IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of an application by Meridian Energy Limited for the resource consents related to the construction of a new channel to enable a permanent diversion of part of the flow of the Waiau Arm and the associated removal of bed material and gravels, together with any maintenance and ancillary activities.

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INTRODUCTION

1. My full name is Martin Bernard Single.

2. I hold a Ph.D. in Geography, which investigates coastal processes and geomorphological change.

3. I am an associate member of Engineering New Zealand, a member of the International Coastal Navigation Association PIANC, and a member of the New Zealand Coastal Society.

4. I am an environmental consultant with over 30 years of experience. My areas of specialisation are coastal processes and coastal management of New Zealand ocean beaches, lakeshores and harbours.

5. Currently, I am a director and principal consultant for Shore Processes and Management Limited, specialising in the science, management and planning of coastal lands and waters. I also hold an adjunct position as a Senior Fellow in the School of Earth and Environment, University of Canterbury.

6. I have authored or co-authored over 250 reports dealing with coastal and lakeshore geomorphology and management in New Zealand, Scotland and Fiji. My area of expertise includes physical coastal processes; coastal hazard assessment and identification of hazard mitigation measures; nearshore, beach and estuarine sediment transport; dredge spoil dispersal; beach nourishment, and beach management prescriptions.

7. I have been engaged by Meridian Energy Limited (**Meridian**) to provide expert advice in relation to coastal process issues raised in submissions on the resource consent applications for the Manapōuri Lake Control Structure Improvement Project (**MLC:IP** or **the Project**). These matters are raised in submissions from property owners and residents of the Bluecliffs community, which is located near the mouth of the Waiau River (**Bluecliffs submissions**).[1]

8. Meridian has engaged me because of my expertise in coastal geomorphology, and because of my knowledge of, and background to, the specific situation at Bluecliffs.

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[1] [Ref Bluecliffs submissions]

9. I am familiar with the Manapōuri Power Scheme (**MPS**) and previous consent applications relevant to Waiau River flows and potential effects, having provided technical information for Meridian for the Manapōuri Tailrace Amended Discharge (**MTAD**) project consent process (2006 to 2009) and for lakeshore management of Lakes Manapōuri and Te Anau (from 1987 to present day).

10. My coastal geomorphology and process background includes extensive study and university teaching on the shore type and hāpua river mouth forms as found at Bluecliffs. I have carried out and supervised studies on these river mouth types in the Canterbury and West Coast regions. I am familiar with research carried out at Bluecliffs (Kirk and Shulmeister 1994 *Geomorphic processes and coastal change in the lagoon system, Lower Waiau River, Southland*), having reviewed that work for the authors. I have carried out research on this river mouth type at the Rakaia, and Waitaki River mouths and for smaller hāpua such as the Waikoriri Lagoon, Westland.

11. With regard to the MLC:IP consent application, I confirm that I have read the following in preparing my evidence:

    (a) Assessment of Environmental Effects supporting the resource consent application for the MLC:IP;

    (b) The statement of Mr Andrew Feierabend (Meridian);

    (c) The statement of Mr Daniel Murray (Tonkin + Taylor;

    (d) The statement of Dr Dougal Clunie (Damwatch);

    (e) The statement of Dr Jo Hoyle (NIWA); and

    (f) The Bluecliffs Submissions.

12. I have also visited the Waiau River mouth and observed the recent erosion of the cliff backshore, attended the first pre-hearing meeting on behalf of Meridian to present on the physical processes at the river mouth, and authored the material addressing this topic in the Meridian response to the s92 request.

13. The purpose of my evidence is to describe the physical processes of the Waiau River mouth, and in particular the distinctive hāpua processes, and to address the submissions on this environment.

14. The existing configuration of the Waiau Arm, the MLC and the Lower Waiau River, as well as the proposed Project are described in Sections 2, 4 and 5 of the Assessment of Effects on the Environment (**AEE**) and in Mr Feierabend's evidence and are not repeated in detail here.

CODE OF CONDUCT

15. Although this is not an Environment Court hearing, I confirm that I have read the 'Code of Conduct for Expert Witnesses' contained in the Environment Court Consolidated Practice Note 2023. I agree to comply with this Code of Conduct. In particular, unless I state otherwise, this evidence is within my sphere of expertise, and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

SCOPE OF EVIDENCE

16. In my evidence I will address the following:

    (a) The methods employed in my assessment of the effects of the MLC:IP on the Waiau River mouth;

    (b) A description of the existing physical environment of the Waiau River mouth and hāpua processes;

    (c) Responses to specific issues raised by submitters;

    (d) Responses to issues raised in the Officers' Report; and

    (e) Provision of my conclusions.

SUMMARY OF EVIDENCE

17. My evidence describes the geomorphological processes of the Waiau River mouth in relation to changes in the river discharge from both flooding and low flow events, and from changes in the wave energy and wave approach, and from sediment

movement on the barrier beach due to storms and climatic variation. The Waiau River mouth is a dynamic physical environment driven by both fluvial and oceanic processes and is categorised as a hāpua type river mouth.

18. I describe the hāpua morphodynamics in detail as adequate understanding of this river mouth type is important in assessing the effects of MLC:IP on observed river mouth movement along the coast and erosion of the backshore of the hāpua waterbody. The Waiau River hāpua geomorphology is consistent with other hāpua systems found in the South Island and changes in response to changes in the river flow and wave environment consistent with theoretical and observed hāpua behaviour.

19. I also present anecdotal and empirical descriptions of historical changes to the Waiau River hāpua that provide background to the processes that drive change to the geomorphology. The descriptions of this environment include movement of the position and form of the outlet of the river, including flood conditions when the outlet is directly in line with the main river channel, and conditions when the outlet is at the distal end of the narrow barrier beach that impounds the hāpua waterbody.

20. My evidence addresses submissions that oppose the MLC:IP because of worsening erosion of the shore at Bluecliffs and the Waiau River mouth resulting from alteration of the flow regime, sediment carrying capacity and sediment load of the Waiau River. Monitoring of the river flow and sediment movement as part of the MTAD consent conditions shows that the changes measured between 2009 and 2017 showed no evidence of the consented flow regime having an effect on shoreline behaviour at the coast that was detectable from the variable behaviour of the coastal system due to changes in natural processes.

21. From my assessment of the processes and historical observations of the Waiau River hāpua, I consider that recent changes to the Waiau River hāpua and river mouth are consistent with hāpua process theory and with historical variability that predates and postdates the construction of the MPS and the MLC. Recent erosion at Bluecliffs is not unique or a direct consequence of the MPS.

22. The MLC:IP does not propose to amend the consented flow regime for the MPS. It is my opinion that the MLC:IP construction activities and improvements in reliability of achievement of supplementary flows will not adversely affect the coastal and hāpua processes.

METHODS EMPLOYED IN MY ASSESSMENT

23. In preparing this evidence, I have read the submissions relating to the MLC:IP project. To provide background to recent erosion at Bluecliffs Beach Road, I have read the recent reports to Environment Southland by Tonkin and Taylor (*Bluecliffs Beach Road Papatotara, Preliminary hazard and geotechnical assessment – October 2023*, letter dated 8 February 2024) and Pattle Delamore Partners (*Waiau River mouth opening*, memorandum dated 25 March 2024).

24. I have refreshed my understanding, and refamiliarised myself with the reports to the Waiau River Working Party by Kirk and Shulmeister, Delwyn Day (1993 *Historical review of the Waiau River and coastal area*), and the statements of evidence of Dr Mark Mabin and Dr Murray Hicks with regard to the geomorphology and river sediment transport (respectively) of the Waiau River and Te Waewae Bay shore presented at the hearing for resource consents for the MTAD Project in August 2009. I also re-read the comments relating to submissions by the Bluecliffs Beach Landowners Group in the MTAD consent decision.

25. As background to the potential effects of the MPS and the MLC:IP on the Lower Waiau River and river mouth processes, I have also read the AECOM report on changes in the Lower Waiau River between 2009 and 2017 (*Lower Waiau River geomorphic monitoring 2016/2017*, May 2018) to provide insight as to sediment supply changes in the Waiau River.

26. The description of the coastal environment for my evidence is based on a review of literature, maps, and ground and aerial photographs. I have visited the site but have not carried out field research at the Waiau River mouth.

27. Attached as Appendix 1 to this evidence is a list of relevant publications on hāpua processes that provide context to these environments in general that is applicable to the Waiau River mouth situation.

PHYSICAL COASTAL ENVIRONMENT AND HĀPUA PROCESSES

Environment overview

28. Figure 1 shows the Waiau River and associated hāpua and lagoon. The main channel of the river is noted as is the barrier beach impeding the direct flow of the river to the sea and enclosing the hāpua and lagoon water bodies. The outlet to the sea at the time of the photograph (27 January 2022) is at the far western end of the hāpua and is a narrow channel through the barrier beach.

Figure 1 – Waiau River mouth area (Image from GoogleEarth)

29. Although the Waiau River has a large discharge of water to the sea, the Lower Waiau River is a "small" river with regard to the contribution to the coastal geomorphology of Te Waewae Bay. The small river concept relates to the ability of the river to supply sediment to the coast at quantities and at a rate that offset the volume of sediment lost due to erosion by oceanic processes of waves and currents. The suspended sediment load is relatively small compared to other large South Island rivers, and the bedload sediment supply of the Waiau River is also relatively

small, at about 50,000 m^3 per year. The imbalance between the water discharge and the sediment discharge arises due to the effects of the large lakes at the head of the Waiau River catchment. Sediment is supplied to the Lower Waiau River from the Mararoa River, other smaller tributaries, and from the river bed and channel margins.

