Lake Pūkaki Reservoir Hydro Storage and Dam Resilience Works

Lake Processes and Geomorphology

Meridian Energy Limited

26 October 2025

→ The Power of Commitment

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1. Introduction

Meridian Energy Limited (Meridian) have engaged GHD Limited (GHD), to assist with obtaining consents to authorise the operation of Lake Pūkaki below the current normal minimum level of 518.0 m above mean sea level (m RL) for a three-year period, and for civil works at Pūkaki Dam to improve the structures resilience to wave action during lower lake operational levels.

1.1 Project background

1.1.1 Waitaki Power Scheme

The Waitaki Power Scheme (WPS) is a nationally and regionally significant component of New Zealand's electricity supply infrastructure. It is New Zealand's largest and most flexible hydroelectricity power scheme and therefore has a critical role to play in the electricity system and economy. It consists of eight power stations (two owned by Genesis Energy and six owned by Meridian Energy), commissioned between 1935 and 1985, together having an installed capacity of 1,761 MW, being ~32% of New Zealand's installed hydro capacity.

Lake Pūkaki is a modified natural lake and is managed as part of the WPS. It is New Zealand's largest hydro storage lake and provides an average of 1,767 GWh of stored water in normal operating conditions, with an additional 545 GWh available during a national electricity shortage.

Meridian is currently authorised to dam the Pūkaki River to control and operate Lake Pūkaki between the levels of 518.0 m RL (normal consented minimum lake level) and 532.5 m RL (maximum consented storage level).

1.1.2 Previous Plan Changes - Waitaki Catchment Allocation Regional Plan (WAP)

The WAP is a sub regional plan and provides objectives, policies and rules for the use and development of water resources within the Waitaki Catchment. Prior to 2012, it was a prohibited activity in the WAP for Meridian to draw the lake level below 518.0 m RL.

1.1.2.1 Plan Change 1 (PC1)

In 2012, Meridian initiated Plan Change 1 (PC 1) to the WAP which sought to introduce a new minimum lake level for Lake Pūkaki during circumstances when the System Operator (SO) had commenced an Official Conservation Campaign (OCC) in regard to electricity supply. PC1 allowed additional water from Lake Pūkaki to be used for generating electricity as a permitted activity when an OCC is declared by the SO.

When assessing the potential operation of Lake Pūkaki below 518.0 m for PC1, the duration of an entire event (time below 518.0 m RL) was considered likely to be between 4-7 months (this includes the time spent operating below 518.0 m RL while the OCC was in place, as well as the time required to restore the lake level to above 518.0 m RL once an electricity supply emergency ended). Supporting technical effects assessments were submitted as part of this plan change process. It was ultimately concluded that allowing access for electricity generation purposes to water stored between 513.0 and 518.0 m RL, as a permitted activity once an OCC had been declared, was appropriate and promoted the sustainable management purpose of the RMA. PC1 was adopted by Environment Canterbury on 27 September 2012.

The technical studies completed for this project have relied on the PC1 2012 effects assessments as being appropriate and have focused on both the changes that have occurred in the environment since 2012, and the differences between the activities permitted by PC 1 and the proposed activities. This is the 'Baseline' that is referred to throughout this report.

1.1.2.2 Plan Change 3 (PC3)

PC3 included a new rule regarding the use of Lake Pūkaki between 518.0 m RL and 515.0 m RL. In addition to the PC1 Permitted Activity rule, at times of a Security of Supply Alert (SSA) initiated by the SO, the lake may be operated between the alert minimum control level of 515.0 m RL and 518.0 m RL. The rule is not a permitted activity and to implement this, Meridian applied for and was a granted resource consent in 2018 (CRC185833). This consent expired on 30 April 2025 but has been granted a section 124 continuance while the new replacement consent (CRC240441) is being processed.

1.1.3 Meridan's Application

Meridian is seeking approvals under the Fast Track Approvals Act (FTAA) to enable access to water stored in Lake Pūkaki below 518.0 m RL, without the currently applicable security of supply triggers, thereby enabling the better planning and utilisation of the available stored generating capacity. Further information on the background to the proposal and the benefits of allowing access to additional water is provided in the Substantive Application[1] document that supports the FTAA application.

Meridian is proposing to access the additional storage for a time-bound period of three years, until the end of 2028. For the purpose of this report 'Eased Access', refers to the ability to use water from Lake Pūkaki between 513.0 m RL and 518.0 m RL without a SSA or OCC being initiated by the SO. The ability to access stored water below 518.0 m RL will be incorporated into Meridian's electricity generation models and water stored in Lake Pukaki (both above and below 518.0 m RL) will continue to be managed to supply the market. The three-year period is to allow for additional generation capacity that is currently being built, to come online. For further clarification, the existing lake operation framework and proposed activity is detailed below in Table 1.

Existing Framework	Proposed Activity
Operation of Lake above 518.0 m RL (CRC905321.7).	Operation of Lake above 518.0 m RL (CRC905321.7). UNCHANGED.
Operation of Lake between 518.0 m RL and 515.0 m RL as a discretionary activity at times of a Security of Supply Alert initiated by the System Operator (CRC185833).	Operation of Lake between 518.0 m RL and 513 .0m RL for a period of 3 years without a Security of Supply Alert or Official Conservation Campaign being initiated by the System Operator.
Operation of Lake between 518.0 m RL and 513.0 m RL as permitted activity during an Official Conservation Campaign initiated by the System Operator (Permitted Activity).	

Table 1 Proposed Activity – Eased Access

In addition to the temporary ability to lower the lake level, Meridian seeks consent for the installation of rip-rap on the face of the Pūkaki dam and its left and right abutments to provide protection from wave erosion, when operating the lake below 518.0 m RL. Rip-rap will be placed to a maximum depth of 510.5 m RL, with earthworks/site preparation activities extending to a maximum depth of 509.6 m RL. Rock armouring will take a total of 12-18 weeks to complete but is expected to be done over multiple stages over several years and works may be required to be completed beyond 2028.

Meridian has stockpiled rock for this purpose on its land adjacent to the Pūkaki dam since 2014, but the rock armouring has not been undertaken due to the existing supply triggers never being initiated by the SO, with the result that the lake level has not been low enough over that period to allow the works to be completed.

[1] FOOTNOTE OF SA HERE

1.2 Purpose of this report

This report summarises a focused review of available information regarding lake processes and geomorphology of Lake Pūkaki relevant to the proposed drawdown of lake levels below 518.0 m RL and proposed rock armouring works.

1.3 Scope and objective

GHD's desktop assessment of Lake Pūkaki processes and geomorphology involves a review of available information relevant to the FTC application. This review includes:

– Available project information, including relevant studies, design reports, as-built data, aerial imagery, survey data (hydrographic and topographic), dam inspection reports and monitoring records associated with inflows/outflows, water quality, sediment quality, wave, wind and currents. Specifically:
– Available publicly available information, including:
    - Historic aerial imagery from Google Earth
    - Retrolens - Historical Imagery Resource

1.4 Report author and contributions

The qualifications and experience of the report authors are set out in Appendix B. The author confirms that they have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note (2023) and agree to comply with it. In that regard the lead author confirms that this lake processes and geomorphology report is written within their expertise, except where stated that the author is relying on the assessment of another person. The author confirms that they have not omitted to consider material facts known to them that might alter or detract from the opinions expressed.

1.5 Limitations

This report has been prepared by GHD Limited on the instructions of Meridian Energy, in accordance with the agreed scope of work. It is intended to support Meridian's application under the Fast-track Approvals Act 2024 and may be relied upon by the Expert Panel and relevant administering agencies for the purposes of assessing the application. GHD otherwise disclaims responsibility to any other person in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible

While GHD Limited has exercised due care in preparing this report, it does not accept liability for any use of the report beyond its intended purpose. Where information has been supplied by the Client or obtained from external sources, it has been assumed to be accurate unless otherwise stated.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

The opinions, conclusions and any recommendations in this memorandum are also based on site observations by others in the project team and external consultants. Site conditions at other parts of the site may be different from the site conditions found at the specific observation points. Investigations undertaken in respect of this memorandum are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this memorandum.

GHD's assessment of Lake Pūkaki processes and geomorphology is not intended to be an exhaustive academic assessment. This memorandum presents a focused review of information pertinent to the FTC application for a proposed temporary reduction in lake levels to below 518 m RL. The assessment does not include numerical or physical modelling of lake processes. GHD assumes that, given the proposed three-year timeframe, assessment of climate change impacts would not be appropriate

1.6 PC1 Application

Previous relevant factors for drawdown of lake water to 513.0 m RL have been used as a guideline for this impact assessment, as follows:

– The 2012 PC1 application assessed the environment which included events where the lake level were to be reduced to 513.0 m RL, with the Rule limiting this to times when there is an infrequent OCC event. The PC1 application noted:
  - Electricity demand is typically high during late autumn / winter and inflows are low. An OCC event would be triggered if catchment inflows have been low during the preceding seasons resulting in low lake levels. Typically, late spring / summer refill is likely to reinstate lake levels to 518 m RL and above due to prevailing westerly winds and rainfall along with snowmelt.
  - Drawdown rates of 1.5 m to 3 m per month in low inflow conditions are typical. Lake refilling is generally more rapid and based on Meridian records can be as high as 1 m per day.
  - Low lake levels were anticipated for between 4 and 7 months.
  - Drawdown of lake levels was calculated to expose up to an additional 9.5 km^2 of lake bed, which had been submerged since initial lake filling during the late 1970s.

1.7 Summary of lake level modelling

The modelling undertaken by Meridian was based on the 91 years of hydrological and meteorological data for the lake (Meridian 2025), using the current understanding of the New Zealand energy system (supply and demand analysis), and applying this to the forecast period between Jan 2026 and Jan 2029 (the period of interest for the FTC application).

1.7.1 Restrictions in place (Status quo)

– Total time in days between January 2026 – January 2029 in which the lake is below 518.0 m RL is essentially zero.
– There is one hydrological sequence which dips below 518.0 m RL for a short period. (i.e. when storage below 518.0 m RL is used, it is only just used and not for long). This reflects the current risk-averse approach of Meridian's operators to ensure that the 518 m RL level is not breached as part of normal operations.

1.7.2 Proposed Eased access (no restrictions in place)

Modelled first year of eased operation (2026)

– Under eased conditions of operation, typically lake levels are held lower, but still in the normal operating range above 518.0 m RL most of the time, only falling below 518.0 m RL on occasion.
– There is approximately a 3% probability that lake levels in any given week will be below 518.0 m RL. Therefore, on average the lake level will be below 518.0 m RL for approximately1.5 weeks in the first year of operation.
– 23% of the modelled hydrological sequences dip below 518.0 m RL in the first year. However, most instances are short duration and not deep. Of the 91 hydrological sequences modelled, 21 sequences fall below 518.0 m and of these 21 sequences:
  - 9 fall between 518.0 – 517.0 m
  - 6 fall between 517.0 m – 516.5 m
  - 3 fall between 516.5 m – 516.0 m
  - 2 fall between 516.0 m – 515.0 m
  - 1 falls below 515.0 m
– In terms of duration, in the worst-case scenario, the lake level falls below 518.0 m RL in early September and does not return above 518.0 m RL until December (a duration of no more than 4 months). However, the likelihood of this scenario is extremely low – approximately 1% (1 of the 91 hydrological sequences modelled).

Modelled subsequent years of eased operation (2027 and 2028)

– The pattern is broadly the same in subsequent years although the probability of falling below 518.0 m RL in any given week increases very slightly to 3.5% in 2027 and 4% in 2028.

The modelled statistical distribution of water levels for the period of Jan 2026 – Jan 2029 based on the 91 years of data is presented for both restricted (status quo) and eased (proposed) conditions in the plots shown in Figure 1 and Figure 2. The minimum water levels shown (blue dotted line) represent the worse-case modelled conditions for both scenarios, whilst the 95%ile stored energy (relating to water levels) shows only few instances when discretionary storage (below 518.0 m RL) is used. Meridian have indicated that the full engineering storage range would be used when needed.

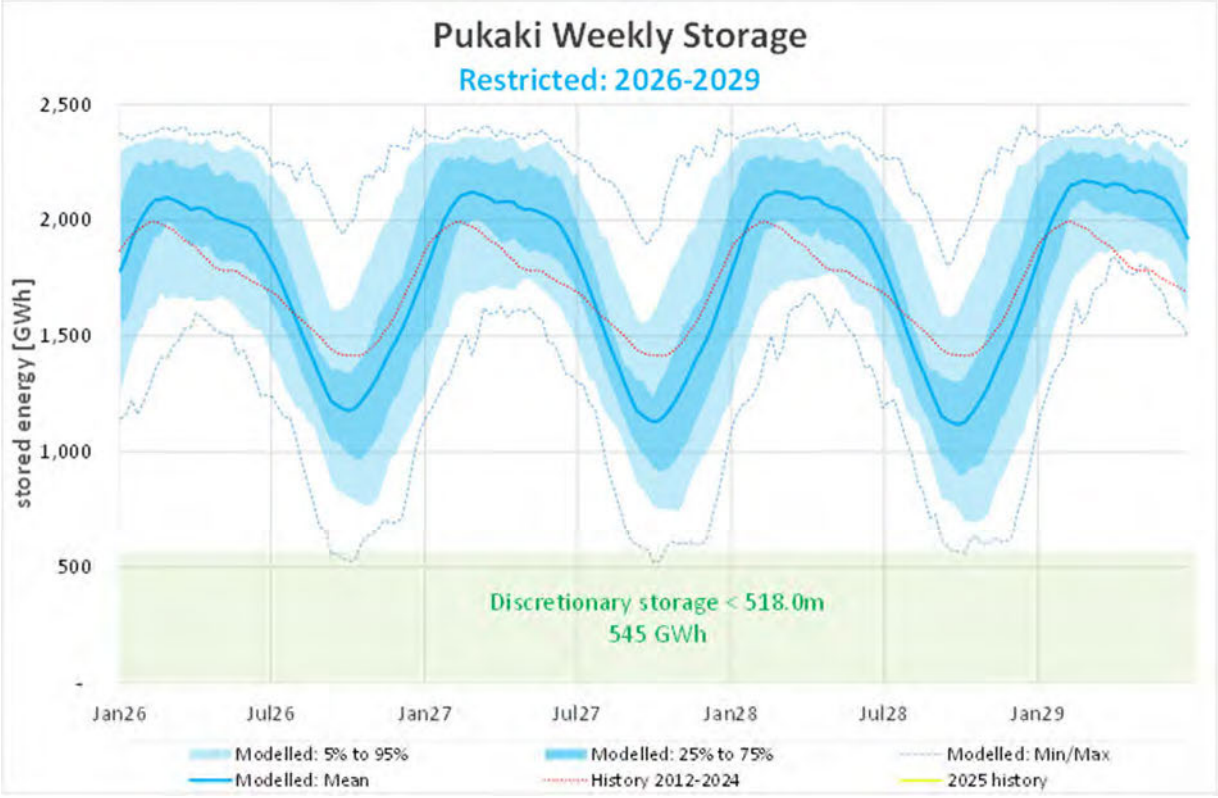


Figure 1 *Modelled status quo weekly storage 2026 – 2029, assuming current lake level restrictions, showing the distribution of outcomes from the minimum through to the maximum observed across the year, and compared to recent historical seasonal average, (supplied: Meridian)*

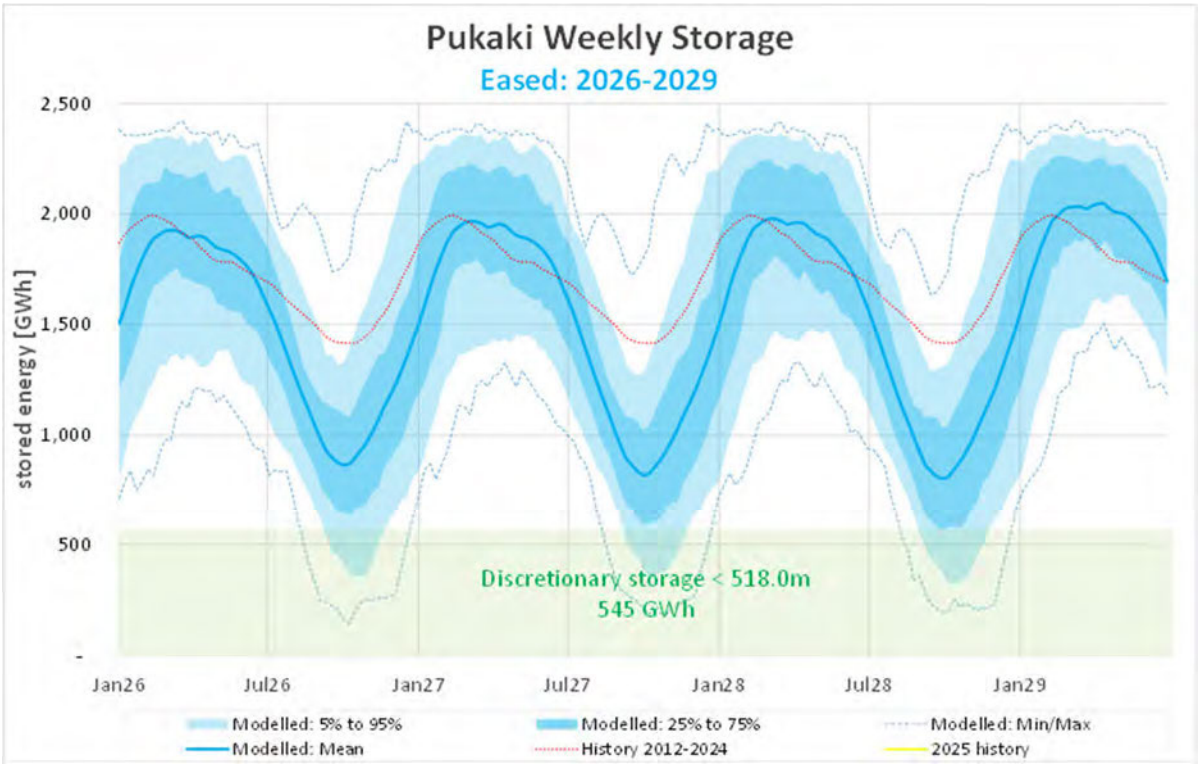


Figure 2 *Modelled weekly storage 2026 – 2029, with restrictions eased , showing the distribution of outcomes from the minimum through to the maximum observed across the year, and compared to recent historical seasonal average (supplied: Meridian)*

2. Lake Pūkaki background

Lake Pūkaki is a 30+ km long, 8+ km wide glacial lake formed from natural and artificial damming of the Tasman River. Lake Pūkaki is connected to the artificial Lake Tekapō, Lake Ōhau and Lake Benmore via canals and natural rivers. Lake Ōhau and Lake Benmore are at a lower elevation than Lake Pūkaki and are not anticipated to significantly affect the geomorphology of the study area. Lake Tekapō discharges water to Lake Pūkaki through the canal. GHD's review focuses on the geomorphological process / form relationships within Lake Pūkaki only. This review relies, in part, on information from Single (2022[2]), who conducted a geomorphological and wave climate assessment assessing the impacts of the WPS. Single used coastal nomenclature to describe the lacustrine landforms. To avoid confusion, GHD has used lacustrine nomenclature, as shown in Figure 4 (over).

2.1 Lake formation

The natural Lake Pūkaki was formed behind glacial deposits as glaciers retreated at the end of the last ice age, approx. 18,000 to 14,000 years BP (before present). Natural lakes formed behind the terminal moraines at the southern end of the valley. Lake Pūkaki was first dammed in 1947, raising the natural lake levels by about 18 m. A larger dam was constructed for hydro-electric power (WPS) generation in 1975, filling by 1979 (Single, 2022) and raising lake levels by another 35 m. As previously noted, the current normal operating range is between 518 m RL and 532.5 m RL (14.5 m).

2.2 Lake levels

Lake levels determine the wave impact zone along the lake shore. As noted in Section 2.1, Lake Pūkaki levels have been raised twice due to dam construction (see Figure 3). Prior to artificial control, lake levels were about 484.0 m RL (Sutherland *et al.*, 2019[3]). Lake level fluctuation has been dependent on different operational regimes. Since 1999, levels have been higher, on average, than during the 1979 – 1999 period, with lake levels typically over 527.0 m RL. Typically, the full extent of the operating range is not experienced every year, with minimum and maximum levels associated with extreme climatic conditions.

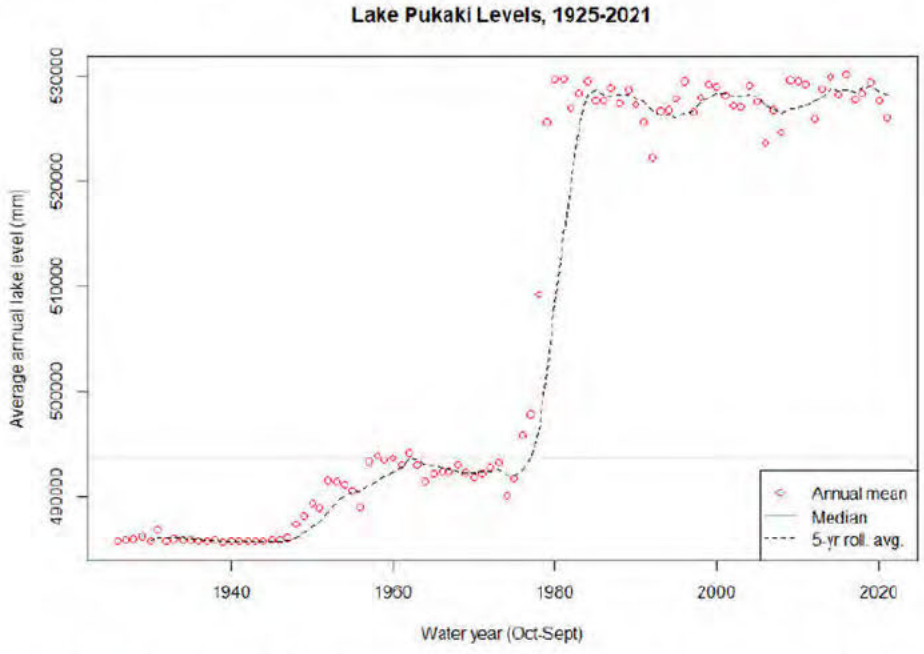
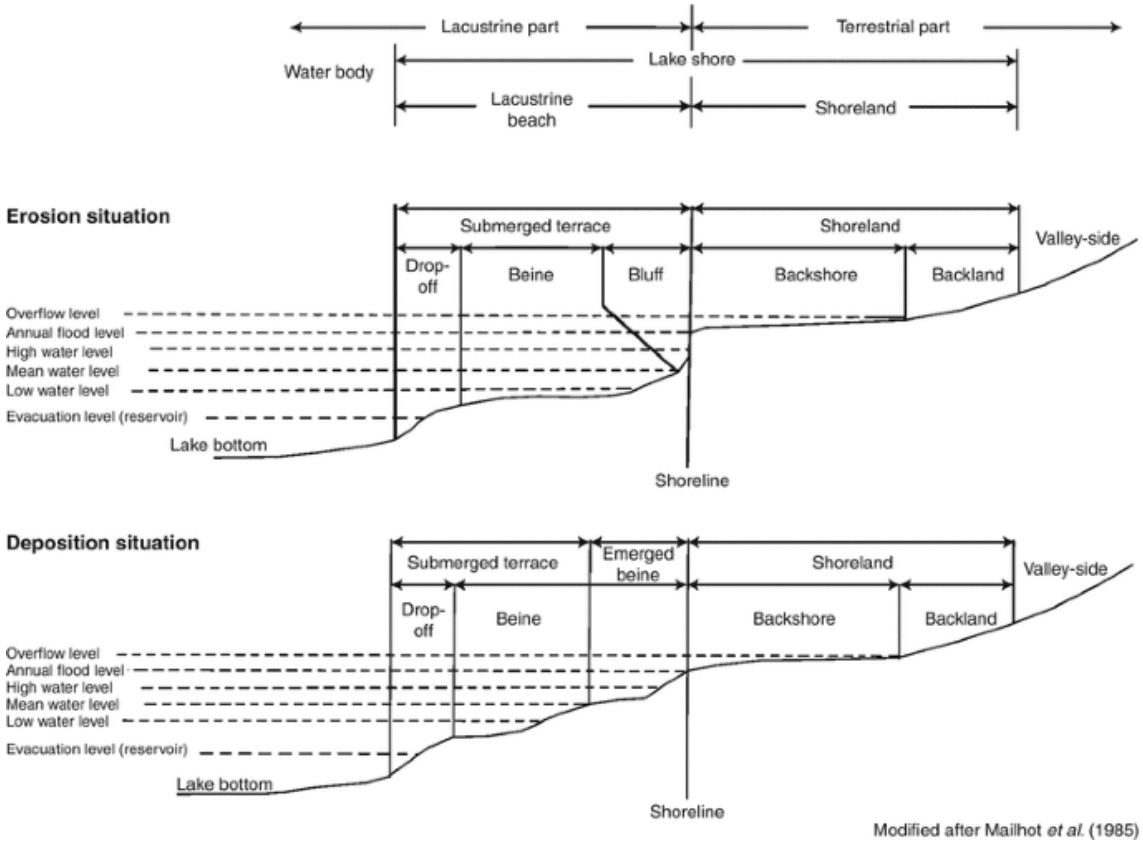


Figure 3 ***Mean annual lake levels in Lake Pūkaki, 1925 – 2021. The notable change reflects the change in operations when the operational level was raised by 37 m (source: Figure 2.4, NIWA, 2024)***

[2] Single, M. 2022. Assessment of Environmental Effects of the Waitaki Power Scheme – lakeshore geomorphology and processes, report prepared for Meridian Energy Limited, Shore Processes and Management Ltd., November 2022.
[3] Sutherland, J.L.; Carrivick, J.L.; Shulmeister, J.; Quincey, D.J.; James, W.H.M. 2019. Ice-contact proglacial lakes associated with the Last Glacial Maximum across the Southern Alps, New Zealand, *Quaternary Science Reviews* 213

A: Lacustrine geomorphological nomenclature



B. Coastal geomorphological nomenclature

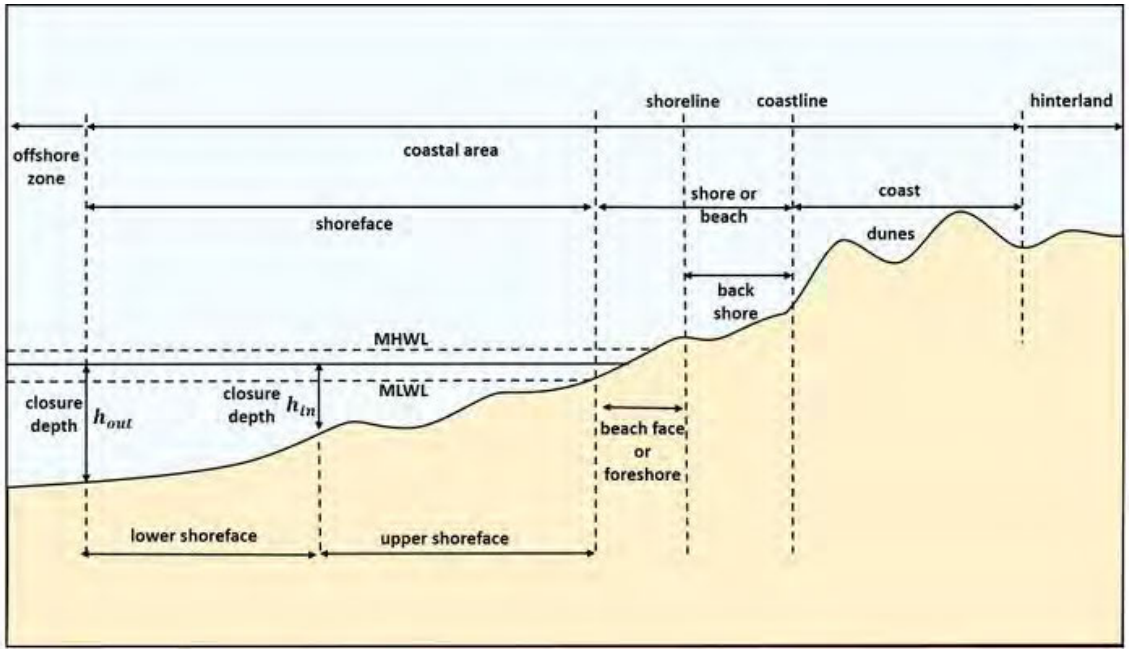


Figure 4 *A. Lacustrine geomorphological nomenclature source: Lacustrine: Provencher and Dubois, 2012 [4]; B. Coastal geomorphological nomenclature: CoastalWiki, 20255)*

[4] Provencher, L., Dubois, JM.M. (2012). Lake Shore Nomenclature. In: Bengtsson, L., Herschy, R.W., Fairbridge, R.W. (eds) Encyclopedia of Lakes and Reservoirs. Encyclopedia of Earth Sciences Series. Springer, Dordrecht. **https://doi.org/10.1007/978-1-4020-4410-6_118**; **Lake Shore Nomenclature | SpringerLink** Accessed February 2025.

