Memo

From	**Richard Measures**
To	Arzan Irani, Department of Conservation
Date	5 May 2025
NIWA Project	SCJ255GOV/08F
NIWA Report No.	2025107CH
Subject	**Review of PDP memorandum relating to Aqualinc report for Lower Selwyn Huts**

Background

The Department of Conservation (DOC) is in the process of reviewing lease concession applications for 50 properties in Lower Selwyn Huts (https://www.doc.govt.nz/get-involved/have-your-say/all-consultations/2024-consultations/lower-selwyn-huts/). The Aqualinc report "Impact of climate cycles and trends on Selwyn water assets" (referred to as "the Aqualinc report", Rutter et al. n.d.) has been used to inform this review process. The Lower Selwyn Hut Owners Association commissioned PDP to undertake a technical review of the Aqualinc report to support their applications, this review is documented in a memorandum titled "Review of Aqualinc report for Lower Selwyn Huts" (referred to as "the PDP memorandum", Gallop and Kirstein 2024).

The Department of Conservation has commissioned NIWA to review the PDP memorandum.

This memo reviews the PDP memorandum as well as the Aqualinc report and pertinent references cited in those documents with a focus on findings most relevant to decision making regarding the Lower Selwyn Huts lease concession applications. The memo:

1. Summarises key findings of both the PDP memorandum and Aqualinc report relating to the impacts of climate change on Lower Selwyn Huts.
2. Identifies and discusses points on which the two reports agree and disagree.

Key findings of the Aqualinc report relating to Lower Selwyn Huts

The Aqualinc report analyses the impact of climate on Selwyn District Council potable water, wastewater, stormwater, land drainage, and water race assets for the 2018–2048 period. The approach involved analysis of historic data to identify correlations with various climate drivers including: climate change, El Niño/Southern Oscillation (ENSO), the Southern Annular Mode (SAM) and the Interdecadal Pacific Oscillation (IPO).

No correlation was found between the frequency of high flow events in the Selwyn River (flow exceeding 95th percentile) and any of the investigated climate drivers.

The Aqualinc report uses 2008 MfE guidance on sea level rise (SLR), recommending an allowance of 0.17 to 0.23 m sea level rise by the 2040s relative to the period 1995–2015, but notes that if sea level rise continued at the historic trajectory the rise in levels would be limited to 0.08 m by 2048 (1.9 mm/yr) relative to the same period.

Sea level rise is identified as affecting Te Waihora/Lake Ellesmere Water Levels, with sea level rise meaning either the lake needs to be opened more frequently, and/or there being an increase in lake levels. Lower Selwyn Huts is identified as a community likely to be affected by sea level rise.

The Aqualinc report states that without any change in lake level management, lake levels would rise by the same amount as sea level rise, based on the assumption that lake opening trigger levels are based on lake level relative to sea level.

The report notes that the highest recorded lake levels were 1.81 m "amsl" on 30 June 2013. Maps included in the report show that Lower Selwyn Huts would be inundated at this lake level. The report considers that this lake level could impede drainage of land lower than approximately 3.8 m "amsl" (due to the backwater effect within the drainage network and the typical drain depths).

Key findings of the PDP memorandum

The PDP memorandum is focussed entirely on Lower Selwyn Huts. It reviews the Aqualinc report and applies guidance on coastal and fluvial flooding which was not available at the time of the Aqualinc report.

The memorandum presents LiDAR data on ground levels around Lower Selwyn Huts, finding that "*the area of the Huts is characterised by low lying topography with elevations between approximately -0.5 to +0.5 m NZVD-2016*" and "*the banks of the Waikirikiri/Selwyn River reach a maximum elevation of approximately 3 m NZVD-2016*".

The memo refers to recent guidance on sea level rise allowances (MfE 2024) which was not available at the time of the Aqualinc report. Key relevant aspects of the guidance identified in the PDP memorandum and applied to Lower Selwyn Huts are:

1. The guidance suggests a precautionary initial planning and design response before undertaking a detailed risk assessment, suggested to be followed by the development of an adaptive planning strategy.