30. Work by Dr Murray Hicks and NIWA for the MTAD consent showed that the capacity of the Waiau River to transport sediment is greater than the amount of sediment available to be transported. The river is undersupplied with sediment relative to the sediment carrying capacity. River bed transect monitoring carried out by AECOM has found that the river bed below Tuatapere has aggraded between 2009 and 2017 (the last available reporting of monitoring). This indicates that there is sediment moving in the river and the river bed is not eroding, and that there is no evidence of a reduced sediment supply to the coast.

31. Te Waewae Bay is a micro-tidal, high-energy coastal environment with waves predominantly approaching from the west-southwest. Large swell and storm waves shoal within the bay, resulting in a wave approach at the beach that is nearly parallel with the shoreline. This is illustrated by the formation of beach cusps along the beaches of the central section of the bay. However, there is potential for incomplete refraction (or bending) of the wave crest so that the waves break at an angle to the shore under more westerly conditions. This results in an alongshore energy gradient that is predominantly to the southeast, but with a lesser but measurable component to the northwest. In addition, there is a potential longshore energy flux due to wave energy being lower in the western part of the bay than in the centre and to the southeast. This results in nearshore currents that can transport fine sediments from the southeast to the northwest along the shore.

32. Dr Mark Mabin provided a description of the Te Waewae Bay coast in his technical reports and evidence for the MTAD consent process. Rather than repeat his description, I present it here as Appendix 2 to my evidence.

33. Of significance are the coastal landforms that comprise the river mouth. Two distinct but connected lagoon systems are present at the coast where the Waiau River enters Te Waewae Bay. To the southeast is a narrow waterbody, separated from the sea by a narrow gravel barrier beach. It is rarely connected to the sea with regard to outflows, although ocean waters from storm waves do overtop the narrow barrier beach with run-up flowing into the lagoon. This type of coastal waterbody is known

as a *waituna* or coastal lake. The Waiau waituna has inflows from the Waiau River, and the water volume and extent of the waterbody is associated with the discharge volume of the river.

34. To the northwest, or true right of the Waiau River, the lagoon system has a connection to the sea that is rarely closed but is often offset from the main river channel. This type of lagoon system is known as a hāpua, the processes of which are important in understanding the dynamic behaviour of the Waiau River mouth and changes to the physical geomorphology.

Hāpua processes

35. Hāpua are a distinctive type of river-mouth lagoon found on high-energy, typically stable to eroding coasts, where high-energy waves are common and longshore drift is a significant agent in sediment movement on the shore. The presence of hāpua is coincident with the dominance of waves in the interaction between marine and fluvial processes occurring at river mouths.

36. Hāpua are non-estuarine, predominantly freshwater, and typically maintain one semi-stable opening to the sea. Multiple outlets are common during floods but are extremely short-lived. Unlike estuaries these lagoons are not characterised by recurring tidal flows inward and outward. They have no tidal prism and therefore cannot be classified in terms of tidal hydraulics.

37. Hāpua are best known and researched on the east coast of the South Island. They have been identified to occur at the mouths of the Waitaki, Opihi, Rangitata, Hinds, Ashburton, Rakaia, Kowhai, Waipawa, Hurunui, Waiau, Conway and Kahutara Rivers. Smaller streams and rivers on the west coast of the South Island also have hāpua systems.

38. Hāpua-type lagoons form when longshore currents rework river and cliff-erosion supplied sediments on the foreshore to build a coarse, clastic barrier in front of a river mouth, offsetting the fluvial outlet to the sea. The offset outlet creates a coastal depression between the beach and hinterland in which the lagoon waterbody forms. The enclosing barrier is long and narrow relative to lagoon width and is subject to prevalent wave wash-over. The term barrier is used here to refer to the entire formation in preference to spit because, although the barrier is formed through spit-growth processes, it is usually attached at both ends of the waterbody.

39. Hāpua function as temporary sediment sinks. They usually have small seaward deltas at the river outlet and extra sediment deposited at the outlet after a flood is rapidly dispersed along the shore by wave action or along the margins of the lagoon by fluvial processes. Over geologic time, such lagoons are commonly displaced landward by long-term coastal erosion. Hāpua are maintained as erosion proceeds due to parallel retreat of the lagoon barrier and landward margins.

40. Little is known concerning the occurrence and functioning of hāpua on prograding coasts. However, rivers and streams on prograding sandy shores can be temporarily impounded at the mouth by moving beach sediment, often resulting in deflection of the fluvial channel parallel to the shore and subsequent erosion of the backshore. Examples of this process can be found along the Kapiti coast in the North Island.

Balance of marine, fluvial and sedimentological processes operating on hāpua

41. Waves and tides are important influences on hāpua barrier growth and outlet offsetting at low to moderate river discharge stages. Storm waves also play a significant role in overtopping lagoon barriers and initiating breaches, particularly in small hāpua and elongated hāpua with narrow barrier beaches.

42. River flow is another important forcing function in hāpua dynamics. High river flows can initiate barrier breaches while low river flows are associated with outlet channel migration and possible outlet closure.

43. In hāpua-type lagoons, the combination of a hydraulic head between lagoon and sea and concentration of freshwater outflow in the barrier opening normally prevents tidally induced inflow of salt water. Hāpua barrier openings are thus true outlets, like a river mouth, rather than an inlet as found with estuaries. Tides do produce a ‘backwater’ effect in hāpua as elevation of the sea level decreases drainage of the lagoon by barrier throughflow and channel outflow, causing the lagoon level to rise temporarily. This effect generally results in a change in the lagoon water level that is less than the tidal range.

44. Throughflow in hāpua barriers is a function of the hydraulic head between the lagoon and sea and the permeability of barrier deposits. Permeability and throughflow vary widely between different hāpua barriers, at different levels and locations along each barrier and under different beach conditions. Along with antecedent barrier morphology, permeability variations within the beach enclosing

hāpua are important controls on thresholds of lagoon response to waves and river flow. In rising river stages, high rates of throughflow can initiate frequent, ‘early’ breaching thereby reducing the length of mouth offsets. Such ‘early’ breaching can be important in reducing the likelihood and duration of closures at low river flow levels.

45. Conversely, during periods of low river flow, high rates of throughflow can cause mouth closure by reducing the amount of water draining from the lagoon through the outlet. The decreased outlet flows are then unable to maintain an opening in the barrier against longshore drift or onshore sediment movement.

Hāpua dynamics

46. Hart (2009) and Measures *et al.* (2020) have described a distinctive sequence of river mouth offsetting and freshwater lagoon development following floods for several South Island hāpua, including the Waiau, Waitaki, Opihi, Rangitata, Ashburton, Rakaia and Hurunui River mouths. In this sequence, during large floods the mouth is open to the sea opposite the main river channel, where a lobate ‘delta’ of fluvial sediment is deposited into the nearshore. This is shown in “A” in Figure 2.

47. After the floodwaters recede, this sediment is pushed landward by waves and transported along the shore seaward of the river mouth. A spit forms across the river mouth in the direction of longshore transport, offsetting the outlet to the sea. The narrowed outlet migrates along the shore in the direction of longshore drift, transformed from a wide, shore normal channel to one flowing diagonally through the barrier beach (“B” and “C” in Figure 2).

