Tekapo Power Scheme – Hydrological and Hydrogeological Analyses

Prepared for

Genesis Energy Ltd

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This report has been prepared by Pattle Delamore Partners Limited (PDP) on the basis of information provided by Genesis Energy Ltd and others (not directly contracted by PDP for the work), including the National Institute of Water and Atmospheric Research (NIWA) and Environment Canterbury (ECan). PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

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Executive Summary

Genesis Energy Ltd (Genesis) is lodging applications to reconsent the water permits for its Tekapo Power Scheme (TekPS). The existing consents are due to expire in 2025. This report provides an understanding of the groundwater and surface water environments relevant to the reconsenting and the effect of the existing TekPS on these environments. This report also informs other expert assessments, for example freshwater and terrestrial ecology and landscape and natural character.

The TekPS is located at the head of the Waitaki Valley in the Mackenzie District and uses water from the glacial-fed Lake Tekapo to generate electricity. The TekPS controls Lake Tekapo water levels for storage purposes and diverts water from Lake Tekapo to Lake Pukaki along the 26 km Tekapo Canal. Electricity is generated at two hydroelectric power stations—Tekapo A and Tekapo B.

Lake Tekapo forms the storage reservoir for the TekPS and several waterways contribute flow into Lake Tekapo including the Godley River and Cass River.

The upper reach of the Tekapo River between the Lake Tekapo control gates (Gate 16) and Lake George Scott is generally dry as almost all the water from Lake Tekapo is diverted through the Tekapo Canal. The reach of the Tekapo River between Lake George Scott and the confluence with Fork Stream was observed during site visits to have ponding and minor flows which is expected to be from a combination of leakage from Lake George Scott and minor groundwater inflow further downstream. The Tekapo River still receives flow from tributaries, Fork Stream, the Mary Burn, Irishman Creek (via the Mary Burn) and the Grays River. The combined flow from these sources is much less than the historic flows from Lake Tekapo.

The climate in the area is strongly influenced by Ka Tiritiri O Te Moana/ Southern Alps. The climate of the region has a marked influence on hydrology. The main rivers that feed into Lake Tekapo are partially snow and ice–fed and have their highest discharges during the spring/summer snowmelt season. The streams and rivers which are predominantly rain-fed (such as Mary Burn and Irishman Creek) tend to have their highest discharges in winter and spring.

The Mackenzie Basin is a tectonic depression that has been infilled by the erosion of greywacke and schist associated with uplift of the Alpine Fault. The thickness of the material (predominantly glacial deposits) infilling the basin varies (estimated to be between 300 to possibly 2,000 m) and there are a number of faults across the basin. Groundwater occurs within these deposits. Monitoring of groundwater levels and flow losses around the Tekapo River indicates relatively permeable strata occurs around the river, consistent with geological mapping. Bedrock outcrops in the Mary Range and Grays Hills subdivide the Mackenzie Basin into the Tekapo and Twizel Basins. These outcrops restrict

groundwater flow and result in the emergence of groundwater at the southern end of the Tekapo Basin.

Groundwater flow directions generally follow topography and are sub-parallel to the Tekapo River. Piezometric surveys undertaken in 2020 have confirmed groundwater flow patterns around the Tekapo River. Monitoring of wetland levels around Lake Tekapo supports the expected pattern of groundwater flow towards the lake.

Lake Tekapo Hydrology

Genesis is required to manage Lake Tekapo lake levels within the consented minimum and maximum levels. Maximum and minimum consented operating levels vary throughout the year; however, the normal minimum and maximum control levels are 702.1 masl and 710.9 masl respectively, with an extreme minimum operating level of 701.8 masl.

Analyses of lake levels indicate that levels are typically lowest in winter and spring following a period of drawdown due to high power demand in winter. The level of Lake Tekapo is generally higher in summer and autumn when inflows are high and/or the demand for power decreases. The mean lake inflow and outflow is around 84 m^3/s.

Climate change impacts on Lake Tekapo inflows and hydro-electricity generation potential for the Tekapo Power Scheme has been well researched. The studies indicate an increase in average annual inflow to Lake Tekapo for both the Mid-century as well as for End-Century model periods. The greatest changes in flow characteristics can be expected under the high emission scenario (RCP 8.5), while for the low emission scenario (RCP 2.6) there is generally little change in inflow expected. In terms of seasonality, flows are likely to increase in winter due to increased precipitation which will primarily be as rain in winter with less snow and earlier melt. A small decrease in flow in summer is predicted.

Climate change is expected to increase floods in winter and spring. Due to increased rainfall and snowmelt in winter, low flows and extreme low flows are also projected to increase. The potential increase in flood flows in winter and spring due to climate change is unlikely to result in increased spill flows, although there is significant uncertainty in climate change projections and impacts.

No changes are proposed to the Lake Tekapo operating regime, so no changes to the hydrology of the lake are expected to occur as a result of the reconsenting.

Tekapo River Hydrology

Flow statistics

For approximately 72% of the time there is no or very little flow in the upper reaches of the Tekapo River between the control gate (Gate 16) and Lake George Scott. Gate 17 and Lake George Scott Weir have no or very limited flow for approximately 72% and 90% of the time respectively.

The median flow in the Tekapo River increases from approximately 3.1 m^3/s at the confluence with Fork Stream to approximately 10 m^3/s at the ECan Tekapo River recorder site downstream of the Mary Burn. This is predominantly due to flow contributions from tributaries such as the Grays River and Mary Burn.

The lowest median monthly flows in Fork Stream (which is representative of flows in the Tekapo River between the Fork Stream confluence and the confluence with the Grays River) tend to occur in June to September (2.3 – 2.8 m^3/s) although flows are also relatively low in March and April (2.7 and 2.6 m^3/s respectively). The Tekapo River at downstream Mary Burn generally has its lowest flows between January and May (median monthly flow of 6.8 to 9.0 m^3/s).

The lower 4 km of the Tekapo River is influenced by flow from the Pukaki River. The Pukaki River generally has no or only a very limited amount of flow except for periods when the Pukaki Spillway discharges into the Pukaki River (approximately 7% of the time).

Groundwater – Surface water interaction

Due to a limited amount of historical flow gauging information available for the Tekapo River, five flow gauging surveys were undertaken by PDP between February 2019 and November 2020 to better understand both increases to flow from groundwater discharging to the river, and flow losses to groundwater within the mainstem of the Tekapo River.

The available historical and recently collected flow data suggests that the Tekapo River typically has relatively stable flows in the upper reaches with some flow being lost to groundwater above the Grays River confluence. A significant flow increase typically occurs due to the Mary Burn and Grays River inflows, although there is an additional gain in flow that can be attributed to groundwater inflows immediately downstream of the Mary Brun and Grays River confluences. In the lower reaches as the river enters the Twizel Basin but upstream of the Pukaki River confluence, an overall loss of river water to groundwater typically occurs.

Fresh and flood flows

Freshes or floods with different magnitudes (such as 3, 6 and 10 times the median flow) are important for matters such as scouring and flushing periphyton and to mobilise and transport bed material. The number of freshes or floods of varying magnitudes that occur over a certain time period (for example one year)

is called the fresh or flood flow frequency. The Tekapo River between the confluence with Fork Stream down to the confluence with the Grays receives infrequent fresh and flood flows of 3 times the median flow (on average around 4 per annum). Flows of 6 times the median or greater occur even more infrequently (on average less than 2 per annum).

The Tekapo River between the Mary Burn confluence and Pukaki River confluence receives infrequent fresh and flood flows of all magnitudes (3, 6 and 10 times the median). The average frequency of these fresh and flood flow events is 3 or less per annum.

The Tekapo River downstream of the confluence with the Pukaki River has a much greater fresh and flood flow frequency than the two upstream reaches (especially for flows 3 times the median) due to the Lake Pukaki spill flows. The average frequency of fresh and flood flow events is around 6, 4 and 3 per annum for flows with a magnitude of 3, 6 and 10 times the median respectively.

Mean and maximum accrual times (which are the mean and maximum time between fresh and flood events flows) are very long especially for the larger floods with a magnitude of 6 times the median or greater.

The flow data indicates that the frequency of fresh and flood flows in the cooler months (May – September) is relatively low compared to the warmer months (November – April), and that the accrual time is relatively long in winter compared to the warmer summer months.

No changes are proposed to the operation of the diversion of water from Lake Tekapo, so no changes to the hydrology of the Tekapo River are expected to occur as a result of the reconsenting.

Tekapo Canal Hydrology

Flows at the Tekapo A and Tekapo B power stations vary depending on several factors including for example electricity demand, lake levels and Lake Tekapo inflows. Median and mean Tekapo Canal flows (estimated by using Tekapo B power station flows) are estimated to be around 90 and 76 m^3/s respectively and 84 and 69 m^3/s for Tekapo A. The difference is made up by flows bypassing Tekapo A via releases at the Tekapo control gate (Gate 16) into the upper Tekapo River discharging back into the Tekapo canal at Gate 17.

Mean monthly flows are typically high in winter, especially July and August (82 m^3/s for Tekapo A and 83-84 m^3/s for Tekapo B), when electricity demand is high and low in September and October (56 and 57 m^3/s respectively for Tekapo A and 65 and 59 m^3/s for Tekapo B) when electricity demand drops off and the level of Lake Tekapo increases following drawdown in winter. When the lake level is high in summer, higher canal flows can be seen to reduce the likelihood of spill.

No changes are proposed to the operation of the diversion of water from Lake Tekapo via the Tekapo Canal, so no changes to the hydrology of the Tekapo Canal are expected to occur as a result of the reconsenting.

Lake Tekapo Hydrogeology

A number of wetlands and other water bodies border Lake Tekapo. To understand the effect of water level fluctuations in Lake Tekapo on these wetlands/water bodies, PDP monitored water levels in seven representative wetlands/water bodies. This indicated that wetlands/water bodies above approximately 711 masl are unlikely to be impacted by lake levels, except during infrequent events when lake levels exceed the maximum operating levels. Wetlands/water bodies less than 711 masl are expected to have some degree of hydraulic connection with Lake Tekapo, although the degree of connection will vary depending on Lake Tekapo water levels. Therefore, some of the wetlands/water bodies surrounding Lake Tekapo are influenced by lake level fluctuations as a result of the scheme operation. However, this pattern of interaction will not be altered as a result of the reconsenting as Genesis is not proposing to change the current operating levels for the lake.

There are a small number of domestic supply bores around Lake Tekapo that could potentially be affected by lake level fluctuations. These bores have all been installed since 2000 (post-scheme) and Genesis is not proposing to change the current operating levels for the lake. No changes in groundwater level fluctuations already experienced at these bores are expected to occur as a result of the reconsenting.

Tekapo River Hydrogeology

The Tekapo River is bordered by a number of bores, wetlands and other water bodies throughout the Tekapo River Basin. PDP undertook monitoring of water levels within a number of these bores, wetlands and other water bodies throughout the Tekapo River Basin for the purpose of understanding groundwater and surface water interaction and how these interactions change with flows/stage height in the Tekapo River.

Water levels were monitored within two wetlands east of the Tekapo River and in five wetlands located west of the Tekapo River. The data collected indicates that there is generally no clear hydraulic connection to most wetlands located more than approximately 1 km from the river. For wetlands closer to the river, there may be some influence from the Tekapo River flow and stage height. This is because permanent flow in the river is expected to be interacting with/contributing to groundwater surrounding the river and therefore wetland levels close to the river will respond more clearly to changes in river flows and levels.

As no changes are proposed to the operation of the diversion of water from Lake Tekapo, no changes to the hydrology of the Tekapo River and therefore hydraulically connected wetlands are expected to occur as a result of the reconsenting.

Water level monitoring was undertaken in six existing bores located more than 400 m from the Tekapo River that were all deeper than 6 m. The monitoring showed that bores closer to the river displayed strong responses to flow in the Tekapo River compared to bores located further away from the river.

Deeper monitoring bores (up to 23 m deep) located on both sides of the Tekapo River and close to or downgradient of smaller tributaries of the Tekapo River (i.e., Edwards and Sawdon Streams east of the Tekapo River and Irishman Creek west of the Tekapo River), responded strongly to flows within these tributaries. The changes in groundwater levels as a result of the tributary flows were much larger compared to the smaller effect of changes in flow within the Tekapo River.

Groundwater monitoring was also undertaken in eight shallow (<6 m deep) bores located within 160 m of the Tekapo River installed as part of the monitoring program (referred to as riparian margin monitoring bores). The water level data measured in these bores showed that all of these bores generally displayed a strong response to flow and corresponding stage (water level) changes in the Tekapo River.

While the groundwater level monitoring has shown that monitoring bores close to the river respond to Tekapo River flow and stage changes, ECan's database shows no bores used for abstraction near the Tekapo River such as drinking water supply or irrigation use, with the exception of a surface water take via an infiltration gallery on the lower reaches of the Tekapo River. This consent was granted after the TekPS was already in place, meaning the infiltration gallery and take will have been designed based on the current flow pattern in the Tekapo River and groundwater levels. There are no other surface water takes located on the main stem of the Tekapo River. On this basis and given that no changes to the scheme are proposed, effects on groundwater availability around the Tekapo River are not considered to be an issue.

A review of existing groundwater quality data was undertaken which indicated that groundwater quality within the Tekapo River Basin is relatively good. Slightly elevated concentrations of some parameters, (E.coli, nitrate-N) have been observed occasionally in some bores, which likely reflect localised upgradient landuse. The ongoing operation of the TekPS is not expected to cause any changes in groundwater quality.

Tekapo Canal Hydrogeology

Monitoring data collected by PDP prior to, during and after the canal relining process between 2012 and 2013, as well as a review of available historic and recent aerial imagery, indicated that any seepages from the canal to groundwater and adjacent wetlands/water bodies were minor compared to the much larger natural water level variations (such as from rain/snow fall and seasonal fluctuations) measured within the groundwater monitoring bores and receiving wetlands/water bodies downgradient of the canal.

Some interaction between the canal and the surrounding groundwater system is expected to continue with the on-going operation of the TekPS and remain unchanged with normal operation. Effects of any further maintenance works on that interaction, such as canal relining, would be considered as part of specific consent applications.

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Glossary

7DMALF: 7-day mean annual low flow. Calculated by taking the mean of the lowest moving 7-day average flow recorded each year (7-day annual low flows).

Aquifer: A geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs.

Autumn: months from March to May based on meteorological seasons in New Zealand.

Darcy's Law: An empirical law which states that the velocity of flow through a porous medium is directly proportional to the hydraulic gradient assuming that the flow is laminar, and inertia can be neglected.

ECan: Environment Canterbury.

Electrical conductivity: Measure of the ability of material to conduct an electrical current.

Flow duration curve: A graph showing how often certain flows are equalled or exceeded during a given period. For a typical river, high flows will only be exceeded a small percentage of time (during floods) while lower flows will be exceeded a large percentage of time.

Gaining reach: A stream or reach of a stream where flow is being increased by surface inflow of groundwater.

Genesis: Genesis Energy Limited.

Groundwater: All water which occurs below the land surface.

Groundwater mound: A raised area in a water table or other potentiometric surface created by groundwater recharge.

Groundwater recharge: The process of the addition of water to groundwater.

Groundwater recharge rate: The rate at which water is added to groundwater.

ha: unit of area - hectares**.**

Holocene: Geological epoch starting from 11,700 years ago through to the present.

Hydraulic conductivity: The volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured perpendicular to flow direction.

Hydraulic gradient: The change in static head per unit of distance in a given direction.

km: unit of distance - kilometres.

km²: unit of area - square kilometres.

L/s: unit of flow - litres per second.

LiDAR: 'light detection and ranging' which for the purposes of this report refers to elevation data collected by aircraft equipped with laser remote sensing technology.

Losing reach: Reach of a stream in which water flows from the stream into the ground.

m: unit of distance - metres.

m/day: unit of velocity - metres per day.

m²/day: unit of transmissivity - square metres per day.

m^3: unit of volume – cubic metres.

m^3/s: unit of flow - cubic metres per second.

MAF: Mean annual flood.

masl: metres above sea level.

mbgl: metres below ground level.

mbmp: metres below measuring point.

mm: unit of distance - millimetres.

NIWA: National Institute of Water and Atmospheric Research.

Permeability: The property of a porous medium to transmit fluids under a hydraulic gradient.

Piezometric contours: Lines of equal groundwater level elevation for a particular point in time.

Porosity: The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium.

Pressure transducer: A device that automatically measures and records water pressure data that can be used to provide a continuous water level record.

Semi-confined aquifer: An aquifer, whether artesian or water-table, that loses or gains water through adjacent less permeable layers.

Spring: months from September to November based on meteorological seasons in New Zealand.

Storativity: parameter that describes the capacity of an aquifer to store or release water. It is defined as a volume of groundwater per unit surface area of the aquifer and per unit reduction in hydraulic head**.**

Strata: A layer or a series of layers of rock and sediment in the ground.

Streambed conductance: Parameter that describes the permeability of the stream and relates the head difference between the stream and aquifer to stream flow losses or gains along a reach. Can be calculated from the change in stream/river flow rate between two flow gauging sites and the hydraulic gradient.

Summer: months from December to February based on meteorological seasons in New Zealand.

TekPS: Tekapo Power Scheme.

Transmissivity: The rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Unconfined aquifer/groundwater system: A condition in which the upper surface of the zone of saturation forms a water table under atmospheric pressure.

VCSN: Virtual Climate Station Network. A series of artificial climate stations developed by NIWA which covers New Zealand on a regular grid. The data is based on interpolation of data from actual stations.

Winter: months from June to August based on meteorological seasons in New Zealand.

1.0 Introduction

Genesis Energy Ltd (Genesis) is lodging applications to reconsent its water permits for the Tekapo Power Scheme (TekPS). The existing water permits are due to expire in 2025.

This report describes the work that Pattle Delamore Partners (PDP) have undertaken for Genesis to provide an understanding of the groundwater and surface water environment and the effect of the existing TekPS on this environment.

The hydrological work described in this report includes:

- Review and analysis of Lake Tekapo lake levels, inflow and outflows based on available historical lake level and lake inflow data.
- An overview of climate change impacts on Lake Tekapo inflows and hydro-electricity generation potential for the TekPS.
- Analysis of the available hydrological information for the Tekapo River and its tributaries based on historical flow data.
- An assessment of groundwater-surface water interaction and preparation and analysis of long sections showing surface flow losses and gains in the Tekapo River between the confluence of Fork Stream and the Tekapo River and Lake Benmore.
- Analysis of the available hydrological information for the Tekapo Canal (using Tekapo B power station flow data) and Tekapo A.

The groundwater work described in this report includes:

- Desktop analysis of available groundwater data around Lake Tekapo, the Tekapo River and the Tekapo Canal.
- Analysis and discussion of water level transducer data collected from several existing bores and new bores to assess interactions between shallow groundwater and the Tekapo River and its tributaries.
- Analysis and discussion of water level transducer data collected from representative Tekapo River Basin wetlands/water bodies to assess interactions with the Tekapo River and tributaries as well as shallow groundwater.
- Review of historic aerial photos of wetlands/water bodies around Lake Tekapo, comparison to lake level records, LiDAR data review and review of wetland water level information.

- Analysis and discussion of water level transducer data collected from selected wetlands/water bodies that border Lake Tekapo to understand interactions between Lake Tekapo and these wetlands/water bodies.
- Review of existing groundwater quality data.
- Assessment of groundwater and surface water interaction between Lake Tekapo, neighbouring wetlands/water bodies and the shallow groundwater system to understand the effect of lake level fluctuations on these environments.
- Assessment of groundwater and surface water interaction between the Tekapo River, the surrounding groundwater system and neighbouring wetlands/water bodies within the Tekapo River Basin to understand the effect of the Tekapo River flows on these environments.
- Assessment of groundwater and surface water interactions between the Tekapo Canal and the surrounding groundwater system.

The information provided in this report describes the existing environment and how the operation of the scheme interacts with the surrounding surface water bodies and groundwater. As a result, the magnitude of the effect of the scheme for the current operational regime on surrounding surface water and groundwater has been considered. In addition, it is noted that Genesis has not proposed any changes to the existing (currently consented) operation of the TekPS. As explained in the Genesis Energy Ltd (2025) "Fast-track Application for Resource Consents and Assessment of Environmental Effects" a state without the TekPS in place was not considered.

The effects of the existing scheme on the hydrological and hydrogeological environments have been assessed and will inform the assessments of other parts of the TekPS reconsenting project, for example freshwater ecology, terrestrial ecology and landscape and natural character.

This report is structured as follows:

- Sections 2.0 and 3.0 describe the existing scheme and the existing environment around the scheme.
- Section 4.0 describes the hydrology of Lake Tekapo, Tekapo River and the Tekapo Canal and provides a discussion on the interactions between these components of the scheme and the surrounding surface water environments.
- Section 5.0 describes the hydrogeology of Lake Tekapo, Tekapo River and the Tekapo Canal to and provides a discussion on the interactions between these components of the scheme and the surrounding groundwater environments.

- Section 6.0 provides a summary of the key findings from the hydrological and hydrogeological investigations and analyses described in Sections 4 and 5.

2.0 Scheme Description

The TekPS is located at the head of the Waitaki Valley in the Mackenzie District and uses water from the glacial-fed Lake Tekapo to generate electricity. The TekPS controls Lake Tekapo water levels for storage purposes and diverts water from Lake Tekapo to Lake Pukaki along the 26 km Tekapo Canal. Electricity is generated at two hydroelectric power stations - Tekapo A and Tekapo B. Tekapo A is situated at the start of the canal, Tekapo B is situated within Lake Pukaki at the downstream end of the canal.

The Tekapo River was the main outlet of Lake Tekapo until construction of the Tekapo A Power Station was completed in 1951. Water was then discharged from Tekapo A power station back into the Tekapo River, until construction of the Tekapo Canal and Tekapo B Power Station was completed in the 1970s.

The TekPS diverts almost all water exiting Lake Tekapo (via Tekapo A power station) through the Tekapo Canal, which has a maximum capacity of 130 m^3/s. Water in Lake Tekapo can bypass Tekapo A Power Station using the Lake Tekapo Control Structure (Gate 16). Water released from Lake Tekapo can then flow down the upper Tekapo River to Lake George Scott and can then be released into the Tekapo Canal via Gate 17 or into the Tekapo River via the Lake George Scott Weir (refer to Appendix A, Figure A1).

Genesis typically only spills water into the Tekapo River downstream of Lake George Scott for operational reasons. There are also periodic releases down the upper Tekapo River and into the Tekapo kayak course (constructed in 1998) between the Lake Tekapo Control Gates and Lake George Scott. Therefore, under normal conditions the Tekapo River channel between the Lake Tekapo control gates (Gate 16) and Lake George Scott has no or very little flow. The reach of the Tekapo River between Lake George Scott and the confluence with Fork Stream was observed during site visits to have ponding and minor flows which is expected to be from a combination of leakage from Lake George Scott and minor groundwater inflow further downstream. Spring fed flows and tributaries such as Fork Stream, Grays River and the Mary Burn increase the flow in the Tekapo River until the river enters Lake Benmore approximately 55 km downstream of the Lake Tekapo Outlet.

3.0 Overview of Existing Environment

Several previous reports describe the hydrology of the catchment. The most notable reports include Environment Canterbury (2013 and 2005), Electricity Commission (2009), Ministry for the Environment (2005), Young (1987) and Jowett et al. (1980). The general description of the Waitaki, Lake Tekapo and Tekapo River catchments provided below draws on information from these reports. The description of Lake Tekapo lake levels, flow characteristics of the rivers and streams in the area and in the Tekapo Canal presented in sections 4.1-4.3 of this report are based on the available flow and water level data provided by Environment Canterbury (ECan), Genesis and the National Institute of Water and Atmospheric Research (NIWA) and focus on the period from 1991 since that represents the hydrological regime that has existed under the exercise of the existing consents for the TEKPS.

3.1 General catchment description

3.1.1 Waitaki catchment

The TekPS is part of the Waitaki Catchment which is one of the most extensive river basins in New Zealand. The catchment drains from Ka Tiritiri O Te Moana/ Southern Alps to the Pacific Ocean and has a total catchment area of approximately 11,800 km². The upper reaches of the catchment near the main divide are over 3,000 m high and include several major glaciers. The lower reaches of the catchment comprise of hill country, rolling downlands and gently sloping plains. The Waitaki is a major region of hydro-electricity generation with eight power stations and several natural and man-made lakes.

The upper Waitaki comprises four major tributary basins being Tekapo, Pukaki, Ohau and the Ahuriri. With the exception of the Ahuriri, all these basins contain large glacially formed lakes being Lake Pukaki, Lake Tekapo and Lake Ohau. Above and below the lakes the rivers generally have braided gravel beds except where the riverbed is occupied by hydro lakes such as Lake Benmore, Lake Aviemore and Lake Waitaki. The lower Waitaki, which extends from the Waitaki Dam to the Pacific Ocean receives flow from the Hakataramea and Maerewhenua rivers along with a number of smaller tributaries as shown in Appendix A, Figure A2.

The climate in the catchment varies greatly mainly due to the influence of Ka Tiritiri O Te Moana/Southern Alps. Precipitation is very high near the main divide and low in the areas surrounding Lakes Benmore, Aviemore and Waitaki and the Tekapo River.

A key feature of the Waitaki hydrology is that approximately 80% of the flow at Waitaki dam comes from Lakes Tekapo, Pukaki and Ohau. On average the outflow from Lake Tekapo contributes approximately 23% (85 m³/s) of the flow

at Waitaki dam. The ability to store water in these lakes greatly enhances the Waitaki catchment power generation.

3.1.2 Lake Tekapo, Tekapo Canal and Tekapo River

The catchment of Lake Tekapo is bounded by Joseph Ridge, Gamack, Liebig and Two Thumb Ranges and Ka Tiritiri O Te Moana/Southern Alps. Several waterways contribute flow to Lake Tekapo, which forms the storage reservoir for the TekPS. The main inflows are the Godley River, Macaulay River (via the Godley River) and Cass River, originating near the main divide (refer to Appendix A, Figure A3).

The upper reach of the Tekapo River between the Lake Tekapo control gates (Gate 16) and Lake George Scott is generally dry as almost all the water from Lake Tekapo is diverted through the Tekapo Canal (refer to Appendix A, Figure A1). The reach of the Tekapo River between Lake George Scott and the confluence with Fork Stream was observed during site visits to have ponding and minor flows which is expected to be from a combination of leakage from Lake George Scott and minor groundwater inflow further downstream.

The Tekapo River still receives flow from tributaries including Fork Stream, the Mary Burn, Irishman Creek (via the Mary Burn) and the Grays River (Appendix A, Figure A4), although the combined flow from these sources is much less than the historic flows from Lake Tekapo.

The Mary Burn and Irishman Creek catchments occur west of the Tekapo River and are primarily located over the gently sloping land to the west of the Old Man Range. The Fork Stream catchment also occurs west of the Tekapo River but has a larger catchment area located within the mountains to the west. The Grays River catchment is located east of the Tekapo River and receives inflow from smaller tributaries such as the Snow and Mackenzie River.

Other tributaries of the Tekapo River include Edward and Sawdon Streams. Except during high flow events these streams lose their flow to groundwater as they flow across the plains (ECan, 2005). A stopbank, constructed in 1965, diverts flood flows from Edward and Sawdon Streams into the Tekapo River. There are no significant tributaries contributing flow to the Tekapo River downstream of Grays Hills. The Pukaki River joins the Tekapo River approximately 4 km upstream of Lake Benmore. The Pukaki River generally has no or very limited flow (approximately 93% of the time) due to almost all of the water exiting Lake Pukaki being diverted into the Pukaki Canal by Meridian Energy.

The climate in the area is strongly influenced by the Ka Tiritiri O Te Moana/ Southern Alps. Average annual rainfall near the main divide is approximately 8,000 mm reducing to approximately 500 mm around the mid- and lower reaches of the Tekapo River main stem. The Godley at Panorama Ridge and Godley at Eade Hut rainfall monitoring sites, located near the head of the Godley River in the upper catchment, have a mean annual rainfall of around 6,000 and 5,000 mm

respectively. This decreases sharply to around 1,000 mm for Macaulay at Mount Gerald and to 500 mm near Tekapo Township (Lake Tekapo Ews). The location of the rainfall stations are shown in Appendix A, Figure A3. At higher altitudes, much of the precipitation falls as snow.

The climate of the region has a marked influence on the hydrologic regime of the rivers. The main rivers that feed into Lake Tekapo are partially snow and ice–fed and have their highest discharges during the spring/summer snowmelt season. The streams and rivers which are predominantly rain-fed (such as Mary Burn and Irishman Creek) tend to have their highest discharges in winter and spring.

3.2 Geology and groundwater

The Mackenzie Basin is a tectonic depression, which has been infilled as a result of the erosion of greywacke and schist associated with uplift of the alpine fault. Cooksey (2008) describes how the basement rocks are predominantly greywacke, associated with the Torlesse Supergroup, which outcrops in the surrounding ranges. This is overlain by weathered greywacke conglomerate (associated with the Glentanner Formation), which is in turn overlain by glacial deposits, consisting of glacial tills and glacial outwash gravels, deposited during four major advances. There are alluvial deposits at surface in places (post glacial), which occur predominantly within and around present-day river systems, including the Tekapo River. Around Lake Tekapo, the predominant geology is glacial till, with alluvial deposits around the inflowing rivers and sand and gravel beach deposits bordering the lake in places. The surficial geology of the area is shown in Appendix E, Figure E1.

Formation presence and thickness varies and there are numerous faults across the Mackenzie Basin. These faults are shown in Appendix E, Figure E2. The bedrock outcrops in the Mary Range and Grays Hills further subdivide the basin into the Tekapo and Twizel basins. These outcrops restrict groundwater flow from the Tekapo Basin resulting in groundwater emerging as surface water at the southern end of the basin.

Cooksey (2008) reports that the depth to basement is variable and estimated to range from 300 to 1,000 m, but possibly up to 2,000 m at its deepest point. Cooksey (2008) proposes that the Glentanner Formation is of sufficiently low permeability such that it forms a hydrogeological basement to groundwater in the Mackenzie Basin. Two groundwater systems were conceptualised in that report – a highly permeable shallow groundwater system in the post glacial alluvial gravels near the rivers, which responds rapidly to rainfall and changes in surface water flows, and a deep groundwater system, most likely within the Mt John Outwash Gravels, mainly in clean, gravel lenses and layers, which does not have a clear response to rainfall and changes in surface water flows.

Cooksey (2008) noted that the location of groundwater both vertically and laterally in the deeper system is likely to be highly variable and it is unknown whether the groundwater system is connected at depth. GHD (2009) also noted that differences in piezometric levels between adjacent bores were observed in bores in the north of the Tekapo Basin and commented that this makes the connection between layers and their lateral extent difficult to determine.

Environment Canterbury's interpreted groundwater contours on Canterbury Maps show groundwater flow to generally be parallel to the Tekapo River and Lake Benmore. Further information on groundwater flow directions is provided in Section 5.2.4 of this report. No groundwater flow information is available around Lake Tekapo, but it is expected that groundwater flow follows topography, generally flowing towards the lake, which is consistent with monitoring of wetlands described in Section 5.1.2 of this report.

4.0 Hydrological Information

This section provides a summary of the hydrology for Lake Tekapo, the Tekapo River (and its tributaries) and the Tekapo Canal. Maps showing the location of key hydrological sites can be found in Appendix A and a table of detailed site information is given in Appendix I. For the generation and associated operational data such as Tekapo A and Tekapo B power station, Gate 16 and Lake George Scott data for the period 1991-2022 was analysed as this is considered representative for the current scheme operation. For the natural flow records which have data prior to 1991 both the period 1991 -2022 as well as the full available record length was analysed (for example Fork Stream at Balmoral and Lake Tekapo inflows). Cawthron undertook monthly water quality and ecological monitoring in the Tekapo River between 1 March 2019 and 29 February 2020. In addition, Cawthron undertook drift diving in the Tekapo River in February 2021. At the request of Cawthron, additional hydrological analyses were undertaken to better understand the flow conditions during these period.

In order to assist with describing the historical development of the scheme, four distinct periods were analysed for Lake Tekapo lake levels (1926-1950, 1951-1978, 1979-1991 and 1991-2022). These periods align with key changes in the development and/or operation of the TekPS as described in section 2.0.

4.1 Lake Tekapo

4.1.1 Lake Tekapo lake levels

Prior to the development of the TekPS in 1951, Lake Tekapo lake levels were controlled by the natural inflows and outflow from the lake. The pre-1951 lake levels varied between 704.4 and 707.1 metres above sea level (masl). Note that

all elevation data presented in this report is provided in the Lyttelton 1937 vertical datum.

Lake Tekapo now forms the storage reservoir for the hydropower generation at Tekapo A and Tekapo B power stations and Genesis is required to manage the lake within the consented minimum and maximum levels. Lake levels are continuously monitored by Genesis near the inlet of the Tekapo A power station. Appendix B, Figure B1 shows the recorded lake levels between 1 Jan 1926 and 31 Dec 2022.

Maximum and minimum consented operating levels vary throughout the year; however, the normal minimum and maximum control levels are 702.1 masl and 710.9 masl respectively. The minimum operating level between 1 April and 30 September is 702.1 masl and 704.1 masl between 1 October and 31 March. Between 1 October and 31 March, Lake Tekapo can be further reduced to 701.8 masl in an electricity emergency.

The current maximum operating levels for Lake Tekapo are:

- September to February – 709.7 masl
- March – 710.0 masl
- May – 710.6 masl
- April and August – 710.3 masl
- June and July – 710.9 masl

A visual representation of the minimum and maximum operating levels is included in Appendix B, Figure B2.

Appendix A of Genesis consent CRC183551 (to dam Lake Tekapo) sets out special flood operating procedures which allow lake levels to temporarily exceed the maximum operating levels during flooding events. This procedure was introduced after the 1984 flood and aims to return the lake to the maximum control level as soon as possible while still maintaining reasonable flood discharges down the Tekapo River. The current design flood level for Lake Tekapo is 713.05 masl. As detailed in the evidence of Freestone (2005) the design flood level is based on routing the design flood flow through Lake Tekapo using the discharges specified in "Tekapo Power Scheme, Appendix A, Extracts of Waitaki Operating Rules (9 November 1990)" referred to in condition 8 of consent CRC183551. This assumes maximum control (normal operating maxima) levels as a starting point to the flood range. The maximum control level is therefore part of a detailed and complex series of control measures for Lake Tekapo.

Analyses of the available lake level data indicates that the lower part of the range has been entered less often since 1991. Minimum lake levels for the period 1951-1978 and 1979-1990 are 701.7 masl and 702.1 masl respectively.

This compares with a minimum of 702.9 masl for the period 1991-2022. The lake levels that are exceeded 95% of the time (lowest 5 percent of the lake levels) are also higher for the period 1991 – 2022 compared to the period 1979 - 1990 and 1951 – 1978. A summary of the lake levels for the periods 1925-1951, 1951-1978, 1979-1990 and 1991-2022 is included in Table 1 below. The associated lake level duration curves are included in Appendix B, Figure B3. These periods are aligned with key changes to the scheme as described in section 2.0. The most recent period (1991-2022) reflects the operation of the scheme under the current consent conditions.

The influence of managing the water levels for hydropower generation is clearly visible in the data. The uncontrolled (natural) lake level fluctuation (pre-1951) is approximately 2.6 m. Post 1951 (1951-1978) lake levels are typically in the range between approximately 702.8 (water level exceeded 95 percent of the time) and 710.2 masl (water level exceeded 5% of the time). After 1991, water levels are typically in the range between 704.8 and 710.2 masl. The minimum and maximum water levels are 701.7 and 712.6 masl recorded on 28 August 1976 and 23 December 1984, respectively.

The design flood level of 713.05 masl has never been reached. The maximum recorded lake level since the lake was dammed in 1951 is 712.6 masl recorded during the 1984 flood. Since the time the special flood operating procedures were introduced, lake levels have not exceeded 712.0 masl.

Table 1: Lake level statistics

Statistic	Lake Level (masl)			
	01/01/1926 - 31/12/1950	*01/01/1951 - 31/12/1978*	*01/01/1979 - 31/12/1990*	*01/01/1991 - 31/12/2022*
Maximum	707.0	711.9	712.6	712.0
95th percentile	705.9	710.2	710.6	710.2
Upper Quartile	705.4	709.2	709.9	709.1
Mean	705.1	707.0	708.4	707.6
Median	705.1	707.6	708.9	707.6
Lower Quartile	704.8	705.0	707.4	706.3
5th percentile	704.6	702.8	704.4	704.8
Minimum	704.4	701.7	702.1	702.9

Table 2 and Appendix B, Figure B2 show that for the period 1991-2022 lake levels are typically low in winter and spring (July – November) following a period of drawdown due to high power demand in winter. Lake Tekapo fills up again in late spring and summer when inflows are high and the demand for power decreases resulting in high mean monthly lake levels in summer, autumn and early winter (December – June). Lake levels for the periods 1951-1978 and 1979-1990 show a similar trend.

Prior to 1951, when Gate 16 was commissioned, mean monthly lake levels show a much smaller variation. Levels were slightly lower in the coldest months (May to October) and slightly higher in warmer months (November – April) when snowmelt increases the inflow to the lake.

Table 2: Lake Tekapo mean monthly lake levels

Month	Lake level (masl)			
	01/01/1926 - 31/12/1950	*01/01/1951 - 31/12/1978*	*01/01/1979 - 31/12/1990*	*01/01/1991 - 31/12/2022*
January	705.6	708.1	709.7	708.7
February	705.5	708.7	709.6	708.8
March	705.3	708.8	709.7	708.6
April	705.3	708.5	709.7	708.4
May	705.0	708.3	709.5	708.2
June	704.9	707.8	709.0	707.9
July	704.7	706.6	707.9	707.2
August	704.7	705.2	706.6	706.4
September	704.7	704.6	705.9	705.8
October	705.0	704.8	706.5	706.2
November	705.3	705.8	707.7	707.0
December	705.5	707.1	709.0	707.9
Year	705.1	707.0	708.4	707.6

4.1.2 Lake Tekapo inflow and outflow

As detailed in section 3.1.2 the main inflows into Lake Tekapo are the Godley River, Macaulay River (via the Godley River) and the Cass River. There are no flow recorders on these rivers. However, the daily inflow into Lake Tekapo is estimated by Genesis based on lake outflows and lake levels and flow statistics for the period 1926 – 2022 and for the period 1991-2022 (which is the time during which the existing consents have been exercised) are included in Table 3 below. Table 4 shows the monthly mean inflow and outflow for Lake Tekapo and Appendix B, Figure B4 shows a bar graph of the data since the operating regime under the existing consents began.

Table 3: Flow statistics for Lake Tekapo daily inflows and outflows

Statistic	Lake Tekapo Inflow (m^3/s) [1] [2]		Lake Tekapo Outflow (m^3/s) [5]
	01/01/1926 - 31/12/2022	*01/01/1991 - 31/12/2022*	*01/01/1991 - 31/12/2022*
MAF	606.6 [3]	603.8 [3]	221.0 [6]
Upper Quartile	99.7	97.0	110.2
Mean	83.5	84.5	84.5
Median	66.6	67.6	97.3
Lower Quartile	43.2	47.1	56.2
7DMALF	24.5 [4]	31.7 [4]	- [7]

Notes:

1. *Combined record based on 'L Tekapo at inflow' (1926 – 1965) and 'Lake Tekapo Daily Inflow' (1965 – 2022).*
2. *All statistics are based on mean daily inflows, as instantaneous data is not available. The daily inflows are estimated by Genesis based on lake outflows and lake levels.*
3. *Mean annual flood. Calculated using the peak mean daily flow each calendar year. The calculations include several incomplete years after 1965. These incomplete years were included in the calculation for the Mean Annual Flood as the records for 'L Tekapo at Inflow' during gaps in the 'Lake Tekapo Daily Inflow' record were examined in detail and it was determined unlikely that the gap periods would contain flows higher than the peak flow for the year.*
4. *7 day mean annual low flow. Calculated using calendar years (1 January – 31 December) as the 7 day annual low flows typically occur in winter. The calculation includes several incomplete years. These incomplete years were included in the calculation for the 7DMALF as the record either side of the gaps was examined in detail, and it was determined unlikely that the gap periods would contain flows lower than the lowest recorded 7-day average flow for the year.*
5. *Sum of Tekapo A and Gate 16 combined. Gate 16 combined record uses site 71131 Tekapo River at Spillway when available, Gate 16 otherwise. All statistics are based on instantaneous flows. There are only minor differences in the statistics presented here between using instantaneous or mean daily flows for everything except the MAF, which is slightly higher when calculated on an instantaneous basis (221.0 m^3/s versus 176.3 m^3/s).*
6. *Mean annual flood. Calculated using the peak instantaneous flow each calendar year (1 January – 31 December). The MAF calculations include incomplete years, which were included by scrutinizing the Lake George Scott at Gate 17/Weir flows over the gap period. If Tekapo A/Gate 16 was missing data and the peak spill flow at Lake George Scott Weir plus the capacity of the canal (130 m^3/s) was less than the predicted peak instantaneous outflow for the year, it was assumed there was no significant outflow during the gap period time and the incomplete year was included. After this scrutinization there were only 2 years which were excluded.*
7. *7DMALF not calculated as the outflow record is a combination of two different discharges(Tekapo A and Gate 16), outflows are artificially controlled, and the outflow record does not represent flows in a physical river reach. The 7DMALF is therefore not a meaningful statistic for the Lake Tekapo Outflow.*

The mean lake inflow is around 84 m^3/s and the highest inflows into the lake are in spring and summer during the snowmelt season. The lowest inflows are in winter when most of the precipitation in the catchment is 'locked up' as snow. There is little difference in flow statistics for the lake inflow series when comparing the full available record period (1926-2022) with the period 1991-2022 although low flows are lower for the full record period.

The Lake Tekapo outflows are strongly influenced by the power generation. The naturally occurring high flows in spring and summer are decreased (predominantly October – January) and the winter flows are increased (predominantly June, July, August) due to high power demand. Lake Tekapo is typically low in winter and spring following a period of drawdown and fills up again in late spring and summer when inflows are high and the demand for power decreases.

A comparison between the inflow and outflow statistics (Table 3) indicates that the outflow lower quartile, upper quartile and median statistics are all higher, while the MAF is lower than the inflow statistics for the same period. This is because during floods, releases over the spillway are managed according to specific flood operating procedures (Appendix A of CRC183551) which aim to return the lake to the maximum control level as soon as possible without causing excessive flood discharges down the Tekapo River. Flows in the inter-quartile range (flows between the upper and lower quartile) are typically greater in the outflows compared to the inflow. The main reason for this is that flood flows are typically 'captured' in the lake using the available storage in Lake Tekapo. This water is subsequently used to generate electricity at a flow rate of up to 130 m^3/s (maximum capacity of Tekapo Canal) resulting in inter-quartile flows generally being greater for the outflow compared to the inflow.

Table 4: Lake Tekapo mean monthly inflow and outflow 01/01/1991- 31/12/2022 (m^3/s)		
Month	**Inflow**	**Outflow [1]**
January	119.5	99.8
February	97.5	104.6
March	78.2	88.2
April	77.0	80.3
May	73.6	79.2
June	64.5	79.0
July	56.1	86.2
August	56.9	84.3
September	64.8	66.1
October	88.2	65.4
November	112.0	85.1
December	126.0	96.3

Notes:

1. *Sum of Tekapo A and Gate 16 combined. Gate 16 combined record uses site 71131 Tekapo River at Spillway when available, Gate 16 otherwise.*

4.1.3 Overview of climate change impacts on Lake Tekapo inflows and hydro-electricity generation potential for the TekPS

4.1.3.1 Climate Change in New Zealand

Global warming and the climate change it brings are caused by the build-up of greenhouse gases in the Earth's atmosphere. It is 'unequivocal' that human influence has warmed the atmosphere, ocean and land (IPCC,2021). As recognised in the report *'Climate Change Projections for New Zealand, Atmospheric projections based on simulations undertaken for the IPCC 5th Assessment 2nd edition' (Ministry for the Environment, 2018)* climate change effects over the next decades are predictable with some level of certainty and will vary from place to place throughout New Zealand. A description of what is likely to happen in New Zealand and on a more regional scale has been described in that report. The projected overall changes for New Zealand draw heavily on climate model simulations from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. Overall, these projected changes are similar to those from the previous assessment (Ministry for the Environment, 2008) which were based on the IPCC Fourth Assessment. Uncertainties in climate change

projections are generally large which needs to be recognised when considering the climate change projections summarised below.

The Ministry for the Environment (MfE, 2018) report considers four scenarios for New Zealand. These pathways are known as Representative Concentration Pathways (RCPs). The four pathways are:

- A low emissions scenario (RCP2.6), where global carbon dioxide emissions stop after 2080, after which some is actually removed from the atmosphere;
- A high emissions, business as usual, scenario (RCP8.5); and
- Two middle scenarios (RCP4.5 and RCP6.0) which represent futures where global emissions stabilise at different levels.

The MfE (2018) report provides a detailed description of the climate change projections for New Zealand. In summary the key changes New Zealand is likely to experience, relevant for the hydrology assessment, are:

- Higher temperatures, with an increase of about 0.7°C (low emissions scenario) and 1.0°C (high emissions scenario) by 2040 and about 0.7°C (low emissions scenario) and 3.0°C (high emissions scenario) by 2090;
- A change in rainfall patterns – the overall pattern for changes in annual rainfall is a reduction in the north and east of the North Island and increases almost everywhere else, especially on the South Island's West Coast;
- Increase in the number of hot days, and decrease in the number of frost days and snow days; and
- Increased frequency and intensity of droughts over time, particularly under a high emissions scenario. The strongest increases are over the northern and eastern North Island and along the eastern side of the Ka Tiritiri O Te Moana/Southern Alps.
- Moderately extreme and very extreme precipitation is expected to increase over most of the country.

The summary of key relevant climate change projections in New Zealand provided above is based on the IPCC fifth assessment. It is likely that these climate change projections for New Zealand will be updated in the future based on the more recent IPCC sixth assessment report (2021).

4.1.3.2 Overview of climate change impacts on Lake Tekapo inflows and hydro-electricity generation potential for *TekPS*

Temperature and rainfall

NIWA (2023) provides climate change projections for a range of climate variables including temperature and rainfall. When considering the mid-range climate change scenarios (RCP4.5 and RCP6.0) for the Lake Tekapo catchment this information indicates that by 2055 relative to 1995 levels:

- Annual temperatures increase by approximately 1 – 1.5°C. There is generally little variation between the seasons although spring temperatures are predicted to experience the greatest increase in temperature and winter the least.
- Annual rainfall in the headwaters (close to the divide) is expected to increase by 5-10%. The main increase in rainfall in the headwaters is expected in winter (10-15%) with more moderate increases in summer, autumn and spring (0-5%).

With regard to the projected temperature increases it is noted that work by NIWA (2010) indicates that New Zealand has experienced an increase of approximately 1°C in the past century. Therefore, the projected increase in temperatures is in addition to those already experienced in the last 100 years.

Lake inflow

Purdie (2022) modelled climate change impacts on inflows, lake storage and spill in snow-fed hydroelectric power catchments in the Southern Alps of New Zealand. The modelling in this study incorporates 40 hydroelectric power generation stations, spread over New Zealand but the focus of the paper is on three catchments in the Southern Alps being Waitaki (including Lake Tekapo), Clutha and Waiau.

A modelling chain was applied to downscale climate variables from the Global Circulation Model (GCM) scale to enable the assessment of climate change impacts on river flows. The study estimates changes in river flows to 2050 relative to 2020 for a low (RCP2.6), mid-range (RCP4.5) and high emissions (RCP8.5) scenario. The study states that due to the relatively short timeframe of 30 years between the current (2020) and future (2050) the impact of different emission scenarios on inflows was found to be small. Although impacts on inflows are significant overall, the 30-year period examined was not long enough for clear distinctions between different emissions scenarios to emerge, distinct from that which is already 'locked in' by past emissions. Therefore, only the mid-range emissions scenario (RCP4.5) outcomes are discussed in the paper. With regard to Lake Tekapo inflows the results indicate:

- A moderate increase in annual inflows of approximately 6%.

- A large seasonal change in inflows with an increase in winter flow of 26% and a decrease in summer flow of 10%. The modelled increase in flow in spring and autumn is more moderate at 2% and 6% respectively.

The study attributes the significant seasonal changes in Lake Tekapo inflows (and the other snow-fed South Island hydropower catchments) to the changes in rainfall (main increase in winter) as well as the fact that the 'Waitaki Lakes' receive a significant proportion of their inflow from snowmelt which is anticipated to result in seasonal changes to inflows. For example, increasing temperatures will result in a further increase in flow in winter (i.e. a smaller proportion of the precipitation in winter is 'locked up' as snow).

The study also includes a brief discussion on the effects of climate change on floods and droughts. In summary larger flood volumes are expected in coming decades although uncertainty exists around the magnitude of these changes. This is predominantly due to warmer air being able to hold more moisture, and increased wind speeds are expected to enhance orographic uplift and spillover over the Southern Alps. Little change in drought severity or duration is expected in New Zealand's largest hydropower catchments over the next three decades. It is noted that the projected increase in floods carries the risk of increased spill from Lake Tekapo. Further comments on this are included below.

Zammit (2019) assessed climate change impacts on hydro-electricity generation potential for the hydro-electric lakes Ohau, Pukaki and Tekapo (simulated as inflows to the lakes). Inflows to the lakes were modelled using a calibrated rainfall-runoff model and climate change projections for several climate change scenarios. The climate change projections for the study were based on the IPCC 5th assessment and the 6 Global Climate Models (GCM's) chosen for New Zealand (Mfe, 2018). Four Representative Concentration Pathways (RCPs) were modelled as detailed above.

One baseline period and two future time periods were analysed:

- a baseline period (mid-1985 to mid-2006).
- 2030-2049 (mid-century, referred as 2040s).
- 2080-2099 (end of century, referred as 2090s).

The focus of the study was on high flows (Q1 and Q10) and on low flows (Q75) representing lake inflows that are equalled or exceeded 1, 10 and 75 percent of the time respectively. The report discusses these lake inflows as inflow thresholds and the magnitude of the effect was determined by the difference between these thresholds calculated over the baseline period and future periods (2040s and 2090s). Mean and median lake inflows were not considered in this study.

The results of the modelling indicate the following changes in the low flow characteristics (Q75) for Lake Tekapo:

- An increase in inflow in winter and spring. This is associated with an increase in precipitation in winter which tends to fall as rain (as opposed to being 'locked up' as snow) due to the projected increase in temperature. The increase in spring is thought to be associated with a temperature driven increase in ice melt.
- A decrease in inflow in summer due to reduced summer precipitation, increased evaporation and/or a reduction of summer melt from the glaciers.
- No or limited change to inflows in autumn.

The results of the modelling indicate the following changes in the Q10 and Q1 flows for Lake Tekapo:

- An increase in inflow in winter and spring. This is associated with an increase in precipitation in winter, which tends to fall as rain (as opposed to being 'locked up' as snow) due to the projected increase in temperature. The increase in spring is thought to be associated with intensification of large rainfall events with climate change.
- Summer and autumn inflows are expected to remain stable. This indicates that high summer precipitation characteristics are expected to remain stable over the surface water catchment under climate change. It is noted that a slight increase in Q1 inflows is anticipated in autumn.

The changes in flow characteristics are generally greater with time and increased radiative forcing. In other words, the modelling indicates that the greatest changes in flow characteristics can be expected by the end of the century (2090s) under the highest radiative forcing scenario (RCP8.5). For the lowest radiative forcing scenario (RCP2.6) there is generally little change in inflow (for Q75, Q10 and Q1) between the baseline period and the Mid (2040s) and End century (2090s) scenarios.

Caruso et al. (2017a and 2017b) also studied the potential climate change effects on hydropower operations in Lake Pukaki, Tekapo and Ohau. A hydrological model was used to simulate catchment runoff and lake inflows based on the 1990s (baseline), 2040s and 2090s periods. The simulations were based on the IPCC Fourth Assessment Report, however as previously indicated the projected changes for New Zealand for the IPCC Fifth Assessment are similar to those based on the IPCC Fourth Assessment and as such this study also provides a useful indication of the likely changes for the TekPS.

The Caruso et al. (2017a and 2017b) reports use the A1B emissions scenario from the IPCC Fourth Assessment Report for the catchment modelling based on an

ensemble of the 12 best performing GCM's for New Zealand. This emissions scenario assumes no change in human activity in response to climate change and in terms of severity represents a 'business as usual' scenario. Daily precipitation and temperature data from the Virtual Climate Station Network (VCSN) database was used for the baseline (1990's) simulations. For the future scenarios, downscaled GCM temperature and precipitation data was used. For each of the three catchments (Lake Pukaki, Tekapo and Ohau), a catchment model was developed, calibrated and validated against observed flows for the baseline period.

The results indicate that for the three lakes flows progressively increase in the 2040s and 2090s with the shift greatest for lower flows. Overall changes in lakes Tekapo and Ohau inflow are smaller than Lake Pukaki, but in the same increasing direction. Under future scenarios (2040's and 2090's) Lake Tekapo inflows typically increase in late winter/early spring. For the 2040's scenario the main increase in inflow is predicted to be in the months August to November. In the other months, inflows remain unchanged or changes to inflow are very small.

For the 2090's scenario the main increase in inflow compared to the baseline (1990's) is in July, August, September and October. In the other months inflows remain unchanged or changes to inflow are relatively small. The modelling results indicate that there is some (albeit small) decrease in summer and early autumn flows (December – March) for the 2090's scenario. Overall, the results indicate a 5% and 8% increase in average annual inflow to Lake Tekapo for the 2040's and 2090's respectively.

With regards to floods and extreme low flows the study indicates an increase in both small and large floods especially under the 2090's scenario. The total number of extreme low flow events decreases from 84 in the 1990s, to 72 in 2040s, and 68 in 2090s.

These climate change impacts on river flows are consistent with the predicted change in precipitation and temperature in the future. Modelling has indicated that temperatures and precipitation will likely increase in the west of the South Island, on the west side of the Ka Tiritiri O Te Moana/Southern Alps, and at higher elevations on the east flank. The increased precipitation, however, will primarily be as rain in winter with less snow and earlier melt.

Overall, the Caruso et al. (2017a and 2017b) reports conclude that these flow increases could benefit hydropower generation to help meet electricity demand in the future, but the seasonal changes could make it more difficult to manage water volumes and operations of the lakes (including Lake Tekapo). There also could be increasing risk of floods predominantly in winter and spring.

Another study from Rutledge et al. (2017) labelled '*Climate Change Impacts and Implications for New Zealand to 2100, Synthesis report: RA2 Uplands Case Study, Upper Waitaki Catchment*' includes a brief section on impacts of climate change

on the hydrology and water resources of the Upper Waitaki Catchment. This report is based on the IPCC Fifth Assessment and provides similar conclusions as the Caruso et al. (2017a and 2017b) and Zammit (2019) reports. The study concludes that overall total precipitation in the South Island including the Upper Waitaki catchment is likely to increase. The increase in total precipitation would tend to increase lake inflows and the report includes graphs with modelled future changes in average daily lake inflow for Lake Pukaki, Tekapo and Ohau. The graphs provide for a current as well as two future scenarios being the 2040's and 2080's. The modelled future changes in average daily lake inflow for Lake Tekapo indicate that the main change will be an increase in flow in winter (June – August) and a small decrease in flow in the months November through to January. There are minimal and/or only small changes in lake inflow indicated for the other months. The changes to the inflow are more pronounced for the 2080's scenario. In other words, when comparing the 'current state' with the future scenarios, the increase in flow in winter and decrease in flow in summer is greater for the 2080's scenario than the 2040's scenario.

Other modelling studies of South Island alpine rivers with headwaters near the divide also found similar changes with an overall increase in flow with the largest flow increases in winter/spring (NIWA, 2008; NIWA, 2018; Collins, 2020).

4.1.3.3 Spill Flows

As detailed above climate change is projected to increase flood flows which has the potential to increase spill from Lake Tekapo. Analysis of historical spill flow events indicates that spill events predominantly occur in spring/summer with no or very limited spills in winter. This is not surprising as large inflow events predominantly occur in late spring and summer when lake levels are high (predominantly summer) and snow melt increases Lake Tekapo inflows. This is illustrated in Appendix B, Figure B5 and Table 5 below.

Climate change projections are for an increase in flood flows in winter and spring with no or limited change in summer or in autumn (Zammit, 2019). Lake levels are typically low in winter and spring and therefore this potential increase in flood flows is likely to be mitigated by the lake storage ability to 'capture' these flood flows. Therefore, the potential increase in flood flows in winter and spring due to climate change is unlikely to result in increased spill flows, although as discussed above there is significant uncertainty in climate change impacts.

Table 5: Lake Tekapo inflow count of annual maxima [1] by month for 1926 – 2022 period

Month	1926-2022
January	17
February	13
March	8
April	7
May	5
June	1
July	0
August	2
September	5
October	8
November	13
December	18

Notes:

1. *Annual maxima calculated based on mean daily inflow.*

4.1.3.4 Summary

In summary climate change impacts on Lake Tekapo inflow and hydro-electricity generation potential for the TekPS have been well researched. Several different studies are available which specifically assess climate change impacts on lake inflow and hydro-electricity generation potential for the three hydro-electric lakes Ohau, Pukaki and Tekapo. This is not surprising considering the importance of the lakes for hydro-electricity generation in the Waitaki catchment and New Zealand as a whole (also refer to section 3.1.1).

Overall, the available climate change studies indicate the following in terms of annual and seasonal changes:

- An increase in average annual inflow to Lake Tekapo for both the Mid-century as well as for End Century.
- The main change in inflow is likely to be an increase in flow in winter and potentially a small decrease in flow in summer. Most studies generally predict relatively small changes in flow for spring and autumn although some studies predict an increase in flows in spring.

In terms of floods and low flows climate change is anticipated to result in:

- An overall increase in flood flows. Flood flows are anticipated to increase in winter and spring with no or limited change in summer and autumn.
- Low flows are anticipated to increase due to the increase in rain in winter (when flows are typically low) and increased snow melt. The total number of extreme low flow events is anticipated to decrease.

Climate change modelling indicates that the greatest changes in flow characteristics can be expected by the end of the century under the high emission scenario (RCP8.5 for the IPCC 5th Assessment). For the low emission scenario (RCP2.6 for the IPCC 5th Assessment) there is generally little change in inflow between the baseline period and the Mid and End century scenarios.

The potential increase in flood flows in winter and spring due to climate change is unlikely to result in increased spill flows, although as discussed above there is significant uncertainty in climate change impacts.

4.2 Tekapo River and tributaries

4.2.1 Flow statistics, flow duration curves and hydrographs

4.2.1.1 Upper Tekapo River

ECan operates a flow recorder on the Tekapo River just downstream of the Lake Tekapo spillway (installed in 1968). This recorder has data available for two periods being 1968 until 1978 and 1993 until 2022. In addition, Genesis records flow at the Lake Tekapo control gate (Gate 16). Flow data from this site is available from 1957 through to 2022. Spill flows from Lake George Scott to the Tekapo River (Lake George Scott at Weir) and from Lake George Scott to the Tekapo Canal (Gate 17) are monitored by Genesis. The locations of the monitoring sites are included in Appendix A, Figure A1.

As previously discussed, the upper reaches of the Tekapo River generally have no or very limited flow. Genesis typically only releases water to spill into the Tekapo River downstream of Gate 16 in the following circumstances:

- To manage high lake levels.
- To provide recreational releases for the Kayak Course and to enable kayaking on the upper Tekapo River between Gate 16 and Lake George Scott. These releases are typically around 17 - 20 m^3/s in spring and summer.
- To top up Lake George Scott with the purpose of storing water to enable uninterrupted generation from Tekapo B power station in the case of the loss of generation at Tekapo A, or in rare circumstances to augment

Tekapo B generation capacity. These top up flows typically occur 2 to 3 times a week and are generally of relatively short duration (approximately 1 hour) at a flow of around 10 m^3/s.

- If Tekapo A Power Station is out for any reason and Genesis still wants to generate electricity at the Tekapo B Power Station.
- If Genesis wishes to supplement flow from Tekapo A Power Station to generate higher loads at Tekapo B Power Station.

The discharges from Gate 16 are generally diverted into the Tekapo Canal (via Gate 17) when capacity is available in the Canal. This ensures that the water can be used for generation at Tekapo B power station. The exception to this is when spill flows from Gate 16 exceed the capacity of the Tekapo Canal or when the Tekapo Canal or Tekapo B Station is not operational (for example for maintenance). During these times water is spilt down the Tekapo River via the Lake George Scott Weir. Discharges over the Lake George Scott Weir are managed in accordance with the resource consent and in accordance with the provisions contained in *"Tekapo Power Scheme, Appendix A, Extracts of Waitaki Operating Rules (9 November 1990) as modified by an order pursuant to Section 122 of the Electricity Act 2010*".

A review of the available flow data for the Lake Tekapo Spillway indicates that there is no or very little flow for approximately 72% of the time for the period 1991 to 2022. Over the same record period Gate 17 and Lake George Scott Weir have no or very little flow for approximately 72% and 90% of the time respectively. This demonstrates that when flows are spilled from the Lake Tekapo Spillway (Gate 16) this water is typically diverted back into the Tekapo Canal through Gate 17. Most of the time when water is spilled from the Lake Tekapo spillway there is no discharge to the Tekapo River via the Lake George Scott Weir. In other words, discharges via the Lake George Scott Weir occured approximately 10% of the time over the 1991-2022 period which compares to approximately 28% for Gate 16 and Gate 17.

The period 1/3/2019 to 29/2/2020 (period of water quality/ecological monitoring undertaken by Cawthron) had a significant amount of spillway discharges in December 2019 and again in February 2020 resulting in flow over the weir for approximately 14% of the time. No Lake George Scott weir discharges occurred in the February/March 2021 period when drift diving was undertaken in the Tekapo River by Cawthron.

Flow duration curves are included in Appendix C, Figure C1 and a hydrograph with the weir discharges for the periods 1/1/2021 to 31/3/2021, 1/3/2019 to 29/2/2020 and for the period 2012-2022 is included in Appendix C, Figure C6, Figure C7, Figure C8, Figure C19 and Figure C20. The mean flow over the 1991 - 2022 period for Lake Tekapo Spillway and Lake George Scott Weir was 15.4 m^3/s and 6.3 m^3/s, respectively.

It is noted that Lake George Scott Weir spills (and Lake Tekapo levels) do not appear to have changed from 1991 to present day (see Appendix C, Figure C2 and Appendix B, Figure B1). As demonstrated in Appendix B, Figure B5 lake levels and spills have strong seasonal trends, where spills usually happen during late spring and summer when the lake level is generally higher, and the minimum/maximum operating level range is narrower. The frequency of spill flow over the Lake George Scott weir is closely related to lake levels and operational constraints during maintenance/upgrade projects when portions of the generation network are offline and additional spills are required to manage the lake level. Examples of this are the canal relining project during 2013-2014 and refurbishment of Tekapo B during 2020-2022 which have been annotated on Appendix C, Figure C2. Note that outage information is only available since June 2011 when Genesis took over operation of the Tekapo PS from Meridian. The graph indicates that the majority of the spills since 2011 are related to maintenance/upgrade projects.

Table 6: Flow statistics for Lake Tekapo Spillway and Lake George Scott Weir/Gate 17

Statistic	Flow (m^3/s)			
	Lake Tekapo Spillway [1] *01/01/1991 - 31/12/2022*	**Lake George Scott at Weir** *01/01/1991 - 31/12/2022*	**Lake George Scott at Weir** *01/03/2019 – 29/02/2020*	**Lake George Scott at Gate 17** *01/01/1991 - 31/12/2022*
Maximum	302.7	296.2	172.4	150.0 [2]
99th percentile	160.8	141.3	169.3	114.2
95th percentile	104.6	43.4	131.6	64.5
Upper Quartile	6.0	0.1	0.1	2.0
Mean	15.4	6.3	13.2	9.5
Median	0.1	0.1	0.1	0.1
Minimum	0.0	0.0	0.0	0.0

Notes:

1. *Combined record: ECan data (Lake Tekapo Spillway, site 71131) for period 04/06/1993- 31/12/2022) and Genesis data (Lake Tekapo control gates, Gate 16) for period 01/01/1991 – 03/06/1993).*
2. *Slightly higher than maximum design flow of canal (130 m^3/s) due to several spikes in the instantaneous flow record. The flow is not above 130 m^3/s for any significant periods of time.*

Genesis also makes recreational releases from Gate 16 for the kayak course (refer to Appendix A, Figure A1 for location). Genesis makes up to 4,820 cumec hours (flow in m^3/s multiplied by hours the flow is maintained for) available for kayaking per season, although sometimes planned releases cannot be made due

to an operational requirement to spill at higher flows to control lake levels. Releases for recreational purposes typically occur at flows of around 17-20 m^3/s for 6-8 hours on weekends (or on specific dates requested by kayakers) during spring and summer. As an example, Appendix C, Figure C3 shows a plot of the spillway flows during the 2020-2021 season (1 July 2020 – 30 June 2021) with the recreational releases highlighted. The figure also highlights short-duration minor spills (i.e. flows around 10 m^3/s for around 1 hour) which are used to top up Lake George Scott.