[5] CoastalWiki, 2024. **Definitions of coastal terms - Coastal Wiki** Accessed February 2025

Webby (2019[6]) notes that, historically, lake levels between 1979 and 2018 exceeded normal operating levels of 532.0 m RL for 10% of the time during October to April, and 15% of the time between November to March. Dam design allowed for appreciably higher lake levels than the maximum operating level. This indicates that high lake levels have, in the past, required greater consideration than low lake levels.

Low lake levels were experienced in 1992 (519.0 m RL), 2008 and 2024. However, the 2024 event saw lake level rebound to very high levels, prompting emergency releases into the Pūkaki River later in the year.

2.3 Climate regime

Single (2022) noted that lake shore sediment dynamics are strongly affected by the wave climate and sediment characteristics. Sediment is episodically moved during intense and prolonged wind storms which create high energy waves. Single (2022) indicates that:

– Wave energy is affected by:
  - Wind fetch (length of water).
  - Wind strength, noting that extreme windspeeds of up to 150 km/hr (over 40 m/s) can occur.
  - Wind event duration.
  - Prevailing westerly frontal systems are channelled by the deep north / south oriented glacial valleys of the Southern Alps, producing strong north and north-westerly winds. Wind dynamics can be affected by the high relief topography, causing complex local wind and wave conditions. Winds of over 30 km/hr were recorded at Pūkaki Aerodrome on over 10 days per month (on average) during summer months (September – March), and below 10 days per month during winter months (on average, April – August).

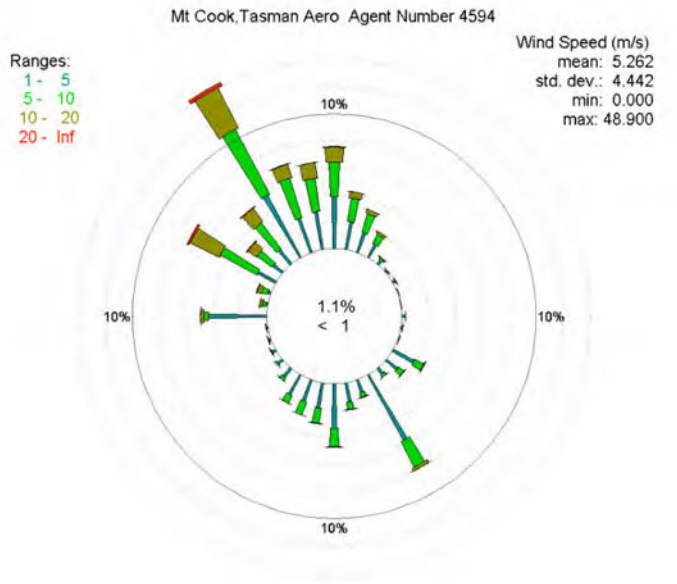


Figure 5 Wind rose, Mt Cook meteorological station (1973-77; 1995-2013; Source Single, 2022)

– Strong north-south, south-north and down-valley longshore sediment transport mechanisms have removed eroded sediment, which was deposited in low-lying areas of the backshore, forming spits and barrier beaches. Longshore processes typically form elongate, continuous landforms, e.g., longitudinally continuous beaches, which infill gullies and form at the base of shoreline bluffs.

NIWA (2024[7]) analysed available climatic data for the period of record concluding:

– Inflows to Lake Pūkaki and temperature / precipitation in the Waitaki Basin were highly variable and only partially sensitive to climatic oscillations. El Niño – Southern Oscillation (ENSO). Southern Annular Mode (SAM) and Interdecadal Pacific Oscillation (IPO) conditions were assessed, but Lake Pūkaki was weakly

[6] Webby, M.G. 2019. Affidavit for Meridian Energy, High Court of New Zealand.
[7] National Institute of Water and Atmospheric Research Ltd. (NIWA). 2024. Analysis of hydroclimatic trends and influences in the Waitaki Power Scheme, Prepared for Meridian Energy Limited, April 2024.

sensitive to the latter two conditions. Lake levels during La Niña events tended to be high during summer and winter, and much higher during spring, with a reversed pattern during El Niño conditions (i.e., lower lake levels). GHD note that the extreme lake levels in 2024 were associated with La Niña conditions.

– There was a general pattern of declining inflows during summer and early autumn; increasing inflows in late autumn and winter; and a significant decline in annual inflows.
– Trends in river flow downstream of the dam indicate that the WPS subdues the impacts of climatic variability through operational water storage / transfer.

Rainfall and temperature patterns also affect the lake geomorphology, affecting lake inflows, and weathering / erosion processes. Summer rain events typically produce more runoff than the snowfall during winter months (Single, 2022). However, freeze-thaw action during winter can result in destabilisation of the steep glacial till slopes. Snowmelt during spring results in piping and rill erosion of the glacial till, and collapse of the shoreline bluffs (Single, 2022). NIWA (2024) note that increases in winter precipitation and glacial meltwater release are not offsetting losses due to decline in summer precipitation and increasing temperature-related increases in evapotranspiration.

2.4 Wave processes

Strong wind conditions producing high energy waves are typically associated with southerly storms, föhn / katabatic conditions (Single, 2022). Maximum wave heights are achieved during two-to-three-hour wind events, due to the restricted lake fetch. Wave modelling for lake levels at 513.0 m RL indicated:

– Maximum wave heights of nearly 2.5 m were derived from northwest by north (330°) winds with an average windspeed of 15 m/s (54 km/hr) and a duration of 3 hours (Single, 2022). This is consistent with field observations, which indicate rare occurrences of 3 m tall waves under extreme wind conditions (i.e., windspeeds of over 30 m/s). Single (2019[8]) indicates that the maximum wave height on Lake Pūkaki is about 4.5 m
– Winds from the southeast (130°) with windspeeds of 10m/s (36 km/hr) for the same duration produced maximum breaker heights of just over 1 m.
– Morphological change and longshore transport volumes are related to wave energy. Single (2019) indicates that lake shore-modifying events occur when wave heights are over about 0.5 m in height. These events occur between 12 to 48 days per year. Webby (2019) indicated that wave heights of 1.4 m – 1.7 m would be expected to occur with a 5% annual exceedance probability (AEP).
– Meridian (2019[9]) observe that wave studies indicate that rock armouring lake shore protection is required to 2.5 m below operating level, indicating the depth of wave energy impact.

Detailed wave modelling was conducted for the southern extent of the lake, focusing on the Intake and Main Dam areas (Damwatch, 2013[10]). This indicated that there was a decrease in wave height as waves propagated from offshore to near shore, although the results were complicated by limitations along the model extents (i.e., along the shoreline). The findings indicate that the maximum 2.5 m wave height is modelled to occur within the centre of the lake. Where the waves impinge the southern shoreline, wave heights are reduced to a maximum of approx. 1.86 m at the main dam and 1.93 m at the Intake Dam. The modelled minimum lake level of 513.0 m RL means that waves break offshore of the protected zone in front of the Intake Dam, but against the dam face along the Main Dam. The left abutment of the Main Dam is sheltered by the promontory to the north, with a recommended significant wave height of 1.5 m.

[8] Single, M. 2019. Affidavit for Meridian Energy, High Court of New Zealand.
[9] Meridian. 2019. Pūkaki Contingent Storage Presentation, November 2019.
[10] Damwatch Engineering Ltd. 2013. Pūkaki Dam Wave and Armouring Assessment, November 2013, report for Meridian Energy Ltd.,

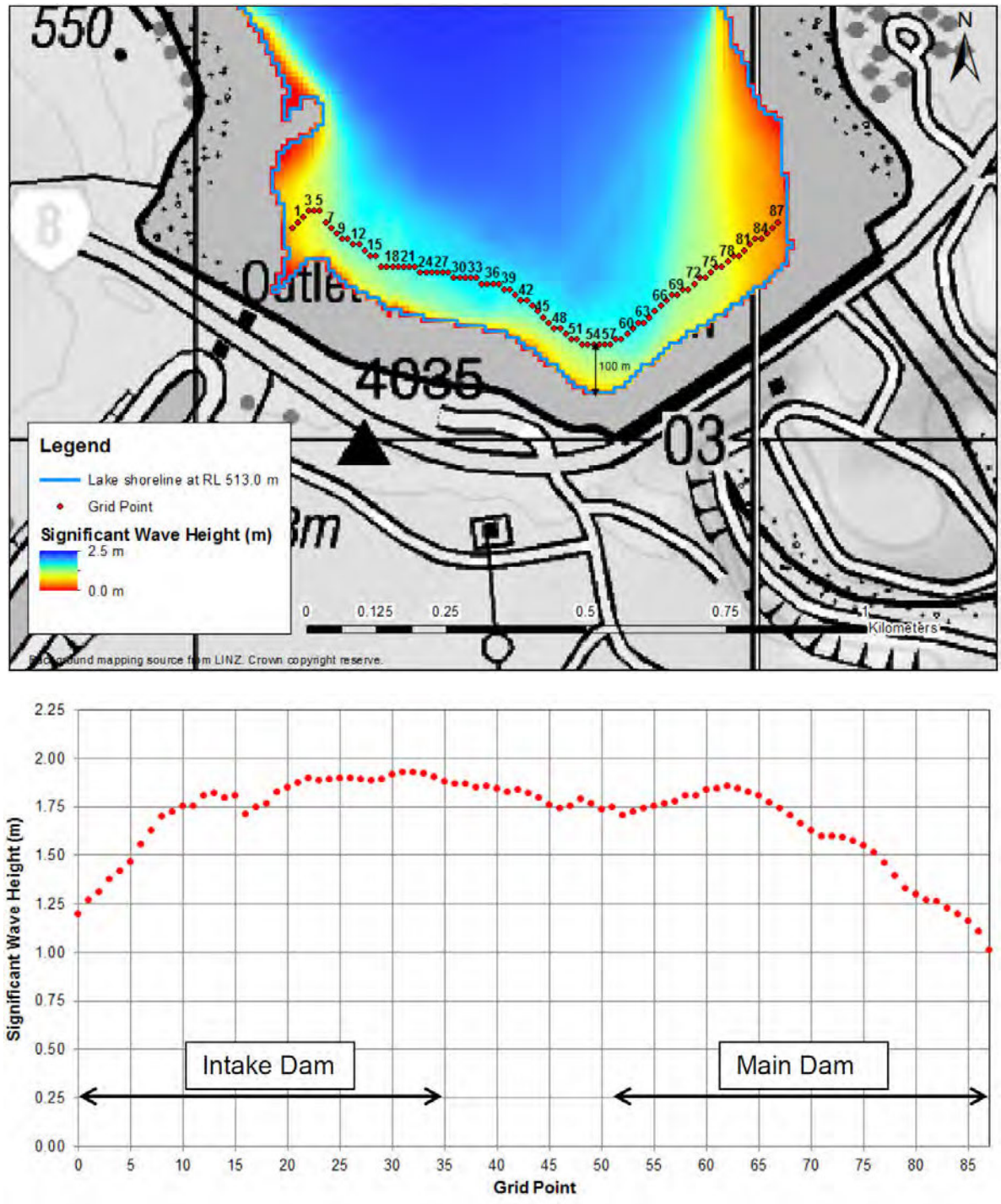


Figure 6 ***1 in 100 AEP significant wave heights at 513 m RL: Top: modelling output plan view of southern section of Lake Pūkaki; Bottom: Modelled wave heights across cross section shown in top image (source: Damwatch, 2013, Figures 2.1 and 2.2).***

These critical wave heights have been re-evaluated in GHD's Pūkaki Dam Protection Works report (GHD, 2025[11]), conducted for the FTCC application. This assessment revised the significant wave height slightly to 2.27 m RL, with a 90th percentile wave height (i.e., design wave height) of 2.59 m.

Away from the dam areas, the steep beine (submerged terrace) typically creates steep, plunging, erosive waves with a narrow surf zone and little wave refraction. Storm-generated waves can reach the base of backshore slopes, transporting sediment offshore.

[11] GHD. 2025. Lake Pūkaki Reservoir Hydro Storage and Dam Resilience Works – Dam Protection Works, for Meridian Energy.

2.5 Shoreline and lake sediments

There are several different sediment types within the lake area (extents from Single, 2022):

– Moraine deposits form over 70% of the shoreline: variable sediment size from fine to large boulders dominate the shoreline, with published geological mapping (GNS Science, 2016; in Single, 2022) describing the material as “bouldery till in well-preserved moraine ridges and rock glacier deposits, merging with scree and associated outwash gravel”. The moraines are derived from the late Triassic greywacke forming the adjacent uplands.
– Fluvial / hillslope deposits form around 10% of the shoreline: typically, sand, gravel and some larger cobbles / boulders accumulated in large quantities associated with river deltas, alluvial fans, inundated valleys and landslides [debris flows].
– The Tasman River supplies high sediment volumes (including fine glacial flour) to Lake Pūkaki, forming a large, dynamic delta at the upstream / north end of the lake.
– Fine sediment is preferentially mobilised from variably-sized beach sediments on the shore and deposited on the lake bed. The remnant coarse sediment is episodically mobilised by high energy wave events. This sediment is transported in pulses, particularly during northerly wind / wave conditions.
– Glacial till (Tekapo Till) is present on the submerged valley floor, concentrated in the southern section of the lake (Single, 2019) and is vulnerable to erosion.
– Nearly 10% of the lake margin has been protected with gabions and dumped rock riprap, as discussed in GHD’s Engineering Structures Report (GHD, 2025b[12]).

The accumulated lake sediments are appreciably different in character to lake shore sediments. Sutherland *et al*. (2019) describe these as largely glaciolacustrine facies, of which over 50% is fine-grained. The facies include deltaic foreset bedding, interlaminated silts and sands, and coarse ice-rafted mixed deposits (including diamictons and drop stones). The accumulation of fines is consistent with high recorded turbidity, due to suspended glacial flour (NIWA, 2023[13]). Turbidity / suspended sediment concentrations are strongly related to inflow volumes.

3. Lacustrine geomorphological processes

The lacustrine geomorphology of Lake Pūkaki is related to changes in the external driving variables of waves, currents and lake levels on the lacustrine geomorphology and sediment dynamics. Single (2022) observes that Lake Pūkaki is still geomorphologically adapting to changing environmental conditions, including lake level and wave energy.

– Shore development under the WPS operating regime has been slow and episodic, again associated with high-energy waves during periods of high lake levels.
– Degradation of the erosional scarps due to sub-aerial weathering has resulted in slow reduction of scarp slopes.
– Eroded sediment was deposited on near-shore shelf, adjacent to the eroding lake margins, accumulating to form steep, coarse sand and gravel beaches.
– Storm events during periods of low lake levels can result in sediment being removed and potentially lost from the lacustrine beach system.

Single (2022) calculated that approx. 66% of the Lake Pūkaki shore was eroding (or artificially protected), in contrast to only 7% accreting and 26% quasi-stable. This contrasts with the adjacent WPS lakes, which are predominantly quasi-stable due to a wave climate which is ineffective in transporting the lake shore sediments.

[12] GHD. 2025b. Lake Pukaki Reservoir Hydro Storage and Protection Works - Engineering Structures Assessment, report for Meridian Energy Ltd, October 2025.
[13] NIWA. 2023. Assessment of the Environmental Effects of the Waitaki Power Scheme – Water Quality. Report prepared for Meridian Energy Limited, March 2023

Lake shore morphology takes time to adjust to any new regime before [quasi[14]-] equilibrium is reached (Webby, 2019; Single, 2019 and Single, 2022). Single (2019) indicates that a report by R.M. Kirk (1988) estimated a [quasi-] equilibrium lag of between 5 and 100 years, depending on site-specific conditions.

3.1 Erosion

Creation of the artificially dammed lake resulted in extensive episodic erosion of the newly inundated lake margins (backshore), particularly during the first 10 – 20 years. Episodic wave action eroded the base of the valley sides during periods of high lake levels, creating sub-vertical cliffs / bluffs. Average erosion rates of between 0.5 m and 7 m per year have been recorded (Single, 2019). The strong northwest by north wind / wave climate results in waves which break at acute angles along the western and eastern shorelines, but near-parallel to the north and south shorelines (Single, 2022). This produces strong southerly longshore transport and sediment sorting.

The large operating range of the Lake Pūkaki WPS has resulted in a broad active nearshore (beine) with three components (Single, 2022), broadly aligning with the morphology shown in Figure 4. The width of the beine means that the upper beine (upper foreshore / shoreface) is out of the reach of wave action for the majority of the time. Lake shore erosion is generally associated with episodic removal of the bluff base during high energy wave events, oversteepening, and finally collapse. Removal of vegetation can reduce lake shore stability, exacerbating this erosion (Single, 2022). The accumulated failure material provides toe protection until removed during storm events. Fine material is preferentially winnowed, leaving larger cobbles and boulders. Bluff / cliff erosion is common along the southwestern shore (Single, 2022). Rates of shoreline erosion of up to 5 m per year within single storm events have been observed (Single, 2022).

Single (2019) discusses lake shore response to fluctuating lake levels. At low water levels, the upper beine is no longer within the wave-affected zone, and the active beine effectively narrows. Sediment removed from the lower beine is transported into the lake.

The high energy wave climate within Lake Pūkaki, combined with erodible hillside material, has resulted in a dynamic landform. Eroded hillside material is rapidly transported long-shore. Localised erosion rates are controlled by the geology and sediment characteristics of the backshore material.

Shoreline erosion inspections of protected sections of the lake shore have been ongoing since at least 1987. The latest monitoring report, by WSP in 2024[15], is included as Appendix B. Repeat inspections at selected monitoring locations indicate that erosion is typically caused by:

– Undermining of the existing rock or gabion protection, causing damage to roads and other assets on occasion.
– Uncontrolled overland flow causing either rilling or erosion around overwhelmed culverts. These observations indicate that surface water processes, as well as lacustrine processes, should be considered. A geotechnical appraisal of road instability associated with Jack's Stream notes that heave due to ice formation is also a destabilising process in the moraine material (Downer NZ, 2024[16]). The destabilising effect of subaerial processes was also noted by Single (2022).
– Single (2022) observed that erosion can be exacerbated within unprotected ground adjacent to artificial structures.

3.2 Deposition

3.2.1 Beach and spit formation

Longshore transport has created depositional features at the upper lake / wave run-up levels (Single, 2022). Linear barrier beaches have formed across shallow sloping ground and shallow embayments, blocking minor tributaries. Spits have formed on the lee of protruding promontories.

[14] The use of "quasi" by GHD recognizes that equilibrium geomorphological form is dynamic and responsive to the driving variables.
[15] WSP. 2024. Lake Pūkaki shoreline erosion inspection report, October 2024, Report No. 6-XE067.00 for Meridian Energy Ltd.
[16] Downer NZ. 2024. Preliminary Geotechnical Appraisal, SH80-RP8.600 -8.700 Jacks Stream Slip, April 2024.

3.2.2 Alluvial fan and delta formation

Larger tributary streams (i.e., which are sufficiently large or high energy to prevent blockage by longshore transport) deposit their transported sediment load on reaching the lake. This sediment forms arcuate alluvial fans, referred to as deltas, protruding into the lake. Tributary streams entering from the steep western hillside / mountain slopes carry high sediment loads fed by debris flows and landslides in their steep catchments.

The head of Lake Pūkaki, is dominated by the Tasman River delta formed due to the high sediment load of the Tasman River. High energy, competent (i.e. with a high sediment transport capacity) flood flows can cause hyperpycnal flows, where dense, sediment-laden flow can extend some distance into the lake. However, the shallow lake depth adjacent to the delta front encourages rapid deposition of coarse bed sediments, with fine suspended sediment moving further into the lake (Single, 2022).

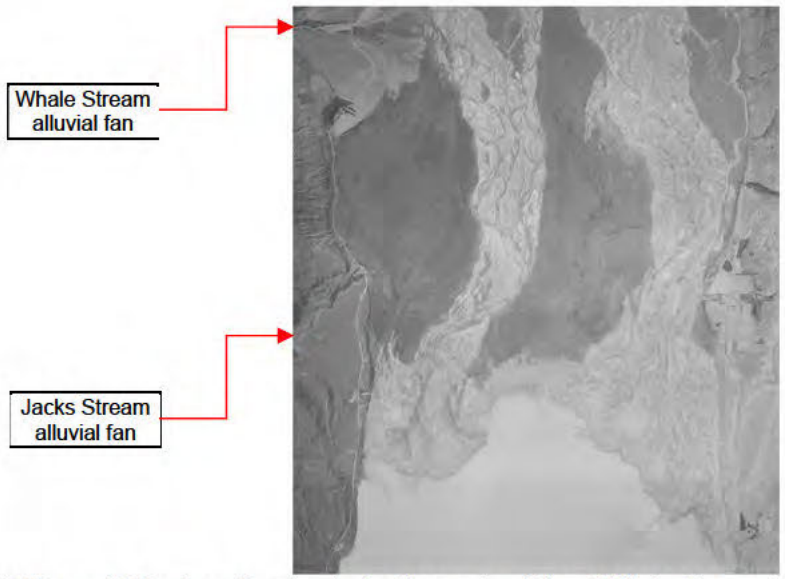
The lake-wards extent of the delta-front location is highly variable due to the range of operational lake levels (Single, 2022). Annual fluctuations can be as much as 1.5 km, with long-term variations under the current operating scheme exposing as much as 3.2 km of the deltaic plain. This variability in Tasman delta extent is shown in Figure 7, which also shows the changing location of the active Tasmin River braid belt anabranches and associated plume of sediment. This figure also shows the prominent alluvial fan / delta of Twin Stream entering from the west.

A review of lake bathymetry and Tasman Delta morphology (Sutherland *et al.*, 2019) shows that Lake Pūkaki has a prominent terminal moraine, which trapped the pre-dam lake (see Figure 8). The northern section of the lake is significantly shallower than the southern section, indicating the pre-dam extent of the Tasman Delta. This is clear in pre-dam aerial imagery (see Figure 7), which shows the complex braid belt of the Tasman River extending to the pre-1970s dammed lake. There is, therefore, a steep drop-off at the former delta front, which the 1992 Operating Range map shows as having a bathymetric range of 513.0 m RL – 518.0 m RL.

Accumulation of sediment, which GHD assumes is due to longshore sediment transport, adversely affects the functioning of the Pūkaki Canal intake and boat ramp south of Tekapō B Power Station (Single, 2022).