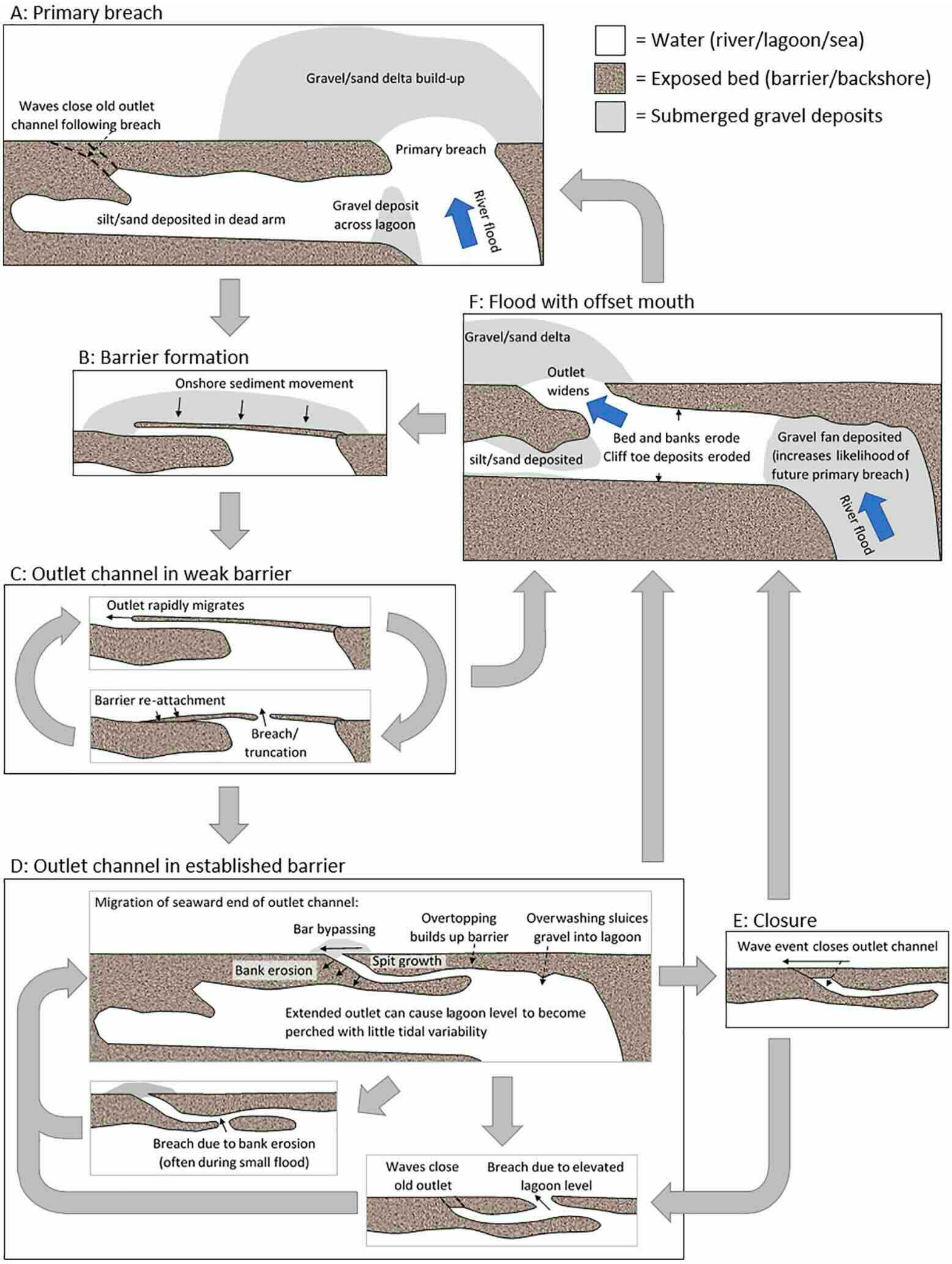

Figure 2 – Hāpua conceptual morphodynamics (Source: Measures, Hart, Cochrane, Hicks 2020, Processes controlling river mouth lagoon dynamics on high-energy mixed sand and gravel beaches Marine Geology, 420).

48. As the river mouth becomes progressively choked, water ponds behind the barrier, increasing the length of the lagoon. The hāpua will remain in a state of fluctuating outlet migration and lagoon growth until another large flood breaches the barrier in front of the main river channel (a 'direct breach'), truncating the lagoon, and the cycle begins anew ("D" and "F" and links in Figure 2).

49. Fluvial processes dominate hāpua-type river mouths and lagoon outlets only during large floods, when the lagoon barrier is breached opposite the main river channel.

50. Sediment movement within the river mouth system is a complex mix of fluvial, hāpua and marine processes. Delivery of sediment from the river can be as bedload and suspended load. The suspended load is mainly carried out to sea and deposited on the seabed, usually at some distance from the shore. Some suspended sediment will settle to the bed of the hāpua lagoon in areas off the main channel flows such as at the ends of flooded arms of the lagoon.

51. Coarser sediment carried as bedload is a mixture of sand and gravel to cobble sized particles. This material is deposited on the lagoon bed, the channel margins and as a delta at the outlet. The sediment is reworked by subsequent fluvial action within the lagoon and river channel, and by waves and wave induced currents on the beach and the nearshore seabed. Depending on the wave energy and refraction of incoming waves, sediment is moved onshore and along the shore to reform the barrier beach and further influence the formation of the hāpua outlet through the barrier. This is shown in Figure 2 in the different morphodynamic stages.

52. Although not all stages are present or occur in all hāpua, additional behaviours may occur. This is due to the wide range of rivers with hāpua and because sea conditions also influence thresholds of lagoon closure. Large storm waves, for example, have the ability to close hāpua outlets at the same time as they overtop the barrier, increasing lagoon water levels so that a new outlet is breached as the hydraulic head between lagoon and sea increases on the falling tide. This mechanism is termed 'storm breaching' to differentiate it from breaches initiated by river floods. Storm breaching is believed to be an important but unpredictable control on the duration of closures at moderate to low river flow levels in hāpua-type lagoons.

Hazards associated with hāpua systems

53. The extreme range of marine versus fluvial dominance of hāpua is associated with a number of human-use concerns. Three primary concerns have been expressed by the Bluecliffs Beach community and are common to most hāpua. These are 1) flooding due to barrier growth and offsetting, 2) prolonged lagoon closure, and 3) erosion of the backshore.

54. Barrier growth and outlet offsetting can reduce the capacity of river mouth outlets, resulting in increased flooding adjacent to the lower river channels during high flows, and during medium to low flows when the outlet channel is closed, restricted or outflow is impeded by ocean waves and tides. Attempts to increase the efficiency of drainage through coarse barrier beaches and prevent mouth offsetting include construction of box-culverts to allow flow through the barrier, construction of rock revetments to channel flow towards the barrier, and manual channel dredging. However, these types of solutions to enhance drainage are problematic due to the high-energy oceanic processes and can be very short-lived, especially on shores subject to longshore drift and sediment movement on the beach.

55. Prolonged lagoon closure is another major concern in the resource use of marine-dominated hāpua environments. Outlet closures can occur at all but the flood-breaching stage of hāpua dynamics, but prolonged closures are common when river flows are low, and the outlet channel is considerably offset. Factors contributing to closure include low outlet flows, high rates of longshore sediment transport and increased sediment in the outlet causing aggradation of the channel bed. Hāpua closures result in ongoing restriction of fish passage to river systems and the loss of recreational fishing opportunity.

56. Closed outlets may re-open naturally when the balance between marine and fluvial forces becomes less marine-dominated and the lagoon builds sufficient hydraulic head to scour a channel through the barrier beach or to cause a piping failure from high rates of throughflow. The Opihi and Ashburton River hāpua outlets are occasionally artificially reopened by bulldozing a new outlet opposite the main river channel. Although total closure of the Waiau River hāpua outlet has occurred, it is not common.

57. Lagoon waterbody development and channel flow behind the barrier beach can result in accelerated erosion of the backshores of hāpua-type lagoons. On eroding shores such as the Canterbury Bight and Te Waewae Bay, the backshore cliffs of the hāpua are further landward than the cliff line behind adjacent beaches. Examples of this type of backshore cliff are shown in Figure 3. The backshore cliffs of the hāpua retreat at a rate that is near equal to the rate of erosion of the adjacent coast.

58. Erosion of the backshore of the Rangitata and Ashburton River hāpua is ongoing and has resulted in loss of land occupied by fishing huts. Erosion of the cliff backshore of the Waituna lagoon in the southeast section of the Waiau River mouth is a process from when the outlet of the river was positioned at the southeast end of the hāpua.

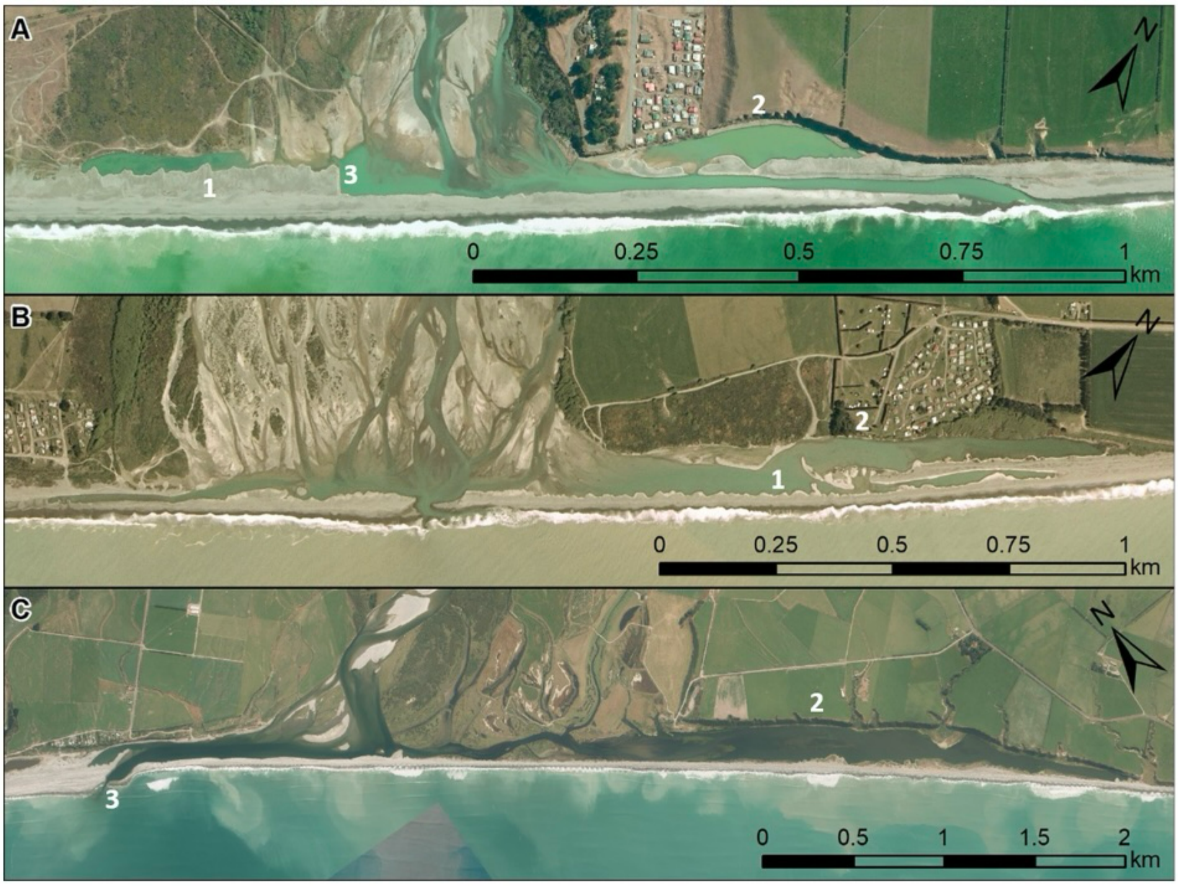

Figure 3 – Examples of New Zealand hāpua showing key morphological features. A) Ashburton hāpua; B) Rangitata hāpua; C) Waiau lagoon and hāpua. 1) Wave overwash gravel lobes; 2) lagoon backshore cliffs set back relative to open coast cliffs; 3) differences in lagoon width as a result of barrier re-setting caused by outlet migration (Source: Measures et al. 2020)

59. Studies in Canterbury have recognised that the processes of cliff retreat on the open coast and within hāpua are different and are not necessarily in phase with the former controlled by coastal storms removing sediment from the coast and the latter controlled by the capacity of river flows to remove sediment that sits at the base of the cliff. This capacity is related to the hāpua lagoon width and length, and the fluvial flow velocities. As the beach retreats, this causes the lagoon to narrow and concentrates flood flows through the hāpua.