4.2.1.2 Mid reach Tekapo River

The Tekapo River has a permanent flow downstream of the confluence with Fork Stream. An indication of flows in the Tekapo River in the reach between the Fork Stream confluence down to the Grays River confluence can be provided using the NIWA flow recorder for Fork Stream at Balmoral along with an allowance for the flow contribution from the Tekapo River upstream of the Forks Stream confluence as further detailed below. It is noted that this analysis ignores any surface or groundwater gains or losses downstream of the Tekapo River and Forks Stream confluence and the spill flows from Lake George Scott that influence flows in the Tekapo River in the higher flow bands. Further comments on surface - groundwater interaction are provided in section 4.2.2 of this report.

ECan also operates a permanent flow recorder in the Tekapo River downstream of the Mary Burn confluence. This site has a relatively short record length with flow data available from 2013 through to 2022. Key flow statistics for Fork Stream at Balmoral and Tekapo River at downstream Mary Burn are provided in Table 7 below and the associated flow duration curves are included in Appendix C, Figure C4 and Figure C5. Appendix C, Figure C6 to Figure C11 show hydrographs for the period 1/3/2019 to 29/2/2020 (water quality monitoring period) and 1/1/2021 to 31/3/2021 (period just before, during and after the drift diving). It is noted that the significantly differing available record lengths for these sites (and the flow recorders on the other tributaries of the Tekapo River) means that comparisons are for indicative purposes only.

The data indicates that the median flow in Forks Stream at Balmoral is around 2.5 m^3/s. As detailed in Table 11 the measured gains between gauging site 'Fork Stream upstream of Tekapo River confluence' and 'Tekapo River downstream of Fork Stream confluence' indicate a gain of between 0.4 – 0.7 m^3/s (refer to Appendix A, Figure A5 for location of gauging sites) with an average gain of around 0.6 m^3/s. Due to the limited amount of flow gauging data it is recognised that there is some uncertainty associated with estimating this gain in flow. However, this is considered the best estimate based on the available information. A comparison between the available concurrent flow data for the Fork Stream at Balmoral recorder site and 'Fork Stream upstream of Tekapo River confluence' indicates that gains/losses between these two sites are negligible

(refer to Appendix C, Figure C12). It is noted that no concurrent gauging information is available between Forks Stream at Balmoral and 'Tekapo River downstream of Forks Stream confluence'. Therefore, when allowing for a 0.6 m^3/s gain in flow the median flow in the Tekapo River increases from approximately 3.1 m^3/s at the confluence with Fork Stream to approximately 10 m^3/s at the ECan recorder site downstream of the Mary Burn.

This gain is predominantly due to flow contributions from tributaries such as the Grays River, the Mary Burn and Irishman Creek (via the Mary Burn). The flow duration curve for the Tekapo River at downstream Mary Burn (Appendix C, Figure C5) clearly shows the impact of spills over the Lake George Scott Weir which increase the flows in the higher flow bands.

A comparison between the four different periods analysed for Forks Stream indicates that flows at and below the upper quartile are generally similar. Appendix C, Figure C4 shows that flows above the upper quartile are significantly greater for the period 1/3/2019 – 29/2/2020 due to the high flows experienced in November and extreme flood in December 2019 (refer to Appendix C, Figure C6 and Figure C7).

Table 7: Flow statistics for Fork Stream at Balmoral and Tekapo River at downstream Mary Burn

Statistic	Flow (m^3/s)					
	Fork Stream at Balmoral [1]				Tekapo River at downstream Mary Burn	
	01/01/1963 - 31/12/2022	*01/01/1991 - 31/12/2022*	*01/01/2013 - 31/12/2022*	*01/03/2019 - 29/2/2020*	*01/01/2013 - 31/12/2022*	*01/03/2019 - 29/02/2020*
Maximum	60.5	60.5	49.6	49.6	241.7	213.0
MAF [2]	23.0	23.5	25.3		129.4	
Upper Quartile	4.4	4.4	4.5	4.4	15.6	14.1
Mean	3.8	3.8	3.9	4.5	18.0	23.2
Median	3.1	3.1	3.2	3.3	10.2	10.8
Lower Quartile	2.4	2.4	2.4	2.6	7.4	9.2
7DMALF [3]	1.9	1.9	1.9	2.1 [4]	5.8	6.9 [4]
Minimum	1.2	1.4	1.6	2.0	4.0	6.7

Notes:

1. *Includes an allowance for flow contribution of 0.6 m^3/s from the Tekapo River upstream of Forks Stream confluence.*
2. *Mean Annual Flood. Calculated using the peak instantaneous flow each calendar year. The calculations for Forks Stream at Balmoral include several incomplete years. These incomplete years were included in the calculation for the Mean Annual Flood as the records for other sites in the catchment either side of gaps in the Forks record were examined in detail and it was determined unlikely that the gap periods would contain flows higher than the peak flow for the year.*
3. *7 Day Mean Annual Low Flow. Calculated using hydrological years for Tekapo River at downstream of Mary Burn as low flows occur over summer. Calculated using calendar years for Forks Stream at Balmoral as low flows occur in winter and late summer. The calculations for Forks Stream at Balmoral include several incomplete years. These incomplete years were included in the calculation for the 7DMALF as the record either side of gaps was examined in detail and it was determined unlikely that the gap periods would contain flows lower than the lowest recorded 7-day average flow for the year.*
4. *No 7DMALF can be calculated. Reported value is 7 Day Annual Low Flow.*

The median monthly flows for these sites (refer to Table 8) indicate that the Tekapo River at downstream Mary Burn generally has its lowest flows between January and May. Low flows in Fork Stream tend to occur in July and August although median monthly flows are also relatively low in March, April, May, June and September. The main reason for this is that Fork Stream has a relatively large proportion of its catchment at higher altitudes which means that precipitation is 'locked up' as snow in winter. The Tekapo River at downstream Mary Burn derives a larger proportion of its flow from rivers and streams which have a much smaller proportion of their catchments at high altitudes (such as Mary Burn and Irishman Creek).

Table 8: Median monthly flows (m^3/s)		
Month	**Fork Stream at Balmoral** [1] *01/01/1963 - 31/12/2022*	**Tekapo River at downstream Mary Burn** *01/01/2013 - 31/12/2022*
January	4.0	8.9
February	3.0	9.0
March	2.7	7.1
April	2.6	6.8
May	2.9	8.2
June	2.8	11.1
July	2.4	11.9
August	2.3	12.9
September	2.6	10.7
October	4.0	11.0
November	5.4	13.9
December	5.4	13.0

Notes:

1. *Includes an allowance for flow contribution of 0.6 m^3/s from the Tekapo River upstream of Forks Stream confluence.*

The flow statistics and flow duration curves for the Tekapo River at downstream Mary Burn indicate that flows in the higher flow bands are significantly increased for the period 1/3/2019 – 29/2/2020 due to the Lake George Scott spill flows in December 2019 and February 2020.

4.2.1.3 Lower Tekapo River

The lower 4 km of the Tekapo River is influenced by spill flows from the Pukaki River. Like the upper reaches of the Tekapo River, the Pukaki River generally has no or only a very limited amount of flow due to the Pukaki Spillway only spilling water when required to lower Lake Pukaki water levels during and following a flood. Meridian also releases water for recreational (kayaking) purposes. This typically occurs two weekends of the year resulting in a flow between approximately 45 and 90 m^3/s for approximately 10 hours per day.

Gate testing at Lake Pukaki typically occurs once a month resulting in a small amount of flow for less than an hour down the spillway. These flow releases for gate testing purposes do not result in any measurable flow down the river as they are absorbed in the 'basin' immediately below the spillway (personal

communication, Eddie Stead – Meridian hydrologist, 24/5/2021). The much larger and longer spillflows (including the recreational releases) from Lake Pukaki will result in significant flow in the Pukaki River and the lower reaches of the Tekapo River. Flow statistics and flow duration curves for the Lake Pukaki Spillway for the period 1991 – 2020 and for the period 1/3/2019 to 29/2/2020 are included in Table 9 below and in Appendix C, Figure C13. Hydrographs showing the spillway discharges for the 1/1/2021 to 31/3/2021 and 1/3/2019 to 29/2/2020 period and for the 2013 – 2020 period (the overlapping period with available record for Tekapo River at downstream Mary Burn) are shown in Appendix C, Figure C9 to Figure C11 and Figure C21 to Figure C22. The very small, short duration gate testing flows were removed from the Lake Pukaki spillway record as the purpose of these hydrographs is to show the effect of the Lake Pukaki spillway flows on flows in the lower Tekapo River below the confluence with the Pukaki River. These short duration gate testing flows are absorbed in the basin immediately below the Lake Pukaki spillway and do not reach the Tekapo River.

Table 9: Flow statistics for Lake Pukaki Spillflow (Gate 19)

Statistic	Flow (m^3/s)	
	01/01/1991 - 31/12/2022	*01/03/2019 – 29/02/2020*
Maximum	1,070.0	611.0
99th percentile	331.0	498.0
95th percentile	67.6	269.0
Upper Quartile	0.5	0.3
Mean	12.3	38.9
Median	0.3	0.2
Minimum	0.0	0.0

Like the Lake George Scott Weir flows, significant spillway flows occurred in December 2019 and February 2020. For the Lake Pukaki spillway there were other significant spillway discharges from 23 to 25 January 2020 (up to 300 m^3/s), 14 to 21 May 2019 (around 90 m^3/s) and from 30 May to 13 June 2019 (peaking at around 270 m^3/s) and two smaller spillway discharges on 16 and 17 March 2019 of 45 m^3/s (10 hours) and 90 m^3/s (13 hours). It is noted that there was also a significant spill release on 13 February 2019 that lasted around 17 hours and peaked at a flow of around 230 m^3/s. This spillflow release is not shown on

Appendix C, Figure C9 but may be of interest to the Tekapo River water quality and ecological monitoring that started in March 2019.

One spillway discharge of around 45 m^3/s occurred on 21 February 2021 (around the period when drift diving was undertaken) which would have resulted in increased flow in the lower reaches of the Tekapo River (refer to Appendix C, Figure C11).

The relatively large amount of spillflows from the Lake Pukaki spillway for the period 1/3/2019 to 29/2/2020 is clearly visible in the flow duration curve which shows significant discharges for approximately 19% of the time (refer to Appendix C, Figure C13. For the period 1991-2022 spillway discharges occur for approximately 7% of the time.

4.2.1.4 Tekapo River tributaries

There are a number of other existing and historical flow recorders on the Tekapo River tributaries. Existing flow recorders include Grays River at Days Bridge (ECan, installed in 2009), Mary Burn at SH8 (ECan, installed in 2003) and Mary Burn at Mt McDonald (NIWA, installed in 1969). In addition, there is historical flow recorder data available for Irishman Creek at Windy Ridge for the period 1962 till 1972. Flow statistics for these recorders are given in Table 10. The location of these flow recorders is included Appendix A, Figure A4 and flow duration curves are included in Appendix C, Figure C14 and Figure C15. Flow statistics for the full available record period (1970 – 2022) for the Mary Burn at Mount McDonald are very similar to the period 1991 – 2022. Therefore, only the flow duration curve for the full record period is included.

The statistics and flow distribution for each of the rivers can be explained by the catchment characteristics. ECan (2005 and 2013) suggest that the Grays and Mary Burn are predominantly spring fed and have similar flow patterns with long slow recession periods. Flow variability is low, and the flow duration curve has a relatively flat slope, especially for the Mary Burn which receives limited rapid runoff from mountainous areas.

Table 10: Flow statistics for Tekapo River tributaries

Statistic	Flow (m^3/s)				
	Grays River at Days Bridge *01/01/2010 - 31/12/2022*	Mary Burn at Mount McDonald		Mary Burn at SH8 *01/01/2004 - 31/12/2022*	Irishman Creek at Windy Ridge *01/01/1963 - 31/12/1971*
		01/01/1970 - 31/12/2022	*01/01/1991 - 31/12/2022*		
Maximum	110.17	17.09	9.66	14.15	75.29
MAF [1]	28.06	4.23	4.48	3.95	24.92
Upper Quartile	4.03	0.63	0.62	0.74	1.46
Mean	3.49	0.55	0.55	0.63	1.32
Median	2.65	0.40	0.40	0.45	0.80
Lower Quartile	2.00	0.30	0.29	0.33	0.47
7DMALF [2]	1.69	0.27	0.26	0.29	0.25
Minimum	1.08	0.10	0.18	0.14	0.02

Notes:

1. *Mean Annual Flood. Calculated using the peak instantaneous flow each calendar year. The calculations include several incomplete years. These incomplete years were included in the calculation for the Mean Annual Flood as the records for other sites in the catchment were examined in detail and it was determined unlikely that the gap periods would contain flows higher than the peak flow for the year.*
2. *7 Day Mean Annual Low Flow. Calculated using 1 October – 30 September for Grays River at Days Bridge, Mary Burn at Mount McDonald and Irishman Creek at Windy Ridge as low flows typically occur in summer/autumn but can also occur in winter at these sites. It is noted that there is no significant difference compared to calculations using hydrological years for these sites. Calculated using hydrological years for Mary Burn at SH8 as low flows occur over summer. The calculations for Mary Burn at Mount McDonald and Irishman Creek at Windy Ridge include several incomplete years. These incomplete years were included in the calculation for the 7DMALF as the records either side of gaps were examined in detail, and it was determined unlikely that the gap periods would contain flows lower than the lowest recorded 7-day average flow for the year.*

4.2.2 Groundwater – surface water interaction

As outlined in SKM (2004), Cooksey (2008) and ECan (2005), flow losses to groundwater have been observed in Irishman Creek below State Highway 8 bridge, while in contrast, the Mary Burn gains flows from groundwater between State Highway 8 and its confluence with the Tekapo River. Irishman Creek loses water to groundwater below State Highway 8 and commonly dries up around 1 km downstream of the highway, even at flows greater than 1,500 L/s, and reappears close to the Tekapo River. This is confirmed in flow gain/loss profiles for Irishman Creek and Mary Burn (ECan, 2013) which indicate that it is likely that Irishman Creek loses water to shallow groundwater below Windy Ridge (near SH8) as the Creek spreads out into numerous channels across the plains. The flow gain/loss profiles show that the lower reaches of the Mary Burn gain a

significant amount of flow between SH8 and just above its confluence with the Tekapo River. The report concludes that '*It is likely that a good portion of the Irishman Creek water flows, both through surface flows and subsurface flows, into the Mary Burn above the Tekapo confluence site.'*

Grays River and its tributaries follow a similar pattern of losing water to groundwater in the upper basin and gaining groundwater in the lower sections. Historical gauging runs in the Grays River indicate that the mainstem of the river gains significant flow from groundwater in its middle and lower reaches. Based on 7DMALF estimates from ECan (2005) for six different locations in the Grays River it was estimated that the river gains approximately 1.8 m^3/s under 7DMALF conditions between the gauging site Grays River at Station 1, located approximately 1 km upstream of the confluence with the Mackenzie River and Grays River upstream of the confluence with the Tekapo River.

The ECan (2005) work suggested that the Tekapo River may lose water to groundwater before gaining water again near the Grays River confluence. To better understand gains and losses in the mainstem of the Tekapo River, five flow gauging surveys were undertaken by PDP on 21 February 2019, 18 June 2019, 3 October 2019, 14 January 2020 and 23 November 2020. The first and fifth gauging runs (undertaken in February 2019 and November 2020 respectively) consisted of nine gaugings in the Tekapo River and also included gauging the three main tributaries (Fork Stream, Grays River and Mary Burn) just upstream of their confluence with the Tekapo River. On 23 November 2020 the Pukaki River upstream of the Tekapo River was also gauged. The other three gauging runs involved gauging the main stem of the Tekapo River at five or six locations as well as gauging the three main tributaries. The main stem of the Tekapo River upstream of the Fork Stream confluence was not gauged during each of the flow gauging runs. In the reach of the Tekapo River between Lake George Scott and Fork Stream there was ponded water and minor flow immediately above the Forks Stream confluence. The source of this water was expected to be a combination of seepage from Lake George Scott and minor groundwater discharges further downstream. Gauging information indicates that the main stem of the Tekapo River immediately upstream of the fork Stream confluence contributes between 0.4 and 0.7 m^3/s of flow. This was calculated by subtracting the flows measured at gauging site 'Fork Stream upstream of Tekapo confluence' from measured flows at 'Tekapo River downstream Fork Stream confluence' (refer to Table 11). The flow contribution from the Tekapo River upstream of the Fork Stream confluence to flow in the Tekapo River downstream of the confluence is relatively small but is more significant at times of low flow. The details of the gauging sites and results for each gauging run are included in Table 11, and the locations of the sites are shown in Appendix A, Figure A5.

Flow gain/loss profiles using the results for the gauging surveys are included in Appendix C, Figure C16. This figure also includes the results of an additional PDP gauging survey on 9 May 2013.

The results of the 21 February 2019 gauging survey indicate no or a very limited loss of flow in the upper reaches of the Tekapo River down to Mid-Reach 2 and a loss of around 0.6 m^3/s between Mid Reach 2 and Upstream Grays River Confluence. Flows increase significantly just before the Tekapo River flows through the Grays Hills due to flow contributions from the Mary Burn (including Irishman Creek) and Grays River. Only small changes were observed in the lower reach above Lake Benmore.

The gauging survey on 18 June 2019 was undertaken during slightly higher flow conditions and generally shows a similar pattern of flow gains and losses to those measured during the 21 February 2019 gauging run. A minor flow loss of around 0.3 m^3/s was observed between Mid Reach 2 and Upstream Grays River Confluence. A flow increase of 2.8 m^3/s was measured between Upstream Grays River Confluence and Upstream of the Mary Burn Confluence as a result of flow contribution from the Grays River (flow in the Grays River upstream of the Tekapo River was measured at 2.9 m^3/s during this gauging survey).

The gauging survey on 3 October 2019 was carried out during flow conditions similar to those during the 21 February 2019 gauging survey and generally shows a similar flow pattern along the length of the Tekapo River. A flow loss of around 0.5 m^3/s was measured between Mid Reach 2 and Upstream Grays River Confluence. Flows in the Tekapo River were measured to be 8.8 m^3/s downstream of the confluence with the Mary Burn, indicating a flow increase of 7.3 m^3/s between there and Upstream Grays River Confluence. Accounting for surface water inflows from the Mary Burn (2.8 m^3/s) and Grays River (3.7 m^3/s), it is expected a groundwater discharge of around 0.8 m^3/s into the Tekapo River was occurring during the gauging survey. It is worth noting that during the 3 October gauging run, the flow of 3.7 m^3/s measured in the Grays River was the largest flow recorded in the Grays River for the gauging surveys undertaken by PDP.

The gauging survey on 14 January 2020 was undertaken at higher flow conditions and generally shows an overall flow pattern similar to those observed in the Tekapo River during the previous flow gauging runs but at a slightly higher magnitude. The January 2020 gauging run showed a decrease in flow of around 1 m^3/s between Mid Reach 2 and Upstream of the Grays River.

Table 11: Gauging site details and gauging results

Site Name		Easting NZTMX	Northing NZTMY	Gauged flows (m^3/s)					
				09 May 2013 [1]	*21 Feb 2019*	*18 Jun 2019*	*03 Oct 2019*	*14 Jan 2020*	*24 Nov 2020*
Tekapo River	Downstream Fork Stream Confluence	1395293	5120339	1.42	1.93	3.40	2.15	4.74	3.90
	Mid Reach 1	1394852	5110538		2.10	3.44	2.05	4.56	3.86
	Mid Reach 2	1392488	5106335		1.91	3.44	2.01	4.59	3.89
	Upstream of Grays River Confluence	1388045	5098217	1.71	1.31	3.12	1.54	3.57	2.86
	Upstream of Mary Burn Confluence	1386105	5096078	2.81	5.37	5.89	5.15	6.42	5.15
	Downstream of Mary Burn Confluence	1385989	5094697	6.10	6.96	-	8.82	11.08	9.65
	Grays Hill	1383651	5090667		6.98	-	-	-	8.37
	Upstream of Pukaki River Confluence	1379424	5090134		6.30	-	-	-	7.80
	Downstream of Pukaki River Confluence	1378847	5088500		6.61	-	-	-	8.36
Fork Stream Upstream of Tekapo Confluence		1395211	5120798		1.26	2.87	1.53	4.12	3.50
Grays River Upstream of Tekapo River Confluence		1387992	5097110		3.27	2.92	3.71	2.70	2.00
Mary Burn Upstream of Tekapo River confluence		1385997	5096309		2.01	3.80	2.82	3.10	3.13
Pukaki River Upstream of Tekapo River		1378632	5090547		-	-	-	-	0.31

Notes:

1. *Mid reach 1 and Mid reach 2 were not gauged so it is not known if there was a small increase through the entire reach or whether it rose to Mid Reach 1, fell to Mid Reach 2 and then rose again to Upstream of Grays River Confluence.*

The final gauging survey on 24 November 2020 was undertaken during flow conditions relatively similar to those during the June 2019 survey although, as previously mentioned, the survey in November 2020 included three additional sites downstream of Grays Hill. This survey showed a flow loss of around 1 m^3/s was measured between sites Mid Reach 2 and Upstream of Grays River Confluence. Between sites Upstream of Grays River Confluence and Downstream of Mary Burn Confluence, the Tekapo River gained around 6.8 m^3/s predominantly as a result of flow contributions from the Grays River and Mary Burn. Overall, the November 2020 gauging survey is generally consistent with the results of the other gauging surveys although the November 2020 survey shows a larger overall flow loss downstream of the Tekapo River Downstream of Mary Burn Confluence gauging site (a loss of around 1.3 m^3/s) compared to the February 2019 survey (overall flow loss of around 0.35 m^3/s).

PDP previously (9 May 2013) completed a series of flow gaugings in the Tekapo River during a period when no spilling was occurring and measured a small flow increase within the Tekapo River from below the confluence of the Tekapo River with Fork Stream to above the confluence with the Grays River. This gauging survey suggested limited net groundwater inflows or river outflows along the majority of the Tekapo River channel through the Tekapo Basin which is generally in line with the more recent gaugings.

Flow data collected for the instream habitat studies undertaken by Jowett (2004) indicated that the Tekapo River loses approximately 1 m^3/s of flow in the reach of the Tekapo River upstream of the Grays River. It is noted however that those 2004 gaugings were undertaken at times when variable experimental flow releases were made from Lake George Scott over a number of days and as such may not be representative of stable (natural) conditions.

Flow gain/loss profiles for the lower Tekapo River (downstream of the confluence with the Mary Burn) are included in Appendix C, Figure C17 and Figure C18. These are based on available historical gauging information from ECan and the PDP gauging surveys undertaken on 21 February 2019 and 23 November 2020. With the exception of the gauging on 27 November 2012 all concurrent gaugings (i.e., gaugings undertaken on the same day) indicate a loss of flow between the gauging sites Tekapo River Downstream of Mary Burn Confluence and Tekapo River Upstream of Pukaki River Confluence. The average loss rate is approximately 960 L/s and varies between a gain of 200 L/s (27 November 2012 – around 2% increase in flow) and a loss of 1,900 L/s (24 February 2014 – around 7% loss of flow).

It is worth noting that while the maximum loss rate was measured at a relatively high flow (29.2 m^3/s at the Tekapo River recorder Downstream of the Mary Burn Confluence), there does not appear to be a clear pattern of higher loss rates along this reach of the river at higher flows (over the range of gauged flows).

There is no clear pattern of gains or losses between the gauging sites Tekapo River Upstream of Pukaki and Tekapo River Downstream of Pukaki. Three concurrent gaugings show a gain and three concurrent gaugings show a loss of flow.

Overall, all the available data suggests that the Tekapo River typically has relatively stable flows in the upper reaches (above the Mid Reach 2 gauging site), with some losses to groundwater then occurring above the Grays River confluence. A significant flow increase then typically occurs as a result of the Mary Burn and Grays River surface water inflows, although there is an additional gain in flow that can be attributed to groundwater inflows. In the lower reaches as the river enters the Twizel Basin, an overall loss to groundwater typically occurs.

4.2.3 Fresh and flood flows

To provide an indication of the existing flow frequency of freshes and floods in the Tekapo River, the available flow data for Fork Stream at Balmoral and Tekapo River at downstream Mary Burn was analysed for flows with a magnitude of 3, 6 and 10 times the median flow. The flow calculations are based on a filter period (inter-flood period) of 5 days and hourly flows. Further details on the ecological functioning of the river in relation to fresh and flood flows is provided in the Cawthron 2025 (Young, et al, 2025) report.

For the purpose of analysing fresh and flood flows in the Tekapo River, the river can be split up into three reaches. Flows in the Tekapo River between the confluence with Forks Stream down to the confluence with the Grays River can be estimated by using the flows for Forks Stream at Balmoral increased by 0.6 m^3/s (as detailed in section 4.2.1.2) and adding the spill flows from Lake George Scott. The recorded flows in the Tekapo River at downstream Mary Burn are representative of flows in the Tekapo River between the Mary Burn confluence and Pukaki River confluence (spill flows from Lake George Scott are already included in this flow record). The Tekapo River downstream of the confluence with the Pukaki River is influenced by spill flows from the Lake Pukaki spillway and therefore flows in this stretch of the river are estimated by adding the Lake Pukaki spill flows to the Tekapo River at downstream Mary Burn flow record. This approach does not allow for losses to or gains from surface or groundwater along each reach but is considered reasonable based on the purpose of the assessment and the magnitude of flows being considered.

Table 12 summarises the frequency of freshes and floods (mean number of distinct events) and the mean and maximum accrual time for the three Tekapo River reaches mentioned above. Generally speaking, the main period that periphyton can grow to nuisance levels is in the relatively warm months (1 November – 30 April). Table 13 and Table 14 therefore show fresh and flood flow and accrual time information for the period November – April and May - September. It is noted that for Table 13, due to considering the period

November – April only, the accrual count stops at the 30 April and restarts again at 1 on 1 November on the following year resulting in much shorter mean and maximum days of accrual compared to Table 12. The same goes for the May - September period considered in Table 14.

It is noted that a significant amount of the fresh and flood flows (especially for flows with a magnitude of 6 and 10 times the median flow) are due to spillflow releases from either Lake George Scott or the Lake Pukaki Spillway.

Appendix C, Figure C19 to Figure C22 show hydrographs for Fork Stream at Balmoral (increased by 0.6 m^3/s) and Tekapo River at downstream Mary Burn for the period 2012-2022 along with lines indicating a flow of 3, 6 and 10 times the median flow. The graph for Fork Stream at Balmoral includes flows over Lake George Scott Weir and the graphs for Tekapo River at downstream Mary Burn include Lake Pukaki spillway flows.

Fork Stream receives infrequent flows of 3 times the median for the full year (Table 12) and the November to April (Table 13) period. Flows of 6 times the median or greater occur even less frequent for these periods. In the colder months (May- September, Table 14) the frequency of freshes and floods for all magnitudes (3,6 and 10 times the median) is very low.

Flows of all magnitudes (3, 6 and 10 times the median) occur infrequently at the Tekapo River at Mary Burn. With the exception of the winter months (May to September) the fresh and flood flow frequency is much greater (especially for flows 3 times the median) in the lower reach of the Tekapo River, due to the Lake Pukaki spill flows.

The low frequency of fresh and flood flows in winter throughout the Tekapo River is due to a larger proportion of the precipitation falling as snow during this period. This results in lower flood flows in the tributaries of the Tekapo River (especially Fork Stream) and hence the Tekapo River. In addition, spillflows from Lake Tekapo (and Lake George Scott) and Lake Pukaki are rare during these colder months due to lower inflow into the lakes and high electricity demand.

Mean and maximum accrual times (which are the mean and maximum time between freshes and floods) are very long especially for the larger floods with a magnitude of 6 times the median or greater. Due to the relatively low frequency of fresh and flood flows in the colder months, the mean accrual times during this period (May – September) are generally much longer than in the warmer months (November – April).

Table 12: Fresh and flood flow statistics for Tekapo River (calendar years)					
Statistic		**Forks Stream at Balmoral [1] + Lake George Scott at Weir** *01/01/1991 - 31/12/2022*	**Forks Stream at Balmoral [1] + Lake George Scott at Weir** *01/01/2013 - 31/12/2022*	**Tekapo River at downstream Mary Burn** *01/01/2013 - 31/12/2022*	**Tekapo River at downstream Mary Burn + Pukaki Spillway** *01/01/2013 - 31/12/2022*
Mean number of distinct events per annum (count)	3 x median	3.6	3.4	3.0	6.2
	6 x median	1.8	1.9	1.7	4.2
	10 x median	1.3	1.4	1.4	3.1
Mean number of days absent/accrual time (days)	3 x median	89	94	108	49
	6 x median	183	174	201	78
	10 x median	265	243	250	109
Maximum number of days absent/accrual time (days)	3 x median	663	353	1,121	251
	6 x median	1,302	1,302	1,469	471
	10 x median	1,739	1,457	1,480	472

Notes:

1. *Includes an allowance for flow contribution of 0.6 m^3/s from the Tekapo River upstream of Forks Stream confluence.*

Table 13: Fresh and flood flow statistics for Tekapo River (1 November – 30 April)					
Statistic		**Forks Stream at Balmoral [1] + Lake George Scott at Weir** *01/11/1991 - 30/04/2022*	**Forks Stream at Balmoral [1] + Lake George Scott at Weir** *01/11/2013 - 30/04/2022*	**Tekapo River at downstream Mary Burn** *01/11/2013 - 30/04/2022*	**Tekapo River at downstream Mary Burn + Pukaki Spillway** *01/11/2013 - 30/04/2022*
Mean number of distinct events per annum (count)	3 x median	2.2	1.8	1.2	4.0
	6 x median	1.3	0.8	1.0	2.7
	10 x median	1.0	1.0	0.9	1.9
Mean number of days absent/accrual time per annum (days)	3 x median	61	69	107	31
	6 x median	98	114	117	59
	10 x median	112	113	127	84
Maximum number of days absent/accrual time per annum (days)	3 x median	182	181	182	83
	6 x median	182	182	182	181
	10 x median	182	182	182	181

Notes:

1. *Includes an allowance for flow contribution of 0.6 m^3/s from the Tekapo River upstream of Forks Stream confluence.*

Table 14: Fresh and flood flow statistics for Tekapo River (1 May – 30 September)					
Statistic		**Forks Stream at Balmoral [1] + Lake George Scott at Weir** *01/05/1991 - 30/09/2022*	**Forks Stream at Balmoral [1] + Lake George Scott at Weir** *01/05/2013 - 30/09/2022*	**Tekapo River at downstream Mary Burn** *01/05/2013 - 30/09/2022*	**Tekapo River at downstream Mary Burn + Pukaki Spillway** *01/05/2013 - 30/09/2022*
Mean number of distinct events per annum (count)	3 x median	0.9	1.1	1.3	2.0
	6 x median	0.3	0.6	0.6	1.4
	10 x median	0.0 [2]	0.1	0.4	1.2
Mean number of days absent/accrual time per annum (days)	3 x median	104	101	98	66
	6 x median	137	125	125	92
	10 x median	149	145	134	101
Maximum number of days absent/accrual time per annum (days)	3 x median	153	153	153	153
	6 x median	153	153	153	153
	10 x median	153	153	153	153

Notes:

1. *Includes an allowance for flow contribution of 0.6 m^3/s from the Tekapo River upstream of Forks Stream confluence.*
2. *There is 1 event which occurs during the 2013-2022 period, however the average of events per year rounds to zero over the period 1991-2022.*

4.3 Tekapo canal

The Tekapo Canal receives flow from the Tekapo A Power Station and inflow from Gate 17 via the upper Tekapo River and Lake George Scott. Flows at the Tekapo A and Tekapo B power stations (and hence the discharge of water to Lake Pukaki) vary depending on several factors including for example electricity demand, lake levels and Lake Tekapo inflows.

The Tekapo Canal has a maximum design flow of 130 m^3/s. For the period 1991-2022, there has been no flow through Tekapo A for about 19% of the time and no flow through the canal for about 7% of the time, due to occasional 'parking' of Tekapo A, Tekapo B or the canal for maintenance activities. Flow statistics and a flow duration curve are included in Table 15 and Appendix D, Figure D1. Mean monthly flows are included in Table 16 and the associated bar graph in Appendix D, Figure D2.

Median and mean Tekapo Canal flows for the period 1991 – 2022 are estimated to be around 90 and 76 m^3/s respectively and 84 and 69 m^3/s for Tekapo A. The difference is made up by flows bypassing Tekapo A via releases at the Tekapo control gate (Gate 16) into the upper Tekapo River discharging back into the Tekapo canal at Gate 17. As detailed in section 4.2.1.1 the maximum flow at Gate 17 is approximately 130 m^3/s[1] with a mean flow of around 9.5 m^3/s. There is no or only a very limited amount of flow through the gate for approximately 72% of the time.

Table 15: Flow statistics for Tekapo A and Tekapo Canal at Tekapo B (m^3/s) for 01/01/1991 – 31/12/2022

Statistic	Tekapo A	Tekapo Canal at Tekapo B[1]
Maximum	135.5	138.0[2]
Upper Quartile	105.2	106.0
Mean	69.1	76.2
Median	84.0	90.2
Lower Quartile	42.2	52.4
Minimum	0.0	0.0

Notes:

1. *Combined record (Tekapo B Power Station at Machine Output until 11 Nov 2000, Tekapo B Power Station afterwards)*
2. *Slightly higher than maximum design flow of canal (130 m^3/s) due to flows being measured at power stations which can be slightly higher than 130 m^3/s for short periods of time*

[1] Occasional spikes of up to 150 m^3/s but these happen very infrequently.

The Canal flows vary from a mean monthly minimum of around 59 m^3/s to a mean monthly maximum of approximately 84 m^3/s. Mean monthly flows for Tekapo A are generally slightly lower and vary from a minimum of 56 m^3/s to a maximum of 82 m^3/s. Flows are typically high in winter (especially July and August), when electricity demand is high and low in September and October when electricity demand drops off and the level of lake Tekapo increases following drawdown in winter. Once the lake is relatively full again in summer high inflows into Lake Tekapo (due to snowmelt) increases the outflow through the Tekapo Canal.

Table 16: Mean monthly flows for Tekapo A and Tekapo Canal at Tekapo B (m^3/s) for 01/01/1991 – 31/12/2022

Month	Tekapo A	Tekapo Canal at Tekapo B [1]
January	69.2	81.0
February	73.1	80.8
March	70.7	79.8
April	67.0	74.4
May	62.4	73.8
June	71.0	78.0
July	82.4	84.3
August	81.6	82.9
September	56.1	65.4
October	56.5	59.3
November	67.4	75.2
December	71.0	80.0

Notes:

1. *Combined record (Tekapo B Power Station at Machine Output until 11 Nov 2000, Tekapo B Power Station afterwards)*

5.0 Hydrogeological Information

5.1 Lake Tekapo

5.1.1 Groundwater - surface water interaction

The extent of and levels in wetlands and other water bodies bordering Lake Tekapo can be influenced by lake level fluctuations, via changes in groundwater flows and levels, where the wetlands/water bodies are connected to groundwater. Prior to this study, there was an absence of information on the degree of connection between Lake Tekapo and the wetlands bordering the lake. These wetlands/water bodies are described in more detail in the following section of this report.

5.1.2 Wetlands/water bodies

There are a number of wetlands/water bodies located around Lake Tekapo. Environment Canterbury have classed Lake Tekapo, as well as the inflowing Godley and Cass rivers, together with Lake McGregor and Lake Alexandrina and some smaller lakes such as Lake Murray as "Wetlands of Representative Importance" (Environment Canterbury, 2016).

An initial review of existing wetland/water body information was undertaken to determine which wetlands/water bodies may be hydraulically connected to Lake Tekapo. Those that appeared, based on elevation, to potentially be influenced by lake levels, via groundwater interaction, included Mailbox Exclosure (Pierce Pond), wetland areas near the Cass River mouth and an area bordering the Godley River to the east. In addition to those wetland/water body areas, Lake McGregor and Lake Alexandrina together with surrounding wetland areas, Rapuwai Lagoon, wetland areas west of the Godley River and smaller areas on the eastern lake edge appeared to be potentially influenced by lake levels. Also identified was an area that forms part of the lake on the southern lake edge by Tekapo Township that is classified by DOC as a wetland on Canterbury Maps[2] according to Environment Canterbury's database. This appears to be an area that becomes submerged at higher lake levels but is dry at lower levels.

To assess which wetlands/water bodies around Lake Tekapo may be affected by lake level fluctuations via groundwater inflows, PDP undertook an initial desktop review of historic aerial imagery around Lake Tekapo, a comparison with lake level records, a LiDAR data review and a review of available wetland/water body information, including NZTopo50 map data, ECan's Wetlands of Representative Importance layer (Environment Canterbury, 2016) and the ECan Canterbury Wetlands layer. It is worth noting that ECan have now removed the Canterbury Wetlands layer as they are currently in the process of updating it, although for completeness we have included this layer as part of the initial desktop

[2] https://canterburymaps.govt.nz/

assessment. Based on this initial desktop review, any wetland/water body below a threshold of 720 masl was initially considered to potentially experience changes in water level as a result of lake level fluctuations via changes to the underlying groundwater. Appendix E, Figure E3 provides a map of all areas identified as swamp/wetland or lake/water body located between Lake Tekapo and an elevation of 720 masl. It should be noted that the wetlands/water bodies identified below an elevation of 720 masl using available data are generally open water areas and it is possible that there may be other wetlands/water bodies (including other open water bodies) that may be visible on satellite/aerial imagery or identified through field observations that have not been displayed in Figure E3.

Following the desktop review, PDP consulted with the Project Ecologist (Gary Bramley of The Ecology Company) to select a number of representative wetlands/water bodies considered to be suitable sites to monitor water levels and help understand the effect of Lake Tekapo water level fluctuations on these wetlands/waterbodies. As result, PDP have monitored water levels in seven wetlands/water bodies around Lake Tekapo and a summary of the seven sites that were monitored is provided in Table 17 below. Figure E4, Appendix E shows the locations of the monitored sites.

Table 17: Details of Lake Tekapo wetland/water body monitoring locations

Site Name/Water Body	ECan Wetland ID [1]	Easting NZTMX	Northing NZTMY	Approx. Distance from Lake Tekapo (m)	Approx. Site Elevation (masl) [2]
Lake Alexandrina	-	1396136	5131998	1500	711.9
Lake McGregor	6029	1397758	5132238	330	709.2
Wetland 16135	16135	1398706	5137199	160	707.7
Rapuwai Lagoon	5915	1399660	5141196	70	710.4
Lake Tekapo West 3	5893	1399016	5143311	80	713.0
Lake Tekapo East 2	5895	1403256	5145129	50	708.0
Godley River Wetland 23	5833	1403883	5149801	580	709.4

Notes:

1. *ECan Wetland ID is sourced from ECan's Canterbury Wetlands GIS Layer.*
2. *Site elevation based on the LINZ GIS layer "Canterbury LiDAR 1m DSM (2016)" flown between November 2016 and 2017.*

The water level monitoring installations at each wetland/water body consisted of a metal waratah embedded in the base of the wetland/water body with a submerged pressure transducer attached to the waratah to measure water pressure above the sensor. Photos of each wetland/water body and the monitoring installation at each site are provided in Figure F1A through to Figure F1G, Appendix F.

Water levels at all monitoring sites were measured using a non-vented pressure transducer. A dedicated barometric pressure transducer was installed at the Lake Alexandrina settlement to measure changes in atmospheric pressure in the area. The barometric pressure sensor data was used to remove the atmospheric pressure component from the transducers at the wetland/water body monitoring sites. All sensors were set to continuously record pressure measurements every 15 minutes.

With the exception of monitoring sites Lake Tekapo East 2 and Godley River Wetland 23, water level monitoring equipment was installed by PDP on 2 and 4 October 2019. Water level monitoring installations were installed at Lake Tekapo East 2 and Godley River Wetland 23 on 17 January 2020.

The transducers at Lake Alexandrina, Rapuwai Lagoon, and Lake Tekapo West 3 were downloaded by PDP on 16 January 2020, 2 June 2020 and 12 October 2020, and were removed on 9 February 2021. The transducer at Lake McGregor was downloaded on 16 January 2020 but was not able to be accessed on 2 June 2020 due to elevated water levels. The transducer was removed from Lake McGregor on 12 October 2020.

Following the installation of the transducers at monitoring sites Wetland 16135 and Godley River Wetland 23, the transducers at these sites were unable to be accessed due to elevated water levels until 12 October 2020, at which time they were removed. The transducer at Lake Tekapo East 2 was removed on 2 July 2020 as the water level in the wetland had dropped below the transducer.

It should be noted that all pressure transducers recorded a continuous record of measurements between the time of their installation and removal.

During PDP's visit to the Tekapo area on 2 June 2020, the elevations of the monitoring sites were surveyed to tie the measured water levels into a common datum to compare the water levels with fluctuations in Lake Tekapo. PDP used a Trimble RTK (Real Time Kinematic) survey system to undertake a survey of the elevations for each monitoring site. All site elevations are provided relative to the Lyttelton 1937 vertical datum, consistent with the datum used by Genesis for measuring water level elevations in Lake Tekapo. The vertical measurement uncertainty of the survey equipment used is around 10 to 20 mm, depending on the horizontal distance between the base station and the surveyed water level measuring point.

The available water level elevation data downloaded from the seven wetland/water body monitoring sites along with Lake Tekapo water levels are presented as a time series plot in Figure F2, Appendix F. Lake Tekapo water level elevation and total daily rainfall has also been plotted in Figure F2. Lake Tekapo water level data is measured at the stilling well near the inlet for Genesis' Tekapo A Power Station and rainfall data has been sourced from Genesis' rainfall recorder located at the Eade Memorial Hut, near the head of the Godley River and also at the NIWA Cliflo environmental rainfall gauge at Tekapo Airfield (agent number 24945).

With the exception of Lake Tekapo, minor fluctuations (generally less than 0.02 m) were observed in the monitoring data for most of the monitoring sites. These fluctuations are most likely to be related to wind and associated wave action during the monitoring period as the transducers were not installed within stilling wells (unlike the water level recorder in Lake Tekapo). However, the fluctuations are not considered to be of concern due to their small magnitude.

A detailed discussion of the data for each site with available water level data is provided in subsequent sections below, following a discussion of lake level changes.

5.1.2.1 Lake Tekapo Water Levels

In addition to the diversion for hydropower generation via the Tekapo A power station, water levels in Lake Tekapo are managed by a control gate (Gate 16) at the lake outlet to the Tekapo River channel located at Tekapo Township. Under the existing resource consent, water levels in Lake Tekapo are required to be between a minimum and maximum water level which vary throughout the year and are displayed in Figure F2. When water levels exceed the maximum water level in the lake, Genesis is required to release water to lower lake levels. When Lake Tekapo water levels are low, Genesis is required to reduce releases from the lake in order to ensure lake levels do not drop below the consented water level.

Inputs that affect water levels in Lake Tekapo are rainfall and surface water inflows, including inflows from the Godley River, Macaulay River (a tributary of the Godley River), Cass River, Mistake River and other minor tributaries on the eastern side of the Lake. The Godley River has headwaters that extend into a glaciated area on the main divide of Ka Tiritiri O Te Moana/Southern Alps. The Cass River headwaters extend into a smaller glaciated area in the Liebig Range and the Mistake River has a slightly smaller catchment which extends into the Hall Range. The Mistake River catchment has seasonal snow cover but does not have permanent snow or ice cover. As a result of this, inflows to Lake Tekapo via these rivers are affected by seasonal snow melt and large weather events that spill over from the west (in particular, north-west storm events).

Inflows from the Godley, Macaulay, and Cass Rivers into Lake Tekapo are not measured directly by Genesis, but inflows are modelled based on level changes in Lake Tekapo and measured outflows from the lake. Forecast inflows are modelled days in advance using forecast and observed rainfall data.

The data presented in Figure F2, Appendix F shows that water levels in Lake Tekapo during the monitoring period (between 1 October 2019 and 9 February 2021) ranged between 704.2 and 710.9 masl with the lowest level recorded on 1 October 2019 and the highest water level on 11 December 2019. The water levels in Lake Tekapo displayed in Figure F2 are also plotted with daily rainfall totals measured at a rainfall recorder site at the Eade Memorial Hut in the upper Godley River valley and also at Tekapo Airfield. The rainfall gauge at the Eade Memorial Hut is operated by Genesis and is at an elevation of around 980 masl and located around 7.5 km from the main divide of Ka Tiritiri O Te Moana/Southern Alps. The rainfall gauge at Tekapo Airfield (agent number 24945) is operated by NIWA, at an elevation of around 762 masl and located around 50 km from the main divide of Ka Tiritiri O Te Moana/Southern Alps. Together these two rainfall gauges provide a range of rainfall events and that may impact Lake Tekapo and also indicate when large weather events occur that spill over into the wider Tekapo Basin area. The rainfall totals at the Tekapo Airfield are generally significantly lower than those recorded in the Godley Valley (around an order of magnitude lower) generally as a result of the predominant weather pattern being from the west (weather events spilling over the main divide from the west) and Tekapo township being located within the rain shadow of Ka Tiritiri O Te Moana/Southern Alps.

Between 2 October 2019 and 11 December 2019, the water level in Lake Tekapo increased by around 6.7 m as a result of a relatively high rainfall period where a total rainfall of around 2570 mm was recorded at the Eade Memorial Hut recorder over this period, resulting in higher inflows to the Lake. In particular, a significant rainfall event of around 1320 mm of rainfall was recorded at the Eade Memorial Hut recorder over a period of 12 days between 27 November and 7 December 2019 (referred to as the December 2019 inflow event). Given the time of the year that this occurred (spring/early summer), it is expected that the lake level increase was also partly associated with snow melt.

Following this water level increase in late 2019, water levels in Lake Tekapo remained relatively high between early December 2019 and May 2020 with water levels ranging between 709.4 and 710.9 masl during this period. Two additional water level increases occurred between 10 January 2020 and 6 February 2020, and also between 7 April 2020 and 16 May 2020.

Between 10 January and 6 February 2020 (referred to as the February 2020 inflow event), a total of 592 mm of rainfall was recorded at the Eade Memorial Hut recorder, during which an increase of 1.2 m (from around 709.3 masl to 710.5 masl) was observed in Lake Tekapo.

The water level responses in Lake Tekapo as a result of the December 2019 and February 2020 high inflow events display a relatively similar pattern (i.e. a sharp increase with peak water levels sustained over a period of 1 to 2 days, followed by a relatively quick recession). This type of lake level response is expected to be due to high rainfall and inflows to the lake over a relatively short period of time. The water level data for Lake Tekapo and flow records from the Lake George Scott Weir show that Genesis spilt water from Lake Tekapo into the lower Tekapo River during the December 2019 and February 2020 events, likely explaining the relatively quick decrease in water levels after the peak.

Between 12 April and 4 May 2020 (referred to as the April/May 2020 inflow event), 628 mm of rainfall was recorded in the upper Godley River Valley resulting in a water level increase in Lake Tekapo of 0.9 m from 709.7 to 710.6 masl. In contrast to the water level response during the December 2019 and February 2020 high inflow events, water levels during the April/May 2020 event display a much more gradual increase and decrease with peak water levels sustained for around 6 days before water levels began to decrease. The flow record from the Lake George Scott Weir indicates that Genesis did not spill water into the Lower Tekapo River during the April/May 2020 event.

As a result of each of the three inflow events (December 2019, February 2020 and April/May 2020), peak water levels in Lake Tekapo went above the Maximum Control Level for that particular time of the year for short periods of time, triggering the spill rules to manage high lake levels.

Following the three high inflow events, water levels in Lake Tekapo decreased steadily between mid-May (water level of 710.6 masl) and early September 2020 (water level of 704.6 masl), decreasing by around 6 m as a result of Genesis releasing more water through the TekPS to keep up with increased electricity demand during the winter period. During the remainder of the monitoring period, water levels increased to 708.5 masl in February 2021 likely as a result of rainfall, reduced electricity production/demand and increased inflows to the lake during this period but did not approach the elevated water levels measured between December 2019 and May 2020.

5.1.2.2 Lake Tekapo Wetland West 3

Lake Tekapo Wetland West 3 (referred to as "Wetland West 3") has the largest vertical separation with Lake Tekapo of the wetlands monitored by PDP and a plot of the water levels for this wetland are shown in Figure F2, Appendix F. Water levels at Wetland West 3 generally remained above 716.35 masl (more than 5 m above the maximum recorded level in Lake Tekapo of 710.9 masl during the monitoring period) with only minor fluctuations of up to 0.2 m observed during the monitoring period. The largest water level increase at Wetland West 3 occurred immediately prior to the start of a large rainfall event on 3 and 6 December 2019 where water levels at Wetland West 3 gradually

declined by 0.18 m over a period of 10 days before recovering relatively rapidly back to around 716.35 masl following the start of the rainfall event on 3 December 2019. A similar but slightly smaller response in water levels occurred around 20 March 2020 where water levels in the wetland dropped by around 0.1 m over a period of around 20 days before water levels recovered rapidly back to around 716.35 masl. The highest water level at Wetland West 3 of 716.42 masl was recorded on 2 December 2020 and appears to be related to a rainfall event of 20.8 mm on 1 December 2020. It is worth noting that water levels in the wetland were already elevated around this time (between early October and early December) possibly as a result of increased surface inflows from snow melt.

The available monitoring data suggests that the water level fluctuations in Wetland West 3 were due to direct rainfall/inflows to the wetland, with no apparent change due to lake levels. Based on the data collected for this wetland to date, it is unlikely to be impacted by fluctuations in Lake Tekapo water levels under current operating conditions.

5.1.2.3 Lake Alexandrina

Lake Alexandrina has the largest horizontal separation distance between it and Lake Tekapo of the wetlands being monitored (around 1.5 km). Based on aerial imagery and topographic maps, Lake Alexandrina is fed by a number of minor surface waterways around the perimeter of the lake which are sourced from a number of small wetlands, together with expected groundwater and surface water run-off components. Lake Alexandrina has one surface water outlet (Outlet Creek) which connects it with Lake McGregor and ultimately Lake Tekapo. The water level data for Lake Alexandrina is shown in Figure F2, Appendix F and indicates that water levels in the lake remained relatively stable throughout the monitoring period with water levels generally remaining between 712.8 and 713.1 masl with minor fluctuations of around 0.1 m throughout the monitoring period. Water levels measured in Lake Alexandrina during the monitoring period generally remained around 1.9 m above the maximum recorded water level of 710.9 masl in Lake Tekapo. The water level data for Lake Alexandrina also displays spikes of around 0.1 m which may potentially be related to wind forcing/wave action as the transducer was not housed in a stilling well and was located near a shoreline edge of the lake exposed to the north and north-west.

Overall, the water level data for Lake Alexandrina remained relatively stable although the water levels appear to display an overall seasonal fluctuation with a general decline during the late summer months/early autumn months and an increase in water levels during the late winter/early spring months.

The data indicates that a small increase in water level in Lake Alexandrina of around 0.1 m occurred following the start of the rainfall/high inflow event on 3 December 2019 with water levels in Lake Alexandrina peaking on

8 December 2019 following the peak of the rainfall (303.5 mm total daily rainfall on 6 December 2020 at the Eade Memorial Hut rainfall recorder) before declining slightly to around 712.9 masl.

The high rainfall/inflow and associated high water levels in Lake Tekapo in February 2020 and April/May 2020 do not appear to have any significant effect on water levels in Lake Alexandrina. The relatively stable water level record for Lake Alexandrina and the fact that it did not appear to be affected by the February 2020 high rainfall/inflow event suggest that inflows to Lake Alexandrina may be attenuated by groundwater and other minor wetlands discharging to Lake Alexandrina over a longer period of time compared to Lake Tekapo and the other wetlands/water bodies monitored by PDP.

During the December 1984 flood (the highest recorded historical water level in Lake Tekapo, 712.6 masl) the peak Lake Tekapo lake level was reportedly 0.34 m below the level at which Lake Alexandrina would have been inundated (Freestone, 2005). This appears to be generally consistent with the observed water levels of between 712.8 and 713.1 masl during the monitoring period. It is also noted that the design flood level for Lake Tekapo (713.05 masl, refer to section 4.1.1) is lower than but similar to the maximum Lake Alexandrina water level recorded during the recent monitoring, so in the extremely unlikely event that water levels reach this design flood level, Lake Tekapo may have some influence on Lake Alexandrina water levels.

In summary, the available information shows that Lake Alexandrina water levels were higher than Lake Tekapo during the monitoring undertaken by PDP and did not appear to be affected by changes in water level in Lake Tekapo for either high or low Lake Tekapo water levels. Furthermore, there is no historical information available which indicates that water levels in Lake Alexandrina are influenced by either high or low water levels in Lake Tekapo.

5.1.2.4 Rapuwai Lagoon

The transducer data for Rapuwai Lagoon indicates that the water levels in this water body were generally between 710.4 and 710.6 masl for the majority of the monitoring period. Water levels for Rapuwai Lagoon relative to Lake Tekapo and the other monitored wetlands are shown in Figure F2, Appendix F and Figure F3, shows the water level data for Rapuwai Lagoon on an expanded scale along with rainfall and Lake Tekapo Water Levels.

Water levels in Rapuwai Lagoon generally display an overall increasing trend throughout the monitoring period, increasing from around 710.4 masl at the start of monitoring to 710.55 masl at the end of the monitoring period. The data also displays minor diurnal fluctuations (<0.02 m) possibly as a result of wind/wave action. It is worth noting that there appears to only be one ephemeral surface water inflow to Rapuwai Lagoon, although based on historic aerial imagery,

satellite imagery and the 1:50 000 topographical map for the area, the lagoon appears to be located on an old remnant alluvial fan of the Mistake River. Therefore, it is possible that the lagoon may receive groundwater inflows due to losses from the Mistake River into the alluvial fan as the river exits the Hall Range combined with rainfall recharge via groundwater over the wider fan area. It is possible that the groundwater inflows to the lagoon from flow losses in the Mistake River may be the cause of the overall increasing trend displayed in the Rapuwai Lagoon water level data throughout the monitoring period, although further investigation would be required to confirm this.

The effect of the three, high rainfall/inflow events in December 2019, February 2020 and April/May 2020 that caused increased water levels in Lake Tekapo can be observed in the water level data for Rapuwai Lagoon. During each of these events, water levels in Rapuwai lagoon increased by around 0.5 m, 0.1 m and 0.15 m respectively with the highest water level in the lagoon of 710.9 masl measured on 11 December 2019.

Rapuwai Lagoon is located relatively close to Lake Tekapo (around 70 m depending on Lake Tekapo water levels) and based on onsite observations, there is a natural gravel embankment separating the two water bodies. An onsite survey indicated that the lowest point on the embankment separating the two water bodies is around 710.7 masl.

During the December 2019 event, water levels in Lake Tekapo exceeded 710.7 masl and Rapuwai Lagoon appears to have become directly connected with Lake Tekapo at the surface, resulting in a relatively significant increase of 0.5 m between 8 December and 11 December. However, there appears to be a delay (around 15-20 hours) in the timing of the peak water levels measured in Rapuwai Lagoon and Lake Tekapo (Rapuwai Lagoon peaks after Lake Tekapo). During the April/May 2020 event, water levels in Lake Tekapo peaked at around 710.6 masl and approximately 16 hours later, water levels in Rapuwai Lagoon peaked at around 710.75 masl. It is worth noting that this peak water level in Rapuwai Lagoon exceeded the outlet of the lagoon and indicates that it would have been discharging into Lake Tekapo for around 8 – 9 days before water levels dropped below the lagoon embankment low point.

During the February 2020 event, water levels in Lake Tekapo peaked at around 710.5 masl with water levels in Rapuwai Lagoon peaking at 710.6 masl around 18 hours later. Neither water levels in Lake Tekapo nor Rapuwai Lagoon exceeded the low point on the embankment of 710.7 masl during the February event.

Based on the relatively consistent delay in the response to water level fluctuations in Lake Tekapo, it appears that water levels in Rapuwai Lagoon may be affected by changes in groundwater levels locally altering the groundwater gradient as a result of increases in Lake Tekapo water levels exceeding an

elevation of around 710.5 masl. In other words, it does not appear Rapuwai Lagoon is significantly affected by Lake Tekapo when Lake Tekapo water levels are below 710.5 masl. While the water level data for both Lake Tekapo and Rapuwai Lagoon indicates that the embankment low point between the two water bodies was exceeded twice during the monitoring period, it is expected that the overtopping occurs slowly through the vegetation and wetland area that surrounds the lagoon. In addition to the hydraulic connection between Rapuwai Lagoon and Lake Tekapo, it is expected that groundwater inflows and surface water inflows occurred during each of the high rainfall/inflow events, contributing to the observed increase in water levels in Rapuwai Lagoon, although it is difficult to quantify the effect of these inflows given the relatively large magnitude of the Lake Tekapo water level fluctuations occurring at the same time.

Overall, the available monitoring data for Rapuwai Lagoon suggests that the lagoon is not significantly affected by Lake Tekapo level changes at lower levels in Lake Tekapo but is affected by higher lake levels (when water levels in LakeTekapo are greater than around 710.5 masl). Based on this, Rapuwai Lagoon is likely to be affected by fluctuations in Lake Tekapo above that higher lake level under the current operating conditions. The pre-1951 Lake Tekapo water levels varied between 704.4 and 707.1 masl, so it is possible that Rapuwai Lagoon may not have previously been directly connected to Lake Tekapo. When water levels in Lake Tekapo are below 710.5 masl, water levels in Rapuwai Lagoon are likely to be influenced by a combination of ephemeral surface water inflows, shallow groundwater inflows and rainfall.

5.1.2.5 Lake McGregor

The transducer data for Lake McGregor is provided in Figure F4 and indicates that water levels in Lake McGregor were relatively stable at around 709.2 masl prior to the December 2019 rainfall/high flow event. There appears to be a very small increase in water level in Lake McGregor following the start of the rainfall event on 3 December 2019 (around 0.05 m) before water levels in Lake Tekapo exceeded 709.2 masl, at which point the two water bodies display a near identical water level pattern from being connected to each other via a culvert located near the north-eastern extent of Lake McGregor (culvert under Godley Peaks Road). This culvert has an invert elevation of 707.95 masl at its western end (Lake McGregor side) and an invert elevation of 707.82 masl at its eastern end (Lake Tekapo side).

While the Lake McGregor and Lake Tekapo water level datasets generally display a near identical pattern once the two water bodies become connected, a small difference of <20 mm between the water level datasets is from measurement uncertainty associated with the survey equipment.

Following the increase in water levels as a result of the December 2019 event, water levels in both lakes peaked at around 710.9 masl on 11 December 2019 and water levels in Lake McGregor followed the same pattern of water level fluctuations as Lake Tekapo until around 29 June 2020 when water levels in Lake Tekapo dropped below 709.3 masl.

Based on the culvert invert elevation on the western side of the culvert under Godley Peaks Road, it is likely that Lake Tekapo and Lake McGregor become connected at the surface via the culvert when water levels in Lake Tekapo exceed an elevation of 707.95 masl. However, based on the data collected as part of this report, Lake McGregor does not appear to be affected by Lake Tekapo until water levels in Lake Tekapo exceed an elevation of around 709.2 masl. It is worth noting that during the water level monitoring in Lake McGregor, the culvert invert at the upstream end of the culvert (western end) was observed to have sediment build up which is likely to affect the outlet level of Lake McGregor and the connection with Lake Tekapo.

Overall, the water level data measured during the monitoring period suggests that Lake McGregor is not significantly affected by Lake Tekapo level changes at lower lake levels but is affected by higher lake levels above an elevation of around 709.2 masl due to the direct connection that occurs. Based on this, water levels in the Lake McGregor will be affected at the upper end of the current operating range of water levels in Lake Tekapo. The pre-1951 lake levels varied between 704.4 and 707.1 masl, so it is possible that Lake McGregor may not have previously been directly connected to Lake Tekapo.

5.1.2.6 Wetland 16135

A plot of the measured water level data for Wetland 16135 is provided in Figure F5, Appendix F and indicates that water levels in this wetland were around 708.7 masl prior to the December 2019 high rainfall/inflow event.

A sharp increase in water levels in the wetland occurred on 26 November 2019 which increased water levels by around 0.3 m to 709.0 masl before a sudden decrease of around 0.05 m occurred on 3 December 2019. Between 5 and 20 November 2019, a total of 820 mm of rainfall was recorded at the Eade Memorial Hut recorder. Localised rainfall in the upstream catchment of the wetland likely to have occurred during this rainfall event. Aerial imagery sourced from Google Earth indicates that there appears to be a reservoir type structure located around 500 m upstream of the wetland. There is a possibility that localised rainfall may have filled this small reservoir up before it over topped sending a pulse of water downstream to wetland 16135, resulting in the increase in water level, before water levels in the wetland stabilised at around 708.8 masl immediately prior to the December 2019 inflow event.

While there is a small offset between the datasets (<20 mm which is associated with measurement uncertainty of the survey equipment), the water level data indicates that the wetland became directly connected to Lake Tekapo once water levels in Lake Tekapo exceeded an elevation of around 708.8 masl from early December 2019. Water levels in Lake Tekapo remained above this elevation until around 3 August 2020 when Lake Tekapo water levels dropped below 708.8 masl and remained relatively stable at this elevation for the remainder of the monitoring period. However, since water levels in wetland 16135 were initially measured at around 708.7 masl when the transducer was installed, the wetland is likely to become connected at elevations greater than 708.7 masl, although the full range of natural fluctuations and low water levels in the wetland may be greater than was recorded.

When water levels in Lake Tekapo are low Wetland 16135 discharges to Lake Tekapo via a single channel which varies in length and width based on the Lake Tekapo water level elevation. However, once water levels exceed an elevation of around 708.7 masl, Wetland 16135 becomes completely inundated and essentially forms part of Lake Tekapo.

Overall, water levels in Wetland 16135 become directly connected with Lake Tekapo when water levels in Lake Tekapo exceed an elevation of around 708.7 masl. Based on this, the wetland is affected by water level fluctuations in Lake Tekapo above that level under the existing operating conditions. Historically (pre-1951), the wetland may not have been or may have been less influenced by lake levels.

5.1.2.7 Godley River Wetland 23

Water level data for Godley River Wetland 23 are displayed in Figure F6 and show that water levels in this wetland were around 709.8 masl prior to the February 2020 high inflow/rainfall event and began to increase around 15 days prior to a rainfall event of 341 mm on 4 February 2020 (during the February 2020 event), likely as a result of increased surface water inflows to the wetland/water body sourced from the Macaulay River and tributaries along the eastern side of the valley upstream of the wetland. Water levels in the wetland/water body peaked at 710.7 masl on 5 February, around 0.2 m higher than water levels in Lake Tekapo. Following the February 2020 event, water levels in the wetland/water body followed a similar but offset pattern (offset by around 0.15 m) to Lake Tekapo until around 20 June 2020 when water levels in Lake Tekapo decreased below 709.8 masl. The data also indicates that there is a slight delay between the timing of water level fluctuations between Lake Tekapo and the wetland with water level changes occurring in the wetland approximately 16 hours before a similar response occurred in Lake Tekapo. Following this decrease in June 2020, water levels in the wetland stabilised and remained at this elevation for the remainder of the monitoring period with the exception of

some short duration increases of up to 0.4 m over a 12 day period as a result of rainfall and possible surface water inflow.