2. Projections of sea level rise must consider local vertical land movement (any subsidence or uplift) to calculate relative sea level rise projections (i.e., sea level rise relative to the land at a specific location). The memorandum refers to the NZSeaRise tool which maps vertical land movement (VLM) along the open coast from recent satellite data. Mapped vertical land movement along Kaitorete spit adjacent to Te Waihora ranges from +0.2 to -0.5 mm/yr. The memorandum notes that there is considerable uncertainty in these estimates of vertical land movement, particularly post 2011 Christchurch Earthquake in this area. Based on this vertical land movement data the PDP memorandum selects a rate of 0.0 ± 2.2 mm/yr for application to Lower Selwyn Huts.

3. The guidance refers to a range of sea level rise projections derived from plausible future scenarios of future global emissions. The memorandum identifies that the appropriate sea level rise allowance for application to Lower Selwyn Huts lease concession renewal (without redevelopment or intensification) is the medium confidence "SSP5-8.5 M" projection. This is the recommended interim precautionary relative sea level rise (RSLR) allowance for "land-use planning controls for existing coastal development and assets planning".

4. Based on the SSP5-8.5 M sea level rise projection, and a VLM rate of 0.0 ± 2.2 mm/yr the PDP memorandum presents relative sea level rise estimates of 0.26 m by 2050 and 1.28 m by 2130, relative to a 1995–2014 baseline.

As well as sea level rise, the PDP memorandum discusses the impacts of extreme sea levels during storms, including the effects of tide, storm surge and waves. The PDP memorandum uses the NIWA Extreme coastal flood map dataset (NIWA 2024) to present inundation maps based on the 1% AEP coastal flood event (i.e., flooding from sea levels which have a 1% chance of being exceeded in any given year) for current sea level and for a projected 0.3 m sea level rise (approximately equal to the projected 2050 sea level rise). Both maps show complete inundation of the Lower Selwyn Huts area.

The PDP memorandum then contains a discussion on the Te Waihora lake opening protocol. The memorandum describes the current opening regime including level thresholds, opening frequency, decision making process and opening process. The PDP memorandum agrees with the Aqualinc report that sea level rise predictions can be used to determine the effects on the physical opening of the lake, resulting in more frequent/extensive flooding around the margins of the lake.

Regarding fluvial flooding, the PDP memorandum agrees with the Aqualinc report that flood flows are unlikely to change significantly as a result of climate change by 2040.

The PDP report makes recommendations to consider conducting hydrodynamic modelling of flood risk to Lower Selwyn Huts. They note that this modelling could be used to inform statistical estimates of the likelihood of flooding and to explore if adaptive planning is an appropriate option for Lower Selwyn Huts.

Discussion

Sea level rise projections

Sea level rise projections from both reports are compared in Figure 1. The sea level rise projections in both reports are relatively consistent, although the PDP report is more recent than the Aqualinc report so has updated data and guidance available to inform its analysis. For this reason, **the PDP reported projections of sea level rise are preferred**. The Aqualinc report also presents a lower bound projection of sea level rise based on continuation of a linear 1.9 mm/yr sea level rise. This lower bound is not realistic as there is strong evidence for accelerating sea level rise, and 1.9 mm/yr is lower than the observed historic sea level rise rate at Lyttelton of 2.3 mm/yr (Bell et al. 2022). **The lower bound for sea level rise presented in the Aqualinc report should be ignored.**

The PDP memorandum includes consideration of vertical land movement (VLM) in the calculation of relative sea level rise. Vertical land movement refers to the rate at which coastal land is uplifting (positive) or subsiding (negative), and affects the rate of sea level rise any given location experiences relative to the land (relative sea level rise). Inclusion of vertical land movement is important and is recommended in the 2024 MfE guidance which the PDP memorandum follows. The PDP memorandum relies on vertical land movement data from the NZSeaRise website (https://www.searise.nz/, see Naish et al. (2024) for full details of how the data were calculated). The PDP memorandum considers the range of vertical land movement measured for the open coast adjacent to Te Waihora and selects a representative rate of 0.0 mm/yr ±2.2 mm/yr for application to Lower Selwyn Huts (this uncertainty is part of the uncertainty represented by the dotted lines in Figure 1). There are significant uncertainties in the NZSeaRise data, but it's application in the PDP memorandum is appropriate. It is notable that in previous DOC analysis presented in the internal report "Selwyn Huts Climate Info" (DOC u.d.) vertical land movement data are

presented from an earlier release of the NZSeaRise data and differs from the PDP memorandum. Vertical land movement data presented in the PDP memorandum supersedes that presented in the DOC internal report. In addition, a recent GNS report (Hamling and Kearse 2023) explores the complexities of vertical land movement associated with, and following, the Canterbury earthquake sequence. In summary, vertical land movement at Lower Selwyn Huts represents a significant source of uncertainty.

