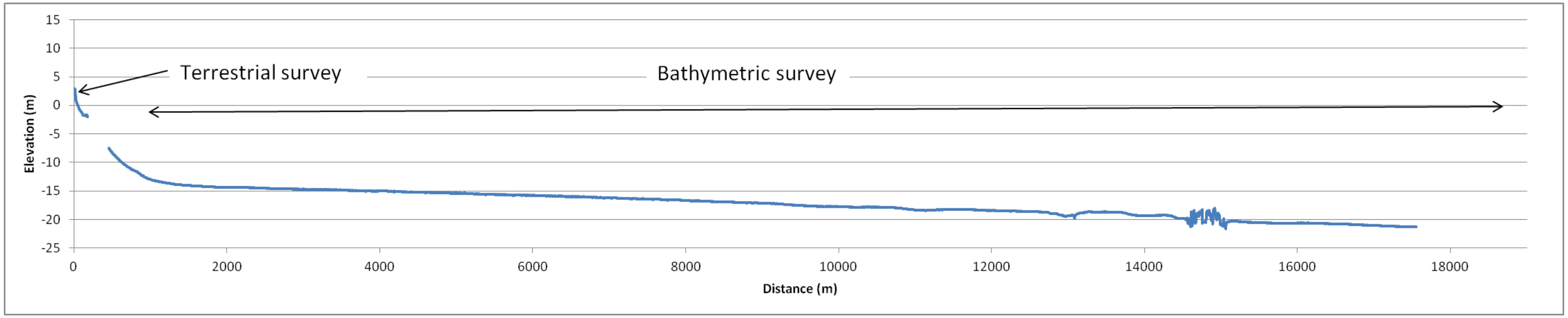


**Figure 19 Combined terrestrial and bathymetric profile of MB9 and KAK7**

# 3. Kaka Point to Koau Mouth

This section of beach extends southwest from the Koau Mouth of the Clutha River/Mata-Au for about 3.8km to the site of the old Port Molyneux, a short distance north of Kaka Point (Figure 20). Port Molyneux was originally designated for development as a major port, and a town was surveyed adjacent to the coast (ORC, 1992). However, plans for port and town were upset by the flood event of October 1878, which forged a new mouth for the Koau Mouth further north. The original Port Molyneux outlet silted up, and there is now no obvious evidence of its former existence.

**Figure 20 Looking north towards Koau Mouth (August 2012)**

Two beach transects (MB01 and MB02) were surveyed in April 2013, extending from the low tide mark to the landward side of the floodbanks, which form part of the Lower Clutha Flood Protection and Drainage Scheme (Figure 21). The 2013 surveyed beach profiles are compared against two sets of LiDAR data collected in 2004 and 2009 (Figure 23 and Figure 24). An analysis of changes in the shoreline position since 1946 was also completed, using historical aerial photographs and GPS. These changes are mapped in Figure 21, and summarised in Table 1.[8]

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[8] See Appendix 2 for an explanation of how changes in shoreline position were mapped.

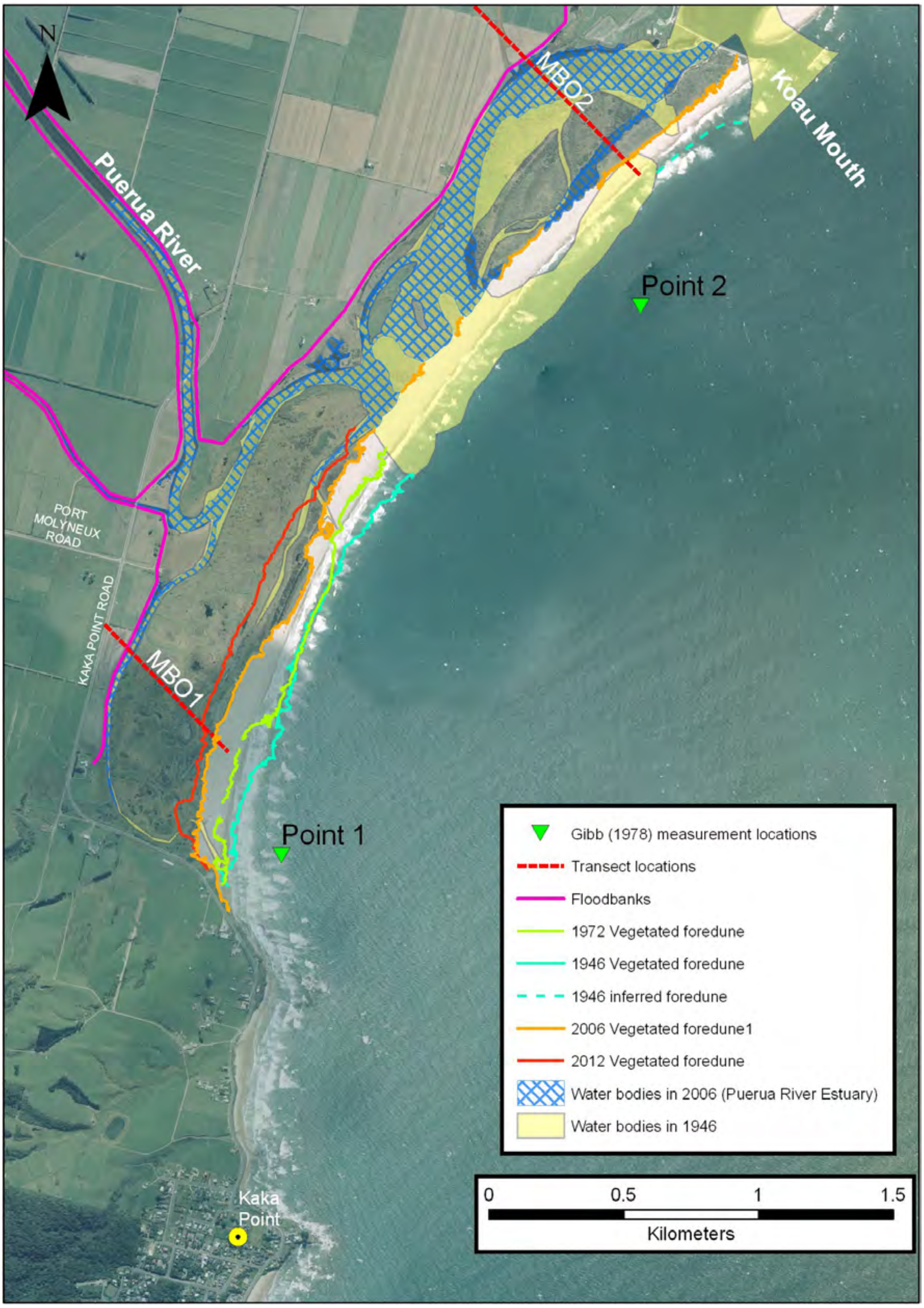


**Figure 21 Mapped shorelines from aerial photography between Kaka Point and the Koau Mouth of the Clutha River/Mata-Au (aerial photograph date: March 2006). The 1946 shoreline at the northern end of this reach is approximate due to the lack of vegetation at that time.**

Figure 21 shows that shoreline erosion was the dominant process along this beach between 1946 and 2012. An analysis of average rates of shoreline change along this part of the beach is summarised in Table 1.[9] This shows an average erosion rate of 3.3m/yr during this 66-year period, and that the rate of erosion increased from 1.8m/yr between 1946 and 1972 to 13.3m/yr between 2006 and 2012.

**Table 1 The average net change and rate of coastal erosion (-) and accretion (+) between Kaka Point and the Koau Mouth of the Clutha River/Mata-Au (1946-2012)**

| Survey period | Net change (m) | Average rate (m/yr) |
|---|---|---|
| 1946 - 1972 | -47 | -1.8 |
| 1972 - 2006 | -90 | -2.6 |
| 2006 - 2012 | -80 | -13.3 |
| **Overall change (1946 – 2012)** | **-217** | **-3.3** |

The amount of erosion or accretion at 20 locations along this stretch of coast for each of the periods in Table 1 is graphed in Figure 22, and the locations of the measured transects are shown in Figure 64.

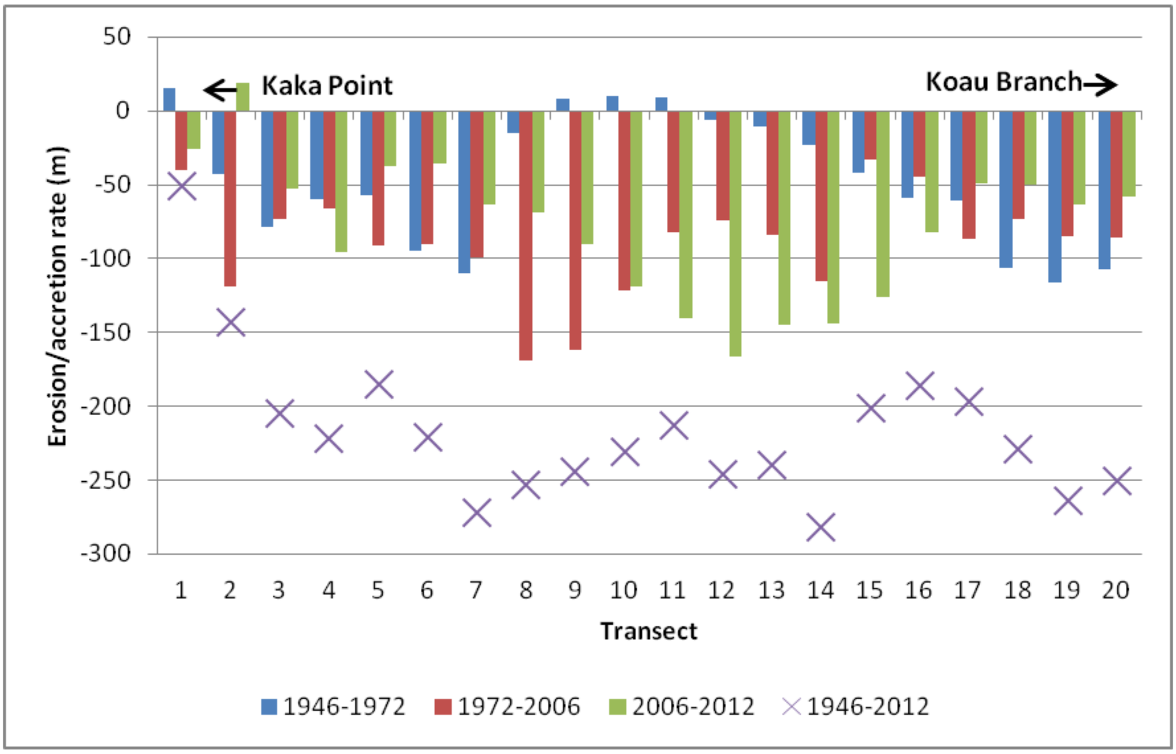


**Figure 22 Rates of coastal erosion/accretion between Kaka Point and Koau Mouth**

Further coastline retreat will have implications for the Lower Clutha Flood Protection and Drainage Scheme, including more elevated water levels within the Puerua Estuary and increased sediment input into the estuary from the beach (both of which will reduce the effectiveness of the gravity drainage into the estuary). If the most recently observed rate of retreat (13.3m/yr) were to continue, floodbanks that form part of the scheme could be affected by coastal erosion in less than three decades. The main access road to Kaka Point lies directly behind these floodbanks.

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[9] Appendix 2 provides more detail on how these changes were determined.

Works to assist in reducing the effects of coastal erosion and sea-level rise on scheme features are scheduled to take place in 2014/2015 (ORC, 2014), including additional drainage pathways from the Puerua Estuary to the Koau branch of the Clutha River/Mata-Au.

An earlier investigation into rates of coastal erosion and accretion in New Zealand (Gibb, 1978) identified that there was no significant change in shoreline position at the location labelled Point 1 on Figure 21 between 1847 and 1962. This estimate was derived by comparing early cadastral plans with historical aerial photographs, and predominantly covers the period before construction of the Roxburgh Dam.[10] After 1962, Gibb determined that there was net erosion at Point 1 of 5.3m per year up to 1977 (Table 2), which is of a similar magnitude to the erosion rates determined by this investigation, as shown in Table 1.

**Table 2 The average net change and rate of coastal erosion (-) and accretion (+) between Kaka Point and the Koau Mouth of the Clutha River/Mata-Au (1847-1977)**

| | **Point 1** | | **Point 2** | |
|---|---|---|---|---|
| Survey period | Net change (m) | Average rate (m/yr) | Net change (m) | Average rate (m/yr) |
| 1847 – 1962 | 0 | 0 | +380 | +3.3 |
| 1962 – 1977 | -80 | -5.3 | n/a | n/a |

Change in shoreline position at the northern end of the beach is more difficult to determine, as it alternates between areas of vegetated foredune (which can be mapped with some accuracy), and areas that were inundated by water at the time aerial photographs were taken. Figure 21 shows the position of any sections of foredune that could be mapped from 1972, 1946 and 2006 aerial photographs. Although no detailed analysis of average rates of shoreline change has been undertaken for the northern end of the beach, Figure 21 does show that erosion of the shoreline has generally occurred along this stretch of coast between 1946 and 2006. Gibb's study identified that there was accretion of some 380m at the location labelled Point 2 on Figure 21 between 1847 and 1962 (Table 2), but did not determine a rate of change for any period subsequent to construction of the Roxburgh Dam.

More recent changes in the morphology of the beach, foredune and backshore[11] area are shown in two representative transects (MB01 and MB02). Figure 23 shows that the foredune crest at MBO1 retreated about 85m between 2004 and 2009. Over the next four years, the foredune remained in about the same position, and increased in height by about 1m. Some degradation of the backshore area also occurred between 2004 and 2013.

The foredune at MBO2 retreated about 35m between 2004 and 2009 (Figure 24), but subsequently showed little change in height or position between 2009 and 2013. As for MBO1, degradation of the backshore area also occurred between 2004 and 2013.

The terrestrial (onshore) surveyed transects extend offshore for up to 18km (Figure 50), and the combined onshore and bathymetric survey data for MB01/MB1 and MB02/MB2 are shown in Figure 25 and Figure 26.

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[10] Although construction of the Roxburgh Dam commenced in 1949, it was not fully commissioned until 1962.