The observed offset and delay in water level response indicates that the hydraulic connection between the lake and wetland may be related to changes in groundwater levels once water levels in Lake Tekapo exceed an elevation of around 709.8 masl. It is also worth noting that Godley River Wetland 23 has an inlet and outlet channel and therefore receives surface water inflows. The presence of the outlet channel also indicates that there is an opportunity for direct surface water outflows from the wetland and also a direct surface water connection with Lake Tekapo, and therefore levels in the wetland are affected via lake levels. Inflows may separately affect the wetland levels and this is observed in the data for the wetland around 13 April 2020 where water levels increased by around 0.5 m in 24 hours as a result of a rainfall event of 179.5 mm at the Eade Memorial Hut in the Godley River Valley. An increase in water levels of 0.2 m occurred in Lake Tekapo at the same time but was smaller than the water level fluctuation in the wetland which is expected to be related to due to water levels in the wetland being affected by a combination of rainfall and surface water inflows.

Overall, Godley River Wetland 23 appears to have a hydraulic connection with Lake Tekapo when water levels in the lake exceed an elevation of around 709.8 masl which may occur via changes in groundwater levels or due to changes in surface water outflows). Based on this, Godley River Wetland 23 is affected by Lake Tekapo water level fluctuations above that level under existing operating conditions. Historically (pre-1951), the wetland may not have been or may have been less influenced by lake levels.

5.1.2.8 Wetland Lake Tekapo East 2

A plot of the water level data for Wetland Lake Tekapo East 2 (referred to as Wetland East 2) is displayed in Figure F7, Appendix F. This wetland/water body is a relatively small pond that has formed behind a gravel embankment that separates Lake Tekapo and the wetland/water body by around 50 m although this distance will be smaller or greater depending on water levels in both water bodies. The wetland/water body does not appear to have any surface water inflows or outlets. While there is a small offset between the datasets which is associated with measurement uncertainty of the survey equipment, the transducer data measured at this site during the monitoring period shows that water levels follow a very similar pattern to Lake Tekapo indicating that there is a strong hydraulic connection between the lake and the water body, likely through the permeable gravel embankment.

The transducer was removed on 2 July 2020 as the water level in wetland had dropped below the transducer installation and during a subsequent site visit on 12 October 2020, the wetland/water body was observed to be dry with the base

of the wetland/water body surveyed at an elevation of 707.6 masl. At this time, the water level in Lake Tekapo was measured to be 705.7 masl, around 1.9 m below the base of the wetland/water body. An additional manual water level in the pond was measured on 17 November 2020 where a water level of 707.9 was measured and was around the same as Lake Tekapo at this time. Based on this data, it is expected that Wetland East 2 becomes hydraulically connected with Lake Tekapo when water levels in the lake exceed an elevation of around 707.6 masl. When water levels in Lake Tekapo are below this elevation, it is expected that the wetland/water body will be dry.

Based on the above information, Lake Tekapo East 2 is affected by water level fluctuations in Lake Tekapo under existing operating conditions.

5.1.3 Wetland/water body level and extent assessments

For wetlands/water bodies that have been identified as having a hydraulic connection with Lake Tekapo, changes in water level within Lake Tekapo have the potential to affect the terrestrial ecological environment in the wetland/water body (but this is predominantly at higher lake levels and only wetland LT East 2 was observed to be affected at lower lake levels). Quantifying this effect would require an understanding of the change in wetted area of the wetland/water body water level caused by fluctuations in Lake Tekapo.

Based on the observed changes in water level in each of the wetlands/water bodies discussed above during the December 2019 high rainfall/inflow event, LiDAR data flown between November 2016 and January 2017 for the Tekapo area was used to determine the water level elevation of each wetland/water body when they are connected with Lake Tekapo and comparing this surface area with the projected surface area based on a vertical offset from the observed increase in water level during the December 2019 rainfall/inflow event. In addition to this water level, surface areas were also estimated based on a measured water level in all of the wetlands/water bodies between the maximum measured water level and the level at the time of the 2016 LiDAR. The surface areas for each water body at the different Lake Tekapo water level elevations are provided in Table 18. Maps showing each of the change in wetted area of each wetland/water body listed in the table below are displayed in Figure E5 to Figure E9, Appendix E.

Note that the “mid-point water elevation data” were arbitrarily selected and are from different times throughout the period that water levels in each wetland/water body were monitored. The dates of the mid-point water elevations are:

- Rapuwai Lagoon – 15 December 2019
- Lake McGregor – 18 June 2020
- Wetland 16135 – 1 April 2020

- Godley River Wetland 23 – 16 June 2020
- Lake Tekapo East 2 – 23 June 2020

It is worth noting that the elevations at which each of the wetlands/water bodies listed above become hydraulically connected with Lake Tekapo will likely vary depending on the time of year with changes in local groundwater levels and resulting changes in the hydraulic gradient of the groundwater system around the margin of the wetlands/water bodies and Lake Tekapo and potentially surface outflow changes.

Based on Genesis' water level record for Lake Tekapo, water levels in the Lake ranged between 707.0 and 709.23 masl for the period between 1 November 2016 and 31 January 2017. The LiDAR data indicates that water levels in Lake Tekapo were less than 707.6 masl as there was no water in Lake Tekapo East 2 (it becomes dry when water levels Lake Tekapo drop below 706.2 masl). Based on this, the measured surface area based on the 2016 LiDAR data is assumed to represent the area of each wetland/water body during conditions when the wetlands/water bodies are not hydraulically connected with Lake Tekapo.

Table 18: Summary of estimated surface water areas at various water level elevations for wetlands/water bodies hydraulically connected with Lake Tekapo

Wetland/Water body	Hydraulic connection water level elevation (masl) and surface area (ha)	Water elevation (masl) and surface area (ha) at time of 2016 LiDAR Survey	Mid-point water elevation (masl) and surface area (ha)	Peak monitored water elevation (masl) and surface area (ha) on 11 December 2019	Percentage of time wetland/water body is hydraulically connected to Lake Tekapo [3]
Rapuwai Lagoon	710.4 (4.8)	710.2 (3.2)	710.7 (8)	710.9 (9.5)	4%
Lake McGregor	709.2 (47.2)	709.0 (43.5)	709.9 (50.3)	710.9 (54)	22%
Wetland 16135	708.7 (0.5)	708.2 (0.07)	709.8 (1.8) [1]	710.9 (4.2) [1]	39%
Godley River Wetland 23	709.8 (0.8)	709.8 (0.8)	710.1 (1.9)	710.7 (7) [2]	12%
Lake Tekapo East 2	707.6 (0, Dry)	707.6 (0, Dry)	709.6 (0.12)	710.7 (0.24) [2]	49%

Notes:

1. *Wetted areas for wetland 16135 are indicative as once this wetland/water body becomes connected to Lake Tekapo, it essentially becomes part of the Lake.*
2. *Peak monitored level conditions for Lake Tekapo East 2 Wetland and Godley River Wetland 23 occurred on 15-16 May 2020.*
3. *Based on Lake Tekapo water levels for the period between 1 January 1991 and 31 December 2020.*

The information provided in Table 18 can be used to graphically display the percentage of time that each wetland/water body is estimated to be hydraulically connected to Lake Tekapo based on the water level record for the lake between 1991 and the 2020. This information is graphically displayed as wetted elevation and wetted area duration plots which are graphically displayed in Figure F8 to Figure F12, Appendix F. It is worth noting that dotted straight line for the wetland/water body represents the condition when there is no hydraulic connection with Lake Tekapo. In reality, (with the exception of Lake Tekapo East 2) the water level in the wetland/water body will fluctuate based on rainfall, surface inflows and changes in groundwater level around the water body. The information provided in Figure F8 to Figure F12 and in Table 18 indicates that Rapuwai Lagoon and Godley River Wetland 23 are hydraulically connected with Lake Tekapo over less than 15% of the water level record for Lake Tekapo. Lake McGregor is indicated to be hydraulically connected to Lake Tekapo less than 25% of the time, while wetland 16135 and Lake Tekapo East 2 are estimated to be connected around 40 to 50% of the record for Lake Tekapo respectively.

The sites described above were chosen as representative wetlands/water bodies around Lake Tekapo. Based on this monitoring, it is considered that other wetlands/water bodies surrounding the lake (refer to Figure E3, Appendix E) and with similar levels to lake levels will also be influenced by lake levels in a similar manner. Based on the monitoring, it is considered that wetlands above around 711 masl are unlikely to be impacted by lake levels, except perhaps in infrequent events when lake levels exceed the maximum operating levels. Figure E3, also shows the 711 masl contour, below which wetlands/water bodies around Lake Tekapo may be affected by water level changes in Lake Tekapo.

Overall, the information indicates that some of the wetlands/water bodies surrounding Lake Tekapo are influenced by lake level fluctuations, predominantly at the higher water levels, as a result of the scheme operation. However, this pattern of interaction will not be altered as a result of the reconsenting as Genesis is not proposing to change the current operating levels for the lake.

5.1.4 Groundwater levels

In addition to the wetland/water body hydraulic assessments discussed in the previous section, groundwater level data are relevant to groundwater-surface water interaction and potential changes caused by the scheme. Unfortunately, there are very limited groundwater level data around Lake Tekapo and very few bores shown on ECan's database.

A search prior to the wetland/water body monitoring showed that there was no groundwater data near the wetlands/water bodies around Lake Tekapo to use to establish whether nearby wetlands/water bodies could be connected to the lake, via groundwater. Groundwater levels are reported on ECan's online database for

two bores on the eastern side of the lake (I37/0073 and I37/0061) and in Genesis bores located around the control gates and the intake structure but only initial water levels from when the bores were installed are provided. ECan's online database indicates that there are eight readings for bore I37/0013 on the western shores of the lake below Mt John. There is only one other bore recorded near to the lake (I37/0037), but this has no information and an expired bore permit. There are two bores more than 1 km from the lake on the western side (BY17/0039 and BY17/0042). BY17/0039 only has an initial water level reported.

There are a small number of domestic supply bores around Lake Tekapo that could potentially be affected by lake level fluctuations (e.g., I37/0013 below Mt John and I37/0073 and I37/0061 on the eastern side of the lake). However, these bores have all been installed since 2000 (post-scheme). Genesis is not proposing to change the current operating levels for the lake, so no changes in groundwater level fluctuations currently experienced at these bores are expected to occur as a result of the reconsenting.

While there is an absence of groundwater level data around Lake Tekapo, the key groundwater issue is the potential effects of lake level fluctuations that occur under the scheme on wetlands/water bodies, via groundwater as detailed in the section above.

5.1.5 Hydrogeological properties

There was limited existing hydrogeological parameter information for the Tekapo Basin, including around Lake Tekapo that could have assisted with understanding interaction between the lake and the surrounding wetlands. Therefore, the detailed monitoring and assessments presented in Sections 5.1.2 and 5.1.3 were undertaken to understand the influence of the effect of the scheme on representative wetlands/water bodies surrounding Lake Tekapo.

5.1.6 Groundwater quality

A review of existing groundwater quality data has been undertaken around Lake Tekapo. There is limited groundwater quality information around the lake, with only one bore with data available on Environment Canterbury's database (I37/0013). The two samples for this 22 m deep bore from 2007 indicated very low nitrate concentrations.

Overall, the existing data for the wider area generally indicates good groundwater quality, reflecting the current low intensity of land use in this area of the Tekapo Basin.

Further data on groundwater quality was not considered necessary for this project as the TekPS does not directly influence groundwater quality and any indirect influence, for example a reduction in the unsaturated zone at higher lake

levels, will not be altered as a result of the reconsenting (as Genesis is not proposing to change the current operating levels for the lake).

5.2 Tekapo River

5.2.1 Groundwater – surface water interaction

The existing information on groundwater – surface water interaction is outlined in Section 4.2.2 of this report, including gains/loss profiles using historical and recently collected flow data.

The following sections of this report provide a description of the field work undertaken by PDP to monitor groundwater and wetland/water body levels around the Tekapo River, the associated data analysis and further discussion of groundwater and surface water interactions through the wider Tekapo River Basin.

The following sections refer to two separate controlled spill events by Genesis from Lake George Scott into the Tekapo River during December 2019 and February 2020. The December 2019 event occurred between 7 and 30 December 2019 where up to 170 m^3/s was released. Around the time of this spill, 125 mm of rainfall was measured at Tekapo Airfield over a period of 18 days (measured between 2 and 20 December 2019), followed by a period of minimal rainfall throughout January 2020. Prior to the December 2020 event, relatively little rainfall was recorded (around 80 mm) during October and November 2019 (a period of 54 days). The February 2020 event occurred between 1 and 19 February 2020 where up to 160 m^3/s was released down the Tekapo River. Around the time of the February 2020 spill event, 56.4 mm of rainfall was recorded over a period of 40 days (measured between 1 February and 11 March 2020), indicating that relatively little rainfall fell during and after the February 2020 spill event near the Tekapo River compared to the December 2019 spill event. These two spill events are referred to as the December 2019 spill event and the February 2020 spill event in the following sections of this report.

5.2.2 Tekapo River Basin wetlands/water bodies

In addition to the rivers and streams (described in Section 4.2.2 of this report) that could receive groundwater inflows from water lost from the Tekapo River, flows and levels in smaller tributaries and riparian wetlands/water bodies could be influenced by changes in groundwater flows, via losses and gains from the Tekapo River. Prior to this study, there was an absence of information on the degree of connection between the Tekapo River and wetlands/water bodies bordering the river. It is noted that Environment Canterbury have classed the Tekapo River system as a "Wetland of Representative Importance" (Environment Canterbury, 2016). The extent of the "Wetlands of Representative Importance" GIS layer along the Tekapo River is displayed on Figure E10, Appendix E along

with wetlands/water bodies identified from NZTopo50 map data. It is worth noting that the NZTopo50 map areas for wetlands/water bodies are quite small as displayed on Figure E10.

Water level monitoring was undertaken by PDP in seven wetlands/water bodies located near the reach of the Tekapo immediately upstream of Grays Hills on both sides of the river. In addition to the seven wetlands, a transducer was also installed in the Grays River to measure stage height near monitoring bore MW5 (referred to as "Lower Grays Stage Recorder" in this report), just upstream of the confluence of the Grays River and Tekapo River.

A summary of the details for each of the Tekapo River Basin wetland/water body monitoring sites, including the Lower Grays Stage Recorder is provided in Table 19 below and the locations of the monitoring sites are shown in Figure E10.

Table 19: Summary of details for Tekapo River Basin wetland/water body monitoring sites

Monitoring Site	Installation Date	Easting NZTMX	Northing NZTMY
DOC Wetland 3 [1]	30 January 2020	1388195	5101732
DOC Wetland 4 [1]	30 January 2020	1387553	5101905
DOC Wetland 7 [1]	30 January 2020	1389092	5104082
DOC Wetland 8 [1]	30 January 2020	1386669	5099990
Irishman Creek Wetland	18 June 2019	1386965	5097799
Grays Hills Wetland 1	31 January 2020	1389696	5098847
Grays Hills Wetland 2	31 January 2020	1393600	5099609
Grays River Stage Recorder [2]	31 January 2020	1388309	5097487

Notes:

1. *Note DOC Wetlands 3, 4, 7 and 8 are also monitored by the Department of Conservation (DOC) and have been labelled as such to be consistent with DOC.*
2. *Grays River Stage Recorder was located in the Grays River near bore MW5 and upstream of the Grays River/Tekapo River confluence.*

These wetland/water body monitoring sites were selected to help assess any interactions between the Mary Burn, Irishman Creek, Grays River and the Tekapo River as well as shallow groundwater. The monitoring sites at each of these wetlands/water bodies consisted of a transducer attached to a metal waratah driven into the substrate of the wetland/water body. Except for the Irishman Creek Wetland monitoring site, transducers at the wetland/water body monitoring sites were installed on 31 January 2020. The transducer at the

Irishman Creek Wetland was installed on 18 June 2019. The transducers at all the wetland/water body monitoring sites were downloaded approximately every 3 – 4 months and all transducers were removed on 9 February 2021. All transducers were set to record absolute pressure measurements every 15 minutes and a dedicated barometric pressure transducer located at bore I38/0049 was used to record atmospheric pressure measurements. The pressure measurements recorded by the barometric transducer were used to remove the atmospheric pressure component from the raw transducer data for each of the wetlands/water bodies to obtain water levels.

Figure G1, Appendix G provides a plot of the available water level data for the wetland monitoring sites along with daily rainfall totals recorded at the NIWA climate station located at the Tekapo Airfield (Agent Number: 24945).

Figure G2 and Figure G3 provide plots of the wetland/water body water level data located on the eastern and western sides of the Tekapo River respectively, along with flow data for the Tekapo River and its tributaries. The water level measurements for each of the wetlands/water body are given as the level below the measuring point (in metres below top of the waratah – referred to as "MP") and enable a comparison of the relative change in magnitude of the measured water levels. It should be noted that the wetland/water body water level data displayed in Figure G2 and Figure G3 are provided on a linear scale while the flow data are provided on a logarithmic scale.

A discussion of the data collected for the eastern and western wetlands/water bodies is provided in the sections below.

5.2.2.1 Eastern Tekapo River Basin Wetlands

The eastern wetlands monitored by PDP consist of two wetlands located near the Grays River. The Grays Wetland 1 monitoring site was located in an abandoned channel of the Grays River (located around 250 m north of the active Grays River channel) and the Grays Wetland 2 site located within a modified (used to provide water for stock) located around 700 m north from the Grays River.

As previously mentioned, the transducers were installed on 30 and 31 January 2020, 1 day prior to the start of Genesis spilling water into the Tekapo River on 1 February 2020. The water level data for both wetlands display an initial increase in water level after the installation of the transducers with water levels at both sites peaking around April/May 2020. Following this, both wetlands display a decrease beginning between this time until around October 2020 where water levels at both sites stabilised before increasing slightly again around January 2021.

While an initial increase in water level of 0.14 m in Grays Wetland 2 around 5 February 2020 appears to occur following a small flow of around 3.8 m^3/s in

Grays River and also around the same time as the February 2020 controlled spill event in the Tekapo River, the overall pattern of water levels in two wetlands for the complete period of monitoring does not appear to clearly correlate to changes in Tekapo River or Grays River flow, however, a delayed response may be occurring in the form of a gradual increase followed by a gradual decrease after the February 2020 spill event. It is also worth noting that the flow and stage data for the Grays River as well as the water level data from both Grays Wetland 1 and 2 display a similar pattern of diurnal fluctuations, although the overall pattern of water levels/flows are generally different. However, the overall water level pattern in the two wetlands appears to have some similarity (although delayed) to the water levels measured in monitoring bore I38/0085 and to a lesser extent, I38/0049. Both bores are located on the eastern side of the Tekapo River and are around 10 km upgradient (north) of the two wetlands. A more detailed discussion of the data from these two bores is provided in the following section of this report, but it appears that water levels in these bores are predominantly affected by flow events in Edwards and Sawdon Streams discharging water into a manmade diversion channel that loses water to ground up-gradient of these two bores, rather than changes in flow within the Tekapo River.

The data from bore I38/0085 for the period between December 2019 and February 2020 (refer to Figure G5), indicates that water levels increased following the controlled spill event into the Tekapo River in December 2019 until early January 2020 where levels in the bore began to decline steadily until June 2020 when the bore became dry. Water levels were able to be measured in the bore again on 10 October 2020 and display an increase until early January 2020. In Figure G5, it should be noted that water level data are provided on a linear scale and flow data are provided on a logarithmic scale.

The relatively short monitoring period for the wetlands compared to bore I38/0085 makes it difficult to determine the overall controlling influence on water levels within the Grays Wetlands. However, given the similarities with the water level pattern in I38/0085 and the differences in the pattern of flows in the Tekapo and Grays River, it is expected that the water level patterns in the Grays Wetlands may be influenced in a similar manner to groundwater around I38/0085, albeit with a delay.

Water levels in Grays Wetland 2 appears to respond to rainfall with rapid but brief increases in water level. Water levels in Grays Wetland 1 do not appear to respond rapidly to rainfall events. While Grays Wetland 1 has a smaller total overall range of water level fluctuations (0.3 m) compared to Grays Wetland 2 (total overall range of 0.45 m), the overall pattern is generally similar between each wetland. The water level data for both wetlands do not appear to display an obvious correlation between flow changes in the Tekapo River or the Grays

River during the period of monitoring, however, a delayed response may be occurring.

The PDP Grays River Stage transducer shows a very similar response to the flow recorded at Days Bridge. There does not appear to be an obvious connection to flow changes in the Tekapo River, which the exception of flow increases as a result of rainfall events in the Tekapo River Basin. However, given that water levels in MW5 (located around 15 m from the Grays River stage recorder transducer) show a response to Tekapo Flows during the December 2019 and February 2020 spill events, it is expected that the reach of the Grays River downstream of the stage recorder transducer will increase by some degree in response to large increases in Tekapo River flows, via increased groundwater levels, although the stage recorder indicates the actual impact on flows is minimal at that particular location.

Although the water level records for the Grays Wetlands 1 and 2 are relatively short, the available data does not appear to display a clear effect from flow changes in the Tekapo River, however, a delayed response may be occurring. Furthermore, flow data in the Grays River at Days Bridge also appear to be unaffected by increases in flow in the Tekapo River that do not coincide with rainfall. Based on this information, it is expected that the reach of Grays River and the wetlands adjacent to the Grays Wetlands 1 and 2 do not have a direct hydraulic connection with the Tekapo River, although a more delayed response may be occurring.

5.2.2.2 Western Tekapo River Basin Wetlands/Water Bodies

The area to the west of the Tekapo River from around the mid reach of the river to where it passes through Grays Hills is characterised by two types of surface geology; glacial outwash plains and historic flood plains of the Tekapo River. These two surfaces are separated by a large and relatively continuous terrace scarp around 5 to 10 m high that runs roughly sub parallel to the current Tekapo River channel, with the historic flood plain located between the Tekapo River and the terrace and the glacial outwash plain on the elevated surface west of the terrace scarp. PDP monitored water levels within five wetlands/water bodies located on the historic flood plain west of the Tekapo River using transducers. These wetlands were:

- DOC Wetland 3
- DOC Wetland 4
- DOC Wetland 7
- DOC Wetland 8
- Irishman Creek Wetland

The water level data for each of the wetlands is displayed in Figure G1 and Figure G3, Appendix G and the locations of each of the monitoring sites are shown in Figure E10, Appendix E. A discussion of the measured data for each wetland is discussed below.

Irishman Creek Wetland, DOC Wetland 3 and DOC Wetland 7

DOC Wetland 7 is the northern most wetland west of the Tekapo River monitored by PDP and is located at the base of the terrace scarp near spring BZ16/0025 which is registered on ECan's online GIS database as a gravitational seepage spring. This spring is one of a cluster of nine springs registered on ECan's database in this area of the Tekapo River Basin. On the glacial outwash plain to the west of DOC Wetland 7, the Irishman Creek channel flows in a south-south westerly direction to its confluence with the Mary Burn around House Hill, just south of SH8.

As mentioned earlier in this report, the reach of Irishman Creek downstream of SH8 at Windy Ridges is known to lose flow before gaining again just upstream of the confluence with the Mary Burn. Available satellite imagery from Sentinel Hub Playground indicates that this reach of Irishman Creek had continuous flow along this reach between June 2019 and January 2020 before the flow ceased. The flow in this reach of Irishman Creek appears to begin again around mid-September 2020 but had ceased flowing along this reach again by around mid-December 2020. The available aerial imagery also indicates that there is an old historic stream channel located around 3 km upstream of the confluence with the Mary Burn which appears to be connected to Irishman Creek but does not have any surface flow. This channel is orientated in a southerly direction away from Irishman Creek and cuts through the terrace scrap. DOC Wetland 7 is located where this channel opens onto an old historic flood plain of the Tekapo River, near TopoMap50 spot elevation 521 m. DOC Wetland 7 is also located at the start of a stream channel in the historic flood plain which flows roughly parallel to the Tekapo River.

Based on aerial imagery from Sentinel Hub Playground and Google Earth, it appears that Irishman Creek Wetland, DOC Wetland 7 and DOC Wetland 3 are hydraulically connected by this surface water channel and the relative similarity in the overall water level patterns recorded at each site are consistent with this connection. However, the water levels measured at both DOC Wetlands 3 and 7 displayed a decline during the February 2020 spill event where Irishman Creek Wetland displayed an increase coinciding with the controlled spill into the Tekapo River and rainfall on 5 February 2020.

Relatively low rainfall was recorded during the February 2020 spill event (compared with the December 2019 spill event) and given the elevated flows within the Tekapo River during the February 2020 event (up to 160 m^3/s), this data provides a good opportunity to isolate the effect of the Tekapo River on

water levels within the wetlands/water bodies. A measured increase in water levels of around 0.07 m in Irishman Creek Wetland during the February 2020 spill event suggests that changes in flow within the Tekapo River isolated from rainfall events have a relatively small effect on this particular wetland compared with the effect of higher rainfall combined with elevated Tekapo River flows. For example, during the December 2019 event an increase in water level of up to 0.14 m was observed in the Irishman Creek Wetland. Corresponding decreases in water level recorded in DOC Wetland 3 and 7 during the February 2020 spill event may indicate that these two wetlands/water bodies do not have a strong hydraulic connection with the Tekapo River. Except for the December 2019 and February 2020 spill events, flows within the Tekapo River are controlled by rainfall events. The Irishman Creek Wetland appears to respond with a similar pattern to the Tekapo River.

The overall pattern of flows in the Tekapo River is relatively similar to flows within the Mary Burn which also responds primarily to rainfall events. While both DOC Wetland 3 and 7 do not appear to respond rapidly to rainfall events, the overall similarity in the pattern of water levels with the Irishman Creek Wetland and the Tekapo River suggest that the predominant influence on water levels in DOC Wetland 3 and 7 is expected to be from a combination of rainfall runoff and changes in shallow groundwater as a result of rainfall recharge throughout the wider area. It is possible that the Tekapo River may have some small influence, with the permanent flow in the river contributing to groundwater levels in the surrounding area, but there is no clear response in the water level data for DOC Wetland 3 and 7.

DOC Wetland 4

DOC Wetland 4 is located in an old, abandoned stream channel on the old historic flood plain of the Tekapo River which has now formed a wetland area. The water level data for this site shows that water levels fluctuated between 1.02 mbmp (9 February 2021) and 0.86 mbmp (17 November 2020), providing an overall water level fluctuation range of 0.16 m. The data for this wetland shows that when the transducer at the site was installed immediately prior to the February 2020 spill event in the wetland on 30 January 2020, water levels declined by around 0.13 m until 12 April 2020 before they started to increase. Water levels in this wetland appear to respond relatively rapidly to rainfall events in the short term. Following this initial decline, water levels in DOC Wetland 4 increased gradually and continuously by around 0.16 m, peaking in November 2020 before declining relatively rapidly to the end of the monitoring period in February 2021. The data indicates that there are some minor similarities with the data from DOC Wetlands 3 and 7 (particularly a small increase between August and September 2020), although the water levels for DOC Wetland 4 appear to have a different overall pattern compared to the other water level and flow datasets for the area and appear to be primarily affected by rainfall events. Given the proximity of this

wetland to the confluence of the Irishman Creek surface channel with Mary Burn (ECan record - spring BZ16/0036 located around 140 m west of DOC Wetland 4) there may be some influence from shallow groundwater discharging to the surface in this area of the basin. The Tekapo River may have some small influence, with the permanent flow in the river contributing to groundwater levels in the surrounding area, but there is no clear response.

DOC Wetland 8

DOC Wetland 8 is located in a branch of the Mary Burn and the water level data recorded at this site shows short-term increases in level from rainfall and the resulting increase in flow in the Mary Burn. Water levels at this monitoring site indicate that levels ranged between 0.82 mbmp (3 February 2021) and 0.6 mbmp (12 October 2020), providing an overall range of 0.22 m. The overall pattern of water level fluctuations in the DOC Wetland 8 is relatively similar to the pattern of flows within the Mary Burn. While the data for DOC Wetland 8 appears to have an overall similar water level pattern to Tekapo River flows, it is unlikely that there is a strong hydraulic connection between the Tekapo River and DOC Wetland 8/Mary Burn and any similarities are likely to be related to rainfall. In addition to this, during the February 2020 spill event, water levels recorded at the DOC Wetland 8 increased slightly in tandem with an increase in flow in the Mary Burn, but displayed a decrease in water level of 0.07 m between 30 January 2020 and 6 April 2020. Corresponding flows in the Mary Burn also decreased during this time by around 150 L/s whereas flows in the Tekapo River were significantly higher; measured up to 160 m^3/s.

Overall, the available data for DOC Wetland 8 indicates that water levels at this site are primarily affected by rainfall events and subsequent elevated flows in the Mary Burn. There does not appear be an obvious correlation between flows in the Tekapo River with water levels at DOC Wetland 8. The Tekapo River may have some small influence, with the permanent flow in the river contributing to groundwater levels in the surrounding area, but there is no clear response.

Additional Wetlands/Water Bodies

Patersons Ponds are a well-known wetland area, formed from the inundation of old gravel borrow pits from the TekPS construction. These were not monitored by PDP as part of this assessment. However, available satellite imagery shows that they are well connected to the Tekapo River. This connection can be viewed via available Satellite imagery (imagery taken on 8 December 2019) during the December 2019 spill event. During this event, turbid water from Fork Stream can be seen mixing with relatively clean water being spilled from Lake George Scott. The turbid water is much browner in colour in the satellite imagery and there is a visible change in colour of Patersons Ponds, indicating that some of the turbid flood water in the Tekapo River had flowed through the gravel embankment between the ponds and the Tekapo River.

In addition to the assessments described above, a high-level assessment of other wetlands throughout the wider Tekapo River Basin that were not monitored by PDP was undertaken using satellite imagery sourced from Sentinel Hub: Playground. The available satellite imagery (taken on 8 February 2020) shows that a number of small wetlands and ephemeral channels (possibly old, abandoned channels of the Tekapo River) show an increase in water extent as a result of the December and February spill events. These wetlands/water bodies are located near the mid reach of the river on the western side, and also on the eastern side of the river, just downstream of the confluence of the Tekapo River with the Gray River. The satellite imagery does not appear to show any significant visible changes in shape or size of wetlands/water bodies located at larger distances from the river (i.e., more than 1 km from the Tekapo River) during any of the spill events, which is generally consistent with the physical monitoring data collected by PDP. However, it is worth noting that it is not clear from the satellite imagery which wetlands/water bodies that appear to have an increase in water area (as a result of a water level increase) during the February 2020 spill event are wetlands and not simply low-lying areas that have become inundated by the elevated flows in the Tekapo River at that time.

Overall, the high-level assessment of the additional wetlands/water bodies indicates that wetland/water bodies up to 1 km from the Tekapo River appear to display changes in water area extent and colour as a result of flow changes in the Tekapo River, but wetlands/water bodies located at larger distances show no clear response.

Based on the high-level satellite imagery assessment of additional wetlands, along with the physical water level monitoring in the seven wetlands/water bodies, an estimated areal extent of the area in which the Tekapo River is expected to affect wetland/water bodies from Tekapo River flow increases (i.e., up to 160 m^3/s) has been estimated. The extent of this area is shown in Figure E10, Appendix E and indicates that wetlands/water bodies expected to be hydraulically connected to the Tekapo River are generally less than 1 km from the river. It is noted that much of the extent of this estimated area matches the base of terrace scarps associated with the glacial outwash surfaces and older alluvial sediments compared with the younger alluvial gravels closer to the river.

5.2.2.3 Wetland/water body summary

Available Sentinel Hub: Playground satellite imagery indicates that the only occasion that Irishman Creek had continuous flow along its full reach during the water level monitoring in DOC Wetlands 3, 4 and 7 was between mid-September and mid-December 2020. The highest water levels recorded in Wetlands 3, 4 and 7 coincide with flow along the full reach of Irishman Creek with lower water levels coinciding with periods where flow in Irishman Creek receded upstream. This may suggest that there is some degree of hydraulic connection between

Irishman Creek and these three wetlands/water bodies although further investigation would be required to establish the magnitude of connection between Irishman Creek and DOC Wetlands 3, 4 and 7, which is not required for characterising the interaction with the Tekapo River.

Based on the absence of a response to the February 2020 spill event which occurred during a period of relatively low rainfall, the available water level data for all four DOC Wetland monitoring sites indicates that there is not a strong correlation between changes in water levels and flows in the Tekapo River. DOC Wetland 8 appears to be primarily affected by changes in flow within the Mary Burn which is in turn influenced by rainfall. Water levels in DOC Wetlands 3, 4 and 7 do not appear to display a direct relationship with rainfall in the short-term but appear to be affected by rainfall over longer periods of time, likely due to changes in shallow groundwater from rainfall recharge in the area over this longer time-period. It is possible that the Tekapo River may have some small influence, with the permanent flow in the river contributing to groundwater levels in the surrounding area, but there was no clear response during monitoring.

The available water level data indicates that the Irishman Creek Wetland is affected by changes in flow in the Tekapo River, although the predominant effect on water levels in this wetland appears to be rainfall with changes in flow in the Tekapo from spill events (of up to 160 m^3/s) only having a relatively minor effect on water levels in this wetland/water body (up to around 0.07 m). An additional primary driver on water levels within this wetland aside from direct rainfall and a relatively small hydraulic connection with the Tekapo River is expected to be an indirect effect from rainfall increasing flows in the reach of the channel downstream of DOC Wetland 3 resulting in water level fluctuations in the Irishman Creek Wetland.

A high-level assessment of additional wetlands/water bodies along the Tekapo River was also undertaken using satellite imagery available from Sentinel Hub: Playground. Overall, this assessment indicated that wetlands/water bodies located up to 1 km from the river are likely to be affected by changes in Tekapo River flow and wetlands/water bodies located at larger distances (i.e., more than around 1 km) are less affected.

5.2.3 Groundwater levels

While there are few groundwater supply wells around the Tekapo River that could be affected by the TekPS, groundwater level data is relevant to groundwater-surface water interaction and potential changes caused by the scheme, in particular recharge to other connected surface water bodies (wetlands and streams).

Groundwater level data is available for some bores in the Tekapo Basin and the Twizel Basin in the lower reaches of the Tekapo River. This includes continuous monitoring (via transducers) by ECan for three bores – I38/0084, I38/0085 and BZ16/0073. The data for bores I38/0084 and I38/0085 was previously reviewed in PDP (2013) to help assess interaction between the Tekapo River and groundwater and this data is included in this report along with the most recent from these two bores.

In addition to analysis of data collected for bores I38/0084 and I38/0085 since 2013, additional monitoring of groundwater and analysis of flow data has been undertaken by PDP to help understand the effects of flows in the Tekapo River on groundwater levels and subsequent discharge to other waterways.

To provide additional groundwater data and better understand interactions between flows in the Tekapo River and groundwater levels, PDP installed six monitoring bores within the riparian margin (within the Holocene flood plain) of the Tekapo River (bores MW1 to MW6). Pressure transducers were installed in each of these new bores as well as six additional existing bores along the Tekapo River. The details of these bores as well as the details of the ECan monitoring bores I38/0084 and I38/0085 are summarised in Table 20 and the locations of the bores are shown in Appendix E, Figure E10.

A barometric transducer was also installed at bore I38/0049, which was used to remove the barometric pressure component from the pressure data for each bore. All the pressure transducers were set to record pressure measurements every 15 minutes and had their internal clocks synced when they were installed.

The transducers were downloaded by PDP approximately every three to four months with all the transducers being removed on 9 and 10 February 2021. A manual groundwater level measurement was also recorded in each bore at the same time the transducers were installed, downloaded and when they were removed. Unfortunately, the transducers in bores I38/0092, MW1 and MW3 became stuck following the transducer downloads on June 2020 and November 2020 and were unable to be removed following these final downloads.

The data recorded from each bore has been grouped depending on its distance from the Tekapo River with all bores less than around 160 m from the Tekapo River referred to as the “Riparian Margin Bores” and bores located further from the Tekapo River referred to as the “Deeper Monitoring Bores” for distinction, although these bores are still relatively shallow (especially bores I38/0045 and I38/0092 at 6 m deep). The groundwater level data recorded in the Deeper Monitoring Bores and the Riparian Margin Bores are discussed in the following sections respectively.

Table 20: Monitoring bore details

ECan bore number	Depth (mbgl)	Diameter (mm)	Screened interval (mbgl)	Depth to water level (mbgl)	Start of transducer data	Easting NZTMX	Northing NZTMY
I38/0084	11.5	150	9.9 – 11.9	3.6	ECan Bore	1390442	5107699
I38/0085	23.2	150	20.9 – 22.9	18.24	ECan Bore	1396553	5107476
I37/0029	20.9	35	- [2]	19.8	22/02/2019	1396223	5119966
I38/0049	16.1	35	- [2]	12.4	22/02/2019	1394598	5107261
I38/0092	5.3	50	0 - 6	2.6	22/02/2019	1384785	5091787
I38/0045	6.4	35	- [2]	3.4	30/01/2020	1392324	5107498
BZ16/0093 [1]	5.5	50	4.5 – 5.5	0.56	15/01/2020	1385973	5096181
BZ16/0096 [1]	5.5	50	4.5 – 5.5	1.8	16/01/2020	1385581	5091630
BY16/0007 (MW1) [1]	2.8	50	0.4 – 2.8	1.3	02/10/2019	1395280	5120132
BZ16/0114 (MW2) [1]	2.7	50	0.5 – 2.7	1.9	15/01/2020	1394596	5111571
BZ16/0115 (MW3) [1]	2.5	50	0.5 – 2.5	1.9	01/10/2019	1392438	5106315
BZ16/0116 (MW4) [1]	2.6	50	0.6 – 2	1.6	04/10/2019	1388014	5098250
BZ16/0117(MW5) [1]	2.2	50	0.4 – 2.2	1.1	02/10/2019	1388283	5097493
BZ16/0118 (MW6) [1]	2.9	50	0.4 – 2.9	2.0	15/01/2020	1386297	5094698

Notes:

1. *Riparian Margin monitoring bores.*
2. *Neither I37/0029 or I38/0049 have any screen information available but is suspected that they are screened from near ground level to the bottom of the bore.*

5.2.3.1 Deeper monitoring bore groundwater levels

Plots of water level transducer and manual water level measurements from bores, I37/0085 (ECan), I38/0045 and I38/0092 located west of the Tekapo River and bores I37/0029, I38/0049 and I38/0084 (ECan) located east of the Tekapo River are shown in Figure G4, Appendix G along with total daily rainfall. The rainfall data was sourced from NIWA's Cliflo data base for their Lake Tekapo climate station (agent number 24945). Manual water level measurements are available for the bores monitored by PDP but not the ECan bores. The manual measurements generally provide a good fit with the transducer data. All water level data is provided relative to ground level at each bore.

Figure G5, Appendix G shows the transducer water level measurements for the above mentioned bores plotted with flow data from ECan's flow recorders in the Tekapo River (at Downstream of Mary Burn Confluence – 1071103), Mary Burn (at SH8 – 71130) and the Grays River (at Days Bridge – 71162). Flow data for the weir at Lake George Scott (monitored by Genesis) is also shown on Figure G5 which only shows a flow when water is discharged by Genesis into the Tekapo River.

The measured groundwater levels in I37/0029 (20.9 m deep) appear to have remained relatively stable with no significant variations in water level between February 2019 and October 2019. The water level data from around October 2019 through to June 2020 shows a gradual declining trend with minor fluctuations in water levels of around 0.14 m in early December 2019 as a result of rainfall where 125 mm fell between 2 and 20 December 2019. From 26 June 2020, water levels in the bore dropped below the transducer (around 20.7 mbgl) and the bore essentially became dry for the remainder of the monitoring period. It is worth noting that bore I37/0029 is located almost 1 km east of the Tekapo River on an elevated glacial outwash plain and has a head difference of around 30 m above the river channel and the water levels measured in the bore. While some low magnitude and delayed influence may potentially be occurring, bore I37/0029 does not have any clear response to changes in flow within the Tekapo River and appears to only have a very small response to rainfall.

Bore I38/0049 (16.1 m deep) is located approximately 560 m east of the Tekapo River channel. The water level data from bore I38/0049 shows that water levels fluctuated between 12.4 and 14.2 mbgl throughout the monitoring period. The data indicates that levels in the bore do not respond immediately to rainfall events, although significant increases in water level appear to occur following rainfall events. These increases are apparent around July 2019, December 2019 and February 2020. The increases in water level during December 2019 and February 2020 coincide with controlled spill events in the Tekapo, although the December 2019 event also coincided with a significant rainfall event as previously mentioned. It is worth noting that I38/0049 is located near a man-

made surface channel which diverts flows from Sawdon Stream and Edward Stream into the Tekapo River. Based on satellite imagery from Sentinel Hub: Playground, the reaches of Sawdon and Edwards Streams between SH8 and the diversion channel are typically dry with flow in the streams losing to ground along these reaches. However, the satellite imagery indicates that a flow event from both streams into the diversion channel and Tekapo River coincides with the observed increases in water level in I38/0049. Figure G6A to Figure G6G, Appendix G provides Sentinel Hub: Playground Satellite imagery of the Sawdon and Edwards Stream diversion channel along with the location of bore I38/0049 which shows flows within the streams and the diversion channel during July 2019 and December 2019. It is also worth noting that another flow event in the diversion channel occurred during November and December 2018 which appears to have resulted in an increase in water level with I38/0049 although since the transducer in I38/0049 was installed on 22 February 2019, it only managed to capture the receding water level in this bore as a result of the November and December 2018 diversion channel flow event. The timing of the flow events in the diversion channel are annotated on the plot in Figure G5.

An increase in water level during the February 2020 event appears to coincide with the controlled spill event into the Tekapo River at that time. The satellite imagery indicates that no flow event in the diversion channel occurred during February 2020 which suggests that the observed increase in water level of around 0.14 m at this time in I38/0049 is likely to be the effect of the controlled spill into the Tekapo River (when up to 160 m^3/s was discharged into the Tekapo River). Comparatively, the increase in water level of around 1.5 m during the July 2019 water level increase occurred when a significant flow event occurred in the diversion channel and flows in the Tekapo River only reached 71 m^3/s for a brief period of time.

ECan monitoring bore I38/0085 (screened between 20.9 and 22.9 mbgl) is located around 2 km east of I38/0049, located around 2.4 km east of the Tekapo River channel and is also downgradient of diversion channel. This bore also shows significant increases in water level which coincide with the Edwards and Sawdon Stream diversion channel flow events (in November/December 2018, July 2019 and December 2019) with an increase of around 11.1 m during the December 2018 diversion channel flow event. In addition to this, there does not appear to be a clear response in water level fluctuations in bore I38/0085 during the February 2020 controlled spill event in the Tekapo River, although the water level data indicates a slight change in the slope of the water level data which coincides with the cessation of the February 2020 spill in the Tekapo River. It is worth noting that water levels within bore I38/0085 dropped below the bottom of the screen in June 2020 but increased again around October 2020.

Based on the information above, it is expected that the flow events in the Edwards and Sawdon Stream diversion channel allows large volumes of water to

be recharged to shallow groundwater up-gradient of bores I38/0049 and also ECan bore I38/0085. These diversion channel flow events appear to have a much larger effect on water level changes in these two bores (more than1 m) than the high flow events in the Tekapo River which appear to have a relatively minor effect (generally less than 0.2 m) on water levels in bore I38/0049 and appear to be indiscernible in ECan bore I38/0085.

Bore I38/0045 (6.4 m deep) is located around 800 m north east of the Tekapo River on a lower terrace of glacial outwash terraces. Water levels in this bore appear to have remained relatively stable with relatively minor water level fluctuations. Following a small increase of around 0.07 m that occurred around 6 days after the February 2020 spill event in the Tekapo River began, water levels in this bore declined by around 0.2 m over the reminder of the monitoring period. Rainfall events do not appear to have any significant effect on water levels in the bore. Based on the monitoring, it appears that the effect of changes in flow within the Tekapo River on water levels in bore I38/0045 are relatively small, although it is noted that the water level record for this bore is relatively short.

Bore I38/0084 (screened between 9.9 and 11.9 mbgl) is monitored by ECan and is located on the older and more elevated glacial outwash terrace around 2.4 km west of the Tekapo River. This bore is also located around 1 km east of the lower reach of Irishman Creek which is known to lose water to groundwater and dry up regularly. The water level data for bore I38/0084 shows that groundwater levels remained relatively stable at around 2.6 mbgl through the monitoring period although increases in water level of up to 0.38 m occurred around November/December 2018, July 2019 and December 2019. These water level increases appear to coincide with flow events within the adjacent reach of Irishman Creek based on the available satellite imagery. These flow events are annotated on Figure G5. During the February 2020 controlled spill event into the Tekapo River, the adjacent reach of Irishman Creek to the bore was dry and no significant change in water level occurred in the bore. Based on this, it appears that changes in water level within the Tekapo River do not appear to have any clear effect on groundwater levels in this bore with the predominant cause of water level fluctuations being from flow events in the adjacent reach of Irishman Creek.

Bore I38/0092 (screened between 0 and 6 mbgl) is located downstream of Grays Hills and is around 700 m west of the Tekapo River Channel. This bore is used by ECan for state of the environment groundwater quality monitoring. The timing of ECan's sampling events is shown in the data as 13 sudden decreases in water level in this bore when the transducer was removed during the sampling of the bore. The water level data from this bore appears to display a strong correlation to changes in flows within the Tekapo River with level increasing by around 0.58 m during the December 2019 controlled spill event and then decreasing following the cessation of the spill. While some of the response may have been

due to rainfall, there is also a clear response and recovery to flows in the February 2020 spill. With the exception of the increases in water level from Tekapo River flow variations, water levels within the bore remained relatively stable remaining around 2.6 mbgl for the majority of the monitoring period. Overall, it appears that bore I38/0092 has a strong hydraulic connection with the Tekapo River and responds to flow changes, although the actual magnitude of fluctuations is not large.

As previously mentioned, there are few bores that could be considered affected, via changes to water availability as a result of reduced river recharge or lower water levels in bores. From a review of ECan's database, there appear to be no recorded bores used for abstraction such as drinking water supply or irrigation use near the Tekapo River, with the exception of a surface water take via an infiltration gallery on the lower reaches of the Tekapo River (CRC022037.1), which is located where the centre pivot irrigation areas are visible on the eastern side of the Tekapo River opposite bore I38/0092 on Figure E10, Appendix E. This consent was granted on 7 May 2007, a significant time after the TekPS was already in place, meaning the infiltration gallery and take will have been designed based on the current flow pattern in the Tekapo River and groundwater levels. There does not appear to be any other surface water takes located along the main stem of the Tekapo River.

There is one bore shown within the Tekapo Basin as being used for domestic and stock water supplies (BZ15/5033) but this is incorrectly located on Canterbury Maps, and according to ECan's bore information is actually located in Twizel. There are no known community supplies that could be affected around Lake Tekapo or the Tekapo River (the Tekapo township and Tekapo military camp supplies are from Fork Stream, outside the area of influence). On this basis, effects on groundwater availability around the Tekapo River are not considered to be an issue for reconsenting.

5.2.3.2 Riparian margin monitoring bore groundwater levels

As previously described, groundwater levels have been monitored in six shallow monitoring bores installed by PDP (MW1 to MW6) and also two additional bores BZ16/0093 (located near the confluence of the Mary Burn and Tekapo River) and BZ16/0096 (located downstream of the Grays Hills). With the exception of MW5, all of these riparian margin bores are within 160 m of the Tekapo River and are all less than 6 m deep. Bore MW5 is located on the true right of the Grays River (around 20 m away) and is located approximately 600 m upstream of the Grays River and Tekapo River confluence.

The continuous water level data for these bores is plotted with rainfall (NIWA Cliflo station at Tekapo Airfield – Agent Number 24945) along with the manual water level measurements for each bore in Figure G7, Appendix G. All

water level data is provided relative to ground level at each bore and the manual measurements generally provide a good fit with the transducer data.

Figure G8, Appendix G shows the transducer water level measurements for these bores plotted with flow data from ECan's flow recorders in the Tekapo River (at Downstream of Mary Burn Confluence – 1071103), and the Grays River (at Days Bridge – 71162) and also flow data for the weir at Lake George Scott (monitored by Genesis).

Transducers were installed in bores MW1, MW3, MW4 and MW5 in late September / early October 2019 with transducers installed in the MW2 and MW6 in January 2020. With the exception of the transducers in bores MW1 and MW3, which became stuck in their respective bores following a download of the transducer in November 2020, all transducers were removed in early February 2021.

The data shows that all of the shallow riparian monitoring bores generally responded strongly to changes in flow within the Tekapo River, which in turn responds strongly to changes in rainfall, in addition to the spill releases. Given the relatively close proximity of these bores to the River, the strong responses from changes in Tekapo River flow are expected and are particularly clear during the controlled spill events in December 2019 and February 2020 which are annotated on Figure G7, Appendix G.

The largest response to changes in Tekapo River flow during the December 2019 spill event was in bore MW3 which displays an increase of around 1.5 m during the December 2019 event and around 1.2 m during the February 2020 event. Bore MW6 was not monitored during the December 2019 spill event but the data for this bore shows an increase of around 1.5 m during the February 2020 spill. Bore MW5 displayed the smallest response during both events showing an increase of around 0.2 m during both the December 2019 and February 2020 spill events. Except for the spill event responses, the water levels in this bore appear to follow a pattern (particularly the data prior to the December 2019 spill event) that is relatively similar to the flow record for the Grays River. Given the proximity of MW5 to Grays River (less than 15 m compared to the Tekapo River which is around 160 m away), the proximity of the Grays River to the bore would be expected to provide a degree of buffering to the effect of Tekapo River flow changes on water levels in MW5. This is likely to be the cause of the more subdued water level response in this bore during Tekapo River high flow events.

It is worth noting that water levels in bore BZ16/0093 were recorded up to 0.3 m above ground level during the February 2020 spill event. Given that the top of the casing on this bore was measured by PDP to be 0.31 m above ground level, this bore became close to being inundated during the February 2020 spill event. It is also worth noting that this bore had the shallowest water level in all of the

riparian monitoring bores with water levels being no deeper than 0.6 mbgl throughout the monitoring duration.

The observed changes in flow, particularly as a result of the February 2020 controlled spill event into the Tekapo River have been used to estimate hydrogeological parameters along the length of the Tekapo River between the Lake George Scott weir and the ECan flow recorder in the Tekapo River Downstream of the Mary Burn Confluence. This assessment is detailed in Section 5.2.5 of this report.

5.2.4 Piezometric contours

Piezometric contour information is available from ECan's database for the Tekapo River Basin from 4 datasets. These survey datasets are:

- Piezometric contours Upper Waitaki average water table
- Piezometric contours Upper Waitaki Feb 2007
- Piezometric contours Upper Waitaki Sept 2007
- Piezometric contours Upper Waitaki GHD 2009 b set

ECan's database indicates that the available piezometric contour sets listed above are relatively sparse along the Tekapo River as there have previously been very few bores along the Tekapo River and the existing surveys either do not have any groundwater level elevations near the river or rely on interpolated groundwater levels based on ECan staff's local knowledge of the area.

Since PDP were already monitoring groundwater levels and surface water levels at a number of monitoring sites along the Tekapo River, to better understand flow directions and groundwater levels around the Tekapo River, a piezometric survey was undertaken by PDP between 3 and 5 June 2020 measuring water level elevations in 20 bores and wetlands/water bodies that PDP were already monitoring with pressure transducers. A second piezometric survey was undertaken by PDP between 25 and 27 November 2020 with water levels surveyed in the 20 bores and wetlands/water bodies with transducers installed by PDP as well as 37 additional sites which included a combination of bores, measurements in the Mary Burn, Tekapo River, Lake Tekapo, stock watering holes excavated below the shallow groundwater table and wetlands/water bodies throughout the wider Tekapo River Basin.

The elevations for each of the monitoring sites were surveyed to tie the measured water levels into a common datum. PDP used a Trimble RTK (Real Time Kinematic) survey system to undertake a survey of the elevations for each monitoring site. All water level measurements recorded during each survey were measured in the New Zealand Vertical Datum 2016 (NZVD 2016). However, given that Genesis provides the water level elevation for Lake Tekapo in Lyttelton

1937 vertical datum, all elevation measurements recorded during the two piezometric surveys were converted to the Lyttelton 1937 vertical datum (LVD 1937).

The water level elevation data as well as the x and y coordinates for each measurement site from the two surveys were collated and plotted in GIS software. The water level elevation data was then interpolated between each site using GIS software and then refined manually to remove artifacts such as boundary constraints.

A map of the June 2020 piezometric contours are shown in Figure E11 and a map of the November 2020 piezometric contours are shown in Figure E12, Appendix E.

Both piezometric contour datasets are relatively consistent and show that the overall shallow groundwater flow direction is in a general south to south-southwest direction and is roughly parallel to the Tekapo River.

The groundwater flow direction downstream of Lake Tekapo indicates a general flow direction to the southwest away from Lake Tekapo before curving around the Tekapo River to indicate groundwater flows in a general southerly direction towards the Tekapo River. The curvature of the contours between bores MW1 and MW2 progressively straighten before becoming roughly perpendicular the Tekapo River. The curvature of the contours and progressive straightening of the contours indicates a gain in flow in the upper reaches and then less interaction in the middle reaches, which is consistent with the flow gauging survey data mentioned earlier in this report. The hydraulic gradient of the contours within the upper to middle reaches of the Tekapo River is around 0.011 m/m for both contour sets.

The June 2020 piezometric contours are roughly perpendicular to the Tekapo River channel from around bore I38/0049 downstream to the confluence of the Pukaki River, although the November 2020 contours display a slight curve towards the river around where the Tekapo River passes through Grays Hills indicating gaining conditions. The hydraulic gradient around this reach of the river is flatter, ranging between 0.0074 to 0.0071 m/m based on the June and November 2020 contours respectively.

5.2.5 Hydrogeological properties

There is virtually no hydrogeological parameter information for the Tekapo Basin, with the exception of three bores located on the west margin of the basin at the edge of the Mary Range and distant from the Tekapo River (bores I38/0014, I38/0012 and I38/0015 – all located more than 4 km west of the Tekapo River), which indicate a reduction in hydraulic conductivity with depth. According to Cooksey (2008), bore I38/0014 (24 m deep, screened from 23 to 24 mbgl) is expected to be abstracting groundwater from a relatively shallow aquifer with

transmissivity ranging from 2,000 to 4,500 m²/day. Bore I38/0012 in this area is notably deeper (screened from about 95 to 104 mbgl) and exhibits an estimated potential range of aquifer transmissivity values (226 to 355 m²/day) by applying the empirical aquation for estimating transmissivity from specific capacity derived by Bal (1996). There are some transmissivity estimates available for the Twizel Basin, including near the lower Tekapo River (BZ16/0073, with an estimated transmissivity of 250 m²/day). Specific capacity provides an indication of the strata permeability, but this is only available for a few bores located towards to the outer edge of the Tekapo River Basin (more than 6 km from the Tekapo River).

Streambed conductance is a parameter that measures how readily water in a stream or river can flow through the stream or riverbed and the underlying strata into the shallow groundwater system, or from groundwater into surface water, and therefore provides an indication of the ease with which groundwater-surface water interaction occurs. As a general rule of thumb, higher streambed conductance values can indicate where there will be larger flow gains or losses.

Streambed conductance can be estimated from flow gauging data using the following equation (Environment Canterbury, 2000):

Streambed conductance (λ) = $\Delta q/(L \times \Delta h)$

Where: Δq = change in stream/river flow rate between two flow gauging sites;

L = length of streambed between upstream and downstream gauging sites; and

Δh = difference in elevation between the water surface in the stream/river and the underlying/adjacent groundwater table.

Based on the groundwater level monitoring and flow gauging undertaken by PDP in October 2019, January 2020 and November 2020, estimates of streambed conductance have been calculated. Table 21 provides a summary of the estimated range of streambed conductance values. The closest upstream and downstream gauging sites and the locations of the bores used to estimate the stream bed conductance ranges are shown in Figure A5 Appendix A and Figure E10, Appendix E respectively.

The distance between the bores and the Tekapo River were all generally less than 50 m although movement of the Tekapo River braids meant that the separation distance varied at some bores during the monitoring period. It is worth noting that the range of values allow for up to 10% uncertainty in the flow gauging measurement.

Table 21: Estimated range of streambed conductance values		
Bore Number / Tekapo River Reach	**Gauging Sites Upstream / Downstream**	**Streambed conductance λ (m/day)**
MW1 / Upper Reach	Tekapo River DS of Fork Stream / Tekapo River Mid Reach 1	0.6 – 4
MW3 / Mid Reach	Tekapo River Mid Reach 1 / Tekapo River Mid Reach 2	0.6 – 2.0
MW4 / Upstream Grays Hills	Tekapo River Mid Reach 2 / Tekapo River US of Grays	27 – 50
BZ16/0093 / Grays Hills	Tekapo River US of Grays / Tekapo River US of Mary Burn	4 – 15

There is significant uncertainty in these estimates given the large distances between gauging sites, which means losses and gains could occur within these reaches rather than simply an overall net loss or gain in flow. It is also ideal to have groundwater measurements directly next to the river, but in this case the monitoring bores were up to around 50 m from the river. There were also inconsistencies where the difference in groundwater and surface water levels at the sites on some occasions indicated a different pattern of losses and gains versus measured flow differences. This means these estimates should be used as indicative only. The rapid response in the riparian bores to river flow changes indicates a high level of groundwater-surface water interaction. The estimates are presented here for completeness, but they are not used for any assessments detailed in this report.

Typical values for streambed conductance for rivers of similar scale to the Tekapo River are generally expected to be in the range of 10 – 1000 m/day, but there is considerable variability in different geological environments and fluvial depositional settings. The estimates provided in the table above indicate that stream bed conductance values are generally lower (<4 m/day) for the reach of the Tekapo River downstream of Fork Stream and the middle reaches of the river. The lower values for this reach are consistent with the flow gauging surveys undertaken by PDP and the piezometric contours which showed generally minimal changes in flow (indicating limited net groundwater-surface water interaction) between bore MW1 and MW3 (between Tekapo River downstream of Fork Stream Confluence and Mid Reach 2). The gauging surveys showed that the largest changes in flows in the Tekapo River occurred just upstream of Grays Hills where a consistent flow loss was measured between bores MW3 (near Mid Reach 2 gauging site) and MW4 (near the Upstream of Grays River gauging site). The stream bed conductance values were higher along this reach, with estimates between 27 and 50 m/day.

Between MW4 (upstream of the Grays River) and BZ16/0093 (Upstream of the Mary Burn), a smaller change in flow occurs depending on surface water flows entering the Tekapo River along this reach and indicates a slightly lower range in values between 4 and 15 m/day.

It is worth noting that the range in streambed conductance values listed in Table 21 were calculated based on flow data during lower flow conditions in the Tekapo River. In addition to this, the difference in water level elevation between the bore and River is dependent on the position of the river braids relative to the bore at the time of the measurements. Due to the changing nature of the braids, the water level elevation in the river relative to the riparian monitoring bores can change by more than 0.5 m in some cases, resulting in groundwater gradients that were both positive (groundwater flow towards the River) and negative (groundwater flow away from the River) at the same monitoring bore depending on the time of the measurements and if the river braids had altered over time. These changes in flow conditions and river water level elevation also indicate that a larger range of stream conductance values for each reach of the river may be possible than what has been calculated, and therefore the above values are considered to be estimates, as described above.

In addition to the estimate of stream bed conductance, estimates of transmissivity and storativity were made using data recorded during the spill event in February 2020 and the observed changes in groundwater level at each of the riparian margin monitoring bores along the length of the Tekapo River between the weir at Lake George Scott and the ECan flow recorder site located Downstream of the Mary Burn Confluence (ECan flow recorder site 1071103).

During a controlled spill event, Genesis is required to discharge water into the Tekapo River at progressively higher increments over time, resulting in a stepped or staged discharge pattern. Losses to groundwater were estimated for the first discharge stage (30 m^3/s discharge beginning on and 1 February ending 3 February 2020) and also at the peak discharge of 160 m^3/s. The peak discharge step was reached on 5 February 2020 and ceased on 9 February 2020. The change in groundwater level observed in the riparian margin monitoring bores during these two discharge steps were used to model flow losses in the Tekapo River to groundwater using a combination of empirical and analytical groundwater models along with measured flow losses between the weir at Lake George Scott and the flow recorder in the Tekapo River Downstream of Mary Burn Confluence. The estimated flow losses to groundwater for the first stage of the February 2020 spill event are shown on Figure G9, Appendix G. Groundwater level monitoring at riparian zone bores along the main stem of the Tekapo River exhibited an average groundwater response of about 0.45 m during the first stage of the spill event. Other wetland/water bodies and bore water level monitoring locations that displayed little to no response during the spill event

stages provided an empirical basis for the expected extent of groundwater storage changes.

The groundwater monitoring data were used along with LiDAR data (ECan), satellite imagery of active channel areas (Sentinel Hub: Playground), and geologic data (GNS) to empirically interpret the expected extent of rapid groundwater storage changes within lower elevation young alluvium (Holocene river gravels) as well as areas within and around wetted areas where groundwater level responses could be expected to be equivalent to the riparian zone groundwater monitoring bores during the spill events. The groundwater level response to the first stage and the peak of the spill event was then interpolated using GIS software according to the expected extent of storage changes and the interpreted area of equivalent response noted above. The resulting volume estimates from the interpolated groundwater storage changes for the first and peak spill stages were found to vary with storativity, which could be expected to range from 0.1 to 0.3 for the unconfined sandy/gravelly strata as shown in Figure E13, Appendix E.

In order to constrain parameters such as storativity and refine estimated losses to groundwater to match the observed loss for the first step of the spill event, the Hunt (2012) solution for the growth of a groundwater mound due to recharge over a rectangular area was used to estimate mounding effects associated with the spill event stages. As there was cloud cover during the first stage of the spill event, a similar-magnitude spill event was identified (9 March 2020), referred to as the "9 March 2020 proxy flow event". Satellite imagery available through Sentinel Hub: Playground for the 9 March 2020 proxy flow event was initially filtered on bands 11, 8, and 2 for showing open water surfaces and then further processed in GIS software using unsupervised iso cluster analysis for estimating the approximate wetted area of the Tekapo River in the modelled area (about 2.9 km^2). This wetted area of the Tekapo River was then applied to the Hunt (2012) solution by simulating the wetted area of the river as a recharge basin that is a 34 km long, 86 m wide, rectangle adjacent to the monitoring bores. The recharge rate for the first stage to the spill event was set to the observed first stage loss between the discharge and downstream flow recorder sites (approximately 1.4 Mm^3). The empirical estimate of groundwater storage change for the first spill step was found to match the observed loss at a storativity of about 0.14. Using this storativity and a transmissivity of 7,000 m^2/d, the simulated groundwater level response for the first stage event as found to match the observed average response of about 0.45 m in the riparian margin monitoring bores along the River. This bulk transmissivity estimate is considered reasonable for the hydrogeologic setting and is in line with Kruseman and de Ridder (2000) who suggest that sand and gravel mixes have an expected range in hydraulic conductivity of about 5 to 1,000 m/day and that the unconfined strata along the river could be expected to be tens of metres thick according to Cooksey (2008).

The aquifer parameters derived from the mounding model for the first stage of the February 2020 spill event noted above were further checked by analysing mounding over time and bore responses over time. The average travel speed of the first stage of the spill event was estimated at about 3.8 km/hour (according to the initiation of the spill at the George Scott Weir and the initial response to the spill at the downstream of Mary Burn recorder site about 9.3 hours later, 35.8 km downstream). This estimated average travel speed was then applied as an initial recharge time condition at MW1 (about 6.9 km downstream of the release with recharge near the bore expected to start around 1.8 hours after the start of the spill). Figure G10, Appendix G shows that there is generally a good fit between the measured response at MW1 and the modelled response over time from the mounding analysis for the first day of the spill event. This analysis applies the known loss across the first stage of the event as a constant recharge rate (about 0.24 m/d) and the aquifer parameters described above (storativity 0.14 and transmissivity of 7,000 m^2/day). The upper-range recharge rate and parameters shown on Figure G10 are described further below.