60. The hāpua and adjacent coast cliff erosion processes are event-driven, for example flood flows and storm waves respectively, resulting in loss of support of the cliff, collapse of the cliff face and then a period of relative stability afforded by protection of the base of the cliff by the deposited sediment.

61. In general, the hinterlands of hāpua-type lagoons are more protected from wave-induced coastal erosion than those of the adjacent coast. However, they are subject to the additional erosion agent of river flow. Concern that the backshores of hāpua-type lagoons are subject to accelerated erosion is the primary reason that Environment Canterbury allows bulldozer openings of the Ashburton River hāpua outlet during periods of prolonged mouth closure. Erosion of the hinterland at Bluecliffs Beach in late 2023 resulted in emergency work to prevent refuse from a landfill being washed into the coastal environment. Retreat of the hinterland is a concern expressed by the Bluecliffs Beach Road community in their submissions to the MLC:IP.

Comments on the existing environment processes at the Waiau River mouth

62. The Waiau River mouth is a dynamic physical environment driven by both fluvial and oceanic processes but dominated by the local wave regime and movement of sediment on and offshore and along the coast. The river mouth system displays long-term variability relating to short-term changes in the river discharge from both flooding and low flow events, and from changes in the wave energy and wave approach due to storms and climatic variation.

63. In the long term, there have been changes to the catchment below the lakes resulting in periods of higher and lower sediment supply to the river. This may be due to natural and/or human agents including climate change, vertical land movement, land instability, loss of vegetation cover and changes in land use. For example, work by the NZ SeaRise: Te Tai Pari O Aotearoa programme shows vertical land movement of about -1.5 mm per year at the Waiau River mouth.

64. The geomorphologically “small” nature of the Waiau River, the long-term coastal erosion and high-energy wave environment are consistent with the process environments of Canterbury hāpua. The hāpua dynamics described for the Canterbury river and process theory developed from those studies are appropriate and consistent with observed behaviour for the Waiau River mouth hāpua including

periods of time before and after the operation of the MPS and modification to the river hydrograph.

65. The work of Delwyn Day presents a number of recorded historical observations about the state and position of the Waiau River mouth between 1850 and the 1940s. Work by Dr Mark Mabin for the MTAD consent process added to the record of historical mouth positions from early maps of the area. These written descriptions of historical snapshots of the river mouth, showing the position of the “outlet” of the river relative to the main river valley are presented in Appendix 3. It can be seen that the outlet of the river to the sea varied in position from southeast of the main valley at about the distal end of the present waituna to the true left of the Waiau River to over 3 km to the northwest of the main channel “under the sandstone cliffs” and west of Cameron Creek.

66. Flood breach episodes are noted, such as in March 1896 and May 1899, and movement of the outlet backwards and forwards along the shore to the west of the line of the main channel. The power of the sea to close the mouth of the river is also noted in February 1896.

67. Aerial photographs since 1946 also show snapshots of the variable nature of the position of the hāpua outlet channel, sedimentation with the hāpua and changes to the width and position of the barrier beach resulting from storm wave action, outlet migration along the shore, and periods of retreat and progradation due to erosion and deposition of sediment.

68. A selection of aerial photographs is included in Appendix 4. These show that the dynamic nature of the hāpua processes is a long-term aspect of the Waiau River. These types of changes are consistent with hāpua dynamics observed and measured in Canterbury and with the type of coastal change associated with hāpua as found at the Rangitata, Ashburton and Hurunui River mouths, and with the coastal geomorphology along the Te Waewae coast southeast of the Waiau River valley.

Conclusions regarding the Waiau River mouth hapua processes

69. The Waiau River hāpua lagoon system behaviour is consistent with hāpua dynamics at other South Island river mouths. The Waiau River has a small sediment load relative to the flow and is not able to fully supply the coast with sediment to nourish the beach and offset what is lost through erosion, alongshore sediment transport and abrasion in response to the high-energy wave environment.

70. The variability of the Waiau River mouth includes the morphodynamic stages as shown conceptually in Figure 2 of my evidence. These include:

    (a) Primary breaching opposite the main river channel during large floods;

    (b) Rebuilding of the barrier beach across the breach area;

    (c) Offsetting and movement of the outlet channel along the shore;

    (d) Overtopping of the barrier beach by waves;

    (e) Impedance of the river flow to the sea and increases in the lagoon water level;

    (f) Erosion of the landward shore of the lagoon.

71. Contemporary hāpua behaviour at the Waiau River mouth is also consistent with recorded “snapshot” observations from over the last 150 years. At a broader geomorphological timescale, erosion of the backshore of the hāpua lagoon is reflected locally by evidence of paleo erosion of the backshore cliffs to the east of the main river channel that is similar in form to the eroded backshores of the Ashburton and Rangitata Rivers.

72. I conclude that recent observations of changes to the Waiau River hāpua and river mouth through 2023 and 2024 are consistent with hāpua process theory and with historical variability that predate and postdate the construction of the MPS and the MLC, and that although likely influenced by the MPS, are not a result of the MPS operation.

PROJECTED EFFECTS OF THE MLC:IP ON THE COASTAL PROCESSES

73. The MLC:IP applications do not seek to amend the existing consented flow regime in the Waiau River. On this basis the flows will remain consistent with that considered and assessed in detail for the MTAD project and presented at a hearing in August 2009.

74. Based on the technical reports and hearing evidence of Dr Mark Mabin and Dr Murray Hicks it was projected that the flow regime associated with MTAD would likely have some influence on sediment transport in the Waiau River and on the Waiau River hāpua and Te Waewae Bay coastal processes, but that natural processes, flood events and oceanic storms are more significant. The effects of MTAD on the coastal processes were assessed at that time as likely to be minor.

75. Subsequent monitoring has been carried out by AECOM as part of the MTAD consent conditions and including periods under the protocol for controlled release of supplementary flows. This monitoring has confirmed the dynamic nature of the Te Waewae Bay shoreline resulting from the range of high-energy coastal processes, including sediment transport along the barrier and over the barrier into the lagoon and hāpua waterbody, and occasional floods down the Waiau River delivering "pulses" of sediment to the coast. The 2018 AECOM report concludes that changes measured between 2009 and 2017 showed no evidence of the consented flow regime having a detectable effect on shoreline behaviour at the coast.

76. Monitoring of cross-sections within reaches of the Waiau River also show that sediment continues to move down river. The AECOM report concluded from the monitoring results that the sediment carrying capacity of the river is sufficient to transport all sediment that is available to be transported.

RESPONSE TO MATTERS RAISED IN SUBMISSIONS

77. I have considered the submissions that have raised issues relating to effects of the MLC:IP on coastal processes at the Waiau River mouth. The main themes from those submissions, which I address in turn below in my evidence, are as follows:

    (a) No consideration of the effects of the Project on processes at the Waiau River mouth;

(b) Significant alteration of the flow regime of the Waiau River;

(c) Reduction in sediment carrying capacity of the Waiau River;

(d) Reduction in sediment load in the Waiau River;

(e) Worsened erosion at Bluecliffs.

78. The AEE for the MLC:IP does not consider effects at the Waiau River mouth. The Project and the resulting increase in potential to achieve supplementary flows does not alter the operational flow regime to outside of the parameters of the existing consented regime and will not have an effect on the geomorphological processes at the coast that is different in character from the effect of natural flows of this magnitude.

79. I understand that the direct effects of the Project activities, insofar as they may have any effect on the Waiau River downstream of the MLC, are limited to potential sediment generation during construction of the parallel channel and future maintenance activities.

80. The potential effective flushing flow under the existing consented regime has a peak discharge above 160 m^3/s and a 24-hour average discharge of at least 120 m^3/s. This flow is above the average summer flow but is for a relatively short duration. The release of the flushing flow would need to be for 24 hours to be effective in reducing periphyton. Any improvement in the reliability of supplementary flows from the Project is within the consented flow regime and therefore would have no effects at the coast that have not already been considered through the MTAD discharge consent process.

Significant alteration of the flow regime of the Waiau River

81. I do not consider that the MLC:IP will result in a significant alteration of the flow regime in the Waiau River. The Waiau River flow regime was considered in detail during the MTAD consenting. The MLC:IP will not change the flow requirements set in both the main operating and MTAD consents.

82. The Bluecliffs Beach Landowners Group submission refers to findings of the Kirk and Shulmeister technical report (1994) quoting from the 1996 AEE:

> *"Long-term adjustments in river mouth processes as a result of changes in the catchment, including hydro development, will continue. These adjustment processes may take "… in the order of 50 years" although most of the change has already occurred.*
>
> *No management action can reasonably be taken which will prevent the process of river mouth adjustment or reverse the cycle of changes initiated by hydro-electric power development in 1969."*

83. The Bluecliffs Beach Landowners Group submission goes on to note:

> *"This Assessment of Effects clearly implicates "the changes initiated by hydro-electric power development" as the causative factor in river mouth changes. This conclusion is supported by a recent report by Tonkin & Taylor (McDowell 2024) which also states that the erosion at Bluecliffs is caused by a combination of river and coastal actions, with the Manapōuri Hydro Scheme being acknowledged as a contributor."*

84. Although I agree that the MPS is an agent of process change at the Waiau River mouth, I do not agree that hydroelectric power development is "the" causative factor in river mouth changes. River mouth changes as experienced by the submitters are part of the natural character of the hāpua and river mouth. These changes occurred before and after the MPS development. Monitoring of effects on the river and coastal geomorphology does not show an identifiable effect of the MPS that can be separated from natural causes, the most significant being river floods and high-energy ocean wave conditions.