[11] Area behind the foredune

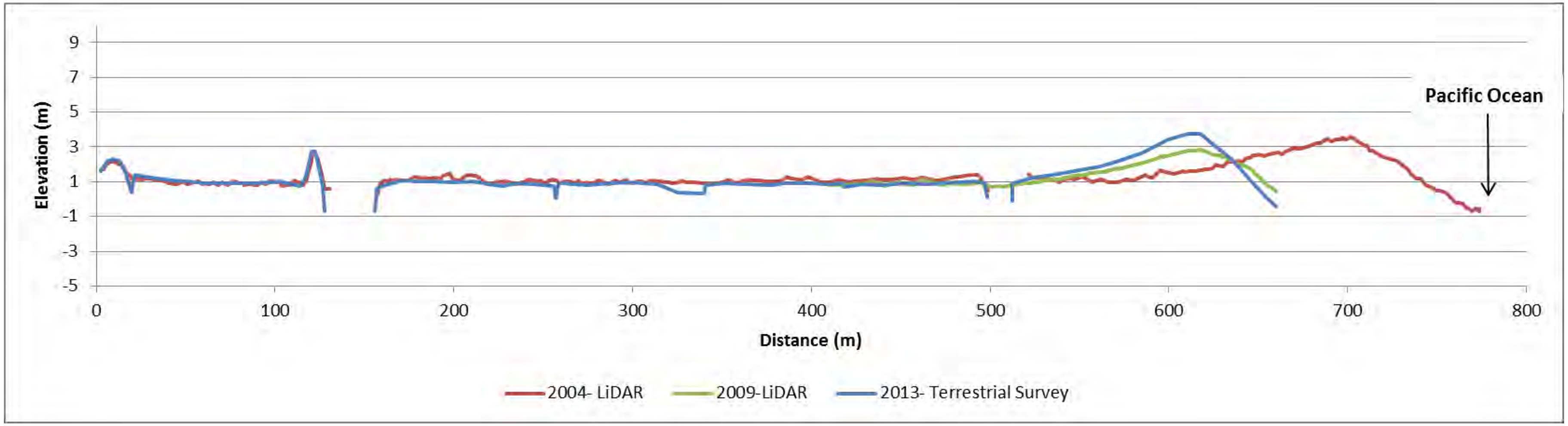


**Figure 23 Cross-section MB01**

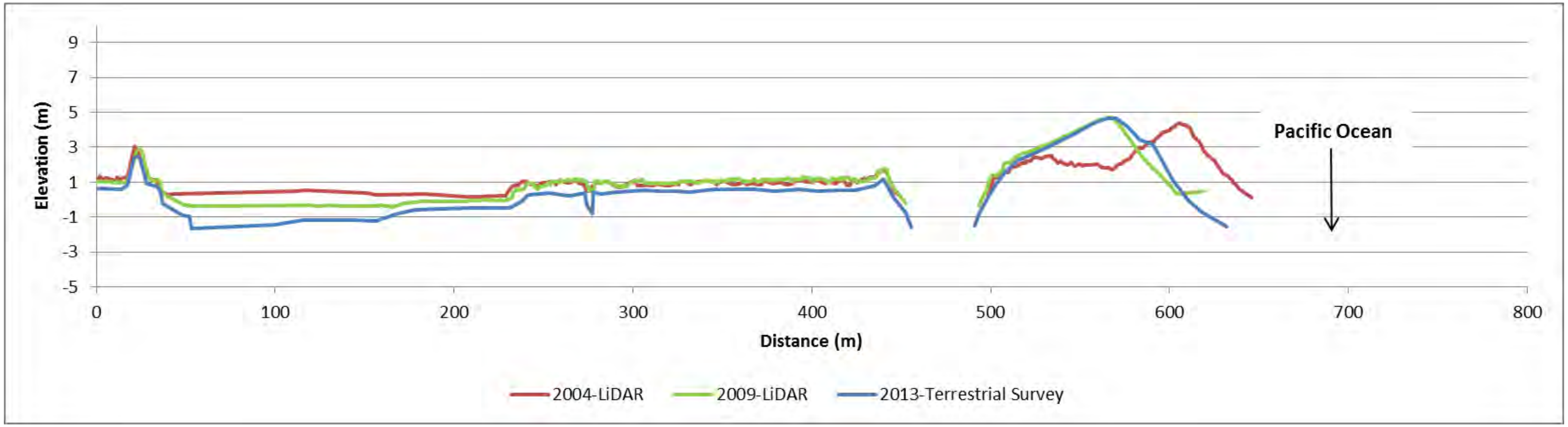


**Figure 24 Cross-section MB02**

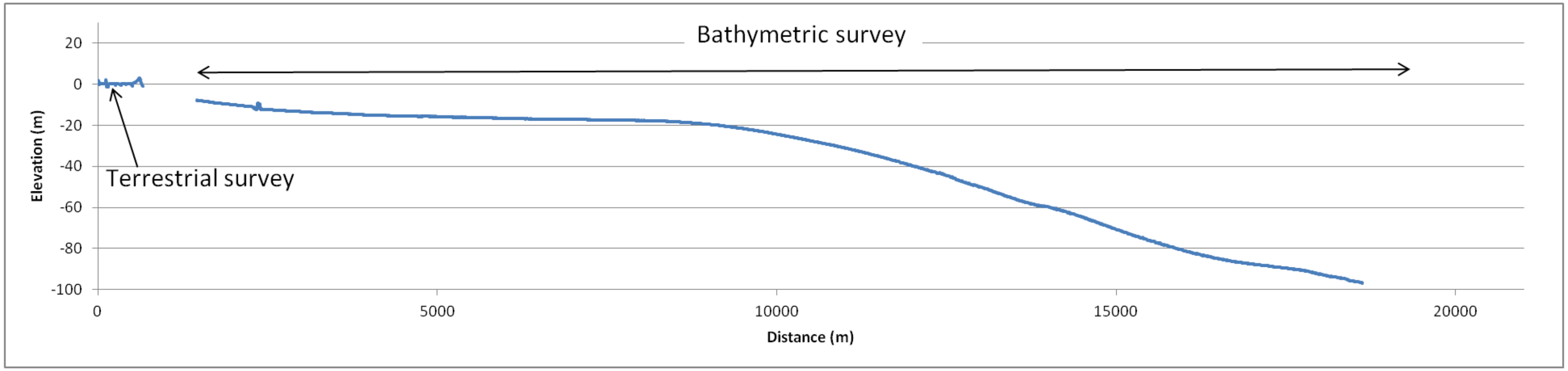


**Figure 25 Combined terrestrial and bathymetric profile of MB1 and MBO1**

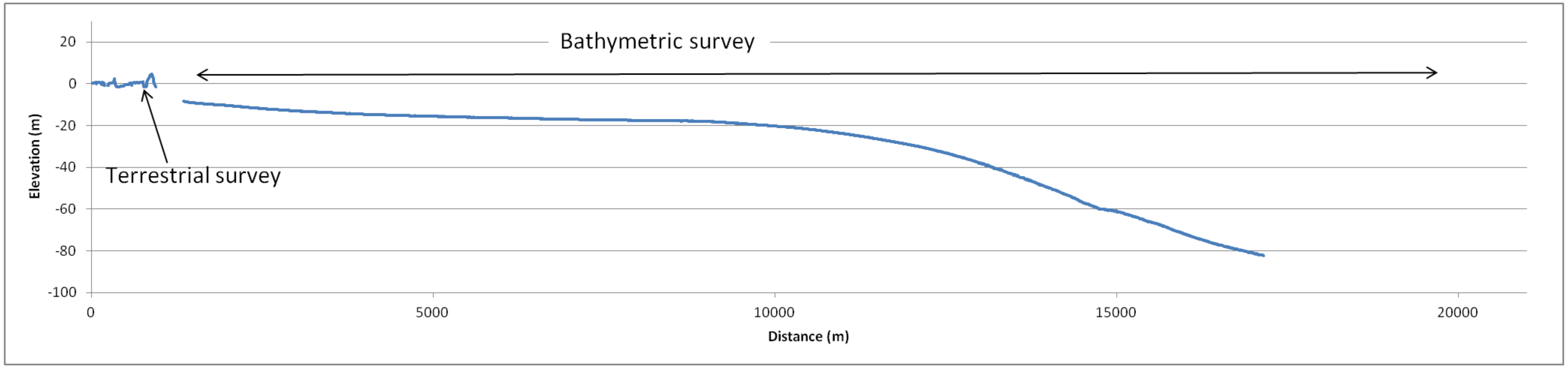


**Figure 26 Combined terrestrial and bathymetric profile of MB2 and MBO2**

# 4. Koau Mouth to Matau Mouth

This 2.8km length of shoreline forms the seaward boundary of the island formed by the bifurcation of the Matau and Koau branches of the Clutha River/Mata-Au, and is bounded at either end by the mouths of these two branches (Figure 27).

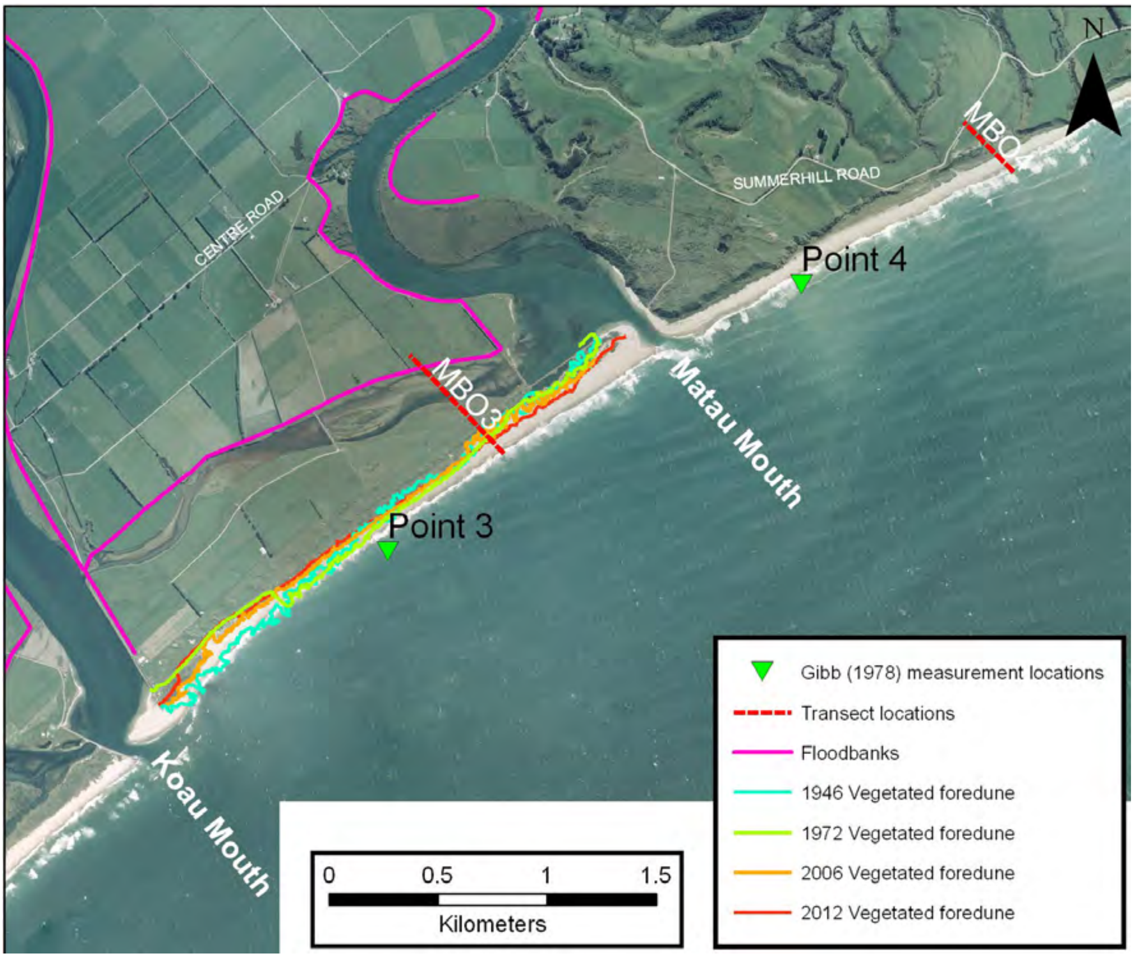


**Figure 27 Mapped shorelines from aerial photography between the Koau Mouth and the Matau Mouth of the Clutha River/Mata-Au (aerial photograph date: March 2006)**

Figure 27 shows that the shoreline generally retreated at the southern end of this beach between 1946 and 2012, particularly in the vicinity of the area shown in Figure 28. During this period, erosion of the shoreline is the dominant process as far north as transect MB03 (Figure 27), while beyond this point, shoreline accretion has been observed. This trend is shown more clearly in Appendix 3 (Figure 30). If the average rate of erosion at the southern end of the beach between 2006 and 2012 were to continue, Lower Clutha Flood Protection and Drainage Scheme flood banks could be affected in about 60 years. Shoreline accretion occurred at the northern end of the beach between 2006 and 2012, at an average rate of 4.5m/yr. While erosion of scheme floodbanks at this end of the beach appears unlikely in the near future, accretion can lead to an increase in mouth offsetting that can lead to an increase in water levels during flood events.

**Figure 28 Looking northeast towards the Matau mouth of the Clutha River/Mata-Au, from the southern end of the Koau Mouth - Matau Mouth stretch of shoreline. The effect of high tides and wave action pushing sand onto previously vegetated areas can been seen.**

**Figure 29 Looking northeast towards the Matau Mouth of the Clutha River/Mata-Au, from midway along the Koau Mouth - Matau Mouth stretch of shoreline**

An analysis of the rate of shoreline change along this section of coast shows that the average rate of shoreline retreat is lower than between Kaka Point and Koau Mouth.

Table 3 shows a net erosion rate of 0.2m per year, although the average annual rate of shoreline change has gone from -0.6m per year in 1946 – 1972 to +0.3m per year in 2006 – 2012. [12]

[12] Appendix 2 provides more detail on how these changes were determined.

**Table 3 The average net change and rate of coastal erosion (-) and accretion (+) between the Koau and Matau mouths of the Clutha River/Mata-Au (1946 to 2012)**

| Survey period | Net change (m) | Average rate (m/year) |
|---|---|---|
| 1946 - 1972 | -15.5 | -0.6 |
| 1972 - 2006 | -2 | -0.06 |
| 2006 - 2012 | +2 | +0.3 |
| **Overall change (1946 – 2012)** | **-15.5** | **-0.2** |

The amount of erosion or accretion at 20 locations along this stretch of coast for each of the periods in Table 3 is shown graphically in Figure 30.

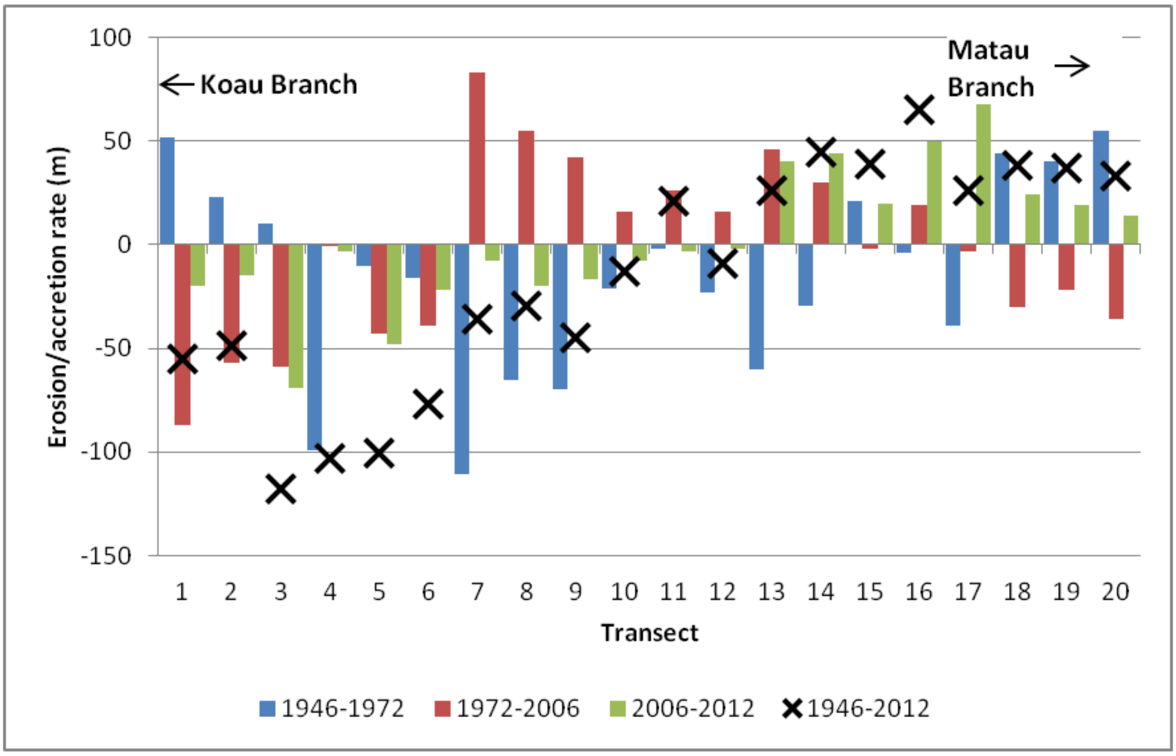


**Figure 30 Rates of coastal erosion/accretion between Koau Mouth and Matau Mouth**[13]

**Previous work by Gibb (1978) found that from 1847 to 1962, the average rate of coastal accretion was 2.52m/yr at the location labelled Point 3 in Figure 27. To the north of the Matau Mouth of the Clutha River/Mata-Au, the average rate of accretion was 1.26m/yr at the location labelled Point 4 in Figure 27 (**

Table 4).

[13] The location of these measured transects is shown in Figure 63.

**Table 4 The average net change and rate of coastal erosion (-) and accretion (+) between the Koau and Matau mouths of the Clutha River/Mata-Au (1847 to 1962)**

| | **Point 3** | | **Point 4** | |
|---|---|---|---|---|
| Survey period | Net change (m) | Average rate (m/yr) | Net change (m) | Average rate (m/yr) |
| 1847 – 1962 | +290 | +2.52 | +145 | +1.26 |

More recent changes in the morphology of the beach, foredune and backshore[14] area are shown in two representative transects (MB03 and MB04). Figure 31 shows that the crest of the seaward dune at MBO3 retreated by about 30m between 2004 and 2013, but that the stoss[15] accreted during this same period. An older (relict) foredune further back from the shoreline remained in a similar position during this period. LiDAR data is not available for comparison at transect MBO4, and the survey data shown in Figure 32 provides a baseline against which future data can be compared.

The terrestrial (onshore) surveyed transects extend offshore for up to 18km (Figure 50), and the combined onshore and bathymetric survey data for MB03/MB3 and MB04/MB4 are shown in Figure 33 and Figure 34.