Using the same analytical model for matching groundwater responses to the first stage of the spill event, recharge (losses) were adjusted so that the simulated mounding effect matched to observed groundwater mounding effects at the riparian bores (about 1.3 m in magnitude). The simulated recharge volume used to match the peak groundwater level response was then matched to the empirical estimate of the peak groundwater storage change (Figure E14, Appendix E) with a storativity of about 0.24. This in turn suggested that, with the potentially higher storativity of 0.24, the simulated recharge volume could have a higher range in order to match the peak groundwater level response. A sensitivity analysis suggested that the simulated mounding effect was insensitive to the wetted area compared to the total recharge volume and potential range of storativity noted above. A further mounding assessment over time at MW1 (Figure G10 Appendix G) shows that when the initial peak known loss to groundwater during the first stage of the February 2020 spill event is applied as a constant recharge rate (about 12.9 m^3/s or 0.38 m/d across the estimated wetted area) an aquifer transmissivity of 8,000 m^2/day and storativity of 0.28 is required to match the observed response. This recharge rate is considered to be an upper estimate as it is applied as a constant rate to the model although, the resulting storativity and transmissivity values from this assessment appear to be within the range of other estimates.

As previously mentioned in Section 5.2.3.1, a small (0.07 m), delayed response as a result of the February 2020 spill event was observed in bore I38/0045. This bore is located along the mid-reach of the Tekapo River and is located around 800 m west of the Tekapo River on a slightly elevated terrace above the active Holocene riverbed and flood plain of the river. The geological map for the area (Cox, S.C. and Barrell, D.J.A. (2007)) shows that there is transition in the geology moving west from the river towards bore I38/0045 around 70 m from the River.

The geologic description for the material in the Tekapo Riverbed is "*generally unweathered, variable loose gravel, sand and silt in active flood plains*" which indicates permeable gravels. The geology in which bore I38/0045 is located is described as "*generally unweathered mixtures of gravel, sand, silt and clay on low level terraces or abandoned river plains*" and based on the likely presence of clay, it is expected that these older gravels will be less permeable than the gravels within the river bed. An initial assessment to model the observed mounding that occurred in I38/0045 as a result of the spill event in February 2020 was undertaken using the Hunt (2012) solution, although due to the relatively long delay between the start of the spill event and the increase in water level in I38/0045 (around 6 days), it was not possible to get a fit using this solution. However, it was possible to get a fit of the initial observed water level change in the bore using a bank storage solution (Hunt, 2005). It was not possible to fit the complete measured change in water level as a result of the February spill, but the initial increase in water levels could be matched using transmissivity values ranging between 700 and 2200 m^2/day and storativity values ranging between 0.1 – 0.3. Figure G11 shows the measured and modelled increase in water levels at bore I38/0045.

A summary of the estimated aquifer parameters based on the range of estimated recharge rates are provided in the Table 22 below.

Table 22: Estimated range of aquifer parameters from observed water level changes during the February 2020 Spill event

Observation Bore	Recharge Rate (m/day)	Transmissivity (m^2/day)	Storativity	Analysis Method
-	0.24	7,000	0.14	Mounding – (Hunt 2012)
MW1	0.38	8,000	0.28	Mounding – Hunt (2012)
I38/0045	-	700 – 2200	0.1 – 0.3	Bank Storage – Hunt (2005)

It is worth noting that the range of transmissivity values estimated using the bank storage solution are lower than the values estimated using the mounding solution (Hunt 2012). Bore I38/0045 is located much further away from the Tekapo River (around 800 m) and within strata that is less permeable than the strata in the riverbed which likely explains the lower estimates for transmissivity. In addition, due to the delayed response to the spill event, the estimate for transmissivity calculated using the bank storage solution at bore I38/0045 is expected to provide an overall average transmissivity of the wider shallow groundwater system including both the more permeable river gravels and the slightly less permeable and older gravels further from the Tekapo River.

Overall, the interpreted aquifer parameters and other geological and hydrogeological information indicate that the shallow unconfined groundwater system that surrounds the Tekapo River is well connected to the river, with a relatively high transmissivity, which is expected to decrease with distance from the river, coinciding with a transition in geology.

5.2.6 Groundwater quality

A review of existing groundwater quality data has been undertaken around the Tekapo River. Measured nitrate concentrations in the Tekapo Basin and in the Twizel Basin near the Tekapo River are generally low. GHD (2009) reviewed concentrations in thirteen groundwater bores sampled (between 2 and 45 m deep), which ranged from below detection levels to 1.6 mg/L nitrate N, with most below detection level. GHD (2009) noted that nitrate concentrations were higher in areas under intensive irrigation and short crop rotation schemes such as in the Mary Burn immediately upstream of the Mary Hills.

Cooksey (2008) collected 21 water samples during 2007 from bores and the lakes and reviewed this data in conjunction with bore data collected in 2005 as part of an Environment Canterbury water quality investigation. Cooksey noted that the observed water chemistry is typical of groundwater in New Zealand and is relatively young. Many of the water quality determinants including chloride, nitrate and nitrogen are very low when compared to other areas such as the Canterbury Plains. The highest nitrate-nitrogen concentration (1.6 mg/L) and chloride concentration (4.2 mg/L) still represent low concentrations.

More recent monitoring data available via Environment Canterbury and summarised in Environment Canterbury (2015a) indicates nitrate levels are still low in the Tekapo Basin and in the Twizel Basin near the Tekapo River, together with E.Coli levels. Environment Canterbury (2015a) notes higher levels and increasing trends occur in other parts of the Mackenzie Basin, where land use intensification and irrigation have occurred.

Environment Canterbury (2015b) indicates that groundwater concentrations in the Tekapo basin are not likely to increase significantly from current concentrations under current and consented land use, although a more significant change is expected in the Twizel Basin where the Tekapo River enters Lake Benmore.

A review of all available water quality data on ECan's online GIS data for the Tekapo and Twizel basin from 10 bores monitored by ECan indicates that a maximum nitrate-N concentration of 4.2 mg/L has been measured in bore BZ16/0073 in August 2017. This bore is located in proximity to an area of higher intensive irrigation east of the Tekapo River and downstream of Grays Hills. The elevated nitrate-N concentration in this bore and the proximity of the bore to more intensive agricultural land use is consistent with the observations by

GHD (2009). The available data from ECan indicates *E. coli* concentrations (up to 35 MPN/100 ml in bore I38/0092). It is worth noting that bore I38/0092 has had a total of three detections of *E. coli* (including the concentration of 35 MPN/100ml) with the remaining two concentrations being 3 MPN/100ml and 1 MPN/100ml from a total of 31 sampling rounds between 2013 and 2021.

Overall, the existing data generally indicates good groundwater quality data in the area around the Tekapo River, reflecting the current relatively low intensity of land use at present in this part of the Mackenzie Basin. The ongoing operation of the TekPS is not expected to cause any changes in groundwater quality.

5.3 Tekapo Canal

Information from ECan's online database (Canterbury Maps) indicates that there are wetlands along the Tekapo Canal as identified in the layer "Wetland Areas (DOC)". This layer indicates that there are five wetlands within approximately 400 m of the Tekapo Canal. The majority of these wetlands adjacent to the canal were formed from the excavation of "borrow" pits that intercept groundwater and have been left open. It is understood that material from the borrow pits was excavated during the construction of the canal. Some of the most notable of these borrow pit ponds are Patersons Ponds, ponds located near the intersection of SH8 and the Tekapo Canal and also downstream of the Maryburn Fill canal section.

Available aerial imagery indicates that a wetland located immediately upstream of the Maryburn Fill canal section appears to be an existing wetland that is likely to have been enhanced by the canal construction due to diversion/channelisation of the Maryburn through a culvert beneath the canal.

The groundwater environment and effects of the Tekapo Canal on groundwater (including springs/seeps receiving canal seepage) was considered as part of the canal relining process at that time. The Tekapo Canal is known to have a number of minor seeps which are expected to discharge into the shallow groundwater system, and may result in minor recharge contributions to wetlands/water bodies and also into streams (such as Irishman Creek and the Mary Burn). In addition to these seepages, a small number of groundwater inflows to the canal were observed during the canal construction although it was concluded that any groundwater inflows would generally be relatively insignificant compared to the operating flows within the canal.

The seepages from the canal are qualitatively assessed by Damwatch. Three sections of the canal were relined in 2012/2013 to prevent a failure of the canal. These three canal sections are listed below and are shown Figure H1, Appendix H.

- 8.17 km Culvert (chainage 7 – 8.93 km downstream of Tekapo A)

- SH8 (chainage 10.9 – 14.7 km downstream of Tekapo A)
- Mary Burn Fill (chainage 17.8 – 19.61 km downstream of Tekapo A)

The relining of the canal was expected to result in a reduction in the amount of water lost from the canal to ground along these three sections. As part of the relining process, PDP undertook a monitoring programme to assess the effect of the relining on downgradient wetlands/water bodies and streams between October 2012 and April 2015. This monitoring was a requirement of the general resource consent conditions attached to consents CRC122392 through to CRC122411 (excluding consent CRC122408) which authorised the canal relining. The monitoring programme included monitoring prior to, during and following the completion of the canal lining along each of the three sections. This work involved qualitatively assessing a number of known seeps around the canal embankments to monitor for changes, measurement of seepage discharges at a number of permanent weirs, the measurement of groundwater levels in a total of six bores (two bores at each of the canal sections being relined – one bore upgradient of the canal and one bore downgradient), measurement of water levels in nearby surface water wetlands/water bodies and measurement of changes in surface water flows (via flow gauging measurements). The monitoring undertaken by PDP was detailed in three reports dated June 2013, June 2014, and June 2015 and were submitted to ECan by Genesis for each year of monitoring.

The monitoring indicated that the effect of the relining of the three canal sections resulted in a small reduction in seepages and weir flows, although the reduction in seepage affecting the surrounding groundwater system was considered to be minor compared to the much larger natural water level variations (such as from rain/snow fall and seasonal fluctuations) measured within the groundwater monitoring bores and receiving wetlands/water bodies downgradient of the canal (PDP, 2015). Furthermore, the monitoring did not indicate that the canal has altered the hydrogeology to form wetlands, other than the processes described previously in this section (i.e., borrow pit excavations and stream channel diversion).

Copies of each of the three monitoring reports detailing the monitoring undertaken as part of the canal relining project are provided in Appendix J.

No specific monitoring of seeps between the Tekapo Canal and the Tekapo River (specifically between Tekapo A Power Station and the start of the 8.17 km Culvert canal section that was relined) was undertaken as this section of canal was not relined during the 2012/2013 relining works. However, it is understood that Damwatch do monitor seeps along this section of canal. Based on the observations from the groundwater and surface water monitoring undertaken along the other sections of canal by PDP, it is expected that leakage from this section of the canal would likely only provide a minor contribution to flows/water levels in surface water bodies compared to natural fluctuations. In particular, the

prominent Patersons Ponds appear to have a high hydraulic connection with the Tekapo River. This connection can be observed in satellite imagery from 8 December 2019, which shows that Patersons Ponds become discoloured from suspended sediment following natural flood events in Fork Stream, indicating a high hydraulic connection between the Tekapo River and Patersons Ponds, further indicating that any canal leakage is unlikely to contribute much more than minor quantities of water to groundwater and surface water along the canal. Prior to the flood event, the water in Patersons Ponds is clear, as shown in satellite imagery from 6 October 2019. A copy of the satellite imagery showing the interaction between Tekapo River and Patersons Ponds is shown in Figure H2 and Figure H3, Appendix H.

Overall, some interaction between the canal and the surrounding groundwater system is expected to continue with the on-going operation of the TekPS and remain unchanged with normal operation. Effects of any further maintenance works on that interaction, such as canal relining, would be considered as part of specific consent applications.

6.0 Summary

A summary of the hydrology and hydrogeological work undertaken as part of the reconsenting process are provided in the following sections below.

6.1 Hydrology

6.1.1 Lake Tekapo hydrology

Lake Levels, Inflow and Outflow

Lake Tekapo forms the storage reservoir for the hydropower generation at Tekapo A and Tekapo B power stations and Genesis is required to manage the lake within the consented minimum and maximum levels. Maximum and minimum consented operating levels vary throughout the year; however, the normal minimum and maximum control levels are 702.1 masl and 710.9 masl respectively.

Analyses of the lake levels for the period 1991-2020 indicate that levels are typically low in winter and spring (July – November) following a period of drawdown due to high power demand in winter. Lake Tekapo fills up again in late spring and summer when inflows are high and the demand for power decreases resulting in high mean monthly lake levels in summer, autumn and early winter (December – June).

The mean lake inflow and outflow is around 84 m^3/s and the highest inflows into the lake are in spring and summer during the snowmelt season. The lowest inflows are in winter when most of the precipitation in the catchment is 'locked up' as snow.

Climate Change Impacts on lake inflow and hydro-electricity generation potential for the TekPS

Climate change impacts on lake inflow and hydro-electricity generation potential for the TekPS have been well researched. The studies indicate an increase in average annual inflow to Lake Tekapo for both the Mid-century as well as for End-Century model periods. Flows are likely to increase in winter due to increased precipitation which will primarily be as rain in winter with less snow and earlier melt. A small decrease in flow in summer is predicted. Relatively small changes in flow are predicted for spring and autumn although some studies predict an increase in flows in spring.

Climate change is expected to increase floods in winter and spring. Due to increased rainfall and snowmelt in winter, low flows and extreme low flows are also projected to increase. The potential increase in flood flows in winter and spring due to climate change is unlikely to result in increased spill flows, although there is significant uncertainty in climate change projections and impacts.

The greatest changes in flow characteristics can be expected by the end of the century under the high emission scenario (RCP8.5 for the IPCC 5th Assessment). For the low emission scenario (RCP2.6 for the IPCC 5th Assessment) there is generally little change in inflow between the baseline period and the Mid and End century scenarios.

No changes are proposed to the lake level operating regime, so no changes to the hydrology of Lake Tekapo are expected to occur as a result of the reconsenting.

6.1.2 Tekapo River hydrology

Flow statistics, flow duration curves and hydrographs

For approximately 72% of the time there is no or very little flow in the upper reaches of the Tekapo River between the control gate (Gate 16) and Lake George Scott. Gate 17 and Lake George Scott Weir has no or very limited flow for approximately 72% and 90% of the time respectively.

The median flow in the Tekapo River increases from approximately 3.1 m^3/s at the confluence with Fork Stream to approximately 10 m^3/s at the ECan recorder site downstream of the Mary Burn. This is predominantly due to flow contributions from tributaries such as the Grays River, the Mary Burn and Irishman Creek (via the Mary Burn).

The lowest median monthly flows in Fork Stream (used as a proxy for flows in the Tekapo River between the Fork Stream confluence and Grays River confluence) tend to occur in June to September (2.3 – 2.8 m^3/s) although flows are also relatively low in March and April (2.7 and 2.6 m^3/s respectively). The main

reason for this is that Fork Stream has a relatively large proportion of its catchment at higher altitudes which means that precipitation is 'locked up' as snow in winter.

The Tekapo River at downstream Mary Burn generally has its lowest flows between January and May (median monthly flow of 6.8 to 9.0 m^3/s). This is because this site derives a larger proportion of its flow from rivers and streams which have a much smaller proportion of their catchments at high altitudes (such as Mary Burn and Irishman Creek). Spills over the Lake George Scott Weir increase the flows in the higher flow bands for the Tekapo River at downstream Mary Burn flow recorder.

The lower 4 km of the Tekapo River is influenced by spill flow from the Pukaki River. Like the upper reaches of the Tekapo River, the Pukaki River generally has no or only a very limited amount of flow except for periods when the Pukaki Spillway discharges into the Pukaki River (approximately 7% of the time).

The flow statistics and flow distribution for the Tekapo River tributaries can be explained by the catchment characteristics. Grays and Mary Burn are predominantly spring fed and have similar flow patterns with long slow recession periods. Flow variability is low, and the flow duration curve has a relatively flat slope, especially for the Mary Burn which receives limited rapid runoff from mountainous areas.

Groundwater – Surface water interaction

Due to a limited amount of historical flow gauging information available for the Tekapo River, five flow gauging surveys were undertaken by PDP between February 2019 and November 2020 to better understand increases to flow from groundwater discharging to the river, and flow losses to ground within the mainstem of the Tekapo River.

The available historical and recently collected flow data suggests that the Tekapo River typically has relatively stable flows in the upper reaches (above the Mid Reach 2 gauging site), with some flow lost to ground in the reach above the Grays River confluence. A significant flow increase typically occurs due to the Mary Burn and Grays River inflows, although there is an additional gain in flow that can be attributed to groundwater inflows immediately downstream of the Mary Burn and Grays River confluences. In the lower reaches as the river enters the Twizel Basin but upstream of the Pukaki River confluence, an overall loss of river water to groundwater typically occurs.

Fresh and flood flows

Freshes or floods with different magnitudes (such as 3, 6 and 10 times the median flow) are important for matters such as scouring and flushing periphyton and mobilise and transport bed material. The number of freshes or floods of varying magnitudes (such as 3, 6 and 10 times the median) that occur over a

certain time period (for example one year) is called the fresh or flood flow frequency.

Flows in the Tekapo River between the confluence with Fork Stream down to the confluence with the Grays River can be estimated by using the flows for Fork Stream at Balmoral (increased by 0.6 m^3/s) and adding the spill flows from Lake George Scott. This section of the river receives infrequent fresh and flood flows of 3 times the median (on average around 4 per annum). Flows of 6 times the median or greater occur even more infrequent (on average less than 2 per annum).

The Tekapo River between the Mary Burn confluence and Pukaki River confluence receive infrequent fresh and flood flows of all magnitudes (3, 6 and 10 times the median). The average frequency of these fresh and flood flow events is 3 or less per annum.

The last 4 km of the Tekapo River downstream of the confluence with the Pukaki River has a much greater fresh and flood flow frequency than the two upstream reaches (especially for flows 3 times the median) due to the Lake Pukaki spill flows. The average frequency of fresh and flood flow events is around 6, 4 and 3 per annum for flows with a magnitude of 3, 6 and 10 times the median respectively.

Mean and maximum accrual times (which are the mean and maximum time between freshes or floods) are very long especially for the larger floods with a magnitude of 6 times the median or greater.

When comparing the colder months (May- September) with the warmer months (November – April) analyses of the flow data indicates that the frequency of fresh and flood flows in winter is relatively low and that the accrual time is relatively long compared to the warmer summer months.

No changes are proposed to the operation of the diversion of water from Lake Tekapo, so no changes to the hydrology of the Tekapo River are expected to occur as a result of the reconsenting.

6.1.3 Tekapo Canal

Flows at the Tekapo A and Tekapo B power stations (and hence the discharge of water to Lake Pukaki) vary depending on several factors including for example electricity demand, lake levels and Lake Tekapo inflows.

Median and mean Tekapo Canal flows (estimated by using Tekapo B power station flows) are estimated to be around 90 and 76 m^3/s respectively and 84 and 69 m^3/s for Tekapo A. The difference is made up by flows bypassing Tekapo A via releases at the Tekapo control gate (Gate 16) into the upper Tekapo River discharging back into the Tekapo canal at Gate 17.

Mean monthly flows are typically high in winter, especially July and August (82 m^3/s for Tekapo A and 83-84 m^3/s for Tekapo B), when electricity demand is high and low in September and October (56 and 57 m^3/s respectively for Tekapo A and 65 and 59 m^3/s for Tekapo B) when electricity demand drops off and Lake Tekapo is refilled following drawdown in winter. Once the lake is relatively full again in summer, high inflows into Lake Tekapo (due to snowmelt) increases the outflow through the Tekapo Canal.

No changes are proposed to the operation of the diversion of water from Lake Tekapo via the Tekapo Canal, so no changes to the hydrology of the Tekapo Canal are expected to occur as a result of the reconsenting.

6.2 Hydrogeology

6.2.1 Lake Tekapo hydrogeology

A review of existing groundwater data around Lake Tekapo indicated that there was generally very little data available. To understand the effect of water level fluctuations in Lake Tekapo on the wetlands/water bodies that border Lake Tekapo, PDP monitored water levels in seven wetlands/water bodies. The seven wetlands/water bodies that were monitored were considered to be representative of the various types of wetlands/water bodies around the Lake Tekapo and are listed below:

- Lake Tekapo West 3
- Lake Alexandrina
- Rapuwai Lagoon
- Wetland 16135
- Lake McGregor
- Godley River Wetland 23
- Lake Tekapo East 2

The water level data collected for these sites indicates that wetlands/water bodies Rapuwai Lagoon, Wetland 16135, Lake McGregor, Godley River Wetland 23 and Lake Tekapo East 2 have a hydraulic connection with Lake Tekapo during existing water level operating conditions during period of higher lake levels. The water level data for Lake Alexandrina and Lake Tekapo West 3 indicates that they are not affected by fluctuations in Lake Tekapo under existing operating conditions.

The monitoring data indicates that wetlands/water bodies above approximately 711 masl are unlikely to be impacted by Lake Tekapo water levels, except during infrequent events when lake levels exceed the maximum operating levels. Wetlands/water bodies less than 711 masl are expected to have some degree of hydraulic connection with Lake Tekapo, although the degree of connection will

vary depending on Lake Tekapo water levels. Therefore, some of the wetlands/water bodies surrounding Lake Tekapo are influenced by lake level fluctuations as a result of the scheme operation. However, this pattern of interaction will not be altered as a result of the reconsenting as Genesis is not proposing to change the current operating levels for the lake.

Existing Groundwater Users

There are a small number of domestic supply bores around Lake Tekapo that could potentially be affected by lake level fluctuations. However, these bores have all been installed since 2000 (post-scheme). Genesis is not proposing to change the current operating levels for the lake, so no changes in groundwater level fluctuations experienced at these bores are expected to occur as a result of the reconsenting.

Lake Tekapo Groundwater Quality

There is limited groundwater quality information around the lake. Further data on groundwater quality was not considered necessary for this project as the scheme is not considered to have a direct influence on groundwater quality and any indirect influence, for example a reduction in the unsaturated zone at higher lake levels, will not be altered as a result of the reconsenting as Genesis is not proposing to change the current operating levels for the lake.

6.2.2 Tekapo River hydrogeology

PDP undertook monitoring of water levels within a number of bores, wetlands and waterways throughout the Tekapo River Basin for the purpose of understanding groundwater and surface water interaction and how this changes with flows in the Tekapo River.

Wetland Monitoring

Water levels were monitored within two wetlands east of the Tekapo River and near the Grays River and water levels were monitored in five wetlands located west of the Tekapo River.

The data measured at the two wetlands located east of the Tekapo River (Grays Wetlands 1 and 2) indicated that water levels in both wetlands was complex with no overly clear response to changes in flows within the Tekapo River, although a small-delayed effect is possible.

The data measured at the five wetlands/water bodies located west of the Tekapo River indicated that there was no clear response to changes in flow within the Tekapo River with the exception of the Irishman Creek Wetland, although the magnitude of these changes was small and may have been influenced by other factors.

Overall, the data indicates that there is generally no clear connection to most wetlands/water bodies located more than approximately 1 km from the river, although a small and delayed response to flows and stage may occur. For wetlands closer to the river (i.e., approximately less than 1 km) there may be some small influence from the Tekapo River on surrounding wetlands/water bodies via permanent flow in the river contributing to groundwater surrounding the river and therefore wetland levels close to the river. The area where wetlands appear to be affected by Tekapo River flow variations is generally where the alluvial strata is younger/more permeable and compared to the older/less permeable strata further away from the river.

Groundwater Monitoring

Water level monitoring was undertaken in six existing bores located more than 400 mfrom the Tekapo River that were all deeper than 6 m. The monitoring showed that bores closer to the river displayed strong responses to flow (and corresponding stage height changes) in the Tekapo River (bore I38/0092) compared to bores located further away from the river (I38/0084 and I38/0085). The data also showed that water levels within the deeper monitoring bores (particularly I38/0085 and I38/0049) responded strongly to diverted flows from Edwards and Sawdon Streams within a manmade diversion channel located upgradient of these two bores, likely as a result of flow losses to ground in this area of the basin. The changes in water levels within these bores as a result of the diverted flow were much larger compared to the smaller effect of changes in flow within the Tekapo River.

To the west of the Tekapo River, a similar response to flow/stage height within the nearby reach of Irishman Creek caused increases in water level within I38/0084 although no response appeared to occur from changes in flow in the Tekapo River. A small response (around 0.07 m) was observed in bore I38/0045 (located around 1 km west of the Tekapo River) from flow changes in the Tekapo River but the response measured in this bore was considered to be smaller than the natural water level variations observed in this bore.

Groundwater monitoring was undertaken in eight shallow (<6 m deep) bores located within 160 m of the Tekapo River (referred to as riparian margin monitoring bores). The water level monitoring data measured in these bores showed that they all generally displayed a strong response to flow and corresponding stage changes in the Tekapo River.

Piezometric Surveys

PDP undertook piezometric surveys during June 2020 along the Tekapo River and an additional survey that included the Tekapo River as well as the wider Tekapo River Basin in November 2020. Both surveys showed that groundwater flows roughly parallel to the Tekapo River from the middle reaches to downstream of Grays Hills. Along the upper reaches of the Tekapo River,

groundwater flow directions are more complex indicating that groundwater flows toward the Tekapo River with groundwater tending to flow more parallel to the river further downstream.

Hydrogeological Parameters

Based on the observed strong water level response, and measured flow losses between the Lake George Scott weir and the Tekapo River recorder site downstream of the Mary Burn confluence during the February 2020 controlled spill event, hydrogeological parameters were estimated providing the following range:

- Transmissivity = 700 to 8000 m^2/day
- Storativity = 0.1 – 0.3

The estimated transmissivity and storativity values indicate relatively permeable strata. The more permeable strata occur closer to the Tekapo River in the younger alluvial strata likely as a result of more reworking by fluvial processes. At increasing distance from the river, the strata are expected to become progressively less permeable as the strata increases in age as it grades into older outwash gravels.

Groundwater Quality

No groundwater quality sampling was undertaken as part of the work undertaken by PDP but a review of existing groundwater quality data was undertaken which indicated that groundwater quality within the Tekapo River Basin is relatively good, although slightly elevated concentrations of some parameters, (E.coli, nitrate-N) have been observed occasionally in some bores but likely reflect localised upgradient land use. The ongoing operation of the TekPS is not expected to cause any changes in groundwater quality.

Groundwater Users

From a review of ECan's database, there appear to be no recorded bores used for abstraction near the Tekapo River such as drinking water supply or irrigation use near the Tekapo River, with the exception of a surface water take via an infiltration gallery on the lower reaches of the Tekapo River. This consent was granted on 7 May 2007, a significant time after the TekPS was already in place, meaning the infiltration gallery and take will have been designed based on the current flow pattern in the Tekapo River and groundwater levels. On this basis, effects on groundwater availability around the Tekapo River are not considered to be an issue for reconsenting. There are no other surface water take consents along the main stem of the Tekapo River.

Tekapo River Hydrogeology Summary

Overall, understanding the effect of Tekapo River flows on the wetlands/water bodies via groundwater level changes was a key aspect of the monitoring, and the data indicates that there is a low degree of connection to most wetlands/water bodies, located more than approximately 1 km from the river. For wetlands/water bodies closer to the river (i.e., less than approximately 1 km), there may be some small influence from the Tekapo River on surrounding wetlands/water bodies, with the permanent flow in the river contributing to groundwater levels and therefore wetland levels in the surrounding area.

6.2.3 Tekapo Canal

The available monitoring data collected prior to, during and after the canal relining process between 2012 and 2013 by PDP and also using both available historic and recent aerial imagery indicated that any seepages from the canal to groundwater and adjacent wetlands/water bodies were considered to be minor compared to the much larger natural water level variations (such as from rain/snow fall and seasonal fluctuations) measured within the groundwater monitoring bores and receiving wetlands/water bodies downgradient of the canal.

Overall, some interaction between the canal and the surrounding groundwater system is expected to continue with the on-going operation of the TekPS and remain unchanged with normal operation. Effects of any further maintenance works on that interaction, such as canal relining, would be considered as part of specific consent applications.

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Appendix A: Hydrology Maps



SOURCE:
1. AERIAL IMAGERY: LINZ
2. CATCHMENTS: ECAN
3. DEM: LINZ
4. RIVERS: NIWA

FIGURE A1 : TEKAPO A AND UPPER TEKAPO RIVER

SCALE : 1:15,000 (A3)

0 50 100 200 300
METRES

Southern Alps
Godley River
Lake Tekapo
Lake Pukaki
Tekapo River
Pukaki River
Lake Ohau
Ohau River
Lake Benmore
Ahuriri River
Lake Aviemore
Lake Waitaki
Waitaki Dam
Hakataramea River
Maerewhenua River

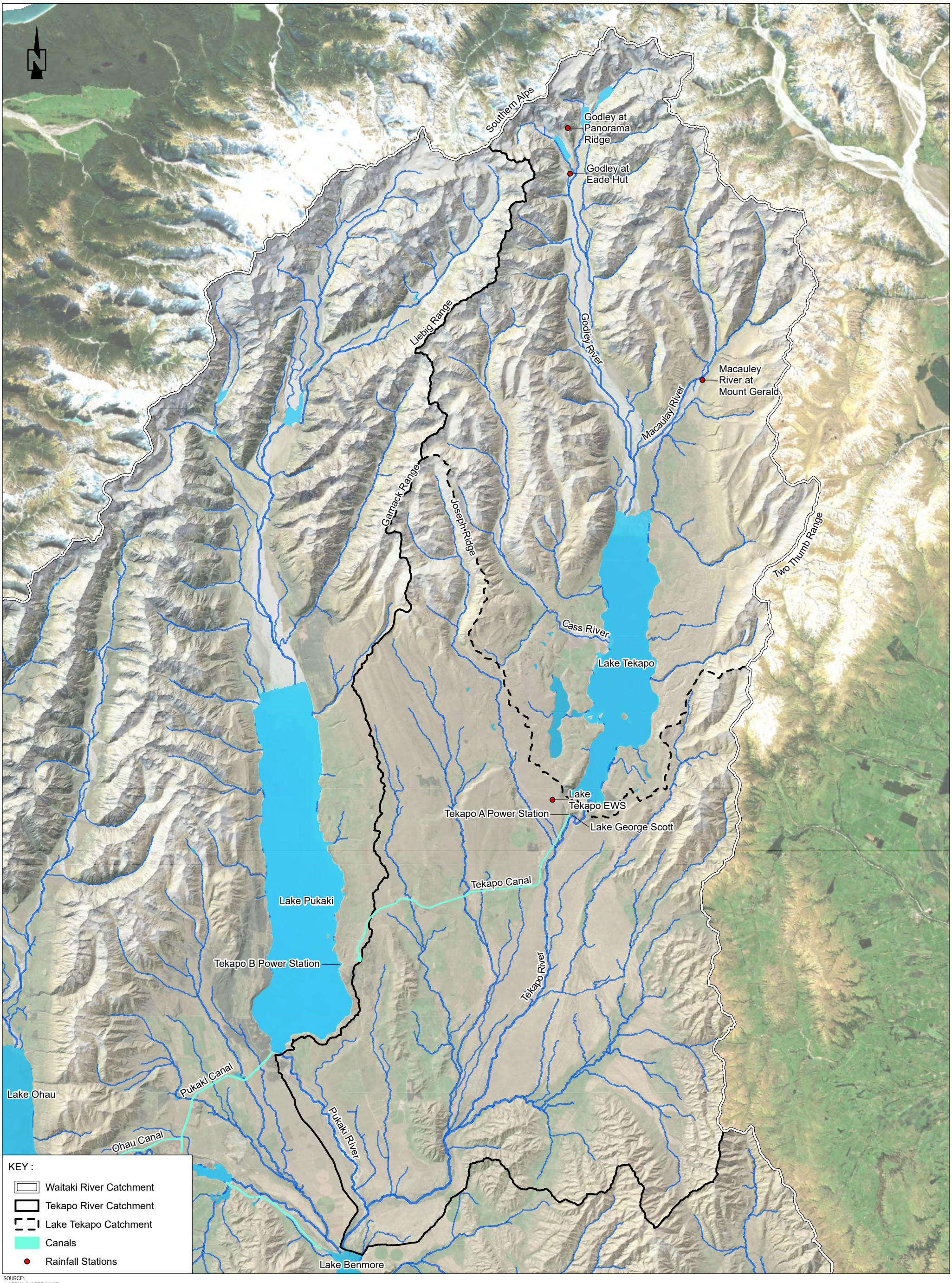
KEY :
- Waitaki River Catchment
- Tekapo River Catchment
- Lake Tekapo Catchment
- Canals

SOURCE:
1. AERIAL IMAGERY: LINZ
2. CATCHMENTS: ECAN
3. DEM: LINZ
4. RIVERS: NIWA

FIGURE A2 : WAITAKI CATCHMENT

SCALE : 1:550,000 (A3)

0 5,000 10,000 20,000 30,000
METRES



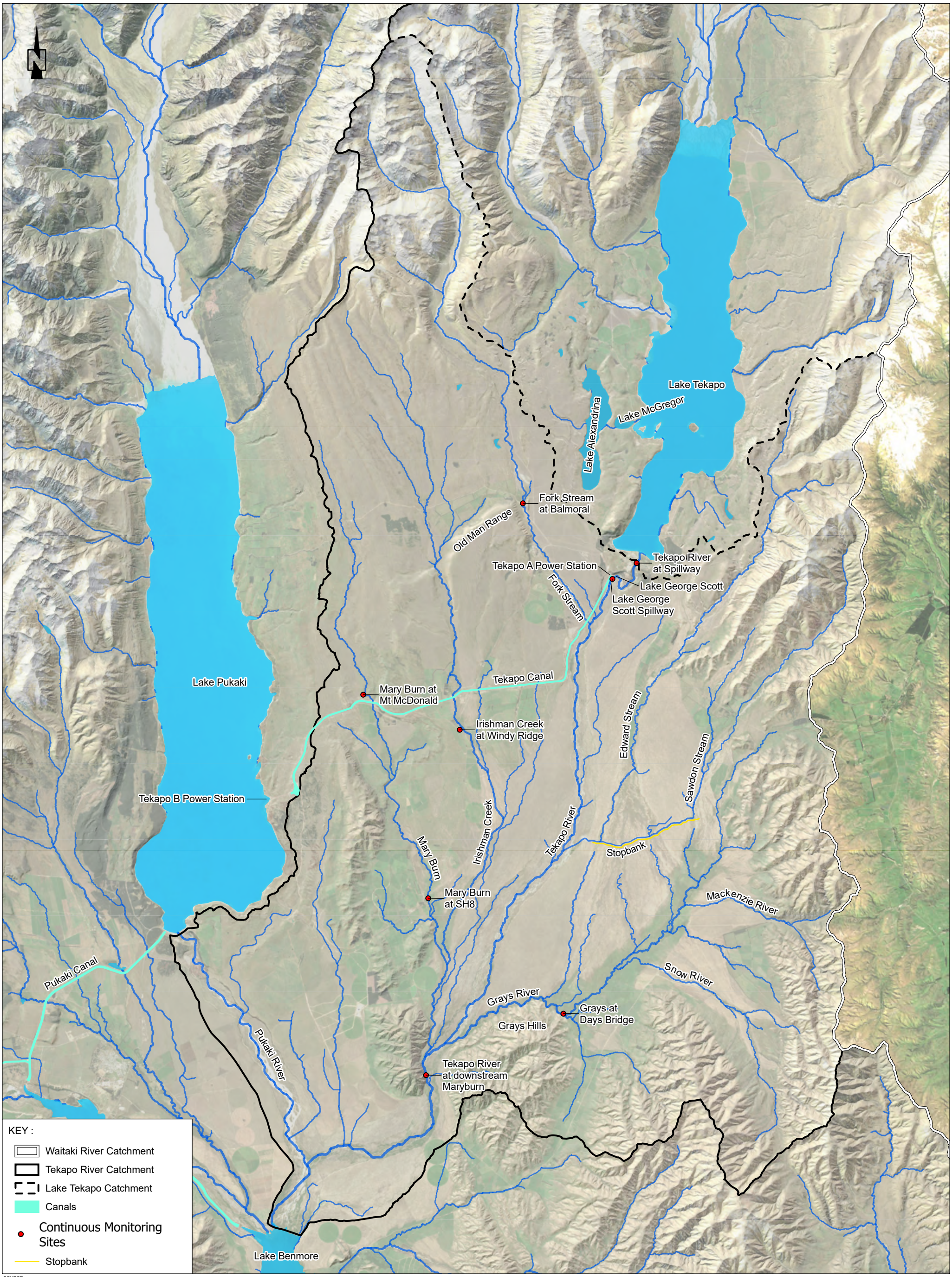
SOURCE:
1. AERIAL IMAGERY: LINZ
2. CATCHMENTS: ECAN
3. DEM: LINZ
4. RIVERS: NIWA

FIGURE A3 : LAKE TEKAPO AND TEKAPO RIVER CATCHMENT

SCALE : 1:300,000 (A3)

0 2,500 5,000 10,000 15,000
METRES

A02482504_505.mxd 25/05/2021 ISSUE 1



SOURCE:
1. AERIAL IMAGERY: LINZ
2. CATCHMENTS: ECAN
3. DEM: LINZ
4. RIVERS: NIWA

FIGURE A4 : TEKAPO RIVER CATCHMENT

SCALE : 1:200,000 (A3)

0 2,500 5,000 10,000 15,000
METRES



SOURCE:
1. SATELLITE IMAGERY: LINZ

FIGURE A5 : Stream Gauging Locations

SCALE :1:180,000 (A4)
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METRES

Appendix B: Lake Tekapo Lake Levels, Inflow and Outflow

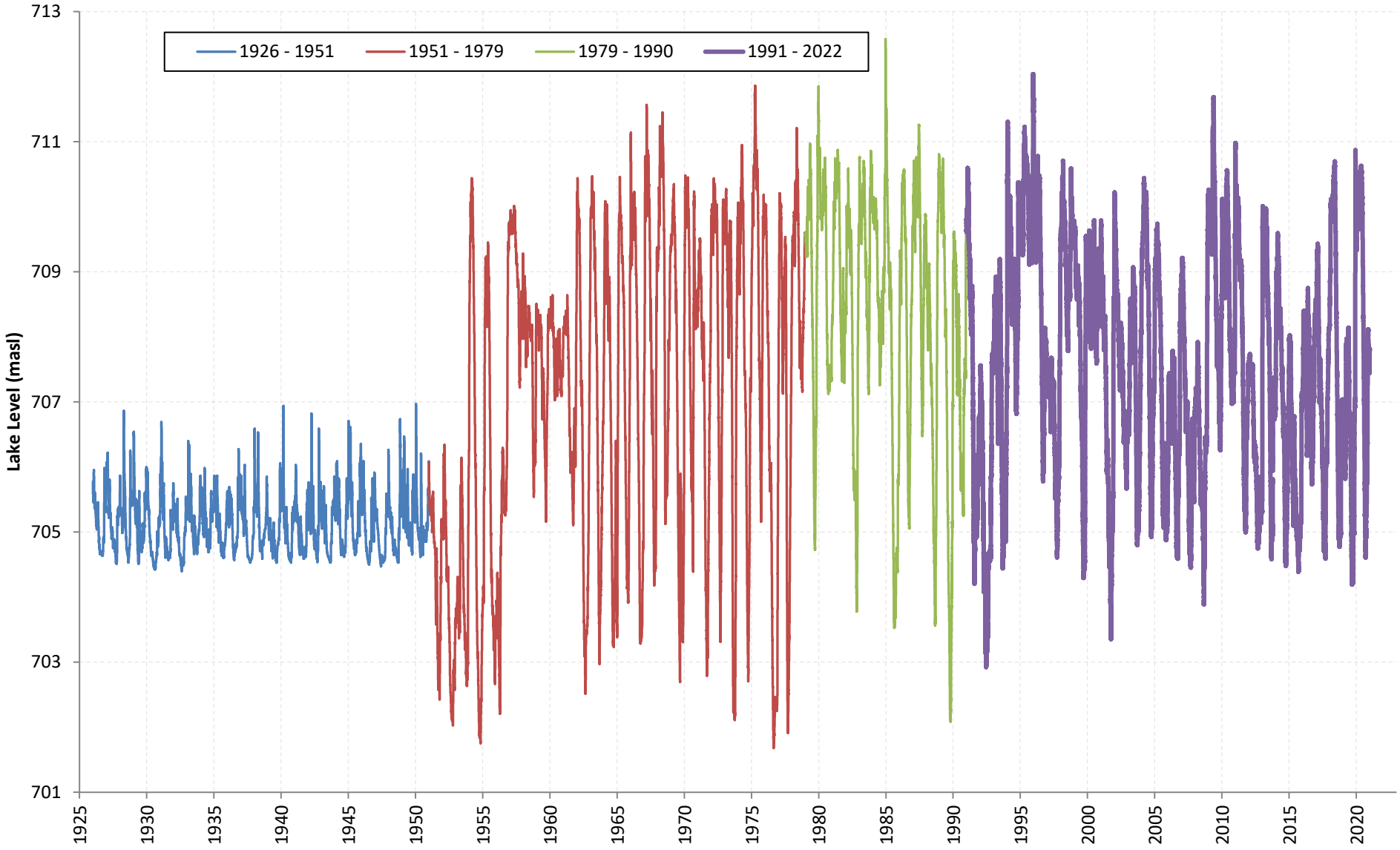


Figure B1: Lake Tekapo lake levels

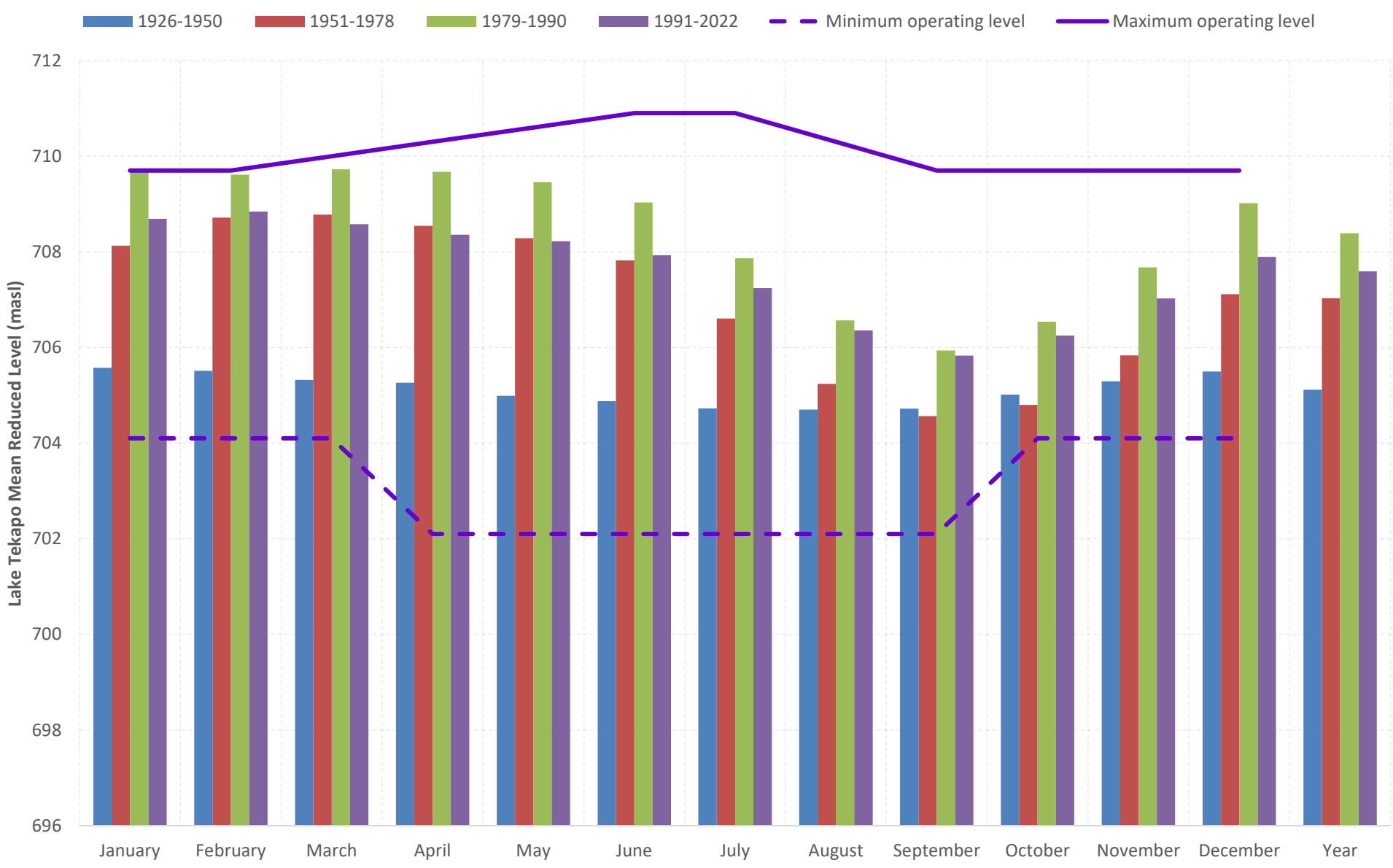


Figure B2: Mean monthly lake levels and current minimum and maximum operating lake levels

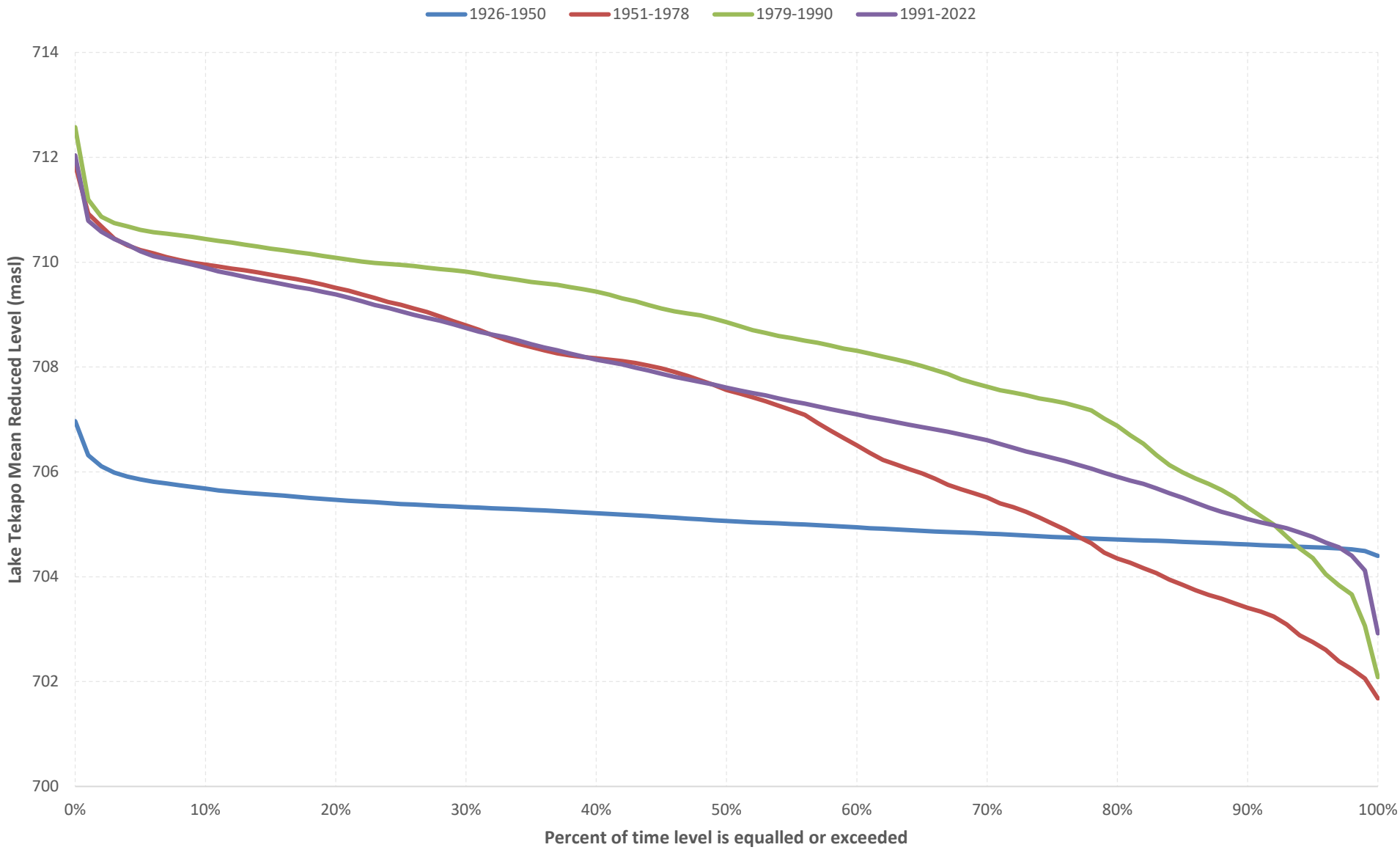


Figure B3: Lake level duration curves

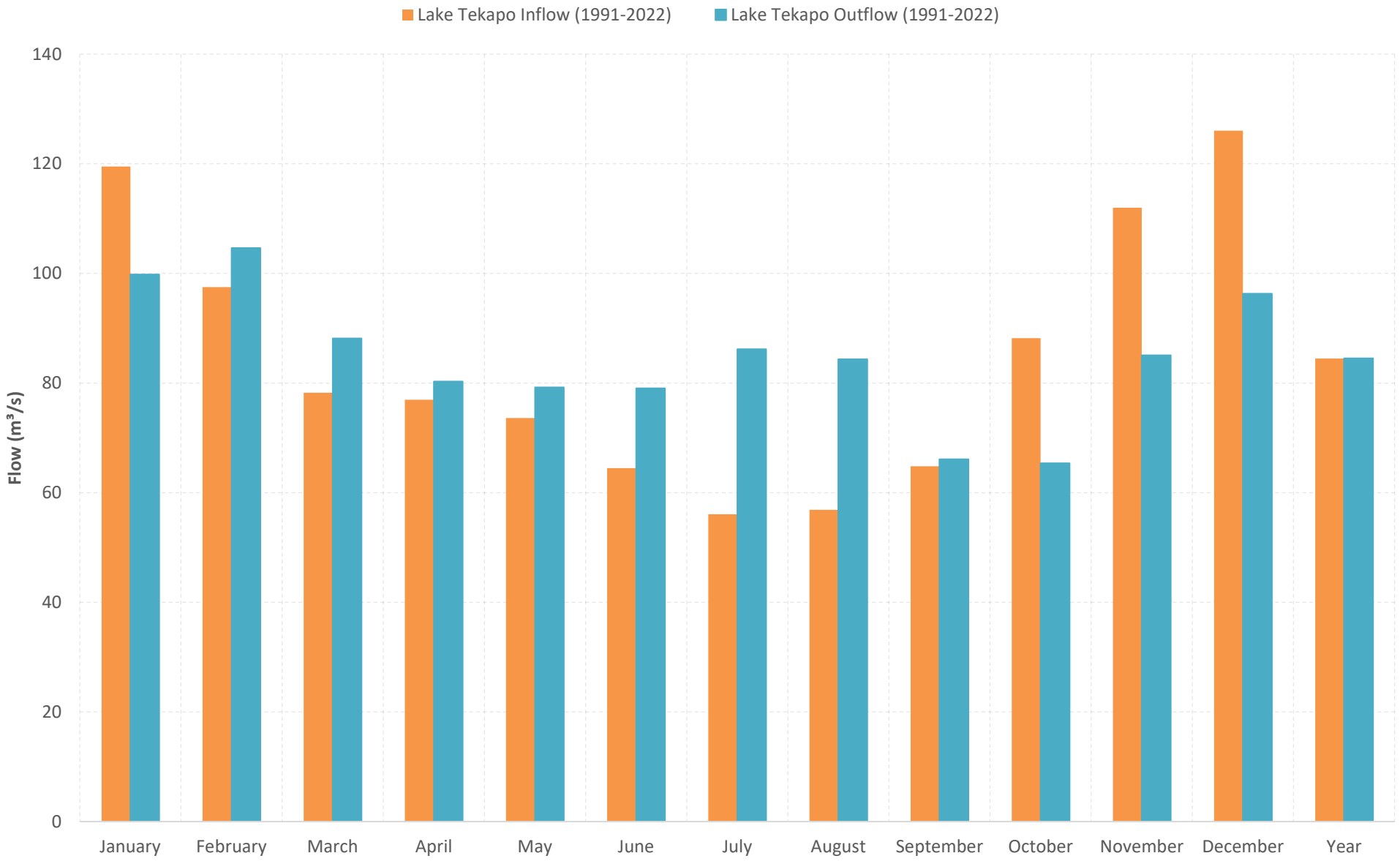


Figure B4: Lake Tekapo mean monthly inflow and outflow

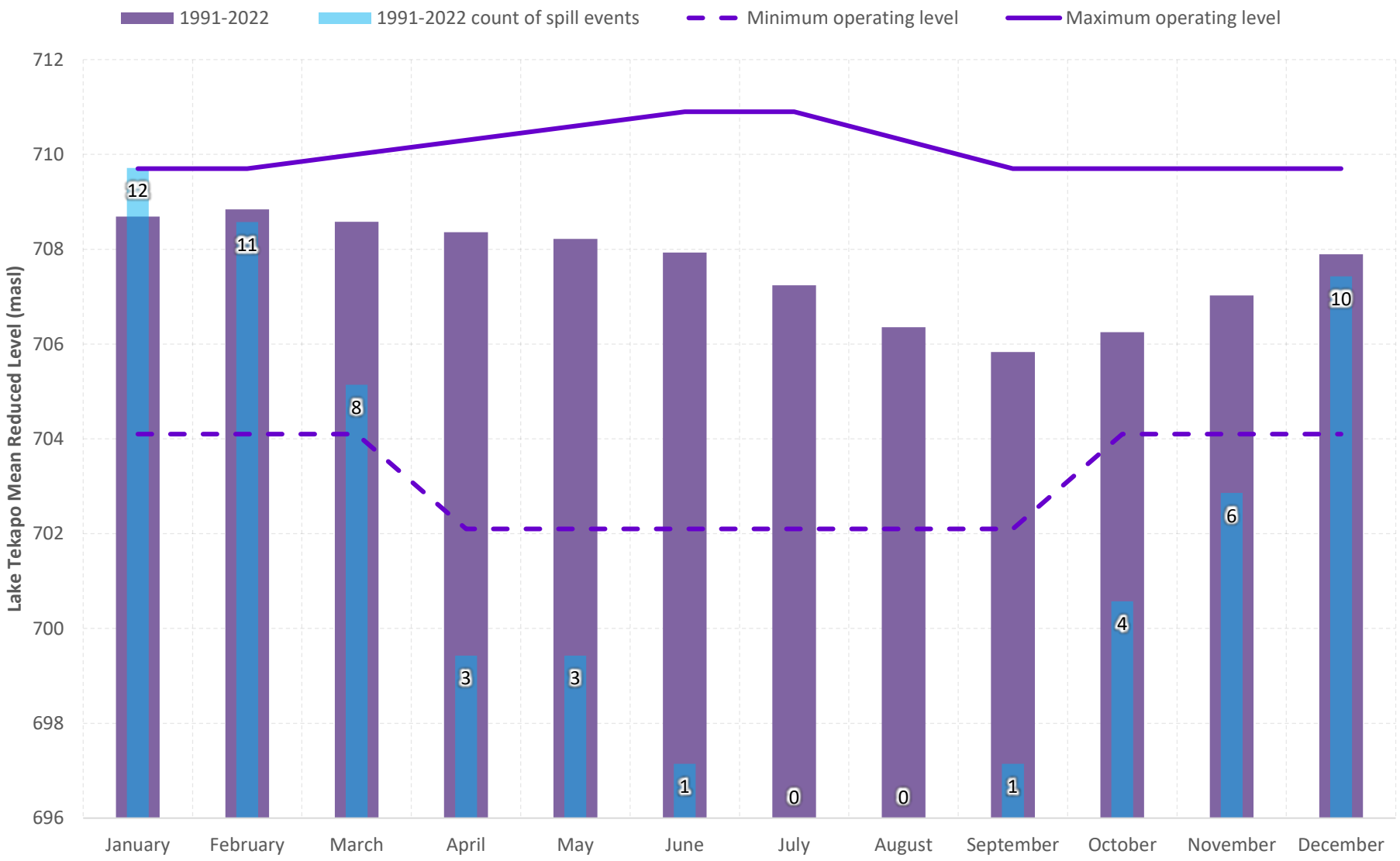


Figure B5: Lake Tekapo spill events 1991-2022

Appendix C: Tekapo River and Tekapo River Tributaries Hydrology Figures

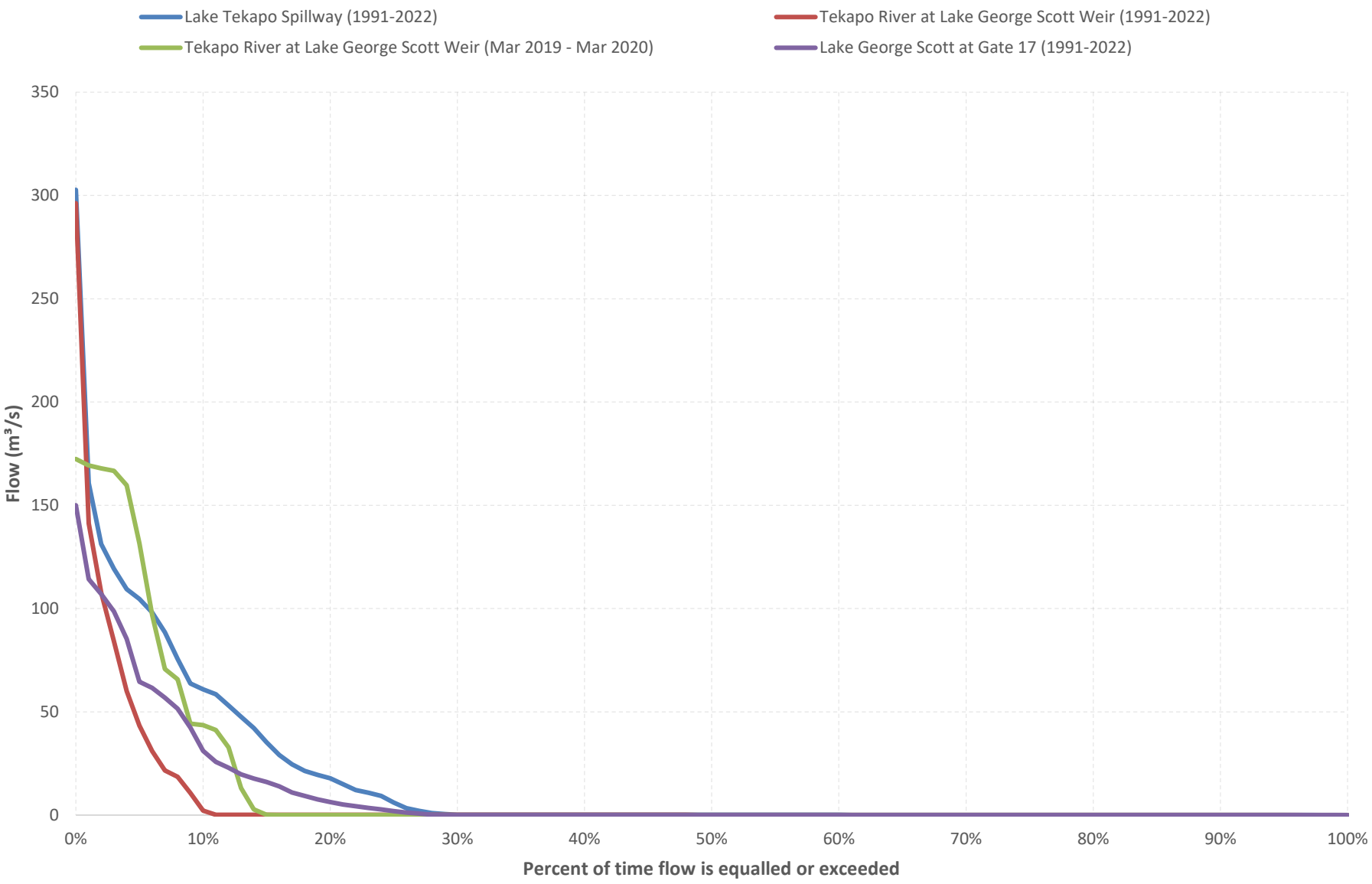


Figure C1: Lake Tekapo Spillway and Lake George Scott Weir flow duration curves

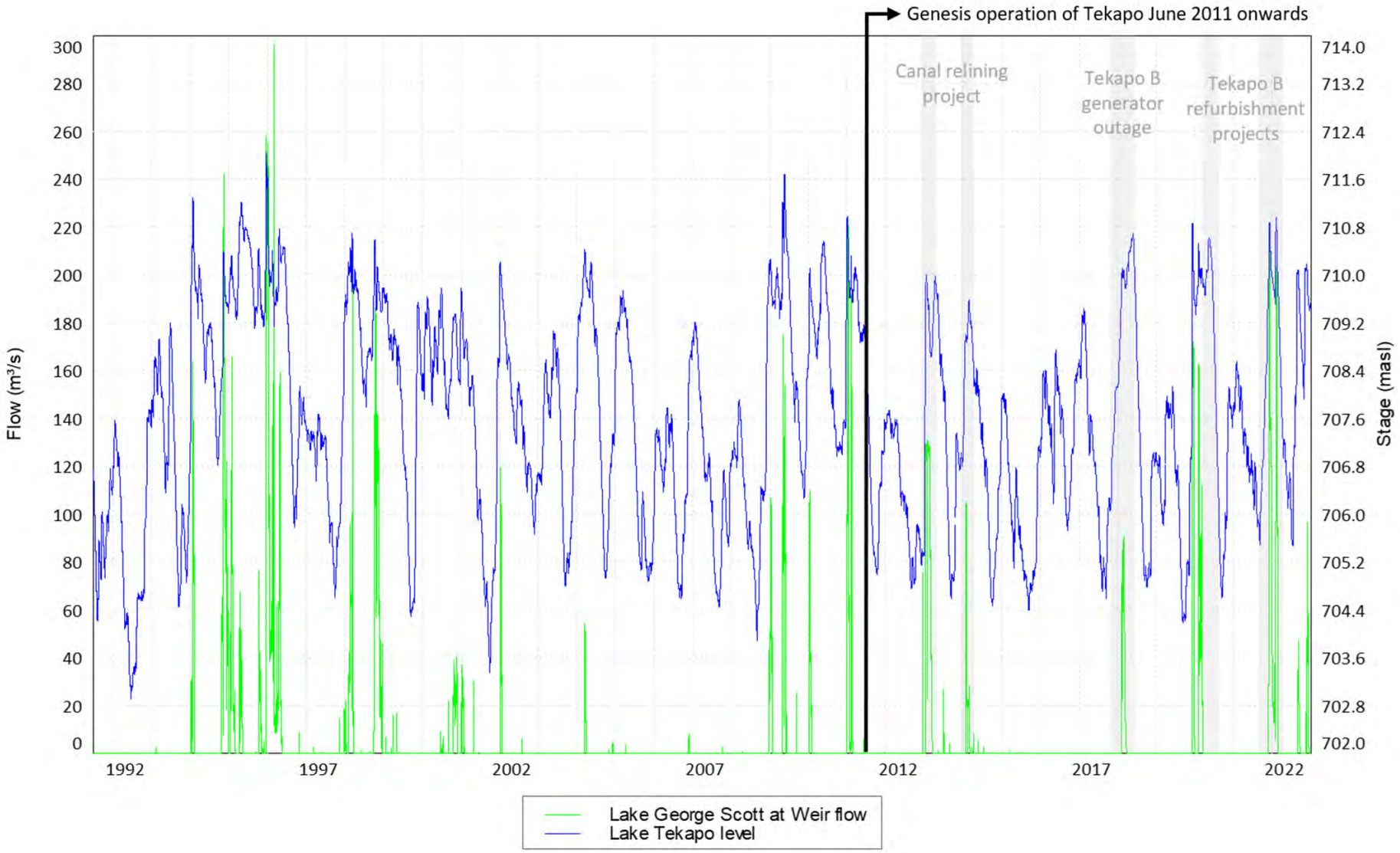


Figure C2: Lake George Scott at Weir and Lake Tekapo Level 1991-2022

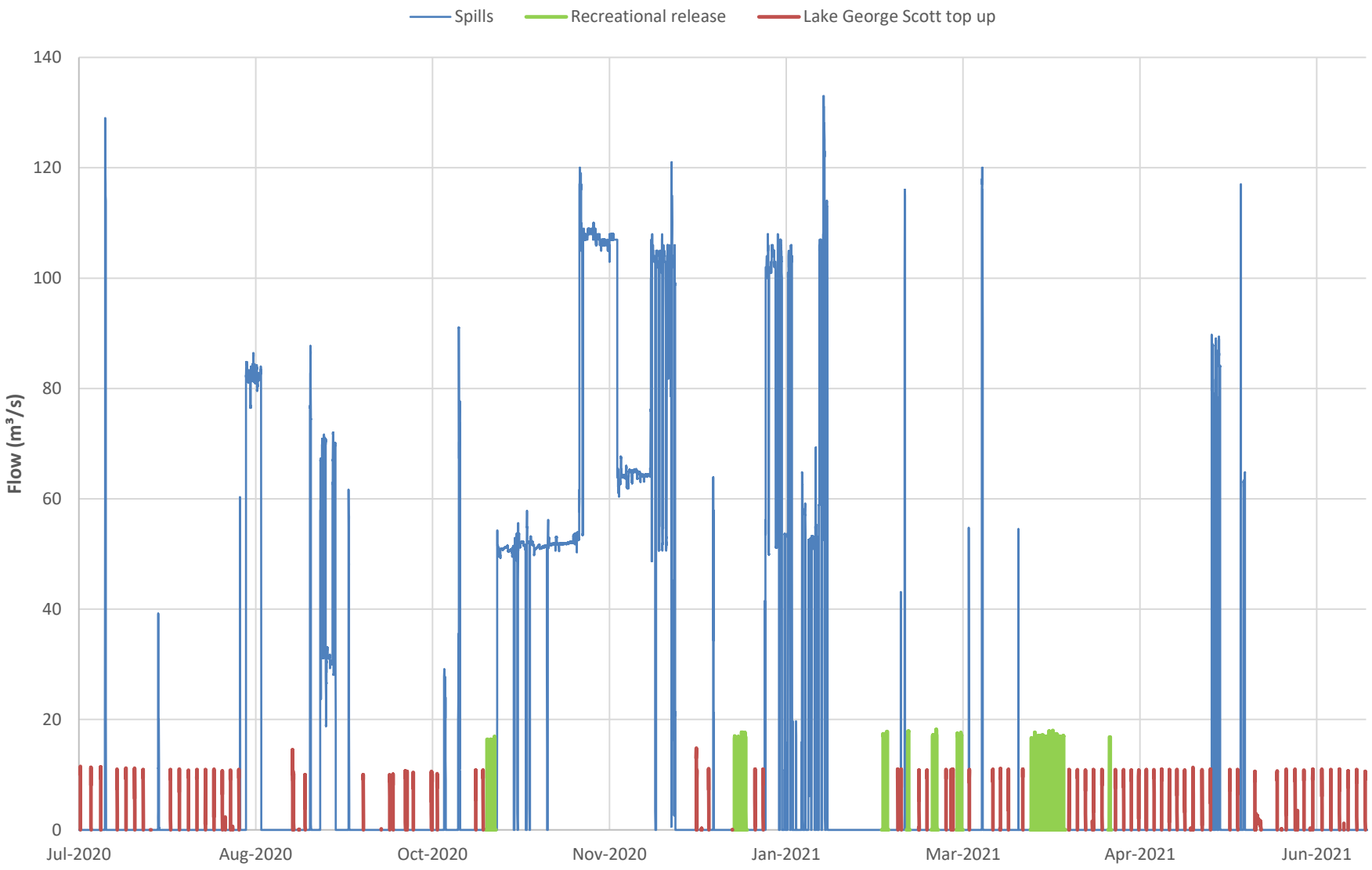


Figure C3: Recreational releases at the Tekapo Spillway during the 2020-2021 season