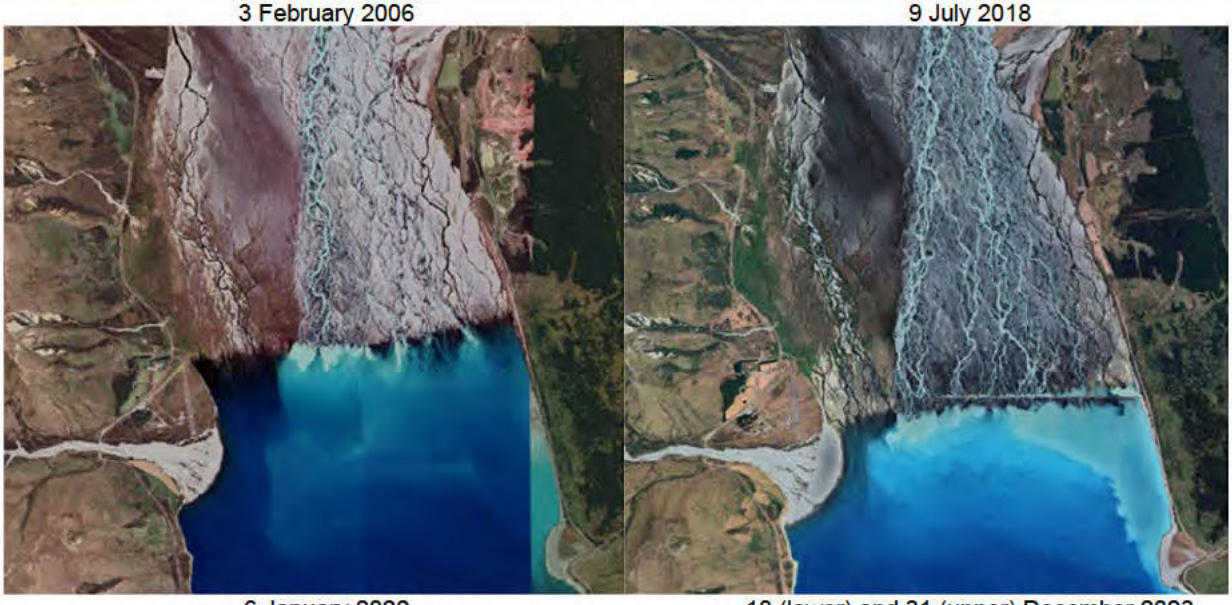
3.3 Effect of existing WPS regime

Single (2022) concluded that continued WPS operation will not change the external driving variables (referred to as physical shoreline processes) acting on the lake. Artificial modification, including development of roads and land-use changes, may require localised management, but not due to operation of the WPS scheme.



24 February 1959, pre-1970s dam showing Jacks Stream (south) and Whale Stream (north) alluvial fans / deltas

3 February 2006 9 July 2018



6 January 2022 18 (lower) and 31 (upper) December 2023

Figure 7 Variability in Tasman delta front location, selected dates (source: 1959[17]; Google Earth)

[17] https://retrolens.nz and licensed by LINZ CC-BY 3.0, **Retrolens - Historical Imagery Resource**

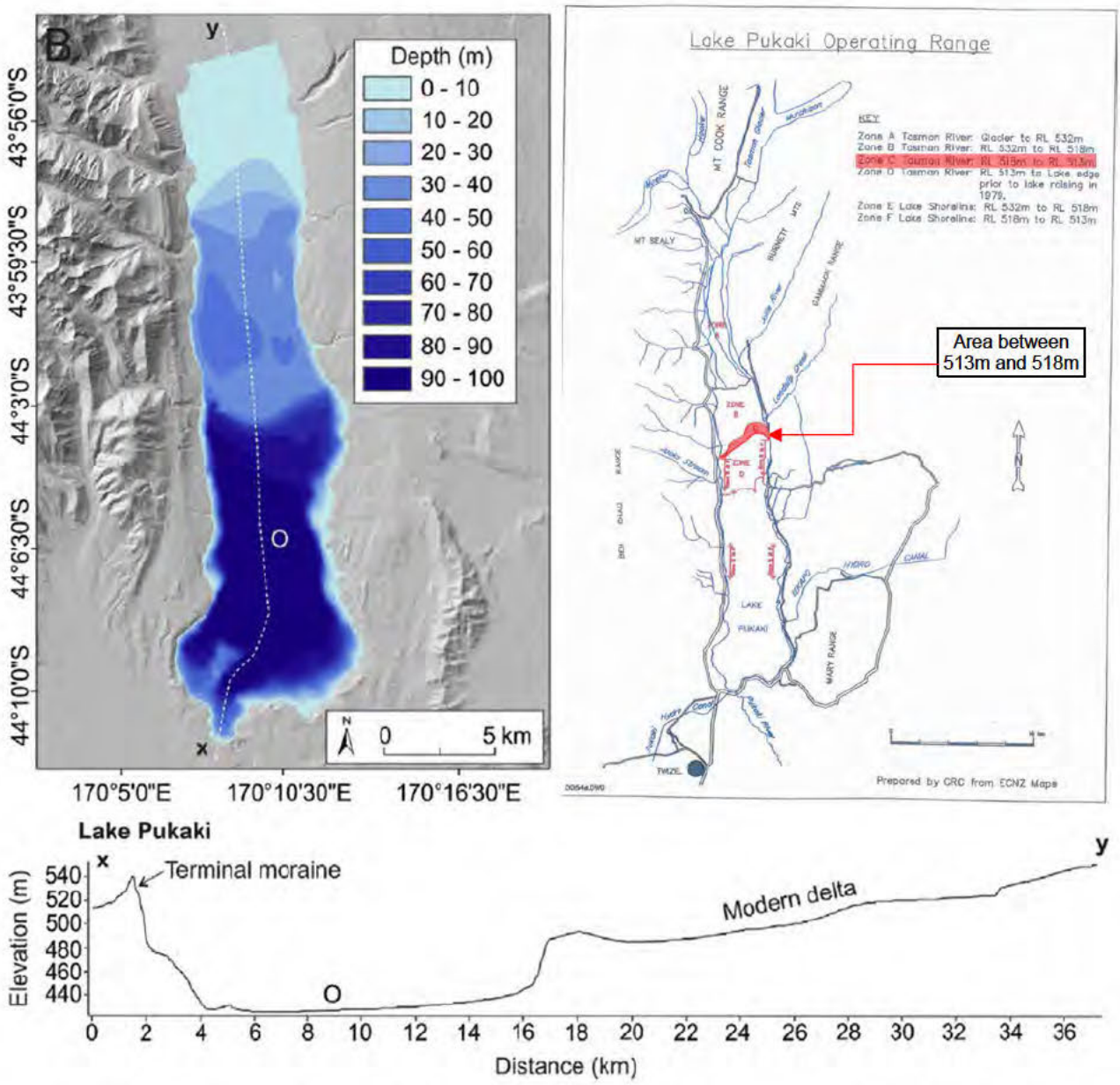


Figure 8 ***Bathymetry and long section of Lake Pūkaki and the Tasman Delta (source: Sutherland et al., 2019); bathymetry reflected in 1992 Lake Operating Range***

3.4 Proposed High Dam and abutment stabilisation works

GHD understands that Meridian plan to extend additional shoreline stabilisation down to 510.5 m RL to protect structures during lake levels as low as 513.0 m RL. Rock armouring of appropriate size will be placed along the High Dam, and right and left abutments (GHD, 2025). Single (2022) observed that the natural shoreline area immediately adjacent to the High Dam was identified as accreting. Assessment of Google Earth imagery indicates that this is particularly the case adjacent to the right abutment, where longshore transport of sediment has created spit and broad beach landforms. The High Dam location, in contrast, is a target for wave attack generated by the strong north-westerly winds.

Information regarding the stabilisation works and construction methodology is provided in the Pūkaki Dam Protection Works Report (GHD, 2025). Of note, this report has updated the rip-rap sizing in line with current design guidelines. The D_{50} has been enlarged from 0.63 m to 1 m, based on revised wave height inputs and stability coefficients. This rip-rap sizing is also in keeping with existing rip-rap sizes, which have been assessed to be

stable (2024 Dam Safety Review). A further revision to the original design is to adopt a uniform rip-rap size, eliminating the requirement for varying rip-rap size with slope.

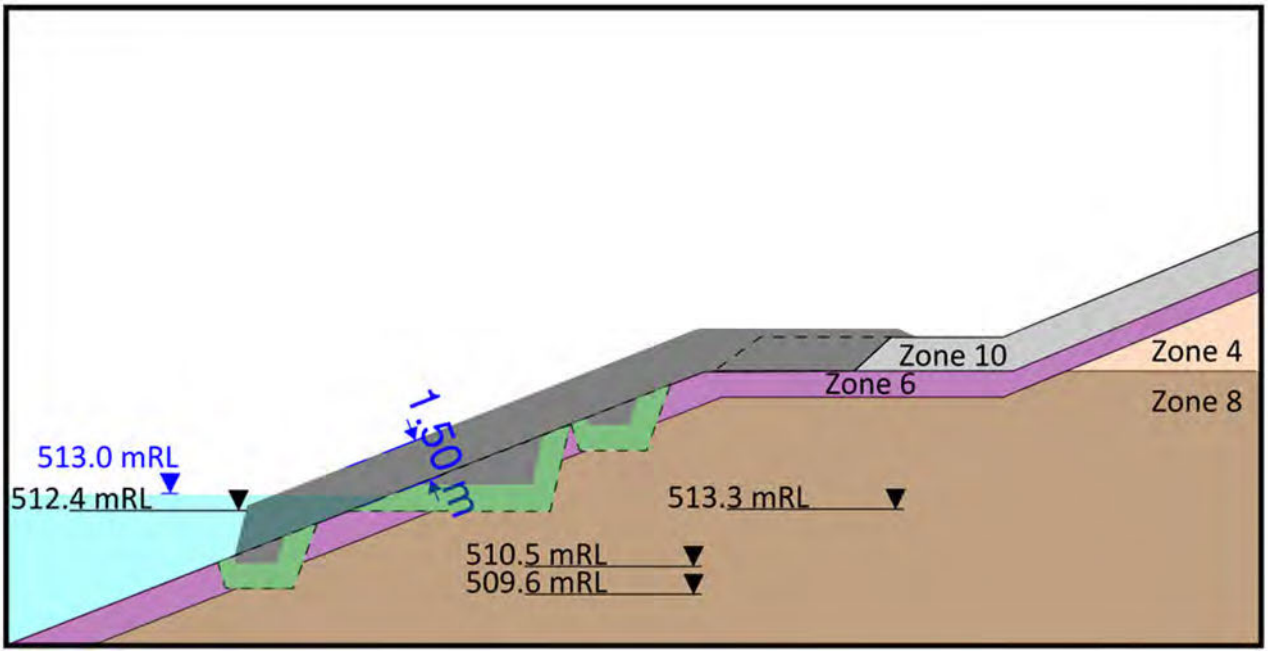


Figure 9 ***Schematic sketch of proposed rock armouring design (source: GHD, 2025, Figure 9 (work zones) and Figure 27 (schematic sketch))***

GHD's 2025 reassessment of rip-rap design has also identified that construction cannot be completed in a single stage. This is because lake levels are anticipated to fluctuate above 518.0 m RL during the anticipated 12 to 18 week construction period. Therefore, a multi-stage approach to construction has been recommended, with construction only occurring during periods of suitably low lake levels, and outside periods of predicted high rainfall events and strong wind / high energy wave events. Contingency plans would be put in place for safe demobilisation (both from a construction and shoreline stability perspective) during these events.

The proposed construction timing is anticipated to reduce impact to the shoreline. Adverse impacts from erosion would be reduced, as the likelihood of high-energy wave events occurring during periods of low lake level would be reduced. A dive survey is proposed to assess existing subsurface condition and rip-rap extent, and inform the final design.

4. Assessment of environmental effects

4.1 Geomorphological effects

GHD's desktop review of existing assessments has indicated that Lake Pūkaki has an erodible lake shore and dynamic associated landforms. The previous shoreline and lacustrine geomorphology assessments have provided information regarding the location and characteristics of vulnerable areas within the lake environment. These vulnerable locations are identified in Single (2022), with location maps shown on p71: Distribution of existing and projected shore geomorphological state.

Single (2022) observes that the shoreline of Lake Pūkaki is dominated by natural erosional processes and will continue to erode. Therefore, erosion protection structures are likely to require ongoing management and monitoring to ensure they are performing effectively. Single's assessment of future conditions considered projected climate change scenarios, with an increase in winter precipitation of up to 20% and a reduced snow pack of up to 20%. This would result in 10% drier summers and 26% wetter winters by 2050, with lake levels anticipated to respond accordingly: Lake Pūkaki is anticipated to be full for greater periods of time, with the increased seasonal fluctuations (i.e., lower lake levels during the spring and higher lake levels during the autumn). The assessment concludes that the projected effects of continued operation of the WPS will not be significantly different from past and current effects. These projected scenarios contrast with the modelled lower lake levels between 2026 and 2028 under eased restriction conditions. However, given Single's conclusion that increased lake level fluctuation and higher average lake levels would have a negligible effect on lake condition, it can be concluded that lake is resilient to change. This resilience is largely due to rapid localised adaptation to changing conditions, a long lag (decades to centuries) in broad-scale morphological adaptation and historically experienced large seasonal fluctuations in lake level.

Adverse effects on lake geomorphology associated with the operation of the lake below 518.0 m RL would be limited by the short duration of proposed low lake level events. Effects are anticipated to be as follows:

- No change to external lake processes, although the location of the shoreline and beine would fluctuate with lake levels, affecting the location where these processes are acting.
- The broad-scale lake morphology has a prolonged adjustment time to a new regime (between 5 and 100 years). Therefore, broad-scale morphological adaptation to a short period of outlying conditions, i.e., a lower lake level, would not be anticipated within this short timeframe.
- However, storm event-driven morphological change would still be anticipated below the current active shoreline of 518.0 m RL:
    - In areas of identified erosion (see Single, p71), erosion would be expected at elevations lower than 518.0 m RL, potentially affecting lower sections of bluffs and the beine.
    - Greater shoreline extent exposed to surface processes, such as uncontrolled overland flow erosion and ice-related heave, particularly around exposed artificial structures.
    - Deltaic and alluvial fan sediment deposition at a lower elevation within the lake area.

The likelihood of these impacts occurring is dependent on storm events coinciding with periods of low lake levels. Low lake levels are projected for spring months, whereas geomorphologically effective storms are characteristic of summer and winter months. Therefore, the likelihood of adverse impact is anticipated to be low. Should minor morphological change occur, it would be anticipated that storm events during subsequent months would result in a reversion to pre-change conditions.

It is recommended that the ongoing lake shore monitoring program (with the most recent example provided in Appendix A) is maintained, continuing to focus on site-specific assessments of vulnerable areas. This has established a baseline and trends at identified erosional and depositional landforms along the Lake Pūkaki shoreline over the past 37 years. Whilst the risk of additional adverse impacts from the lower lake operation is considered low, this monitoring program will assist in identify and quantifying any effects that do occur.

4.2 High Dam engineering works effects

The proposed High Dam and abutment stabilisation works are anticipated to have a minor localised impact during construction, when excavation is required. Impacts would be managed and mitigated to a large extent through construction timing avoiding high-energy wave events and appropriate erosion and sediment controls (see GHD 2025). Following construction, the newly installed riprap is anticipated to effectively stabilise the shoreline adjacent to the High Dam and abutments. Rock armouring design and efficacy has been reassessed in GHD's Pūkaki Dam Protection Works report (GHD, 2025).

4.3 Comparison to PC1

The proposed 2026 – 2028 operating regime is within the approved PC1 operating range conditions, requiring rigorous previous assessment. The proposed restriction easing is not expected to fundamentally change the geomorphological processes or driving variables (particularly wave climate and sediment characteristics). Therefore, the findings of the previous assessments conducted for the approved PC1 application are still appropriate for the proposed 2026 – 2028 operating regime. The key conclusion of these assessments was that areas of artificial modification, such as roads and land-use, may require localised management, but this is ongoing, rather than being an anticipated impact of the WPS scheme operation (Single, 2022).

4.4 Summary

This report provides an overview of the lacustrine geomorphological processes and morphological response of Lake Pūkaki to fluctuating lake levels in support of Meridian Energy's FTCC application to enable access to stored water below 518.0 m RL. The report provides an overview of lake formation, historic lake levels, influence of climatic regime and lacustrine process / form relationships, based on existing reports, monitoring and assessments. The lake sediment dynamics are discussed, focusing on identification of processes forming erosional and depositional landforms.

The assessment of historic morphological change and contemporary geomorphological processes was used to assess the likely effects of the proposed reduction in lake levels below 518.0 m RL

- Lake Pūkaki experiences seasonal fluctuations in lake levels, with low levels during the spring and high levels during the autumn following snow melt. Climate change projections indicate an increase in lake level variability. The lake morphology is, therefore, adapted to the variable regime. Broad-scale response to changing conditions is slow, with a lag of decades to a century. Therefore, short periods of lake levels below 518.0 m RL are not expected to trigger large-scale morphological adaptation.
- Short-term, localised event-driven morphological change is feasible during storm events. Although the external lake processes will not change, impacts could affect the shoreline and being at elevations below 518.0 m RL. However, storm events typically occur in summer and winter, whereas low lake levels are modelled to occur during the spring. Therefore, the likelihood of adverse impact is anticipated to be low. Should minor morphological change occur, it would be anticipated that storm events during subsequent months would result in a reversion to pre-change conditions.
- Meridian Energy are proposing to upgrade the riprap erosion protection adjacent to the High Dam, at the south end of the lake. Minor, localised effects are anticipated during construction, minimised by timing construction to avoid storm events. Long-term impacts are anticipated to be low, with improved resilience to erosion along the protected shoreline.
- Vulnerable sections of the shoreline have been monitored for 37 years, with identification of baseline conditions and site-specific change. Where required, erosion protection has been installed, monitored and maintained. It is recommended that the ongoing lake monitoring programme is continued to identify and quantify the anticipated minor localised, site-specific effects.

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Appendix A

WSP lakeshore inspection report 2024

Meridian Energy Limited

LAKE PUKAKI SHORELINE EROSION INSPECTION REPORT

OCTOBER 2024

6-XE067.00

LAKE PUKAKI SHORELINE EROSION INSPECTION REPORT
OCTOBER 2024

Meridian Energy Limited

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ISSUE DATE	ISSUED TO
Jan 2025	Tim Mills, Meridian Energy, Private Bag 950, Twizel 7944
Jan 2025	Mackenzie District Council, PO Box 52, Fairlie 7949
Jan 2025	Waka Kotahi NZ Transport Agency, PO Box 1479, Christchurch 8140

	NAME	DATE	SIGNATURE
Prepared by:	Elizabeth Hannon	18 December 2024	[redacted]
Approved by:	Rob Bond	18 December 2024	[redacted]

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APPENDICES

1 SUMMARY

1.1 INTRODUCTION

The October 2024 inspection of Lake Pūkaki shoreline was undertaken by WSP[1] using UAV on 10 October 2024.

The lake level on 10 October was 520.70m compared to 529.30m in March 2024. The lake level was typically trending down at this time.

Due to the low lake level there were no safe boat launch ramps that could access the lake.

In addition due to the distance from the lake to the shoreline a visual inspection from a boat was deemed too great to provide accurate observations.

Operating the boat at low lake levels poses additional safety risks with respect to underwater hazards. For these reasons and others the inspection was completed using UAV. This is the first inspection completed using UAV.

Due to time constraints Site 1 and Site 13 were not inspected this monitoring period.

Remedial works are planned for completion at Sites 2, 6 and 5 in October 2024. These repair works comprise extending existing revetment work at Site 5 and topping up and filling of low spots at sites 2 and 6. These works will be inspected as part of the March 2025 inspection.

As of 11 September 2012, the year-round maximum lake control level[2] was increased to RL 532.5m. Prior to this the maximum control level regime was RL 532.0m September to April and RL 532.5m May to August.

Those present on the inspection were:

Meridian Energy	Not present
Waka Kotahi	Not present
Mackenzie District Council	Not present
WSP	Paul Durham (UAV operator)

The report covers the recent history and current status of sections of the lakeshore and adjacent structures. It does not present options for long-term erosion protection nor specific site management strategies. These aspects are covered within the report *'Lake Pūkaki – Five Year Plan for Shoreline Management 2000-2005'*.

[1] Under contract to Meridian Energy Limited

[2] Maximum control level (MCL) is the lake level where Meridian under its Hydraulic Rules and resource consents are required to make mandatory actions to control the reservoir level.

1.2 RISK ASSESSMENT

This report includes a rapid risk assessment using engineering judgement and comparison to previous condition assessments utilising a traffic light system approach as follows:

Red: High risk or significant change noted that requires further action or immediate consideration.

Orange: Medium or Moderate threat to asset requiring further investigation, assessment or monitoring. Some changes noted that may be worsening and need to be monitored or brought forward in the priority programme.

Yellow: Medium or Moderate threat to asset requiring further consideration, assessment or monitoring. A move from Orange to Yellow would indicate a condition considered to be improving from previous assessment, whereas Yellow to Orange would indicate a potentially worsening condition.

Green: Low risk or no significant change noted from previous inspections / assessments.

1.3 CONCLUSIONS

a The October 2024 inspection was the first inspection to adopt a UAV based inspection of critical sites.

b A boat based inspection of all sites is required in March 2025.

c Repair work and topping up of existing revetments has been completed in October 2024 at Sites 2 and 6.

d Extension of the existing revetment has been completed in October 2024 at Site 5. The existing revetment has been extended some 50m northwards. This requires inspection in March 2025.

e Site 2: Continued monitoring of the site is required. Topping up of the rip rap at the northern end should be considered.

f Site 2A: Continued monitoring of the marker post and the generation of erosional holes is required. Consider topping up of the rock rip rap in the next 2-3yrs and extending the rip rap northwards.

g Site 6: Following undercutting, noted since 2020, topping up of the rock rip rap on the middle section and lifting to the underside of the road should be considered. The site status has previously been upgraded to yellow until works are completed and subsequent inspection carried out during next scheduled site visit.

h Site 16: As noted in previous inspections slope erosion north of the retaining wall has vegetation loss. Revetment placement along the northern side should be considered.

i The report "Lake Pūkaki – Shoreline Erosion Management Strategy" including the 3 year rolling programme should be updated to provide a sound basis for future planning based around forecasted lake levels.

Site Number	Previous Status (October 2023)	Current Status (March 2024)	Current Status (October 2024)	Comment: Based on UAV imagery obtained 10 October 2024
1				The site was not inspected as part of this inspection. Inspection of Site 1 is required in March 2025. No change in condition has been reported to WSP / Meridian / MDC.
2				Previous scalloping and deterioration at the northern end of the site is evident. Consideration should be given to extending and topping up of the rip rap at the northern end and monitoring of the south end should continue. Minor bank loss over the top of the rip rap is evident – continue to monitor.
2AN				Runnelling erosion is ongoing and bank erosion continues to be evident. Water egress in the mid slope above the beach level is evident. The site threat has been raised to orange due to proximity to the road.
2A				Erosion around the culvert outlets still requires attention at the southern end of the section. The existing water table on the upslope side of the road requires continued maintenance. Continued monitoring of the marker post and the generation of erosional holes is required. Consider topping up of the rock rip rap in the next 2-3yrs and extending the rip rap northwards.
3				No major change from previous inspections. Ongoing monitoring of the erosion previously noted at the northern end of the site should continue. Consideration should be given to extending the rip rap southwards by a further 50m. Maintenance of the water table and culvert swale may require some maintenance.
4				No major deterioration of the site was noted from the previous 2023 event. Continued monitoring of the site, particularly following strong winds or heavy rainfall is recommended.
5				The site appears stable and relatively dry. The rip rap is remaining with little loss being noted. Closer inspection and monitoring of the northern end is required.
6				Some topping up of the rock rip rap appears to have been completed over the last 12 months. This should continue to be monitored. Some loss of rock

Site Number	Previous Status (October 2023)	Current Status (March 2024)	Current Status (October 2024)	Comment: Based on UAV imagery obtained 10 October 2024
				into the lower beach is evident. Some further topping up of the rip rap along the road edge and filling notable gaps would be beneficial.
7				The outlet was visible during the UAV inspection. Considerations should be given to adding further rip rap around the culvert outlet to reduce erosion effects. As previously noted the outlet should be extended to prevent blocking.
8N				Not specifically inspected this visit. Pine tree removal previously completed continues to cause minor slope erosion. Monitoring should continue.
8				Revegetation continues, minor bank spalling also continues to occur. Monitoring of the effects of pine tree removal should continue
8A				Minor bank loss continues. Continue to monitor. Consideration to placing additional rip rap may be warranted in the future.
9				The site generally continues to perform well. Previous small hollows were still noted however and need to continue to be monitored. Consideration to be given to topping up the rock rip rap along this section to maintain performance. Evidence of rock being lost to the lower beach.
10				Site shows no obvious major change. The low water inspection indicates that rip rap in front of the gabion wall is low in the mid and southern section of the wall. Consideration could be given to extending and filling the mid and southern areas between the existing groynes.
11				The site continues to be stable with no sign of deterioration.
12				The site does was not inspected as part of this inspection.
13				The site was not inspected as part of this inspection.
14				As with previous inspections the site appears relatively stable. No discernible change from previous inspection. Continue to monitor.

Site Number	Previous Status (October 2023)	Current Status (March 2024)	Current Status (October 2024)	Comment: Based on UAV imagery obtained 10 October 2024
15				Minor erosion continues to occur around previous repairs. Main placed rock appears to be stable and holding. Continue to monitor.
16				Water seepage below and through the gabion wall is evident. The rip rap and reno mattress appear to be in a good condition. The bank loss to the north of the wall appears to have slowed. Consideration should be given to extending the rock rip rap northwards of the gabion wall along the base of the exposed cliff and base of the gulley.