[14] Area behind the foredune

[15] Upward or windward side

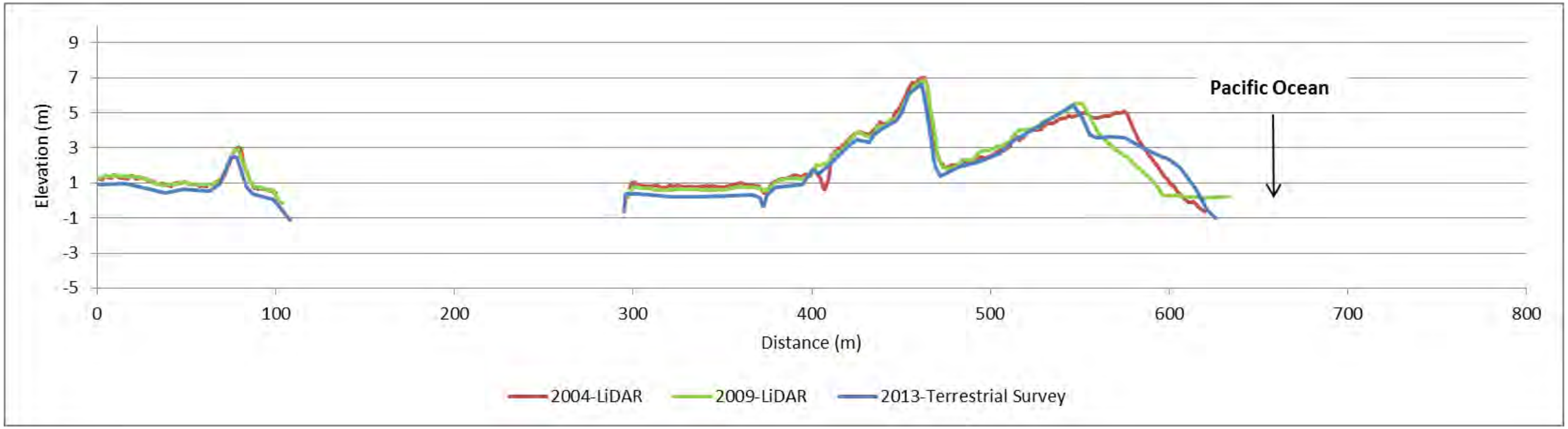


**Figure 31 Cross-section MBO3**

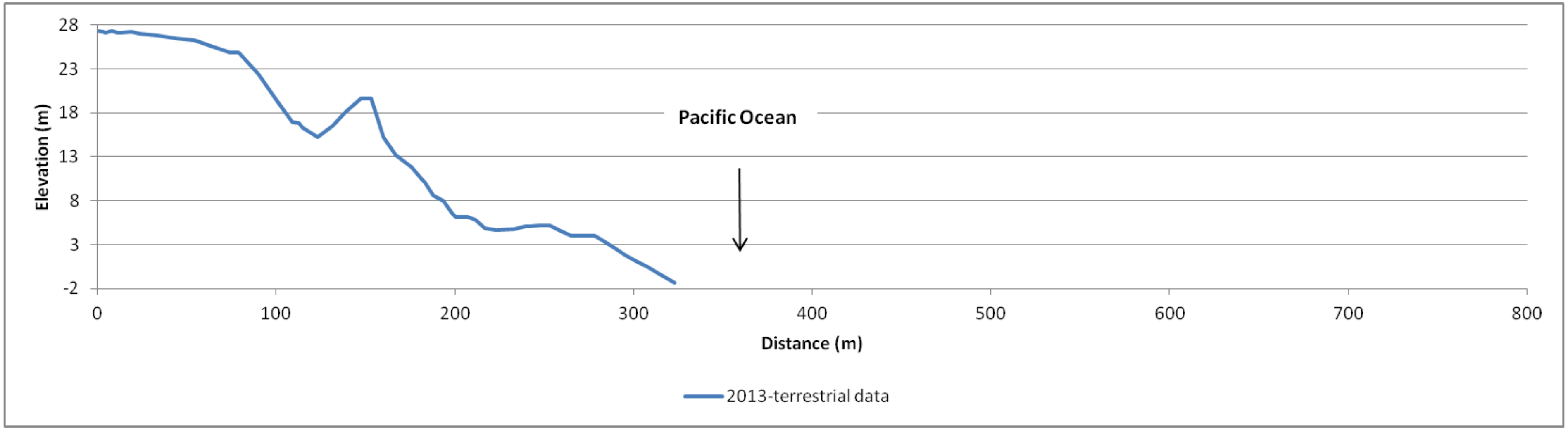


**Figure 32 Cross-section MBO4**

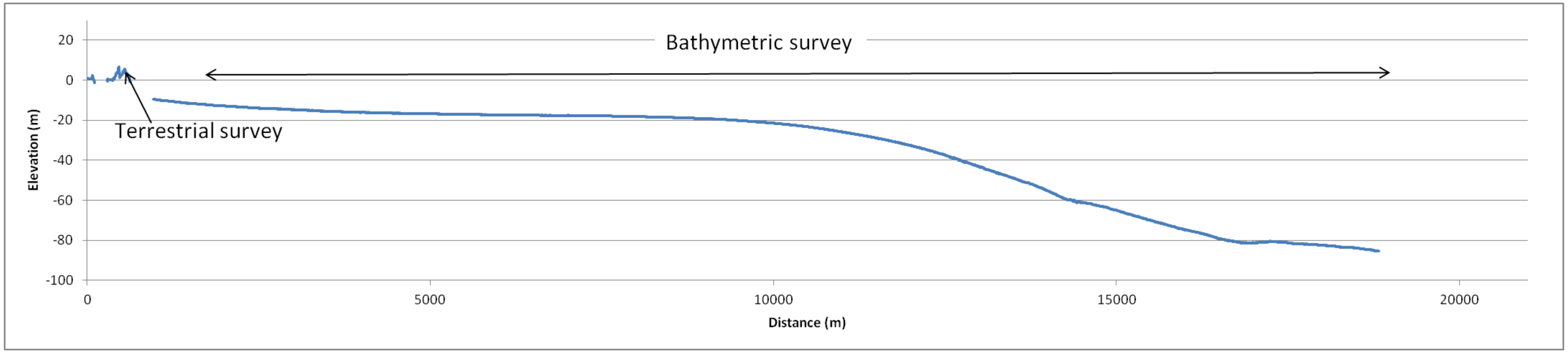

**Figure 33 Combined terrestrial and bathymetric profile of MB3 and MBO3**

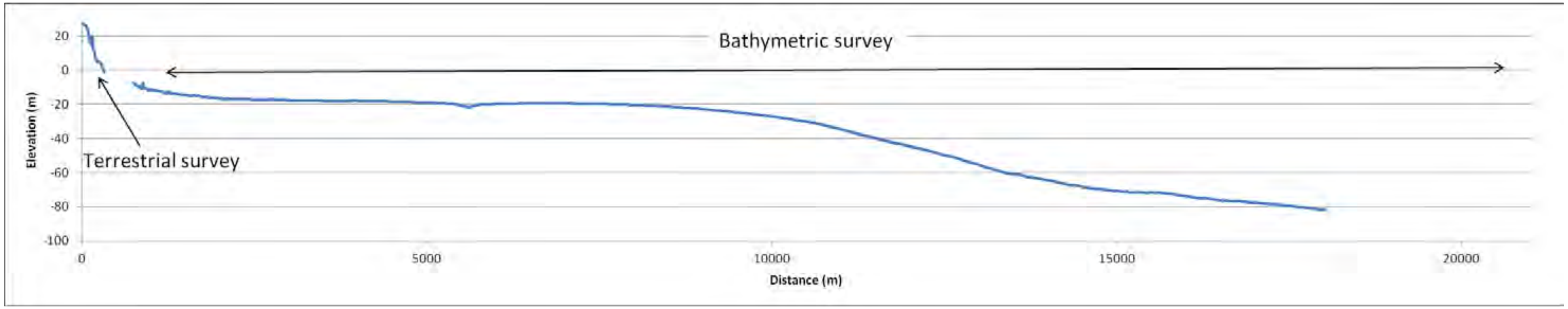

**Figure 34 Combined terrestrial and bathymetric profile of MB4 and MBO4**

# 5. North of the Matau Mouth

North of the Matau Mouth of the Clutha River/Mata-Au, the shoreline is characterised by white sandy beaches bounded by rocky cliffs (Figure 35, Figure 36). An analysis of historic shoreline was not completed for this length of coast due to the lack of a prominent vegetated foredune.

**Figure 35 Looking north from near the Matau Mouth of the Clutha River/Mata-Au (August 2012)**

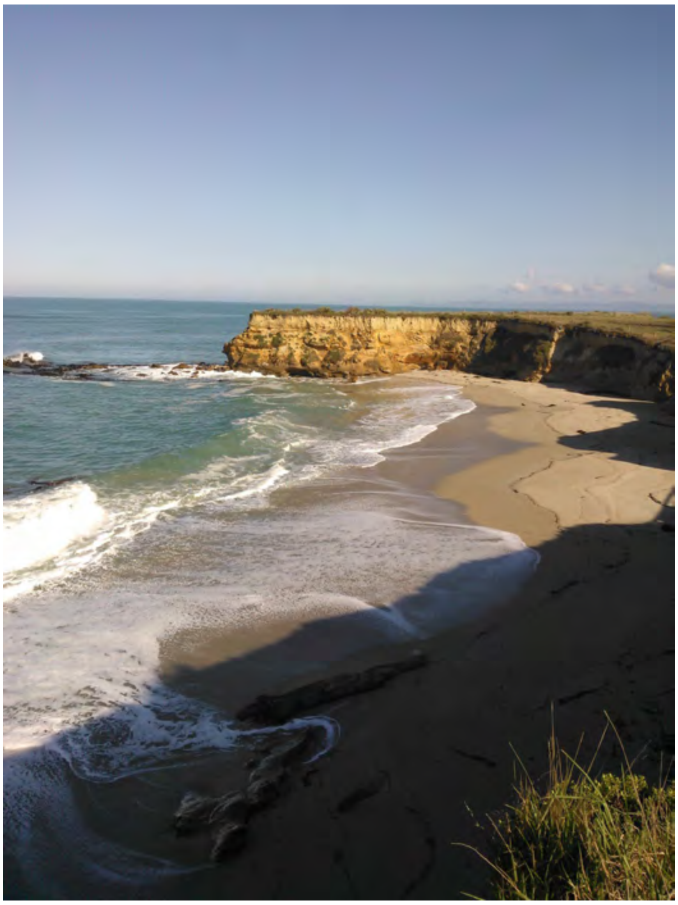

**Figure 36 Coastline north from the Matau Mouth of the Clutha River/Mata-Au (August 2012)**

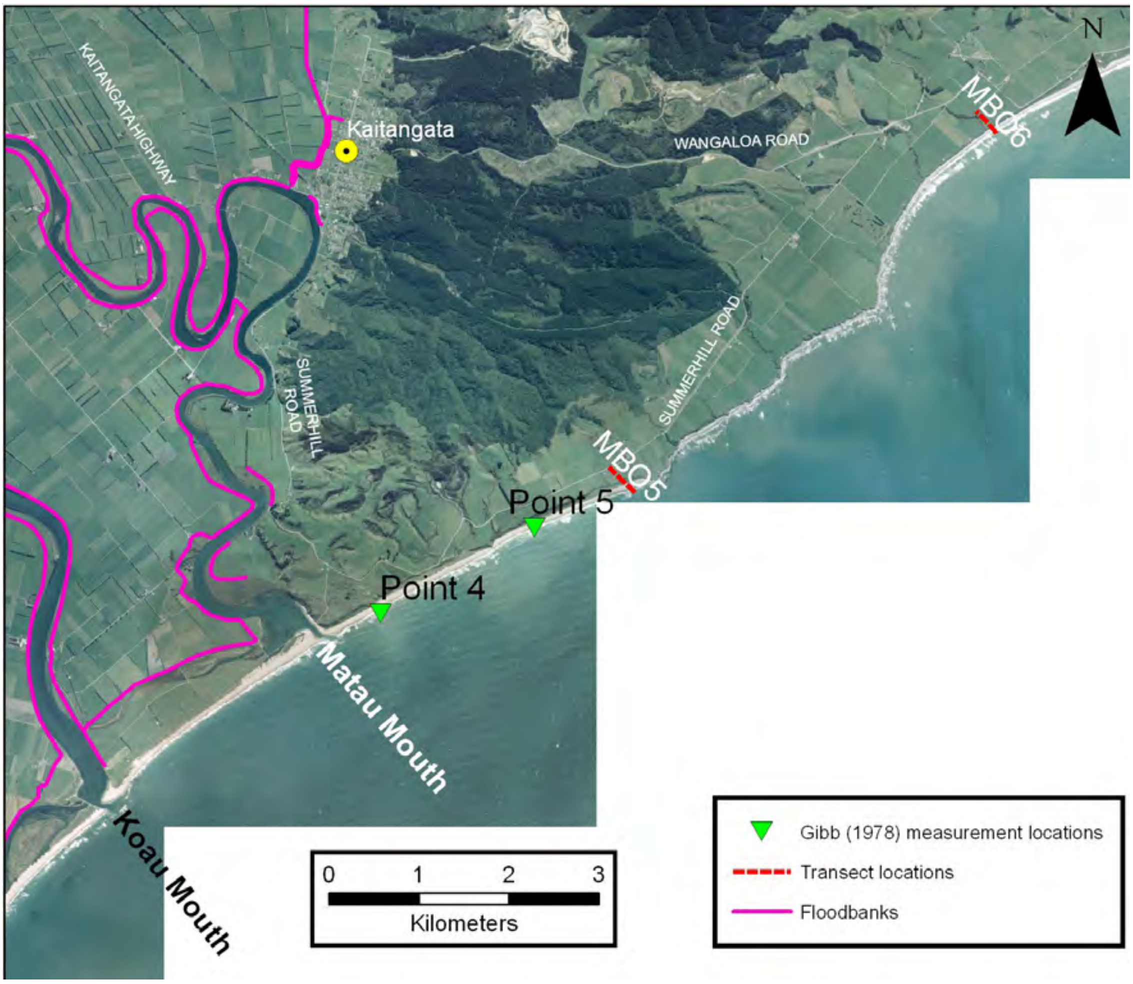


**Figure 37 Location map of MB05 and MB06 (aerial photo date: March 2006)**

MBO5 remained relatively stable between 2004 and 2013. Accretion of the foreshore has occurred, and there has been erosion of the foredune stoss. Some degradation of the backshore did occur (Figure 38). Transect MBO6 shows a general retreat between 2004 and 2013, with a loss of material from the foreshore and backshore (Figure 39).

Gibb (1978) states that between the Matau Mouth of the Clutha River/Mata-Au and MBO5, there was accretion of the coastline of between 0.61 and 1.26m/yr between 1847 and 1962 (Table 5).

**Table 5 The average net change and rate of coastal erosion (-) and accretion (+) north of the Matau Mouth (1847 to 1962)**

| | **Point 4** | | **Point 5** | |
|---|---|---|---|---|
| **Survey period** | **Net change (m)** | **Average rate (m/yr)** | **Net change (m)** | **Average rate (m/yr)** |
| **1847-1962** | +145 | +1.26 | +70 | +0.61 |

The terrestrial (onshore) surveyed transects extend offshore for up to 20km (Figure 50), and the combined onshore and bathymetric survey data for MB05/MB5 and MB06/MB6 are shown in Figure 40 and Figure 41.