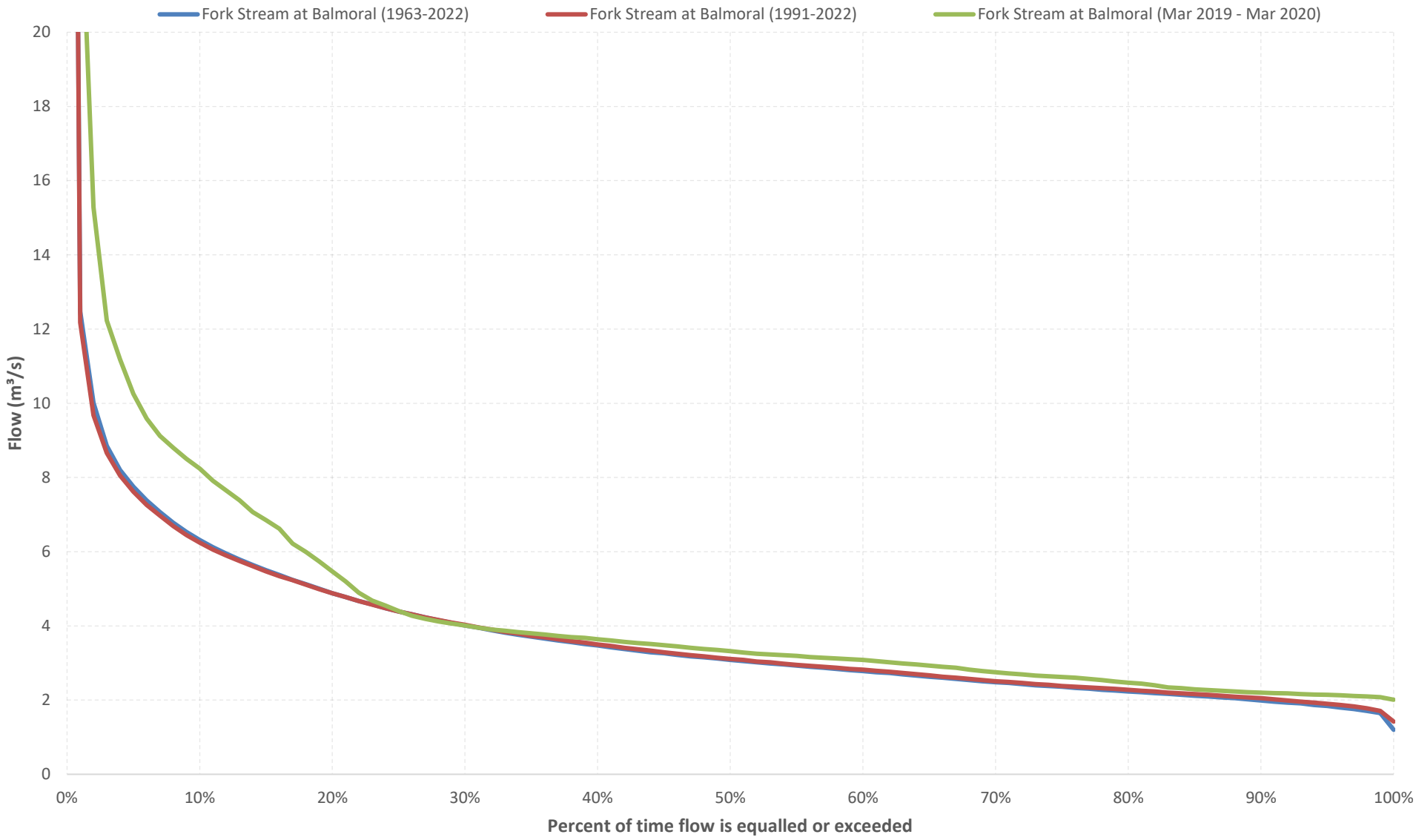


Figure C4: Fork Stream at Balmoral (increased by 0.6 m³/s) flow duration curves

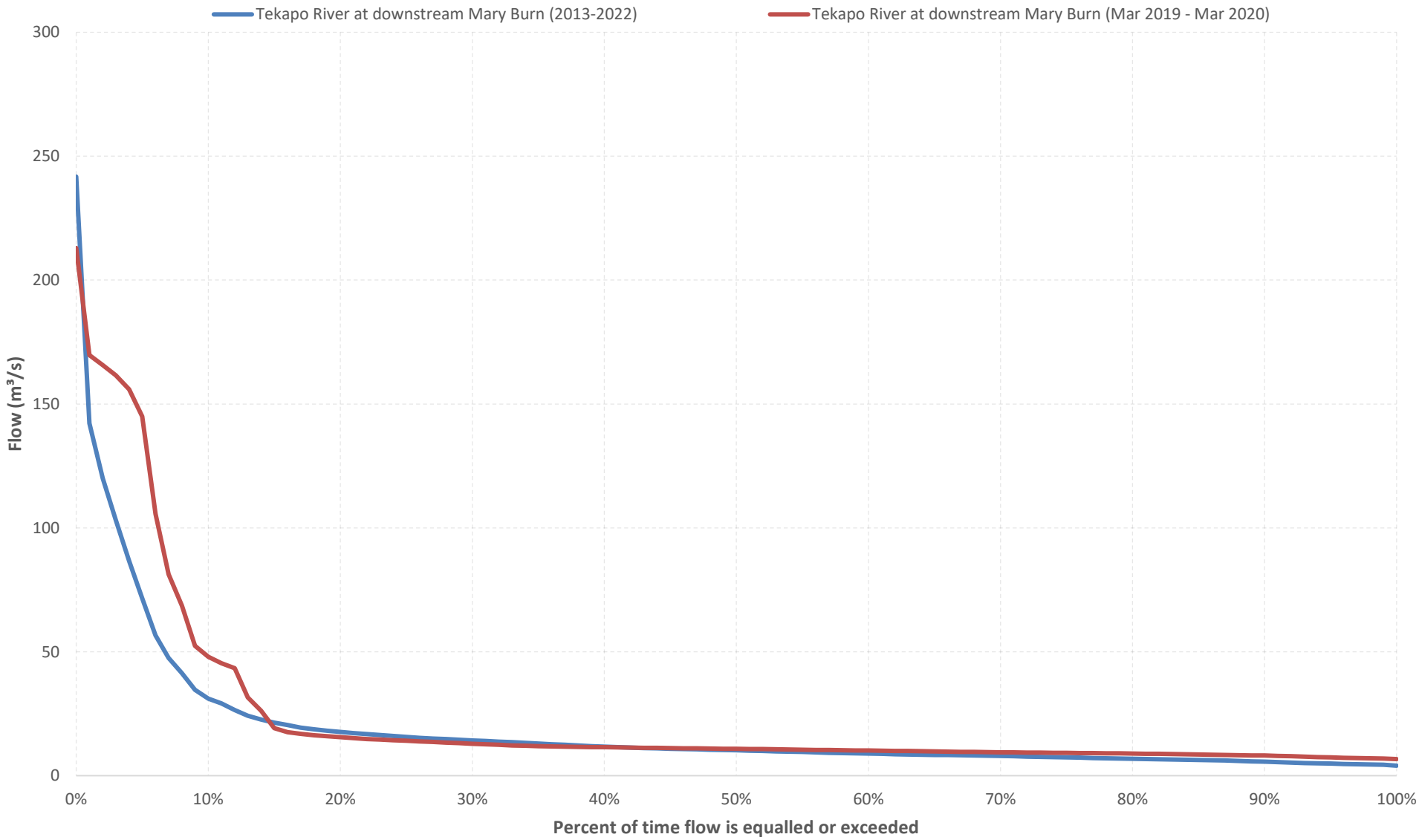


Figure C5: Tekapo River at downstream Mary Burn flow duration curves

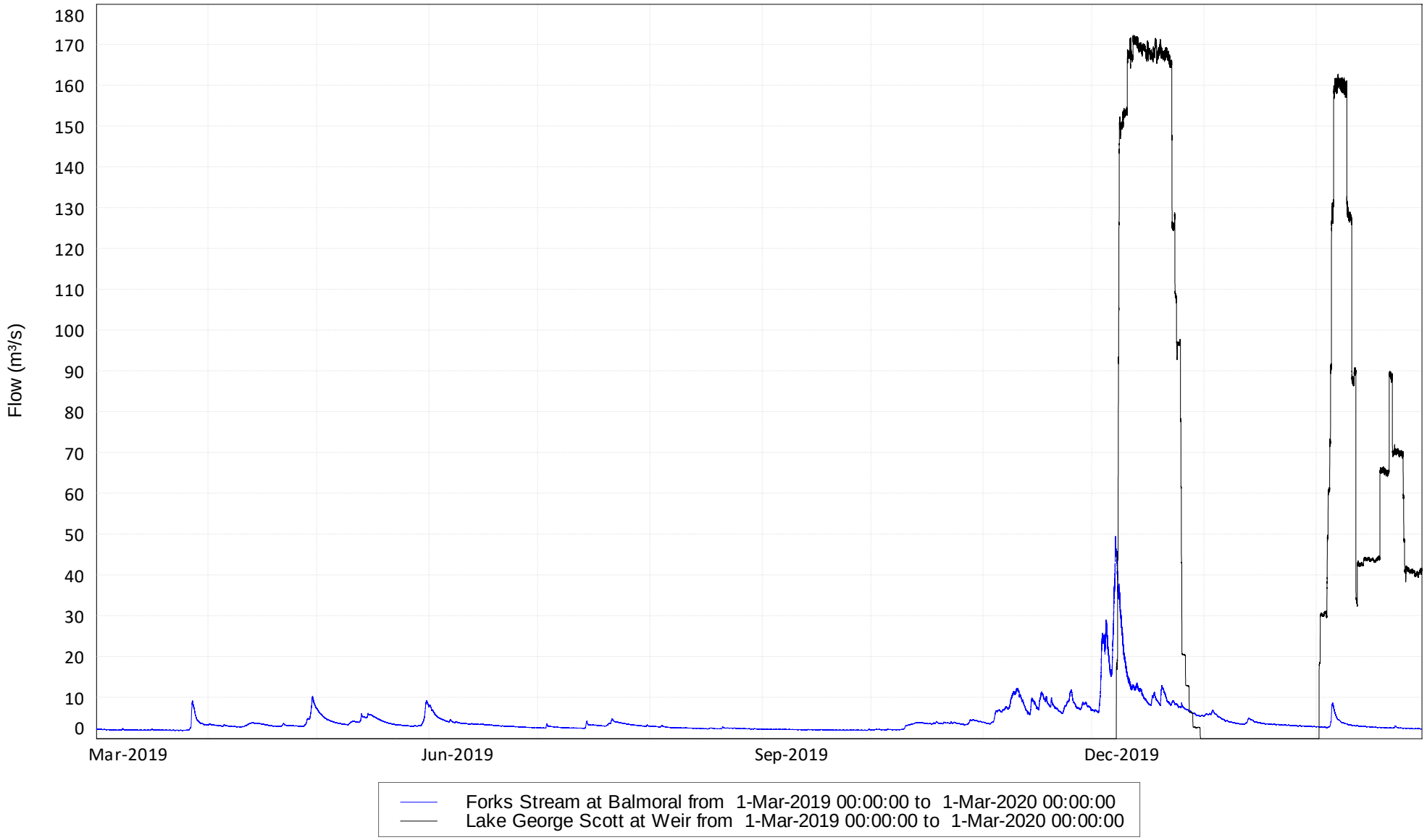


Figure C6: Fork Stream at Balmoral (increased by 0.6 m³/s) and Lake George Scott Weir flows (0-180 m³/s, 1 Mar 2019- 29 Feb 2020)

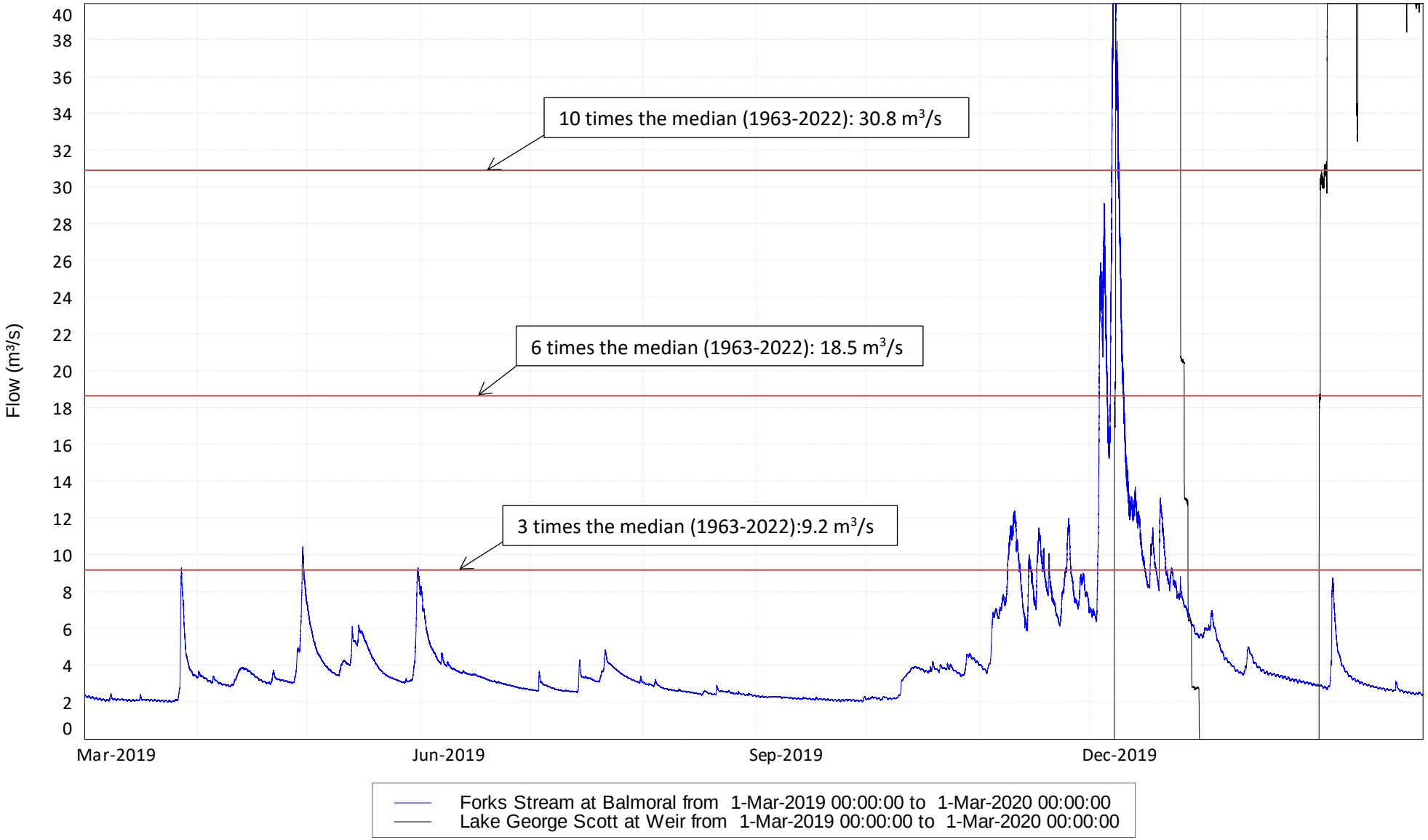


Figure C7: Fork Stream at Balmoral (increased by 0.6 m³/s) and Lake George Scott Weir flows (0-40 m³/s, 1 Mar 2019-29 Feb 2020)

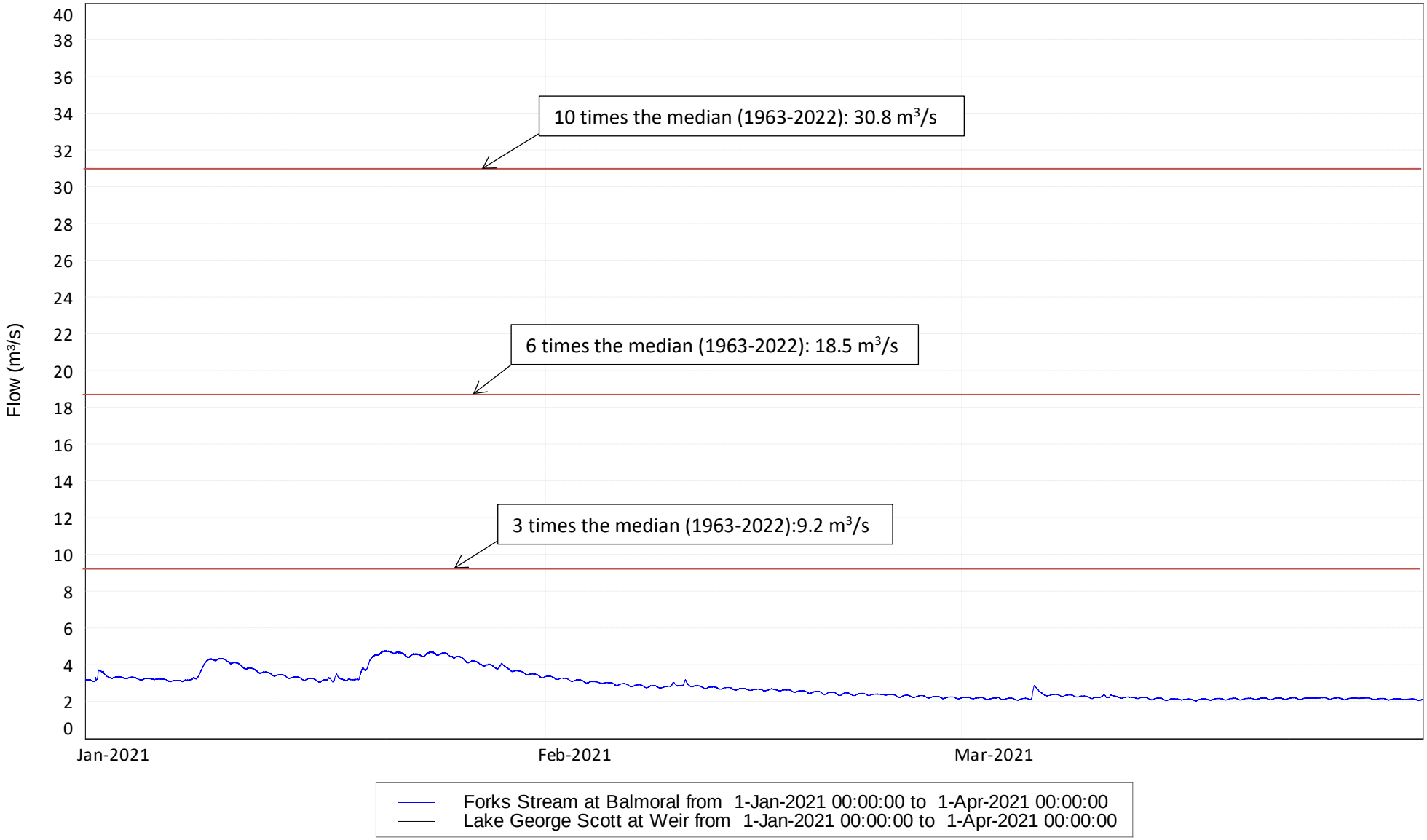


Figure C8: Fork Stream at Balmoral (increased by 0.6 m³/s) and Lake George Scott Weir flows (0-40 m³/s, 1 Jan 2021-31 Mar 2021)

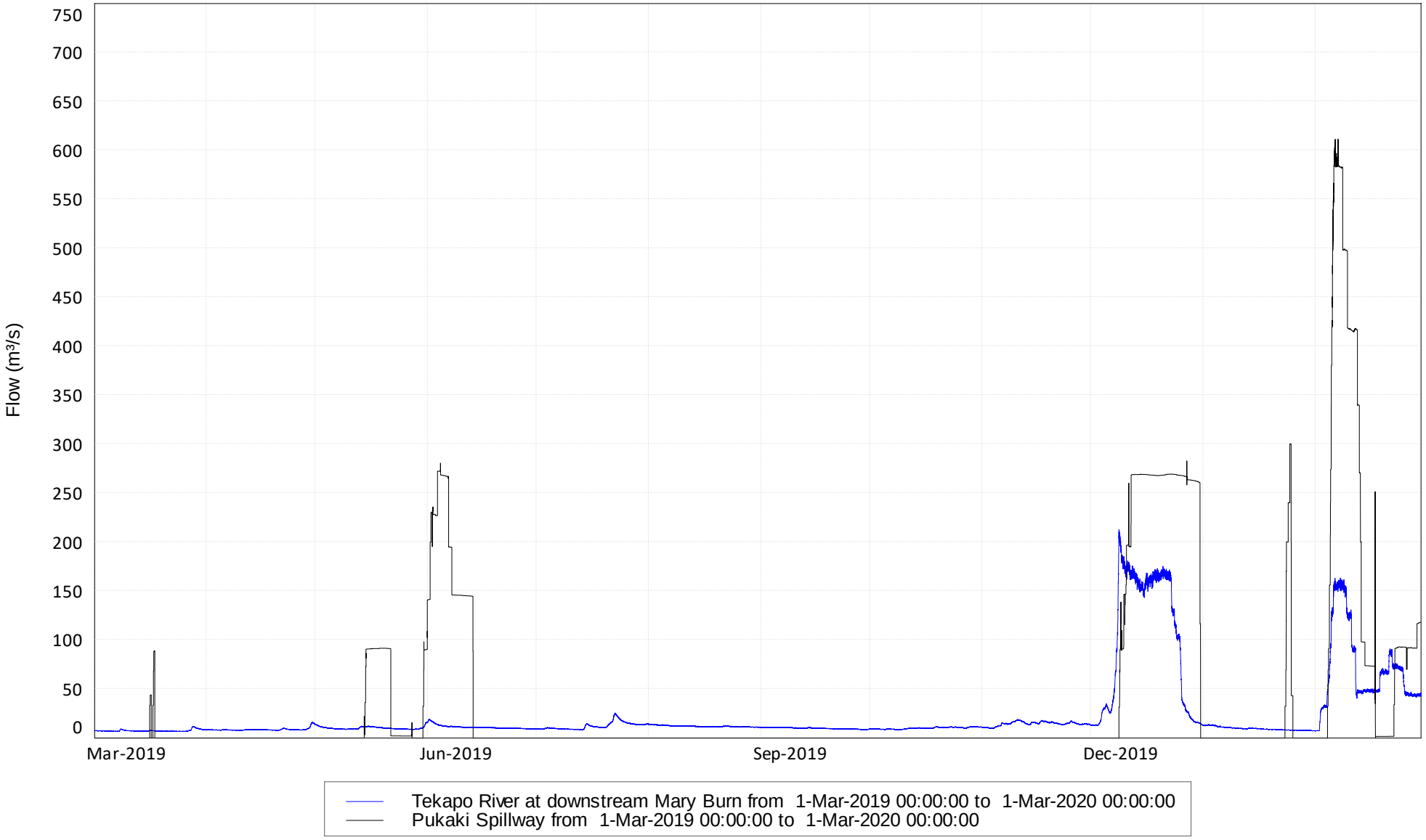


Figure C9: Tekapo River at downstream Mary Burn and Pukaki Spillway flows (0-750 m³/s, 1 Mar 2019 - 29 Feb 2020)

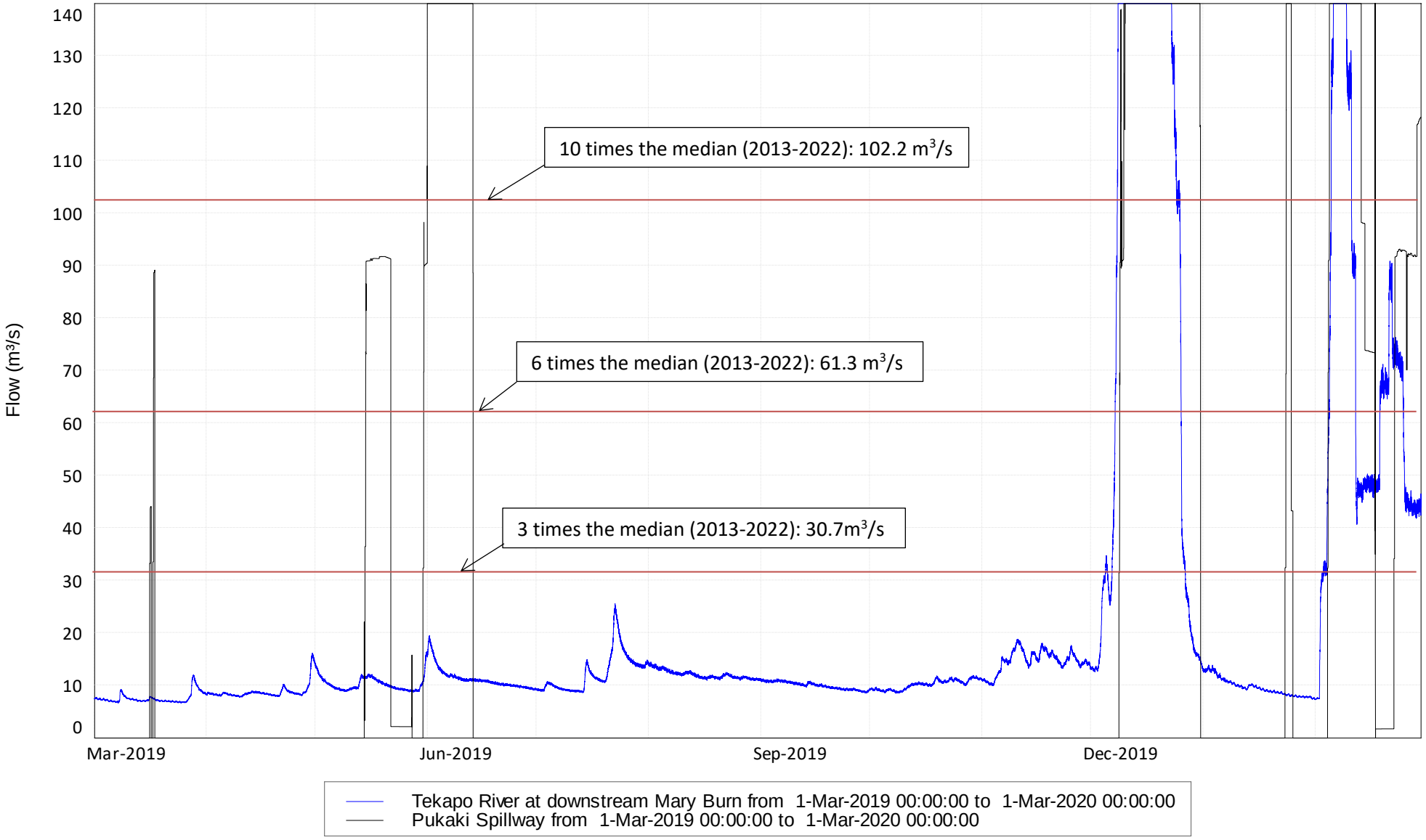


Figure C10: Tekapo River at downstream Mary Burn and Pukaki Spillway flows (0-140 m³/s, 1 Mar 2019 – 29 Feb 2020)

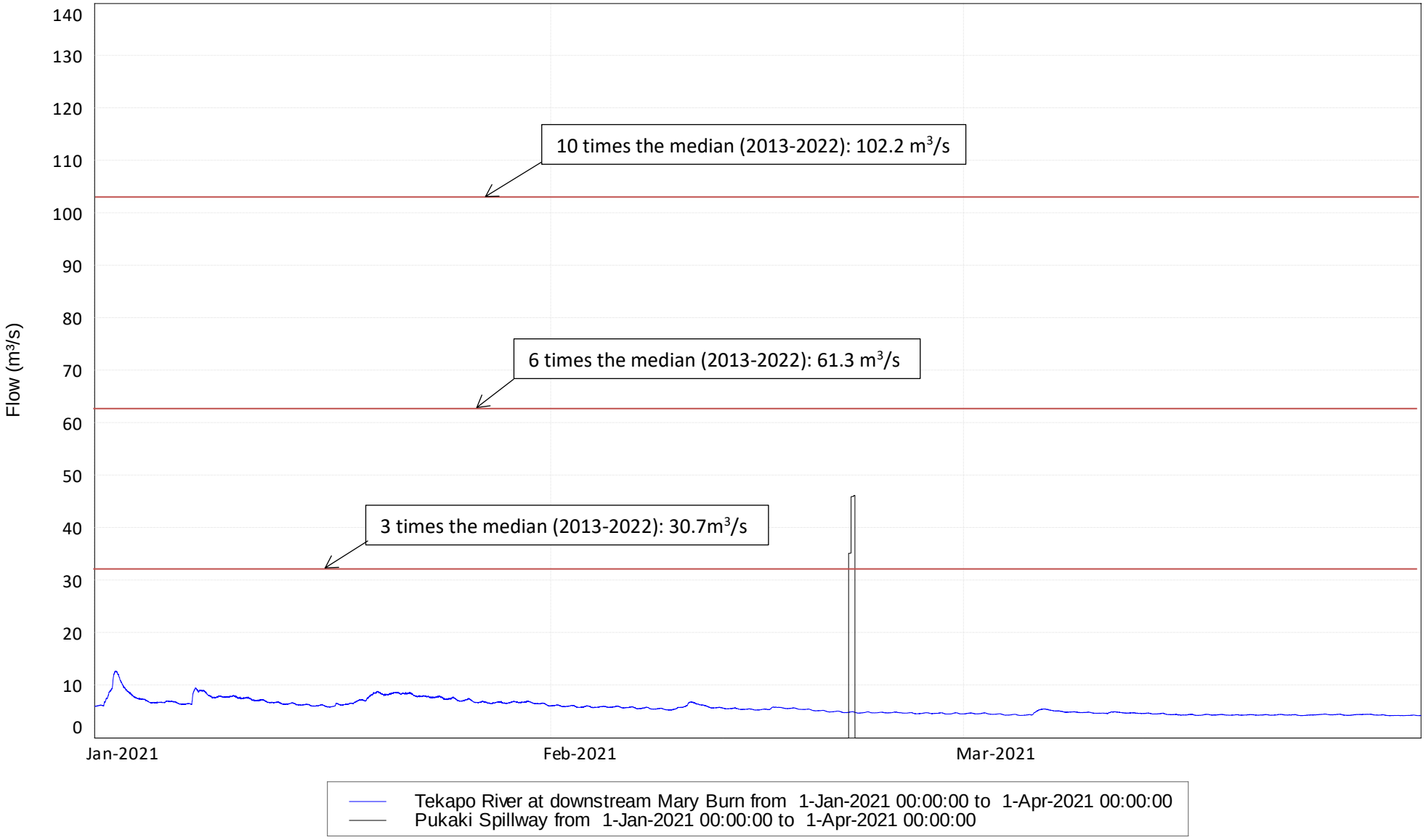
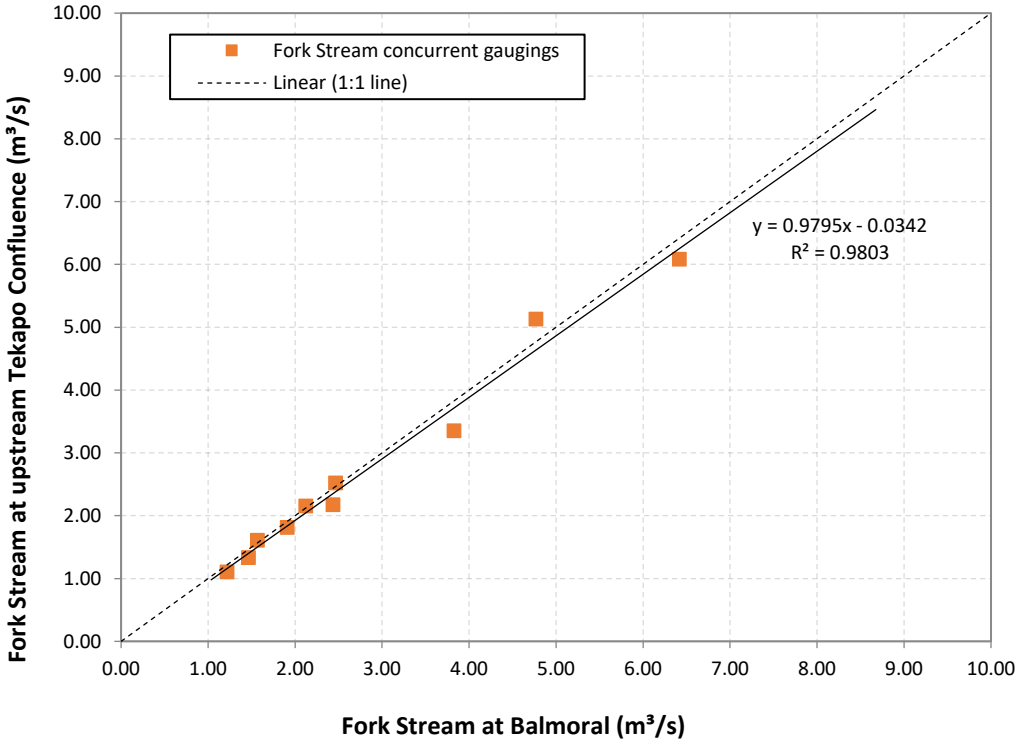


Figure C11: Tekapo River at downstream Mary Burn and Pukaki Spillway flows (0-140 m³/s, 1 Jan 2021 – 31 Mar 2021)



Available concurrent gauging information		
Date	**Fork Stream at Balmoral (m³/s)**	**Fork Stream at upstream Tekapo Confluence (m³/s)**
1-Apr-05	2.466	2.52[1]
27-Nov-12	6.419	6.084
28-Jan-13	3.826	3.353
25-Feb-13	2.124	2.153
15-Apr-13	1.218	1.106
19-Aug-13	1.567	1.609
16-Dec-13	4.767	5.132
24-Feb-14	1.908	1.812
25-Mar-14	1.464	1.333
19-May-14	2.436	2.174

Notes:

1. *Gauged at site 'Fork Stream below canal which is the same location as site 'Fork Stream at upstream Tekapo confluence.*

Figure C12: Available concurrent flow gaugings and regression between Fork Stream at Balmoral and Fork Stream at upstream Tekapo River Confluence

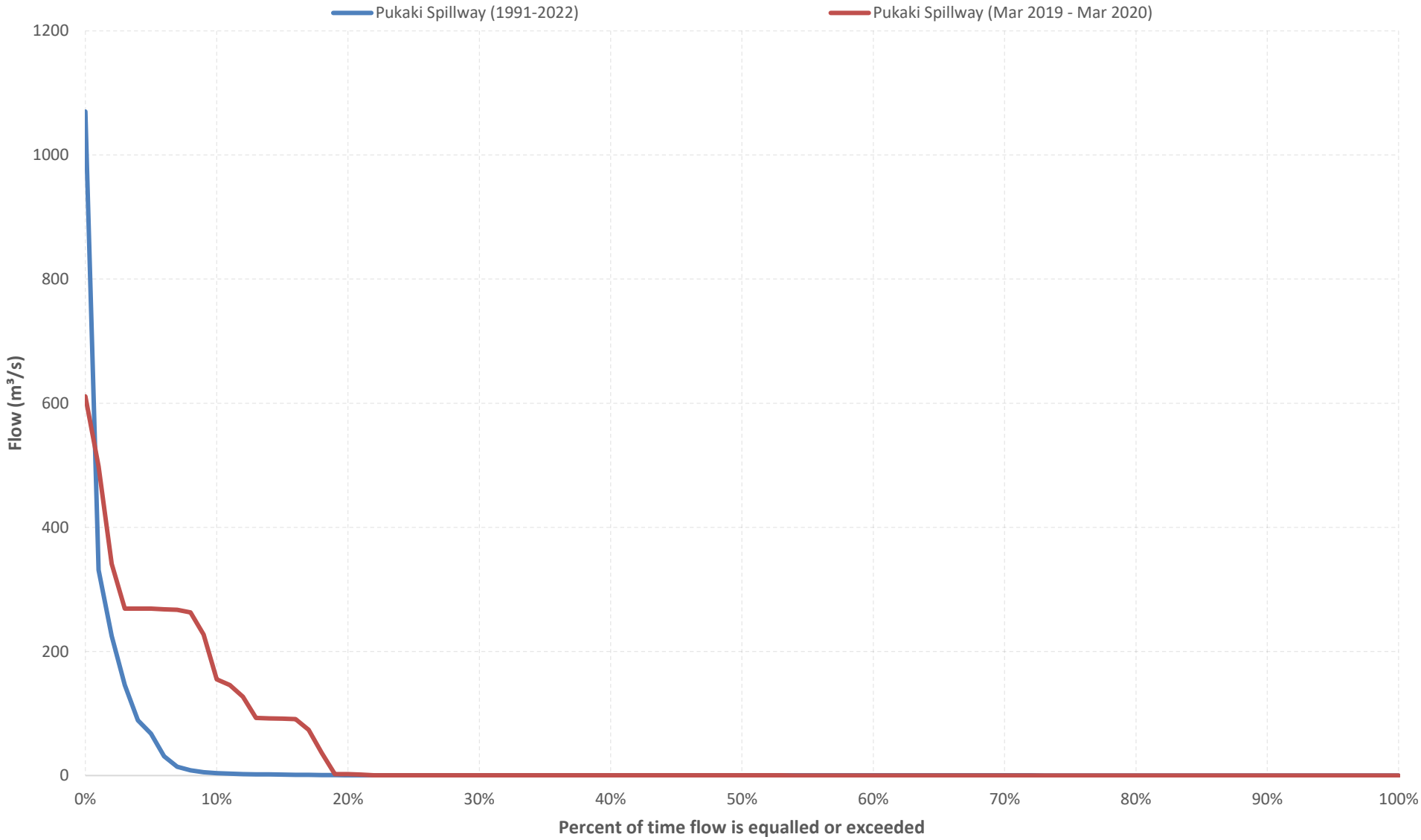


Figure C13: Lake Pukaki Spillway flow duration curves

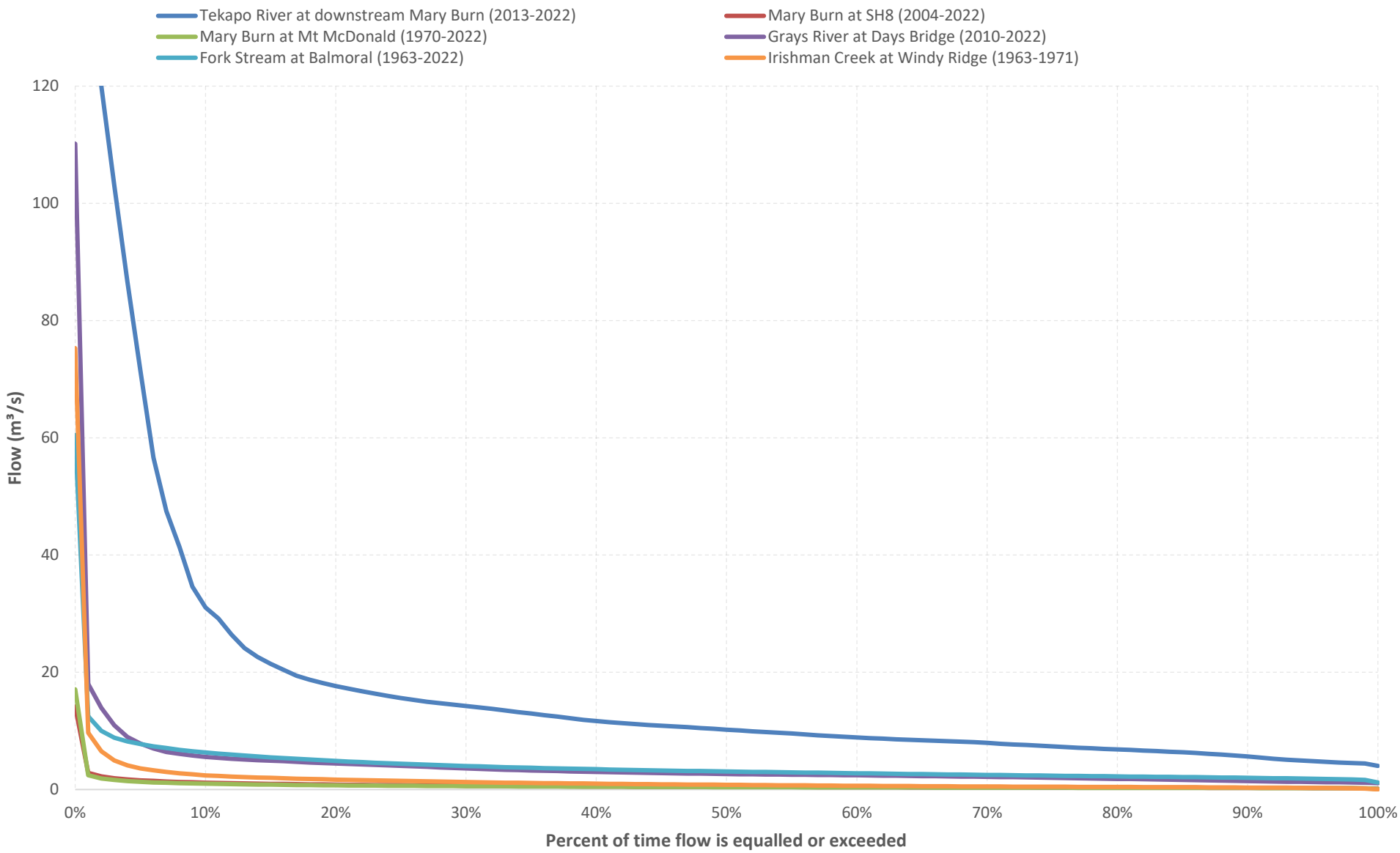


Figure C14: Tekapo River at downstream Mary Burn and Tekapo River tributaries flow duration curves (0 -120 m³/s)

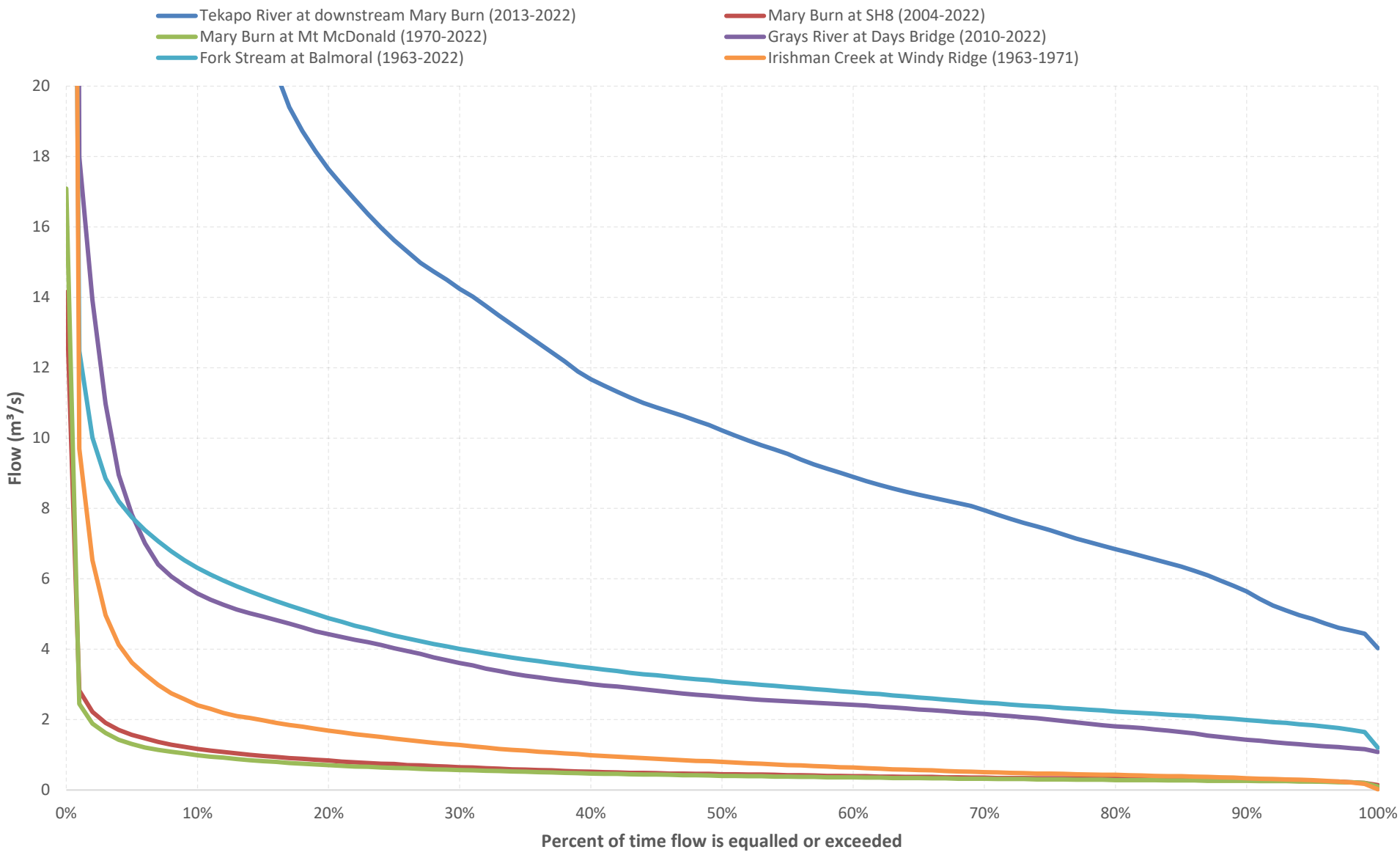


Figure C15: Tekapo River at downstream Mary Burn and Tekapo River tributaries flow duration curves (0 -20 m³/s)

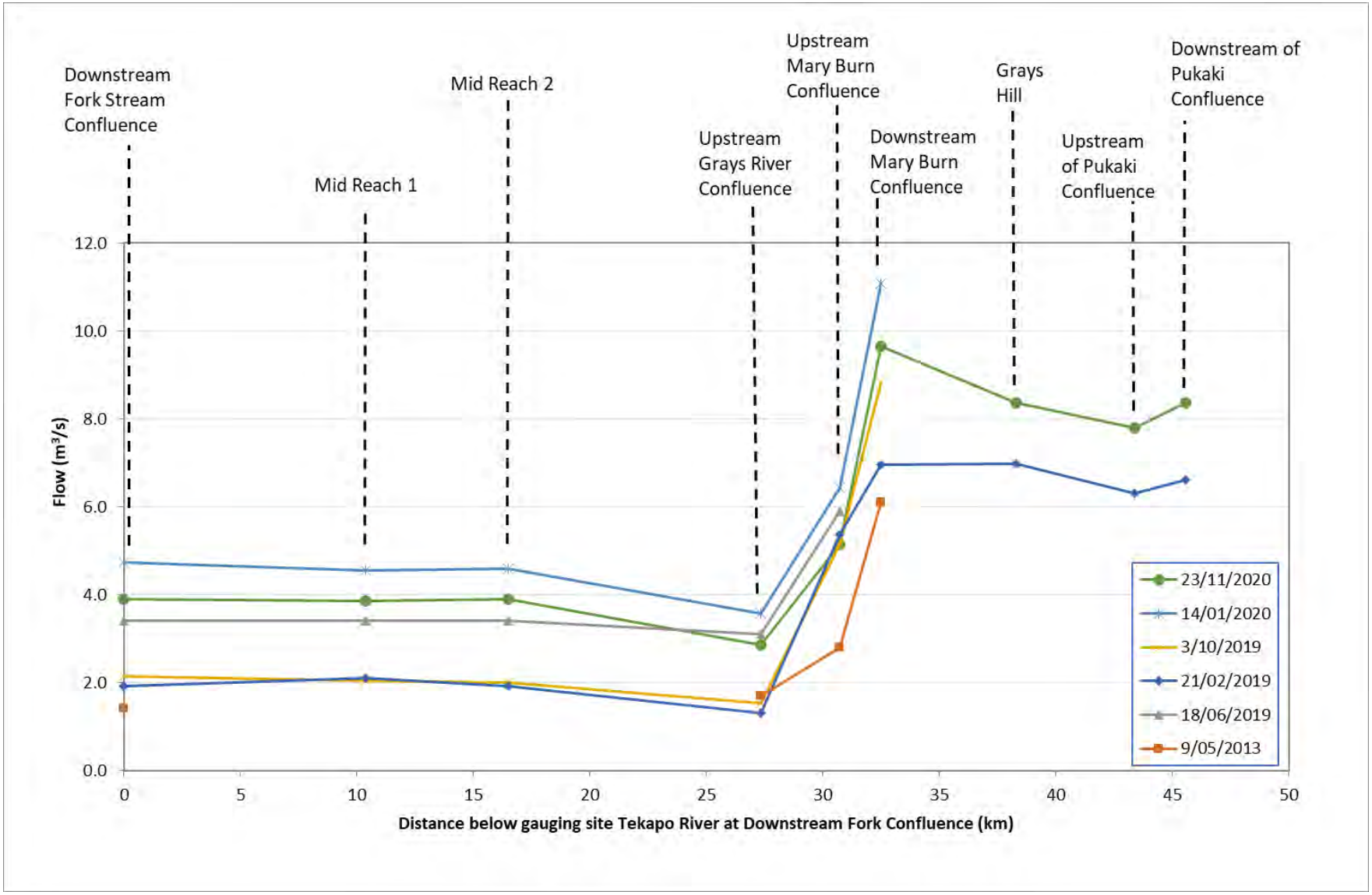


Figure C16: Gain/Loss profile for lower Tekapo River

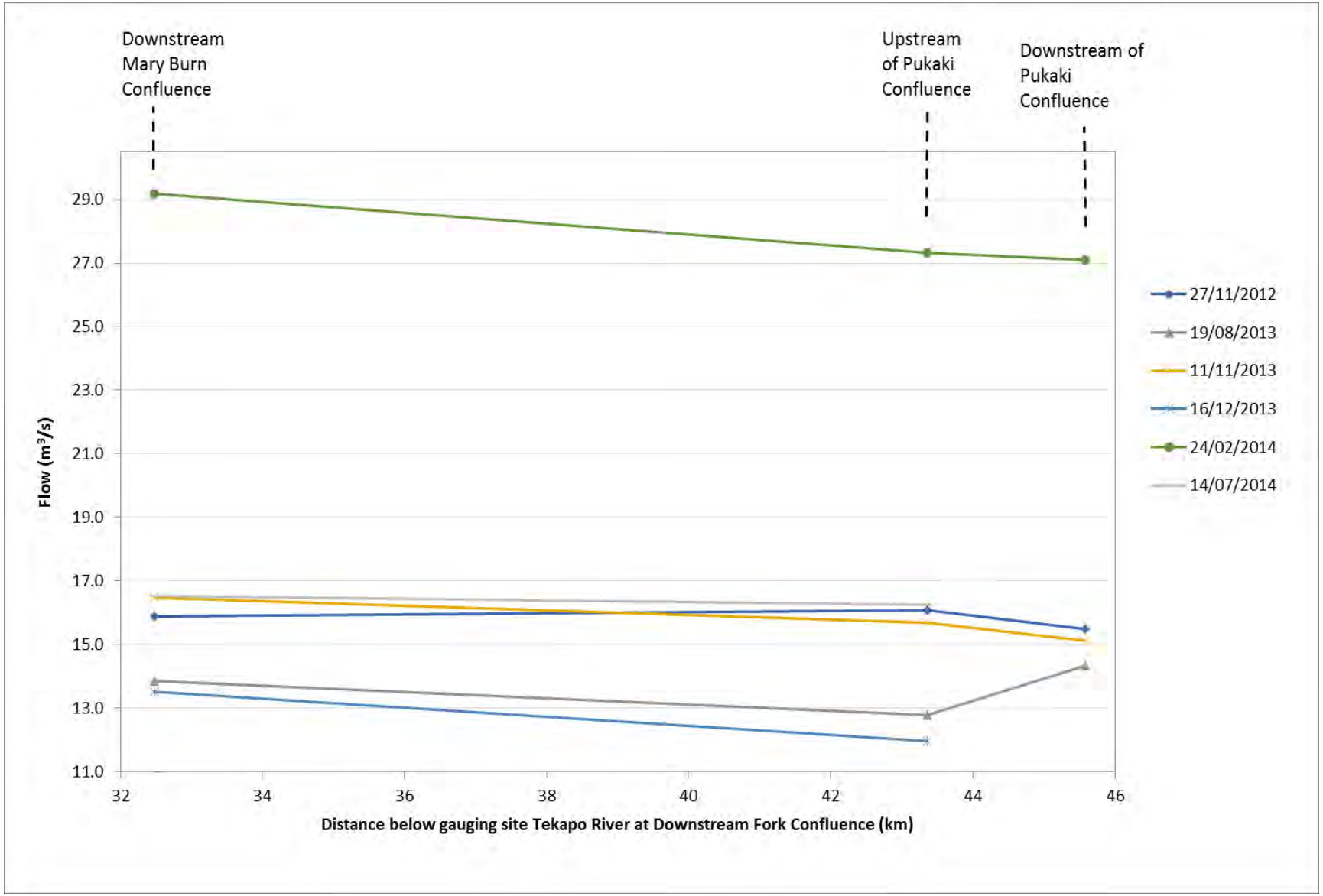


Figure C17: Gain/Loss profiles for lower Tekapo River (Flows greater than 11 m^3/s)

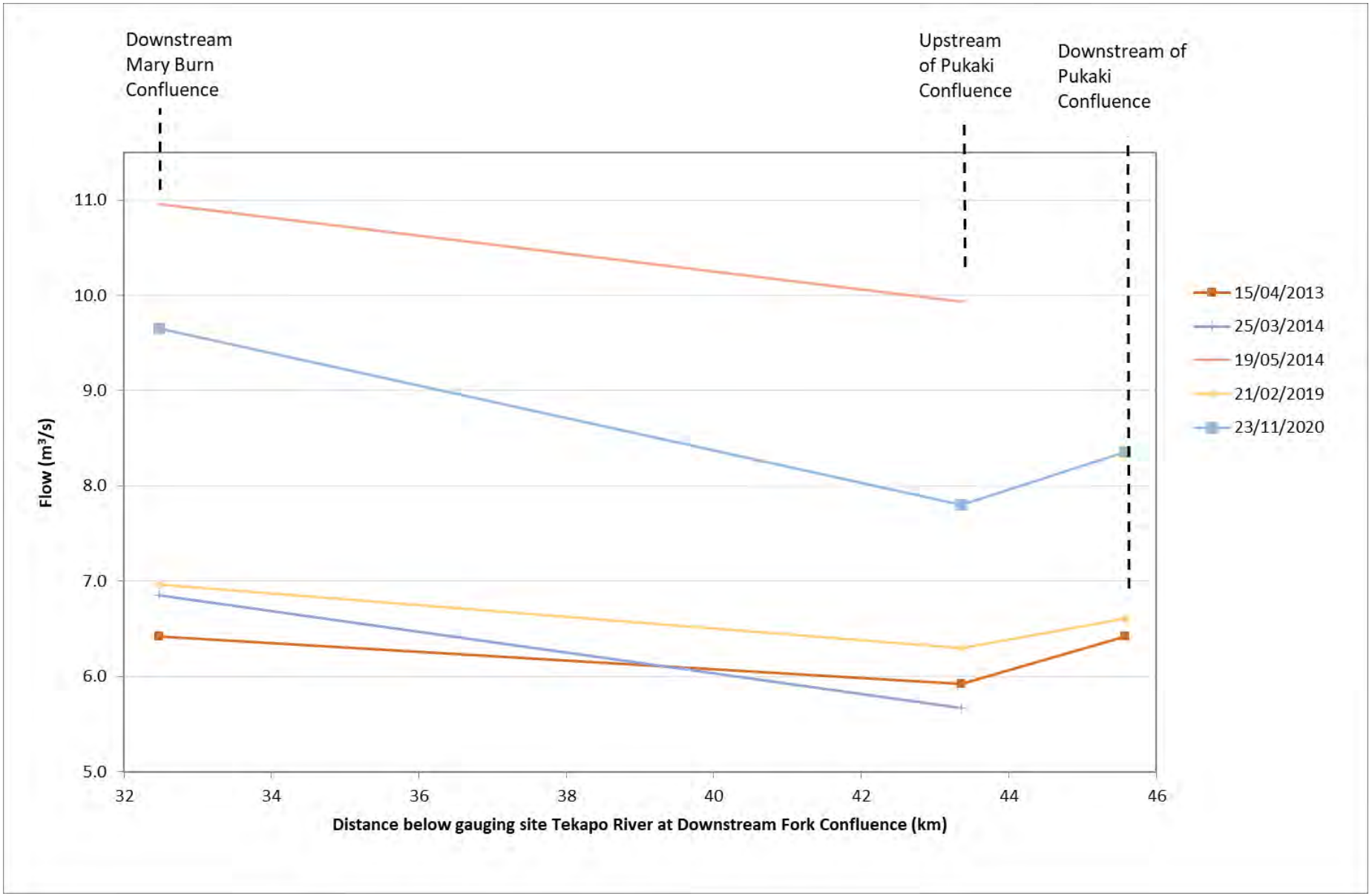


Figure C18: Gain/Loss profile for lower Tekapo River (Flows less than 11 m^3/s)

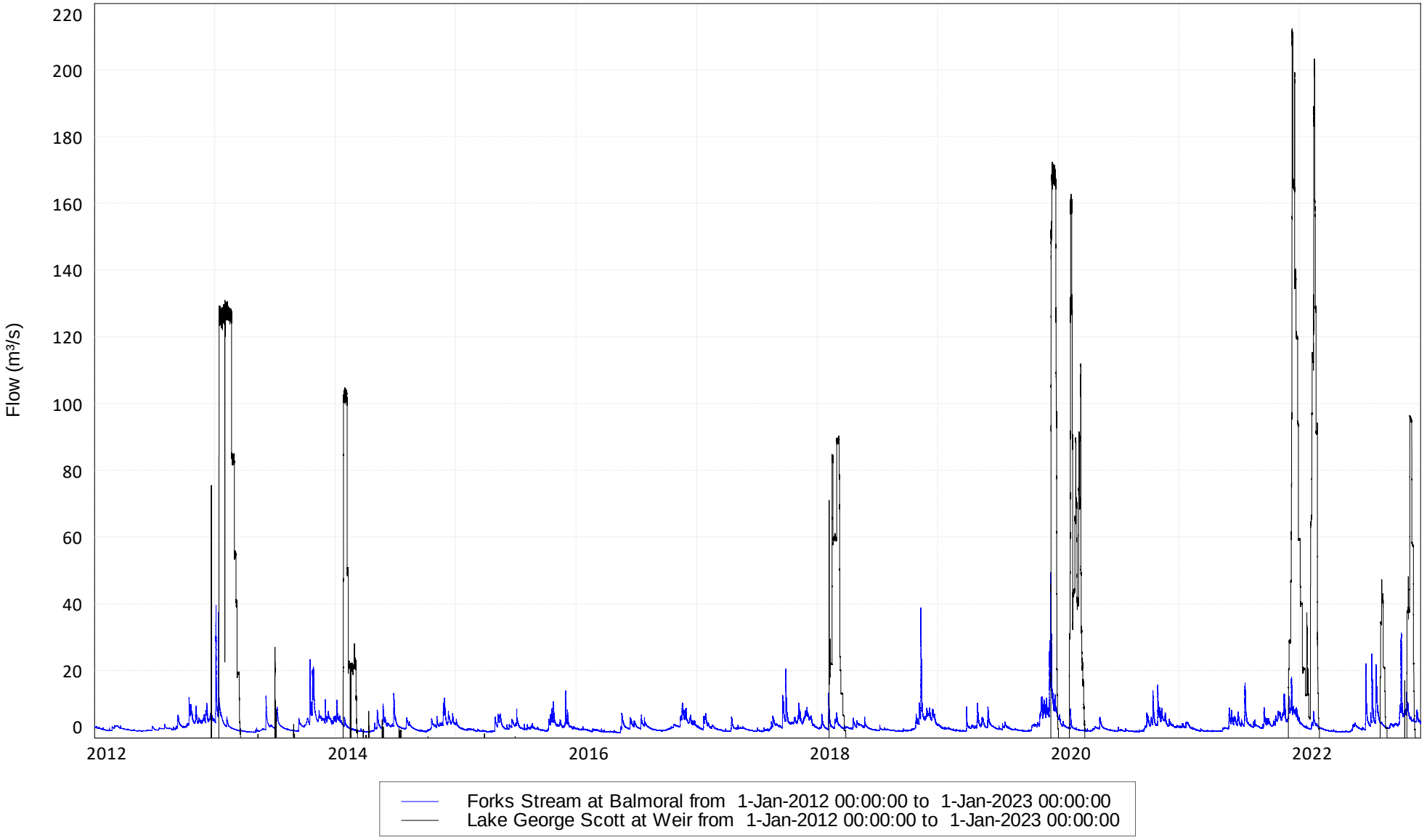


Figure C19: Fork Stream at Balmoral (increased by 0.6 m³/s) and Lake George Scott Weir flows (0-220 m³/s, 2012 - 2020)