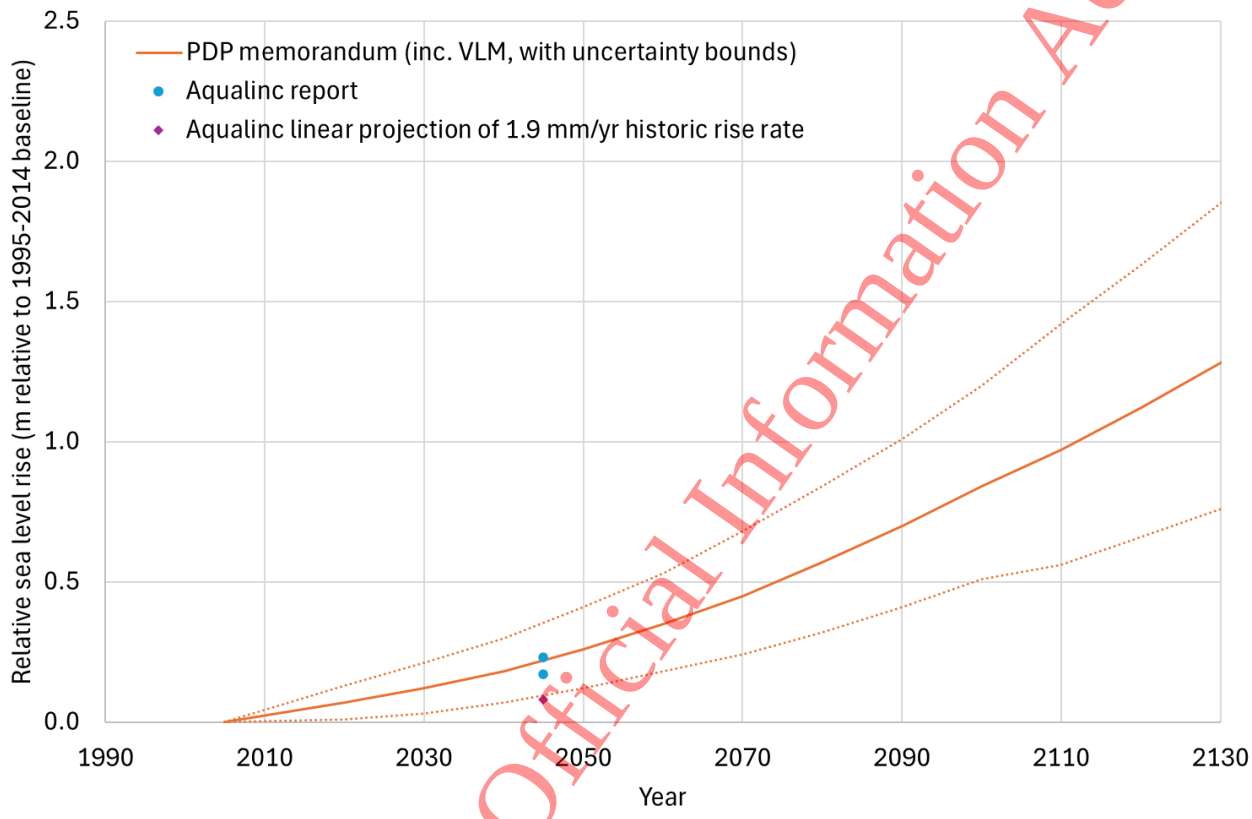

Figure 1: Comparison of sea level rise projections presented in the Aqualinc report and PDP memorandum.