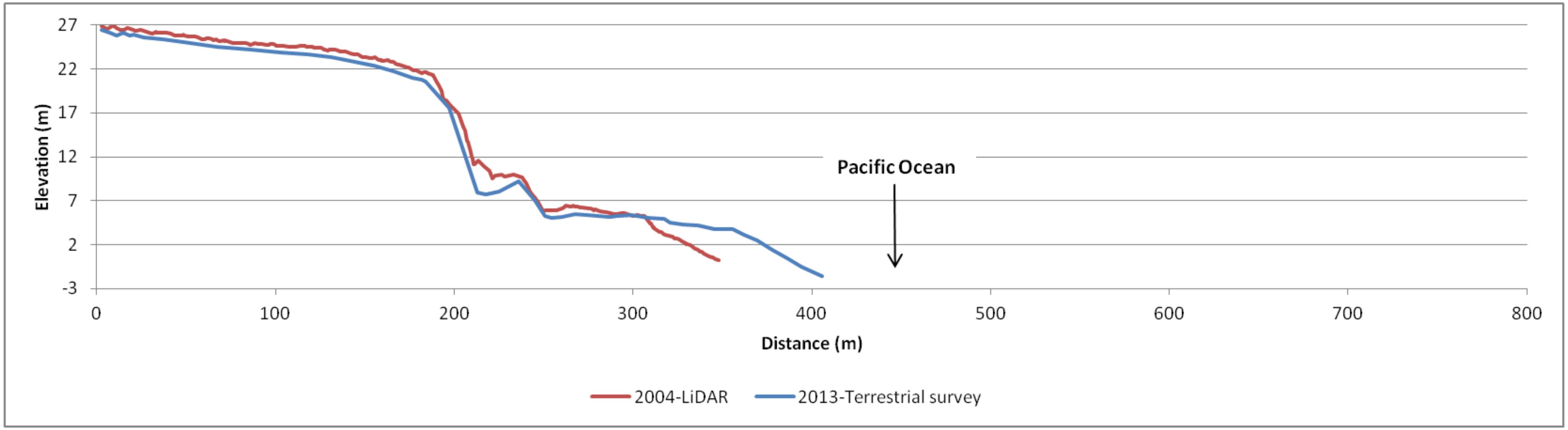


**Figure 38 Cross-section MBO5**

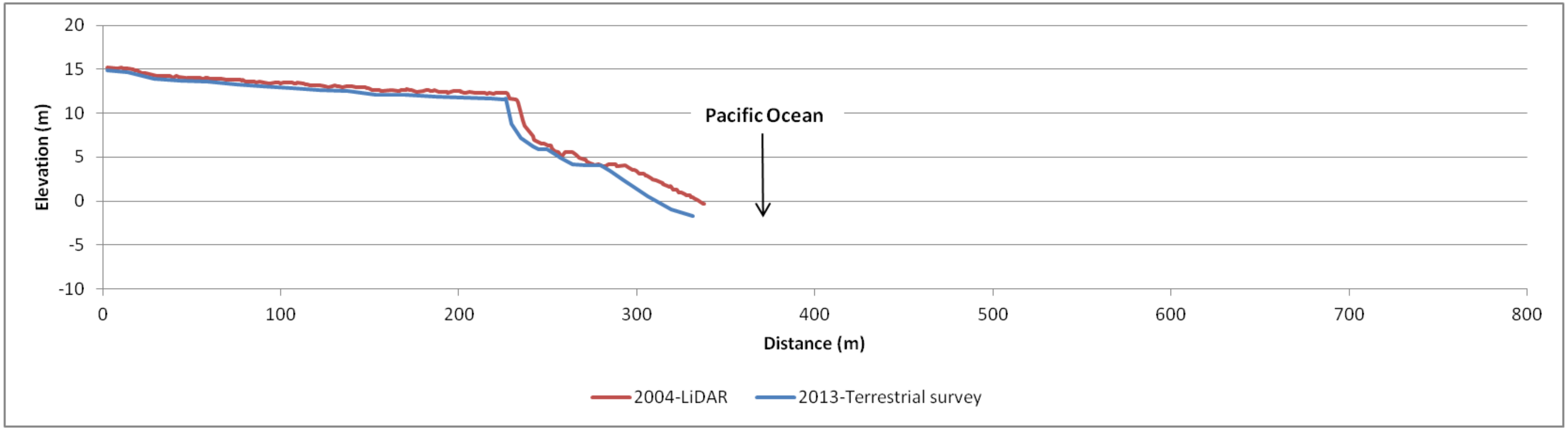


**Figure 39 Cross-section MBO6**

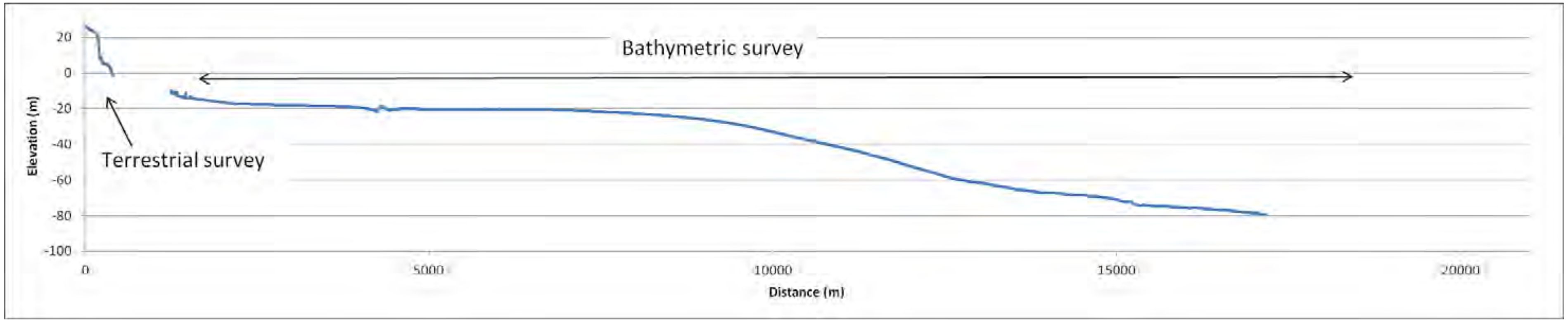


**Figure 40 Combined terrestrial and bathymetric profile of MB5 and MBO5**

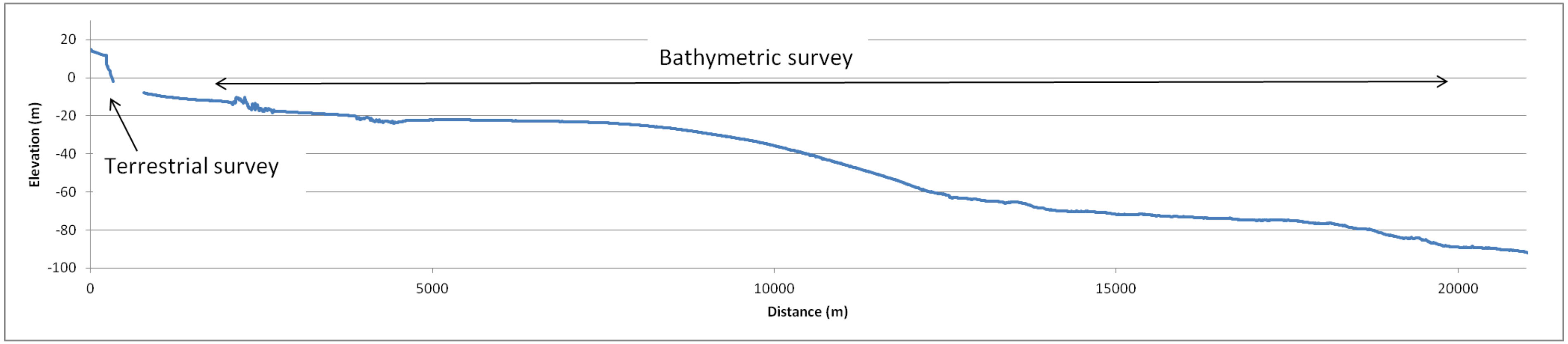


**Figure 41 Combined terrestrial and bathymetric profile of MB6 and MBO6**

# 6. Measly Beach

Measly Beach extends for about 7km to the southwest of Toko Mouth, with Wangaloa Creek entering at the western end of the beach (Figure 42). There are only two historical records of shoreline position for Measly Beach: 1946 and 2006. These records show that the vegetated shoreline accreted at an average rate of accretion of 2.3m/yr over this period (Table 6).[16] The highest rates of accretion occurred at the southern end of the beach (Figure 43).

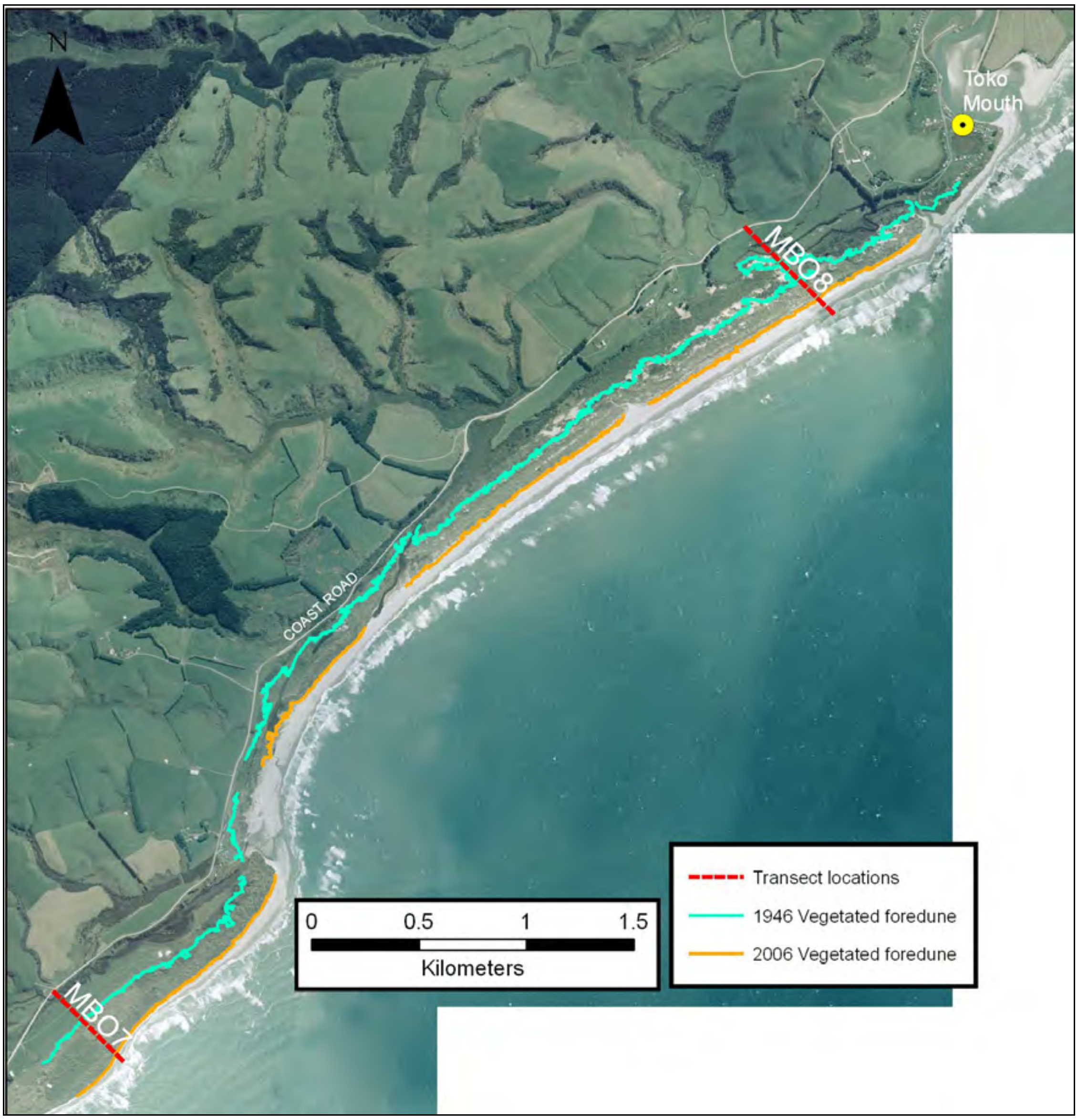


**Figure 42 Mapped shorelines from aerial photography for Measly Beach (aerial photo date: March 2006)**

[16] This was the highest rate average of accretion observed at the four lengths of shoreline mapped as part of this study.

**Table 6 The average net change and rate of coastal erosion (-) and accretion (+) for Measly Beach (1946-2006)**

| Survey period | Net change (m) | Average rate (m/yr) |
|---|---|---|
| 1946-2006 | +137.5 | +2.3 |

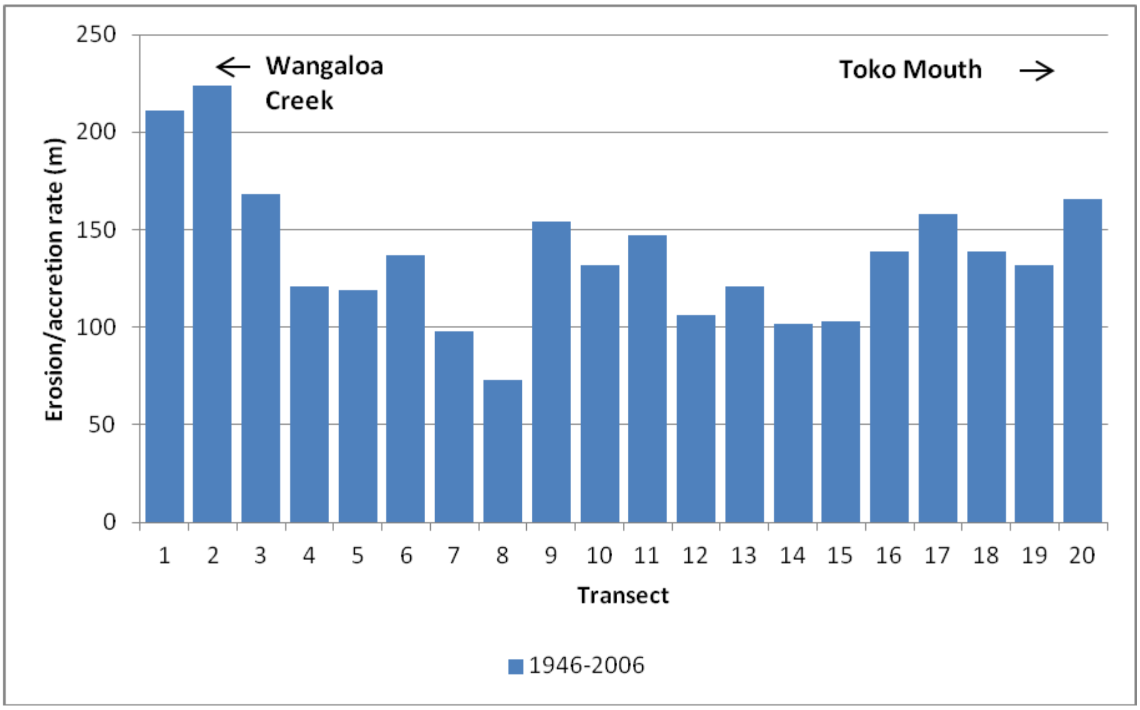


**Figure 43 Rates of coastal erosion/accretion at Measly Beach**[17]

At transect MB07, the foredune decreased in height by approximately 0.6m between 2004 and 2013 (Figure 44). Retreat of the foredune by about 8m occurred during the same period. A loss of volume also occurred in the relict foredunes. Figure 44 shows degradation of the backshore (the backshore is the floodplain for Wangaloa Creek).

MBO8 remained relatively stable between 2004 and 2013, with some accretion of the foreshore and a lowering of the foredune and relict foredunes. Degradation is the dominant process in the backshore, with small areas of aggradation occurring (Figure 45).

**The terrestrial (onshore) surveyed transects extend offshore for up to 20km (Figure 50), and the combined onshore and bathymetric survey data for MB07/MB7 and MB08/MB8 are shown in** Figure 46 and Figure 47.

[17] The location of the measured transects is shown in Figure 62.