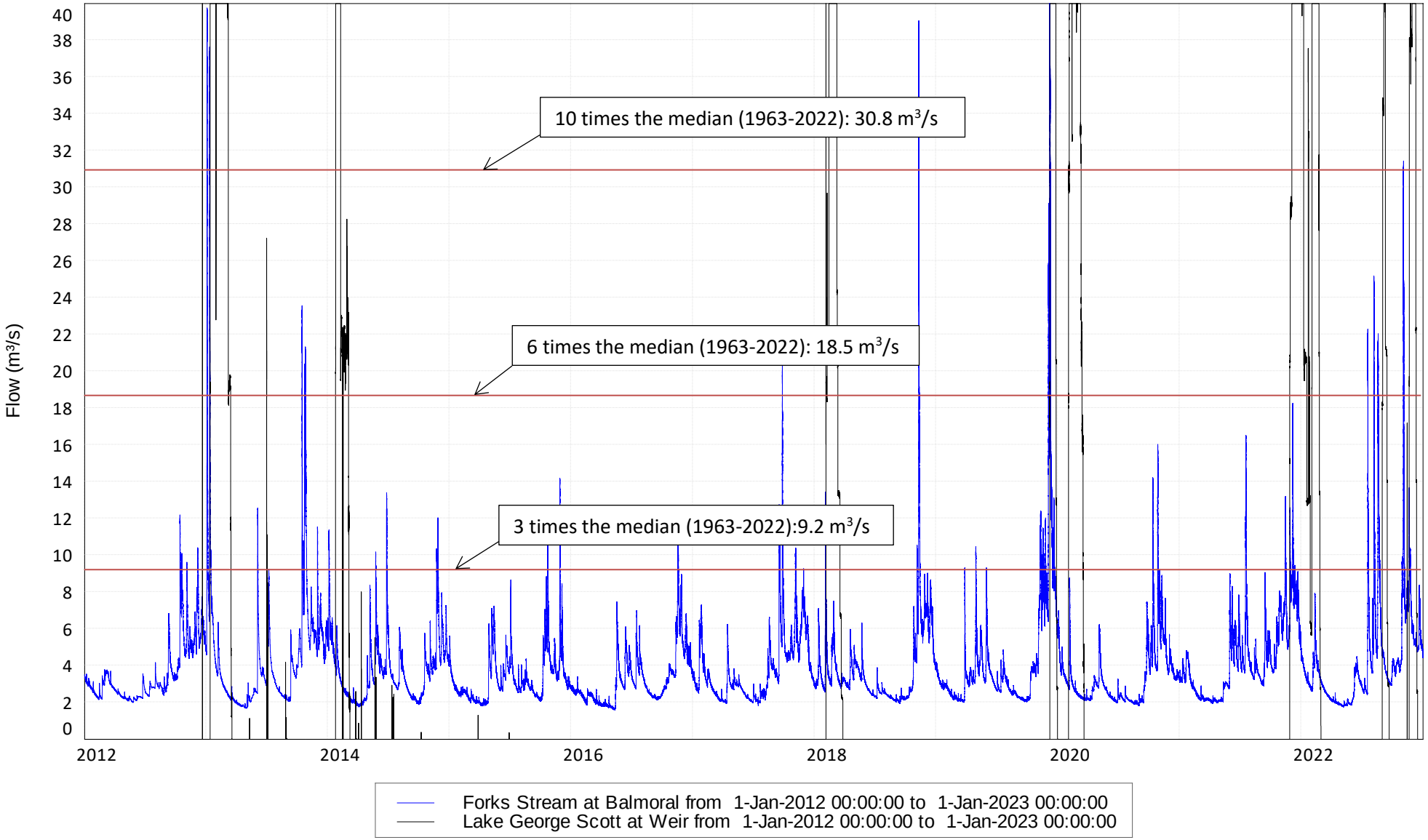


Figure C20: Fork Stream at Balmoral (increased by 0.6 m³/s) and Lake George Scott Weir flows (0-40 m³/s, 2012 - 2020)

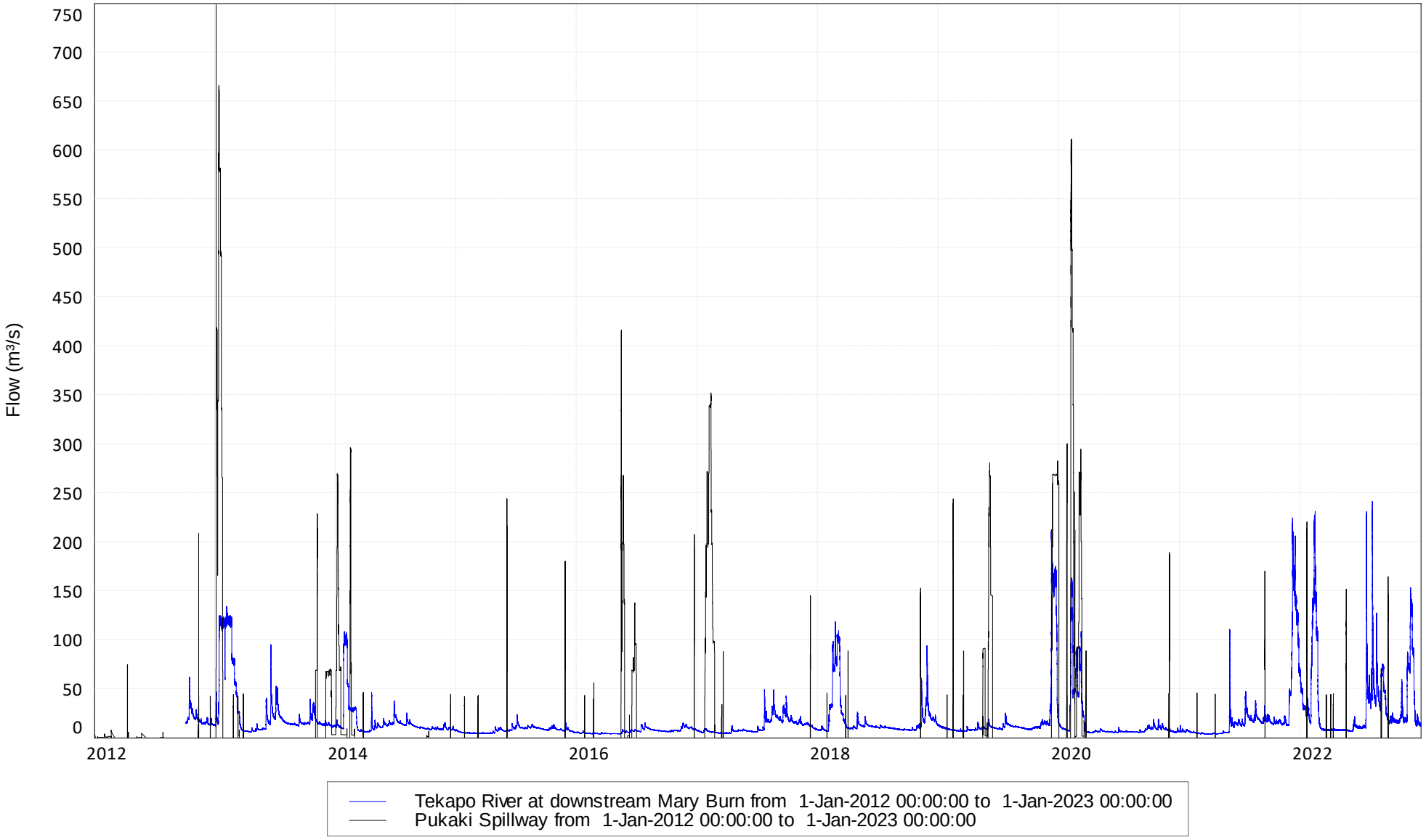


Figure C21: Tekapo River at downstream Mary Burn and Pukaki Spillway flows (0-750 m³/s, 2012 - 2020)

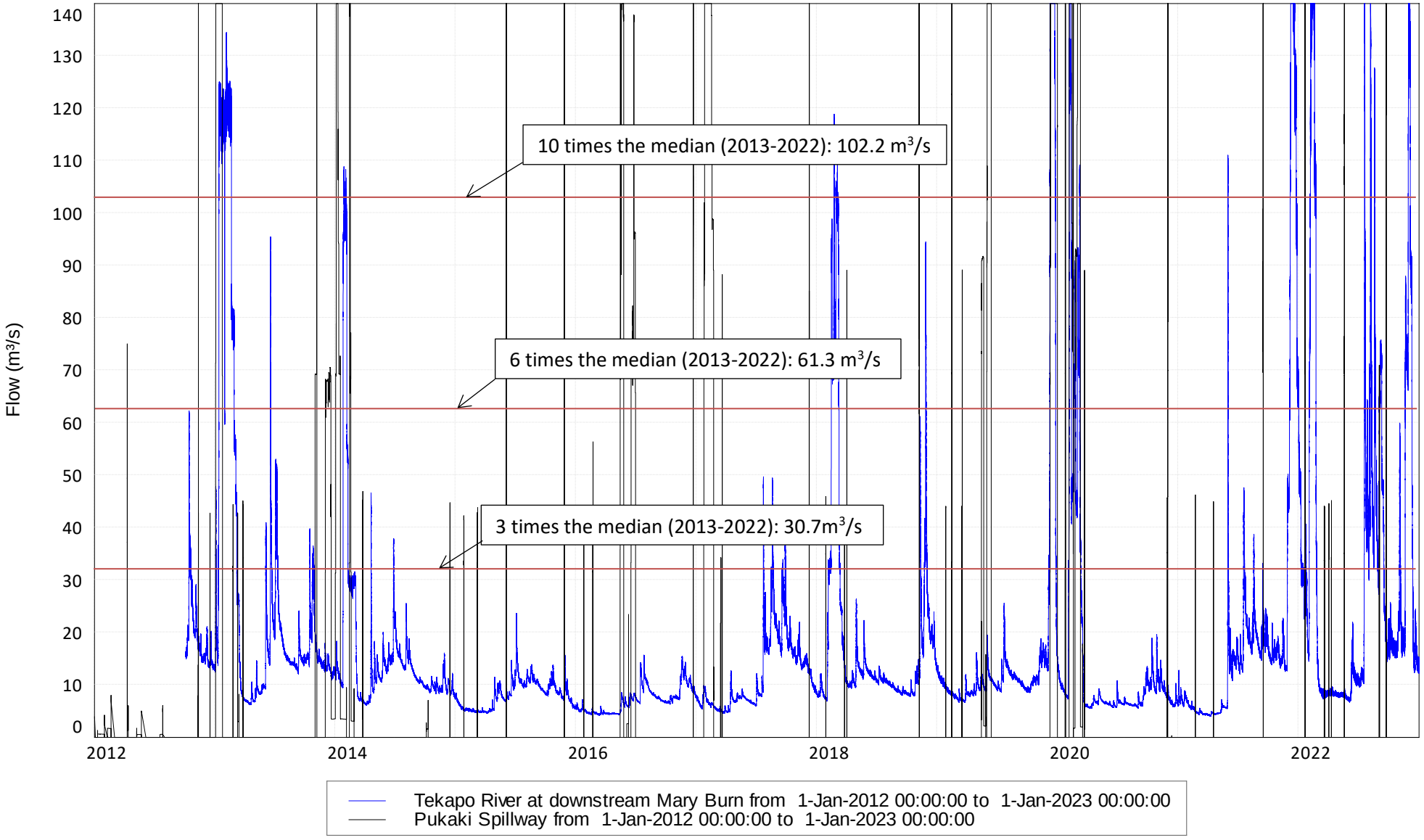


Figure C22: Tekapo River at downstream Mary Burn and Pukaki Spillway flows (0-140 m³/s, 2012 - 2020)

Appendix D: Tekapo Canal Hydrology Figures

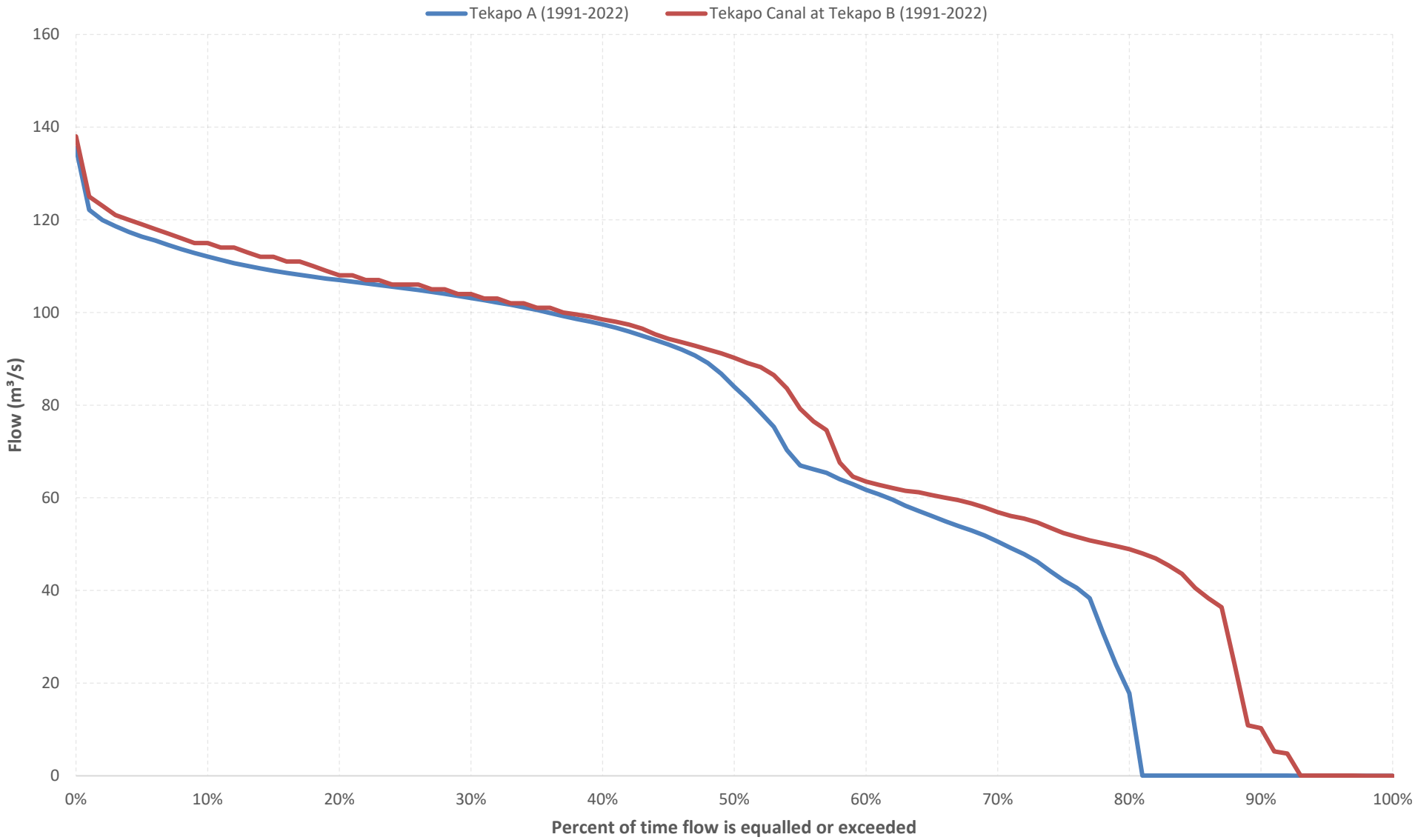


Figure D1: Tekapo A and Tekapo Canal flow duration curves



Figure D2: Tekapo A and Tekapo Canal mean monthly flows

Appendix E: Hydrogeology Maps

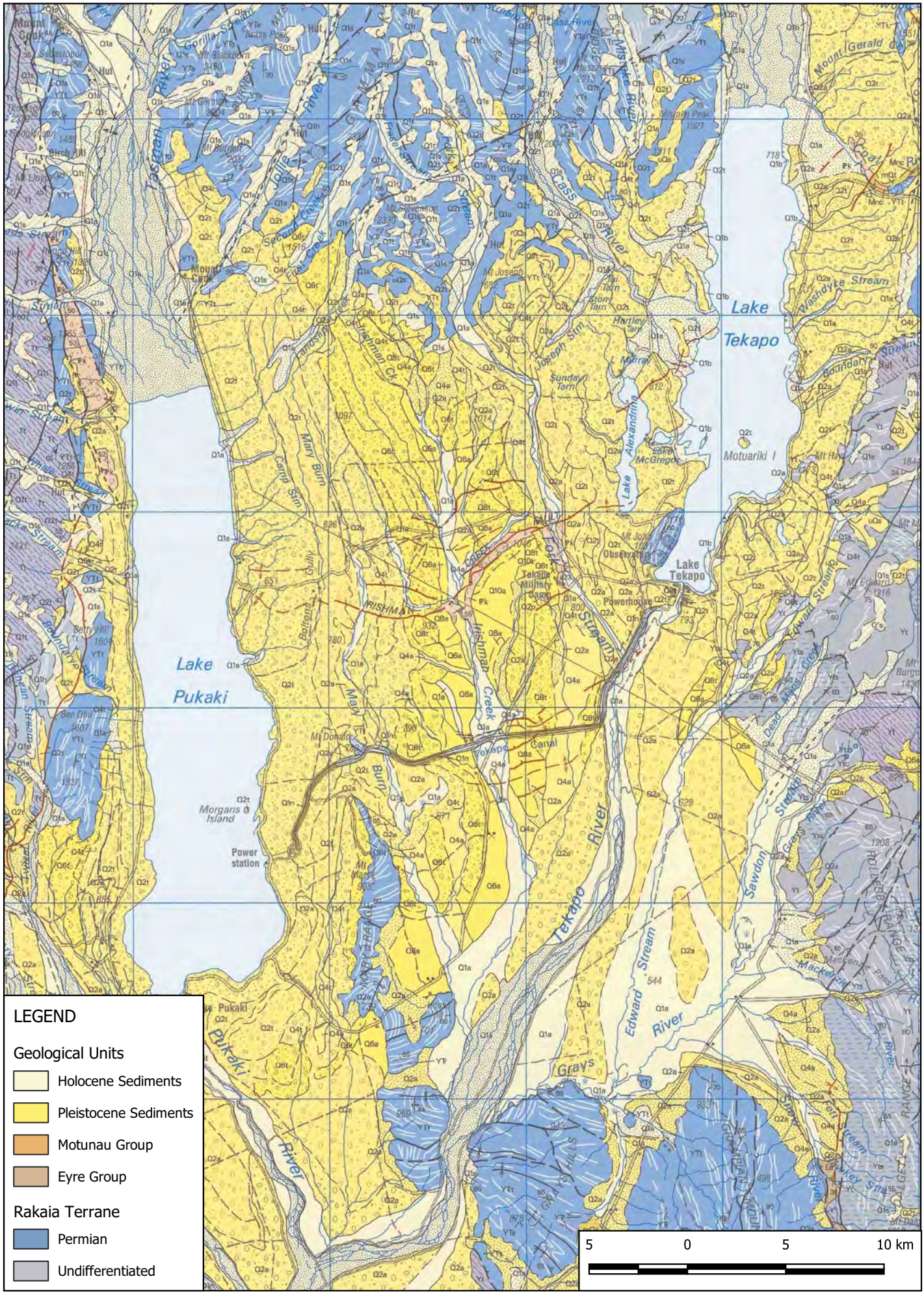


FIGURE E1: GEOLOGICAL MAP FROM COX AND BARREL (2007)

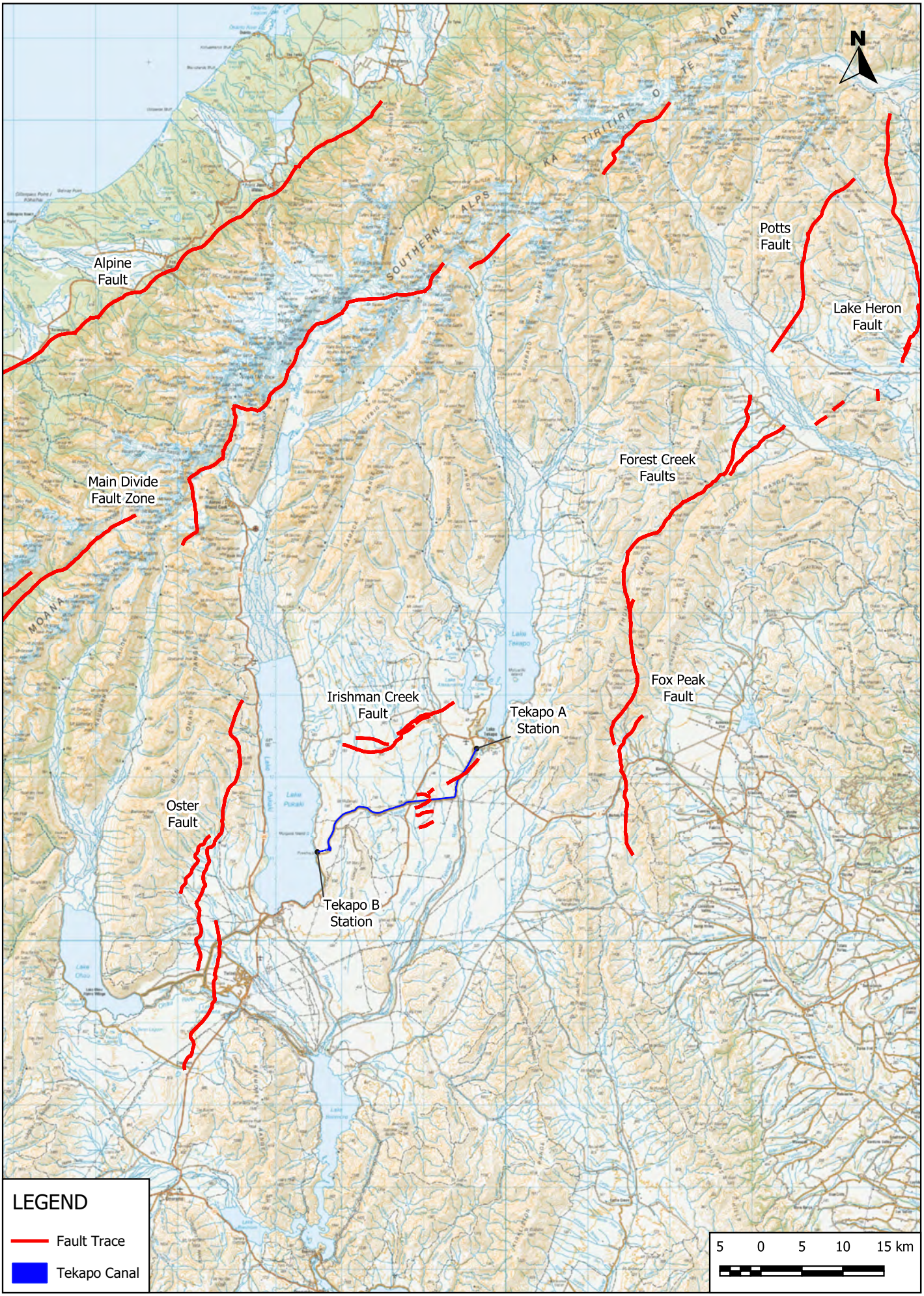
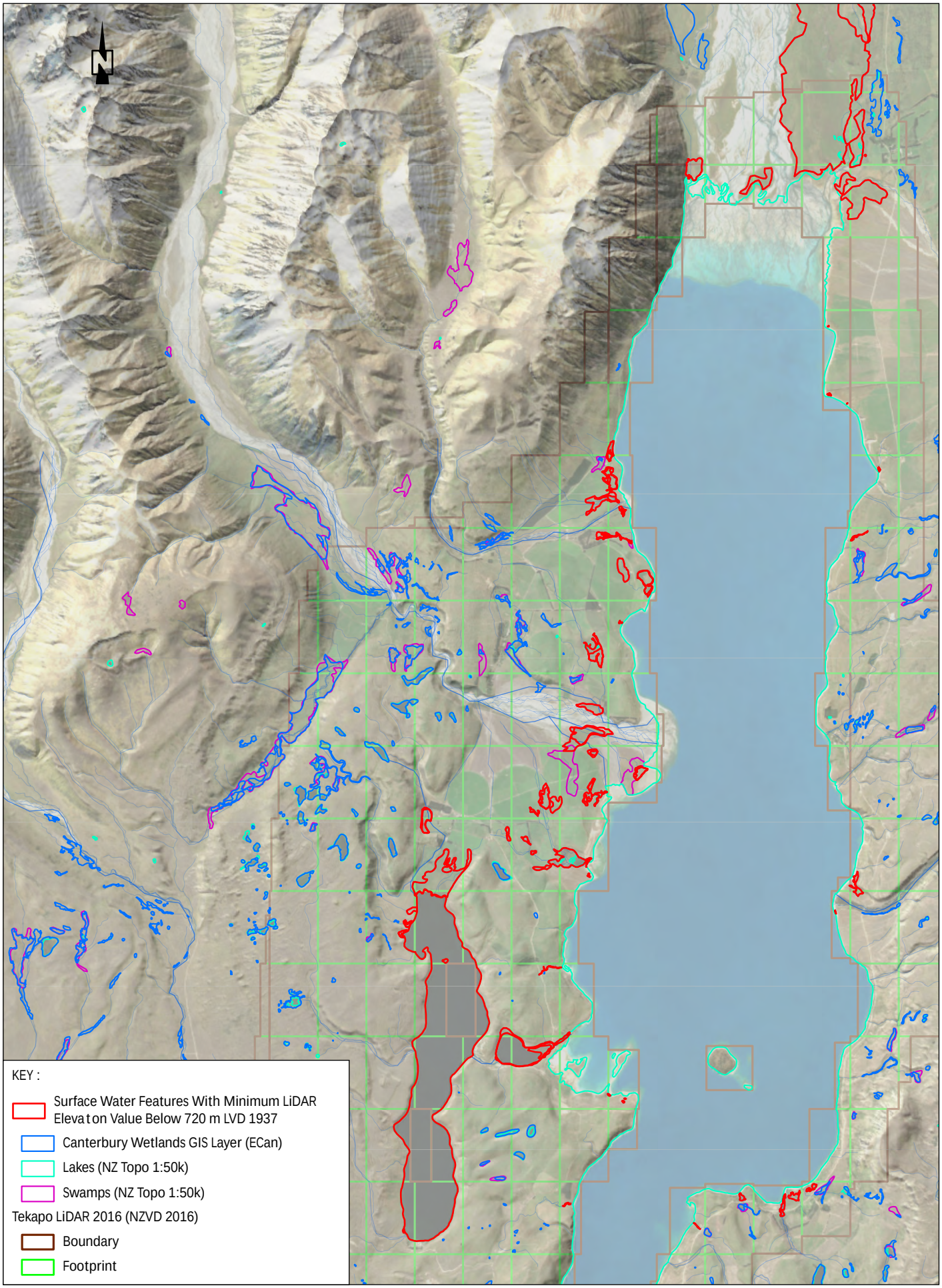


FIGURE E2: FAULTS IN THE TEKAPO AREA - ADAPTED FROM GENESIS (2012)



SOURCE:
1. SATELLITE IMAGERY: LINZ Data Service
1. RIVERS: LINZ Data Service

FIGURE E3: LAKE TEKAPO AREA SURFACE WATER FEATURES BELOW 720 M ELEVATION (LVD 1937)

SCALE :1:100,000 (A4)
0 500 1,000 2,000 3,000
METRES

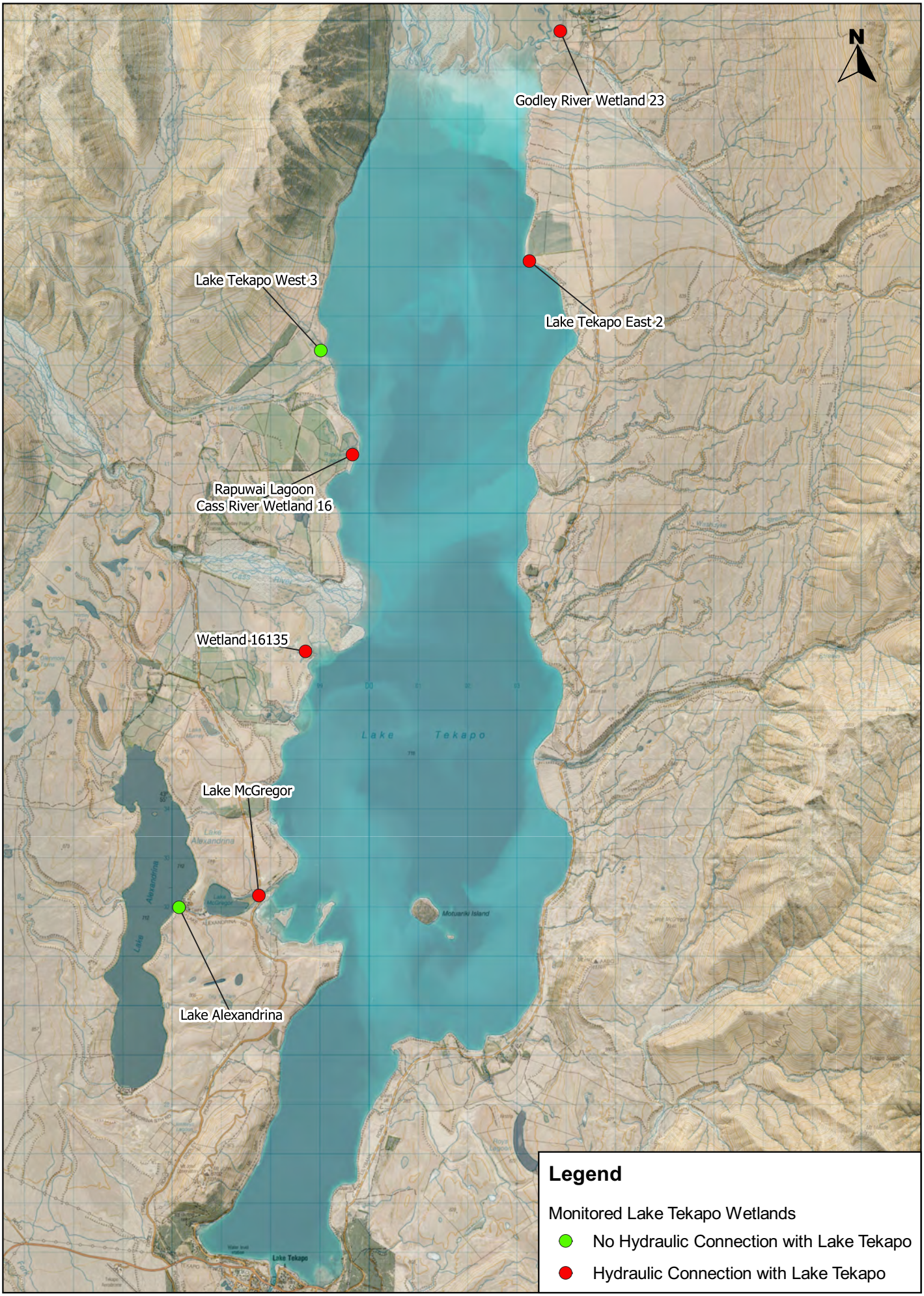
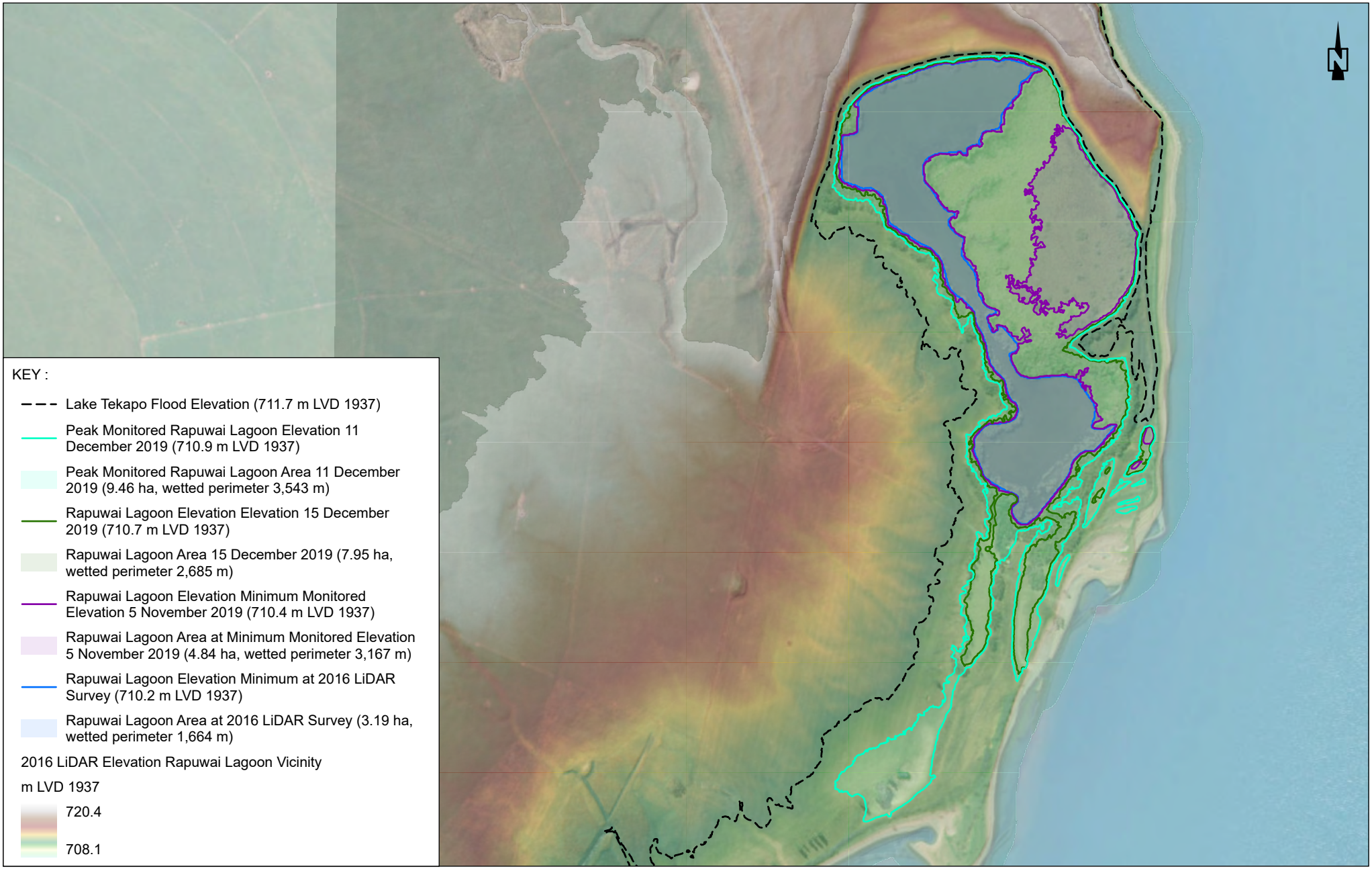


FIGURE E4: LAKE TEKAPO WETLANDS / WATER BODIES MONITORED BY PDP

1:100000 (m)

0 1 2 3 4 km



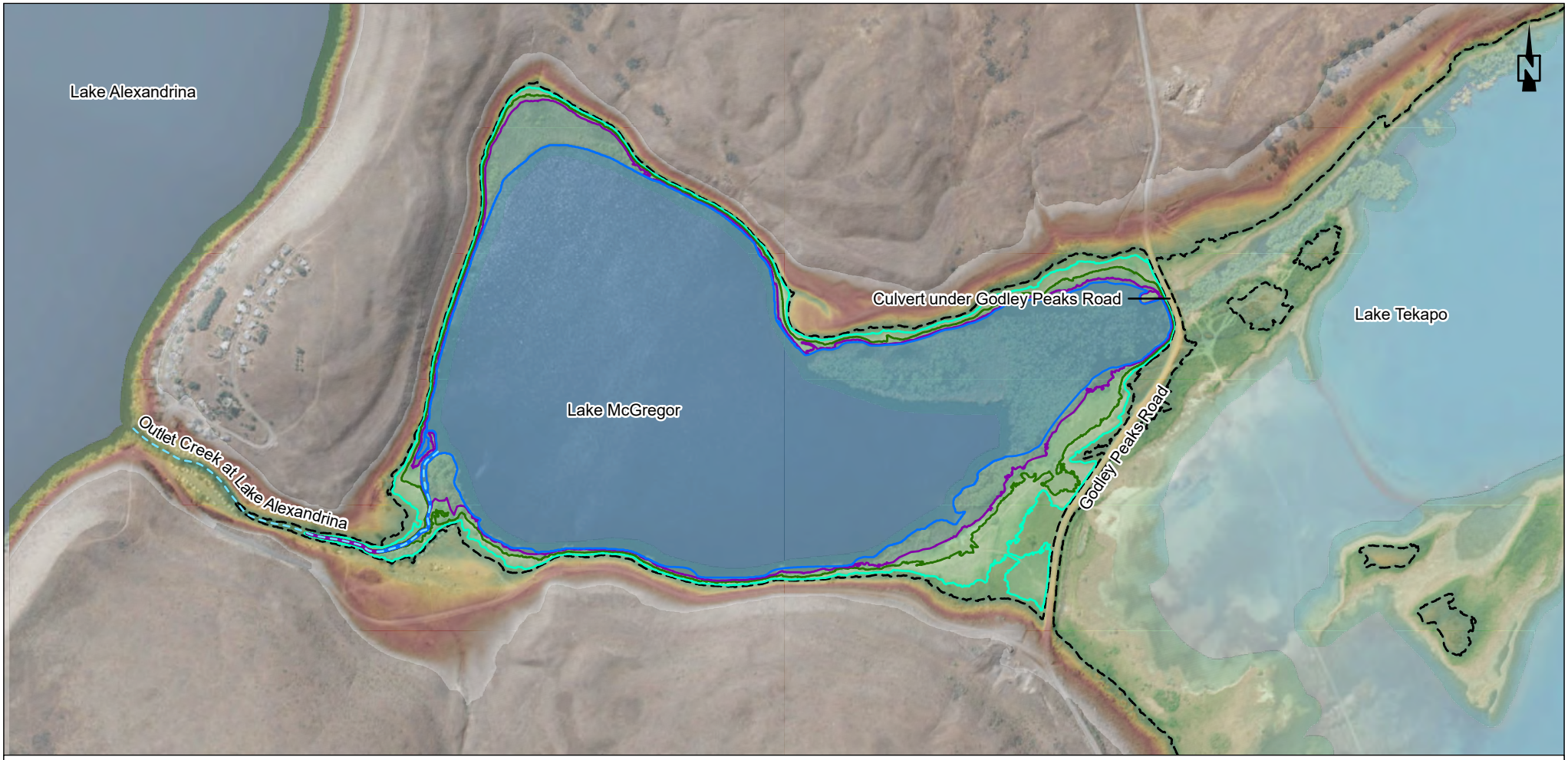
SOURCE:
1. AERIAL IMAGERY: LINZ

SCALE : 1:5,000 (A4)

0 25 50 100 150

METRES

FIGURE E5: RAPUWAI LAGOON WETTED AREA



KEY :

- Lake Tekapo Flood Elevation (711.7 m LVD 1937)
- Peak Lake McGregor Elevation 11 December 2019 (710.9 m LVD 1937)
- Peak Lake McGregor Area 11 December 2019 (54.40 ha, wetted perimeter 4,777 m)
- Lake McGregor Elevation 18 June 2020 (709.9 m LVD 1937)
- Lake McGregor Area 18 June 2020 (50.26 ha, wetted perimeter 4,576 m)
- Minimum Monitored Elevation of Lake McGregor 28 November 2019 (709.2 m LVD 1937)
- Minimum Monitored Lake McGregor Area 28 November 2019 (47.26 ha, wetted perimeter 4,563 m)
- Elevation of Lake McGregor at 2016 LiDAR Survey (709.0 m LVD 1937)
- Lake McGregor Area at 2016 LiDAR Survey (43.52 ha, wetted perimeter 4,042 m)

2016 LiDAR Elevation Lake McGregor Vicinity

m LVD 1937

720.4

708.2

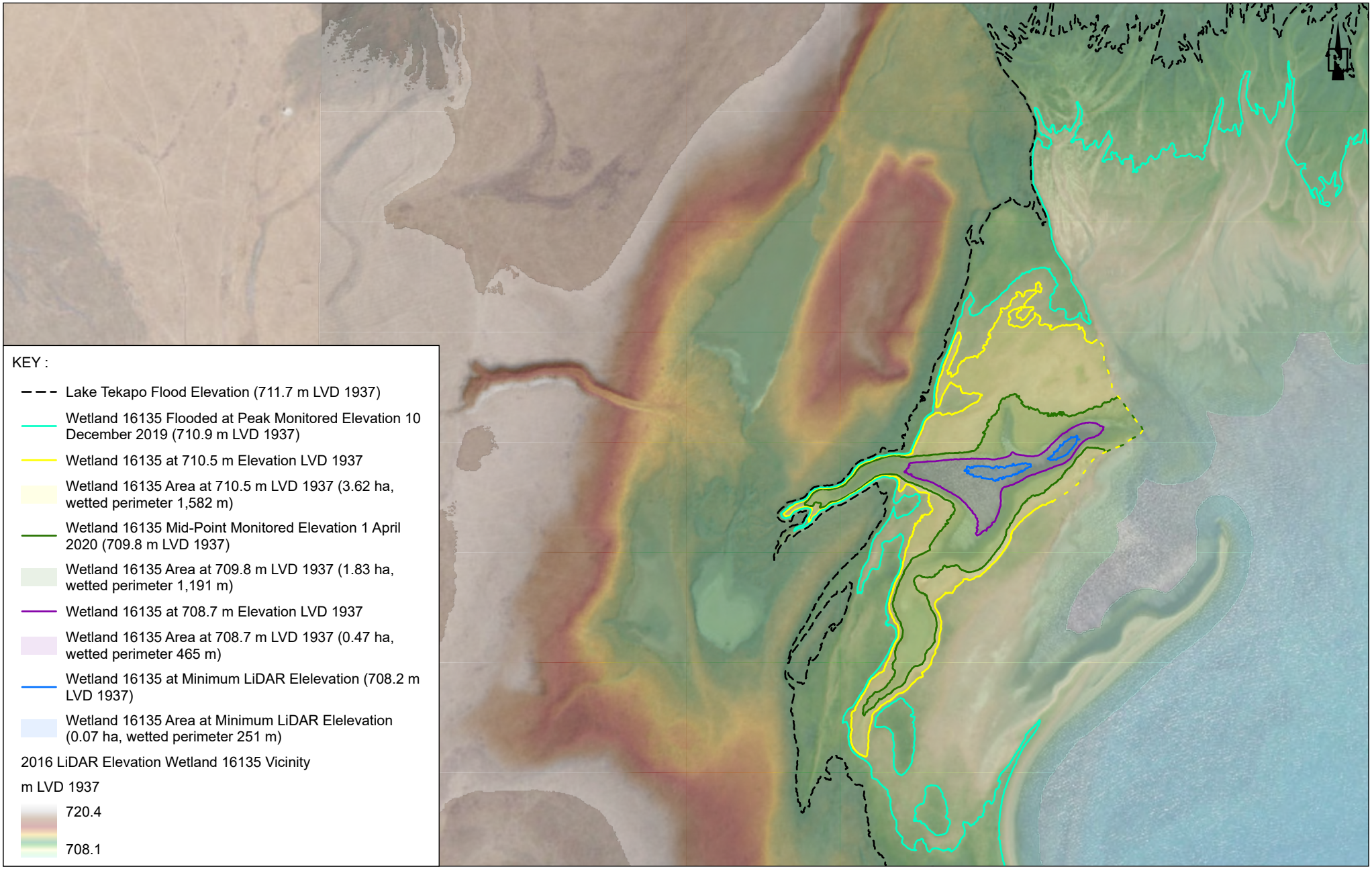
SOURCE:
1. AERIAL IMAGERY: LINZ

SCALE : 1:9,000 (A4)

0 50 100 200 300

METRES

FIGURE E6: LAKE MCGREGOR WETTED AREA



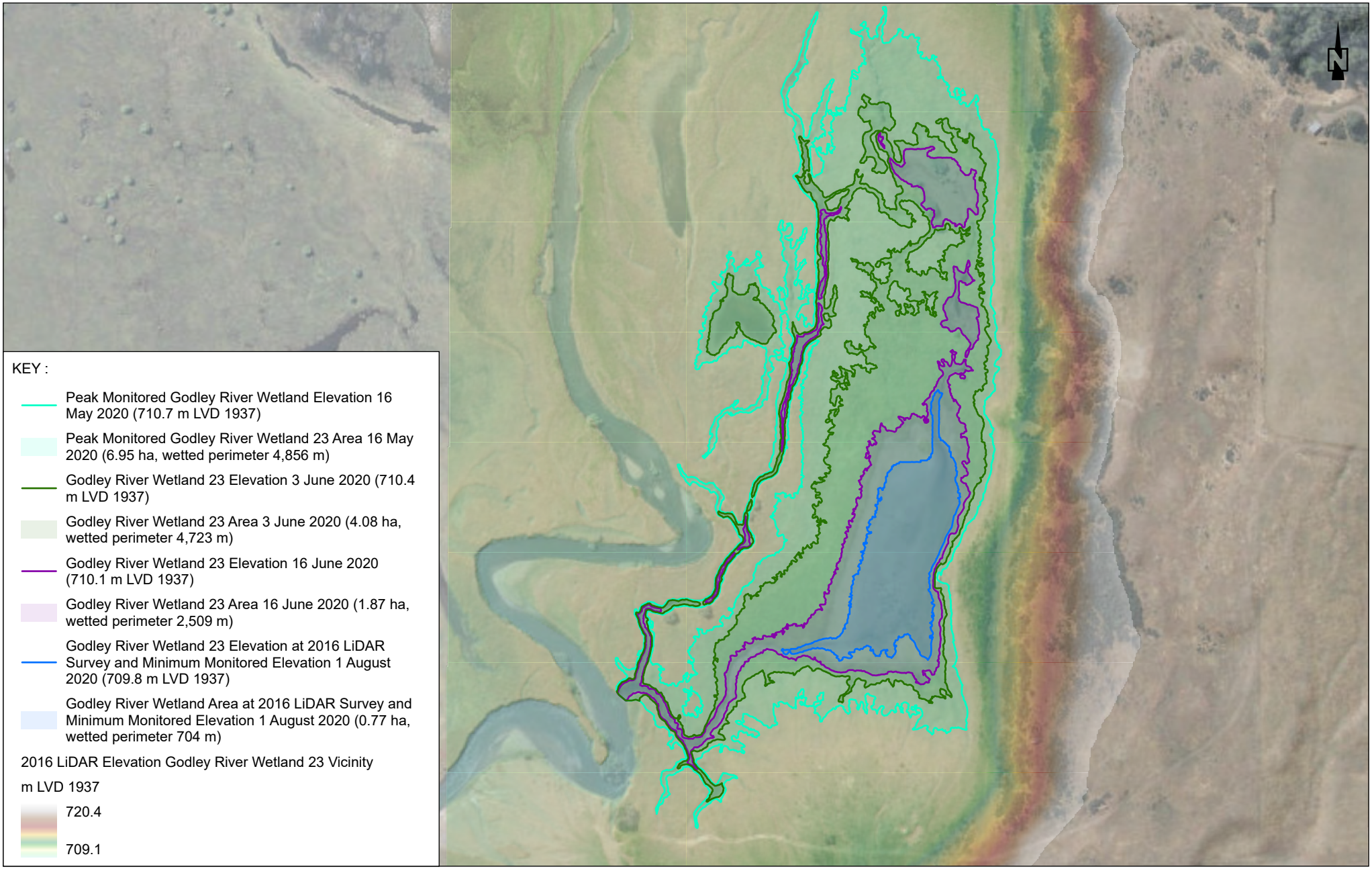
SOURCE:
1. AERIAL IMAGERY: LINZ

FIGURE E7: WETLAND 16135 WETTED AREA

SCALE : 1:4,500 (A4)

0 25 50 100 150

METRES



SOURCE:
1. AERIAL IMAGERY: LINZ

FIGURE E8: GODLEY RIVER WETLAND 23 WETTED AREA

SCALE : 1:3,500 (A4)

0 25 50 100 150
METRES



SOURCE:
1. AERIAL IMAGERY: LINZ

FIGURE E9: LAKE TEKAPO EAST 2 WETLAND WETTED AREA

SCALE : 1:1,500 (A4)

0 10 20 40 60
METRES

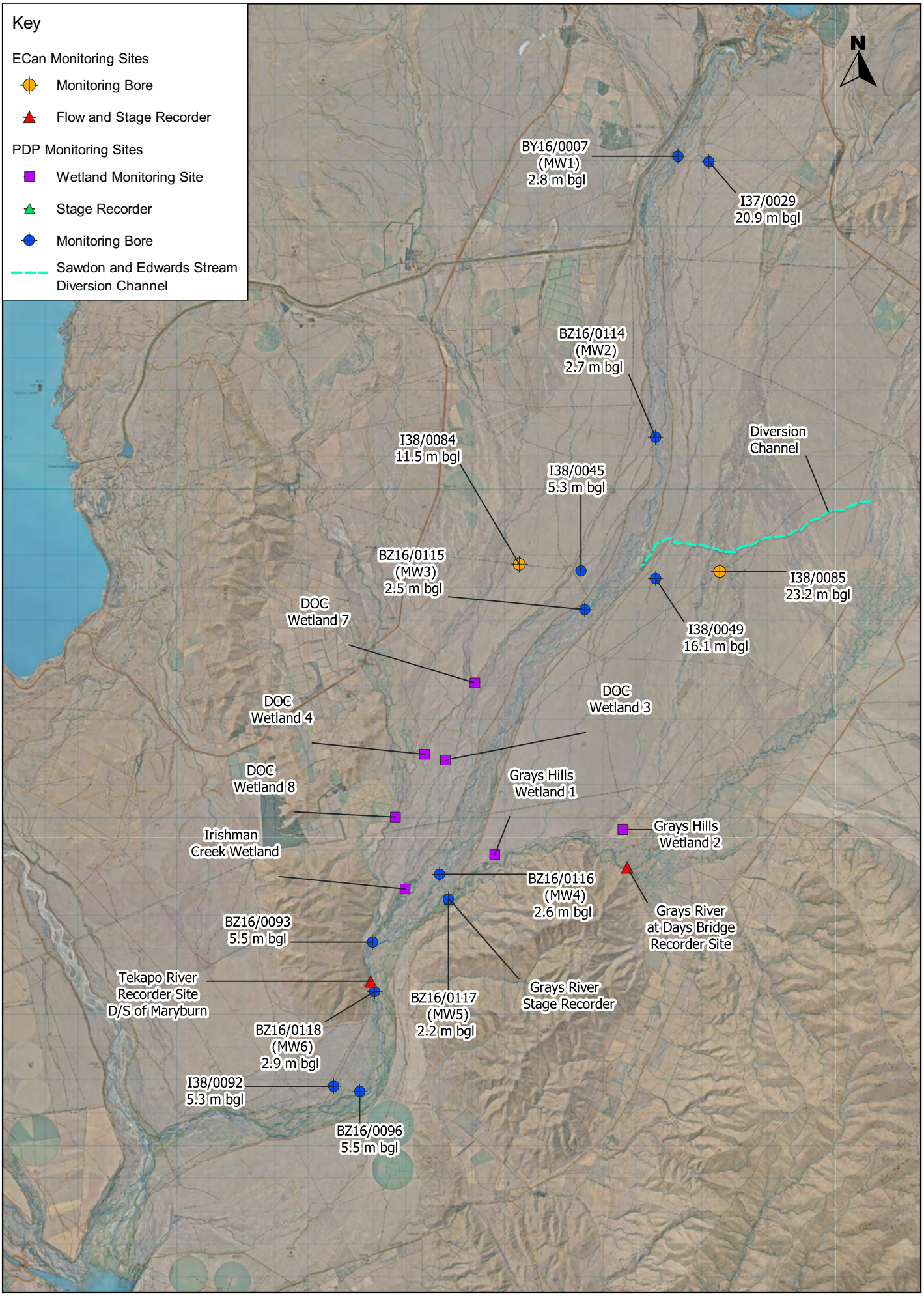
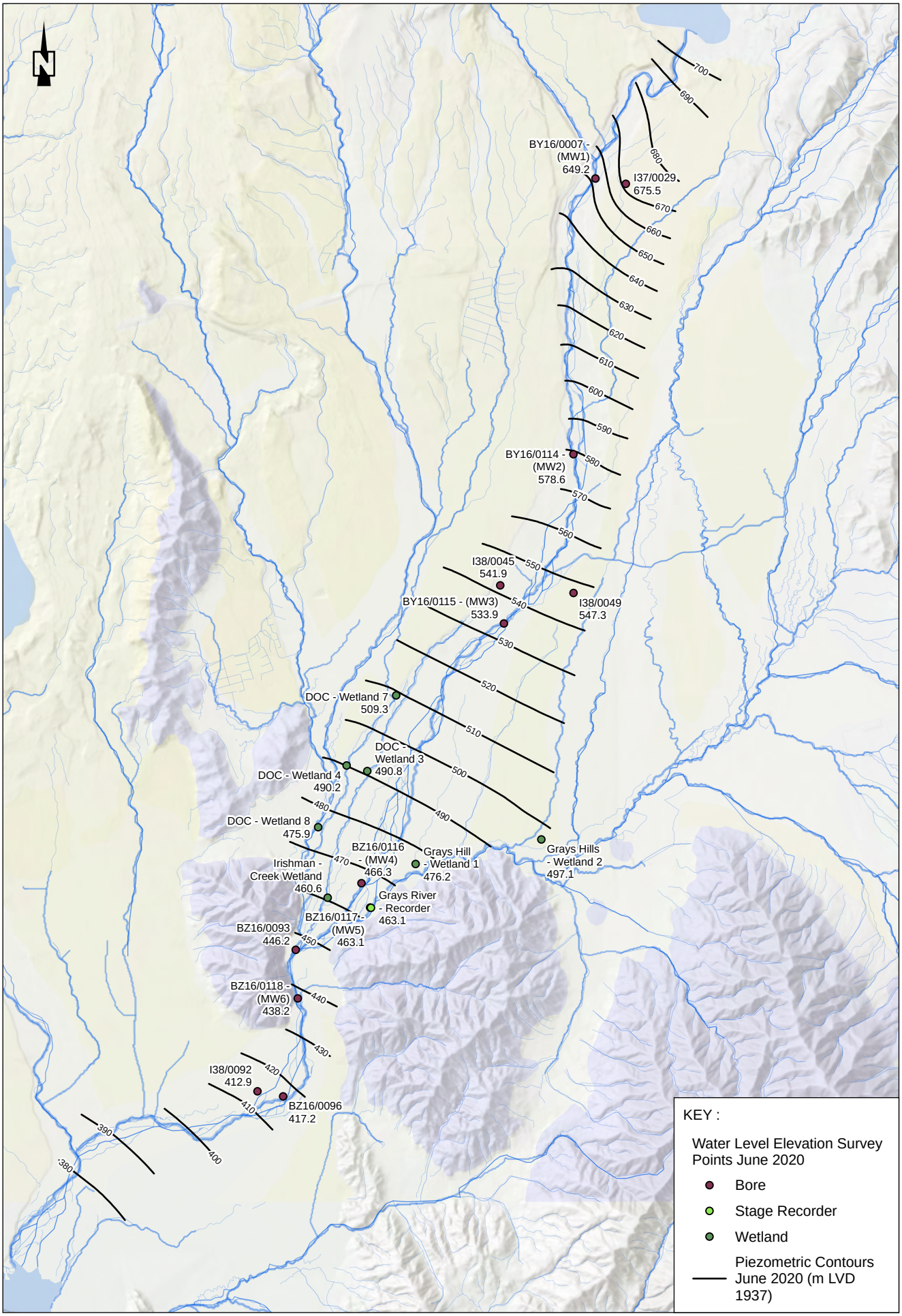


FIGURE E10: TEKAPO RIVER BASIN WATER LEVEL SITES MONITORED AS PART OF RECONSENTING MONITORING

1:150000 m (A4)

0 1 2 3 4 5 km

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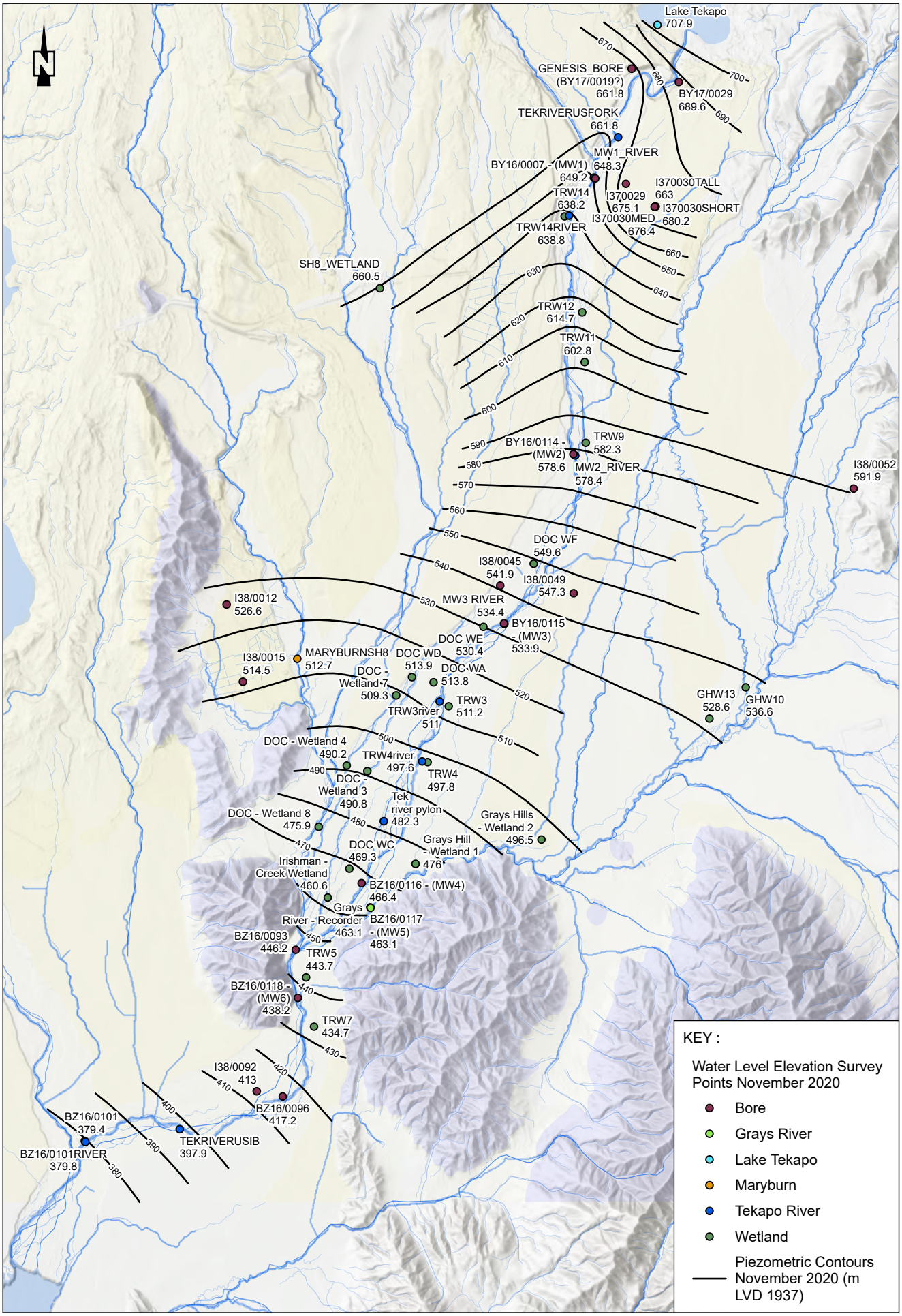


SOURCE:
1. SATELLITE IMAGERY: LINZ Data Service
2. RIVERS: LINZ Data Service
3. GEOLOGY: GNS

FIGURE E11: PIEZOMETRIC CONTOURS FOR THE TEKAPO RIVER BASIN MEASURED BETWEEN 3 AND 5 JUNE 2020

SCALE :1:160,000 (A4)

0 0.5 1 2 3
KM

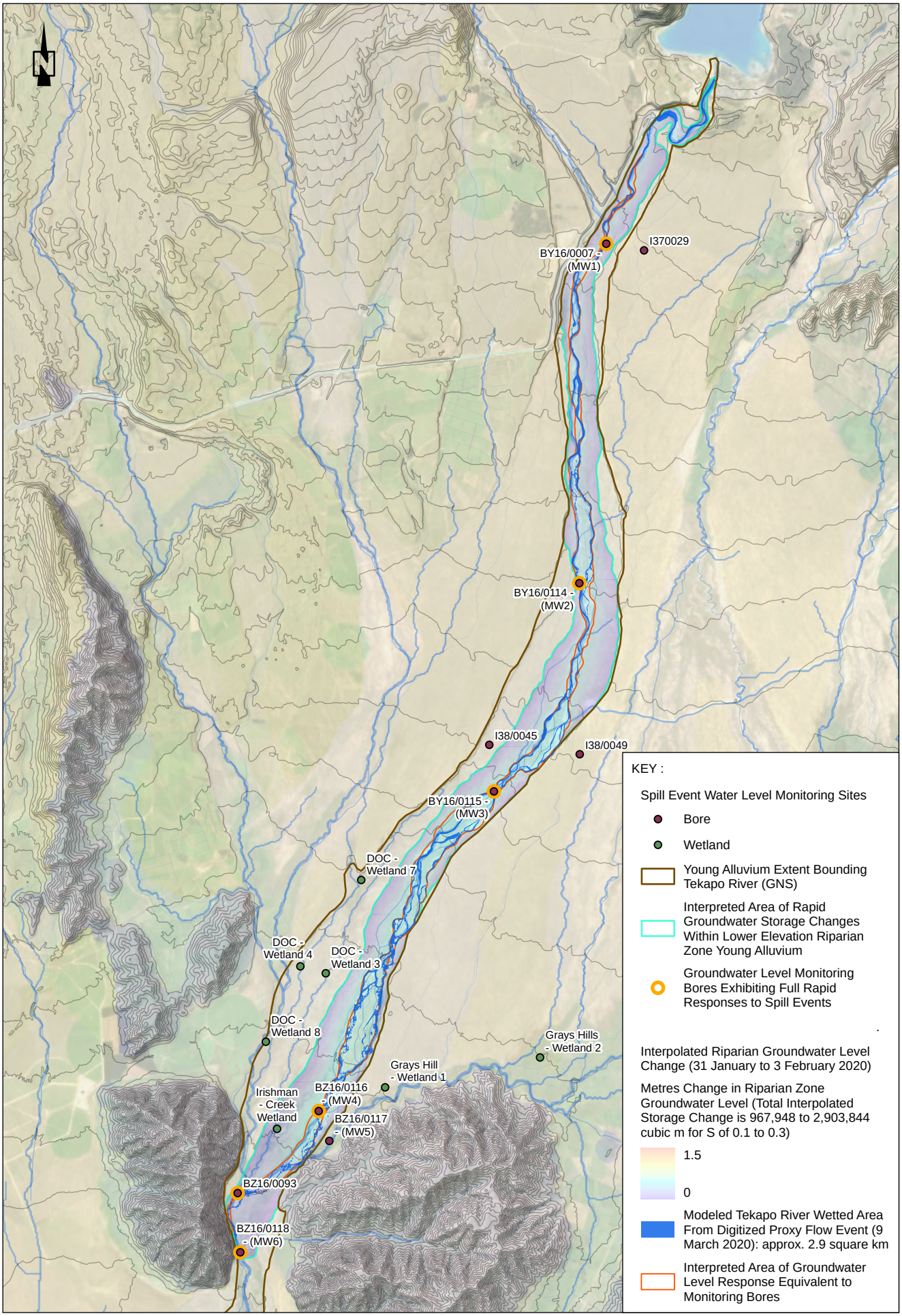


SOURCE:
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2. RIVERS: LINZ Data Service
3. GEOLOGY: GNS