2 EASTERN SHORELINE (RCA – MACKENZIE DISTRICT COUNCIL)

2.1 SITE 1 

8.8 KM NORTH OF BRAEMAR ROAD INTERSECTION

2.1.1 CURRENT STATUS

There is a current low to moderate threat to the road integrity at various locations at this site.

The shoulder width was reduced during winter 2004, May 2009 and has continued to erode during ensuing high lake periods. In January 2013 a high lake level and high wind accelerated scour and erosion at this site. Future maximum lake level/high wind combination is likely to cause erosion into the road embankment.

Meridian placed rock revetments at critical locations along this section in April/May 2013 and March 2015. This has removed the immediate high threat.

In March 2017 the status of this site was reduced to green.

Continued monitoring of this section is required.

2.1.2 HISTORY

- October 1987 to October 1997: Superficial changes, due to slope wash from rainstorms, plus minor erosion at the embankment toe caused by the lake.
- February to April 1998: Active erosion at the embankment toe created several sections with vertical faces extending halfway up the batter over a length of 10m. Not considered in need of remedial work.
- 1999: Several trees blown down gave the impression of recent erosion.
- November 2000 – April 2002: No changes of any consequence. Some new minor erosion at the batter toe and face.
- September 2002: Increased erosion at several locations due to slope wash.
- April 2003: No changes.
- August 2003: No major changes. Minor cliff erosion due to heavy rain.
- March 2004: No major changes. Some superficial change due to high lake and rainstorms.
- September 2004: Marked increase in erosion along 150m of the shoreline. Shoulder significantly reduced from 4m down to 1 to 2m. There is little protection as the vertical bank consisting of coarse gravels, (much of it fill) is easily eroded by wave action.
- April 2005: No changes.
- August 2005: No major changes. Note the comments of September 2004. Edge delineation could be improved.

- March 2006: No major changes.
- September: No major changes. Active pockets of erosion, (due to weather).
- March 2007 to September 2008: No major changes.
- March 2009: No major changes. There had been minor slope-wash.
- May 2009: Moderate change. 150m of road, 1 to 2m from the bank edge had suffered further erosion, not extensive, although the face of the bank had been further eroded (full height). There was no batter toe protection. The beach was reasonably well armoured with large cobbles.
- October 2009 to October 2010: No major changes.
- April 2011: There had been a marked increase in erosion during the previous 6 months along the majority of this site, with a further 50m (approx.) of shoulder being reduced to about 1m from the edge of the bank (50m in total of several lengths). Mackenzie District Council had installed edge marker posts at the affected areas.
- October 2011: No major changes.
- April 2012: No major changes.
- October 2012: No major changes. Noted tree growth.
- March 2013: Increase in erosional scour noted, some sections are very close to road edge. Site should be considered for rock revetment work to slow wave break.
- October 2013: Revetment work completed in April/May improved shoulder and filled around culverts. Culverts flowing and discussion held re water table on east side of road. This is the first time since Lake filling in 1979 that rock revetment works has been placed at this site. Improved water table work to be assessed to better manage surface water adverse effects.
- March 2014: Revetment work holding at key locations. No major scour zones identified that warrant immediate action. No major change observed.
- October 2014: No significant change – prioritisation for rock revetment work is still appropriate.
- March 2015: Ongoing revetment work is providing support and protection to bank profile. Approximately 250m of work complete. Surface water drainage requires assessment and channel clearing maintenance.
- October 2015: Rock revetment work now complete along this section with only minor gaps left. Revetment work to be monitored over coming seasons. Water table work needs to be programmed by third parties to reduce saturation of upper slope.
- March 2016: Revetment work now complete with critical areas now protected. Monitoring of performance to continue. Road surface saturated with seepage from adjoining drainage channel. Drainage maintenance now urgently required as affecting pavement surface and top of bank.
- September 2016: Revetment work now complete with critical areas now protected. Monitoring of performance to continue. Regular inspection required.
- March 2017: No significant change from previous inspection. Monitoring of performance to continue. Regular inspection required. Status reduced to green.

- September 2017: There is no significant change from previous inspection. Monitoring of performance is to continue. Further consideration of filling open sections in the future.
- March 2018: No significant change noted from the previous inspection.
- October 2018: No significant change in condition. Monitoring of performance is to continue.
- March 2019: The Lake level has not been as high recently and there appears to have been no significant change in condition. However, the recent high tide line does appear to have relaxed the beach gravel and revetment. Monitoring of performance is to continue.
- October 2019: There is no significant change to the shoreline at this site. The revetment work holds well and should continue to be monitored.
- March 2020: No significant changes were noted during this inspection, however the bank behind the southern end warrants further monitoring and there should be consideration given to extending the rock rip rap on the norther section.
- September 2020: As per the previous inspection there is no significant change to the shoreline at this site. However, the bank behind the trees at the southern end requires monitoring. The revetment work is holding well. Monitoring should continue. Consider extending rock rip rap on northern end.
- March 2021: There is no significant change to the shoreline at this site, revetment is holding well. Bank behind trees requires ongoing monitoring. Consider installing rock rip at northern end of site and in area behind dead tree at southern end. Trees have been felled recently by LINZ just south of this site, bare bank now warrants monitoring.
- October 2021. The site remains relatively stable with no significant changes to the shoreline and the revetment continuing to hold well. Continue to monitor the tree removal effects. The area is vegetating up well.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: The site appears stable with no significant changes to the shoreline and the revetment continuing to hold well.
- March 2023: The site continues to appear relatively stable. No significant changes to the shoreline and the placed revetment were noted and the site continues to hold well.
- October 2023: The site continues to appear relatively stable. No significant changes to the shoreline or to the placed revetment were noted during this inspection with the site continuing to hold well.
- March 2024: The site continues to appear relatively stable. No notable or significant changes to the shoreline or the placed revetment. The site continues to hold well. The site was identified as low to moderate threat to the road integrity.
- October 2024: The site was not inspected as part of this inspection. Inspection of Site 1 is required in March 2025. No change in condition has been reported to WSP / Meridian / MDC.

Photographs: NA

2.2 SITE 2

4.9 - 5.45 KM NORTH OF BRAEMAR ROAD INTERSECTION

2.2.1 CURRENT STATUS

There is no immediate threat to the road integrity.

The embankment below the remaining pine tree is eroding slowly however revegetation of the bank was noted in 2017.

Small scallops and caves were noted during the October 2019 Inspection. Site condition changed to Yellow.

In 2021 the topping up and extension of the rock revetment was to be considered. In 2024 the revetment was noted to warrant further repair and topping up.

Further monitoring is warranted.

2.2.2 HISTORY

- Winter 1988: 160m of the southern end of this section of road was relocated inland, 8m from the edge of the cliff face. (This was the maximum distance possible within existing land boundary).
- Summer 1989/90: Hay barn/silo/yards constructed.
- 1989 to 1994: Minor erosion along the entire length.
- February 1995: Rapid erosion immediately north and south of the silo/hay barn site.
- Autumn 1995: Rock protection undertaken, 50m to the north and to the south of the silo/hay barn.
- November 1995: Rock protection raised to several metres above maximum lake level opposite the silo/hay barn site.
- October 1997: Minor erosion was occurring to the north and south of existing rock protection.
- February – April 1998: Rapid erosion north and south of rock protection.
- Winter 1998: Erosion increased due to very heavy rains and slope wash.
- October 1999: Erosion to the south of the hay barn protection becoming a concern. Road shoulder was 2m from the cliff edge at the narrowest point.
- December 1999: Rock protection undertaken, extending 150m to the north and the south of the hay barn. Existing protection augmented and repacked.
- December 1999 – November 2000: No further changes.
- May 2000: Profile survey undertaken.
- April 2001: No major changes. Erosion was continuing beyond the rock protection at the southern end over a length of approximately 100m. Not a threat to the road embankment.
- August 2001 to August 2003: No major changes; some minor consolidation of rock protection works.

- March 2004: No major changes.
- September 2004: No major changes.
- April 2005: No major changes.
- August 2005: No major changes. The protection works continued to consolidate. Erosion to the north of the current rock protection was still eroding the near vertical bank.
- March 2006 To March 2008: No major changes.
- September 2006: No major changes.
- May/June 2008: Augmentation of the existing protection was undertaken where the rock had slumped and/or the protection was light, with a major augmentation at the southern end for approximately 140m continuously (see Construction Sketch #1 Appendix D, September 2008 report).
- September 2008: No major changes.
- March 2009: No major changes. There had been minor slope-wash along with consolidation of the augmentation works undertaken at the southern end in winter 2008.
- May 2009: There had been a 30m increase in erosion to the north of the existing rock protection. The road formation was at about 3m from the edge of the cliff along this length. 25m of earlier protection work, north of the hay barn, was looking tired and beginning to unravel.
- October 2009: Some minor increase in erosion to the north of existing protection. This extended for approximately 110m to where there is a reasonable distance to the road from the cliff edge (along with a small promontory which would be a logical tie-in point for future armouring).
- March 2010: No major changes.
- October 2010: No major changes.
- April 2011: No major changes. The increased erosion detailed in May 2009 was continuing, however not at a rate to cause concern.
- October 2011: No major changes.
- April 2012: No major changes.
- October 2012: No major changes.
- March 2013: No major change noted. Some minor caving noted at high water mark. Large fir tree has been trimmed back by council for cyclists.
- October 2013: No significant change to bank. Fir tree should be removed before it falls. Noted ponding water on paddock eastern side of road. No significant change to dropout. Young wilding pines noted in the bank. Decided to leave these saplings for now.
- March 2014: No significant changes noted. The bank below the pine tree is eroding albeit slowly. Improved surface water management is required to manage the lake shoreline. This maintenance activity is outside the maintenance activities identified in the Pūkaki Shoreline management consent agreement. North of the pine tree bank erosion is evident. No immediate threat to the road.

- October 2014: No significant changes noted since last inspection, however erosion features at the base of the cliff have scallops developing at the southern end. Monitor during next inspection. Threat level changed from Green to Yellow.
- March 2015: No significant change noted. 150m of new revetment work installed in March 2015 and 100m of repair work completed in February 2015. Threat level returned to Green.
- October 2015: No change this inspection. Continued monitoring recommended.
- March 2016: No change this inspection. Continued monitoring recommended.
- September 2016: No change this inspection. As with previous inspection continued monitoring recommended.
- March 2017: No further change this inspection. As with previous inspection continued monitoring recommended.
- September 2017: No significant change this inspection however minor drop outs were noted on the right hand side of the slip. As with previous inspection continued monitoring of minor caving at southern end is recommended. Further rock revetment work could be considered in the future.
- March 2018: No significant change from the previous inspection. As with previous inspection continued monitoring of minor caving at southern end is recommended. Consideration should be given to additional rock revetment work in the future.
- October 2018: The site continues to perform adequately. No significant change from previous inspection. Pine tree has been removed.
- March 2019: The site continues to perform adequately. No significant change from previous inspection with new tree growth and bush growth on the prominent slopes.
- October 2019: The site continues to perform adequately however small scallops and caves were noted at the northern end which should continue to be monitored. In addition, approximately 150m south of the site a small cave appears to have formed. This should be inspected next visit. Site condition changed to yellow.
- March 2020: Inspection of the cave revealed no significant changes. Consideration should be given to of an extension to the revetment both north and south.
- September 2020: The site has continued to perform adequately. However, at the northern end, small scallops and caves were noted which should continue to be monitored. A cave noted in the previous inspection approximately 150m south of the site should continue to be inspected. An extension of the revetment has occurred to the southern end as of July. An extension to the north of the revetment should be considered.
- March 2021: The site appears to be relatively stable with some minor changes only. Scalloping at the northern end of site is more pronounced. Extending rock rip rap to the north of the site should be considered. Small cave to the south of the site does not appear to be worsening.
- October 2021: Site continues to remain relatively stable with minor ongoing scalloping at the northern end of the site. Lifting and topping up of the rip rap at the north end should still be considered, some seepage was noted at a low level. The small cave does not appear to have worsened.

- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: Topping up of the rock revetment work at both ends should still be considered. Continue to monitor. Site appears stable.
- March 2023: Minor scalloping at the northern end of the site has been observed. Consideration to topping up of the rip rap at the north end should still be considered.
- October 2023: Minor scalloping at the northern end of the site has been observed. Consideration to topping up of the rip rap at the north end should still be considered and monitoring of the south end should continue.
- March 2024: Minor scalloping at the northern end of the site has been observed. Consideration should be given to topping up of the rip rap at the northern end and monitoring of the south end should continue.
- October 2024: Previous scalloping and deterioration at the northern end of the site is evident. Consideration should be given to extending and topping up of the rip rap at the northern end and monitoring of the south end should continue. Minor bank loss over the top of the rip rap is evident – continue to monitor.

Photographs: S2-101024 (1-16)

2.3 SITE 2AN

3.7 – 3.9 KM NORTH OF BRAEMAR ROAD INTERSECTION

2.3.1 CURRENT STATUS

New site 2A North added in March 2019 as runnelling erosion is now becoming prevalent along this section of Hayman Road.

Site status changed to yellow in March 2021 due to an increased rate of erosion and evidence of small bank collapses.

No constructed revetment in place at this site.

Further monitoring is warranted.

2.3.2 HISTORY

- March 2019: The verge is quite large here (in excess of 10m) and the road does curve away however the erosion rate does appear to be increasing. The site warrants further monitoring as a new site
- October 2019: Erosion now becoming prevalent along this section of Hayman Road. The verge is quite large here (in excess of 10m) and the road does curve away however the erosion rate does appear to be increasing. The site does not appear to have deteriorated from the previous inspection; additional monitoring is warranted.
- March 2020: erosion appears to be increasing with increased caving also noted at the southern end, continued monitoring warranted for this site.
- September 2020: NEW SITE 2A North – added in March 2019 has runnelling erosion now becoming prevalent along this section of Hayman Road. There is a large verge here (in excess of 10m) and the road does curve away. The erosion rate here appears to have plateaued since March 2020. The site displays no significant deterioration from the previous inspection. The increased caving at the southern end noted in March 2020 appears to have stagnated. Additional monitoring is still warranted.
- March 2021: Runnelling erosion is more pronounced than previous inspections. A small collapse has occurred at the northern end of site and has undermined a section of bank. A large verge still exists between the bank crest and Hayman Road, but rate of erosion appears to be increasing. Continued monitoring is required.
- October 2021: Runnelling is ongoing and continuing to worsen with the rate of erosion appearing to still be increasing. The small collapse does not appear to have regressed and the large verge is still intact. Concern around the culvert to the north. Continued monitoring and drainage maintenance north of the culvert is required.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: Runnelling is ongoing and bank erosion is evident. Recent heavy rainfall appears to have caused some slope deterioration. Continued monitoring and drainage maintenance north of the culvert is required.

- March 2023: Continued runnelling erosion is ongoing and continued bank erosion is evident. Continued monitoring and drainage maintenance north of the culvert is required.
- October 2023: Runnelling erosion is ongoing and bank erosion continues to be evident. Monitoring and drainage maintenance north of the culvert is still required.
- March 2024: Runnelling erosion is ongoing and bank erosion continues to be evident. Monitoring and drainage maintenance north of the culvert is still required.
- October 2024: Runnelling erosion is ongoing and bank erosion continues to be evident. Water egress in the mid slope above the beach level is evident. The site threat level has been raised to orange due to proximity to the road.

Photographs: S2AN-101024 (1-7)

2.4 SITE 2A

3.7 – 3.9 KM NORTH OF BRAEMAR ROAD INTERSECTION

2.4.1 CURRENT STATUS

Erosion of the bank is predominantly rill erosion (surface water erosion) however high lake levels and a high windstorm event resulted in rapid cave development of the lower bank in 2016.

Revetment works were completed in 2017 along the base of the bank to slow deterioration from wave erosion.

Continued monitoring and road/drainage/culvert maintenance is required including removal of fallen debris off of the culvert socks.

Erosion around culvert outlets is pronounced and a more robust solution than culvert socks is likely to be required.

Site condition rating changed to Orange in October 2019.

In 2023 the road was re-shaped and graded away from the bank edge. This resulted in the bank appearing to be less damp.

Continued monitoring is required.

2.4.2 HISTORY

- May 2009: The shoulder width along this length varied from 3 to 4m. The embankment consists of medium to coarse gravel and was exhibiting signs of slope wash from heavy rain along with some erosion from the lake at the toe. The extent of increased erosion was not known however it was noticeable. Further observation and reporting at this site will continue.
- October 2009: No major changes. Slope wash continues.
- March 2010: No major changes.
- October 2010: Some increase in erosion had occurred in the last 6 months. At several short lengths the shoulder width was reduced to approximately 2.5m (previously 3m minimum).
- April 2011: There had been a minor increase in erosion along most of this length, plus 1 major increase causing 2 lengths of culvert pipe to be washed out. The road formation was about 3m from the edge of the bank.
- October 2011: No major changes.
- April 2012: No major changes.
- October 2012: No major changes. Water channel to road may require clearing and re-grading).
- March 2013: Erosional rilling of the embankment is very evident. Erosional feature is typical of surface water run off or near surface drainage eroding down slope. Extent of rilling in places is close to road edge. Minor rilling also observed during October 2012 inspection. The change in rilling October to March is significant. This area was also inspected during and following the January 2013 high lake level (RL533.3m) event. From January to March 2013 there was no observed noticeable change in rilling.

- October 2013: No significant change.
- March 2014: No significant change. Surface water management required to ensure overall shoreline maintenance is effective. This is outside of the Pūkaki Shoreline monitoring and maintenance activities.
- October 2014: Erosion occurring from road level. Surface water drainage management by third parties required as previously noted. Threat level increased from Yellow to Orange.
- March 2015: No significant change noted. Erosional features are still present and developing as a result of poor water table drainage. Water table management is not the responsibility of Meridian Energy. Threat level maintained at orange.
- October 2015: Top down erosion still evident along this section. Water table noted to be saturated in places and not free draining. Lenses along lake side also saturated. Erosional features are cutting back towards the road edge. Water table maintenance and culvert maintenance required by third parties to ensure slope stability.
- March 2016: Evidence of top down erosion noted. Drainage maintenance required as road surface noted to be saturated and pot hole generation occurring. Evidence of slope erosion on beach with water channels flowing towards lake. Water table heavily vegetated and saturated. Urgent drainage maintenance now required to reduce edge erosion. Threat level changed to red requiring urgent attention to drainage maintenance.
- September 2016: Evidence of top down erosion noted. Drainage maintenance has been undertaken although water channel is very flat. Further clearance at culvert points is required together with improved gradient of channel.
- March 2017: Drainage maintenance has been undertaken although water channel is very flat and the culvert inlet is overgrown, drainage channel north of culvert is still overgrown and requires maintenance. Further clearance at culvert points is required together with improved gradient of channel. Revetment works to address lake activated erosion is due to be started in the next period. Monitoring of section north of 2A is also required.
- September 2017: The water channel is very flat and the culvert inlet is overgrown, drainage channel north of culvert is overgrown and requires maintenance. Further clearance at culvert points is required to ensure effectiveness. Revetment works to address lake activated erosion is now urgently required.
- March 2018: As with previous inspections the water table channel is quite flat and the inlet is still overgrown. The drainage channel north of the culvert is also overgrown. Vegetation clearance and minor grading as part of routine maintenance is required. The road cross fall gradient has been altered and the water table has been shaped. Additional culverts have been installed with socks. The road formation and sub grade was noted to appear much drier than previous inspections. The road and section requires further monitoring.
- October 2018: The site is much drier than previous inspections. The water table requires ongoing maintenance and culvert inlets require vegetation management. Continued monitoring of culvert locations is warranted.
- March 2019: Minor seepages were noted in the exposed banks at a level close to invert of the culverts. Water seepage is still occurring albeit slower. As with previous inspections the water table requires ongoing maintenance and culvert inlets require vegetation management. Some

minor re-cutting and reducing of levels in the water table should be considered. The culvert socks require clearing of fallen debris and checking that they run clear. Site to be monitored.

- October 2019: Minor seepages were noted in the exposed banks at a level close to invert of the culverts. Water seepage is still occurring albeit slower. As with previous inspections the water table requires ongoing maintenance and culvert inlets require vegetation management. Erosion around the culvert socks is prevalent and this requires the determination of an alternate solution to the headwall of the culverts. Site has been made orange.
- March 2020: No major changes.
- September 2020: Minor seepages in the exposed banks at a level close to invert of the culverts do not appear to have changed. Water seepage is still occurring at a similar rate to the previous inspection. The culvert inlets require vegetation management and the water table continues to require ongoing monitoring. There is still prevalent erosion around the culvert socks and an alternate solution to the headwall of the culverts is still required and yet to be determined.
- March 2021: Exposed banks are very dry, seepage noted in previous inspections has stopped, likely due to maintained culvert inlets and water tables on Hayman Road. Road grading maintenance and cross-fall improvements will also help surface erosion issues. Significant erosion around culvert outlets requires attention, outlet socks are not functioning as intended and an alternate solution is required.
- October 2021: No significant changes since the previous inspection with the banks remaining dry and the erosion around the culvert outlets requiring attention due to the functioning of the outlet socks. Drainage maintenance required to address erosion around culverts.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: The banks appear to remain dry. Erosion around the culvert outlets requires attention due to the functioning of the outlet socks. Drainage maintenance required to address erosion around culverts.
- March 2023: Road has been graded and shaped away from the bank. The bank appears to remain mostly dry as a result. Erosion around the culvert outlets is ongoing and requires attention. Continued management of the water table including maintaining adequate falls, culvert outlets and road shape is required.
- October 2023: The road has previously been graded and shaped away from the bank, as a result the bank appears to remain mostly dry. Erosion around the culvert outlets requires attention. Continued management of the water table including maintaining adequate falls, culvert outlets and road shape is required. Continued monitoring of the marker post and erosional hole generation should be undertaken.
- March 2024: The road has previously been graded and shaped away from the bank, as a result the bank appears to remain mostly dry. Erosion around the culvert outlets still requires attention. Continued management of the water table including maintaining adequate falls, culvert outlets and road shape is required. Continued monitoring of the marker post and the generation of erosional holes should be undertaken.

— October 2024: Erosion around the culvert outlets still requires attention at the southern end of the section. The existing water table on the upslope side of the road requires continued maintenance. Continued monitoring of the marker post and the generation of erosional holes is required. Consider topping up of the rock rip rap in the next 2-3yrs and extending the rip rap northwards.

Photographs: S2A-101024 (1-22)

2.5 SITE 3 

3 KM NORTH OF BRAEMAR ROAD INTERSECTION

2.5.1 CURRENT STATUS

There is no immediate threat to the road integrity.

Drainage management of existing swale and culverts is required. This is not the responsibility of Meridian Energy.

Threat level remains at Green.

2.5.2 HISTORY

- Mid 1988: 50m of road embankment re-established and armoured.
- 1988 to autumn 1991: The reconstruction and protection works of 1988 were slowly demolished until 1991 when they stabilised.
- May 1995: Noted that erosion had progressed to a minor extent north and south of the collapsed reconstruction works.
- Spring 1995: Adverse conditions demolished remainder of the 1988 protection works. Erosion progressed into the original embankment for several metres. An estimated 70m of road was under threat.
- Spring 1996: Embankment armoured with coarse rock.
- 1997: Mackenzie District Council exposed the culvert outlet previously discharging through rock protection and installed a small gabion wall.
- 1997 to November 2000: No further changes.
- May 2000: Profile survey undertaken.
- April 2001 to April 2003: No major changes. Some movement of rock adjacent the batter toe.
- August 2003: No major changes. Erosion to the batter, downstream end of the culvert appeared due to culvert discharge and possible road run-off.
- March 2004: Some loss of gravels above maximum lake level, (approximate 10m length south of culvert outlet), otherwise little obvious change.
- September 2004: The small gabion wall (installed 1997) to protect the culvert outlet had collapsed. This appeared to be due to concentrated surface run-off from heavy rainstorms being directed, via "turn outs" (installed during grader maintenance), down the embankment adjacent to the wall (also occurring elsewhere) and causing severe embankment erosion. The collapsed protection works (refurbished 1996) along the embankment remained basically unchanged.
- April 2005: Gabion wall collapse continued. Culvert discharge was not impeded. The road shoulder width had not reduced further.
- August 2005: There were no changes to existing protection works. The small gabion wall may have collapsed further, to a minor degree. Water was discharging from beneath the pipe, which was partially blocked with gravel and had a broken section near the outlet.

- March 2006: The collapsed gabion wall had deteriorated slightly, possibly as a consequence of rain or overtopping from the creek due to the blocked culvert. Mackenzie District council were currently designing repair/replacement options. A meeting Meridian Energy/MDC/MDC Contractor was planned for the near future.
- September 2006: There was further minor deterioration to the collapsed gabion wall (appeared to be due to road run-off).The site meeting was deferred due to adverse winter conditions.
- March 2007: The collapsed wall continued to deteriorate. The proposed meeting Meridian Energy/MDC was rescheduled.
- November 2007: The culvert and protection continued to deteriorate during rain. Mackenzie District Council had commissioned their consultant to prepare proposals for remedial work.
- March 2008: No major changes. General deterioration at this site continues. Erosion is at the edge of the carriageway.
- September 2008: No major changes. General deterioration at this site continued. Erosion was at the edge of the carriageway.
- March 2009: No major changes. Mackenzie District council were reviewing their remedial works options.
- May 2009: Extensive erosion over 35m. The culvert and gabion baskets had been washed out. Road formation reduced to one lane.
- October 2009: The road embankment had been restored, minus the culvert. The creek had been rerouted to run to the north and south of the repaired embankment, (along a channel cut at the toe of the hill adjacent the boundary fence) and now discharges to the lake via existing culverts, approximately 100m each side of the earlier washout.
- November 2009: Meridian Energy bolstered the embankment toe with coarse rock.
- March 2010: No major changes.
- October 2010: No major changes.
- April 2011: There had been a major washout of the armouring gravels and several metres of the road embankment at this location, extending 15m along the road and full height of the batter. The road formation was unprotected from the next high lake level.
- May 2011: Meridian Energy constructed extensive rock protection along the 15m of unprotected embankment at this site along with a general bolstering of some of the adjacent lighter rock (30m in total).
- October 2011: The recent repairs were stable. There were no major changes to the other sections at this site.
- April 2012: No major changes.
- October 2012: No major changes. Culvert channel has been cleaned and reshaped. Culvert itself has not been cleaned.
- March 2013: Channel appears cleaned but culvert is 30% blocked (culvert 86).