Storm surge and wave effects

The mention of storm surge and wave effects on flooding in the PDP memorandum, and the presentation of inundation maps associated with 1% AEP coastal flood levels, is not relevant and should be ignored. Tides, storm surge, wave setup and wave runup do not directly impact levels in Te Waihora as it is separated from the ocean by Kaitorete Spit. The static "bathtub" modelling approach applied to generate the national coastal inundation maps (NIWA 2024) is not appropriate for Lower Selwyn Huts due to the distance of Lower Selwyn Huts from the coast and the presence of Kaitorete Spit. The limitations of the bathtub modelling approach are discussed in the NIWA report describing the maps (Stephens and Paulik 2023).

Levels and vertical datums

A vertical datum is a horizontal plane from which elevations are measured, acting as a zero point for height measurements. **When considering flood risk to properties, land and infrastructure around Lower Selwyn Huts it is important to use a consistent vertical datum for water levels and ground elevations so that the measurements are comparable.** Neither report does this. Sea level rise is presented relative to a 1995–2014 mean sea level datum (in both reports), lake levels and opening thresholds are presented in Lyttelton

Vertical Datum 1937 (LVD-37) (in both reports; although it is ambiguously labelled "above sea level, asl" in the Aqualinc report which leads to confusion in their analysis of the linkage between sea level rise and lake opening thresholds), and ground level is presented in New Zealand Vertical Datum 2016 (NZVD-2016) in the PDP memorandum. This inconsistency makes it impossible to assess how potential future sea levels and lake levels are likely to affect Lower Selwyn Huts.

LINZ provide datum conversion data between LVD-37 and NZVD-2016 (LINZ 2025). For Lower Selwyn Huts, the conversion is 0.323 m. For example, a lake level of 1.800 m LVD-37 is equivalent to 1.477 m NZVD-2016.

Te Waihora levels are monitored by Environment Canterbury in m LVD-37, and these measurements are widely used so it makes sense to convert all data into LVD-37. Converting the LiDAR data (as presented in the PDP memorandum) from NZVD-2016 into LVD-37 provides information on the lake level at which ground around the Lower Selwyn Huts will flood (Figure 2). Ground elevations around the buildings in Lower Selwyn Huts range from approximately 1.15 to 1.45 m LVD-37 (0.83 to 1.13 m NZVD-2016). The LiDAR elevation data is accurate to approximately ±0.1 m. **The statement regarding ground elevations lying between -0.5 and +0.5 m NZVD-2016 in the PDP memorandum is incorrect.** The huts themselves are raised above ground level to varying degrees and there are no data on the floor level of the huts to estimate at what lake level each of the huts would be inundated.