85. The submitter concern "that further adjustments to the flow regime caused by the proposal will cause river mouth processes to take another 50-years to reset" can be allayed by the impact of the MPS to date being in character with natural changes and hāpua process variability.

Reduction in sediment carrying capacity of the Waiau River

86. The MLC:IP project will not change the sediment carrying capacity of the Waiau River as the river capacity exceeds the amount of sediment available for transport. AECOM monitoring shows that sediment is actively transported in the river system, and that accumulation of sediment in specific reaches of the river is an aspect of the sediment moving mainly in pulses in response to flood flows. The MLC:IP does not lessen (or change in any way) the consented flow regime.

Reduction in sediment load in the Waiau River

87. The Bluecliffs Beach Landowners Group submission presents statements from Kirk and Shulmeister (1994) and from Dr Mark Mabin (from his MTAD hearing evidence) regarding the potential effects of loss of sediment from the Waiau River system. In particular, Dr Mabin notes that the MTAD regime:

> *"…could potentially affect the Te Waewae Bay coastal geomorphic environment by reducing the volume of sediment delivered to the coast. This reduced volume of sediment could in turn lead to a change in beach sediment budgets such that coastal erosion occurs. This could cause:*
>
> *a. Coastal barrier retreat or breaching;*
>
> *b. Reduced or lost coastal lagoon environments; and*
>
> *c. Cliff erosion."* [para 85]

88. In the 2018 AECOM monitoring report, of which Dr Mabin is a co-author, it is noted that:

> *"The pattern of increased sediment transport downstream of MLC is the reverse of what was expected under MTAD consents… The lack of an MTAD signal in the MLC or Tuatapere flow records means none of the geomorphic changes observed along the lower Waiau River can at this stage be related to the exercising of the MTAD consents"* (page ii bullet points).

89. In addition to the river monitoring, beach cross-sections at the Waiau River mouth showed periods of sediment accumulation and loss associated with flood supply of sediment and wave-driven processes moving sediment along, on and off the beach.

The report goes on to note that the data showed the natural variability expected within the lower Waiau River and Te Waewae Bay shoreline and that no potential MTAD signal was apparent.

90. The MLC:IP does not reduce the sediment input to the lower Waiau River. Sediment excavated for the new channel is to be placed on land to the north of the excavation. This sediment is not mobile river bedload and is not part of the sediment supply to the lower Waiau River.

91. There is no sediment supply to the Waiau River from Lake Manapōuri, and there is a limited supply of sediment to the river above the MLC from erosion of the river banks and from input from tributaries such as Home Creek. Sediment carried by the Mararoa River is transported to the lower Waiau River through the Mararoa diversion constructed in 1987 so that the river discharged directly through the MLC gates.

Worsened erosion at Bluecliffs

92. The general theme of the submitters with regard to coastal processes is that the MLC:IP will make erosion at Bluecliffs worse.

93. As I have addressed previously, erosion of the cliffs at Bluecliffs and changes to the hāpua and barrier beach is ongoing. Recent erosion of the cliff backshore of the hāpua has been significant and presents a hazard to resource use of the coastal environment. However, recent erosion at Bluecliffs is not out of character with the coastal landform type, nor out of character with the historical dynamics of the Waiau River mouth. As I have shown with regard to general hāpua process dynamics and with reference to the long-term dynamic nature of the Waiau River hāpua and the similar backshore cliff erosion to the true left of the Waiau River mouth, recent erosion at Bluecliffs is not unique or a direct consequence of the MPS. The erosional processes will not be exacerbated by the MLC:IP construction activities nor by improvements in reliability of achievement of supplementary flows.

RESPONSE TO SECTION 42A REPORT

94. I have reviewed the section 42A Officer's Report prepared by Bianca Sullivan, resource management consultant with Environment Matters Limited, on behalf of Environment Southland, and the supporting technical review provided by Mr Ramon Strong.

95. In reference to key conclusions reached between the applicant, submitters and the Council at the second pre-hearing meeting, the officer notes in paragraph 2.6.3 (b) that "coastal erosion was acknowledged as significant for the Bluecliffs community" and that some Bluecliffs submitters consider that the effect of more control over flow releases on coastal erosion should be considered. The officer agreed with Meridian that "the flow regime is managed through existing consents and is outside the scope of this application". My intent through my evidence is to show consideration of coastal erosion in relation to the MLC:IP.

96. In discussing actual and potential effects, in paragraph 3.2.7 the officer acknowledges submitters concerns about potential effects on coastal erosion at the mouth of the lower Waiau River.

97. I concur with the officer's position in paragraph 3.2.8 that as the MLC:IP does not revisit the flushing flows, the matter of coastal erosion is out of scope for this consent application.

CONCLUSIONS

98. The Waiau River can be considered a "small" river geomorphologically as the flows and sediment supply to the coast are not enough to maintain a stable river mouth and to offset coastal erosion from wave processes. As a result of the lake-fed catchment, and the hinterland the Waiau River and catchment tributaries flow through, the river also has a greater sediment carrying capacity than the amount of sediment in the river.

99. The river mouth system is a result of the relative energies of the river and the high-energy coastal system of Te Waewae Bay. The river mouth comprises a lagoon system fronting an eroding cliffed shore and enclosed by a long, narrow barrier beach. The waterbody to the true left of the river channel is relatively stable in form but fluctuates in size and volume depending on terrestrial fluvial inputs and episodic

wave overtopping barrier beach. To the true right of the river channel, the waterbody changes in form and volume in response to variations in the river flow volume and the oceanic wave environment and sediment transport along the barrier beach. These changes are typical of a hāpua process environment resulting from a complex balance of marine, fluvial and lagoonal process factors.

100. There has been observed long-term variability in the position of the Waiau River outlet channel through the barrier beach as recorded by Day (1993) and shown in the PDP review of the Tonkin and Taylor report (March 2024). The position of the outlet along the barrier is noted to include directly adjacent to the river channel to different positions to the west seaward of Bluecliffs Beach Road and further west. These types of changes to the hāpua and outlet channel position pre-date the MPS and other catchment changes and are consistent with observations of long-term variability for hāpua systems on the Canterbury coast.

101. Models derived from Canterbury rivers show the interaction and significance of river floods, periods of low flows, oceanic storms and combinations of fluvial and oceanic events resulting in variations to the hāpua process environment, the outlet position, the barrier beach geomorphology, and erosion of the land backing the hāpua waterbody over time. Monitoring carried out by AECOM confirms the dynamic nature of the Te Waewae Bay shoreline. The 2018 AECOM report concludes that changes measured between 2009 and 2017 showed no evidence of the flow regulation through MLC having a detectable effect on shoreline behaviour at the coast.

102. Recent erosion of the shore along Bluecliffs Beach Road (in 2023 and early 2024) fits into long-term snapshots of outlet position, hāpua behaviour and coastal change, and is consistent with historical behaviour and erosion of the landward shore of the hāpua of the Ashburton, Hurunui and Waitaki Rivers.

MLC:IP effects

103. The Project does not seek to amend the existing consented flow regime for the MPS. The effects of the MPS on the Waiau River have previously been assessed, and subsequently monitored, and shown to have no detectable effect on shoreline behaviour at the coast.

104. Further, in my opinion, an improved reliability in supplementary flows within that already consented flow regime (which the MLC:IP aims to enable), will not result in

any effects on the coastal and hāpua processes at the Waiau River mouth and Te Waewae Bay shoreline which are distinguishable from the changes to this system occurring as a result of natural processes. In essence, consented flows across the MLC are not driving, and will not worsen, the erosion which is occurring at the coast.

Martin Single

3 September 2024

APPENDIX 1 – REFERENCES

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Tonkin and Taylor 2024 *Bluecliffs Beach Road Papatotara, Preliminary hazard and geotechnical assessment - October 2023,* letter to Environment Southland dated 8 February 2024

URS 2011 *Lower Waiau River Cross Section Surveys 1992-2009* Report to Meridian Energy Ltd, 19-August-2019, 95pp plus figures

APPENDIX 2 – DESCRIPTION OF THE TE WAEWAE BAY COASTAL GEOMORPHOLOGY

From STATEMENT OF EVIDENCE OF MARK CHARLES GRACE MABIN ON BEHALF OF MERIDIAN ENERGY LIMITED GEOMORPHOLOGY
21 August 2009

RMM-476000-51-679

APPENDIX 6 – TE WAEWAE BAY COASTAL GEOMORPHOLOGY

1. I have compiled information on the changing geomorphic systems of the Te Waewae lagoon from the reports by Kirk and Schulmeister (1994), and Day (1992); along with old survey charts (detailed in Appendix 2), Southland District Council cadastral data, and aerial photographs from 1946 to 2008 (detailed in Appendix 6). I have also conducted my own field surveys in the area in 2004, 2008, and 2009.

2. I describe the coastal environment of Te Waewae Bay, in particular the lagoon, barrier system, and beaches around the Lower Waiau River mouth, and I document the environmental changes that have occurred here, particularly over the last 150 years.