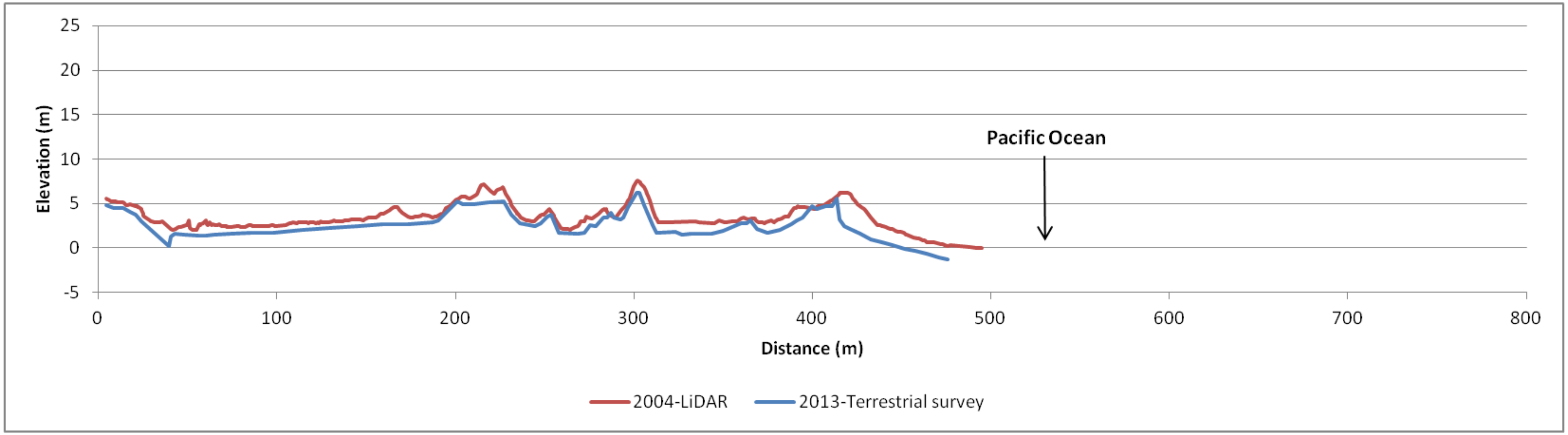


**Figure 44 Cross-section MBO7**

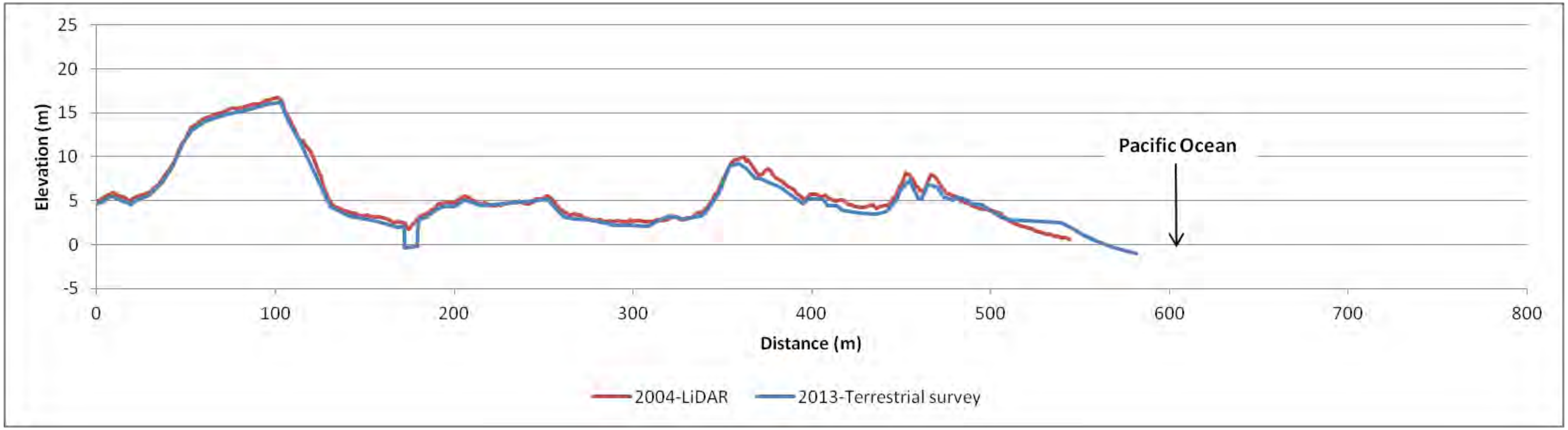


**Figure 45 Cross-section MBO8**

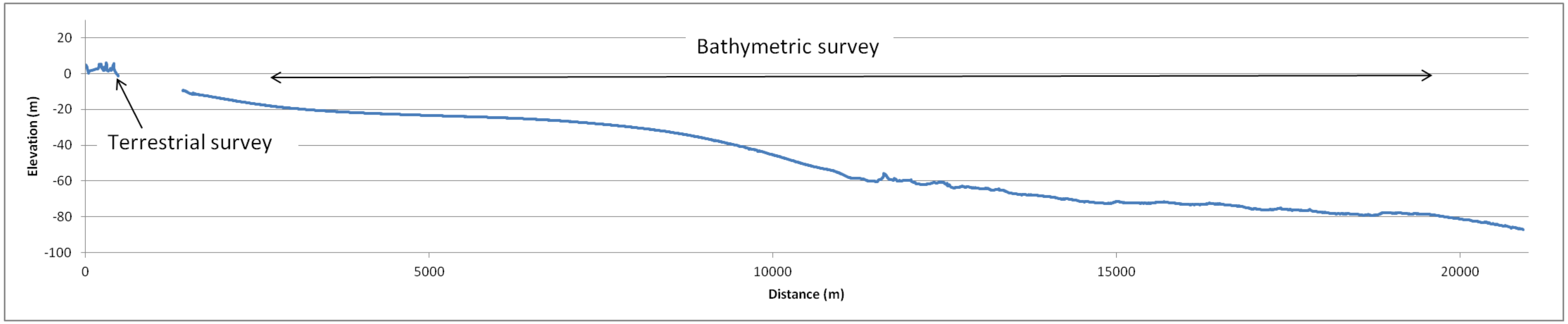


**Figure 46 Combined terrestrial and bathymetric profile of MB7 and MBO7**

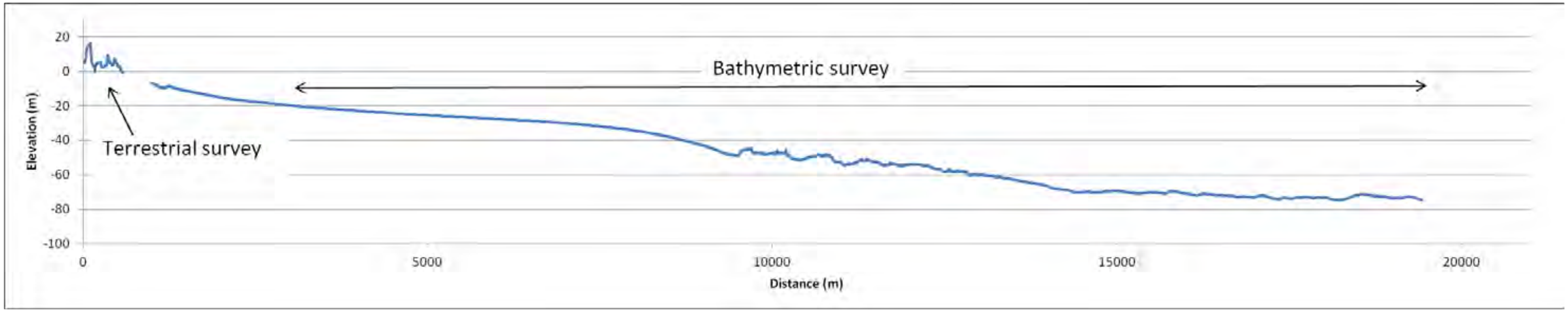


**Figure 47 Combined terrestrial and bathymetric profile of MB8 and MBO8**

# 7. Chrystalls Beach

Chrystalls Beach extends for about 5.5km to the northeast of Toko Mouth, with Nobles Creek entering at the eastern end of the beach (Figure 48). There are only two historical records of shoreline position for this beach: 1946 and 2006. An analysis of these records shows that the vegetated shoreline accreted at an average rate of 0.8m/yr between 1946 and 2006, with average net accretion of 47m (Table 7). The highest rates of accretion occurred at the northern end of the beach (Figure 49).


**Figure 48 Mapped shorelines from aerial photography for Chrystalls Beach (aerial photo date: March 2006)**

**Table 7 The average net change and average rate of coastal erosion (-) and accretion (+) at Chrystalls Beach (1946 to 2006)**

| Survey period | Net change (m) | Average rate (m/yr) |
|---|---|---|
| 1946-2006 | +47 | +0.8 |

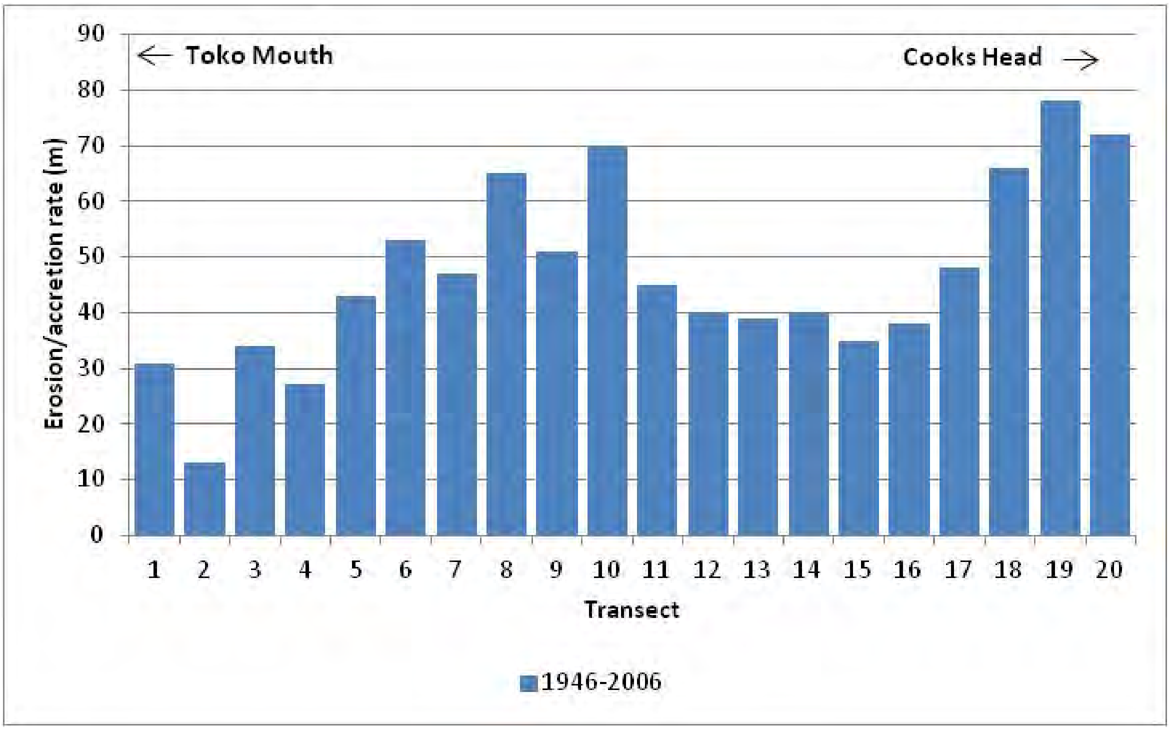


**Figure 49 Rates of coastal erosion/accretion at Chrystalls Beach[18]**

[18] The location of the measured transects is shown in Figure 61.

# 8. Transect monitoring (bathymetric)

This section describes the offshore surface profiles obtained from bathymetric data collected in February 2013. The transect locations are shown in Figure 50, and the offshore profiles are shown above in Figure 25, Figure 26, Figure 33, Figure 34, Figure 40, Figure 41,

Figure **46** and Figure 47. The bathymetry shows that most of the offshore profiles are smooth, with minimal undulations. Some areas show outcrops of rougher terrain, although the extent of these outcrops cannot be measured due to coverage of the data. Pock marks can be seen between the 30 and 50m depth contours (Figure 53). These pock marks are present on transects MB1 to MB8 to varying degrees. These pock marks may be the result of geothermal activity being released, causing a subsidence of the sea floor, such as those recorded on the Chatham Rise (Davy *et al.*, 2010).

The ten onshore and offshore transects were combined to create ten continuous transects. Eight of these transects extended from the backshore coastal zone to the seaward extent of the near-shore sand wedge, with the additional two transects running parallel to the coastline. Limitations in the depth that the survey vessel could operate meant that not all offshore transects could be extended to their on-shore counterparts (MBO1, MBO2, and MBO3). As a result, a small gap was present in these transects.

The offshore profiles for MB1-MB7 show a gently sloping profile until about 10km offshore where the terrace drops away. The terrace drops for about 60m and then levels out 14km from the shore.

The profile MB8 (Figure 47), near Toko Mouth, is similar to MB1-MB7, but the slope drops away about 8km offshore and is not as steep as MB1-MB7.The terrain between 9.5-13km offshore is undulating (Figure 51).

The bathymetric profiles MB9 and MB10 run parallel with the shoreline and cross transects MB1-MB8 and are shown in Figure 18 and Figure 19 (Section 2). These profiles show that the sea floor is deeper at the northern end of Molyneux Bay. Both sections show an area of rougher terrain between the distance of 12-16kms (Figure 52).

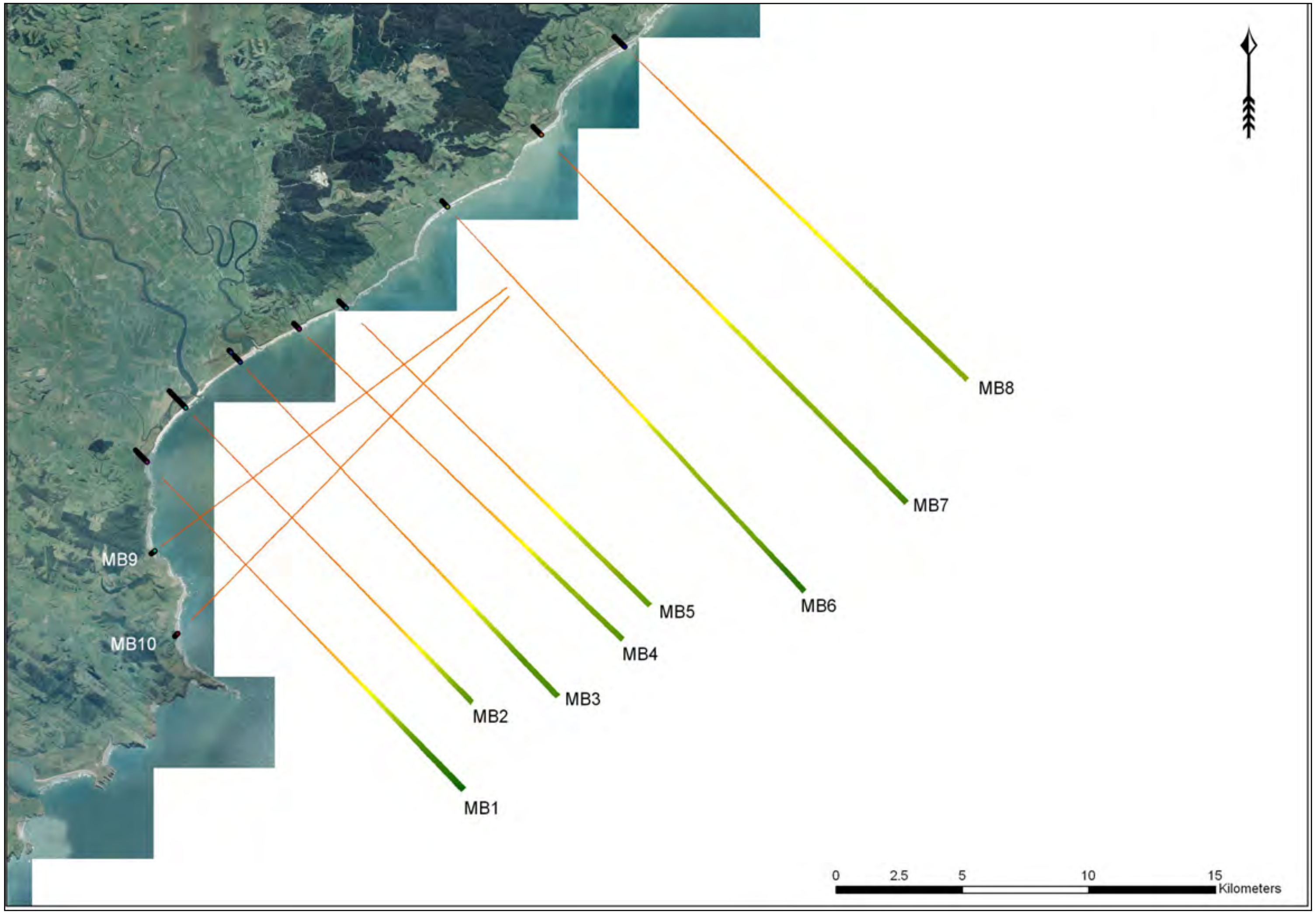


**Figure 50 Location of the ten offshore transects and their landward extensions (aerial photo date: March 2006)**

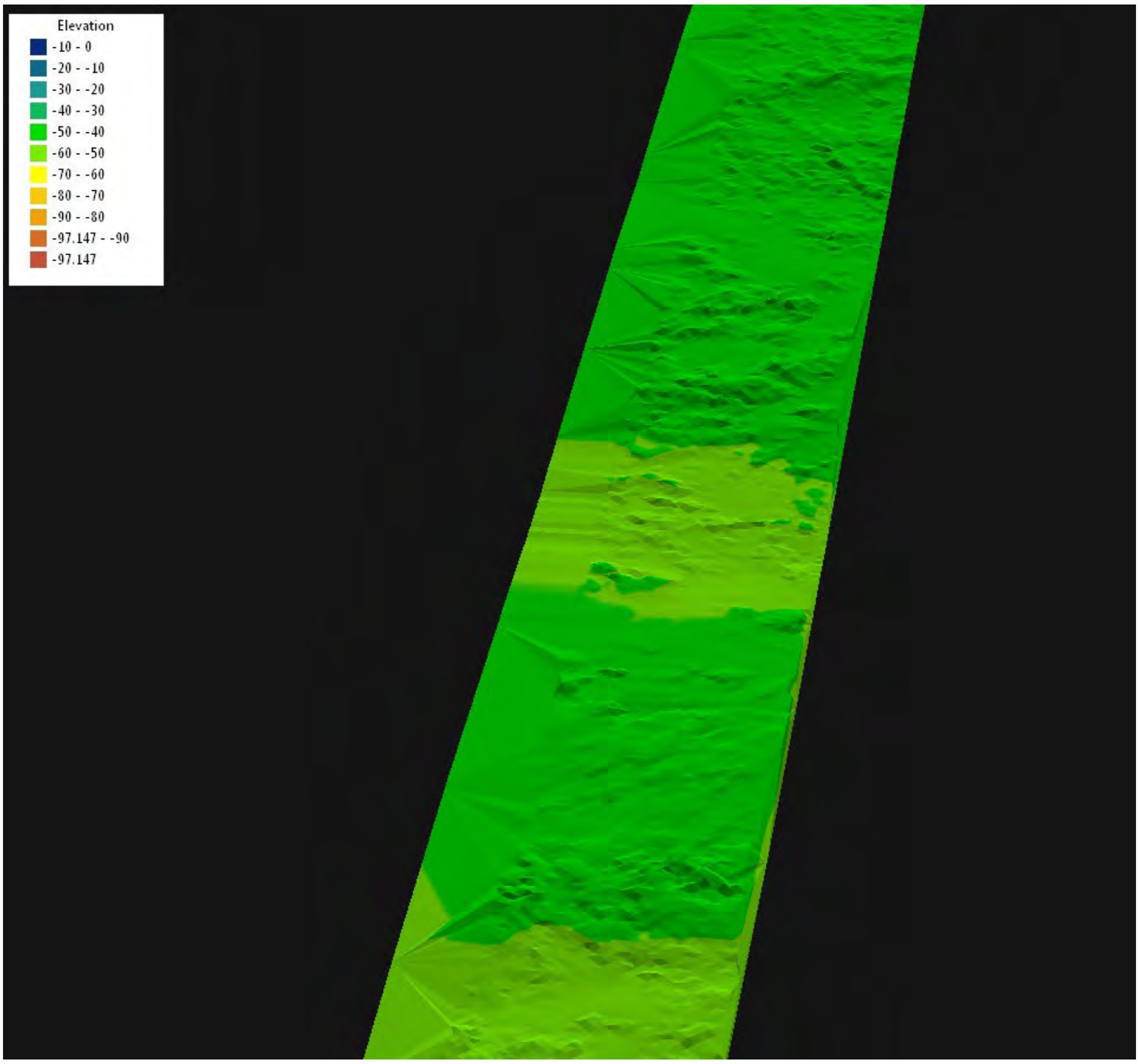


**Figure 51 3D view of undulating terrain in MB08; image taken looking towards the shoreline with 2x vertical exaggeration (elevation is relative to DVD58)**