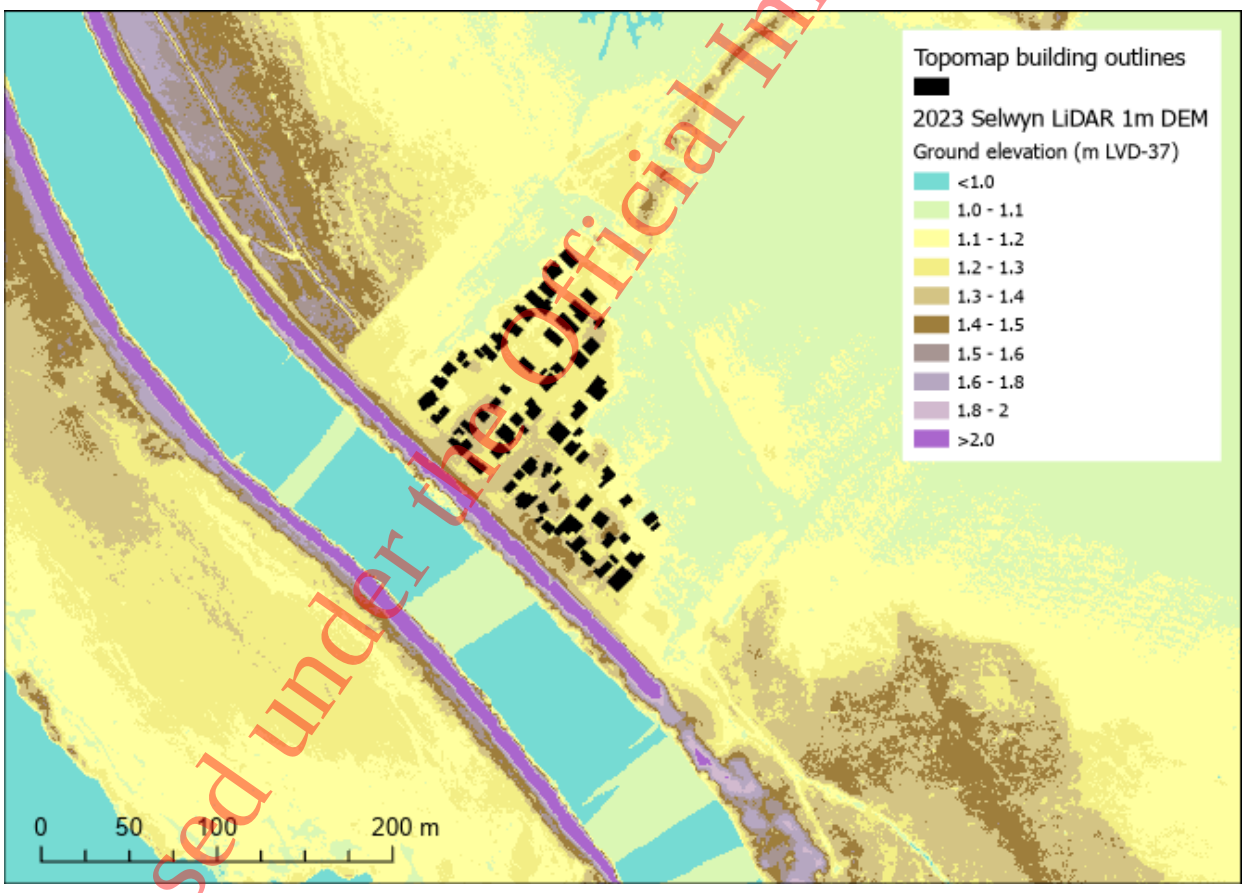

Figure 2: LiDAR ground elevation data for Lower Selwyn Huts. Data sourced from the LINZ Data Service and licensed for reuse under the CC BY 4.0 licence.

Te Waihora historic lake levels

Both reports discuss the current lake opening regime and mention the maximum recorded lake level of 1.81 m LVD-37. This level was recorded on 29–30 June 2013 (erroneously dated 30 June 2012 in the PDP memorandum) following a period of heavy rainfall in the catchment and flood flows in the Waikirikiri/Selwyn River which coincided with a period when the lake was unable to be opened due to southerly swell conditions.

Neither report analyses the frequency with which different historic lake levels have been observed to quantify flood risk to Lower Selwyn Huts. Informing statistical estimates of the likelihood of flooding is one of the recommendations identified in the PDP memorandum. What the memorandum fails to identify is that this **lake level frequency analysis has already been conducted by Environment Canterbury and published in a publicly available report (Wild 2019).** This frequency analysis is based off the historic period 1947 to 2013, representing the time over which the current opening method (i.e., mechanical opening) for the outlet has been in place.

Figure 3 compares this frequency analysis with the LiDAR derived ground elevation data around Lower Selwyn Huts, showing that **historically, some surface flooding around the huts has occurred most but not every year, and complete surface flooding around most of the huts has occurred on average approximately every five years.** The frequency with which the huts themselves flood cannot be calculated without accurate floor level data.