FIGURE E12: PIEZOMETRIC CONTOURS FOR THE TEKAPO RIVER BASIN MEASURED BETWEEN 25 AND 27 NOVEMBER 2020

SCALE :1:160,000 (A4)

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KM

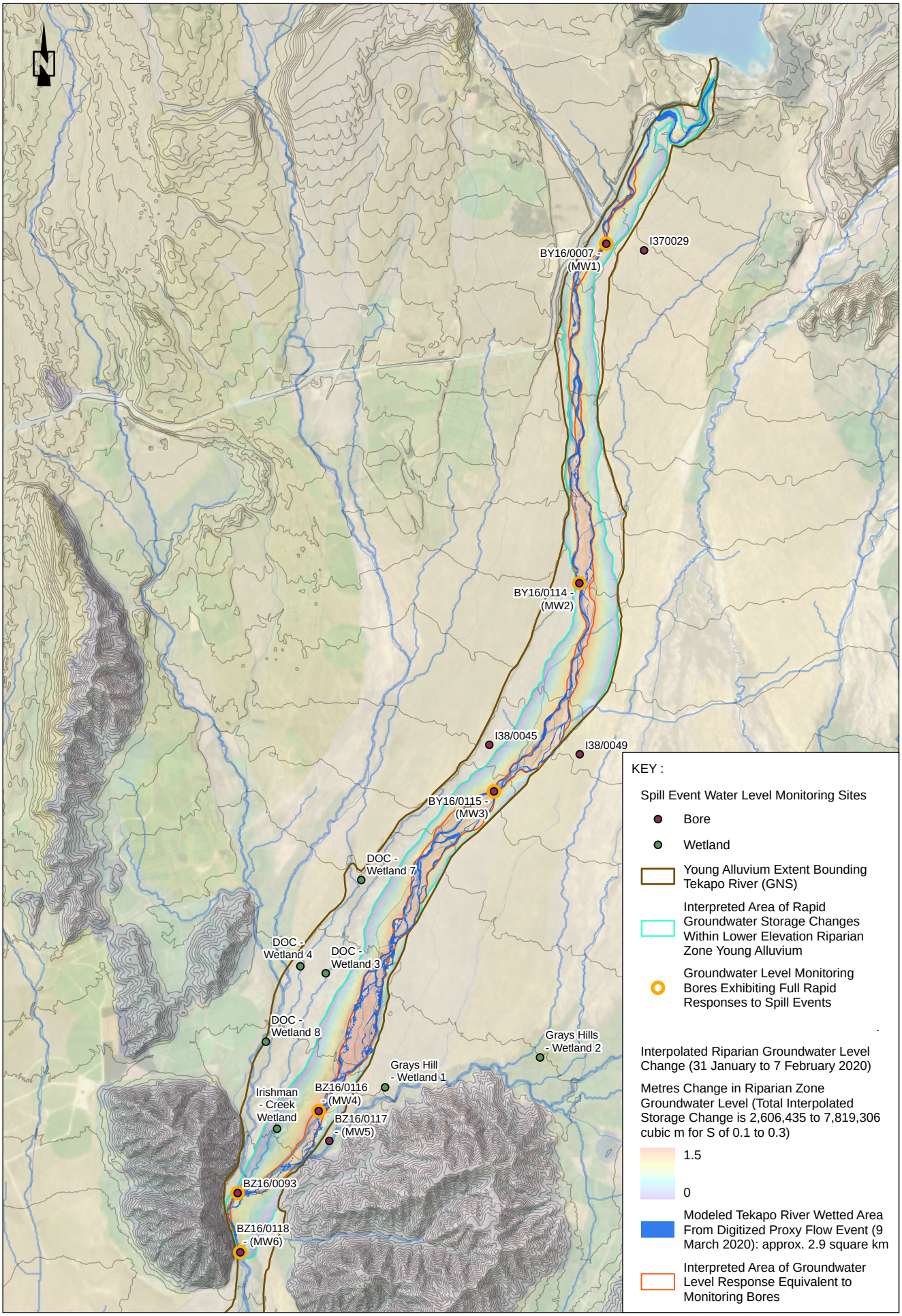


SOURCE:
1. SATELLITE IMAGERY: LINZ Data Service
2. RIVERS: LINZ Data Service
3. GEOLOGY: GNS

FIGURE E13: RIPARIAN ZONE GROUNDWATER STORAGE CHANGE FIRST STAGE FEBRUARY 2020 SPILL EVENT

SCALE :1:130,000 (A4)

0 0.5 1 2 3
KM



SOURCE:
1. SATELLITE IMAGERY: LINZ Data Service
2. RIVERS: LINZ Data Service
3. GEOLOGY: GNS

FIGURE E14: RIPARIAN ZONE GROUNDWATER STORAGE CHANGE PEAK FEBRUARY 2020 SPILL EVENT

SCALE :1:130,000 (A4)

0 0.5 1 2 3
KM

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Appendix F: Lake Tekapo Hydrogeology Figures



FIGURE F1A: LAKE ALEXANDRINA WATER LEVEL MONITORING SITE



FIGURE F1B: LAKE MCGREGOR WATER LEVEL MONITORING SITE



FIGURE F1C: WETLAND 16135 WATER LEVEL MONITORING SITE



FIGURE F1D: RAPUWAI LAGOON WATER LEVEL MONITORING SITE



FIGURE F1E: LAKE TEKAPO WEST 3 WETLAND WATER LEVEL MONITORING SITE



FIGURE F1F: LAKE TEKAPO EAST 3 WATER LEVEL MONITORING SITE



FIGURE F1G: GODLEY RIVER WETLAND 23 WATER LEVEL MONITORING SITE

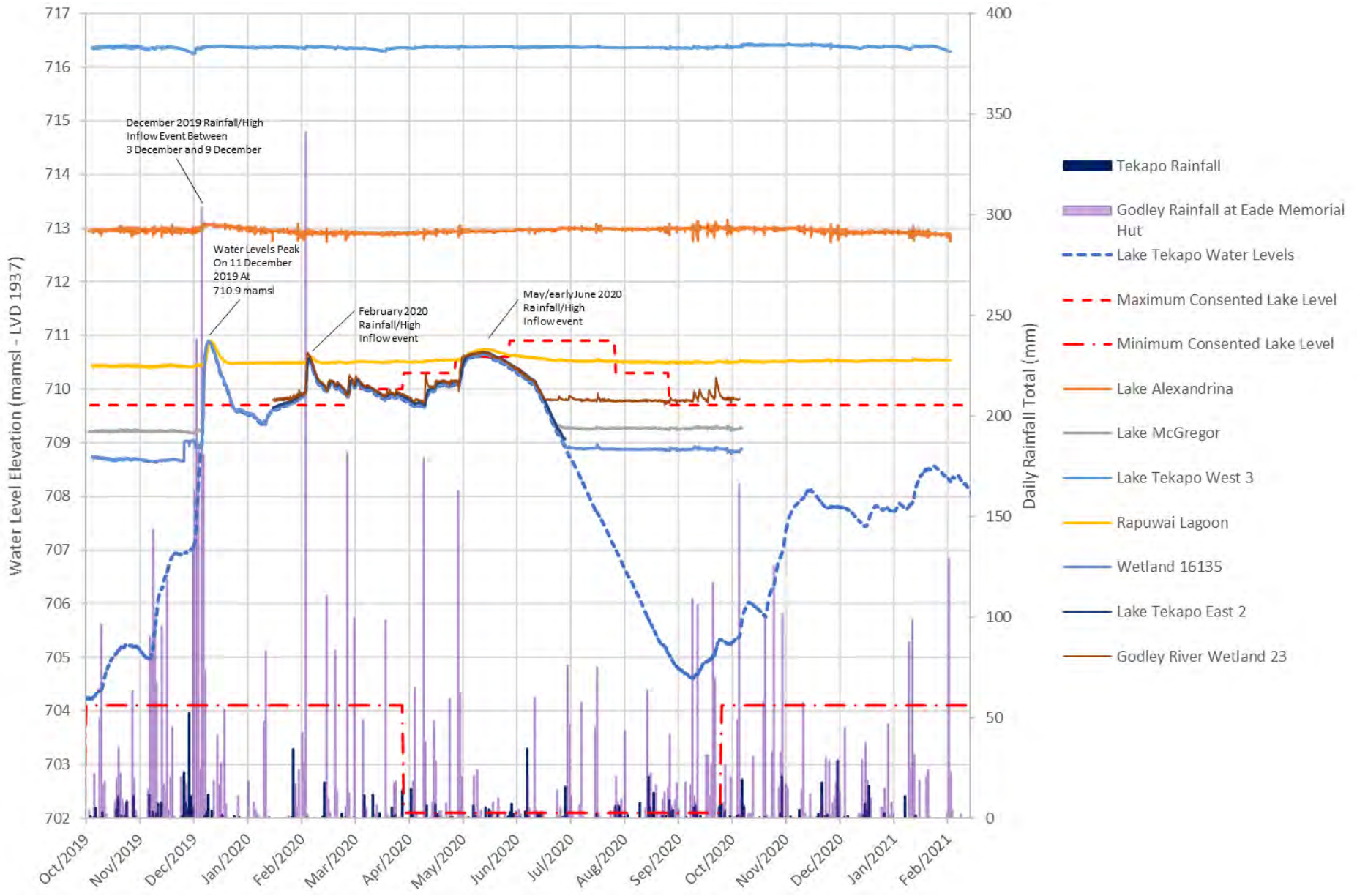


FIGURE F2: MEASURED WATER LEVELS FOR LAKE TEKAPO AND SELECTED WETLANDS/WATER BODIES

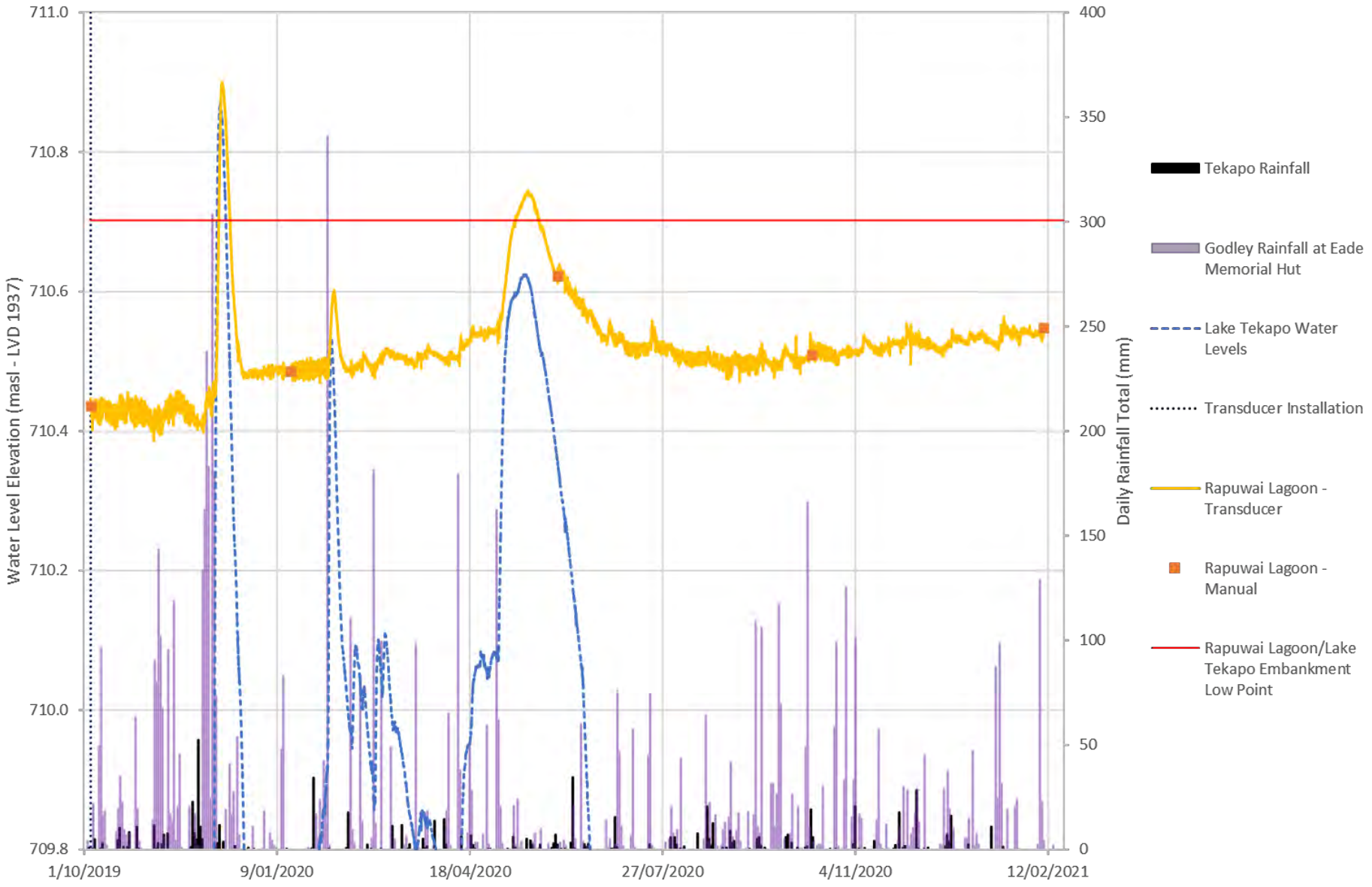


FIGURE F3: MEASURED WATER LEVELS FOR RAPUWAI LAGOON

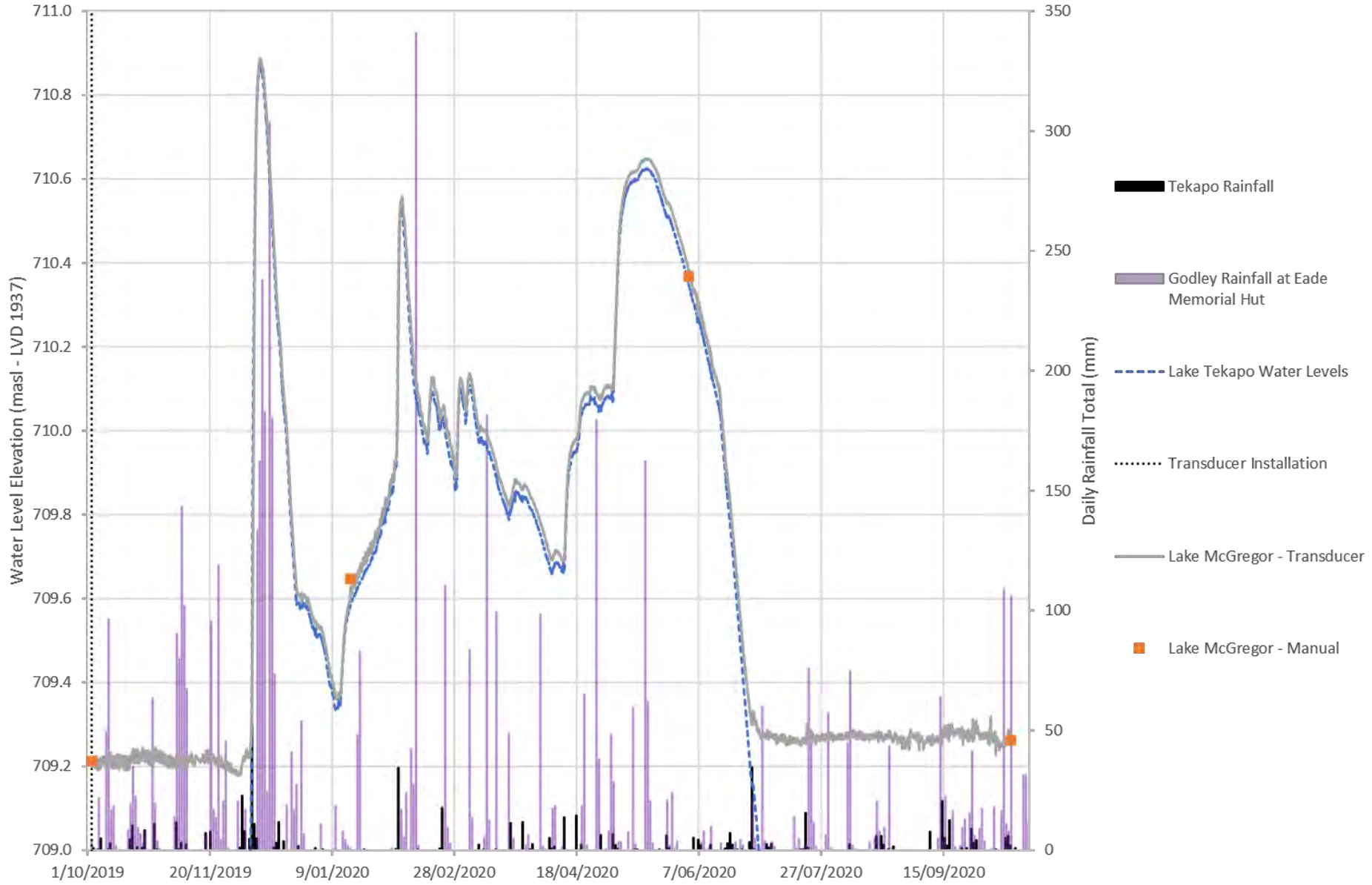


FIGURE F4: MEASURED WATER LEVELS FOR LAKE MCGREGOR

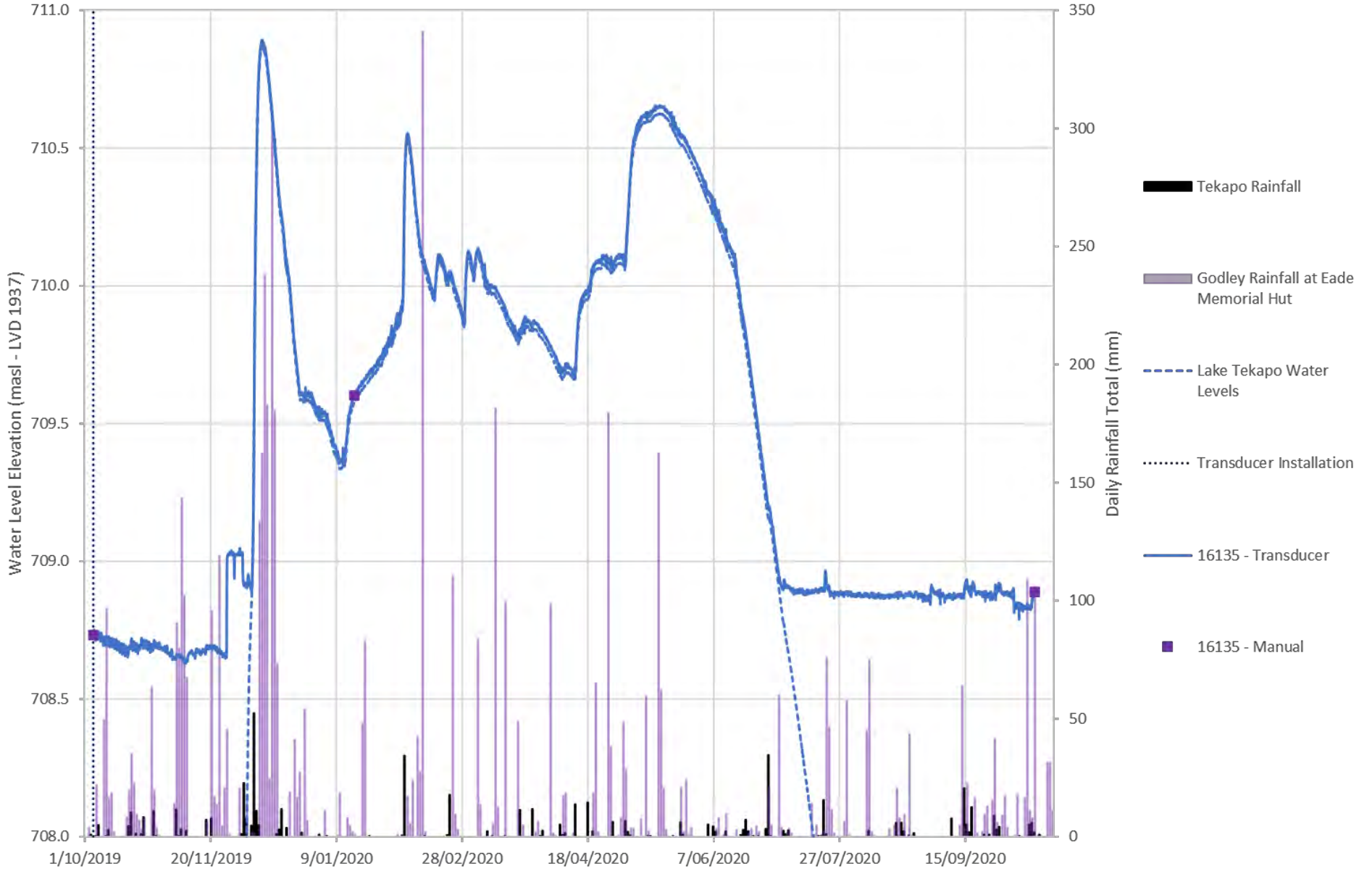


FIGURE F5: MEASURED WATER LEVELS FOR WETLAND 16135

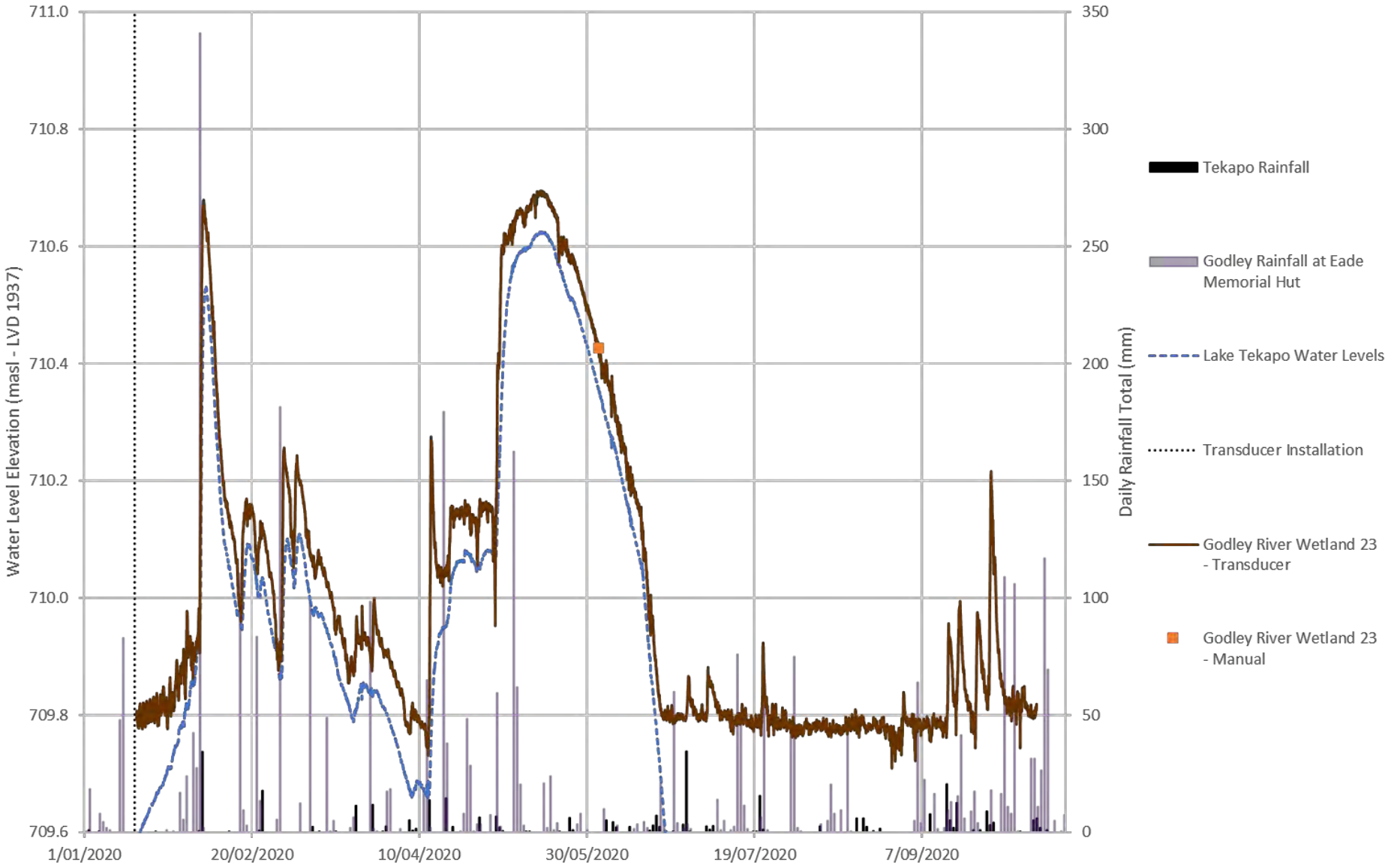


FIGURE F6: MEASURED WATER LEVELS FOR GODLEY RIVER WETLAND 23

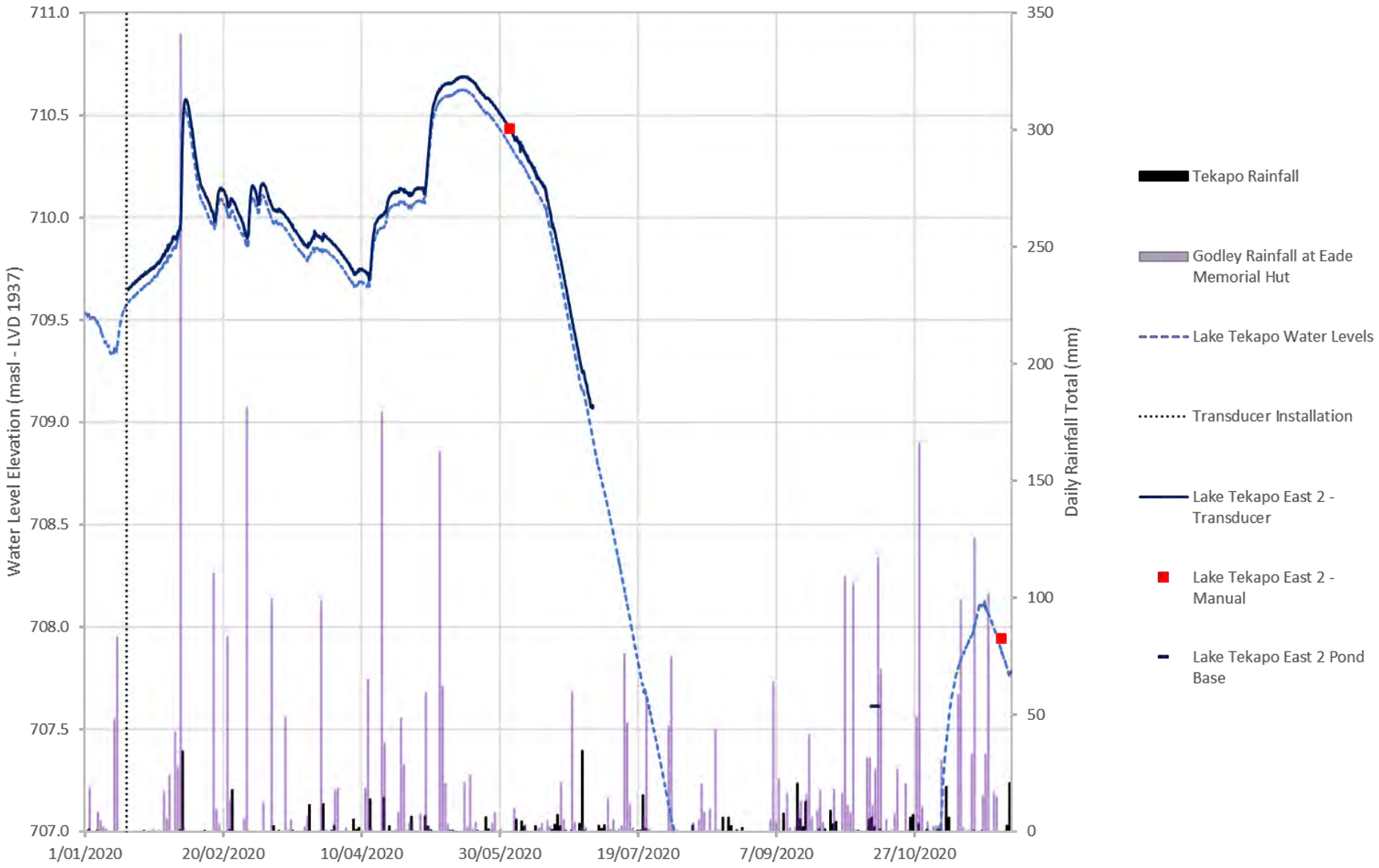


FIGURE F7: MEASURED WATER LEVELS FOR WETLAND LAKE TEKAPO EAST 2

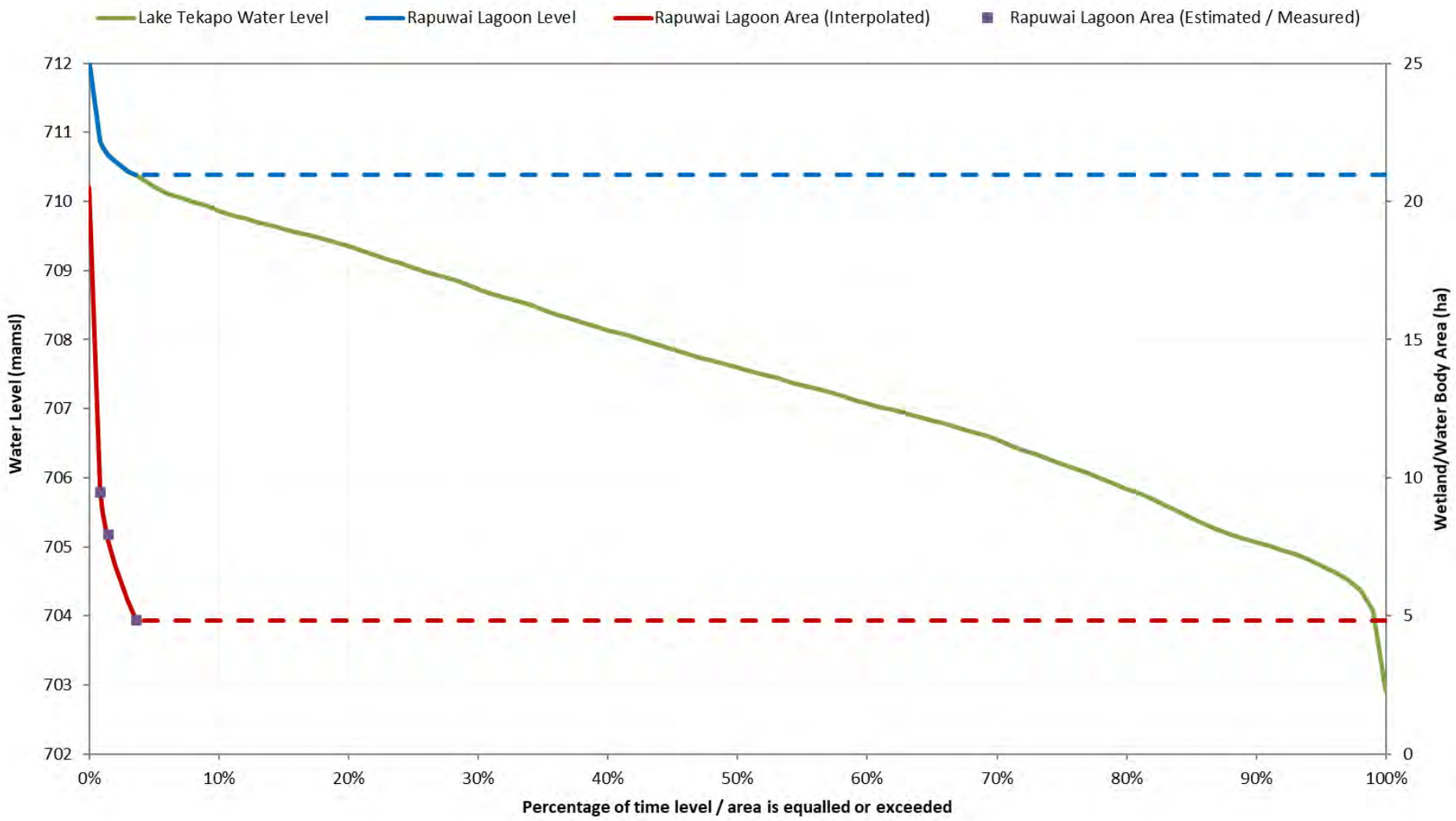


FIGURE F8: RAPUWAI LAGOON WETTED ELEVATION AND AREA DURATION CURVES

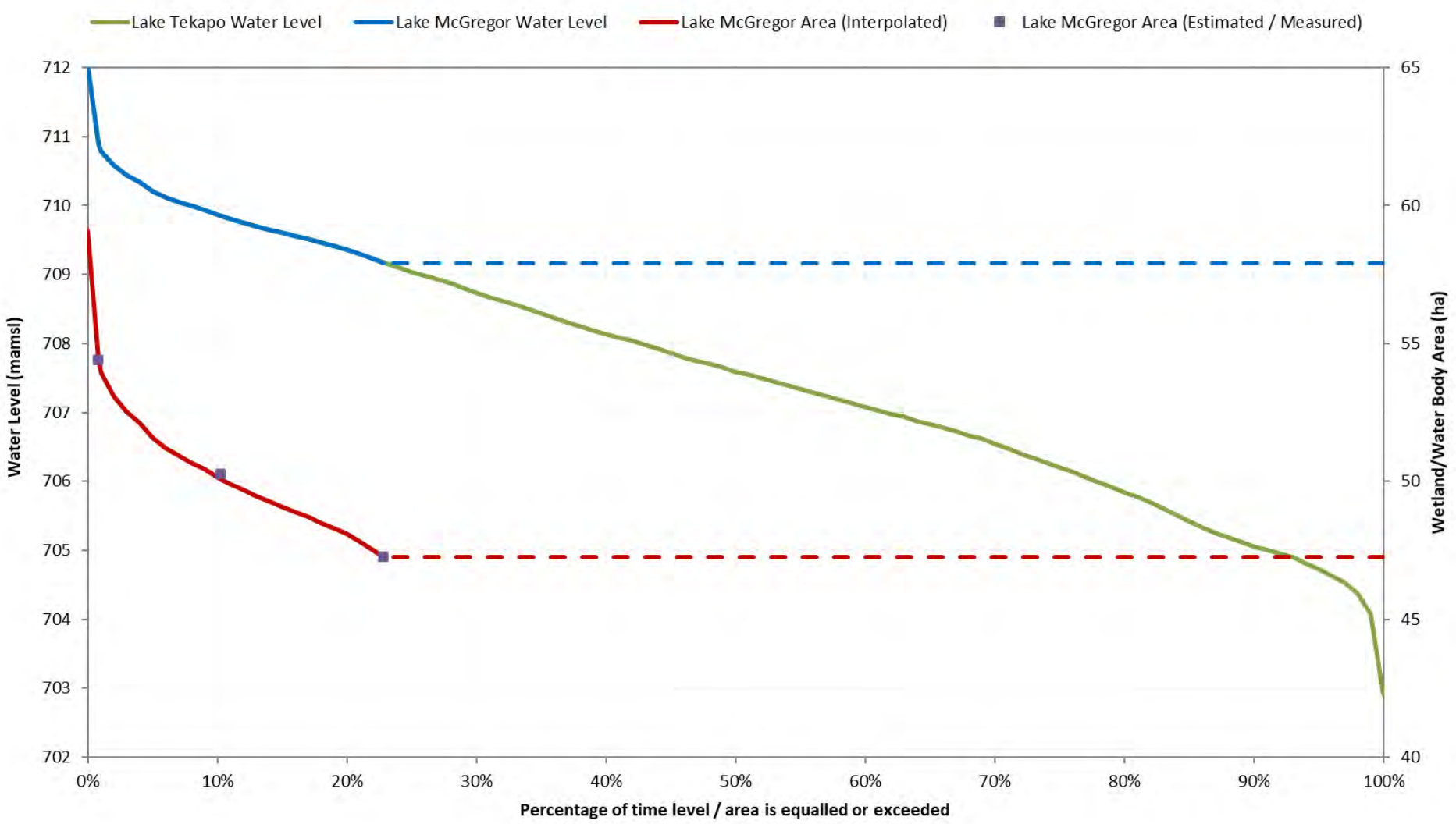


FIGURE F9: LAKE MCGREGOR WETTED ELEVATION AND AREA DURATION CURVES

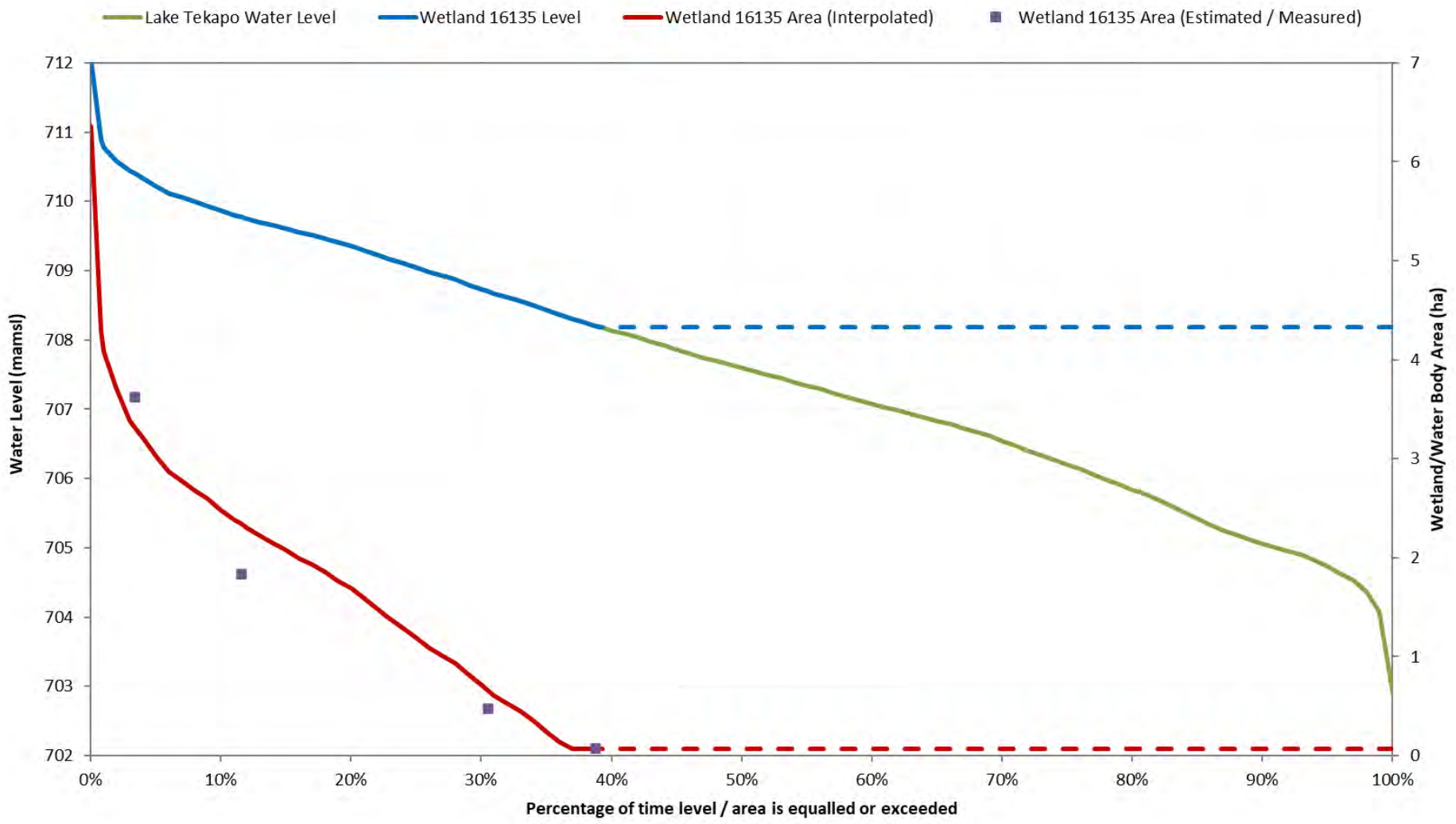


FIGURE F10: WETLAND 16135 WETTED ELEVATION AND AREA DURATION CURVES

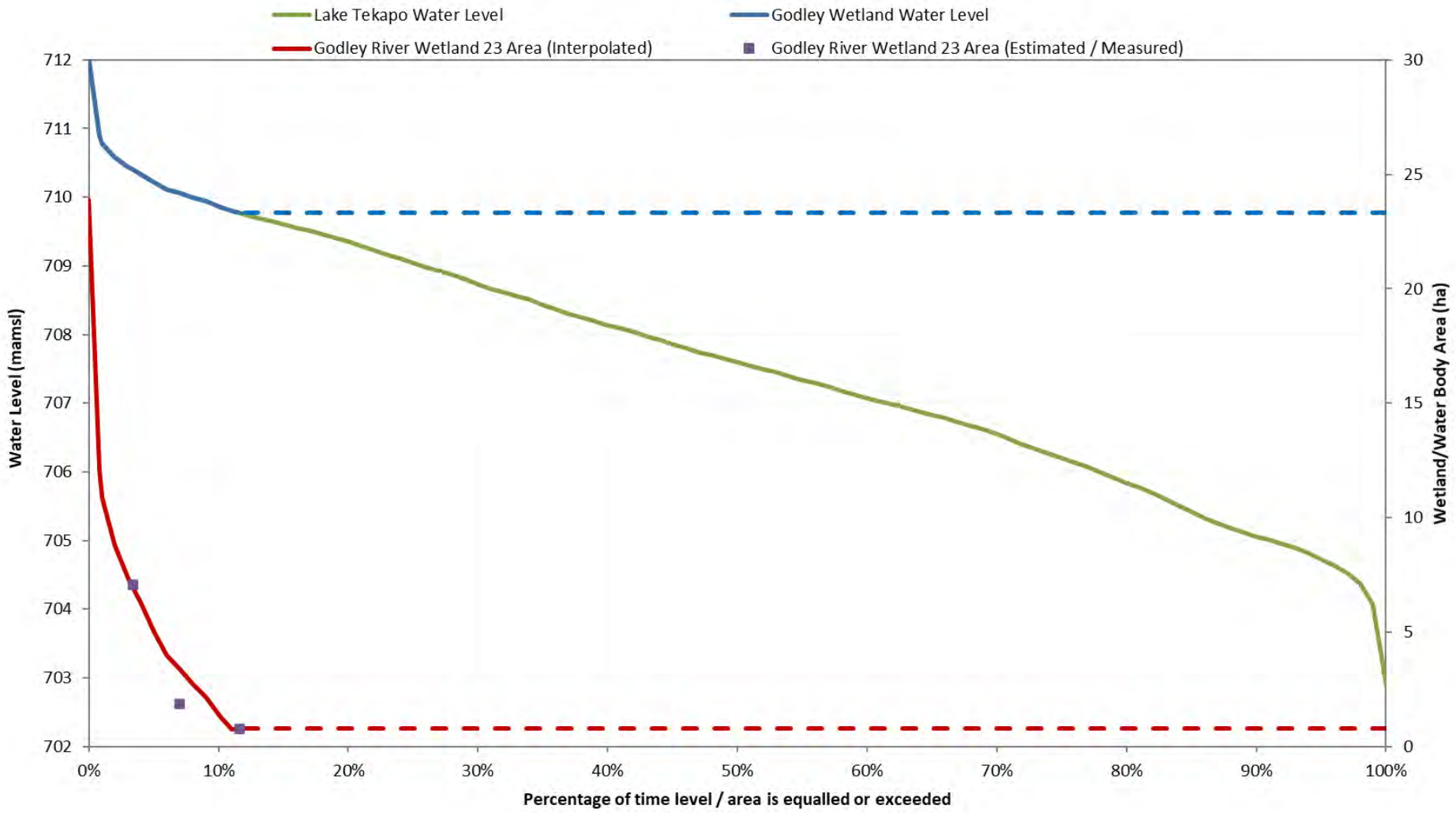


FIGURE F11: GODLEY RIVER WETLAND 23 WETTED ELEVATION AND AREA DURATION CURVES

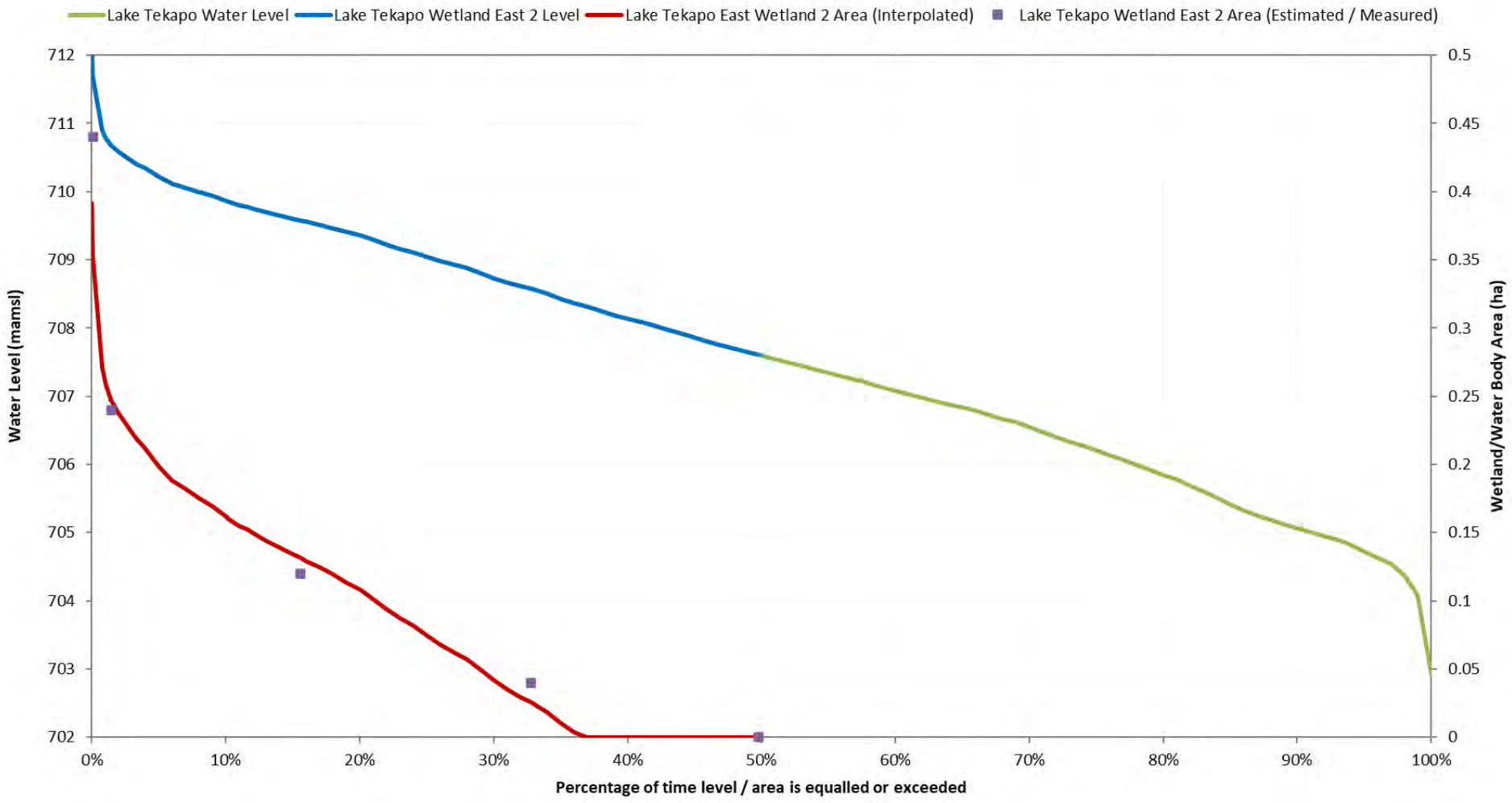


FIGURE F12: LAKE TEKAPO EAST 2 WETTED ELEVATION AND AREA DURATION CURVES

Appendix G: Tekapo River Hydrogeology Figures

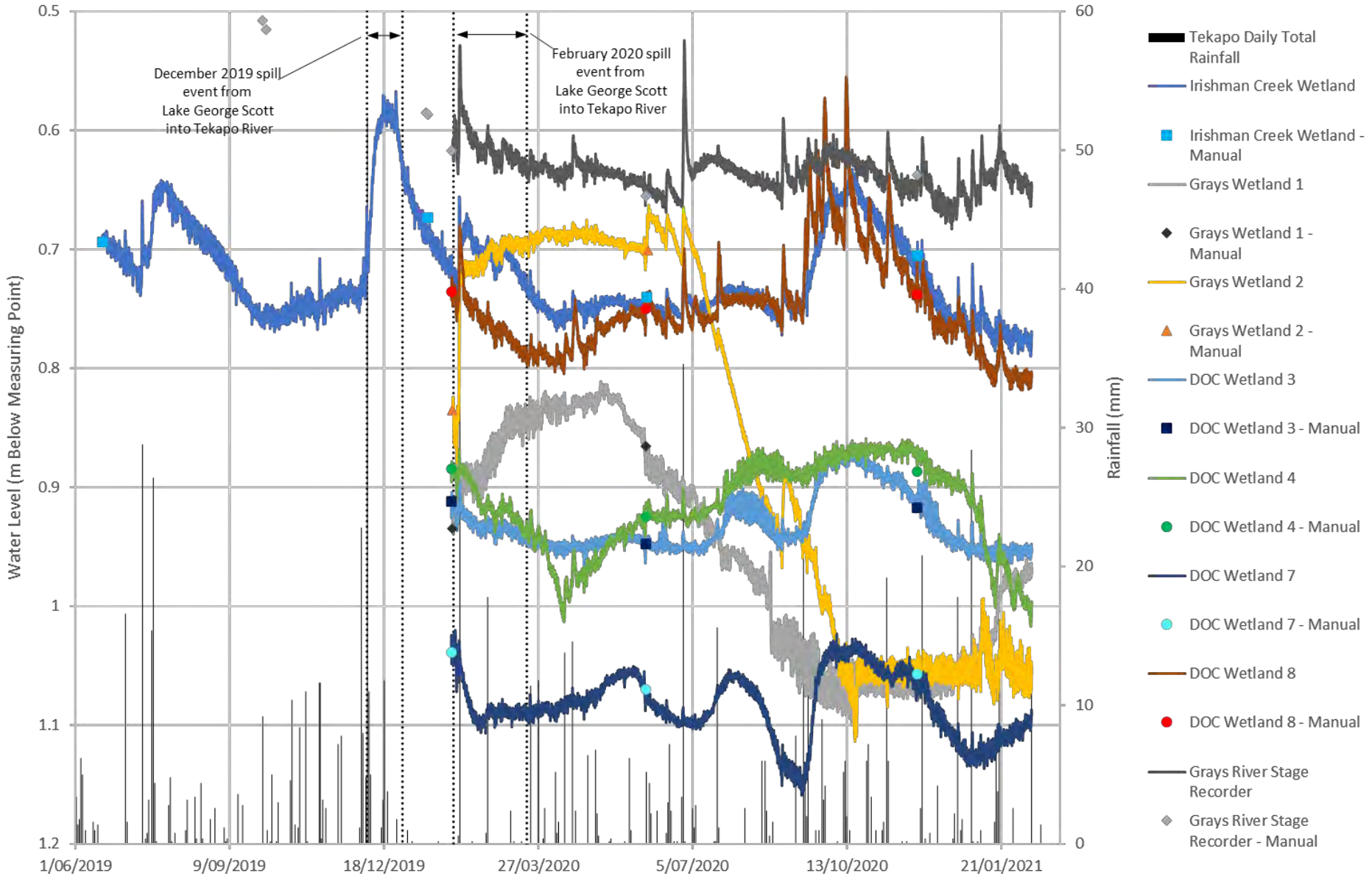


FIGURE G1: MONITORED WATER LEVELS IN TEKAPO RIVER BASIN WETLANDS FOR THE PERIOD JUNE 2019 TO FEBRUARY 2021 WITH RAINFALL

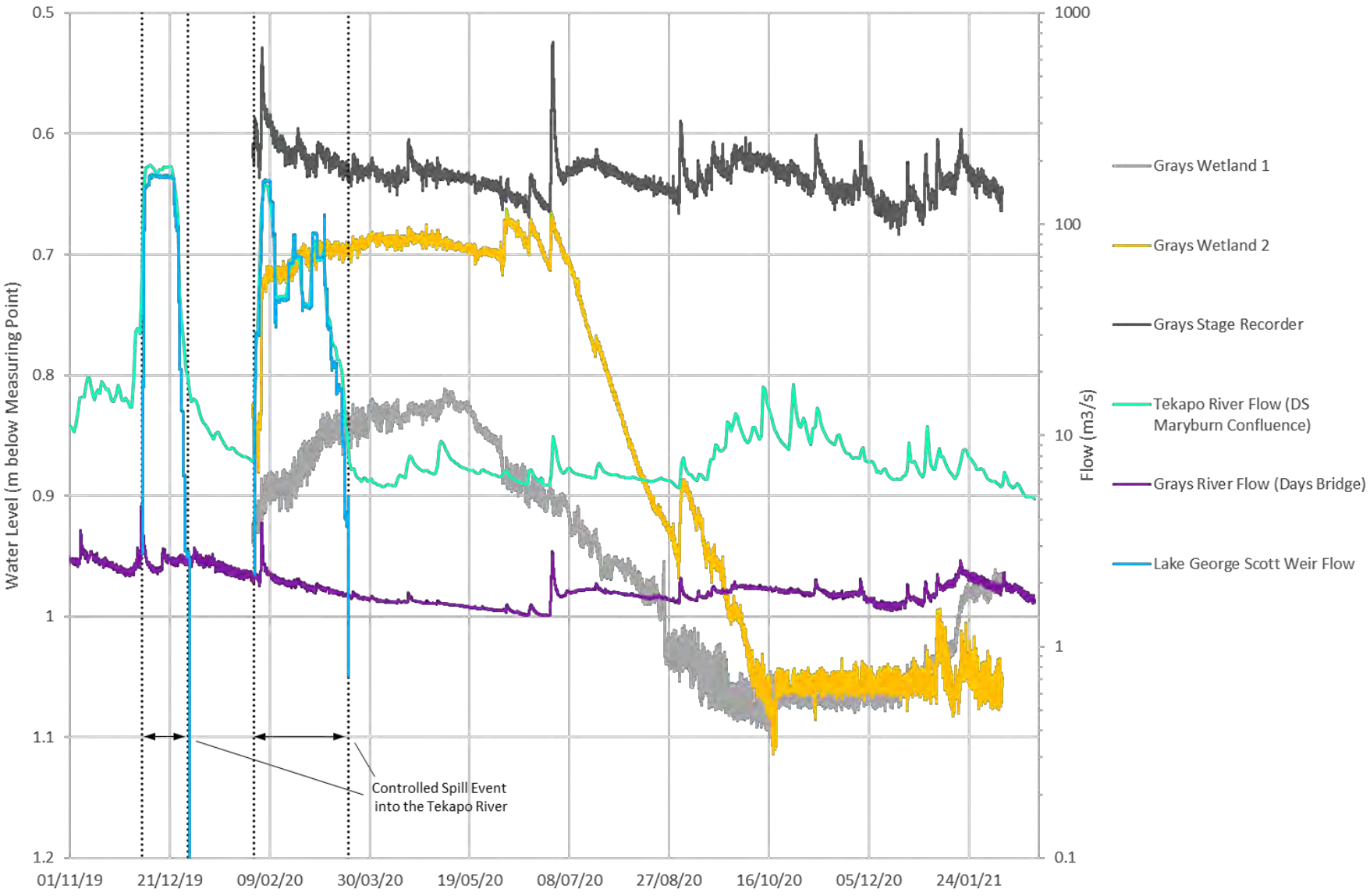


FIGURE G2: MONITORED WATER LEVELS IN EASTERN TEKAPO RIVER BASIN WETLANDS/WATER BODIES FOR THE PERIOD JANUARY 2020 TO FEBRUARY 2021 WITH FLOWS

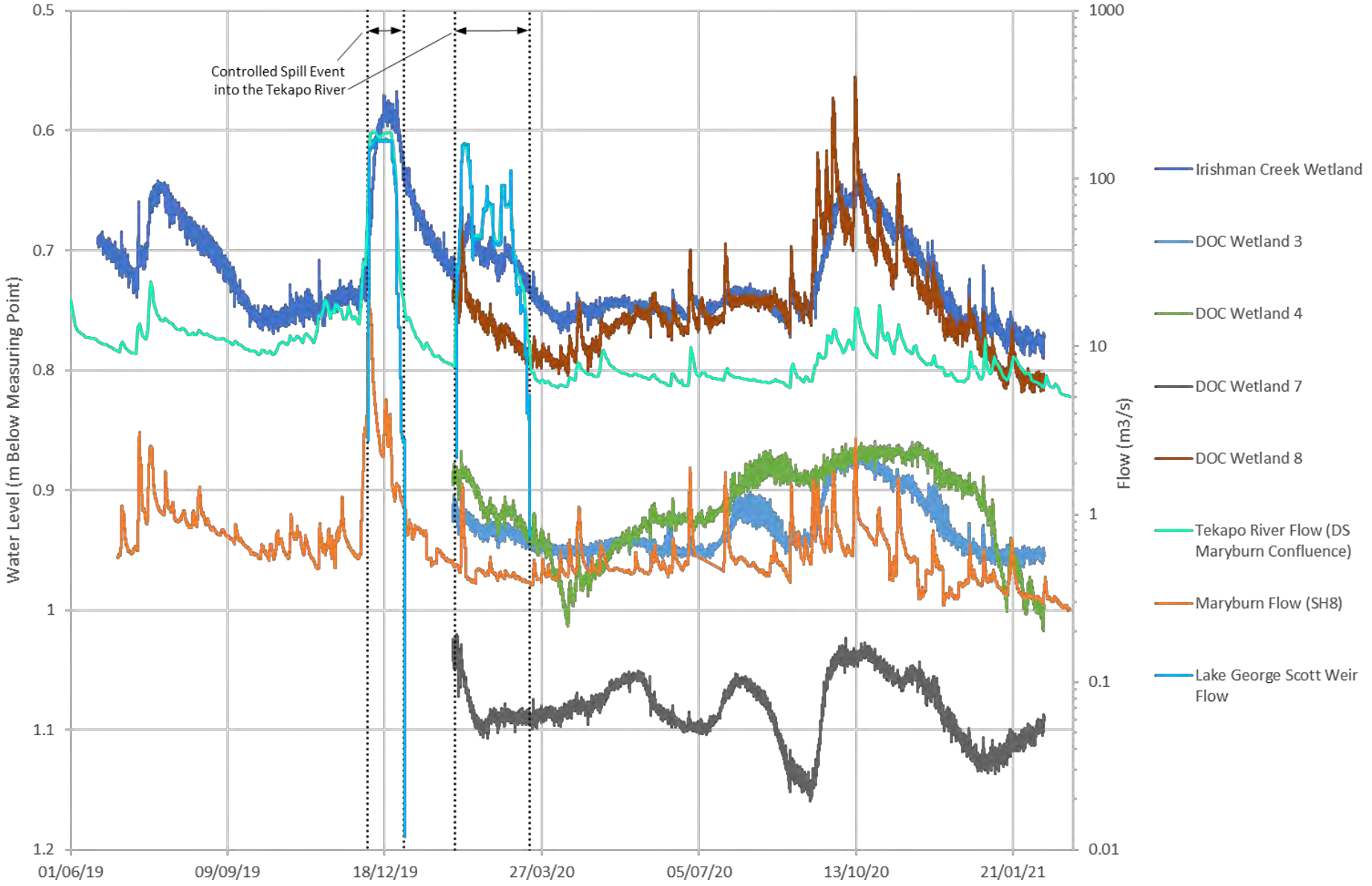


FIGURE G3: MONITORED WATER LEVELS IN WESTERN TEKAPO RIVER BASIN WETLANDS/WATER BODIES FOR THE PERIOD JUNE 2019 TO FEBRUARY 2021 WITH FLOWS

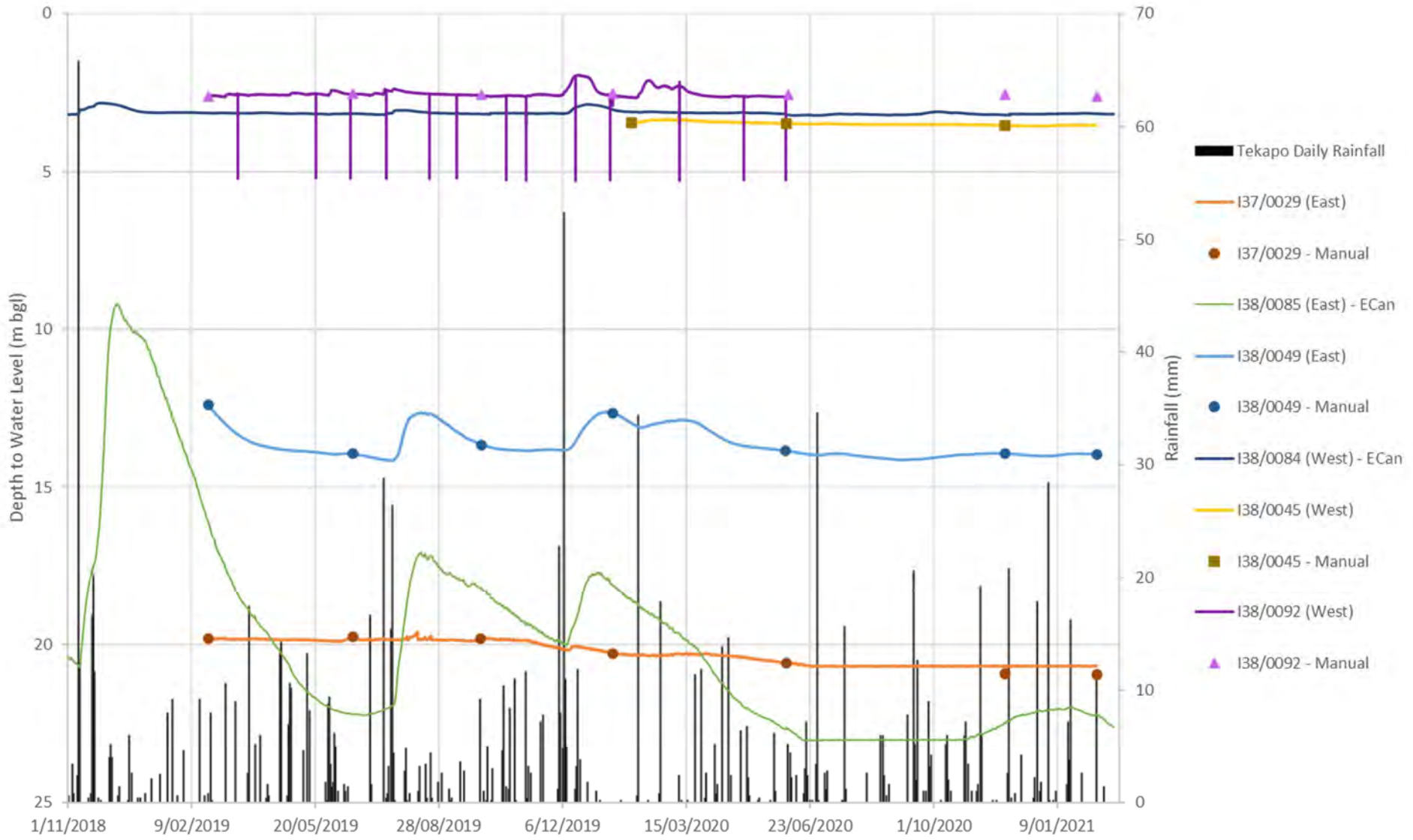


FIGURE G4: GROUNDWATER LEVELS IN DEEPER MONITORING BORES FOR THE PERIOD NOVEMBER 2018 TO FEBRUARY 2020 WITH RAINFALL

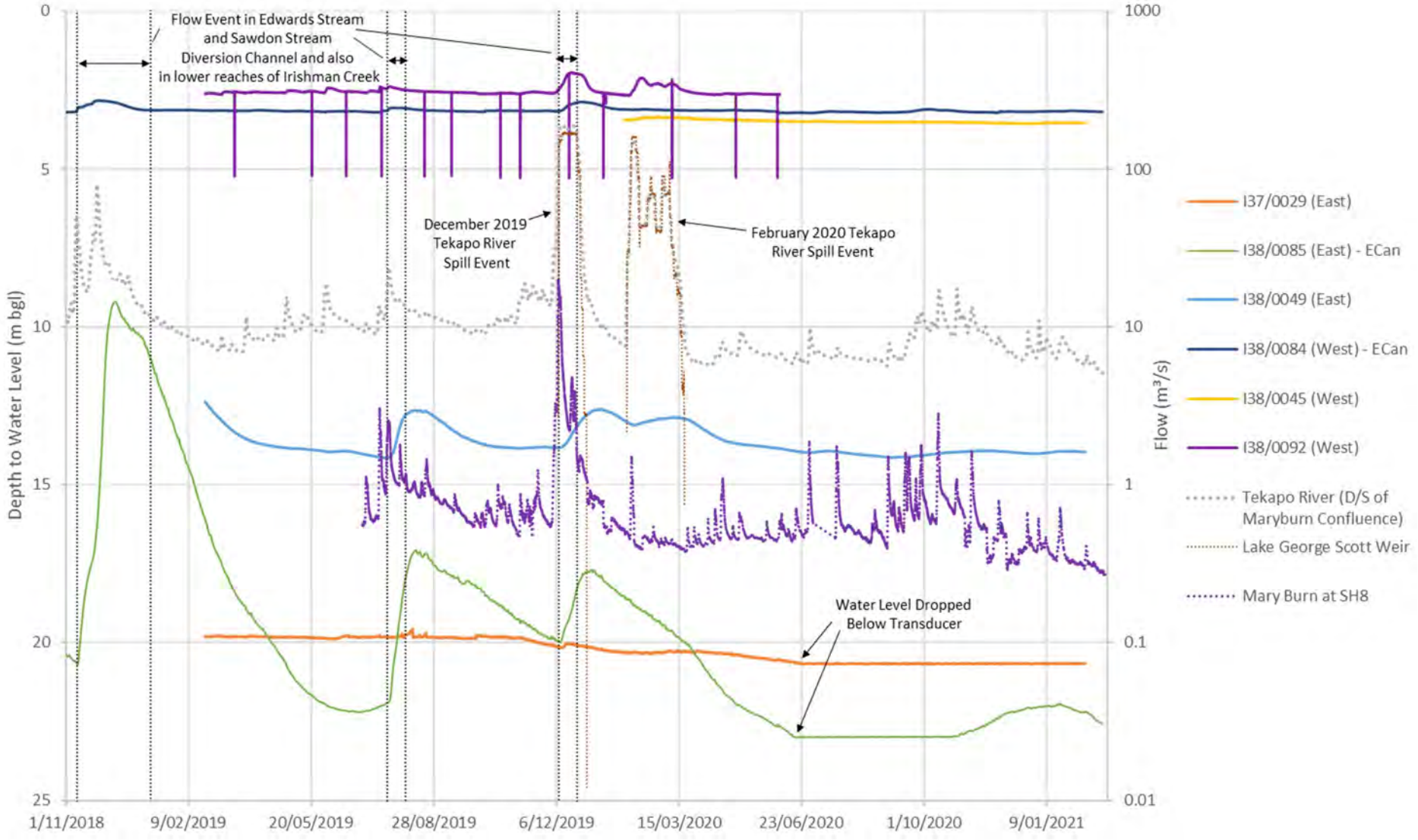


FIGURE G5: GROUNDWATER LEVELS IN DEEPER MONITORING BORES FOR THE PERIOD NOVEMBER 2018 TO FEBRUARY 2021 WITH TEKAPO RIVER FLOW