3. Te Waewae Bay extends for 35 km from Hump Ridge in the west to Pahia Hill in the south-east (Figure 11). It faces south-west, and is open to very high energy waves from the south-west and west-south-west. Along most of its length it is backed by coastal terraces at elevations of 10 m to 110 m above sea level. Numerous streams and several small rivers discharge into the bay. However, the dominant river is Waiau that discharges to the coast near the centre of the bay.

4. I discuss only that section of the Te Waewae Bay shoreline that is directly affected by the Lower Waiau River. The Lower Waiau River gravel load is distinctively comprised of Fiordland and Takitimu Mountains rock materials, and this gravel is confined to the 20 km length of shoreline from Grove Burn 8 km northwest of the Waiau mouth, to the Waimeama River 12 km to the southeast. My assessment concentrates on this part of the shoreline, and in particular the 7.5 km long barrier and lagoon complex across the front of the Waiau valley shown in Figure 12.

5. The coastal geomorphic environment here is very narrow, occupying a strip typically no more than 100 m wide from the base of the marine cliff across slump deposits, dunes, and beach sediments to the low tide line. At high tide the waves can reduce

this strip to less than 50 m. However, across the lagoon and barrier beach system the coastal landforms are wider, up to 300 m from low tide, across the barrier beach and lagoon to the base of the low coastal cliff behind.

6. I documented above the very different fluvial geomorphic landscape system that existed in the Waiau valley during the glacial periods. The large environmental changes that occurred after the last glacial period have also left their mark on the Te Waewae Bay shoreline.

7. At the end of the last glaciation, climate warmed, ice sheets and glacier melted, and the global ocean rose more than 100 m to reach its present level about 6,000 years ago. Thus, coastal landforms along Te Waewae Bay are geologically very young, having formed within the last 6,000 years.

8. The shoreline has developed in response to a complex interplay between the high wave energy environment of Te Waewae Bay, delivery of sediment to the shoreline by the Lower Waiau River and other small rivers and streams, and the redistribution by wave action of this sediment within the nearshore and along the shoreline.

River sediment input

9. I identified above that Lower Waiau River has a small geomorphic footprint in the landscape, and this characteristic flows through to its influence on the coastal zone. Although it was a large discharge river, it did not carry a large bedload. Thus, there is no delta or beach ridge plain landform system at the Waiau mouth that might have formed if the river had been delivering large volumes of sediment to the coast. Although a big river by discharge volume, it is a small river in the context of its influence on Te Waewae Bay shoreline sediments and landforms.

Longshore sediment redistribution

10. The generally small volumes of sediment delivered to Te Waewae Bay by rivers and streams have been redistributed along the coast by longshore drift and other wave processes. There have been different interpretations of the dominant direction of sediment movement. Wood (1969) suggested eastwards movement while Kirk and Shulmeister (1994) argued for a westwards direction.

11. I mentioned above that Lower Waiau River gravels occur on the beach some 12 km southeast of the mouth, and I take this as evidence that the dominant long term

direction of longshore drift is to the southeast. However, Waiau gravels also occur as far northwest as Grove Burn, 8 km from the mouth. Thus, some northwest longshore drift must also occur.

12. For example, from about 1940 to the mid-1950s the direction of longshore drift appears to have been predominantly to the southeast as the alignment of re-curved beach ridges in front of the Papatotara Fishing huts was to the southeast. However, from the late 1960's the deflection of the Waiau mouth to the northwest suggests a reversal of this longshore drift to the northwest, and this persisted until about 2005.

13. Clearly the pattern of longshore drift and redistribution of river- derived sediment to the coastal zone is complex. I expect that longshore drift direction will vary with wave regime, although in the long term will be more generally to the southeast.

Beach environments

14. The variations in shoreline sediment character and exposure to wave energy contribute to some differences in beach environment along the shoreline.

15. Gravel beaches dominate the central part of the bay especially along the 7.5 km of barrier beach southeast of Cameron Creek and across the mouth of the Waiau Valley. This is a very high energy wave environment and the shoreline exhibits small scale features such as storm berms and cusps that are typical of such environments.

16. To the northwest and southeast of this central section of the bay the beach sediments grade through mixed gravel and sand, to sand, and finally very fine sand, in the far corners of the bay. These environments are not directly relevant to this study and have not been investigated in detail.

17. Kirk and Shulmeister (1994) reported that the beach/barrier materials comprised zones of sand and gravel, with gravel clasts of varying sizes, typically between 1 cm – 5 cm in diameter. These mixed gravel and sand barrier beaches occur along 7.5 km of the central Te Waewae Bay shoreline.

COASTAL LANDFORMS

18. The focus of my assessment will be on the landform associations around the Te Waewae lagoon, barrier beach and Waiau mouth system. This is a complex

environment where there is interplay of river flow and fluvial sediment transport processes interacting with wave energy, coastal sediment transfer systems and tidal fluctuations of the sea. This is a critical area for understanding the behaviour of the Waiau-Te Waewae Bay geomorphic system, as it is here that the outputs from the Lower Waiau River fluvial system become inputs to the Te Waewae Bay coastal system.

Coastal lagoon

19. Figure 12 shows the Te Waewae lagoon can extend for some 7.5 km across the end of the Lower Waiau River valley. It is up to 200 m across, a few metres deep, and is held in by an approximately 50 m wide barrier beach.

20. At times there has been a single large lagoon, but it has also occurred as a smaller lagoon with associated chains of smaller ponds at either end.

21. In New Zealand, this distinctive landform association is referred to as a coastal lagoon and two types are identified: waituna or coastal lake that is only rarely open to the sea; and hapua or river mouth lagoon where the mouth is often off-set from the main river channel but rarely closed. Kirk and Lauder (2000) classify the Te Waewae lagoon as a hapua type, although as I will discuss below, I consider a case can be made for south-eastern part being a waituna and the northwest part a hapua.

22. Figure 12 shows that in 2002 there were two lagoons here, connected by a shore-parallel channel across the end of the Waiau valley. The south-eastern lagoon was 3.1 km long and up to 200 m wide. Its shoreline has remained unchanged since at least 1946. As this does not have a permanent opening to the sea, I consider it could be classified as a waituna type lagoon.

23. In 2002 the north-western lagoon was 2.3 km long, and up to 120 m across. It is a quite recent feature, having begun to form in the late 1960s, and reached about its maximum size in the mid 1980s. Since late 2007 its characteristics have changed significantly as I will discuss below. As it has a permanent opening to the sea that is commonly deflected from the axis of the main Waiau valley, I consider this to be a hapua type lagoon.

24. In 2002 the two lagoons were connected by a 2.1 km channel. This ~ 40 m wide feature has been a very stable since at least the mid 1940s.

25. As I will discuss below, in the late 1800s and early 1900s there was only one main lagoon feature here. Growth of the bar and island landforms across the 2 km wide valley of the Tuatapere reach of the Lower Waiau River has constricted the lagoon, separating it into the two features seen today.

Coastal barrier

26. The coastal barrier that holds in the lagoon holds in the lagoons extends for 7.4 km southeast from Cameron Creek. It is 60 – 80 m across and its top is 6 m – 8 m above sea level. As noted above it consists of gravel with some sand material.

27. The barrier is in a very high-energy wave environment but historic reports (Day, 1992) and early cadastral maps show the southeast 4.5 km that extends across the mouth of the Waiau valley has been present here since at least 1852.

28. The northwest part of the barrier extending up to 2.7 km southeast from Cameron Creek is a more dynamic feature, having seen considerable change over the past 150 years as discussed below.

Lower Waiau River mouth

29. 29. The most dynamic part of this coastal environment is the Lower Waiau River mouth. This has shifted position, changed size, and occurred as multiple mouths in response to changing river flow and wave energy.

30. The mouth has occurred in many positions from the extreme southeast to the extreme northwest ends of the lagoon, and has been over 250 m wide, or closed completely for brief periods.

31. Usually, wave generated longshore drift processes result in the mouth being displaced to the northwest or southeast of the main axis of the Waiau valley. However, during very large floods, the river has been observed to cut through the barrier and form a mouth directly opposite the main channel, as occurred in floods in 1896 and 1984, although this has doubtless occurred more frequently than these two occasions.

32. Dual mouths have also occurred for long periods, and multiple mouths have also been observed when the barrier has been breached in two or three places during floods or storms. This presumably occurs at low points along the barrier when high

flood water levels in the lagoon are able to overtop it, and barrier erosion during storm wave conditions would exacerbate this process. However, these multiple mouths only stay open for a few days or weeks before wave action reforms the barrier (A. McCracken, 2004, pers comm).

COASTAL LANDFORM CHANGES

33. I have detailed information on coastal changes along Te Waewae Bay in Appendix 2. The basic arrangement of barrier, lagoon(s), and river mouth(s) has been in place since at least 1852 when the first European explorer Mantel walked through the area and recorded some observations. At that time there was a single lagoon, and the mouth of the Waiau was deflected 1 – 2 km to the northwest of the valley axis.

34. More detailed map information is available from the late 1870s. In 1877 the main lagoon was about 5.5 km long and there was an 800 m long lagoon northwest of Waiomotu Creek. The mouth had moved significantly to be about 3 km southeast of the valley axis.

35. In 1882 the southeast mouth was still in the same position, but there appears also to have been a northwest mouth. In 1891 the northwest mouth was 225 m wide an opposite the mouth of Waiomutu Creek, but the lagoon to the northwest had been filled in.

36. This arrangement continued through to 1893, and there was probably a southeast mouth as well opposite Fishing Camp Road. By 1895 it appears the northwest lagoon and barrier may have been eroded away. However, by 1900 it had reformed as the mouth was under the sandstone cliffs a little to the east of Cameron Creek.