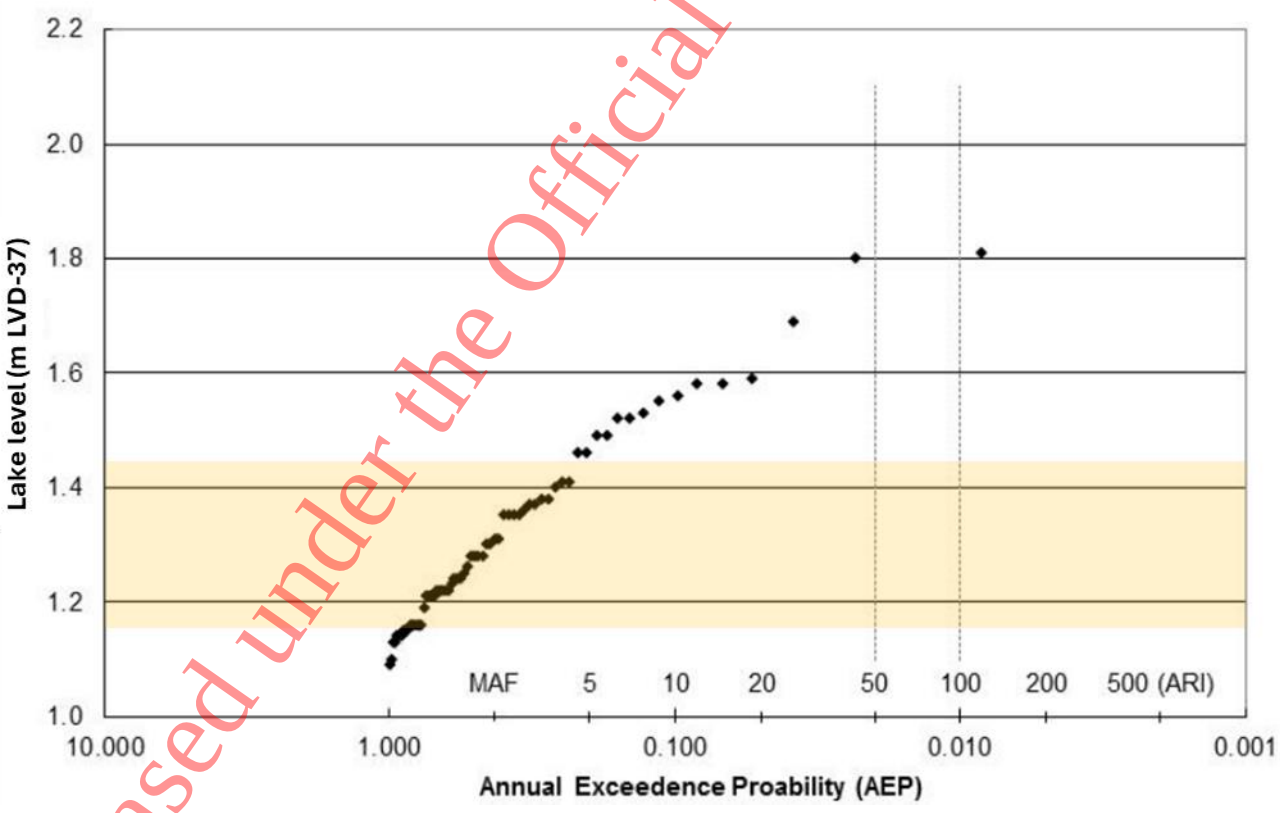

Figure 3: Te Waihora lake-level frequency analysis (1947–2013). Reproduced from Wild (2019) Figure 3-34. The points represent the maximum recorded lake level in each year from 1947–2013, plotted based on a statistical estimate of the likelihood of that level occurring in any given year. Orange shading has been added to indicate the LiDAR derived ground elevations around Lower Selwyn Huts. ARI is Average Recurrence Interval in years (the average interval between lake levels exceeding a given threshold). MAF is Mean Annual Flood (the average of all the annual-

maximum lake levels). AEP is Annual Exceedance Probability (the likelihood of a given lake level being exceeded in any 1-year period). For example, a 10 year ARI lake level has a 0.1 (i.e., 10%) chance of being exceeded in any given year.

Impact of sea level rise on lake levels, and hence on flood risk to Lower Selwyn Huts

Both reports agree that increasing sea levels will affect the Te Waihora lake opening regime and that sea level rise means opening the lake will require higher lake levels. The PDP memorandum correctly identifies that higher lake levels for openings will be required in order to achieve a sufficient water level differential between the lake and the sea to achieve successful opening. The Aqualinc report comes to the same conclusion but appears to be slightly confused by erroneously assuming that the current lake opening thresholds are defined relative to current mean sea level rather than in the fixed LVD-37 datum. This assumption leads them to conclude the lake opening thresholds would automatically increase as the sea level rises.