- October 2013: No major change. Culvert pipe is 30% blocked. Channel needs re-cutting and cleaning.
- March 2014: No major change. Culvert pipe remains blocked >30% and requires clearing. Channel is overgrown and requires re-shaping and clearing. Surface water management activities are outside the consent agreements.
- October 2014: No major issues, however surface water drainage still requires further consideration as mentioned in March 2014 inspection. Since the inspection in October the channel has subsequently been cleared.
- March 2015: No significant change. Meridian to check culvert clearance and note condition of surface water drainage channel. Threat level reduced to Green.
- October 2015: No significant change this inspection. Culvert maintenance required by third parties.
- March 2016: No significant change noted this inspection. Culvert inspections required to ensure flow is not hindered.
- September 2016: No significant change noted this inspection.
- March 2017: No further significant change noted this inspection.
- September 2017: Minor drop outs to the right hand side of the revetment work was noted however no risk to the road. No further significant change noted this inspection.
- March 2018: As with previous inspections minor drop outs to the right hand side of the revetment work were again noted however there is no risk to the road. The obvious pine tree has now been removed.
- October 2018: No significant change in condition from previous inspection. Continued monitoring of minor drop outs is recommended.
- March 2019: No significant change in condition from previous inspection. There is no immediate threat to the road.
- October 2019: No significant change in condition from previous inspection. Minor thinning of rock protection at the southern end of the site was noted. Further monitoring is recommended.
- March 2020: No major changes noted.
- September 2020: This site continues to show no significant change. The minor thinning of rock protection of rock at the southern end noted in March 2020 does not appear to have changed.
- March 2021: The site remains in a stable condition, with no significant change. Small caves at the southern end of site warrant ongoing monitoring.
- October 2021: No significant changes. The small caves appear to be created or exacerbated by birds. Some erosion noted at the northern end which requires monitoring. Culvert is OK.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.

- November 2022: No significant changes from previous inspections. The small caves appear to be created or exacerbated by birds. Some erosion noted at the northern end which requires monitoring.
- March 2023: No significant changes from previous inspections. Erosion previously noted at the northern end of the site should continue to be monitored.
- October 2023: No significant changes from previous inspections. Ongoing monitoring of the erosion previously noted at the northern end of the site should continue. Although not the responsibility of Meridian, it should be noted that water course maintenance leading up to and beyond the road culvert may be required.
- March 2024: No significant changes from previous inspections. Ongoing monitoring of the erosion previously noted at the northern end of the site should continue. It should be noted that water course maintenance leading up to and beyond the road culvert may still be required.
- October 2024: No major change from previous inspections. Ongoing monitoring of the erosion previously noted at the northern end of the site should continue. Consideration should be given to extending the rip rap southwards by a further 50m. Maintenance of the water table and culvert swale may require some maintenance.

Photographs: S3-101024 (1-5)

2.6 SITE 4

1.7 KM NORTH OF BRAEMAR ROAD INTERSECTION

2.6.1 CURRENT STATUS

January 2013 storm event caused damage to the embankment and road at this location. Repairs were immediately undertaken.

A high wind event combined with high lake levels in January 2017 resulted in partial loss of the revetment works. Replacement and repair works were immediately actioned by Meridian. These works were ongoing at the time of the March 2017 inspection. The 2017 September inspection noted that the repairs were holding well but further monitoring was required.

The threat level of this site was elevated to yellow in March 2017 and was subsequently upgraded to orange in March 2020 due to scalloping and a loss of revetment in January/February 2020.

Repair works were completed in June 2020 and the site returned to yellow in 2021.

Site should be monitored for further deterioration especially following storm events.

As of 2024 the site threat level remains at yellow.

2.6.2 HISTORY

- May 1987: Original road at top of the cliff endangered. Erosion to within 0.3m of the road edge.
- October 1987: Tension cracks appeared in the carriageway. Usage reduced to single lane traffic.
- December 1987 to January 1988: Road relocated to toe of the cliff.
- February 1988: Relocated road severely damaged by erosion.
- Mid 1988: Damaged embankment and protection works reconstructed.
- December 1989: Substantial reconstruction and protection works undertaken, along the entire length.
- September 1991: Some minor subsidence of rock noted at high water line. Lower batter rock had begun to move.
- Early summer 1991: Subsided sections replenished with large rock.
- May 1993: Downward movement of rock on the lower side of the railway iron/steel strop retaining system noted.
- October 1993: Downward movement noted in May accelerated.
- June 1994: Further downward movement as in May 1993. The retaining system was totally exposed. All lower rock had been dragged down. Some upper batter slumping was occurring.
- October 1995: Slumped upper batter areas repacked. Lake side of the retaining system repacked with coarse rock and shaped to the original profile.
- June 1996: Noted that settlement of the recent remedial works had occurred after one lake cycle.

- March 1998: Several sections of embankment and carriageway washed out (top third of batter) during severe storms. Access reduced to single lane. Remedial works undertaken.
- March 1998 to November 2000: Minor overall consolidation of rock protection was continuing.
- April 2001: During February 2001 severe storms caused extensive pockets of damage at six locations. Protection rock and gravels were washed into the lake and at several locations erosion reached into the road embankment. Meridian Energy instigated repairs during March. This inspection showed no further changes. The repaired areas were consolidating.
- April 2002: Suspected there may have been some settlement of rock midway down the batter, particularly along the lakeside of the retaining system, mainly in the southern half of the protection works. There was further consolidation at the areas repacked in March 2001 after severe storms.
- September 2002: No changes. There had been some slope wash of material from the cut batter adjacent to the road. (Not an unusual occurrence).
- April to August 2003: No major changes. Consolidation of rock protection continued.
- March 2004: Some loss of protection gravel and rock above high lake level in 5 or 6 pockets extending 10 to 15m in length. Road formation was exposed in some cases.
- September 2004: Situation remained much as it was in March. The exposed protection works at the lower levels appeared reasonably stable.
- April 2005: The eroded sections first identified March 2002 had increased in length depth and number (about 10). The remainder of visible embankment protection appeared unchanged.
- August 2005: The embankment as a whole continued to consolidate.
- The eroded/slumped sections numbered about 25, ranging in size up to 50m^2.
- March 2006: No major changes. Eroded/slumped sections remained unchanged.
- September 2006: No major changes. Eroded/slumped sections remained unchanged.
- March 2007: There were no changes other than minor at the eroded/slumped sections. These had “flattened out” and become broader. There appeared to have been some minor rock movement within these areas, decreasing the protection at maximum lake level.
- November 2007: No major changes.
- March 2008: No major changes.
- May/June 2008: The eroded/slumped sections were topped up with rock and tied into the existing batter slope (see Construction Sketch #2 Appendix D, September 2008 report).
- September 2008: No major changes.
- March 2009: No major changes. 2 new eroded areas (approx. 10m length) had formed (similar to those first occurring in 2002).
- May 2009: Moderate erosion. There had been marked erosion along the embankment at the southern end, (from the end of the existing protection works) for about 20m. The road formation is 2m from the edge of the bank.

- There were numerous small slips (24) along the armoured embankment further north around the promontory, ranging in size up to 15x6m.
- October 2009: No major changes; no increase in the number of small slips.
- November 2009: The majority of small slips were packed with coarse rock.
- March 2010: No major changes.
- October 2010: No major changes. The recent packing of small slips remained stable.
- April 2011: No major changes. 8 eroded areas (up to 12m length) have formed (similar to those occurring in 2004).
- May 2011: The eroded areas were topped up with rock and tied into the existing batter slope.
- October 2011: No major changes.
- April 2012: No major changes. There are several gaps/slips amongst the rock at higher levels. The lake would not have reached these levels during the past 6 months. Rain activated?
- October 2012: Longshore drift continues to deposit gravel on spit at true LHS. Gaps / slips in rock at higher levels exist. Uncertain as to origin/mechanism of slope. Monitor over time.
- March 2013: January 2013 storm event caused damage to road and embankment. Repairs undertaken and gaps in rock rip rap previously noted now filled.
- October 2013: No significant change. Rock fill holding.
- March 2014: No significant change.
- October 2014: No significant change.
- March 2015: No significant change.
- October 2015: No significant change noted this inspection.
- March 2016: No significant change noted this inspection. High water level noted. Continued inspections recommended through high lake levels especially following storm events.
- September 2016: No significant change noted this inspection.
- March 2017: Following a recent storm event several sections of Site 4 are now subject to remedial works. These repairs will need to be monitored. Ongoing monitoring is required.
- September 2017: Following the last storm event several sections of Site 4 were subject to remedial works. These repairs appear to be holding well. Ongoing monitoring is required.
- March 2018: As noted in the previous inspection the former storm repairs appear to be holding well. This section requires ongoing monitoring for performance.
- October 2018: No significant change in condition at this location. Ongoing monitoring is warranted.
- March 2019: The upper levels of the revetment appear stable and continuous. There is no significant change in condition at this location however there has been no significant lake level or rain event this last period. Ongoing monitoring is warranted.

- October 2019: The upper levels of the revetment appear stable and continuous. There is no major change from previous inspections. Some small scalloping is possibly occurring and should be continued to be monitored accordingly.
- March 2020: An event in January/February 2020 has resulted in scalloping and loss of the revetment. Repair works are planned for June 2020. Site has been made orange.
- September 2020: Possible small scale scalloping is occurring and should continue to be monitored accordingly. Wall repairs were conducted in July 2020 following an event in Jan/Feb 2020 which resulted in collapse and loss of revetment.
- March 2021: Some rock rip rap has been lost between the railway irons towards the southern end of site. Consider filling thinning pockets with rock rip rap. Scalloping at the top of the revetment should continue to be monitored.
- October 2021: No significant changes. Scalloping is ongoing and the water table upslope requires clearing. Recommended to consider topping up the areas where the rock rip rap is thinning and continued monitoring of scalloping.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: No major change from previous inspections noted. Scalloping appears to be occurring. Continued monitoring of the site after strong winds or heavy rainfall is recommended.
- March 2023: There is no major change from previous inspections. Continued monitoring of the site after strong winds or heavy rainfall is recommended.
- October 2023: A recent event at the end of September shows possible losses of the bottom revetment . Monitoring of the site, particularly following strong winds or heavy rainfall is recommended.
- March 2024: An event at the end of September 2023 showed possible losses of the bottom revetment . Continued monitoring of the site, particularly following strong winds or heavy rainfall is recommended.
- October 2024: No major deterioration of the site was noted from the previous 2023 event. Continued monitoring of the site, particularly following strong winds or heavy rainfall is recommended.

Photographs: S4-101024 (1-12)

2.7 SITE 5

0.5 KM NORTH OF BRAEMAR ROAD INTERSECTION

2.7.1 CURRENT STATUS

There is no immediate threat to the road integrity.

However as minor erosion has been noted and revetment work is to be considered at this site the site was elevated to yellow in March 2017.

The site was elevated in status to Orange in September 2017 following identification of further development of the scalloping at the southern end of the section.

MDC installed a new culvert and drainage sock at the site in early 2018 and rock revetment work was completed.

Monitoring of the site reduced the threat level to yellow in 2020.

A hole has been noted to be developing on the northern end in 2024 with the rip rap needing to be extended to reduce undercutting.

Further monitoring is warranted.

2.7.2 HISTORY

- Mid 1988: 120m of the road reinstated and protected.
- Mid 1989 to December 1995: Protection works collapsed late 1980's and remained reasonably stable until 1995. Erosion then became active 30m to the north and 35m to the south of the collapsed section. (Total length 185m).
- Spring 1996: Rock protection undertaken along 200m of embankment.
- 1996 to November 2000: Virtually no change.
- April 2001: Some minor erosion to landscaped embankment. Virtually no change to rock protection works.
- August 2001: Further erosion into landscaped and lightly armoured embankment (affected length approximately 20m.) This had been caused by rain rather than lake influence. The now exposed embankment toe was considered to be under threat at maximum lake level.
- April 2002: No changes. The exposed section of embankment had not deteriorated.
- September 2002: No changes to the rockwork. Landscaping at higher levels had slumped due to heavy rainstorms.
- April to August 2003: No changes.
- March 2004: No changes. There was no "packed rock" above high lake level at many areas.
- September 2004: There was little change along the protected embankment, Erosion was continuing into the unprotected bank (about 30m length) to the north of the protected area. This had been caused by surface runoff from the road. A water table "turn out" had channelled run-off from the road down the bank.
- April 2005: No changes.

- August 2005: No major changes. Erosion had reactivated with a slight increase in length along the road embankment for about 50m to the north of the existing protection; superficial at this stage.
- March 2006 to March 2009: No major changes.
- May 2009: There was a large slump at the top of the embankment (6x2m) at the northern end of this site. The road formation remained 3m from the edge of the bank.
- October 2009: Erosion had extended a further 300m to the south since the previous inspection. At one location (within the further 300m) the road formation was within 1m of the cliff edge, the remainder varied 3 to 4 m. The newly eroded embankment toe had no protection from further erosion.
- March 2010: No major changes.
- October 2010: No major changes. The eroded faces were showing evidence of slope-wash; the shoulder widths had not decreased.
- April 2011: There has been a marked loss of road shoulder at one area (12m long and full batter height) at this site, along with a noticeable increase in erosion along the rest of the site. The Mackenzie District Council has installed edge marker posts at the 12m long section (now about 1.5m from the road edge). There are no armouring gravels. This particular eroded section is part of the 300m of increased erosion reported on October 2009 (south of the protection works first undertaken in 1988 and reinstated in 1996).
- May 2011: The 12m long section (with loss of shoulder and protection) was reinstated and armoured, along with a general bolstering of the embankment toe where erosion was becoming active (40m total).
- October 2011: No major changes.
- April 2012: No major changes.
- October 2012: No major changes. Minor slumping of toe of remaining slope (50m).
- March 2013: No major changes noted. Some minor slumping north of rock rip rap noted but minor. Continued minor slumping of embankment south of rock rip rap. No threat to road.
- October 2013: No significant change. No change to dropouts north of wall either.
- March 2014: No significant change.
- October 2014: No significant change – maintain inspection.
- March 2015: No significant change. Routine inspections to be continued.
- October 2015: No significant change noted this inspection.
- March 2016: No significant change noted this inspection.
- September 2016: No immediate threat noted although some scour damage was noted together with undercutting of the toe towards the northern end. Some scalloping in the mid-section warrants further monitoring.
- March 2017: Undercutting of the toe towards the northern end of the section was noted. Some scalloping in the mid-section warrants further monitoring. Future revetment works should be considered.

- September 2017: Previous inspections identified undercutting of the toe towards the northern end of the section and these appear to have worsened. Scalloping in the mid-section has also deteriorated. Bank protection works should now be considered on this section.
- March 2018: Previous inspections identified undercutting of the toe towards the northern end of the section and scalloping in the mid-section. A recent culvert has been installed at this location and the road re-instated. Further bank protection in the form of rock revetment should be considered in the future. Ongoing monitoring since the culvert install should occur.
- October 2018: The site requires ongoing monitoring. Erosion around the new culvert section and scallops north of the revetment works require further inspection.
- March 2019: Continued monitoring of the potential for top down run off erosion around the culvert locations is warranted. Some minor runnelling noted in close proximity to the culvert.
- October 2019: No significant change from previous inspection however it appears more material has been placed recently around culvert outlets. This should be monitored and inspected again in 2020.
- March 2020: No major changes noted.
- September 2020: Rock protection has been extended and the upper bank has been regraded. The site appears to be stable. Status requires reassessment next inspection.
- March 2021: Site remains stable, with rock rip rap performing well along the lower bank. Southern end of the upper bank is starting to be affected by runnelling, continue to monitor.
- October 2021: No significant changes. Spraying and maintenance of the water table is recommended. Continue to monitor the southern end of the upper bank.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: Site appears to be stable. The rock rip rap is performing well along the lower bank. Southern end of the upper bank is starting to be affected by runnelling, continue to monitor.
- March 2023: The site appears to remain stable. As with previous inspections the southern end of the upper bank is noted to be affected by runnelling, continue to monitor.
- October 2023: The site appears to remain stable. As with previous inspections the southern end of the upper bank is noted to be affected by some runnelling. Continue to monitor.
- March 2024: The site appears to remain stable. As with previous inspections the southern end of the upper bank is noted to be affected by some runnelling, this needs continued monitoring. A hole is noted at the northern end. To reduce undercutting the rip rap needs to be extended.
- October 2024: The site appears stable and relatively dry. The rip rap is remaining with little loss being noted. Closer inspection and monitoring of the northern end is required.

Photographs: S5-101024 (1-12)

2.8 SITE 6

ADJACENT TASMAN DOWNS HOMESTEAD

2.8.1 CURRENT STATUS

There is no immediate threat to the road integrity.

In 2022 minor undercutting of the road edge was noted. Whilst there is no immediate threat to the road the continued erosion should be monitored.

Spalling of the bank near road level has continued since undercutting was first noted in March 2020. The middle section of the rock rip rap needs topping up and lifting to the underside of the road.

The status was amended to yellow in November 2023. Topping up and repair of the revetment occurred through 2024.

The threat level is to remain at yellow until further inspections in 2025 have been completed.

2.8.2 HISTORY

- Mid 1988: 120m of embankment reconstructed and armoured.
- October 1989: Noted significant downward movement of rock armour at the embankment toe, particularly towards the centre of the reconstruction, exposing large areas of filter fabric.
- October 1989 to April 1995: Situation remained reasonably stable until 1995 when high lake levels reactivated erosion, particularly at the southern end.
- December 1995: Protection collapsed, severe erosion increased, particularly at the southern end.
- Spring 1996: 150m of embankment armoured with coarse rock.
- 1996 to November 2000: Conditions remained much the same. Erosion still continued at the southern end. The cliff edge was 5 m from the road formation at its closest point.
- April 2001: Erosion was continuing. Most areas previously eroding had lost more material since the last inspection but without dramatic effect. There were many pockets of unprotected embankment, some with undermining, along two-thirds of the length. There was no rock protection at the southern end which left about 60m of road embankment threatened. The road formation remained 5m from the cliff edge in the worst instance.
- August 2001: No change. 265m of collapsing protection rock plus 60m of unprotected cliff south of the existing protecting works left the road embankment at risk during high lake levels.
- April 2002: No change.
- September 2002: No changes except for 1 small pocket of increased erosion (several metres long) at a high level.
- April 2003: No major changes.

- June 2003: Rock previously placed 1988 and subsequently dragged downward during successive lake cycles was used to re-armour the batter toe for approximately 45m. Isolated holes in the bank were also packed with retrieved rock.
- August 2003: No changes.
- March 2004: No major changes. The high lake accentuated the lack of armouring at the southern end, (which is continuing to erode), and the large gaps exposing embankment within the current protection.
- September 2004: Several of the isolated holes in the bank at high water line had increased slightly in size and were eroding. The cliff edge was 3.5m at its closest point along a 50m length. Protection work carried out in June 2003 was covered with a layer of medium gravels. Erosion at the southern end of the site was continuing; remained well beyond the road embankment.
- April 2005: Isolated holes in the bank continued to erode; opposite areas lacking protection at the high water line. The most affected lengths equalled about 50m. Available road shoulder had not decreased in width.
- August 2005: Erosion continued at a slow rate. See comments for April. Erosion to the south of the existing protection works also slowly continued.
- November 2005: An isolated pocket of erosion extending into the embankment was plugged and the batter slope armoured with coarse rock.
- March 2006: No major changes. November 2005 protection works had not been subjected to a complete lake level cycle.
- September 2006: No major changes.
- March 2007: No major changes. The minor protection works completed in November 2005 had not altered due to high lake levels and remained stable.
- November 2007: No major changes.
- March 2008: No major changes.
- May/June 2008: Augmentation of the existing protection was undertaken where the rock had slumped and/or the protection was light. This was tied into the existing batter slope (see Construction Sketch #5 Appendix D, September 2008 report).
- September 2008: No major changes.
- March 2009: No major changes. There had been minor 'freshening' of erosion between the recently protected sections at the southern end.
- May 2009: No major change. There had been some erosion within the gaps between previously armoured lengths at the southern end.
- October 2009: No major changes. The gaps between armoured sections may have eroded slightly.
- March 2010: No major changes. The gaps between armoured sections had continued to increase (to a minor degree).
- October 2010: No major changes.

- April 2011: No major changes. The gaps between armoured sections have continued to increase (to a minor degree).
- May 2011: The protection works at this site was extended 145m to the south along with filling and tying in of the various gaps within the armoured sections along the entire site.
- October 2011: No major changes.
- April 2012: No major changes. The size of several gaps which remained along the embankment armour may have increased due to adverse weather.
- October 2012: No major changes. Minor slumping of embankment continues.
- March 2013: No major changes noted. Some minor caving/tunnelling at high water mark noted.
- October 2013: No significant change. Occasional caving at high water mark but not significant.
- March 2014: No significant change noted although some possible erosion at gaps in rock armour where some caving is occurring.
- October 2014: No significant change, however caves are developing to the north of the section. Consideration should be given to placing small amounts of rock at these locations to slow erosion and/or development of further scallops and caves.
- March 2015: Threat level reduced to Green. 80m of revetment work repaired with 40m of new revetment work completed in February 2015. Continued monitoring of any new cave features required and consideration of placing further rock protection over time. Assess next inspection.
- October 2015: No significant change noted this inspection. Caves previously identified along northern parts are mostly filled. Continued monitoring is recommended.
- March 2016: No significant change noted this inspection. High water level noted as well as minor caves at southern end of revetment work.
- September 2016: No significant change noted this inspection. High water level noted as well as minor caves at southern end of revetment work.
- March 2017: There was no significant change noted this inspection. Minor caves at southern end of revetment work were again noted together with some minor settlement of existing revetment work. Further monitoring is required.
- September 2017: No significant change noted this inspection. Minor caves at southern end of revetment work were again noted together with some minor settlement of existing revetment work. Further monitoring is required.
- March 2018: As with the previous inspection there is no significant change noted this inspection. Further monitoring of caving and bank settlement is required.
- October 2018: No significant change noted this inspection. As noted previously minor maintenance is required to top up the rock fill beneath the shoulder of the road. Consider minor infilling of low points.
- March 2019: As with the previous inspection no significant change has been noted. Consideration should be given to potentially topping up the rock fill in the next 12-18 months.

- October 2019: There did not appear to be any major change in condition however consideration should be given to topping up the revetment works to the north of the section in the next maintenance period.
- March 2020: Undercutting of the road is becoming apparent and should be monitored closely next inspection.
- September 2020: Topping up the revetment works to the north of the section should still be considered next maintenance period. There have been no significant changes to this site. Undercutting of the road noted in March 2020 should be examined again next inspection.
- March 2021: Spalling of the bank near road level has continued since undercutting was first noted in March 2020. Closer inspection of the road should be carried out next inspection. Topping up the rock rip rap in this section should be considered.
- October 2021: No notable changes since the previous inspection.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: Spalling of the bank near road level has continued since undercutting was first noted in March 2020. Topping up the rock rip rap in this section should be considered.
- March 2023: As with previous inspections spalling of the bank near road level has continued since undercutting was first noted in March 2020. Topping up the rock rip rap in this section should be considered.
- October 2023: As with previous inspections spalling of the bank near road level has continued since undercutting was first noted in March 2020. The middle section of the rock rip rap needs topping up and lifting to the underside of the road. The status has therefore been amended to yellow until works have been completed and subsequent inspection during next scheduled visit.
- March 2024: As with previous inspections spalling of the bank near road level has continued since undercutting was first noted in March 2020. Topping up of the rock rip rap should be completed this year to lift the level to the underside of the road. The status remains at yellow until works have been completed and a subsequent inspection during the next scheduled visit.
- October 2024: Some topping up of the rock rip rap appears to have been completed over the last 12 months. This should continue to be monitored. Some loss of rock into the lower beach is evident. Some further topping up of the rip rap along the road edge and filling notable gaps would be beneficial.

Photographs: S6-101024 (1-14)

2.9 SITE 7

1.4 KM NORTH OF BOLTONS GULLY

2.9.1 CURRENT STATUS

There is no immediate threat to the road integrity.

Previous inspections identified evidence of the high-level outlet having had water flow suggesting that the lower outlet pipe was blocked.

Upstream road washout risk is still considered possible at this location. Loss of the road as a result of such an event would not be a Meridian Energy cost.

2.9.2 HISTORY

- August 1991: A major road washout occurred during a torrential downpour as the culvert was unable to cope with the volume of water.
- January 1992: Road reinstated by Whitestone Roading under the direction of ECNZ.
- December 1995: Embankment was eroding, vertical face forming.
- December 1995 to May 1998: Situation remained stable until early 1998. May inspection noted a section of the reinstated embankment totally unprotected and eroding at the toe.
- December 1999: 50m of exposed embankment armoured with coarse rock.
- May 2000: Profile survey undertaken.
- October 2000 to April 2001: No changes.
- August 2001: No changes. The lower culvert was blocked by beach gravels (Mackenzie District Council advised by facsimile 3 September 2001).
- April 2002: No changes. The lower culvert was blocked by beach gravels. Mackenzie District Council advised by facsimile 16 April 2002. Response received from Mackenzie District Council 29 April 2002.
- September 2002: No changes. The bottom culvert was clear of gravel.
- April to August 2003: The beach gravels at the batter toe had been washed away leaving the bottom row of protection rock exposed on the beach with little support. The lower culvert was clear.
- March 2004: No major changes. Noted the gully across the road was full of water corresponding with lake level (high level culvert clear).
- September 2004: No changes. Upper and lower culverts clear.
- April 2005: No changes. Lower culvert blocked.
- August 2005: No changes. Lower culvert blocked.
- March 2006: No changes. Lower culvert blocked.
- September 2006: No changes. Lower culvert clear.
- March 2007: No changes. Lower culvert blocked.