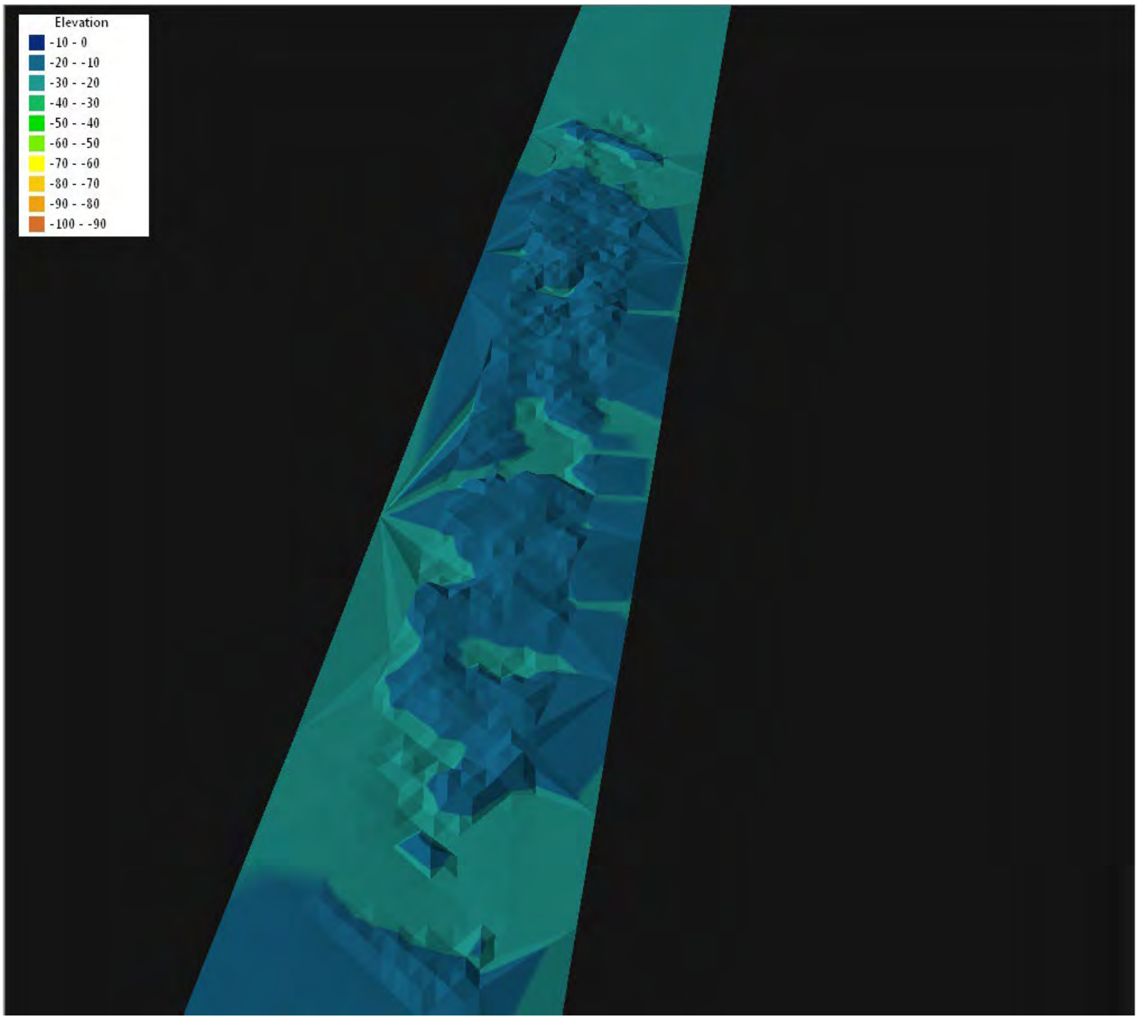


**Figure 52 3D view of undulating terrain in MB09; image taken looking northeast with 2x vertical exaggeration (elevation is relative to DVD58)**

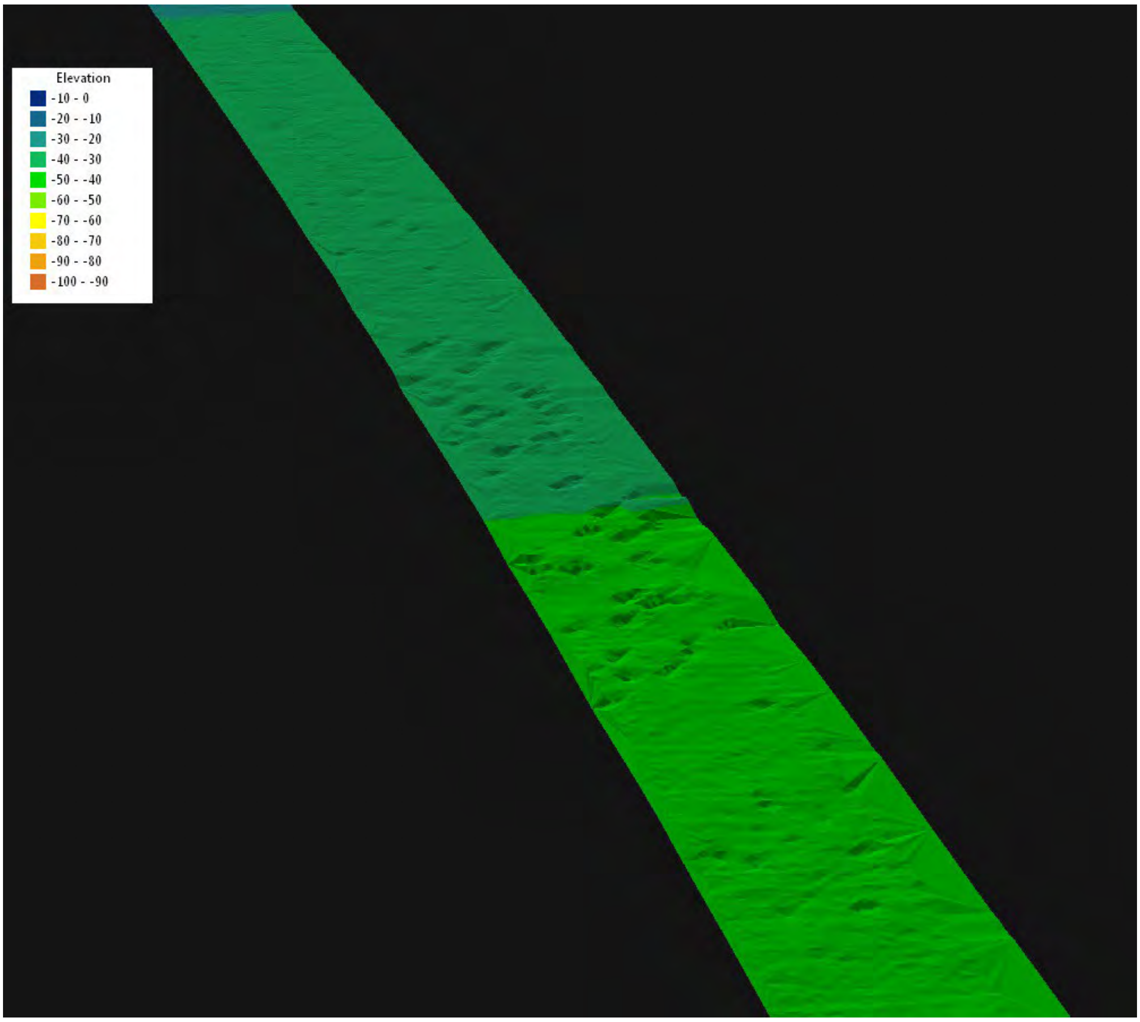


**Figure 53 Evidence of pockmarks on MB07, image taken looking towards the coastline with 10x vertical exaggeration (elevation is relative to DVD58)**

# 9. Conclusion

Between 1946 and 2012, the vegetated shoreline eroded at an average rate of 3.3m/yr between Kaka Point and the Koau Mouth of the Clutha River/Mata-Au. The average rate of erosion decreases between the Koau and Matau mouths of the Clutha River/Mata-Au to 0.2m/yr and then switches to accretion of 2.3m/yr at Measly Beach (south of Toko Mouth) and 0.8m/yr at Chrystalls Beach (north of Toko Mouth). If the trend of retreat continues for the coastline between Kaka Point and the Koau Mouth of the Clutha River/Mata-Au, there will be a number of implications for the Lower Clutha Flooding and Drainage Scheme and Clutha District Council assets, including reduced drainage capacity and erosion of roads.

Between Nugget Point and Kaka Point, accretion of the foredune and an increase in sand volume occurred between 2004 and 2013. Further north, a general retreat of the foredune occurred between Kaka Point and the Matau Mouth during this same period. Limited change in the dune profile has occurred between the Matau Mouth and Chrystalls Beach, with the exception of MBO7, which shows degradation across the whole transect.

The surface profiles of the near-shore sand wedge show that the seafloor is generally smooth, with some areas of pockmarking and undulations (possibly rock outcrops).

The information contained in this report sets a baseline for future surveys to follow. This will allow future comparisons of the coastal environment (offshore and onshore) between Nugget Point and Chrystalls Beach to be made.

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# Appendix 1- Information held by ORC on coastal processes between Nugget Point and Chrystalls Beach

Information relating to coastal processes operating between Nugget Point and Chrystalls Beach is available from several sources, including journal articles, historic surveys, aerial and ground photography and depth soundings. Below is a summary of the available information that is known to ORC, relating to coastal processes along the stretch of coast between Nugget Point and Chrystalls Beach.

*Near-shore sand wedge*

Located off the eastern Otago coastline, between Nugget Point and the Otago Peninsula, is a wedge of fine-grained silty sand that is commonly referred to as the 'near-shore sand wedge' (Carter and Carter, 1986). The sand wedge formed in two main stages: at a still-stand between 9600-8800 years BP, and between a more recent sea-level still-stand, about 6500yrs BP (Carter and Carter, 1986). The extent and thickness of the most recently deposited (about 6500 years BP) near-shore sand wedge were described by Carter and Carter (1986), Carter *et al.*, (1985) and Carter and Ridgway (1974), as shown in Figure 54. The approximate depth[19], offshore extent and thickness of this sand wedge, is described in Table 8. Typical offshore depths along this stretch of coast are shown in Figure 55. The bulk of the sand wedge is centred to the east of Nugget Point, at a water depth of between 40m and 60m. Northward of Taieri Mouth, the wedge thins, and decreases in extent.

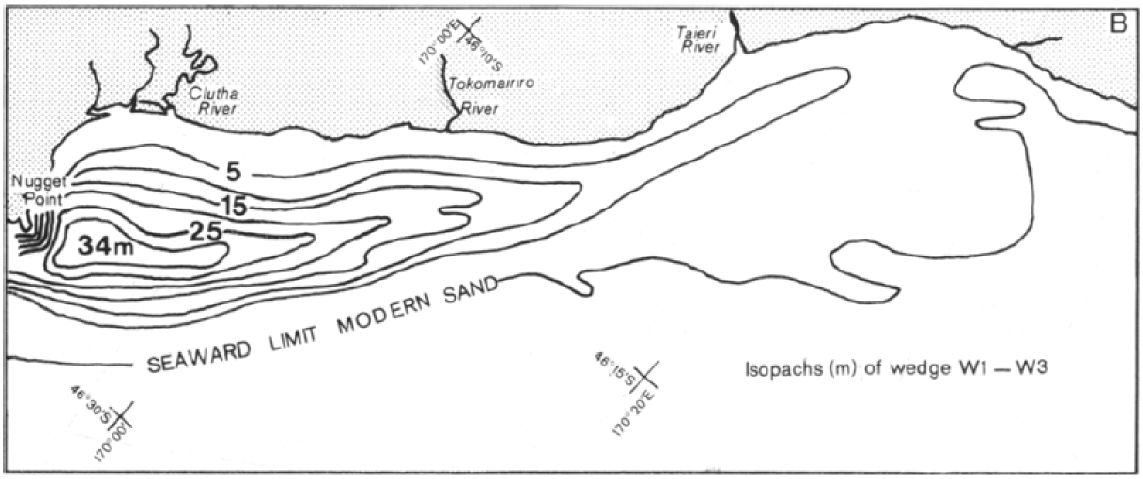


**Figure 54 Map showing the seaward extent of the most recent (Holocene) sand wedge (from Carter and Carter, 1986). Isopachs refer to the thickness, in metres, of Holocene sediments over Pleistocene sediments and basement rock.**

[19] i.e. the depth of the upper limit of the sand wedge below current sea level

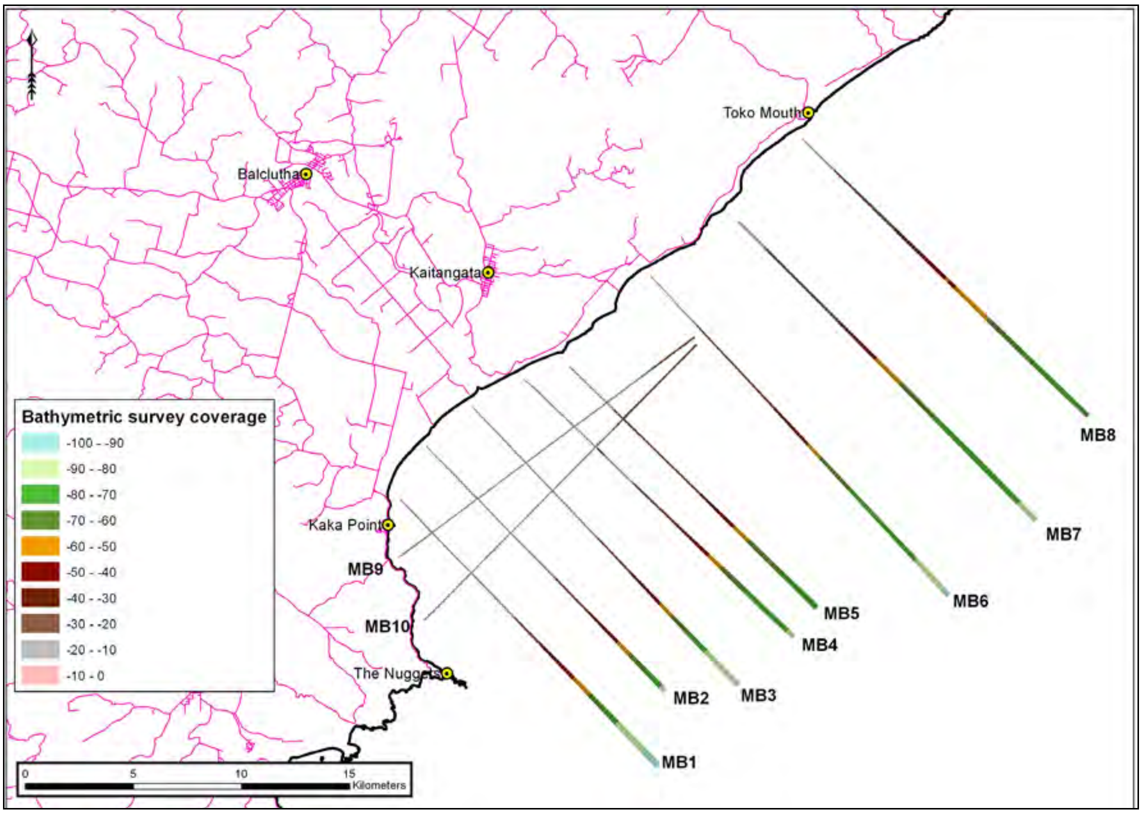


**Figure 55 Bathymetric survey coverage in Molyneux Bay obtained in February 2013 (elevation is relative to DVD58)**

**Table 8 Distance, depth and thickness of the most recently deposited sand wedge at three locations**

| Location | Maximum distance sand wedge extends offshore (km) | Depth of sand wedge at maximum offshore extent (m below current sea level) | Maximum thickness (m) |
|---|---|---|---|
| Offshore Clutha delta | 15 | 80 | 34 |
| Offshore Toko Mouth | 8 | 40 | 15 |
| North of Taieri Mouth | 3.5 | 40 | 5 |

The National Institute of Water and Atmospheric Research (NIWA) holds NZOI (New Zealand Oceanographic Institute) seismic profiles and uniboom (seismic) data for Molyneux Bay, which formed the basis for the paper written by Carter and Carter (1986). Seismic data was also collected for the mineral report MR2115 (Price *et al.*, 1981-82).

*Sediment transport*

Net sediment transport in the Molyneux Bay environs is in a northerly direction (Carter and Carter, 1986). However, there is also southward transportation of sediment. This southward transportation is due to longshore drift from north-westerly storms and the eddy that is formed by Nugget Point impeding the Southland current (Carter and Ridgeway, 1974). The eddy causes a southward flow and an associated southward flow of Clutha River/Mata-Au sediment (Carter and Ridgway, 1974). This process has been noted as occurring at localities on the northern side of the Otago Peninsula (Andrews, 1973). The net northward movement of sediment may be a factor in explaining why the highest rates of coastal retreat occur south of the Koau Mouth of the Clutha River/Mata-Au. Hicks *et al.* (2000) state that the potential yield of sand and gravel from the Clutha River/Mata-Au to the coast has reduced by 95% from 0.91 Mt/yr to 0.06 Mt/yr since the building of the hydro dams in the upper catchment. This may also help to explain why the coastline is retreating between Kaka Point and the Matau Mouth of the Clutha River/Mata-Au.