37. Until the 1940s this northwest mouth moved back and forth between Fishing Camp Road and Cameron Creek. At various times during this period there were two mouths, with the semi-permanent southeast mouth finally disappearing for the last time shortly before 1930.

38. Temporary mouths have opened through the southeast barrier during floods, most recently for a few days in 1999, but this lagoon and barrier has since then been a very stable feature, consistent with my interpretation of it as a waituna type coastal lagoon.

39. In 1940 Tapper (in Day, 1993) reports that a series of significant coastal changes appeared to have begun in the northwest lagoon area as the barrier was eroded away to a “knife-edge”, the mouth started to migrate south-eastwards, and the lagoon “was being rapidly filled by sea action”. By early 1942 the mouth had moved over a mile eastwards.

40. Aerial photographs taken in 1946, 1957, 1963, and 1969 are shown in Figure 13. These show changes in the river mouth and shoreline to the northwest of the Waiau valley in the 23 years prior to flow regulation by the MPS. Due to different flight lines and scales, only the 1963 and 1969 images give coverage of the whole area, while the 1946 and 1957 images show all that is available for those years. There were many significant landform changes over these years.

41. The coastal landforms are best shown on the 1963 aerial photograph (Figure 13) which covers the whole shoreline to Cameron Creek. It shows a 320 m wide belt of beach ridges enclosing four small lagoons. The innermost ridge runs west along the base of the low cliff next to Bluecliffs Road. There are at least ten further ridges between here and the 1963 shoreline.

42. The 1946 and 1957 aerial photographs show the same arrangement of landforms, although the coverage is not as complete as the 1963 images. Of significance in the 1946 image is the lack of vegetation cover on the beach ridges, indicating they had probably been deposited within the preceding few years. This is consistent with Tapper’s observation above of the lagoon here being infilled by sea action after 1940.

43. In 1946, the suite of beach ridges was ~250 wide, while in 1957 it had grown to be about ~320 m across. About 37 ha of material had been deposited here, and assuming an average depth of 4 m this amounts to some 1.5 million cubic metres of sediment.

44. From the evidence of these landform changes I interpret that there had been a significant phase of coastal accretion here between about 1940 and 1955. The source of the material was most likely the Lower Waiau River, and as I noted above there is evidence of increased geomorphic activity along the Waiau valley associated with floods in the 1940s.

45. The 1946 photograph shows the braided character of the Lower Waiau River, consistent with it carrying significant bedload, and the lagoon across the end of the valley has been largely infilled so that only a narrow channel remained there, replacing the former 250 m wide lagoon. This arrangement has persisted to the present day.

46. By 1969, a new phase of landform development was evident as two new small lagoons and a barrier had formed between the river and Papatotara Road. Wave and river erosion had removed some 10 ha of the suite of beach ridges, and wave action had thrown up a new 1.25 km long barrier beach landform.

47. Since 1969, the southeast barrier beach and lagoon has changed very little, aside from slight changes in bulk where short sections of a few hundred metres appear to grow while others shrink. For example in 1975 opposite Fishing Camp Road it had thinned to <30 m across but in 2002 it was >40 m wide here. Occasional barrier breaches occur during floods or storms when water levels rise in the lagoon, but these are temporary and are closed within a few days.

48. In contrast to the stable coastal landforms southeast of the Waiau valley, the area to the northwest has showed significant coastal landform change since 1969, and this has been a continuation of changes that have previously occurred here.

49. I showed in Figure 13 that by the late 1960s a lagoon/barrier system had started to re-form in the northwest, and this process continued for the next fifteen years so that by the mid 1980s there was a single lagoon feature here, extending for over 2 km almost to Cameron Creek.

50. This northwest coastal lagoon then remained in place for the next twenty years with the Lower Waiau River mouth occupying various positions along the enclosing barrier beach. It occupied positions to the northwest through the 1970s and early 1980s, but in 1985 had returned to be opposite the main channel of the Lower Waiau River some 750 m southeast of the fishing huts. This latter position had presumably been opened during a large flood in 1984.

51. Until at least 1992 the mouth did not move significantly from its 1984/85 position. I have no further information until 2002 when it was located some 2.0 km north-west of the main Lower Waiau channel. This position is illustrated in Figure 14. It was still

in this position when I saw it in 2003, and by May 2004 had moved a further 500 m west.

52. Since about 2005 the mouth has moved back to the southeast and the lagoon here has started to change character again. This is illustrated in Figure 14 where by September 2007 the mouth had moved a kilometre southeast to be opposite the mouth of Waiomotu Creek. Much of the lagoon to the northwest of the mouth had been infilled, in a similar fashion to what had happened here in the 1940s.

53. The February 2008 photograph shows it had moved a further 720 m southeast to be opposite the end of the Papatotara Road, and when I saw it on 18th February 2008, it had moved a further 480 m southeast to be opposite the mouth of Kowhai Creek. I understand from Mr Holloway of Meridian, that it has oscillated around this position since that time.

54. At the same time as the infilling of the northwest lagoon area and migration of the mouth, there has been a thinning of the northwest barrier. This can be seen in Figure 14. By February 2008 the barrier had been driven a considerable distance northeast towards the inner shore of the lagoon.

55. The movement of the mouth to the southeast from 2005 onwards suggests that the dominant longshore drift direction has recently been to the southeast. This will have resulted from wave approach directions being more from the southwest.

56. The recent changes in the northwest barrier and lagoon are unusual in the context of the last 30 years. However, from the coastal changes I have identified from the 1850s to the 1960s it is clear that these changes are not unprecedented in this environment.

57. The final observations I will make on coastal landform change are in relation to the size and behaviour of the Waiau mouth. The reduced flow in the Lower Waiau River arising from the MPS has had an obvious effect on the size of the Waiau mouth. Prior to the 1970s it was typically 150 to 250 m wide, although in 1969 it was only 85 m wide. The width varied in response to river flow and wave effects. After the MPS the mouth has been generally narrower, typically 30 – 40 m across, although in 2007 and 2008 it has been 160 – 80 m across.

58. The reduced flow in the river lead to occasional closures of the mouth in the 1970s when wave action was able to wash sediment into the mouth area and the reduced

river flow was unable to take this back out to sea. The closures occurred during periods of prolonged low river flow, and MTAD will not have any effect on these discharges. Since 1996 there has been a resource consent condition requiring Meridian to release water at MLC if a mouth closure occurs. The Te Waewae lagoon has a water level recorder that sets off an alarm if the water rises to high levels thus giving advance warning of a potential closure.

59. Summarising my observations of the Te Waewae Bay coastal geomorphology, I have shown that in a coastal dynamics sense, the Lower Waiau River has always been small as it has never delivered sufficient sediment to Te Waewae Bay to allow build-up of a delta or beach ridge plain at the river mouth. This is due to the high energy wave environment of the bay, and the relatively small sediment load delivered by the river.

60. The Waiau-derived gravels that do occur at the coast have been spread along some 20 km of the shoreline. Longshore drift processes have redistributed this material from the mouth of the river both to the north-west and south-east, with the predominant direction being to the south-east.

61. Episodically some larger volumes of river sediment are delivered to the coast as happened in the middle decades of the 20th Century. Over subsequent decades this material is re-worked by wave action, and most of this has recently been in the area to the northwest of the Waiau valley.

62. The dominant landform features of the bay are the barrier and lagoon environments at the mouth of the Lower Waiau River. The southeast barrier and lagoon has been a very stable feature since it was first mapped in the early 1850s. The only significant departure from this stability was during a forty to fifty year period between the early 1880s and late 1920s when a main Lower Waiau River mouth was open here.

63. The northwest barrier and lagoon area is a more dynamic environment, with lagoons, coastal barriers, and beach ridge plains forming, being eroded and reforming over the last 150 years. I have documented a barrier and lagoon here from the 1850s to the early 1890s. It then appears to have been eroded away, only to reform by about 1900. In 1940 the barrier here was again eroded away and sediment infilled the lagoon forming a beach ridge plain enclosing a number of small lagoons and ponds. From the mid-1960s the beach rides were progressively eroded

away by wave action and river flow, and a barrier beach/lagoon complex had been fully formed here by about 1980. This remained intact until about 2005 when the lagoon started to in-fill from the northwest. The pace of change accelerated in late 2007 and early 2008 when a barrier breach occurred and a part of the beach has been driven onto what was the inner shore of the former lagoon.

64. The Waiau mouth, coastal lagoon and barrier beach are very dynamic landform environments where high wave energy coastal processes interact with fluvial processes. The main driving force is wave energy that redistributes sediment across and along the shoreline. Significant episodes of sediment input have been episodic, with only one major pulse of sediment having been delivered to the coast in the last hundred years. It is likely that in the absence of further major sediment inputs the overall trend of coast landform change here in future will be one of erosion. It is likely that this will initially affect the northwest barrier and lagoon area such that the barrier here will be driven onto the shoreline at the back of the lagoon.