- November 2007: No changes. Lower culvert clear.
- March 2008: No major changes. Lower culvert clear.
- September 2008: No major changes. Lower culvert clear.
- March 2009: No major changes.
- May 2009: There were no changes at this site. However the top culvert had been flowing at a rapid rate, indicated by erosion at the outlet. If the culvert had not coped there would have been road damage as a consequence.
- October 2009: No major changes.
- March 2010: No major changes. Lower culvert blocked.
- October 2010: No major changes.
- April 2011: The lower culvert was underwater. The creek upstream of the road embankment appeared to be flowing normally.
- October 2011: No major changes. The lower culvert outlet was clear.
- April 2012: No major changes. The lower culvert outlet is clear.
- October 2012: No major changes. The lower culvert outlet is clear. The upper culvert outlet has a sock attached.
- March 2013: No major changes noted. Discussion held on site regarding extension of culvert outlet further out to beyond spit, approx. 20m.
- October 2013: No significant change. Continued discussions re pipe extension but no immediate need. Possible extension 10m or so is more realistic.
- March 2014: No significant change.
- October 2014: No significant change, continue to monitor.
- March 2015: No significant change. The outfall pipe is submerged and covered over by silt. Reconsider options to extend outfall to prevent blocking.
- October 2015: No significant change noted this inspection. The outlet pipe was completely submerged by saturated gravel with water backing up on paddock side. Third party drainage maintenance and/or modification required to ensure pipe free flows. Consideration should be given to extending the outlet. (Remediation of a lost embankment would not be a Meridian cost.)
- March 2016: No inspection of the outlet pipe due to high lake level. Pipe was totally submerged. The pond level was potentially higher than the lake level suggesting possible blockage of the outlet pipe. Pipe outlet should be extended to remove potential of blockage.
- September 2016: Pipe outlet buried in beach gravel. Pond back up and inlet flooded and partially buried in mud. Pipe requires clearing.
- March 2017: Unable to inspect the outlet this inspection due to high water level. The pipe is however submerged. Evidence of flow through the high level outlet pipe was noted indicating that the lower pipe was most likely blocked at one point.

- September 2017: No change to the current situation. Very low water during this inspection. The outlet pipe is still covered by gravel.
- March 2018: As with previous inspection there is no change to the current situation. Very high water level during this inspection. The outlet pipe could not be observed.
- October 2018: Site continues to appear stable. No significant change noted from previous inspection. Site condition returned to green.
- March 2019: The outlet was below the lake level during this inspection. No significant change in the embankment was noted. Site condition remains Green.
- October 2019: The outlet was exposed during this inspection. No significant change in the embankment was noted.
- March 2020: No significant changes noted.
- September 2020: There continues to be no significant change in the embankment.
- March 2021: Small flow of water visible from low level culvert, otherwise no notable changes to this site.
- October 2021: No significant changes noted.
- March 2022: Inspection was undertaken from the roadside and not from the lake. No notable changes since previous inspection.
- November 2022: The outlet was below the lake level during this inspection. No significant change in the embankment was noted. Site condition remains Green.
- March 2023: The outlet was below the lake level during this inspection. A road level No inspection completed this period has not identified any significant change in the embankment.
- October 2023: The outlet was below the lake level during this inspection.
- March 2024: The outlet was below the lake level during this inspection.
- October 2024: The outlet was visible during the UAV inspection. Consideration could be given to adding further rip rap around the culvert outlet to reduce erosion effects. As previously noted the outlet should be extended to prevent blocking.

Photographs: S7-101024 (1-9)

2.10 SITE 8N 

NORTH OF SITE 8

2.10.1 CURRENT STATUS

There is no immediate threat to the road integrity. Dropouts and carving of the slope identified in 2017 and again in 2018.

Site separated from Site 8 and formed as new site in October 2018.

The site condition was raised to yellow in March 2018 but was reduced to green in 2020.

Continued monitoring of the site is warranted.

2.10.2 HISTORY

- October 2018. Site created in October 2018. Minor drop outs and carving of the cliff face. Continue to monitor in 2019.
- March 2019: Slope failure and carving of the embankment was noted. Minor drop outs and bank erosion has continued but is relatively minor. Site to be retained at yellow for further inspection in 2020.
- October 2019: Slope failure and carving of the embankment appears to be continuing at this site. Minor drop outs and bank erosion was previously noted but is relatively minor. Site to be retained at yellow for further inspection.
- March 2020: No significant changes: Continue to monitor
- September 2020: Slope failure and carving of the embankment is generally prevalent at this site although no significant changes are noted. In previous inspections minor drop outs and bank erosion have been noted but have been relatively minor for the last two inspections. Site to be retained at yellow for further inspection and monitoring.
- March 2021: Slumping and erosion of exposed banks has continued at this site, but generally in a similar condition as two prior inspections. This site should continue to be monitored and warrants a walkover next inspection.
- October 2021: Site not inspected due to covid 19 restrictions.
- March 2022: Some vegetation coming back. No major change. Monitor effect of removal of pine trees at southern end of S8 over next 12 – 18 months.
- November 2022: Recent heavy rainfall has resulted in some slope degradation. Continue to monitor the effect of removal of pine trees.
- March 2023: Since removal of the pine trees the upper slope has been subject to minor slope erosion. Continue to monitor.
- October 2023: Removal of the pine trees on the upper slope has likely caused minor slope erosion. Continue to monitor.
- March 2024: Pine tree removal previously completed continues to cause minor slope erosion. Monitoring should continue.

— October 2024: Not specifically inspected this visit. Pine tree removal previously completed continues to cause minor slope erosion. Monitoring should continue.

Photographs: None this visit

2.11 SITE 8

TEKAPO 'B' POWERHOUSE ACCESS RD, 3.09 - 3.52 KM NORTH OF SH 8 INTERSECTION

2.11.1 CURRENT STATUS

There is no immediate threat to the road integrity. However, the storm event recorded in January 2017 combined with high lake levels caused localised scour of the bank and some minor dropouts to be noted. The threat status was raised to yellow accordingly.

As such revetment work should be considered for this site in the future and the site continue to be monitored.

The threat status of the site has been elevated to yellow since March 2017.

2.11.2 HISTORY

Erosion has been superficial since the early 1990's. The gravel embankment constructed autumn 2008 reduced the potential for further erosion. In some areas there is little toe protection therefore potential exists for further erosion during periods of high lake.

In 2013 a cut/excavated face was noted towards the southern end of the section.

This road provides essential access to Tekapo 'B' Powerhouse.

— September 2002: Noted some minor increases in erosion within the top-soiled upper levels of the embankment. Some slipping and formation of tension cracks had occurred. No increased threat to the road integrity.

— April to August 2003: No further changes.

— March 2004: No major changes. Fresh erosion on the cliff face evident.

— September 2004: No major changes. Erosion was active but not rapid.

— April 2005: No major changes.

— August 2005: No major changes.

— March 2006: No major changes. Continuing erosion was evident, possibly due to slope wash.

— September 2006: There were no changes, other than superficial, at this location. Noted the close proximity of the fibre optic cable to the edge of the cliff (2 to 3m at the closest point). The cliff consists mainly of sand with some silt and gravel. Rock from an early protection works, believed to be at least 30years ago, litters the beach.

— March 2007: No major changes. The close proximity of the cliff to the fibre optic cable was stressed. Serious repercussions could result from sideways movement of the cable due to batter slump or tension cracks causing significant movement of the cable.

— November 2007: No major changes.

- March 2008: No major changes.
- May/June 2008: An embankment (gravel with rock rip rap outer surround) was constructed at the toe of the cliff.
- September 2008: No major changes.
- March 2009: No major changes.
- May 2009: No major changes.
- October 2009: No major changes. Some rock settlement was apparent.
- March 2010: No major changes. Erosion at the northern end and beyond (previously armoured in excess of 30 years ago) was becoming more active.
- October 2010: No major changes. Erosion at the northern end was continuing slowly.
- April 2011: No major changes. There had been a general increase in erosion activity along sections of the site; nothing of significance.
- October 2011: No major changes.
- April 2012: No major changes.
- October 2012: No major changes.
- March 2013: No major changes noted.
- October 2013: No change. Minor soil slips, superficial.
- March 2014: No significant change. Noted excavated cut face/drop out at down-ramp area, no change to previous inspections.
- October 2014: No significant change.
- March 2015: No significant change this inspection.
- October 2015: No further deterioration of this site noted this inspection. Continued monitoring of slope face recommended.
- March 2016: No significant change noted. High lake level was same level as the wave cut platform and revetment work. Level appeared good.
- September 2016: No significant change noted this inspection.
- March 2017: Recent high lake levels appear to have scoured the bank and caused some localised drop outs. Future revetment work should be considered for this site. Monitoring of this section is required.
- September 2017: Evidence of recent scour was again noted. Monitoring of this section is recommended.
- March 2018: Evidence of recent top down rain erosion was noted. Ongoing monitoring of this section is recommended.
- October 2018: Continued evidence of top down rain erosion was noted. Ongoing monitoring of this section is again recommended. No significant change from previous inspection.
- March 2019: Further minor spalling of the faces was noted along this section. Although minor falls the site warrants further inspection.

- October 2019: Further minor spalling of the faces was noted along this section in March 2019. The site warrants continued monitoring.
- March 2020: Further spalling has led to the development of toe caves with the spur likely to continue to erode.
- September 2020: Minor spalling of the faces occurred along this section in March 2019. The development of caves at the toe previously noted and likelihood of the spur eroding warrants continued monitoring.
- March 2021: Some fresh slumping of banks has occurred in the same area that minor spalling was noted in March 2019. Scalloping of the banks was noted at the northern end of the revetment, consider extending rock rip rap. Caves at the toe of the slope do not appear to be worsening but should continue to be monitored.
- October 2021: No significant changes from previous inspection.
- March 2022: Some vegetation coming back. No major change. Monitor effect of removal of pine trees at southern end of S8 over next 12 – 18 months.
- October 2022: Some vegetation coming back. No major change was noted. Continue to monitor the effect of pine tree removal.
- March 2023: Some vegetation coming back. No major change was noted. Continue to monitor the effect of pine tree removal.
- October 2023: Some revegetation is occurring, however some bank spalling has occurred. Continue to monitor the effect of pine tree removal.
- March 2024: Revegetation continues, however small amounts of bank spalling also continues to occur. Monitoring of the effects of pine tree removal should continue.
- October 2024: Revegetation continues, minor bank spalling also continues to occur. Monitoring of the effects of pine tree removal should continue.

Photographs: S8-101024 (1-10)

2.12 SITE 8A

TEKAPO 'B' POWERHOUSE ACCESS RD, 0.95 - 1.13KM NORTH OF SH 8 INTERSECTION

2.12.1 CURRENT STATUS

There is no immediate threat to the road integrity.

2.12.2 HISTORY

Formal reporting at this site commenced April 2005. The existing rock protection work was placed many years ago, possibly during construction of the road.

Minor erosion to the south of the protection has been active (prior 2005) although in recent years appears to have stabilised.

The beach has a relatively flat slope.

- April 2005: No changes.
- August 2005: No changes.
- November 2005: Rock revetment extended 40m to the south.
- March 2006: No major changes. Extended revetment had not been subjected to a complete lake level cycle.
- September 2006: No major changes. The extended revetment had not been subjected to a complete lake level cycle.
- March 2007: No major changes. The extended revetment completed in November 2005 had not altered due to high lake levels and remained stable.
- November 2007 to May 2009: No major changes.
- October 2009: No major changes. Minor erosion (15m long) above the rock protection at the northern end.
- March 2010: No major changes.
- October 2010: No major changes.
- April 2011: No major changes. The minor erosion at the northern end had freshened slightly.
- October 2011: No major changes.
- April 2012: No major changes.
- October 2012: No major changes.
- March 2013: Some minor scour noted at the southern end of the rock revetment with some minor vegetation loss.
- October 2013: Minor vegetation loss. Small caving towards the southern end of the section.
- March 2014: No significant change noted. Caving and deterioration of rock armour in central section to be monitored.
- October 2014: No significant change.

- March 2015: No significant change noted. Rock armour inspected and continued monitoring of outer limits of protection still required. No change in threat level.
- October 2015: No significant change noted this inspection.
- March 2016: No change noted this inspection. Minor slope failure noted at southern end of section. Continue to monitor.
- September 2016: No significant change to this site from previous inspection.
- March 2017: There was no significant change to this site from the previous inspection.
- September 2017: No significant change in condition noted this inspection.
- March 2018: Observations made during the inspection identified a number of minor drop outs to have occurred since the last inspection. These should continue to be monitored.
- October 2018: No significant change noted over previous inspections. Continued monitoring is recommended.
- March 2019: No significant change noted over previous inspections. Continued monitoring is recommended.
- October 2019: No significant change noted over previous inspections. Consideration of topping up the rock revetment work at the northern end. Continued monitoring is recommended.
- March 2020: There has been some minor change noted since the last inspection with a top up of the southern end of the protection recommended as well as at the northern end.
- September 2020: No Significant change has occurred. However, topping up the rock revetment work at both the northern and southern ends should still be considered as noted in the previous inspection. Continued monitoring is recommended.
- March 2021: As per previous inspections, no significant change. Topping up the rock revetment work at both ends should still be considered. Continued monitoring is recommended.
- October 2021: Site not inspected due to covid 19 restrictions.
- March 2022: As per previous inspections, no significant change. Topping up the rock revetment work at both ends should still be considered. Continue to monitor.
- November 2022: Some vegetation coming back. No major change was noted. Continue to monitor the effect of pine tree removal.
- March 2023: No change noted from previous inspection. Continued maintenance and management of the rock revetment work at both ends should still be considered. Continue to monitor. Site appears stable.
- October 2023: Maintenance and management of the rock revetment work at both ends needs to be undertaken. Site appears stable at present, but careful monitoring needed.
- March 2024: Maintenance and management of the rock revetment work at both ends still needs to be undertaken. Site appears stable however a hole which previously appeared at the northern end continues to need careful monitoring.

— October 2024: Minor bank loss continues. Continue to monitor. Consideration to placing additional rip rap may be warranted in the future.

Photographs: S8A-101024 (1-5)

3 SOUTHERN SHORELINE (RCA – WAKA KOTAHI NZ TRANSPORT AGENCY)

3.1 SITE 9

SH 8 RP 131/10.97 - 11.67, (OPPOSITE KATHERINE FIELDS)

3.1.1 CURRENT STATUS

There is no immediate threat to the road integrity.

The 2017 storm event did result in some erosion of the bank below the cycle trail.

On-going proposed monitoring and maintenance programme supported.

The threat status of the site has been elevated to yellow, inspection and monitoring should continue.

3.1.2 HISTORY

Since lake filling in the mid 70's this section has had active erosion although at irregular rates, depending on lake level/wind conditions. Noticeable erosion occurred prior to December 1998.

- December 1999: Approx. 500 m3 rock stockpiled on beach for future use.
- May 2000: Profile survey undertaken.
- April 2001: Erosion continuing. Cliff face almost vertical. Groyne construction was planned for during the next low lake levels.
- August 2001: No further changes.
- October 2001: Two rock groynes and 70m of rock revetment constructed. Benchmark, profile 3A, installed for monitoring purposes.
- April 2002: No major changes to exposed cliffs. Some gravel build-up occurred to the east of the groynes.
- September 2002: No major changes.
- April 2003: Beach gravel build-up was continuing. Rock revetment sound.
- August 2003: No change. The lake level had not been high enough to effect gravel build up at the groynes.
- March 2004: No obvious major changes. Some fresh cliff erosion.
- September 2004: The rock revetment works remained sound. The groynes were collapsing. There was evidence of gravel build up.
- April 2005: No visible changes.

- August 2005: No major changes to the cliff faces, although erosion was still continuing in places. The eastern groyne had collapsed and was being dispersed. Noted the build-up of gravels between the two groynes since installation in October 2001.
- November 2005: Rock revetments extended east and west by approximately 30m in each direction.
- March 2006: No major changes. Continuing erosion evident. Extensions to the rock revetment had not been subjected to a complete lake level cycle.
- September 2006: No major changes. Continuing erosion due to weather was evident. Extensions to the rock revetment had not been subjected to a complete lake level cycle.
- March 2007: No major changes. The eastern groyne had collapsed and was being dispersed. The build-up of gravels between the two groynes since their installation in October 2001 had been extensive.
- November 2007: No major changes. Erosion continued into the toe of the cliff east of the rock revetment (now several metres) to a degree that collapse would eventually occur over about a 30m length. The eastern groyne continued to be dispersed.
- March 2008: No major changes.
- September 2008: No major changes.
- March 2009: No major changes. There was new erosion with an increase of tunnelling at the toe along much of the cliff at the southern end.
- May 2009: Moderate erosion had occurred. There was continued erosion with quite extensive collapse of the bank in some places. The existing protection works did not incur damage at the high water line.
- October 2009: Erosion since late May had not increased; however, compared with September 2008, significant erosion had occurred along the majority of the southern shoreline. Existing protection remained sound. The collapsed eastern groyne had not deteriorated markedly.
- March 2010: No major changes.
- October 2010: No major changes. Erosion at the unprotected sections continued along the cliffs.
- April 2011: No major changes. The recent erosion at the toe of the cliff (in various pockets along the majority of the site) signalled the start of a new round of collapse above. The existing protection works completed in October 2011 remained sound. Collapse of the groynes had slowed and they were continuing to encourage a deep gravel build-up along the beach.
- August/September 2011: One rock groyne, 100m (approx.) of rock revetment and 60m (approx.) of cliff toe protection constructed.
- October 2011: No major changes. Erosion at the unprotected sections was continuing along the cliffs.
- April 2012: No major changes. There was insufficient lake rise in the past 12 months to submerge the protection works of spring 2011.
- October 2012: No major changes. Some minor slumping noted along section. No significant failures.

- March 2013: Increased amount of slope failures noted along eastern section. Some failures relatively large and recent. Noted continued filling of shoreline gravel between groynes. Minor slumping at western end although no significant change at this end of the site. Discussion held regarding monitoring points and proximity of the Alp to Ocean cycle track constructed in early 2012. New Bank erosion monitoring pegs installed in June 2013.
- October 2013: Continued minor slumping. Performance at eastern end worse, possibly consider revetment at base of cliff. At western end performance acceptable.
- March 2014: No significant change noted. Continued erosion at eastern end albeit not as pronounced as recent inspections.
- October 2014: Revetment work during June to August mostly complete, however a 50m section is incomplete. Toe protection has been created and placed. The remaining section should be prioritised and completed as soon as practicable.
- March 2015: Re-inspection of completed revetment work. 65m of work completed in December 2014. Appears to be providing good protection. Threat level reduced to yellow. Monitoring and inspection to continue.
- October 2015: All revetment work on this section was completed early 2015. Continued monitoring of the completed works is recommended. Maintain observations of slope face above revetment work.
- March 2016: No significant change to section. Revetment work is standing and looking in good condition. No issues noted with slope above revetment work.
- September 2016: Minor slope dropouts noted above the revetment works. Continue to monitor slope deterioration above rock works. Revetment work is unchanged from previous inspection.
- March 2017: Following recent storm event and high lake levels a walkover inspection of the site is required to assess repair works to existing revetment. This will need to be completed at low lake level accordingly. Further monitoring and repair work is required.
- September 2017: Remedial revetment work is now underway. No detailed inspection completed this inspection. Monitoring of remedial work is required.
- March 2018: The revetment work on this section is complete. The inspection identified some localised low spots and possible hollows occurring behind the main face. These hollows should be further monitored and potentially filled.
- October 2018: As with previous inspections some localised low spots and possible hollows were noted occurring behind the main face. These hollows should be further monitored and potentially filled. Consider raising the height of the rip rap.
- March 2019: As with previous inspections some minor erosion was noted behind the rip rap areas. These hollows should be further monitored and potentially filled. Further monitoring is required to assess whether raising the height of the rip rap will be of benefit.
- October 2019: As with previous inspections some minor erosion was noted behind the rip rap areas. Continued monitoring is recommended.
- March 2020: Minor spalls noted otherwise no significant change.

- September 2020: There is no evidence of change other than vegetation which is taking hold. The site currently appears to be stable.
- March 2021: No sign of fresh failures and revetment seems to be holding. The site is generally stable, but monitoring should continue.
- October 2021: No evidence of further failure. Continue to monitor.
- March 2022: Revetment appears to be performing well. Some small hollows forming at northern end but generally good. Continue to monitor
- November 2022: Revetment appears to be performing well. Some small hollows forming at northern end but generally good. Continue to monitor.
- March 2023: The site continues to perform well. Previous small hollows are to be monitored.
- October 2023: The site generally continues to perform well, however previous small hollows toned to continue to be monitored. Minor spalling noted above the revetment with a minor drop on the right-hand side.
- March 2024: The site generally continues to perform well. Previous small hollows were still noted however and need to continue to be monitored. Minor spalling was noted above the revetment with a minor drop on the right hand side.
- October 2024: The site generally continues to perform well. Previous small hollows were still noted however and need to continue to be monitored. Consideration to be given to topping up the rock rip rap along this section to maintain performance. Evidence of rock being lost to the lower beach.

Photographs: S9–101024 (1-7)

3.2 SITE 10 

SH 8 RP 131/12.7 (ADJACENT GUARDRAIL)

3.2.1 CURRENT STATUS

There is no immediate threat to the road integrity. However, recent storm damage in January 2017 resulted in minor damage to the gabion baskets.

The threat level status of this site was elevated to yellow in March 2017 as damage to the gabions was noted to be increasing with material loss from the lower tier.

The threat level was increased to orange in March 2018 as further material loss and minor slumping of the wall was noted.

Repairs to the gabion baskets was completed in 2019 to reduce further material loss. Further monitoring in March 2020 has led to a reduction in status to green.

3.2.2 HISTORY

- February 1988: Gabion wall constructed. 160m long with 6m wide Reno mattress.
- December 1988: Reno mattress extended both ends to give added wall protection.
- Summer 1989: Coarse rock armour replaced at the toe of the mattress. (Washed away previous winter). Sections of the eastern end (coarse gravel movement abrasion damage) overlaid with Terramesh panel.
- February 1992: Empty and partially empty sections of the Reno mattress repacked. To prevent undermining, a blanket of coarse gravels up to 300mm deep was placed at the toe of the mattress between meterage 0 and 60 from the eastern end.
- November 1994: Noted 14m of the eastern end of the Reno mattress 'perched' above beach level, due to all surrounding gravels having been washed away.
- May 1995: Six sections within two areas of the Reno mattress had slumped significantly causing the gabion wall to be undermined but not slumping.
- Movement of gravels continued to cause severe abrasive wear to the mattress wires. Coarse rock was placed at the eastern end of the mattress. This extended 5m north and 6m east from the outer edge and was tied in with the existing rock protection. The mattress was surrounded by rock in an attempt to prevent further slumping.
- Low slump concrete was placed over a randomly selected section of the Reno mattress to a nominal depth of 50mm. Prior to initial set a 40mm deep groove on a 1m grid was formed to encourage a regular cracking pattern. This was carried out as a trial to protect the mattress wires from further abrasion and to prevent entry of fine gravels into the already overfilled mattress sections causing them to burst.
- July 1996: Noted several empty Reno mattress and gabion wall sections. The wall sections were opposite the concrete overlaid areas. The concrete protected the wires but had prevented the mattress from acting as a wave diffuser.
- Summer 1996: The rock apron below the Reno mattress was augmented providing a tight rock matrix adjacent to the toe. Damaged mattress sections were replaced. Concrete was

placed within mattress cavities and into empty gabion wall sections. Rock groynes were constructed at the west end and opposite the middle of the gabion wall. These were intended to act as a barrier to mobile gravels and encourage beach build-up.

- October 1997: Noted significant build-up of gravels to the east of the rock groynes.
- May 1998: Reno mattress wires continued to be severely abraded. 25 sections of the mattress required repacking with rocks.
- December 1998: Coarse angular rock placed over the entire Reno mattress extending several metres above and below maximum lake level.
- October 1999: Rock placed over the Reno mattress remained well packed. Noted the groynes were being 'pulled apart' by wave action. This could be expected as the rocks had been stacked loosely to assess the ability of groynes to trap gravel and initiate beach build-up.
- November 2000: The groynes continued to collapse. A build-up of gravels remained at the higher beach level. The lower beach had not been exposed since construction of the groynes.
- April 2001: There were no significant changes since the last inspection. The groynes were continuing to collapse, although still encouraging gravel build-up on the beach.
- August 2001: No changes. The beach had a significant build-up of gravels adjacent to the groynes.
- April 2002: Extensive gravel build-up east of the groynes; (increase in depth since the previous inspection). No further changes. Rock on Reno Mattress was stable.
- September 2002: Rock placed at the eastern end of the Reno Mattress in 1995 was becoming further scattered. The mattress was not exposed or threatened and although the rock was no longer packed, any voids were well filled with gravel.
- Gravel build-up to the east of groynes had increased and totally covered the beach between the groynes. (Depth tapered in an easterly direction). Rock covering the Reno Mattress appeared unaltered.
- April 2003: No major changes. Rock placed at the eastern end of the Reno Mattress had been further scattered.
- August 2003: No changes.
- March 2004: No changes.
- September 2004: No changes. Gravel build-up continued within the rock placed over the Reno Mattress and along the beach.
- April 2005: No changes.
- August 2005: No major changes. Two sections at the top of the wall had broken open.
- March 2006: No major changes.
- September 2006: No changes.
- March 2007: No major changes. The eastern end of the Reno Mattress had been exposed due to wave action.