*Clutha River/Mata-Au river mouths*

Information pertaining to the location and state of the Clutha River/Mata-Au Mouth positions is present in Mutch (1978) (Figure 57 and Figure 58) and OCB (1978), as well as in historic photos, plans and depth soundings (Figure 56 and Figure 59). The ORC holds aerial photos for Molyneux Bay for the years 1946, 1972, 1997 and 2006. Additional aerial photo runs are held in the the Crown Aerial Film Negative Collection, which is managed by NZAM (New Zealand Aerial Mapping), for the years 1962, 1968, 1982, 1984 and 1995.

**Figure 56 General map of the Settlement Rural sections. Original drawing by C.H. Kettle, 1852**

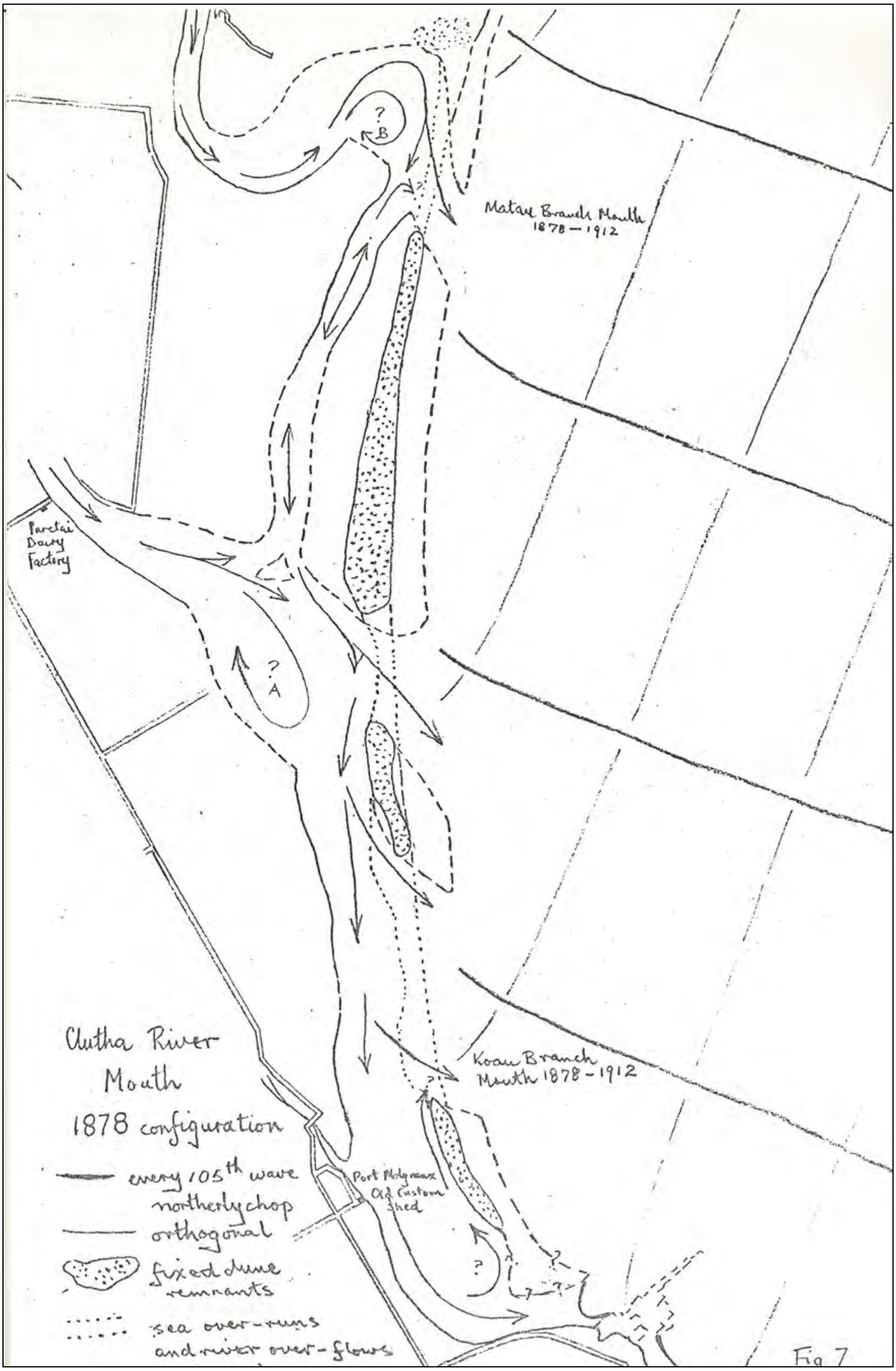


**Figure 57 Clutha River/Mata-Au Mouth configuration (1878) (Mutch, 1978)**

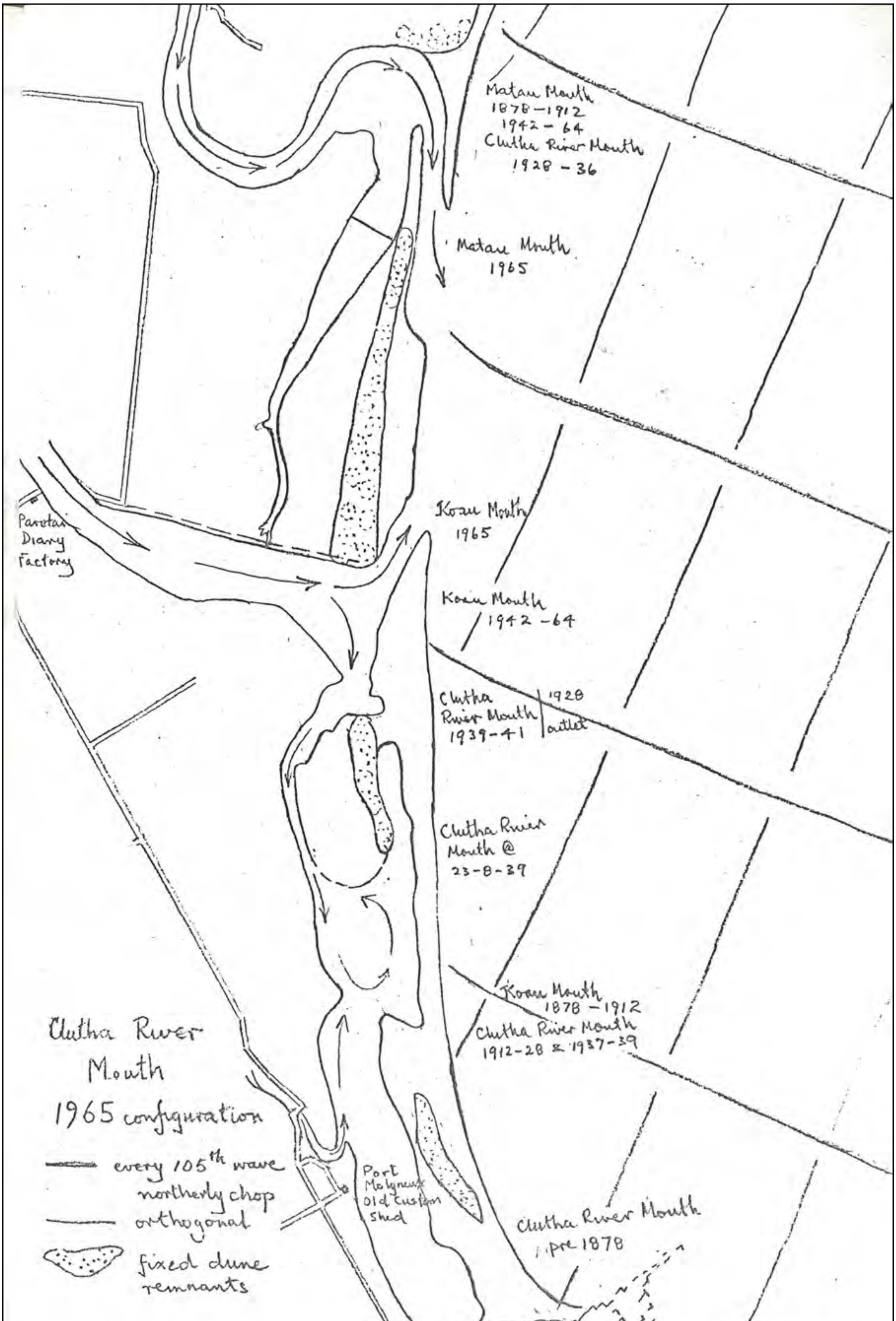


**Figure 58 Clutha River/Mata-Au Mouth configuration from 1965 (Mutch, 1978)**

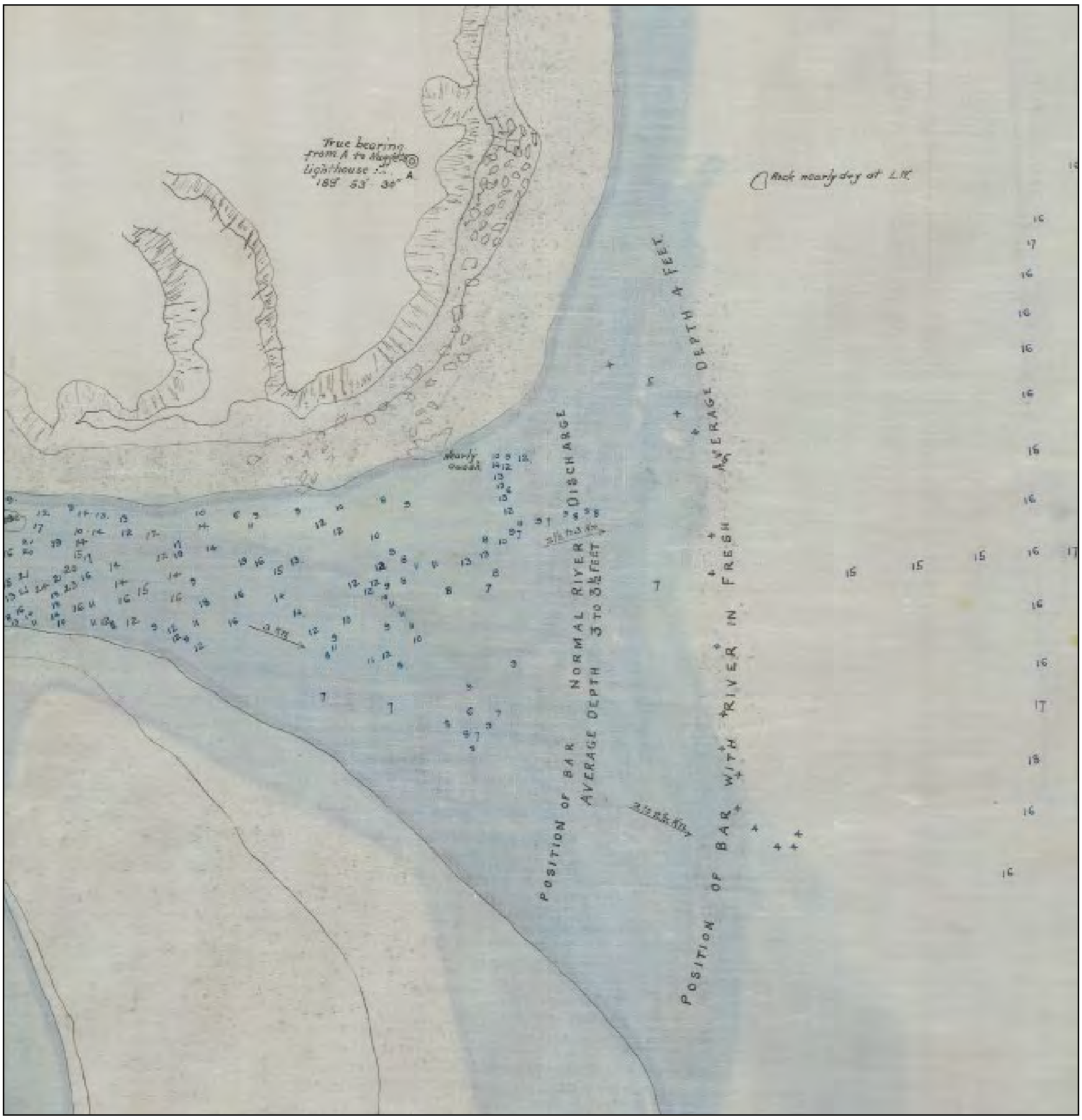


**Figure 59 Clutha River/Mata-Au Mouth (Matau) depth soundings, dated 1901 (surveyed by Leslie H. Reynolds)**

# Appendix 2- Methods

*Transect monitoring (bathymetric and terrestrial)*

To fulfil Contact Energy's Resource Consent 2001.394, condition 13 *ii),* a comprehensive coastal monitoring programme was established in the vicinity of Molyneux Bay. The monitoring (surveyed) area extended from Nugget Point in the south to Chrystalls Beach in the north. The monitoring involved surveying ten offshore and 20 onshore transects that extend from the near-shore zone to the seaward extent of the near-shore sand wedge, which was identified in Condition 13, ii) of Resource Consent 2001.394.

The location of the offshore transects was chosen to coincide with previous surveys completed in this area (Price *et al*., 1981-82). Using the same transects lines as Price *et al.* (1981-82) would allow comparisons between the old and new datasets to be made. However, as such comparisons were considered to be beyond the scope of this summary, they are not discussed here.

The ten offshore transects (MB1-MB10) were completed in February 2013 by the survey company, IX Survey, with the use of a survey vessel and a multi-beam echo sounder that mapped a swath of the sea floor (Figure 50). The width of this swath is four times that of the water depth. The length of transect lines totalled 179km and covered an area of 18km$^2$. The dataset is considered to have a vertical accuracy of $^+/-$ 0.30m and a horizontal accuracy of $^+/-$ 0.25m. The dataset was generated from Digital Terrain Model (DTM) of 2m resolution, with the underlying sounding density exceeding that of the LINZ MB-1 order. A cross-section profile was extracted from the centre of the survey swath and exported for use in Microsoft Excel.

Ten onshore transects (MBO1-MBO10) were surveyed as part of the project and were aligned with their offshore counterparts. Transects were surveyed in April 2013 using Real Time Kinematic (RTK) GPS. The ten onshore and offshore transects were combined to create ten continuous transects. Eight of these transects extended from the backshore coastal zone to the seaward extent of the near-shore sand wedge, with the additional two transects running parallel to the coastline. Limitations in the depth that the survey vessel could operate meant that not all offshore transects could be extended to their onshore counterparts (MBO1, MBO2 and MBO3). As a result, a small gap was present in these transects. Several sections of the onshore transects were impassable on foot (swamps or river channels), resulting in some small gaps in these transects.

Ten additional onshore transects were surveyed between the township of Kaka Point and Nugget Point. These transects extended, as a minimum, from the low tide mark to the landward side of the Kaka Point/ Nuggets Road.

The data from the onshore and offshore surveys is presented relative to the Dunedin Vertical Datum 1958 (DVD58). The zero for DVD58 is Mean Sea Level (MSL), which was determined from tide readings during the years 1918-1937.

*Coastal retreat/accretion*

To fulfil Contact Energy's Resource Consent 2001.394, condition 13 *i)* an analysis of the historic shoreline position was completed with the use of georeferenced aerial photography and GPS tracking. Historic aerial photos of the coastline in the area, described as being dependent on Clutha River/Mata-Au derived sediment, were scanned and georeferenced. Aerial photography was flown in the study area in 1946, 1962, 1968, 1972, 1982, 1984, 1995, 1997 and 2006. This study used photography from 1946, 1972, 1997 and 2006. The coverage of the aerial photography is incomplete across the study area, with the exception of 2006, which shows a complete coverage of the Otago coastline (Appendix 3).

Historic shorelines were mapped from georeferenced aerials at four stretches of the coast: Kaka Point-Koau Mouth, Koau Mouth to Matau Mouth, Measly Beach and Chrystalls Beach. These four stretches of coast were chosen due to the coverage of aerial photos, location of the offshore transects and the presence of a sandy beach with a prominent vegetated foredune. The shoreline position was mapped as the seaward extent of the vegetated foredune. The position of the shoreline was not extended where small outcrops of vegetation were detached from the main body (e.g. Figure 60). The vegetated foredune between Kaka Point and the Matau Mouth of the Clutha River/Mata-Au was mapped using a handheld GPS in August 2012. This information was then assessed to measure the rate of coastal retreat/accretion in the area identified as being dependent on Clutha River/Mata-Au derived sediment.