The degree to which sea level rise is passed on to lake level flood risk is not explored in any detail in either report. The Environment Canterbury floodplain analysis report (Wild 2019) gives some indication of how lake opening thresholds are likely to be influenced by sea level rise:

> *"To maintain the existing lake levels, small increases in sea level will require more frequent openings of the Te Waihora/Lake Ellesmere outlet to the sea. These more frequent openings will be required as the outlet to the sea will tend to close earlier (i.e., at higher lake levels). Once sea level rise increases by more than approximately 0.3 m, it may become more difficult, and potentially less economic, to maintain the opening (Surman, 2013). It is therefore likely that the threshold levels, that currently trigger lake openings, will need to be modified in the future as higher sea levels will make it more difficult to achieve successful lake openings (Renwick et al., 2010)."*

Without more detailed analysis it is not simple to quantify how increasing the required frequency of lake openings (sea level rise up to approximately 0.3 m) or the opening threshold (sea level rise beyond approximately 0.3 m) will affect flood risk to Lower Selwyn Huts. It is clear however that both of these changes (increased frequency and threshold level of openings) will increase the likelihood/magnitude of flood levels occurring in Te Waihora.

Impacts of climate change on Waikirikiri/Selwyn River flows

The PDP memorandum concludes that "*fluvial responses to district rainfall are unlikely to change much on what is occurring presently, up to 2040*". This is based on the finding of the Aqualinc report that there is no trend apparent in the frequency of high flows (95th percentile flow) in the Waikirikiri/Selwyn River or in the frequency of heavy rainfall, and that guidance on climate change induced changes to precipitation show negligible change up to 2040 (referencing MfE 2018).

While the conclusion in the PDP memorandum is likely valid for 95th percentile "high" flows (equivalent to approximately 15 m^3/s at the Selwyn River at Coes Ford flow monitoring site), these flows are not large enough to cause flooding in Lower Selwyn Huts. Flood flows are much higher than the flows investigated in the Aqualinc report. For the Selwyn River at Coes Ford, the historic mean annual flood equates to approximately 100 m^3/s and the 100 yr ARI flood approximately 580 m^3/s (Wild 2019). Selwyn River flows peaked at 163 m^3/s during the June 2013 flood event shortly prior to the record high Te Waihora lake level (Wild 2019). **Neither the Aqualinc report or PDP memorandum addresses the likely effects of climate change on flood flows in the Waikirikiri/Selwyn River, and their conclusions regarding effects on "high" flows are not applicable to flood risk.**

It is notable that the PDP report omits to consider climate change impacts on extreme rainfall or flood flows despite referencing MfE guidance (MfE 2018) which includes analysis of extreme rainfall, based on the analysis undertaken for the High Intensity Rainfall Design System, HIRDSv4 (Carey-Smith et al. 2018). The Environment Canterbury floodplain analysis report (Wild 2019) applies this guidance to the Waikirikiri/Selwyn River and finds that increases in extreme rainfall of 5.6% to 28.8% are expected to affect the catchment from a 1986–2005 baseline out to 2101–2120. Taking the mid-range of this increase they project that "*in 100 years from now, what is currently considered to be a 100 year ARI flood event may become a 50 year ARI flood event.*" This is a significant increase in the frequency/magnitude of flood flows indicating **climate change is expected to significantly increase flood risk from the Waikirikiri/Selwyn River**.

Summary

Apart from minor errors both the Aqualinc report and PDP memorandum are generally sound. Both reports show similar projections for sea level rise and identify that sea level rise means opening the lake will require higher lake levels. Both reports also reach similar conclusions regarding Selwyn River high flows under climate change to 2040.

However, neither report clearly quantifies flood risk to Lower Selwyn Huts or the effect of climate change on flood risk. There are inconsistencies and errors regarding vertical datums preventing any comparison between lake levels and the elevation of land around Lower Selwyn Huts. These vertical datum issues are explained and resolved in this memo.

There are other relevant reports not identified in the PDP memorandum which provide useful information to quantify flood risk and climate change impacts on Lower Selwyn Huts. In particular, the Environment Canterbury report "Selwyn River/Waikirikiri floodplain investigation" (Wild 2019) provides highly relevant analysis, including a flood frequency analysis of Te Waihora lake levels, discussion of sea level rise impacts on lake openings, and flood frequency analysis for the Selwyn River including consideration of climate change.

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