- November 2007: No major changes. Exposure of the Reno Mattress at the eastern end had decreased due to renewed gravel build-up.
- March 2008: No major changes. Increased gravel build-up at the eastern end had increased slightly.
- September 2008: No major changes.
- March 2009: No major changes. Several small areas of Reno Mattress had been exposed at the high water line.
- May 2009: No major changes. Suspected a small increase in the number of areas of exposed Reno Mattress.
- October 2009 to April 2012: No major changes.
- October 2012: No major change. Continued gravel build up between groynes.
- March 2013: Some minor changes noted. Continued gravel build up between groynes as per October 2012. Some minor loss at western end (dam end) of gabion wall. Minor scour at high water mark above large boulders. Filled corner rock is intact.
- October 2013: No significant change.
- March 2014: No significant change.
- October 2014: No significant change. Continued monitoring programme supported.
- March 2015: No significant change this inspection.
- October 2015: No change this inspection.
- March 2016: No changes noted this inspection. High water line.
- September 2016: No changes noted this inspection.
- March 2017: Following recent high lake level and storm, several gabion baskets were noted to be sagging and have material loss. A detailed walkover inspection at low lake level is required to assess minor gabion basket repairs and potential for further deterioration. Consider placement of rock revetment along lower tier and refill gabions. Monitoring is required.
- September 2017: Further slumping of gabions noted this inspection. Loss of material from lower tier of baskets was considered to be worsening. Remedial actions required to stop material loss. Work on lower tier is considered urgent.
- March 2018: As with previous inspections the gabion baskets were noted to be slumping and potentially worsening in condition. Further loss of material from the lower tier of baskets was considered to be continuing. Work to reduce material loss and reduce the slumping effect on the wall is now considered urgent. The road is not at immediate risk.
- October 2018: As with previous inspections the voids in the lower tiers of the gabion baskets was noted to be worsening. Maintenance and repair of the lower tier is warranted. The road is not at immediate risk.
- March 2019: The voids in the gabion baskets have been filled and faced with concrete abutments. Additional rock protection has been placed in front of the gabion walls and the new abutments have been dowelled in to new concrete aprons and the former reno mattress.

The site should be monitored over the winter period and minor movement of the rock revetment is anticipated. Site returned to yellow but requires further monitoring.

- October 2019: No major change noted from the previous inspection. The site should be monitored. Site to remain yellow.
- March 2020: Repairs completed in 2019 appear to be holding well with some minor gaps only noted on the western end. Site has been downgraded to green.
- September 2020: As per previous inspections, no major change has been noted. The site should continue to be monitored. Previous repairs made continue to be holding well. Minor gaps have been noted in the past at the west end.
- March 2021: No significant changes at this site, gabion wall and rock rip rap are performing adequately. Western end of wall should continue to be monitored for loss of rock rip rap.
- October 2021: Site not inspected due to covid 19 restrictions.
- March 2022: Appears to be some stone loss north of the concrete repairs otherwise performing adequately. Inspect at next inspection.
- November 2022: Site appears to be stable. Some evidence of tree wash up on beach. Repairs appear to be holding well.
- March 2023: No obvious change from previous inspection. Site appears to be stable.
- October 2023: Site appears to be stable with no obvious major change from previous inspection. Some loss of gabion cobbles were however noted.
- March 2024: Site appears to be stable with no obvious major change noted from previous inspection. Some loss of gabion cobbles were however noted as per the previous inspection.
- October 2024: Site shows no obvious major change. The low water inspection indicates that rip rap in front of the gabion wall is low in the mid and southern section of the wall. Consideration could be given to extending and filling the mid and southern areas between the existing groynes.

Photographs: S10–101024 (1-8)

3.3 SITE 11

SH 8 RP 131/12.83 - 13.06, (GUARDRAIL WEST)

3.3.1 CURRENT STATUS

There is no immediate threat to the road integrity however deterioration of the revetment work was noted to have occurred in March 2017.

Approximately 120m of rock revetment was installed in May - June 2013 which was noted in March 2014 to be settling and failing from being over steep.

Remedial works were completed in December 2014 with part of the revetment work being re-stacked at a lower face gradient.

Inspection in March 2018 indicated that repairs to the revetment work were complete and appeared to be stable.

Further monitoring is required.

3.3.2 HISTORY

Erosion at this site has had no effect on the highway. The site is very exposed to lake and wind influences. Erosion is active; the rate is slow. The bank is near vertical containing some coarse material which provides a degree of self-armouring on the beach.

- September 2002: Minor increases in erosion.
- April 2003: The face of the large, eroded section at RP 131/13.06 had been freshened by rainstorms. The top of the slip had not moved closer to the road.
- June 2003: Approximately 50m along the high water line at RP 131/13.06 was armoured using rock retrieved from the beach. (Much of this from earlier protection work in excess of 20 years ago).
- August 2003: No changes.
- March 2004: No changes.
- September 2004: No changes. The protection work undertaken in June 2003 remained intact and stable.
- April 2005 to September 2008: No changes.
- March 2009: No major changes. New erosion was apparent.
- May 2009: No major changes. There was some increase in erosion at the higher level; estimated several metres of bank had been lost in some places. The highway formation was approximately 18 to 20m from the edge of the bank along a 100m length.
- October 2009: No major changes. This area was open to further erosion.
- March 2010: No major changes.
- October 2010: No major changes.
- April 2011: There was a noticeable increase in erosion beyond the existing protection (by about 30m). The beach remained well armoured with coarse rock. The cliff consisting of medium

gravels overlaid with silt was vulnerable to further erosion. Undermining had started during the previous high lake.

- October 2011: No major changes.
- April 2012: No major changes. There was some on-site discussion regarding the vulnerability of early protection works (1970's) at the southern end of this site. Much of the embankment is considered to be overlaid fill (coarse gravel over in-situ tightly bound silty gravel), therefore presenting less resistance to erosion. The current protection is still functional but becoming somewhat unravelled at the toe and may eventually become mobile. Augmentation should be considered in the future.
- October 2012: No major changes. Option of future augmentation of protection measures to be monitored.
- March 2013: Some landward retreat of the upper beach was noted during the inspection.
- October 2013: Revetment work completed in June 2013, extended rock protection installed for approximately 120m protecting upper beach and cliff.
- March 2014: Settlement of the revetment work noted together with partial collapse due to over steep construction. Continued maintenance programme supported.
- October 2014: Reconstruction of northern end has been undertaken, however still over steep with rain erosion evident. Monitoring to be undertaken.
- March 2015: No significant change noted this inspection. Continued monitoring programme supported. Threat level maintained at Yellow.
- October 2015: No change from previous inspection. Continue to monitor performance of slope above rock works.
- March 2016: Water level high at time of inspection. Revetment work is very steep. Overall stability of rock placement should be monitored for any movement.
- September 2016: Rock revetment work should continue to be monitored. Some localised scour observed at base of rocks. Continue to monitor.
- March 2017: The placed rock revetment work has notably deteriorated. This is primarily due to having been constructed too steeply and development of scour erosion at base of rock. Detailed inspection at low lake level is required together with repair strategy. Further monitoring is required.
- September 2017: Re-engineered revetment work now complete with rock armour at lower angle of repose. Further monitoring of performance is recommended.
- March 2018: Continued monitoring of the completed revetment work is required. There is no significant change to the condition of the site from previous inspections.
- October 2018: There is no significant change to the condition of the site. Condition returned to green and continued monitoring is recommended.
- March 2019: There is no significant change to the condition of the site. Condition returned to green and continued monitoring is recommended.
- October 2019: There is no significant change to the condition of the site. Continued monitoring is recommended.

- March 2020: No significant changes – continue monitoring
- September 2020: As per the previous inspection, there is no significant change to the condition of the site. Continued monitoring is recommended.
- March 2021: Rock rip rap is holding well, but some runnelling was noted within exposed upper bank. Continued monitoring is recommended.
- October 2021: Site not inspected due to covid 19 restrictions.
- March 2022: Riprap is continuing to hold well, no significant change in the extent or degree of runnelling since previous inspection.
- November 2022: Site appears stable. No obvious deterioration in revetment visible. Site remains green.
- March 2023: The site is stable, and no sign of deterioration was noted.
- October 2023: The site is stable, and no sign of deterioration was noted.
- March 2024: The site continues to be stable with no sign of deterioration.
- October 2024: The site continues to be stable with no sign of deterioration.

Photographs: S11–101024 (1-5)

4 WESTERN SHORELINE (RCA – WAKA KOTAHI NZ TRANSPORT AGENCY)

4.1 SITE 12

There is no perceived risk from accelerated erosion at this location to State Highway 80.

The roading network is located approximately 1km west of the shoreline.

4.2 SITE 13

SH 80 RP: 0/15.14

This site is generally inspected as part of the periodic monitoring however has not been inspected as part of the October 2024 inspection.

4.2.1 CURRENT STATUS

There is no immediate threat to the road integrity.

Rock rip rap placed in 2012 and regular inspection or erosion at outfalls is supported.

4.2.2 HISTORY

- October 2012: Rock revetment work completed between two culvert/stream outlets.
- March 2013: No significant change noted.
- October 2013: No significant change noted.
- March 2014: No significant change noted.
- October 2014: No significant change noted.
- March 2015: No significant change noted. Threat level maintained at Green. Regular inspection of culverts and rock revetment work supported.
- October 2015: No significant change this inspection. State Highway position established as SH80 0000 15.14
- March 2016: No change this inspection.
- September 2016: No change this inspection.
- March 2017: No change this inspection.
- September 2017: This site was not inspected this inspection. This site does not pose a significant risk to the road.
- March 2018: No change this inspection.

- October 2018: The site does not pose a threat to the road network nominally a kilometre to the west.
- March 2019: This site does not pose a significant risk to the road.
- October 2019: This site does not pose a significant risk to the road.
- March 2020: This site does not pose a significant risk to the road.
- September 2020: This site does not pose a significant risk to the road.
- March 2021: This site does not pose a significant risk to the road.
- October 2021: Site not inspected due to covid 19 restrictions.
- March 2022: No significant change since previous inspection
- November 2022: Streams continue to flow with some minor erosion possible at stream location. Beach and revetment appear okay. No current risk to the road.
- March 2023: Minor erosion was noted at the southern stream location. Beach and revetment appear okay. There is no current risk to the road.
- October 2023: Beach and revetment appear okay. There is no current risk to the road, although minor erosion at the southern stream location continues.
- March 2024: Beach and revetment still appear okay. There is no current risk to the road, although minor erosion at the southern stream location continues.
- October 2024: The site was not inspected as part of this inspection.

Photographs: NA.

4.3 SITE 14

SH 80 RP 0/15.42

4.3.1 CURRENT STATUS

There is no immediate threat to the road integrity.

Revetment work completed in April/May 2013.

4.3.2 HISTORY

- This area was last formally reported on in June 1994. There were minor increases in erosion between October 1989 and June 1994.
- September 2004 (recommence formal reporting): Minor changes have occurred in the last 10 years. Erosion not currently active.
- April 2005: No changes.
- August 2005: No major changes. There were signs of recent erosion having occurred.
- March 2006: No major changes.
- September 2006: No major changes.
- March 2007: No major changes.
- November 2007: No major changes. Transit New Zealand had removed all trees at this site.
- March 2008 to October 2010: No major changes.
- April 2011: No major changes. Erosion had increased along this site during the last high lake levels.
- October 2011: No major changes. The edge of the bank was approx. 6m (at the closest point) from the toe of the road formation. Erosion appeared to be active along a 60m length.
- April 2012: No major changes.
- October 2012: No major changes.
- March 2013: Minor slumping noted at southern end of section. No significant change and no immediate threat to road. Cutting in at northern end of site, close to Site 15.
- October 2013: Revetment work completed between two culverts, approximately 70m of rock placed in April/May.
- March 2014: Revetment work holding well. No significant change noted.
- October 2014: No significant change.
- March 2015: No major change this inspection.
- October 2015: No change this inspection. State Highway position established at SH80 0000 15.42.
- March 2016: No change this inspection.
- September 2016: No change this inspection.

- March 2017: No change this inspection although some minor erosion of the southern end bank was noted. Further monitoring is required.
- September 2017: No change this inspection although some minor erosion of the southern end bank was noted. Further monitoring is required.
- March 2018: No change this inspection although some minor erosion of the southern end of the bank was noted. Continued monitoring is required.
- October 2018: No significant change in condition. Continue to monitor.
- March 2019: No significant change in condition. Continue to monitor.
- October 2019: As with previous inspections there is no significant change in condition at this site.
- March 2020: No significant changes, however some spalling noted in cove at southern end of site.
- September 2020: Some spalling in the cave at the southern end has continued from the last inspection. The northern culvert at this site was dry during the inspection. Continue to monitor.
- March 2021: Minor spalling continues around caves at the southern end of site. The northern culvert was dry, but the southern culvert was flowing. Continue to monitor this site.
- October 2021: Site not inspected due to covid 19 restrictions.
- March 2022: Minor spalling around the caves is ongoing. No changes to condition of the culverts. Continue to monitor on-going signs of deterioration.
- November 2022: No major changes noted. Possible some loss of rock from the beach area but minor. Continue to monitor.
- March 2023: The site appears relatively stable. No discernible change from previous inspection. Continue to monitor.
- October 2023: The site appears relatively stable. No discernible change from previous inspection. Continue to monitor.
- March 2024: The site appears relatively stable. No discernible change from previous inspection. Continue to monitor.
- October 2024: As with previous inspections the site appears relatively stable. No discernible change from previous inspection. Continue to monitor.

Photographs: S14–101024 (1-3)

4.4 SITE 15

SH 80 RS 17, BOUNDARY STREAM

4.4.1 CURRENT STATUS

Revetment work was largely stable until early 2017 when it was affected by storms and high lake levels.

The rock revetment work was noted to be locally damaged through wave erosion in March 2017. The threat status of the site has been elevated to yellow since March 2017.

Scalloping is progressing towards the road and required repair; the threat status was elevated to orange in 2020.

Repairs were instigated in 2021. The site remains at orange as the repairs are monitored.

4.4.2 HISTORY

- Pre 2000: No erosion at this site.
- 2 November 2000: Observed minor rock movement on the southern embankment.
- April 2001: Slumping, rough estimate 25m3 pocket of rock several metres above the high-water line, (previously replenished late 1980's), southern abutment, adjacent to the bridge had increased slightly. Further minor erosion into the embankment gravels. Length about 40m. No slumping at lower lake levels. Erosion at both these locations was possibly due to heavy rain rather than lake influence. The slip faces were near vertical and further damage was possible during a rainstorm.
- August 2001: Rain caused a minor increase in erosion along the road embankment. The erosion at the southern abutment appeared much the same as in April 2001.
- September 2001: Slumped section adjacent to the bridge was replenished with coarse rock.
- April 2002: No changes.
- September 2002: Erosion into the road embankment had increased. A section of the embankment extending the full height of the batter had slipped, forming a wedge of slumped material, about 6 m wide adjacent to the road shoulder extending out to about 40 m wide at the base adjacent to the top of the protection rock (above maximum lake level). This slip was caused by rainfall surface run-off. There were no changes at the bridge abutment. Previous rock repairs remained intact.
- April 2003: No further changes.
- August 2003: No further changes.
- March 2004: The current high lake had caused erosion to be reactivated immediately south of the batter toe protection at this site (area last reported on in November 1998). There was no immediate threat to the State Highway. A better assessment of any change was to be made at low lake level. The slip to the south of the bridge abutment continued to deepen due to slope wash during heavy rain.

- September 2004: Erosion south of the batter toe protection remained active, but with no significant increase since the previous inspection. The embankment slip south of the bridge was continuing to deepen due to slope wash during heavy rain.
- April 2005: No changes. Vegetation re-establishing on the slip face.
- August 2005: No changes. Transit New Zealand to be requested to investigate control measures for road surface runoff.
- March 2006: No major changes. The slumped section (observed Sept 2002) above the rock armour was programmed to be tidied by Transit New Zealand.
- September 2006: No major changes. Rock to be locked into place when resources were available had been dumped at the site of the embankment slip.
- March 2007: No major changes. The recently placed rock at the slip site appeared stable.
- November 2007: No major changes.
- March 2008: No major changes.
- September 2008: No major changes.
- March 2009: No major changes. New erosion was apparent.
- May 2009: There had been an appreciable amount of erosion to the south of the Boundary Stream armouring, particularly at the site of the old gravel track (which used to provide access to the beach during initial construction of the protection works). The highway is approximately 8 to 10m from the edge of the bank along a 40m length.
- October 2009: No major changes. Some minor slope wash at higher levels.
- March 2010: No major changes.
- October 2010: No major changes.
- April 2011: Change of status at this site. Erosion was beginning to become an issue. The bank had receded several metres in places exposing the toe of a small fill batter and undermining the bank to the north. This site is to the south of the extensive rock protection placed during initial construction of SH80.
- October 2011: No major changes. The eroded edge of the bank was approx. 5m (at the closest point) from the toe of the road formation. Erosion appeared to be active along a 55m length, stopping at the existing protection placed along the Boundary stream bridge embankment.
- April 2012: No major changes.
- October 2012: No major changes. Monitoring of previous erosion to continue.
- March 2013: No major changes noted. No development of previous erosion feature.
- October 2013: April/May filling at southern end completed (approximately 70m filled). No significant change.
- March 2014: No significant change noted.
- October 2014: No significant change.
- March 2015: No significant change noted this inspection.

- October 2015: No significant change noted this inspection. The top of the revetment should however be monitored and attention paid to surface water run-off from the State Highway. Localised areas of minor face instability may be forming and should be monitored.
- March 2016: High water level this inspection. No major change noted although continued monitoring of slope above rock placement should continue.
- September 2016: No significant change noted this inspection. Continue to monitor surface of slope above revetment for scour damage and slope movement from surface water runoff.
- March 2017: Minor storm damage noted to slope above the revetment work. Minor loss of rock from revetment and possibly some scour damage. A detailed inspection is required at low lake level to assess repair requirements.
- September 2017: Previously identified storm damage noted again on the slope above the revetment work. Minor loss of rock from revetment and possibly some scour damage. Remedial works to the revetment should be considered.
- March 2018: As with the previously inspection minor drop outs and some material loss from the revetment was noted. Some minor surface water runoff erosion was noted closer to the bridge. As with previous report observations some remedial works to the revetment should be considered.
- October 2018: Condition the same as last inspection with minor drop out noted close to the bridge. Continue to monitor and consider top up of rock fill.
- March 2019: Condition the same as last inspection with minor drop out noted close to the bridge. Continue to monitor and consider top up of rock fill.
- October 2019: As with previous inspections minor drops outs are noted close to the bridge. Continue to monitor and consider top up of rock fill.
- March 2020: The southern extent (left side) is noted to be worsening.
- September 2020: Consider filling this season to reduce further erosion. Previous inspections have shown minor dropouts close to the bridge and have displayed evidence of worsening to the southern extent (left side). Continue to monitor.
- March 2021: Scalloping and dropouts close to the bridge have worsened along the steep upper slope. Failures are not yet impacting the road, but they will continue to progress. Filling with rock rip rap is planned for May 2021.
- October 2021: Little change has occurred since previous inspection. Small surficial failures not yet impacting the carriage way.
- March 2022: Repairs completed; material used for repair of dropout appears to be very silty/sandy in some areas. South end is steep at toe. Monitor performance of repairs.
- November 2022: Repairs appear to be holding. Still very silty and clayey and in some places over steep. Continue to monitor. Remain at orange for this season.

- March 2023: The previous infill repairs exhibit some minor erosion and loss of fines. Continue to monitor.
- October 2023: Some minor erosion and loss of fines has occurred at the location of previous infill repairs. Continue to monitor.
- March 2024: Minor erosion and loss of fines has occurred at the location of previous infill repairs. Some minor road runoff is noted. Continue to monitor drainage.
- October 2024: Minor erosion continues to occur around previous repairs. Main placed rock appears to be stable and holding. Continue to monitor.

Photographs: S15–101024 (1-11)

4.5 SITE 16 

SH 80 RP 17/12.77-12.81, NORTH OF FERINTOSH HOMESTEAD

4.5.1 CURRENT STATUS

There is no immediate threat to the road integrity.

Revetment work completed at northern end of the section in April/May 2013.

In March 2017 minor loss of the revetment rock protection at the northern end was noted together with further loss of material from the gabion baskets in the lower tiers. Some minor scour erosion was noted at the southern end of the site. Gabions were noted to be slumped but are not deteriorating.

An inspection in September 2017 noted surface water drainage to be occurring behind the gabion wall and possibly under-scouring the wall. Drainage above the wall should be further assessed.

The threat status of the site was elevated to yellow in March 2017. The site appeared to stabilise, and status was downgraded to green in September 2020 but was reinstated to yellow in March 2021.

Bank loss north of the site was noted in 2021 and monitored through 2022. A major rain event in July-August 2022 triggered a large amount of bank loss north of the retaining wall. The site remains at yellow status.

4.5.2 HISTORY

- December 1987: Gabion wall and Reno mattress constructed.
- December 1989: Reno mattress holes patched, sections replenished with rock. Beach nourishment gravels comprising an all-in gravel mix to 0.5m, maximum size, placed over the mattress to a depth of 0.5m.
- December 1989/January 1990: Beach nourishment gravels were placed at the front of the northern 30m of the Reno mattress and 30m to the north of the structure. The total extent in front of the structure was 25m from the toe of the Reno mattress and the northern cliffs to a depth of one metre.
- July 1990: Noted that erosion was continuing into the cliffs approximately 200m to the north and south of the structure. Rocks in the bottom row of baskets had settled creating a void at the top.
- December 1993: Beach nourishment gravels extended north by a further 160m from the existing gravels (making total of 260 x 25m). Existing gravels were well bedded and appeared to be performing satisfactorily.
- February 1997: Noted erosion occurring immediately adjacent to both ends of the gabion wall. Some abrasive wear to the wires of the bottom row of baskets becoming apparent.
- May 1998: Noted the majority of baskets along the bottom row of the wall were beginning to slump forward due to settlement of the contained rocks. This was creating a gap between the bottom two rows of baskets. The Reno mattress remained covered by gravel except for one small area. Abrasive wear to the bottom row of baskets was continuing.

- October 1999: Erosion that was occurring at both ends of the gabion wall had not progressed further. The mattress remained covered by gravel except for one bare area of about 10-15 m2 (northern end).
- May 2000: Profile survey undertaken.
- November 2000: A single wire had broken along the bottom row of gabion baskets. Abrasive wear and rusting of the wires was continuing. Beach nourishment to the north of the wall appeared satisfactory. More bare areas along the Reno mattress. The area of mattress exposed was approximately 40 m2.
- April 2001: The exposed area of Reno mattress had increased to approximately 50 m2. Increases were predominately at the toe of the gabion wall. Some new erosion had occurred at the toe of the cliff about 20m to the south of the gabion wall. Considered to be minor.
- August 2001: No further changes. The low lake level revealed a compacted, well-armoured lower beach.
- April 2002: The exposed area of Reno mattress had increased to approximately 100m2. There were no changes to the cliff faces each side of the gabion wall.
- September 2002: No changes. The exposed areas of Reno mattress had not increased in area.
- April 2003: The exposed areas of Reno mattress had increased to approximately 150m^2.
- August 2003: No changes.
- March 2004: No visible changes.
- September 2004: The exposed area of Reno Mattress had increased slightly. Previously scattered rocks had moved and packed together. The northern end of the Gabion wall was quite exposed with the finer materials behind the wall being removed. The vertical cliffs north of the wall had eroded slightly for the first time in several years; some silt deposits covered the nourishment gravels at the top of the beach. It was suspected heavy rain has contributed to this erosion (The southern end remains intact and had not eroded in recent time).
- April 2005: No visible changes.
- August 2005: The exposed area of Reno mattress had increased to approx. 250m^2. Erosion was becoming noticeable to the north of the Gabion wall and a length of about 50m could require some protection in the short term. The wires in the bottom row of baskets were abraded. It is 12 years since the last beach nourishment was undertaken. The remainder of the structure and surroundings had undergone no major changes.
- March 2006: No major changes.
- September 2006: No major changes.
- March 2007: Approx. 90% of the Reno mattress was now exposed. One section at the northern end had burst and undermining of the mattress due to loss of beach nourishment was beginning. Large trees at the edge of the cliff, north of the gabion wall, had been removed the previous summer.
- November 2007: No major changes.
- March 2008: No major changes.

- May/June 2008: Major repairs to the existing protection works were undertaken. A concrete facing was poured at the toe of the gabion wall and along the top section of the Reno mattress. The broken Reno mattress sections were overlain with Terramesh panels, followed by a layer of beach nourishment gravels placed over the entire mattress as far as the waters' edge. The gravel within the eroded pockets in the cliff face to the north of the structure was also augmented (see Construction Sketch #4 Appendix D, September 2008 report).
- September 2008: No major changes.
- March 2009: Much of the nourishment gravels placed in May/June last year had been washed away. Some of the coarser rock appeared to have been pulled down from the concrete face (at the toe of the gabion wall) by up to a metre. The void created was filled with light shingle.
- May 2009: There had been extensive cliff erosion immediately to the north of the Gabion wall, exposing the basket ends. There was also some minor erosion further north into the cliff face (extending about 50m). There were no changes at the southern end.
- October 2009 to October 2010: No major changes.
- April 2011: There were some, but not major changes. The north end (of the baskets) was completely exposed and susceptible to further slumping should a prolonged period of high lake level occur. The beach to the north of the wall remained satisfactory (well armoured to the toe of the cliff).
- October 2011: No major changes. Increased erosion to the north end, although altered, was due to heavy rain. The low lake level accentuated the erosion to the south of the gabion wall. No major increase in erosion was evident, (map over-lay 2003 to 2010).
- April 2012: No major changes.
- October 2012: No major changes. Discussion was held regarding erosion at the LHS and RHS of the gabion wall tie backs where minor caving has occurred. Continued erosion should be monitored.
- March 2013: Continued development of the caving behind the gabion wall at the northern end. Slumping of baskets noted and slumping of retained soil. Erosion of slope occurring for a section north of wall of approx. 15m. At southern end of gabion baskets the lower tier of baskets noted to be losing small diameter material creating gaps in the baskets.
- October 2013: April/May completed filling at the northern corner filling up caves. No deterioration of baskets in main wall noted. Loss of fill from lower tier of gabions. Beach sediment still intact.
- March 2014: No significant change noted.
- October 2014: No significant change noted. Some deterioration of slope at true LHS (north) beyond the end wall. This is not considered a concern to the State Highway at this stage. Continue to monitor.
- March 2015: No significant change noted. Maintain threat level at Green.
- October 2015: No significant change this inspection. The Reno mattress was however more exposed and close inspection revealed some damage to the mattress cage and loss of materials. Overall the mattress is still serviceable and erosion is not affecting the wall or foundation. Drainage channels above the wall are still flowing to the southern end of the wall

but there is no significant deterioration or cutting back to the road. Continued monitoring is recommended.