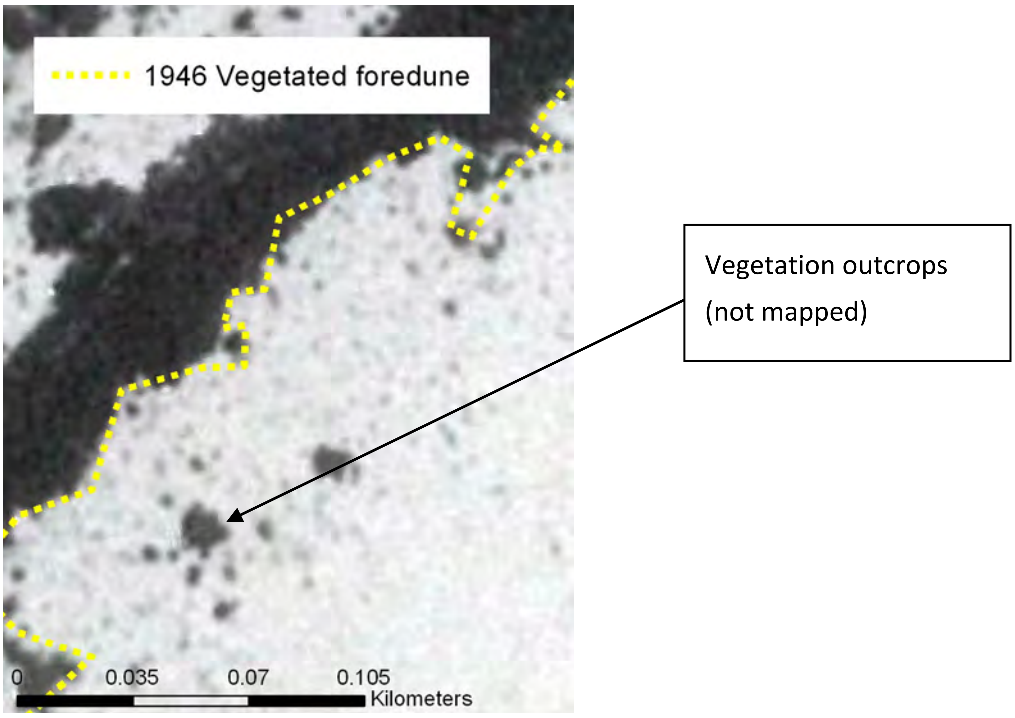


**Figure 60 Vegetation mapping from historic aerial photos (1946)**

The 2006 vegetated foredune was divided into intervals at every 5% of the total extent of the foredune. It was considered that this division was sufficient to give good representation of shoreline change. At each of the 20 reference points, the distance between the 2006 shoreline and the shoreline of interest was measured (Figure 61-Figure 64). The measurement was completed at an angle perpendicular to the 2006 coastline. The 20 distance measurements were averaged to give a mean rate of coastal retreat/accretion for each of the four beaches. The measurements of coastal retreat/accretion were calculated between all the datasets available. Rates of retreat and accretion were not measured close to the mouths of rivers and streams because their inherent instability may lead to inconsistent measurements. The accuracy of the mapped shoreline is approximately $^+/-$ 15m.

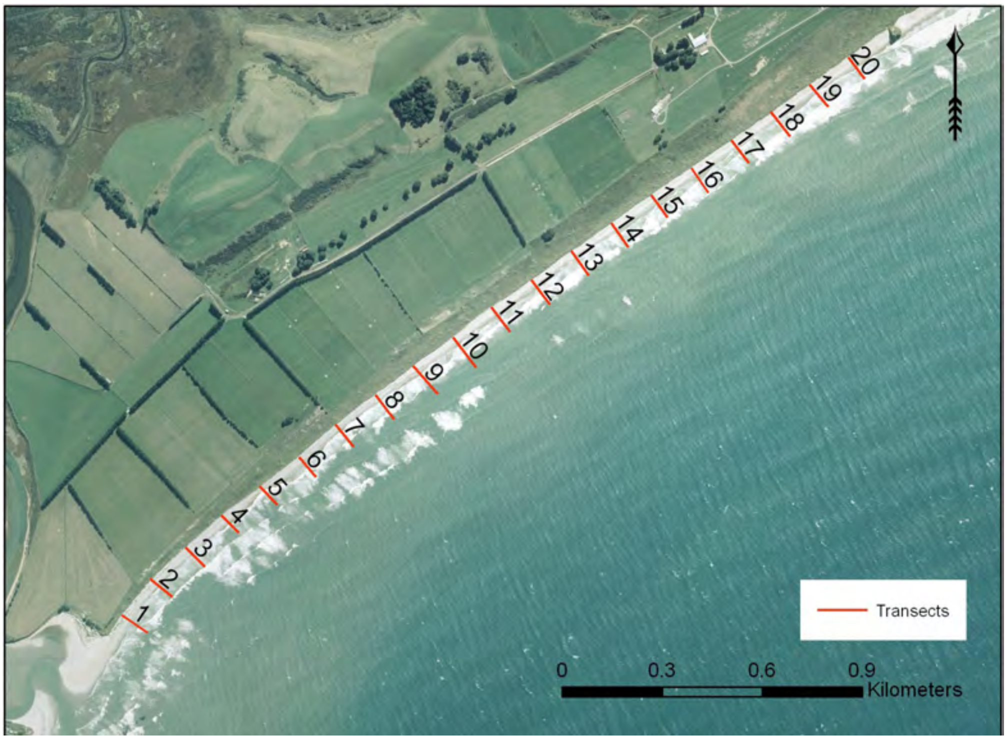


**Figure 61 Transects for erosion/accretion measurements at Chrystalls Beach (aerial photograph date: March 2006)**


**Figure 62 Transects for erosion/accretion measurements at Measly Beach (aerial photograph date: March 2006)**


**Figure 63 Transects for erosion/accretion measurements between Koau and Matau mouths (aerial photograph date: March 2006)**


**Figure 64 Transects for erosion/accretion measurements between Kaka Point and Koau Mouth (aerial photograph date: March 2006)**

The onshore cross-section data collected in April 2013 was also compared to two different sets of airborne LiDAR data (where available) collected in September 2004 and September 2009. The density of the LiDAR data points is about 1 point per $1m^2$. The LiDAR data has a horizontal and vertical accuracy of $^{+}/-$ .15m. As the LiDAR points do not give 100% ground coverage, the heights between the points are interpolated to form a ground coverage terrain. This interpretation leads to the terrain having an inherent inaccuracy that must be taken into consideration when comparing the onshore cross-section data with the LiDAR data.

The onshore cross-section data were collected using methods that take an elevation and distance measurement at every break in slope. This method has limitations in terms of transect resolution, and the interpretations made should be viewed within the context that the data was collected.

# Appendix 3 Aerial photo coverage

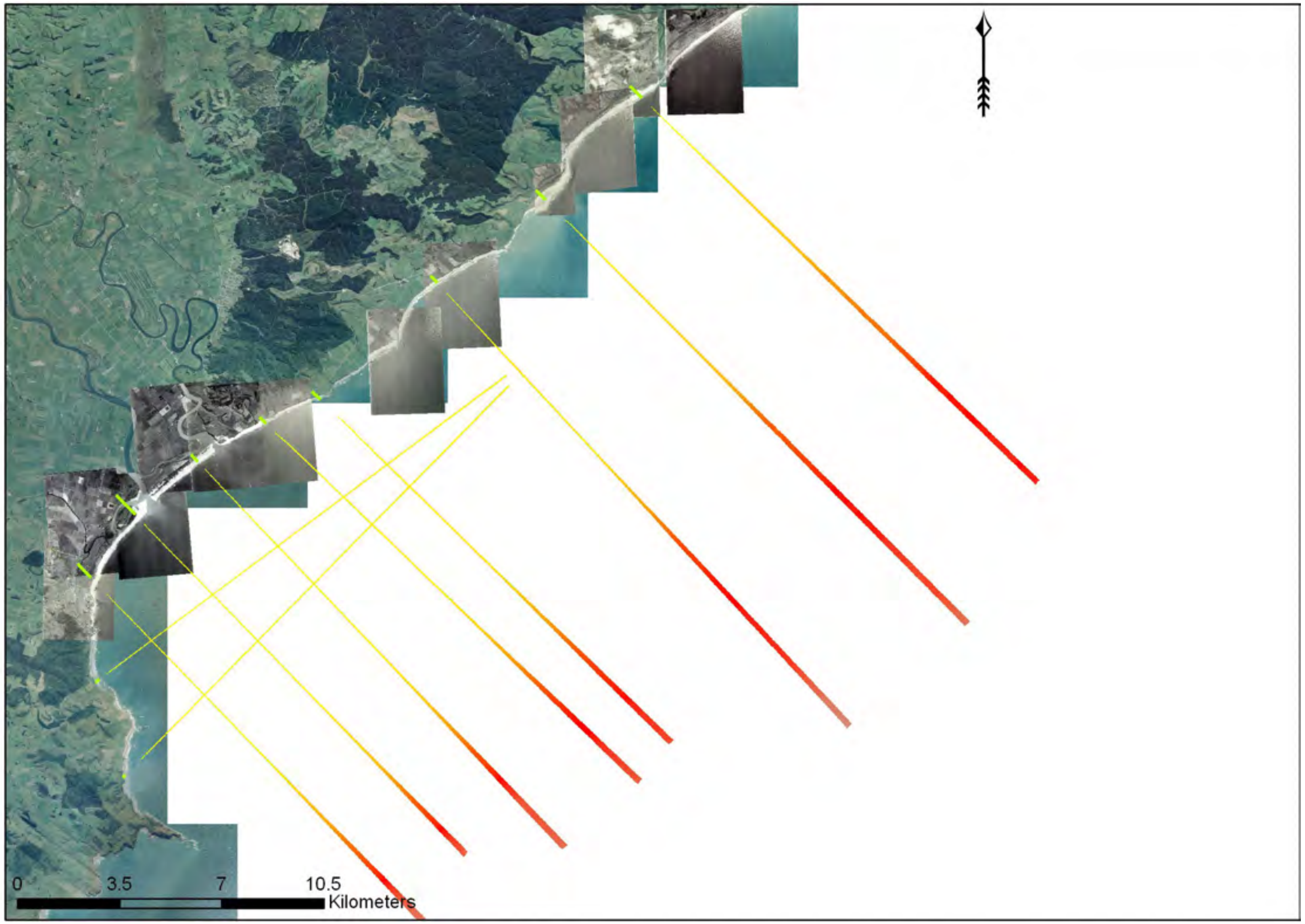


**Figure 65 1946 aerial photo coverage (background aerial photograph date: March 2006)**

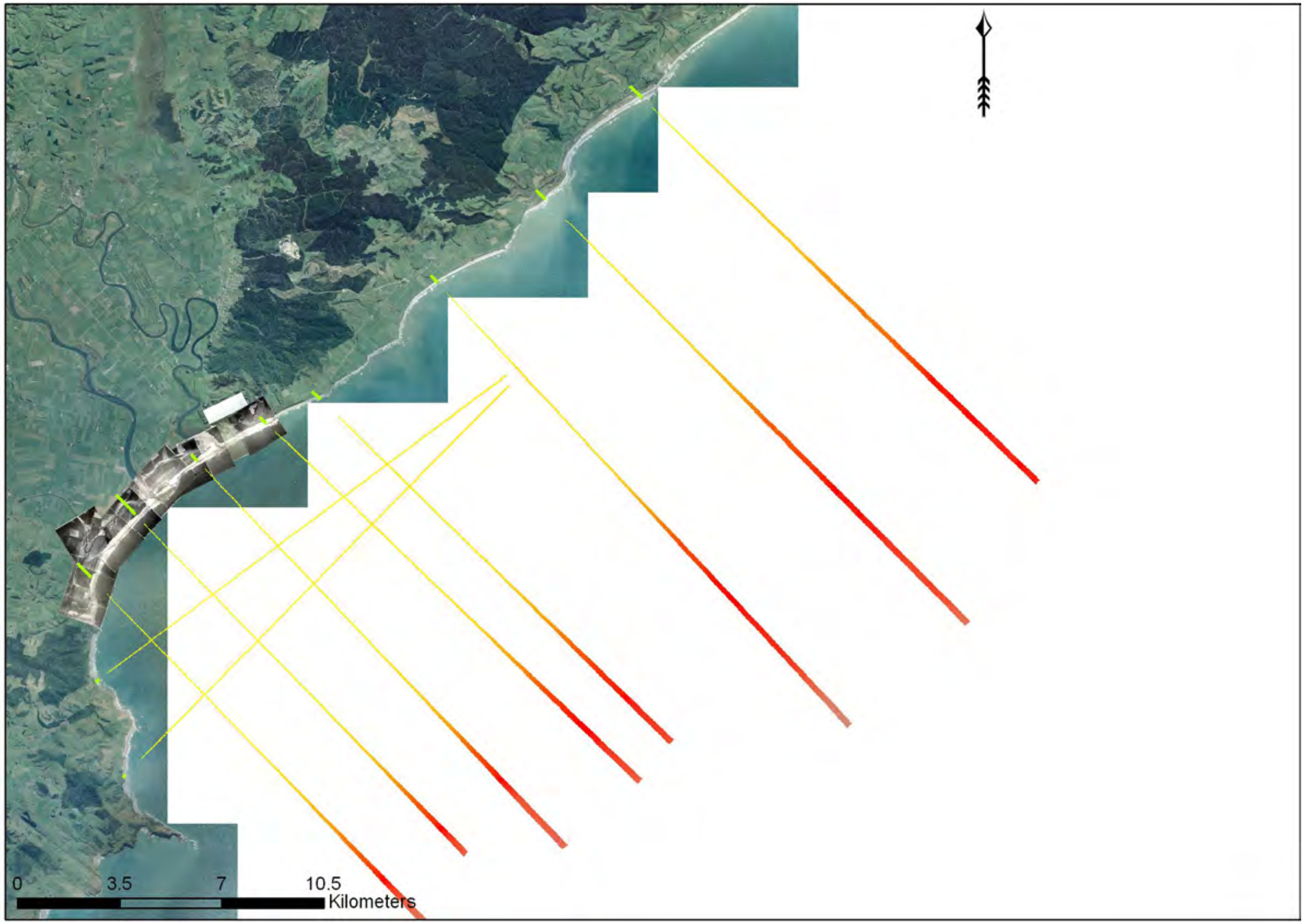


**Figure 66 1972 aerial photo coverage (background aerial photograph date: March 2006)**

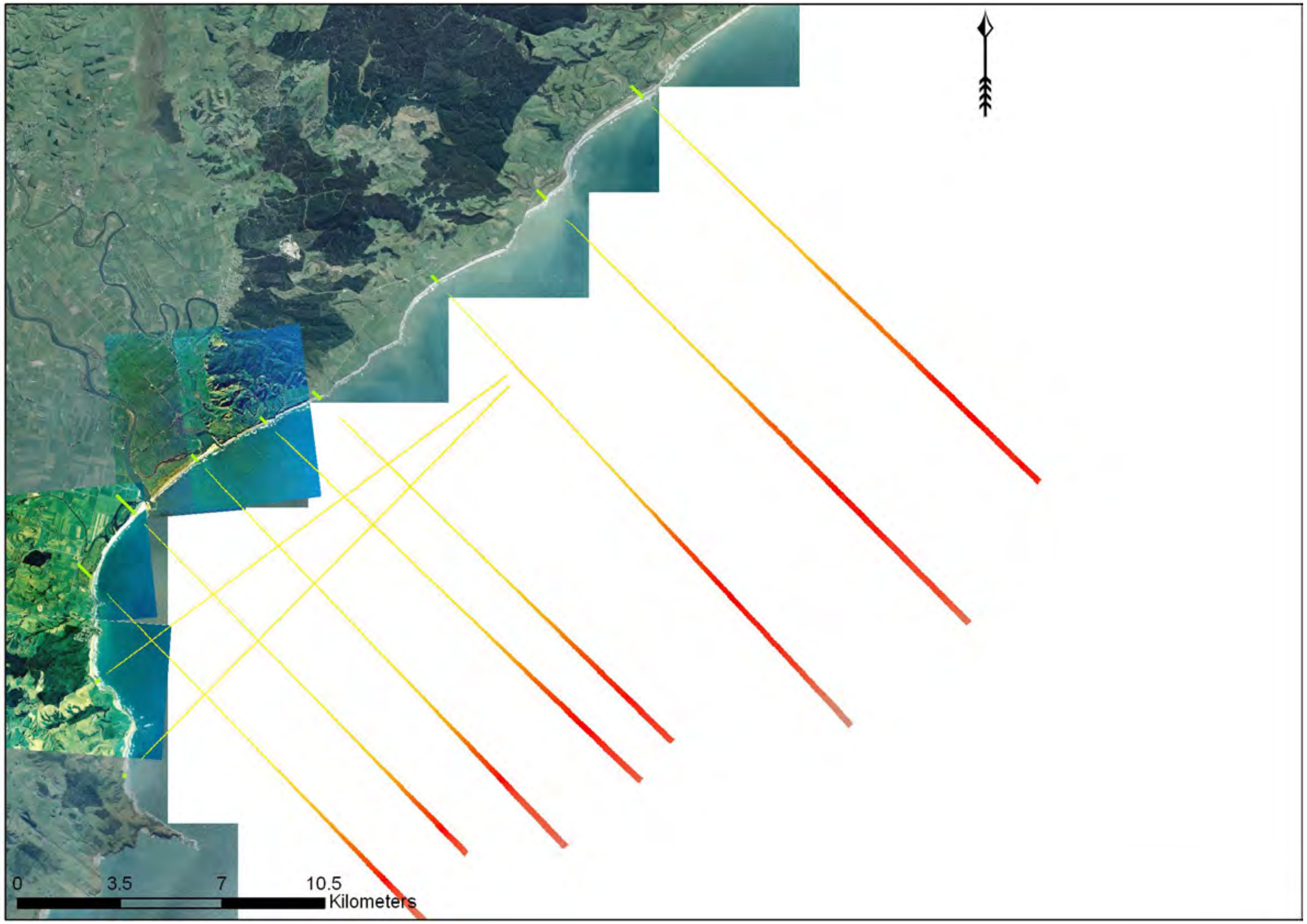


**Figure 67 1997 aerial photo coverage (background aerial photograph date: March 2006)**