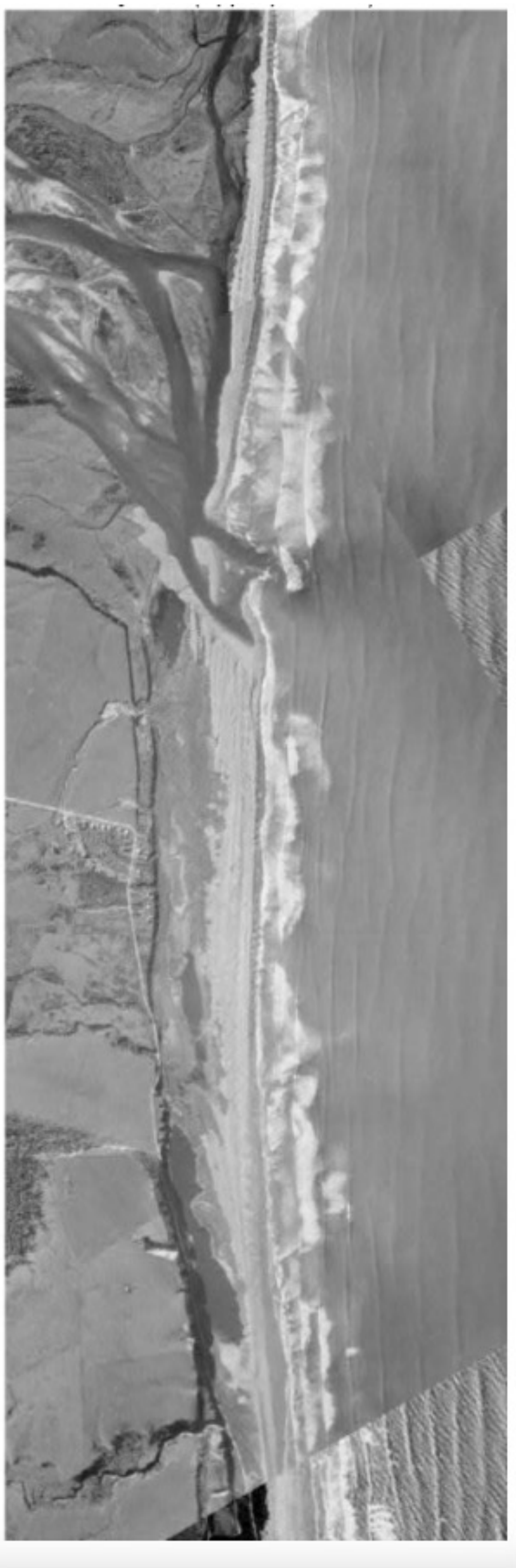
APPENDIX 3 – OBSERVATIONS OF RIVER MOUTH POSITIONAL CHANGE AS NOTED FROM ANECDOTAL RECORDS AND EARLY MAPS OF THE AREA.

Source: Mainly from D. Day, 1993 *Historical review of the Waiau River and coastal area* Written for the Waiau River Working Party.

- Pre 1850 Orchiston* SE 3.5 km Maori sources report mouth had been at SE end of lagoon for hundreds of years
- 1852 Walter Mantell NW 2.6 km Sketch map. Mouth opposite Waimotu Creek
- 1862 ODT 5/5/1863 James McKerrow NW 2 km? Waiau River enters the ocean after running 0.8 km along the inside of a 'narrow spit' and about 0.5 km from the mouth of a small stream. Between Kowhai and Waimotu Creeks is consistent with this description
- 1890s Tapper* NW 3.3 km Under the sandstone cliffs near Cameron Creek
- 1893 June SO 2840 NW 3.0 km? Shows "Waiau River" extending beyond Waimotu Creek so the mouth may have been further to the northwest.
- 1896 Feb, J. Orchiston finds 'the old mouth completely closed with granite boulders piled six or eight feet above water level'. He concluded 'it is therefore remarkable that a river of this dimension should have its mouth closed up by the action of the breakers within a few days after the opening of a new outlet'
- 1896 March WS 12/2/1986 0.0 km "The Waiau River has broken through the spit at the mouth and water flows in a direct line to the sea." Mr Tapper reports this occurred in a flood.
- 1897 Jan SO 3065 0.0 km Shows "Waiau River" to northwest of Holly Burn mouth and "Waiau Lagoon"
- 1899 May 0.0 km "… the river … runs straight into the sea with the speed of a mill race"
- 1899 Dec Opposite Waimotu Creek
- 1900 – 1912 (A. McCracken) The river had shifted 2 miles westward by 1900 creating a tidal island just up the river. Moves eastward circa 1910 but by 1912 has moved close to previous outlet. Locals had to move fishing cribs closer to the new mouth.
- 1934 Jan Tapper NW 3.3 km Under the sandstone cliffs, the track only accessible at low tide
- 1935 Jan Tapper NW 3.7 km The mouth "had travelled nearly a mile to the westward … since our visit the previous year". Thus, it was presumably near Cameron Creek.
- 1941 Feb Tapper* NW 3.1 km? Mouth west of Waimotu Creek in the 1940 –1941 fishing season. It then moved to southeast ~1.6 km by the next fishing season (1941 – 1942).

APPENDIX 4 – A SELECTION OF AERIAL PHOTOGRAPHS OF THE WAIAU RIVER MOUTH AND HĀPUA

March 1946



February 1955

March 1963

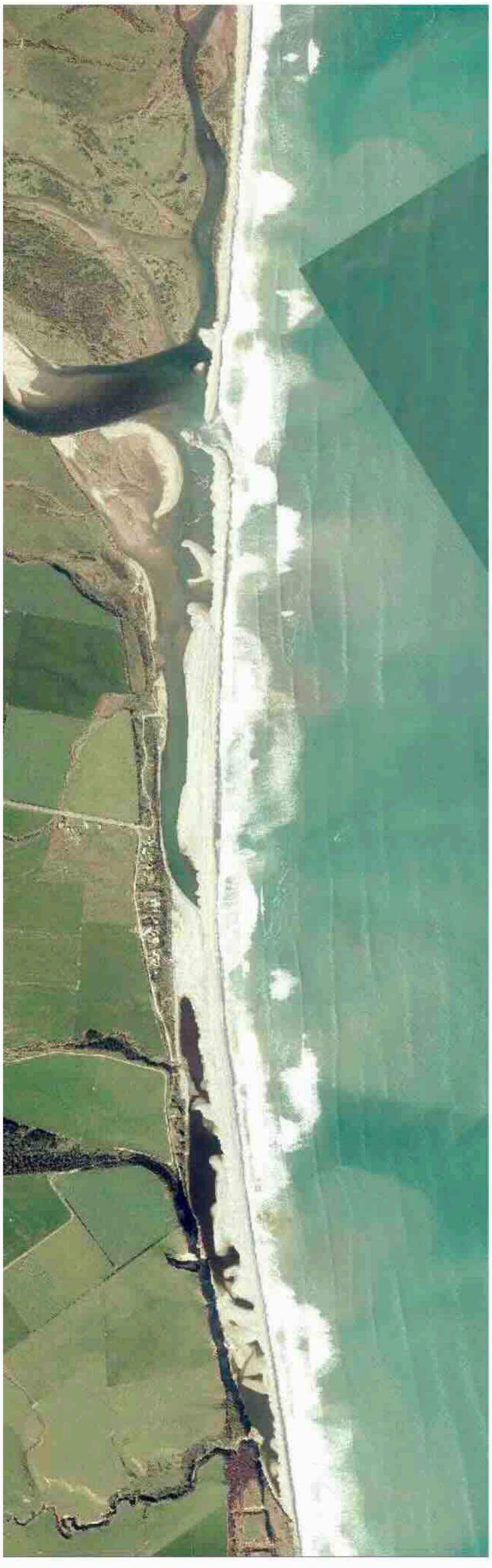
February 1969

February 2002

September 2007

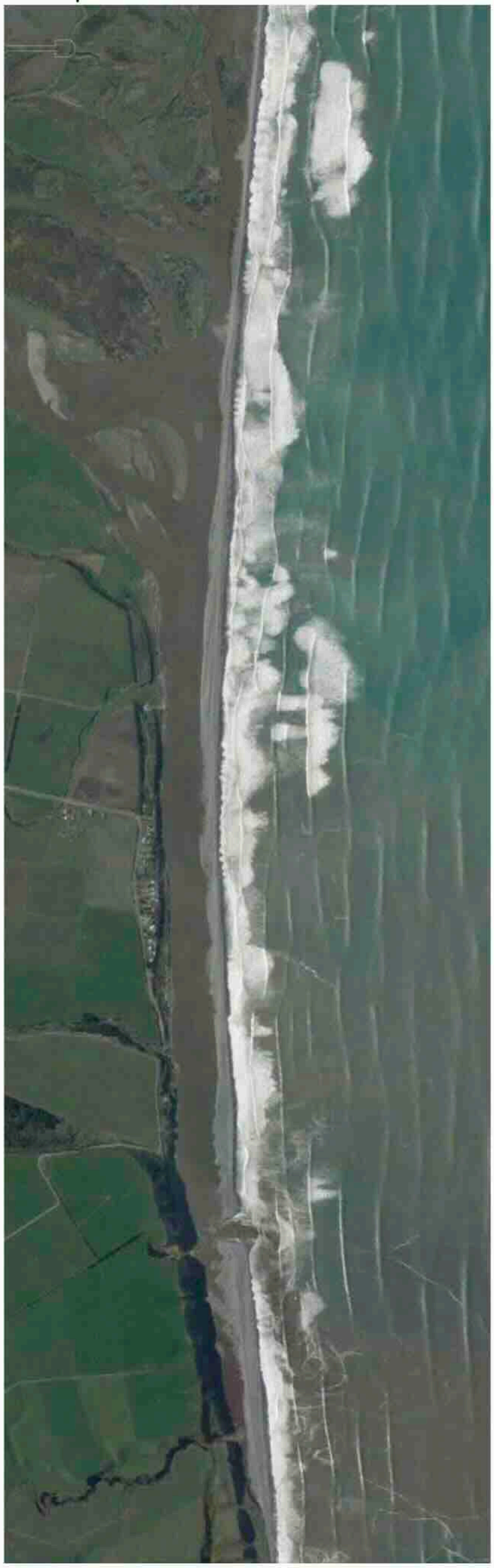
February 2008

February 2009



March 2011

January 2015



13 September 2019

March 2020