- March 2016: No major changes noted. No inspection of mattress or baskets possible due to high water level. Continued monitoring recommended.
- September 2016: No major change this inspection. Noted that the concrete base plinth was clear of gravel on this inspection. Continue to monitor.
- March 2017: Unable to conduct a detailed assessment this inspection due to high lake level. Scour and revetment damage noted at northern end of gabion wall. Gabion baskets may have had some further minor fill loss and scour of slope at southern end is possible. A detailed inspection at low lake level is required.
- September 2017: No significant change in the basket fill noted this inspection however due to low lake level additional scour damage was noted below concrete base to main wall. Water was noted to flow from behind the gabion wall below the wall. Minor drainage control works should be considered above the gabion wall to improve site drainage and reduce the scour potential below and behind the wall. Further monitoring is recommended.
- March 2017: No significant change in condition was noted from the previous inspection. Further monitoring is recommended as well as consideration to improve the drainage above the wall.
- October 2018: No significant change from previous inspection. Continue to monitor gabions and drainage below wall.
- March 2019: No significant change from previous inspection. Continue to monitor gabions and drainage below wall.
- October 2019: No significant change from previous inspection. Continue to monitor gabions and drainage below wall.
- March 2020: The northern banks of this site are now exposed. Spalling in this area requires monitoring.
- September 2020: No significant change from previous inspection. Gabions and drainage below wall should continue to be monitored. The northern banks became exposed during the previous inspection. Continue to monitor the spalling here.
- March 2021: Fresh slumping of bare, over steepened banks just south of the gabion wall was noted. Gabions and caves north of the site appear stable. Runnelling erosion of the northern banks appears to be worsening, warrants closer monitoring next inspection.
- October 2021: On-going erosion of northern banks. Gabions appear stable. Closer inspection required in March 2022.
- March 2022: Site to remain at yellow. Inspection cut short due to injury. Closer inspection of the erosion of the northern bank warrants closer monitoring at next inspection.
- November 2022: Site to remain at yellow. Recent rainfall has triggered bank loss and continued erosion of the northern bank. Continue to monitor.

- Gabion wall appears to be unchanged from previous inspections. Vegetation loss and rainfall erosion of the bank north of the wall continues and should be monitored. This may become a new site in the future.
- October 2023: Gabion wall appears to be relatively unchanged, however some loss of the gabion cobbles was noted. Vegetation loss and rainfall erosion of the bank north of the wall continues and should be monitored. Need to consider revetment placement along the northern side.
- March 2024: The gabion wall appears to be relatively unchanged. Some loss of the gabion cobbles was noted as per previous inspection. Vegetation loss and rainfall erosion of the bank north of the wall continues and should be monitored. Revetment placement along the northern side still should be considered.
- October 2024: Water seepage below and through the gabion wall is evident. The rip rap and reno mattress appear to be in a good condition. The bank loss to the north of the wall appears to have slowed. Consideration should be given to extending the rock rip rap northwards of the gabion wall along the base of the exposed cliff and base of the gulley.

Photographs: S16–101024 (1-9)

5 LIMITATIONS

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Appendix A
Photographs

October 2024

SITE: 2 Date: 10 October 2024 Description: S2 – (1)

SITE: 2 Date: 10 October 2024 Description: S2 – (2)

SITE: 2 Date: 10 October 2024 Description: S2 – (3)

SITE: 2 Date: 10 October 2024 Description: S2 – (4)

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SITE: 2 Date: 10 October 2024 Description: S2 – (15)

SITE: 2 Date: 10 October 2024 Description: S2 – (16)

SITE: 2A Date: 10 October 2024 Description: S2A – (1)

SITE: 2A Date: 10 October 2024 Description: S2A – (2)

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SITE: 3 Date: 10 October 2024 Description: S3 – (1)

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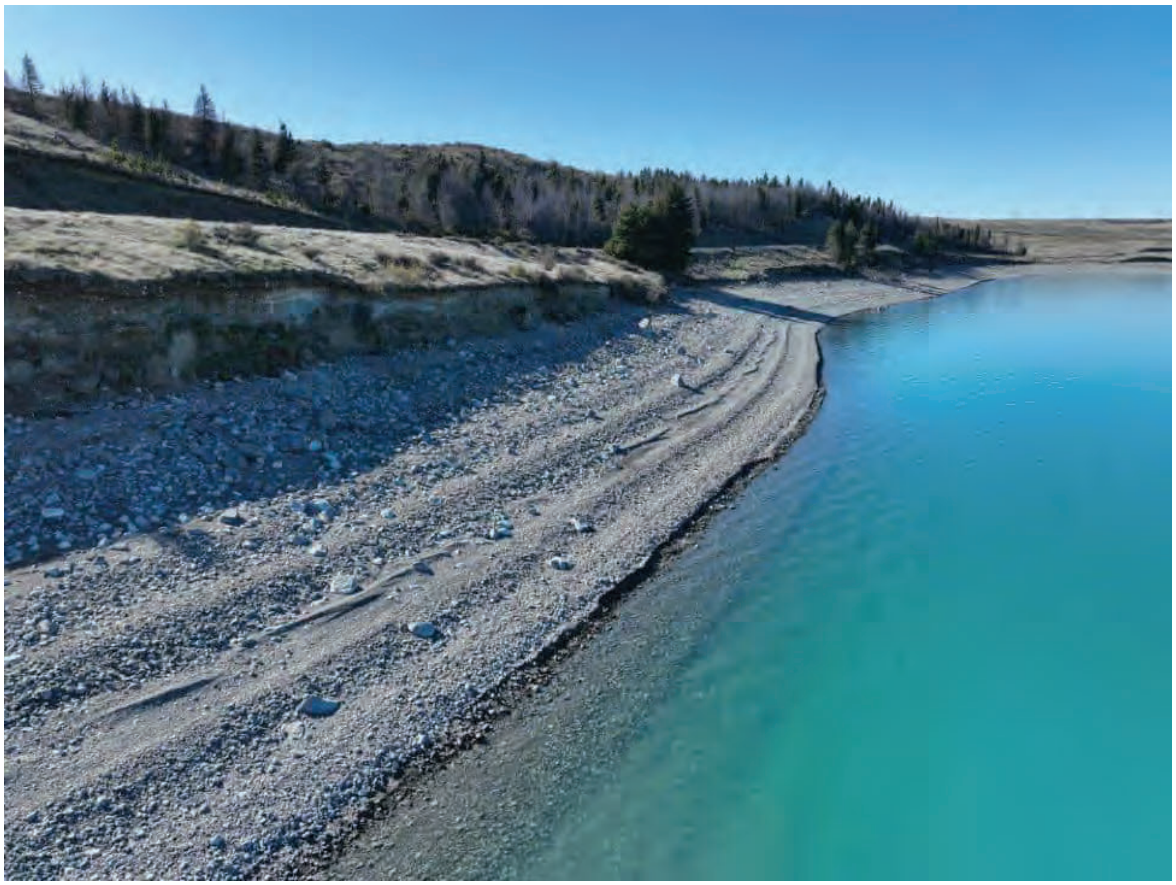

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Appendix B
Lake Level Plots

October 2024


Drawn on 19-Dec-2024 08:39
Lake Level (m)
529.5
529.0
528.5
528.0
527.5
527.0
526.5
526.0
525.5
525.0
524.5
524.0
523.5
523.0
522.5
522.0
521.5
521.0
520.6
Sep-2023
Dec-2023
Mar-2024
Jun-2024
Sep-2024
Lake Pukaki from 1-Sep-2023 00:00:00 to 30-Sep-2024 0


Drawn on 19-Dec-2024 08:42
Lake Level (m)
533.0
532.5
532.0
531.5
531.0
530.5
530.0
529.5
529.0
528.5
528.0
527.5
527.0
526.5
526.0
525.5
525.0
524.5
524.0
523.5
523.0
522.5
522.0
521.5
521.0
520.6
2020
2021
2022
2023
2024
Lake Pukaki from 1-Sep-2019 00:00:00 to 30-Sep-2024 0(

Appendix C
Location Map

October 2024

Plan View

Scale: 1:5000

Site 1

Scale: 1:1000

1	Date of measurement	Dimension X	Dimension Y
	11 February 2016	1.6m	14.5m
	15 March 2017		14.5m
	7 Nov 2017		14.5m
	16 April 2018		14.5m
	Loss of bank		0.0m

Site 2

Scale: 1:1000

2	Date of measurement	Dimension X	Dimension Y
	11 February 2016	5.3m	35.4m
	15 March 2017		27.1m
	7 Nov 2017		26.1m
	16 April 2018		26.1m
	Loss of bank		9.3m

Site 3

Scale: 1:1000

3	Date of measurement	Dimension X	Dimension Y
	11 February 2016	6.9m	17.7m
	15 March 2017		17.7m
	7 Nov 2017		15.7m
	16 April 2018		15.4m
	Loss of bank		2.3m

1:1000 @ A3 — 0 10 20 30 40 m

1:5000 @ A3 — 0 50 100 150 200 m

Key	
	Point showing the location of the survey pillar
X	Dimension from edge of seal to the survey pillar
Y	Dimension from survey pillar to edge of bank

Revision	Amendment	Approved	Revision Date
RA	ISSUED AS A DRAFT	R.B.	17/03/2017
R1	NOVEMBER 2017 UPDATE	R.B.	07/11/2017
R2	APRIL 2018 UPDATE	R.B.	16/04/2018

meridian

wsp
Alexandra Office
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PO Box 273
Alexandra 9340
New Zealand

Designed	Approved	Approved Date
N.GOODWIN	R. BOND	17/02/2017
Drawn	Scales	
N.GOODWIN	1:1000 & 1:5000 ON A3	

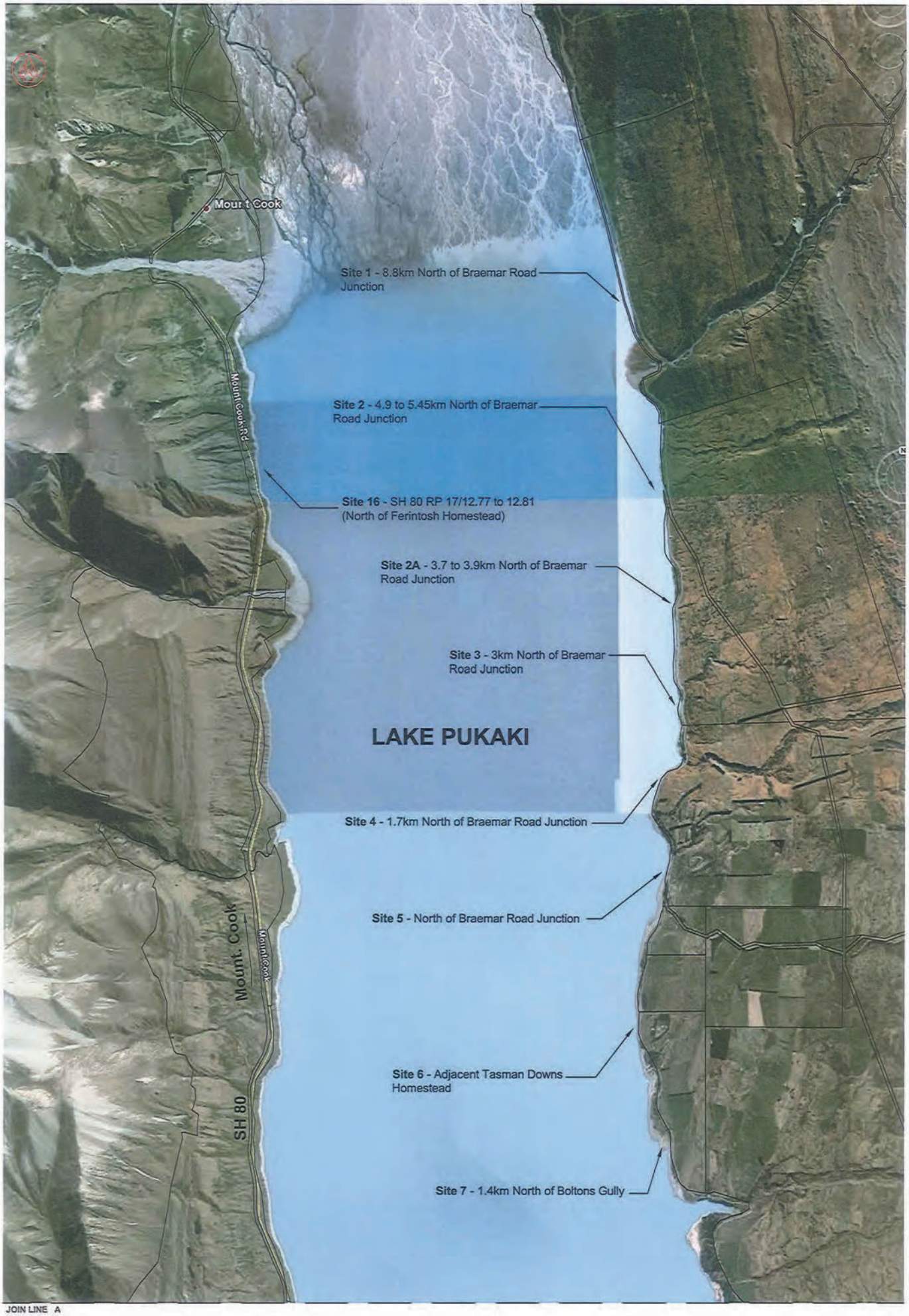
Project
MERIDIAN
LAKE PUKAKI, CANTERBURY
LAKE PUKAKI SHORELINE INSPECTIONS

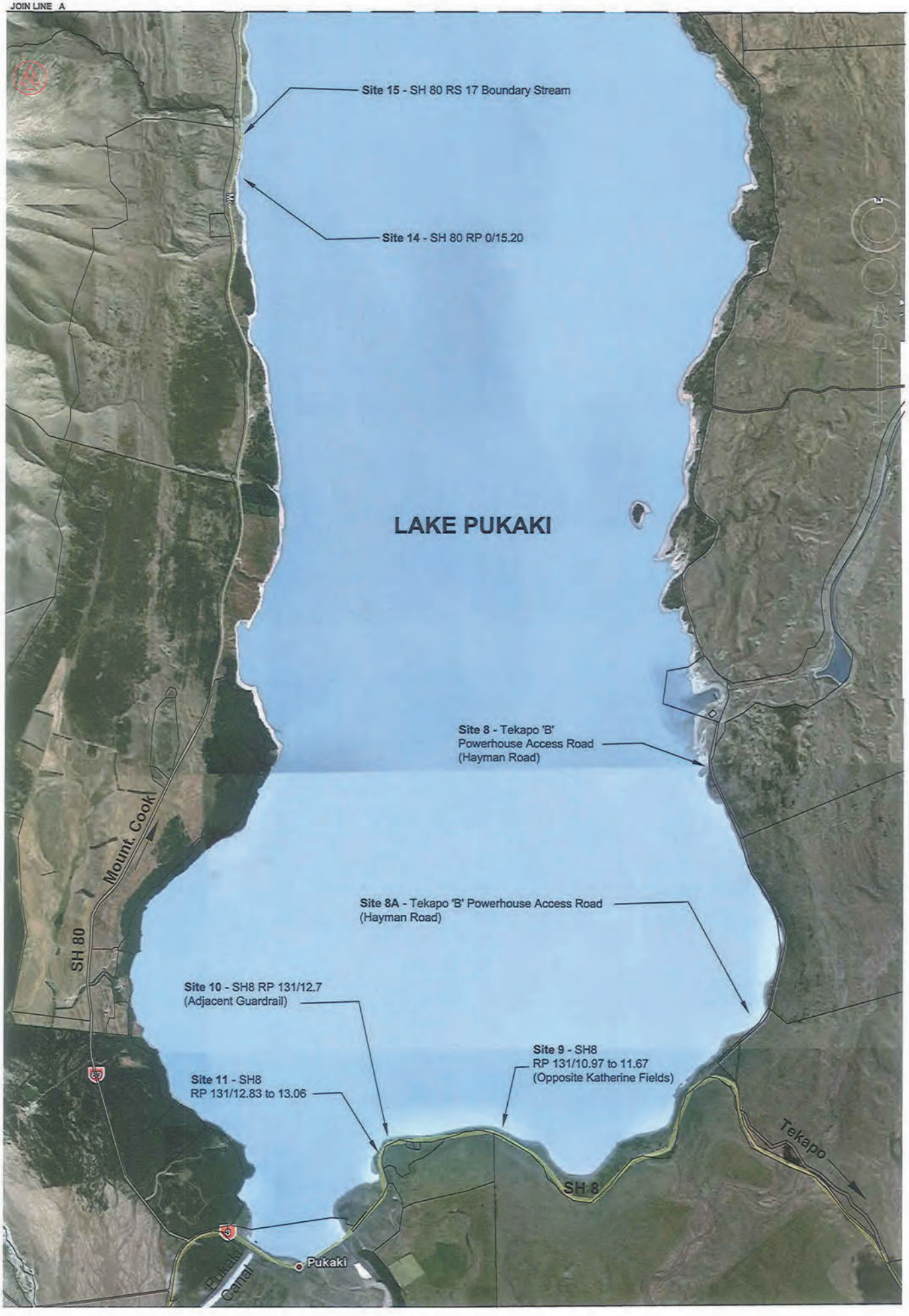
Sheet
ESTABLISHED BANK MONITORING POINTS

SURVEY MONITORING

Project No.	Sheet No.	Revision
6XE067.00(015_01)	C01	R2

Original Sheet Size A3 [420x297] Plot Date 2020-08-26 at 9:52:56 AM Path G:\Meridian Energy\6XE067.00 (Lake Pukaki GEOTECH)\Drawings\Pukaki Shoreline Erosion DWG\6-XE067.00(015_01)_C01_R2.dwg C01(R2)


Mount Cook
Site 1 - 8.8km North of Braemar Road Junction
Site 2 - 4.9 to 5.45km North of Braemar Road Junction
Site 16 - SH 80 RP 17/12.77 to 12.81 (North of Ferintosh Homestead)
Site 2A - 3.7 to 3.9km North of Braemar Road Junction
Site 3 - 3km North of Braemar Road Junction
LAKE PUKAKI
Site 4 - 1.7km North of Braemar Road Junction
Site 5 - North of Braemar Road Junction
Site 6 - Adjacent Tasman Downs Homestead
Site 7 - 1.4km North of Boltons Gully
Mount Cook
SH 80
JOIN LINE A


JOIN LINE A
Site 15 - SH 80 RS 17 Boundary Stream
Site 14 - SH 80 RP 0/15.20
LAKE PUKAKI
Site 8 - Tekapo 'B'
Powerhouse Access Road
(Hayman Road)
Mount Cook
SH 80
Site 8A - Tekapo 'B' Powerhouse Access Road
(Hayman Road)
Site 10 - SH8 RP 131/12.7
(Adjacent Guardrail)
Site 9 - SH8
RP 131/10.97 to 11.67
(Opposite Katherine Fields)
Site 11 - SH8
RP 131/12.83 to 13.06
Tekapo
SH 8
Pukaki
Pukaki Canal

Appendix B

Author qualifications and experience

Lucy ELLIS BSc, MPHIL, PHD

Technical Director - Geomorphology

Location
St Leonards, NSW, Australia

Experience
20+ years

Qualifications/Accreditations
- **PhD, Fluvial Geomorphology, Nottingham University**, 2004
- MPhil, Fluvial Geomorphology, Nottingham University, 1993
- BSc (Hons), Geography, Nottingham University, 1992

Key technical skills
- Geomorphological assessments for a wide range of environments, landscapes and site sizes
- Geomorphology and geohazard mapping
- Hazard and risk assessments
- Image analysis and GIS

Relevant experience summary

Dr Lucy Ellis has experience of consultancy and research projects in a variety of environments and landscapes. Her work has ranged from strategy/management planning studies and option assessments for coastlines and rivers, through to detailed investigations, recommendations, and remediation design for engineering projects.

Dr Ellis has particular experience in the interpretation of aerial photographs, satellite images and the application of GIS to assess landform change and contemporary geomorphological processes for a range of projects.

Selected project experience

Arno Bay, South Australia

Geomorphological assessment of shoreline and near-shore change to inform nature-based management solutions for the Estuary Boardwalk recreational area.

Big Rocks Weir, Queensland

Assessment of impacts to surface water / coastal processes and geology / soils for a 10,000ML weir on the Burdekin River. Included evaluation of potential impacts to coastal landforms and internationally important Great Barrier Reef and Bowling Green Bay RAMSAR site.

Borumba Pumped Hydro Project, Queensland

Geomorphological assessment of sediment dynamics and potential impacts from the proposed pumped hydro scheme on the existing reservoir and affected river systems. Project involved working with the aquatic ecology and dams teams.

Corin Dam, ACT

Desktop assessment of likely impacts of the Corin Dam spillway redesign on the Cotter River. Study focused on likely changes to flow and sediment dynamics, and resultant morphological change.

Geehi Aqueduct, NSW

Assessment of landslides, faulting and river / creek hazards to inform replacement of the Geehi Aqueduct, part of the Snowy Hydro scheme.

Gwent Coastline, South Wales, UK

Geomorphological investigation of historic foreshore (saltmarsh) evolution and coastal/estuarine processes between Newport and Chepstow, using image analysis of aerial photographs, site visits and desk study. Qualitative risk assessment carried out to support management policy recommendations.

Lismore Flood Damage Rehabilitation, NSW

Geomorphological assessment, rehabilitation advice, preliminary design and quantity estimation for roads damaged by river erosion and landslides during heavy rain and flooding near Lismore, NSW. Working with geotechnical engineers and civil design team.

Littlehaven, South Shields, Northeast UK

Geomorphological assessment of historic shoreline change and contemporary processes within a small bay, as part of a study to determine sea wall repair/replacement options. Options appraisal undertaken within the context of the findings of the geomorphological assessment. Coordination of a small team to ensure delivery of four-phase report on time and within a constrained budget.

Manly, NSW

Assessment of coastal processes and likely geomorphological change following removal of an offshore building. This included a review of construction history, beach dynamics and cliff retreat.

Manuherikia River, New Zealand

Geomorphological assessment using fluvial audit methods used to identify the cause of problematic silting in the lower river system.

Mildura Weir, Victoria

Options appraisal for various new weir locations on the Murray River adjacent to Mildura. Study focused on likely impact to sediment dynamics and channel morphology under the different scenarios.

Moonee Creek, NSW, Australia

Geomorphologist expert witness for a successful appeal to allow construction of a road adjacent to a small coastal creek. Desk- and field-based assessment of historic creek migration, current geomorphic condition (including erodibility of soils at the site) and potential impacts of the road.

Pinehaven Stream, NZ

Geomorphological review of newly rehabilitated reaches of Pinehaven Stream, with recommendations for ongoing monitoring and triggers for remedial action, if required.

Pioneer Burdekin Pumped Hydro Project, QLD

Study assessed ground conditions, soil erodibility and sediment dynamics within the proposed project footprint and potential impact area. Project involved working with the FEED design team and assisting with revisions to design based on study findings.

Rainside PHES, NSW

Assessment of geological, soils and geomorphological considerations at a proposed pumped hydro site, including geological structure / characteristics, landsliding / slope instability, soil characteristics and surface / groundwater characteristics / connectivity. Part of a larger fatal flaw assessment.

Scott's Creek Catchment, Victoria

Geomorphological assessment of sediment and nutrient dynamics within the Scott's Creek catchment. Project involved assessment of historic change and contemporary landslide and creek condition, as well as relevant land use change. Nutrient pathways to the Curdies estuary assessed in association with the geomorphological assessment to provide recommendations for strategic management actions to reduce cyanobacterial blooms in the estuary.

Capricornia PHES

Topography, geology and soils, and fluvial geomorphology assessments for an environmental impact statement project for a large PHES in remote Queensland.

Cowarra and Thrumster WWTP, NSW

Study assessed geology, soils and fluvial / estuarine / wetlands landform impacts on and from proposed waste water treatment plant, and associated pipeline infrastructure.

VMFRP, Victoria

Assessments of soils, geology and erosion impacts on and from floodplain and in-channel structures at 9 separate sites. The project aim is to restore pre-regulation floodplain inundation to the Murray River.

Career history

2022 - present	GHD, Technical Director - Geomorphology
2021 - 2022	GHD, Senior Geomorphologist
2008 - 2013	Coffey Geotechnics, Associate Geomorphologist
2005 - 2008	Atkins Ltd., Geomorphologist
1991 - 2005	Various short-term contracts, including – US National Park Service, – US Geological Survey, – Mouchel Parkman Ltd. – Sir William Halcrow and Partners Ltd.

ghd.com

→ The Power of Commitment