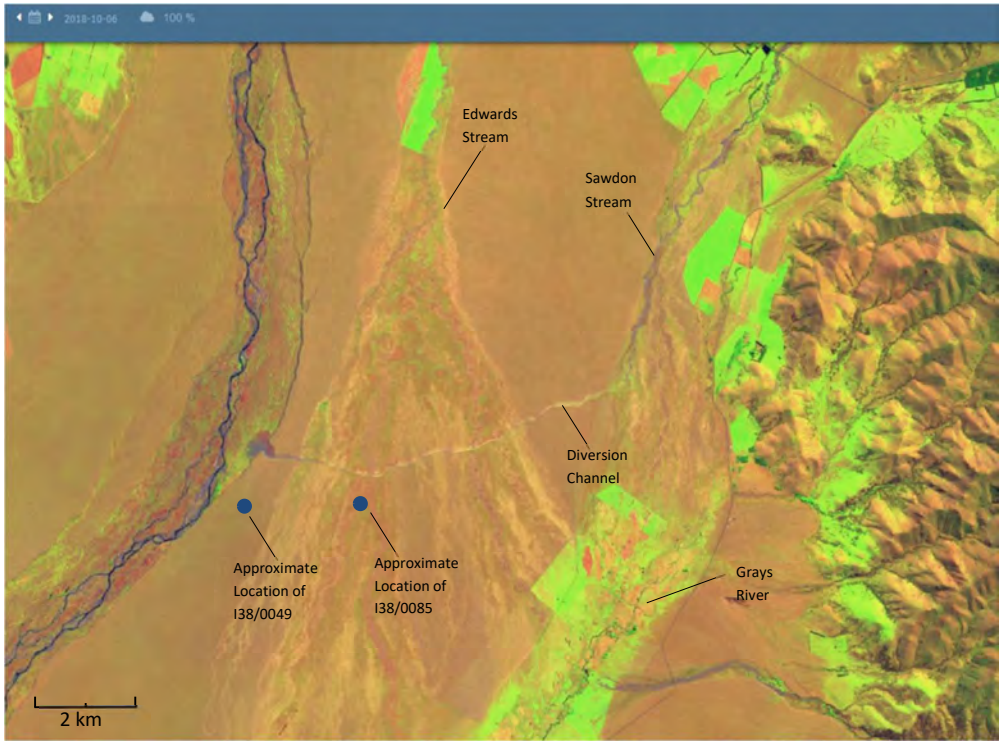


FIGURE G6A: SENTINEL HUB IMAGE OF EDWARDS AND SAWDON STREAMS PRIOR TO NOVEMBER/DECEMBER 2018 FLOW EVENT (IMAGE TAKEN 6/10/2018)

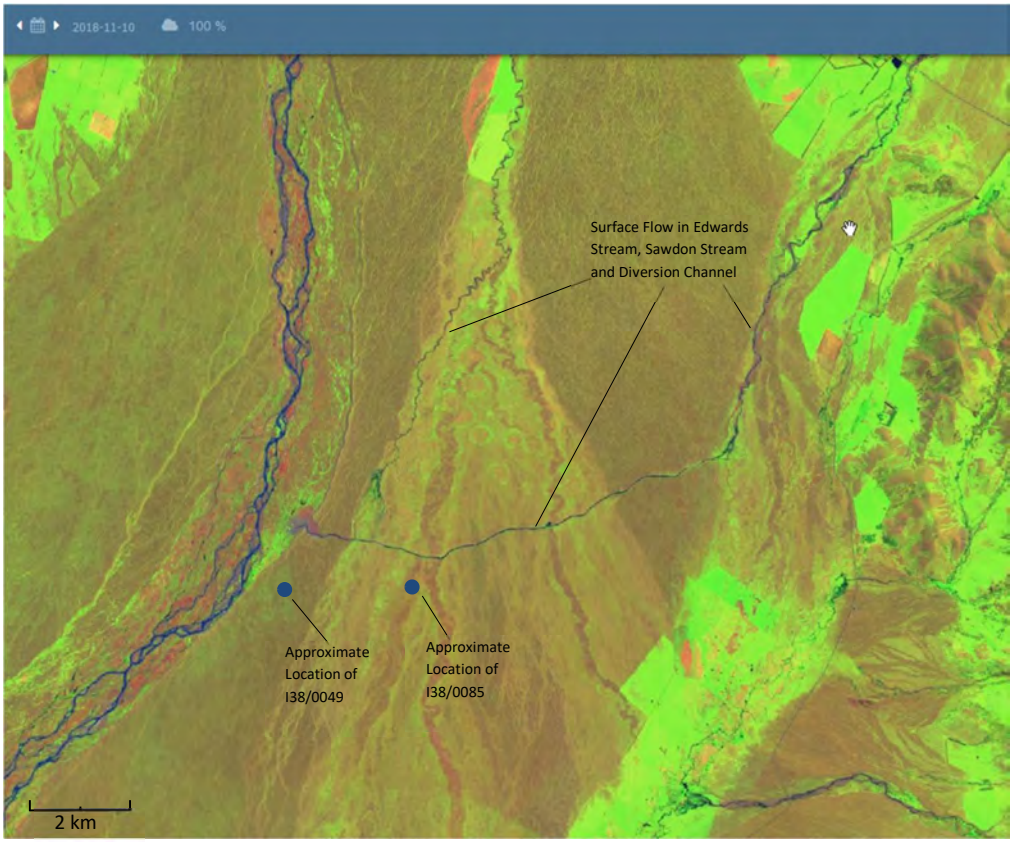


FIGURE G6B: SENTINEL HUB IMAGE OF EDWARDS AND SAWDON STREAMS DURING NOVEMBER / DECEMBER 2018 FLOW EVENT (IMAGE TAKEN 10/11/2018)

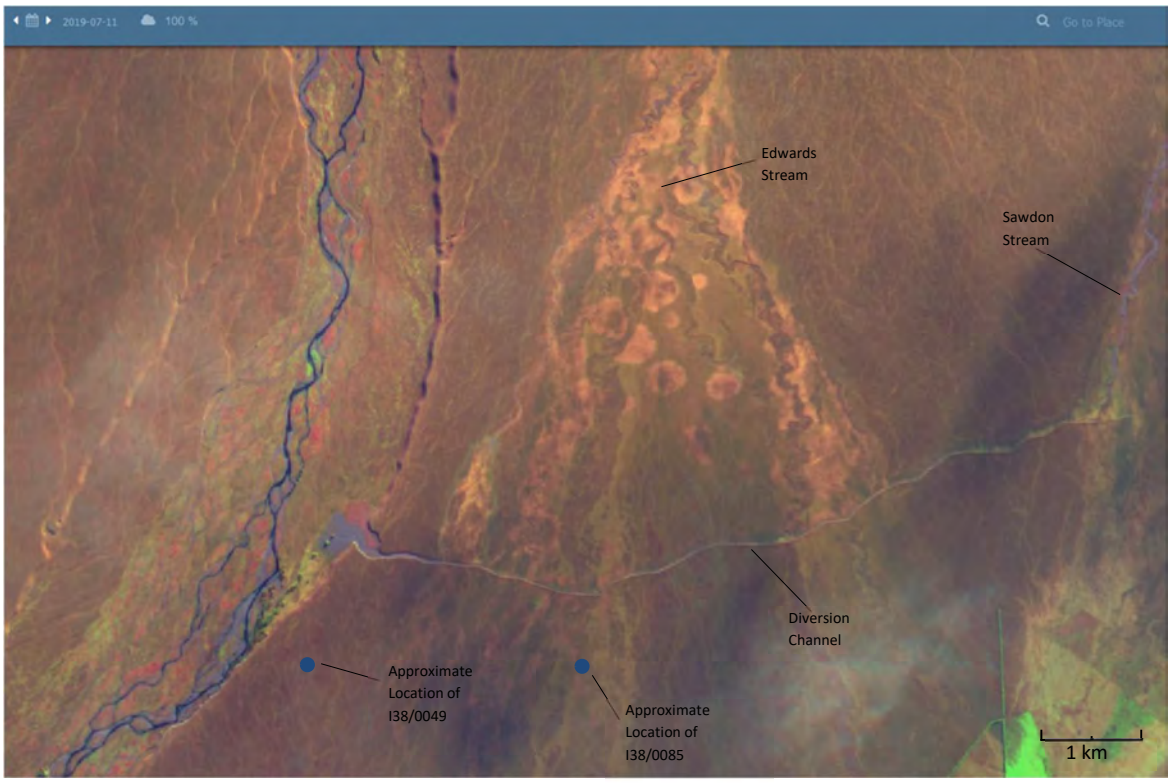


FIGURE G6C: SENTINEL HUB IMAGE OF EDWARDS AND SAWDON STREAMS PRIOR TO JULY 2019 FLOW EVENT (IMAGE TAKEN 11/07/2019)

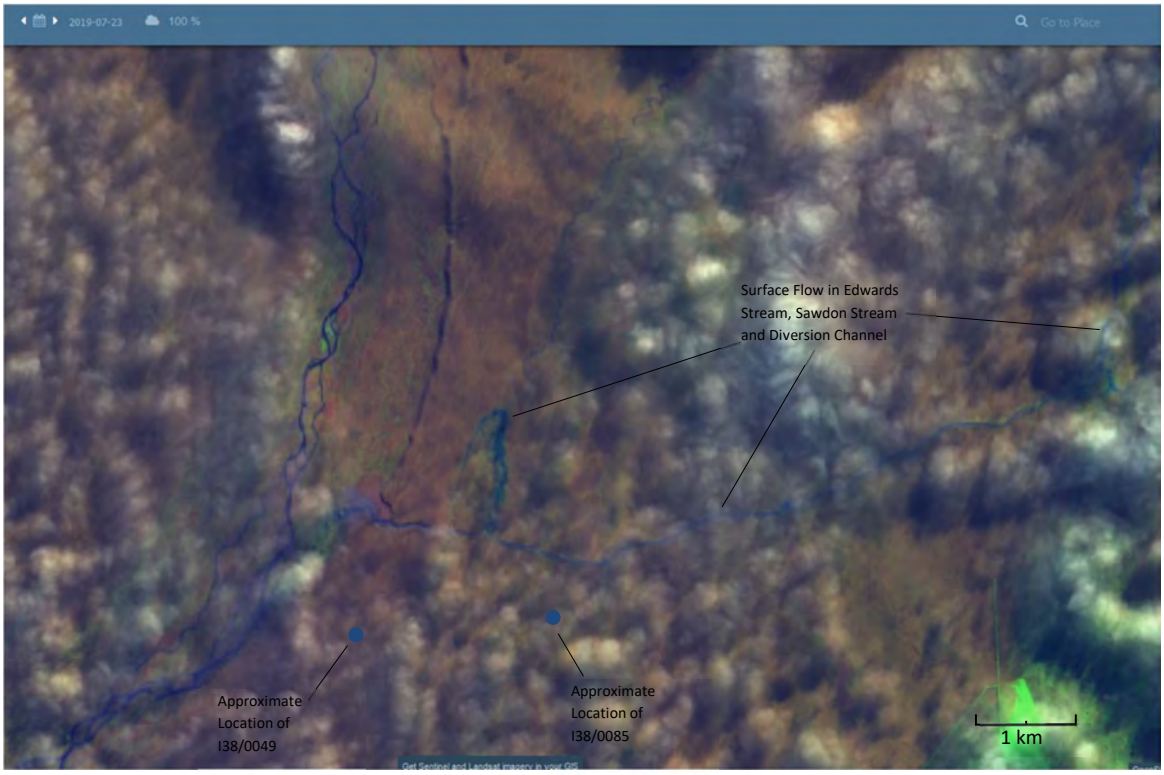


FIGURE G6D: SENTINEL HUB IMAGE OF EDWARDS AND SAWDON STREAMS DURING JULY 2019 FLOW EVENT (IMAGE TAKEN 23/07/2019)

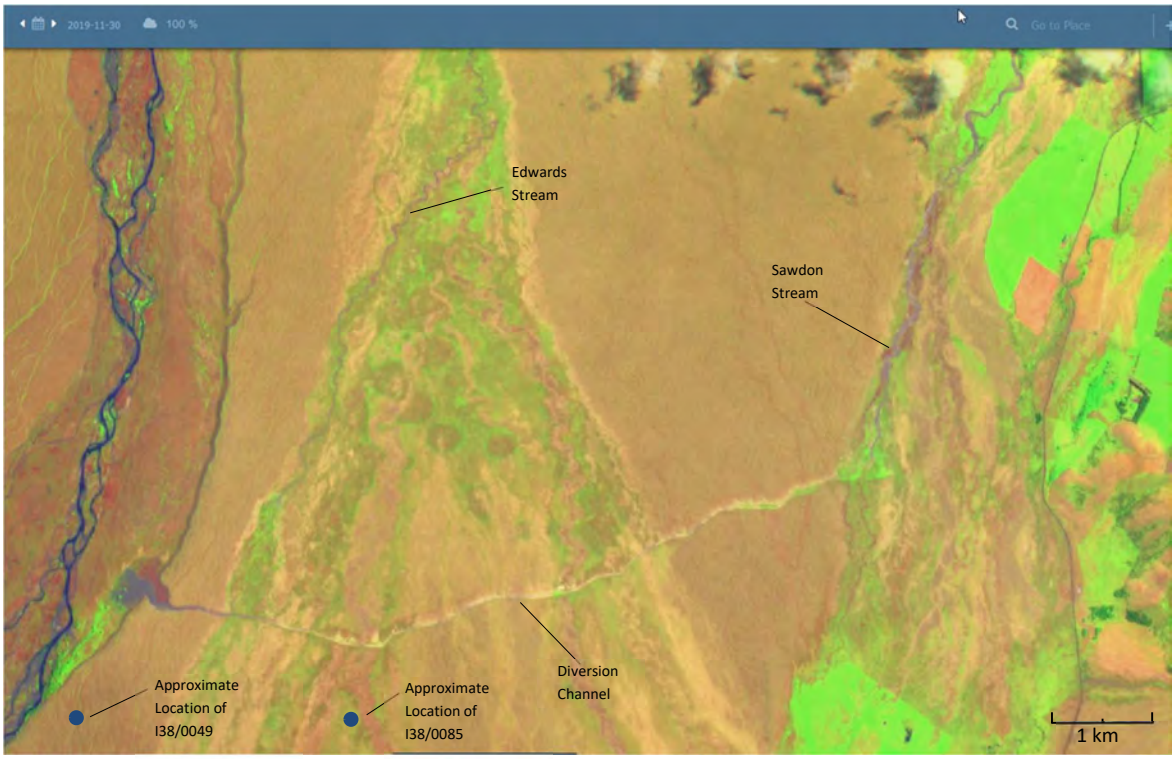


FIGURE G6E: SENTINEL HUB IMAGE OF EDWARDS AND SAWDON STREAMS PRIOR TO DECEMBER 2019 FLOW EVENT (IMAGE TAKEN 30/11/2019)

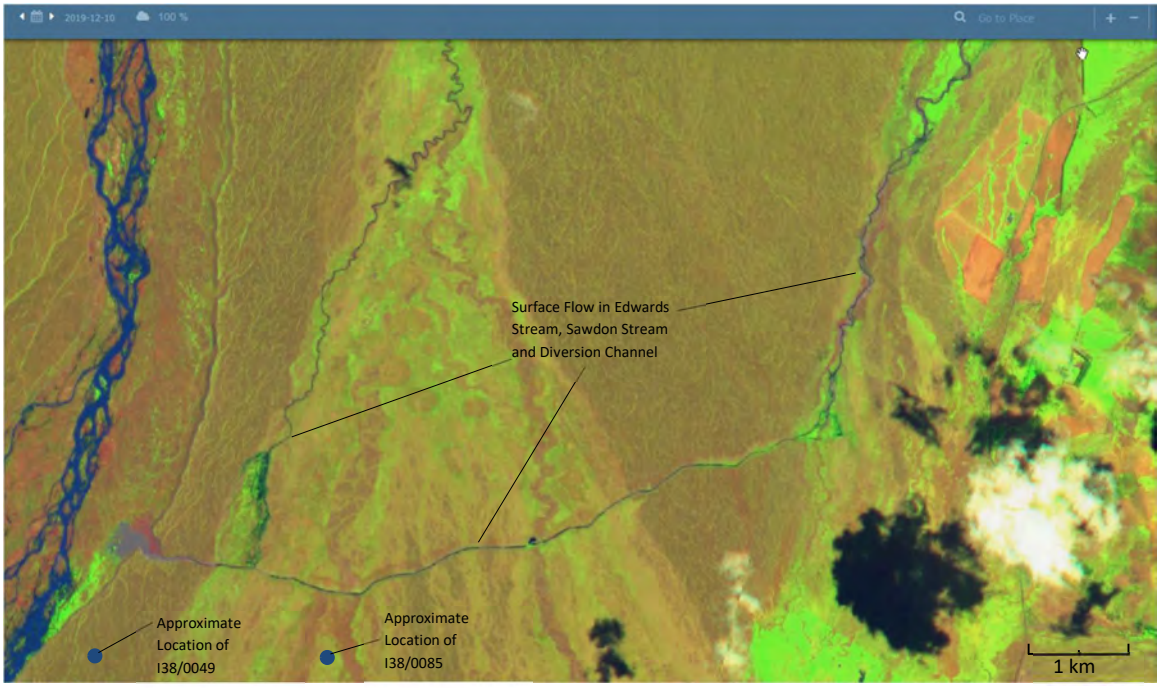


FIGURE G6F: SENTINEL HUB IMAGE OF EDWARDS AND SAWDON STREAMS DURING DECEMBER 2019 FLOW EVENT (IMAGE TAKEN 10/12/2019)

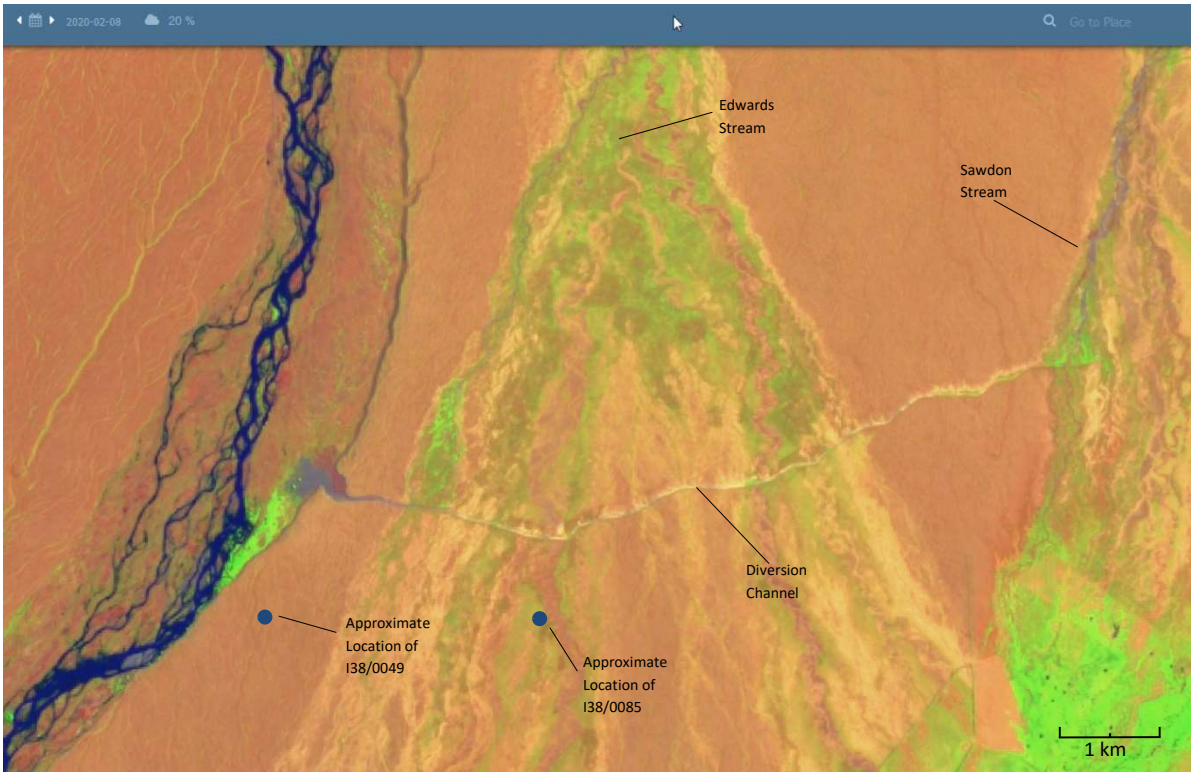


FIGURE G6G: SENTINEL HUB IMAGE OF EDWARDS AND SAWDON STREAMS DURING FEBRUARY 2020 FLOW EVENT (IMAGE TAKEN 08/02/2020)

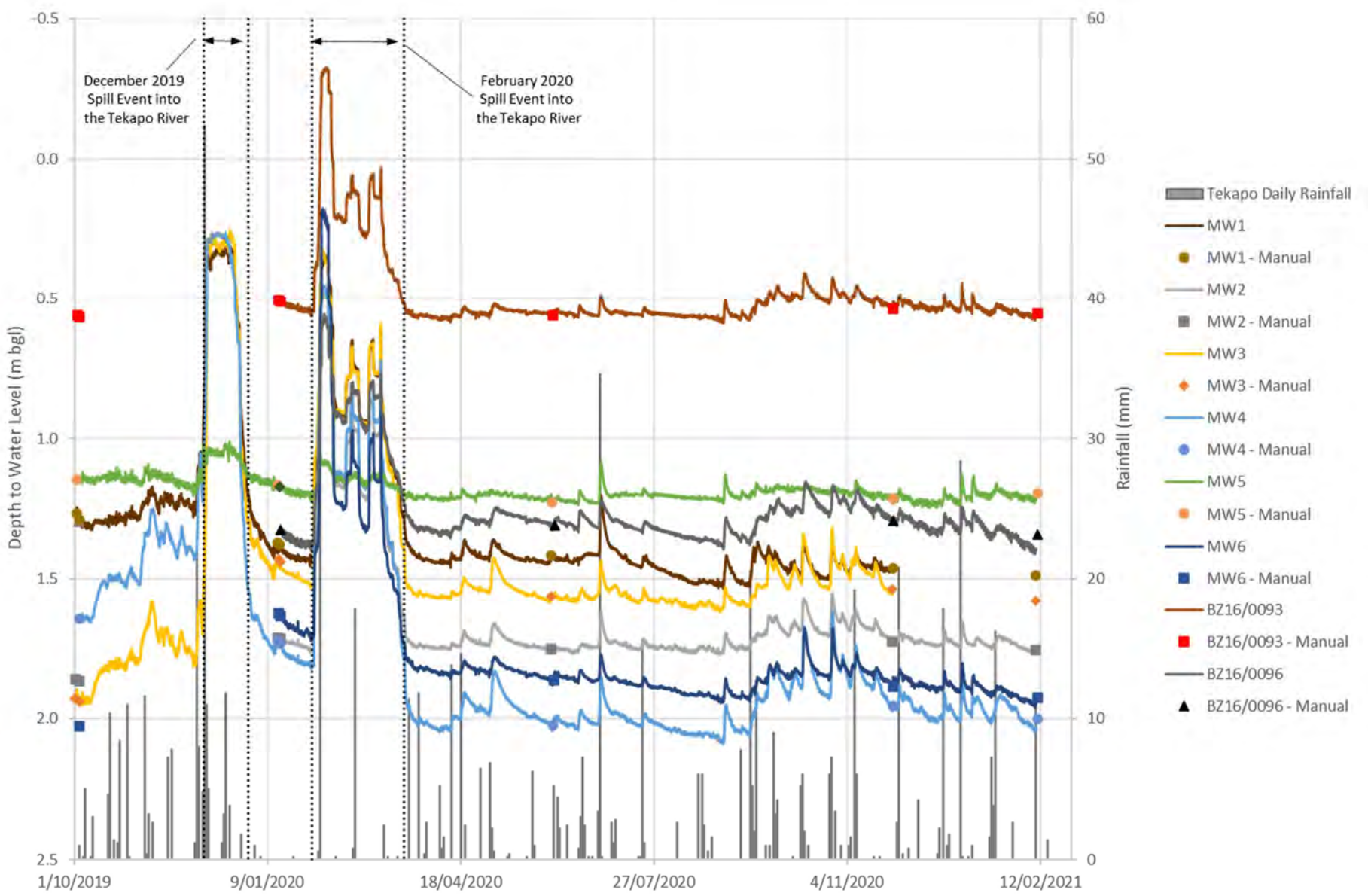


FIGURE G7: GROUNDWATER LEVELS IN RIPARIAN MONITORING BORES FOR THE PERIOD OCTOBER 2019 TO FEBRUARY 2021 WITH RAINFALL

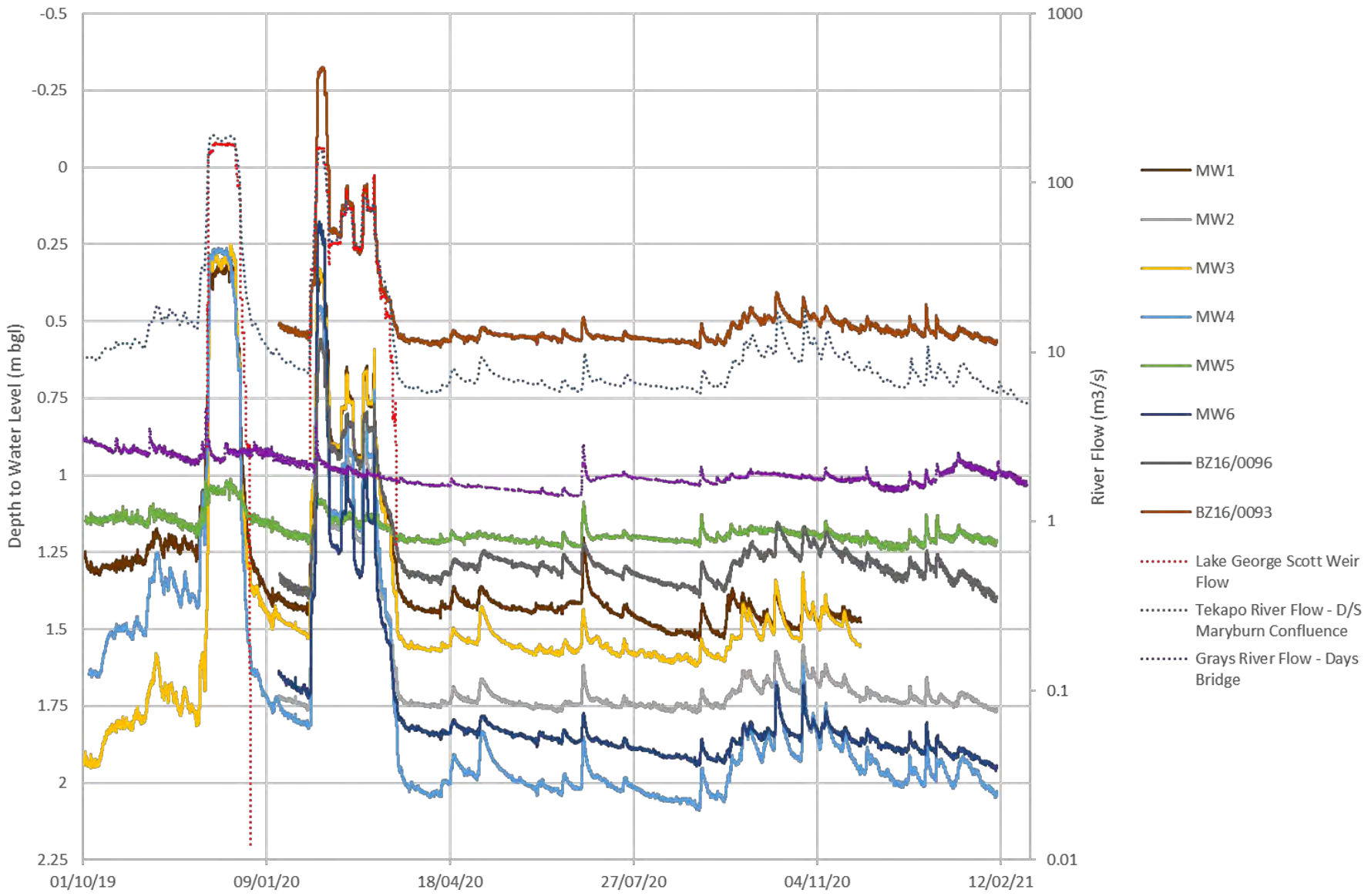


FIGURE G8: GROUNDWATER LEVELS IN RIPARIAN MONITORING BORES FOR THE PERIOD OCTOBER 2019 TO FEBRUARY 2021 WITH RAINFALL

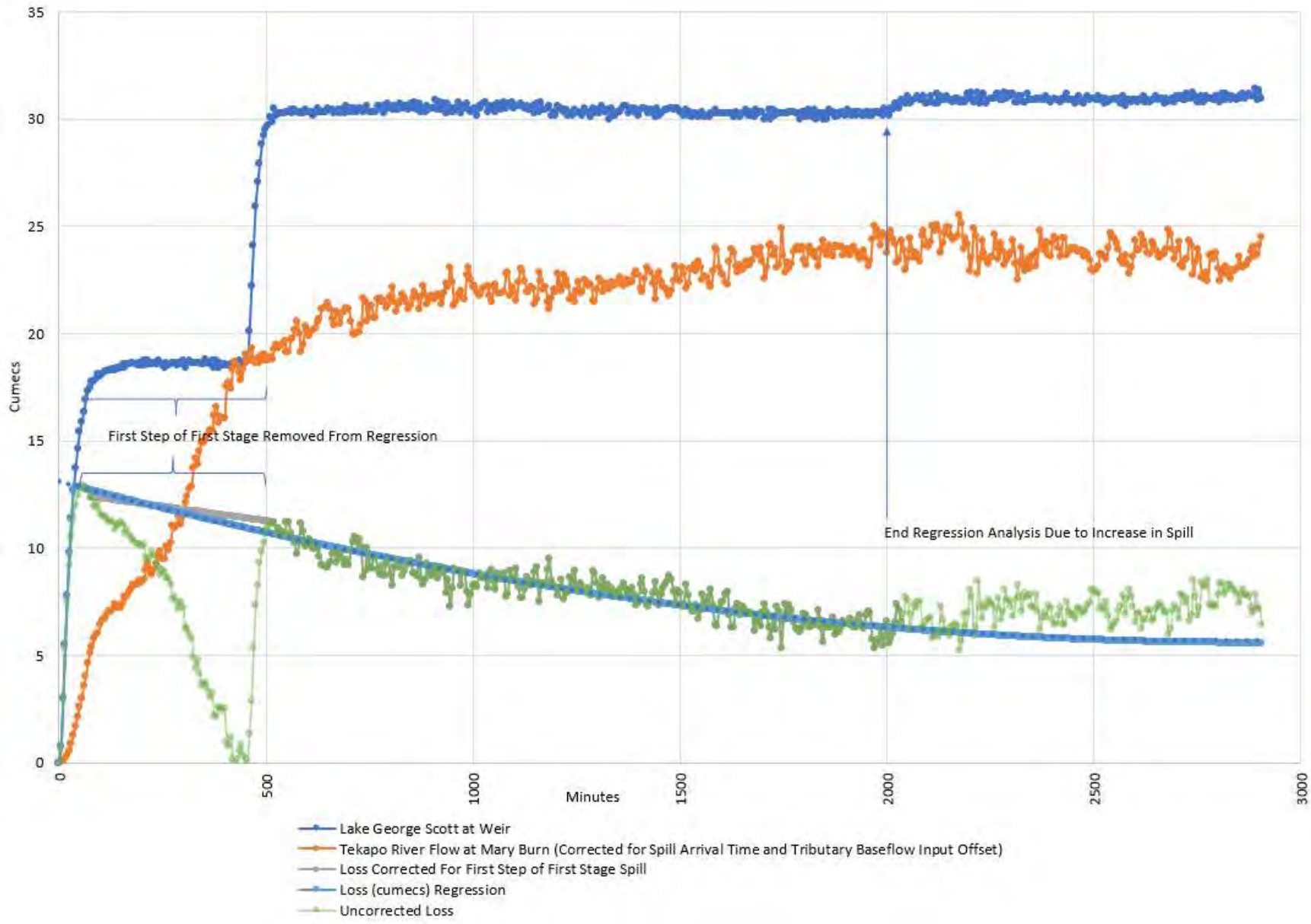


FIGURE G9: MEASURED FLOW LOSSES TO GROUNDWATER DURING FIRST STAGE FEBRUARY 2020 SPILL EVENT

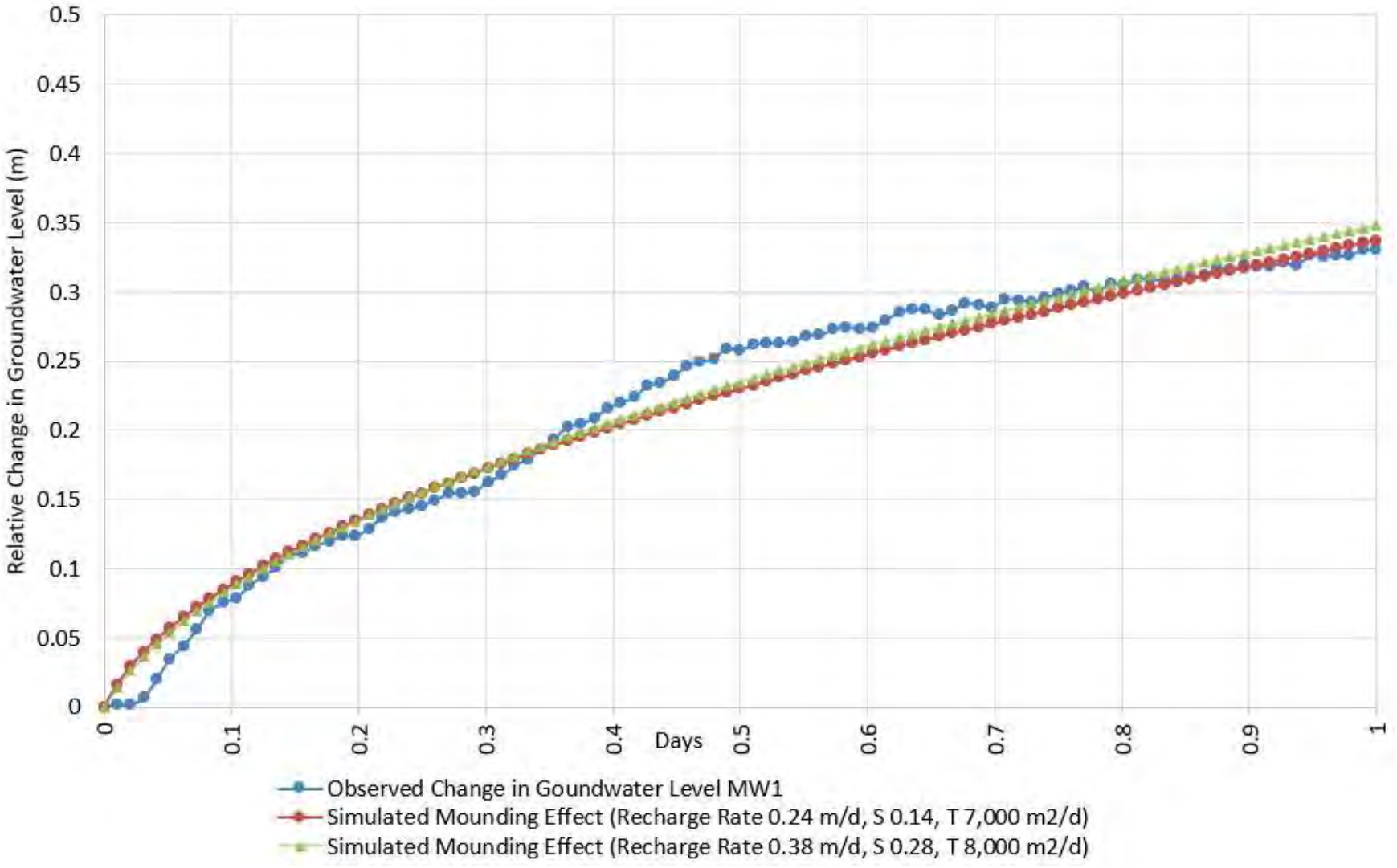


FIGURE G10: MEASURED AND MODELLED GROUNDWATER LEVEL RESPONSE AT MW1 DURING FIRST STEP OF FEBRUARY 2020 SPILL EVENT

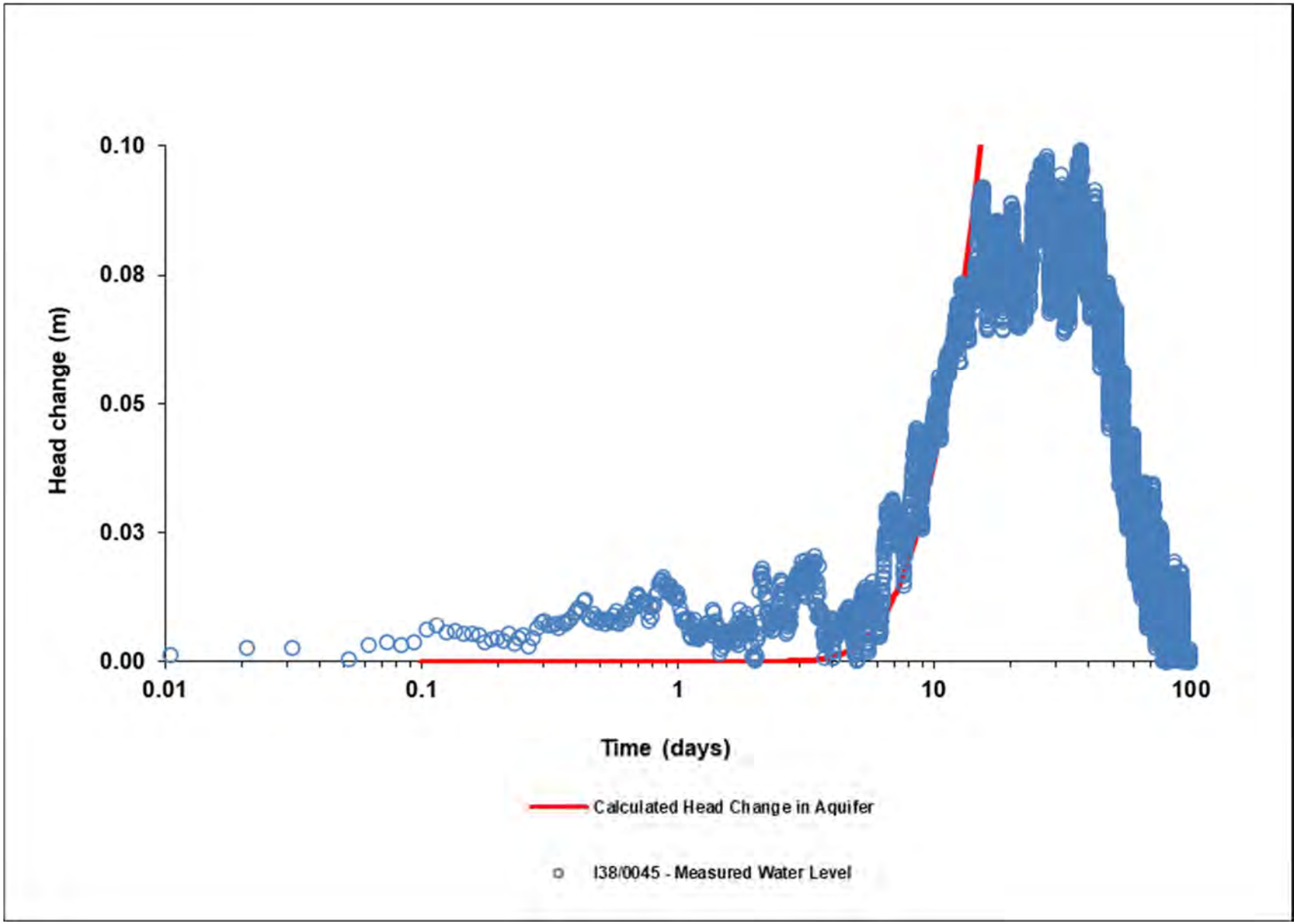


FIGURE G11: MEASURED AND MODELLED GROUNDWATER LEVEL RESPONSE AT I38/0045 DURING FIRST STEP OF FEBRUARY 2020 SPILL EVENT USING THE BANK STORAGE SOLUTION

Appendix H: Tekapo Canal Hydrogeology Figures



Figure H1: Remediated sections of the Tekapo Canal

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FIGURE H2: SATELLITE IMAGERY OF PATERSONS PONDS AND CONFLUENCE OF TEKAPO RIVER WITH FORK STREAM. IMAGE TAKEN ON 6 OCTOBER 2019. (SOURCED FROM SENTINEL HUB PLAYGROUND)



FIGURE H3: SATELLITE IMAGERY OF PATERSONS PONDS AND CONFLUENCE OF TEKAPO RIVER WITH FORK STREAM. IMAGE TAKEN ON 8 DECEMBER 2019. NOTE TURBID WATER IN PATERSONS PONDS FROM HIGH FLOW EVENT IN FORK STREAM (SOURCED FROM SENTINEL HUB PLAYGROUND)

Appendix I: Table of Hydrology Site

Hydrology site details

Name	Number	Agency	Type	Start Date	End Date	Gaps
Lake Tekapo (Level)	-	Genesis	Instantaneous Level	03-Mar-1925	31-Dec-2022	< 0.1%
Lake Tekapo at Inflow [1, 2]	-	Genesis	Daily Flow	04-Mar-1925	03-Aug-1965	< 0.1%
Lake Tekapo (Daily Inflow) [1]	-	Genesis	Daily Flow	03-Aug-1965	31-Dec-2022	0.2%
Lake Tekapo at Spillway (Gate 16)	-	Genesis	Instantaneous Flow	01-Jan-1957	31-Dec-2022	< 0.1%
Tekapo River at Spillway	71131	ECan	Instantaneous Flow	06-Jun-1968	03-Mar-1978	1.1%
				04-Jun-1993	31-Dec-2022	0.3%
Tekapo A	-	Genesis	Instantaneous Flow	01-Aug-1965	31-Dec-2022	0.8%
Tekapo B Power Station at Machine Output	-	Genesis	Instantaneous Flow	21-Jun-1977	11-Nov-2000	0.4%
Tekapo B Power Station	-	Genesis	Instantaneous Flow	11-Nov-2000	31-Dec-2022	< 0.1%
Lake George Scott at Weir	-	Genesis	Instantaneous Flow	02-Mar-1978	31-Dec-2022	< 0.1%
Lake George Scott at Gate 17	-	Genesis	Instantaneous Flow	08-Aug-1977	31-Dec-2022	< 0.1%
Tekapo River at downstream Mary Burn	1071103	ECan	Instantaneous Flow	03-Oct-2012	31-Dec-2022	< 0.1%
Fork Stream at Balmoral [3]	71129	Genesis/Meridian/NIWA	Instantaneous Flow	30-Jul-1962	31-Dec-2022	0.6%
Mary Burn at Mt McDonald [4]	71122	Genesis/Meridian/NIWA	Instantaneous Flow	22-Oct-1969	31-Dec-2022	0.6%
Mary Burn at SH8	71130	ECan	Instantaneous Flow	12-Jun-2003	31-Dec-2022	< 0.1%
Grays River at Days Bridge	71162	ECan	Instantaneous Flow	17-Sep-2009	31-Dec-2022	< 0.1%
Irishman Creek at Windy Ridge [5]	71128	NIWA	Instantaneous Flow	27-Jul-1962	18-Jan-1972	20.4%
Pukaki Spillway [6]	-	Meridian	Instantaneous Flow	02-Feb-1952	31-Dec-2022	20.5%

Notes:

The daily inflows are estimated by Genesis based on lake outflows and lake levels.

Gaps in the record have been filled.

Site jointly funded but data held by NIWA. Have added 0.6 m^3/s to the entire record to account for gain from the Tekapo River upstream of the confluence with Forks Stream.

Site jointly funded but data held by NIWA.

Historic site that is no longer active.

Note all gaps are prior to 1-Jan-1991 (start of analysis period used in this report). Data has been manually edited since 1 Jan 2012 onwards to remove small recorded spill flows associated with gate testing.

Appendix J: Tekapo Canal Relining Groundwater Monitoring Report

Annual Report on Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works

Prepared for
Genesis Power Ltd

June 2013

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Web Site **http://www.pdp.co.nz**
Auckland Wellington **Christchurch**

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Quality Control Sheet

TITLE	**Annual Report on Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works**
CLIENT	Genesis Power Ltd
VERSION	Final
DATE	June 2013
JOB REFERENCE	A02482500
SOURCE FILE(S)	A02482500R003_June_2013-Final

Prepared by



SIGNATURE

Ryan Nicol

Directed, reviewed and approved by



SIGNATURE

Peter Callander

Limitations:

This report has been prepared on the basis of information provided by Genesis Power Ltd. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

This report has been prepared by PDP on the specific instructions of Genesis Power Ltd for the limited purposes described in the report. PDP accepts no liability to any other person for their use of or reliance on this report, and any such use or reliance will be solely at their own risk.

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1.0 Introduction

Genesis Power Ltd, trading as Genesis Energy, has commenced remedial works along various sections of the 26 km long Tekapo Canal, which extends from the Tekapo A Power Station near Lake Tekapo through to the settling pond above the Tekapo B Power Station at Lake Pukaki. In general terms, the proposed remedial works involve:

- de-watering sections of the canal via coffer dams;
- excavation of the current canal liner;
- placement and compaction of fill on the base and sides of the canal;
- laying of a low permeability synthetic liner; and
- various temporary construction and ancillary works around the Tekapo Canal.

These works are scheduled to occur over the following three sections of the canal:

- from chainage 7-8.93 km – a canal section referred to as the 8.17 km culvert;
- from chainage 10.9-14.7 km – a canal section known as SH8;
- from chainage 17.8-19.61 km – a canal section known as the Maryburn Fill.

The chainages listed above are all measured from the Tekapo A Power Station. The location of the Tekapo Canal, together with the canal reach names and chainages, are shown in Figure 1.

The water in the Tekapo Canal interacts with the surrounding groundwater via seepage through the base and sides of the canal. Where the canal is above the groundwater, seepage from the canal will recharge the underlying groundwater. Where the canal is excavated down into the groundwater, then seepage between the groundwater and canal will occur depending on the relative elevation of the groundwater level and the water level in the canal. During the remedial works, the water level of the canal may be lowered by up to 1 m to minimise the stress on the coffer dams and the sections of the canal between the coffer dams will be dewatered completely, which will alter this interaction due to the changed canal levels.

The rate of seepage between the canal and the groundwater is directly affected by the nature of the canal lining. Therefore, the proposed relining works will create an alteration to the rate of seepage interaction with the natural groundwater resource, around those areas that have been relined, that continues beyond the completion of the remedial works.

The shallow groundwater resource that is affected by the interaction with the canal will, in turn, interact with surface waterways in the area.

The purpose of this report is to describe the monitoring that has been undertaken since October 2012 as a part of the Groundwater and Surface Water Monitoring Programme (GSWMP). The report will assess the changes in groundwater and surface water arising

from the Canal remedial works and provide any recommendations for the monitoring programme during the coming 12 month monitoring period.

This report is structured as follows:

- Section 2 outlines the monitoring programme undertaken by PDP for the period October 2012 through to April 2013;
- Section 3 discusses the results of the monitoring and any interpretations of the data;
- Section 4 describes any environmental effects arising from any changes related to the remedial works;
- Section 5 provides an outline of the monitoring period over the next 12 months and discusses any changes to the monitoring programme that may be needed.

2.0 Monitoring data

For the period between October 2012 and April 2013, monitoring focused on groundwater and surface water levels, observations of seeps and flow rates of weirs and surface water ways that flow beneath the sections of canal being remediated. Construction work during the monitoring period occurred on canal sections 8.17 km Culvert and SH8. Maps showing the locations of all monitoring sites along each section of the Tekapo Canal undergoing remediation are displayed in Figures 2a, 2b and 2c (Appendix A). Appendix B provides additional details of each monitoring site. It should be noted that some monitoring sites (i.e. seeps and weirs) have been removed due to construction during the monitoring period. These sites are noted in Appendix B. In addition to the data collected, daily rainfall data from the NIWA Lake Tekapo climate station (Agent Number: 24945) located at Tekapo Airfield was sourced from NIWA's CliFlo climate data for the monitoring period.

The sections below discuss the frequency of monitoring, locations of monitoring sites and the type of measurements made in more detail.

2.1 Frequency of monitoring

The frequency for environmental monitoring during the remedial work on the Tekapo Canal between October 2012 and April 2013 is outlined below:

<u>October 2012 to December 2012</u>

Monthly monitoring of weirs, seeps, pond staff gauges (manual measurement) and groundwater levels (manual measurement) in monitoring wells for 8.17 Culvert, SH8 and Mary Burn Fill Canal sections.

<u>January 2013 to April 2013</u>

Weekly monitoring of weirs, seeps and pond staff gauges (manual measurement) for 8.17 Culvert and SH8 Canal sections, changing to **Daily** for 1 week prior to dewatering/refilling, during dewatering/refilling and 1 week after dewatering/refilling has ceased at each particular canal section;

Monthly monitoring of weirs, seeps, pond staff gauges (manual measurement) and groundwater levels (manual measurement) in monitoring wells for Mary Burn Fill Canal section. Also **Monthly** monitoring of groundwater levels (manual measurement) in monitoring wells for 8.17 Culvert and SH8 Canal sections.

These measurements were made at the frequencies described above by Dave Jenkinson (employed by Genesis Power Ltd) in conjunction with Damwatch Services Ltd.

In addition to the monitoring undertaken by Dave Jenkinson, PDP downloaded nine electronic pressure transducers installed in each of the monitoring wells and two ponds at three monthly intervals. Each pressure transducer measured the relative change in pressure at 15 minute intervals and were installed on 15 October 2012.

Occasional flow gaugings were made in the Mary Burn, Irishman Creek and the unnamed stream immediately east (upstream) of the State Highway Eight (SH8) Bridge. Flow gaugings in each of the streams are carried out approximately every 6 months, although all three streams were gauged at least twice prior to the start of construction.

2.2 Groundwater level monitoring

Six piezometers were installed along the three sections of canal undergoing remediation by McNeil Drilling Co Ltd between 2 October and 5 October 2013. The purpose of these monitoring wells is to measure the response of groundwater levels following the remedial works on the canal. The locations of the piezometers are displayed in Figures 2a, 2b and 2d. At each canal section two piezometers were installed with one located on the true right hand side and one on the true left hand side of the canal. The design of each piezometer is provided in Figure 3 and details of each piezometer are outlined in Table 1 below. Figures 4a and 4b show an example of the finished well head used at each well.

Table 1: Environmental monitoring piezometers

Well number	ECan well number	Depth of well (m bgl)	Screened interval (m bgl)	Initial depth to water (m bgl)*	Easting (NZTM)	Northing (NZTM)	Canal section
Well 1	BZ16/0042	10.38	7.38 – 10.38	-9.80	1392307	5117272	8.17 km
Well 2	BZ16/0043	10.80	7.79 – 10.79	-8.24	1392361	5117388	8.17 km
Well 3	BZ16/0044	5.67	2.67 – 5.67	-2.10	1388729	5116854	SH8
Well 4	BZ16/0045	6.48	3.50 - 6.48	-3.50	1388961	5117010	SH8
Well 5	BZ16/0047	10.96	7.96 – 10.96	-9.85	1382940	5116070	Mary Burn Fill
Well 6	BZ16/0046	26.83	23.83 – 26.83	-24.46	1382834	5116321	Mary Burn Fill

* Initial depth to water measured by driller immediately after well was drilled

Borelogs of each well is provided in Appendix C. The design of the piezometers called for the minimum depth to be 4 m, and to a depth that is 3 m below the depth at which water is encountered (but not greater than 30 m). In other words, the screened interval of the piezometer should be at least 3 m below the depth at which groundwater was

encountered. PDP were onsite to observe the installation of Well 4, however no other well installations were observed by PDP.

Based on Table 1, only Wells 3 and 4 appear to penetrate the groundwater table sufficiently (3 m or greater). The remaining four wells appear to penetrate the groundwater table typically less than half of the screened interval as they have been drilled to a depth that is shallower than what was specified in the design. However, the intention of the piezometers is to identify changes to interactions between groundwater and surface water ways, therefore they are expected to be deep enough so that if they go dry during the monitoring period it indicates that there is no direct effect on any nearby surface water ways.

Pressure transducers were installed in each of the wells to measure the change in water pressure. An additional pressure transducer located inside the well cap of Well 4 was used to measure the change in atmospheric pressure. All the pressure transducers were downloaded at three monthly intervals and manual depth to groundwater measurements were made during each download of the transducers. Additional manual depth to groundwater measurements were made throughout the monitoring period by Dave Jenkinson as part of Damwatch's ongoing monitoring programme. All measurements were recorded to monitor the relative change in groundwater level in each piezometer.

2.3 Surface water level monitoring

Staff gauges and pressure transducers were used to monitor any changes in surface water levels in ponds on the true left hand side (downgradient) of the SH8 canal section and the Mary Burn Fill canal section. Two ponds were monitored at each canal section with a staff gauge installed in each of the four ponds. The locations of the staff gauges are provided in Figures 2b and 2c and the names of the sites are as follows:

- TKBSH8SG1 – SH8 canal section, Pond 1
- TKBSH8SG2 – SH8 canal section, Pond 2
- TKBMBSG1 – Mary Burn Fill canal section, Pond 1
- TKBMBSG2 – Mary Burn Fill canal section, Pond 2

The staff gauges consisted of a plastic builder's ruler, 1 m in length with 1 mm gradations. The ruler was secured to a metal fence post installed into the bed of the pond at depth such that at least half of the ruler was submerged with the remaining length of the ruler above the pond surface. The staff gauge was installed close enough to the bank so as the gradations could still be read but at a depth great enough to measure changes in pond. The water level was then read off the staff gauge from the edge of the pond. Figure 5a shows an example of one of the staff gauges.

In addition to the staff gauges, two pressure transducers were installed close to staff gauges TKBSH8SG1 and TKBMBGS1. The transducers were submerged in the pond by mounting the transducers to a metal fence post installed in the base of the pond. The pressures transducers recorded changes in water pressure in the ponds and were downloaded at 3 monthly intervals. Figure 5b shows an example of the position of a staff

gauge used to keep the pressure transducers in place. The purpose of staff gauges and pressure transducers is to measure the relative changes in water levels of the ponds during construction.

2.4 Surface water flow monitoring

Surface water flow monitoring covers observations of seeps and flow gaugings of weirs from seeps along canal embankments as well as flow gaugings and observations of major waterways that flow beneath the canal at the sections undergoing remedial work. The purpose of the seep observations and surface water flow monitoring is to identify any changes in surface water bodies as result of the remedial works.

2.4.1 Observations of seeps

Damwatch currently carry out monitoring of seeps along the length of the Tekapo Canal. A number of these seeps occur in the three sections of canal undergoing remedial works. During initial site visits by PDP in October 2012, eleven seeps were identified by PDP for monitoring along the SH8 canal section and ten along the Mary Burn Fill canal section. locations of these are displayed in Figures 2b and 2c and the table in Appendix B provides the details of each site. Damwatch monitor these sites as part of their ongoing monitoring program and provide PDP with data for each of the relevant sites identified by PDP. The monitoring of the seeps involves a qualitative assessment of each seep with observations being categorised on a scale ranging from 0 to 4. The scale, created by Damwatch, is as follows:

- 0 – Dry
- 1 – Damp
- 2 – Wet
- 3 – Flowing
- 4 – Alert (significant change, change in flow/turbidity)

The amount of water present at each seep monitoring period increases with the rating. During the monitoring period (October 2012 through to April 2013), all observations of seeps were made solely by Dave Jenkinson in an effort to keep the observations consistent and reduce errors. Figures 6a and 6b show typical examples of wet (2) and dry (0) seeps.

2.4.2 Weir measurements and stream flow gaugings

Weirs are also monitored by Damwatch as part of their ongoing monitoring program and were installed to monitor flows from seeps or springs that had consistent flow. During the site visit in October 2012, PDP identified seven weirs that would be relevant for monitoring; one weir at the 8.17 km Culvert Canal section, five weirs along the SH8 canal section and one weir at the Mary Burn Fill Canal section. These weirs are typically constructed of concrete and have a steel plate with a 45° angle v-notch through which water flows. During monitoring, the height of water that flows through the v-notch is measured and converted to a flow rate. Figure 7a shows a typical v-notch weir used to

measure flow rates from seeps. Weir TKBWELBS at the Mary Burn Fill Canal section is also constructed from concrete but has a single PVC pipe through which water passes through. The flow rate is determined by measuring the time the flow of water from the weir takes to fill a vessel of a known volume. A photo of this weir is displayed in Figure 7b. Flow rates from weirs are measured in litres/minute. All weir flow rate measurements were made by Dave Jenkinson on behalf of Damwatch for the monitoring period from October 2012 through to April 2013.

Stream flow gaugings were carried out by PDP in three major streams that flow beneath the SH8 and Mary Burn Fill Canal sections. The three streams in which flow gauging measurements were made are:

- Unnamed stream east of SH8 – SH8 Canal section
- Irishman Creek – SH8 Canal section
- Mary Burn - Mary Burn Fill Canal section

Flow gaugings were made in each stream both on the upstream and downstream side of the canal, as close to the culvert barrels as possible to try and measure any change in flow across the canal. To provide a more meaningful measurement, flow gaugings were made when streams were at low flow (e.g. <600 L/s in the Mary Burn at SH8). Flow gauging measurements were made using a hand held Acoustic Doppler Velocimeter (Flow Tracker) across a transect of the stream where there was little turbulence and also had parallel banks. Weed was removed from the stream bed along the transect and immediately upstream prior to gauging to reduce turbulence and give accurate velocities. Successive measurements in each stream were made at the same location. Figure 8a shows an example of a flow gauging measurement being carried out.

A third stream that passes through the 8.17 km culvert is typically dry and therefore no flow gaugings were made in this stream. However, qualitative observations were made of the 8.17 km culvert barrels as part of the ongoing monitoring by Damwatch using a rating system similar to the system used for seep observations. All observations of the 8.17 km culvert barrels were made by Dave Jenkinson on behalf of Damwatch for the monitoring period from October 2012 through to April 2013. Figure 8b shows the downstream culvert barrels prior to construction in October 2012.

2.5 Compliance with monitoring programme (GSWMP)

Environmental monitoring of groundwater and surface water during the remedial works on the Tekapo Canal is described in conditions 21, 22 and 23 of Schedule One – General Conditions. Schedule One – General Conditions are a list of conditions attached to number of resource consents related to the Tekapo Canal remediation works held by Genesis Power Ltd. A copy of Schedule One – General Conditions is provided in Appendix D. The PDP report “Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works” (September 2012), prepared for Genesis Power Ltd prior to the beginning of the monitoring period, outlines the monitoring programme. The monitoring works and the frequency of monitoring as described above are consistent with conditions 21, 22 and 23 of Schedule One – General Conditions and the PDP (2012) report.

However, it should be noted that one of the staff gauges (TKBSH8SG1) was stolen sometime in December and was not replaced until after construction on the canal had begun. Also, not all of the seeps and weirs marked on Figure 2 of the PDP (2012) report were monitored as a site visit in October 2012 by PDP confirmed which of these sites would be relevant for monitoring and which would not. The seeps and weirs listed in Appendix B are the sites that were deemed relevant by this site visit and have been monitored since.

3.0 Data analysis

Plots of the data along with the timing of when major construction events occurred during the monitoring period from October 2012 through to April 2013 are provided in this section of the report. It should be noted that the transducer data was not downloaded until early May and therefore there are some measurements recorded in May 2013. The major construction events during the monitoring period are:

- 7 January 2013 – canal flow stopped, water still in canal;
- 14 - 21 January 2013 – dewatering of the 8.17 km Culvert and SH8 Canal sections;
- 3 - 5 April 2013 – refilling of the 8.17 km Culvert and SH8 Canal sections;
- 12 April 2013 – canal operational again.

The sections below discuss the analysis of the data in more detail.

3.1 Groundwater level monitoring

Figures 9a, 9b and 9c show the groundwater levels measured using the pressure transducers and the manual measurements recorded by PDP and Dave Jenkinson on behalf of Damwatch in the six wells.

Figure 9a shows groundwater levels recorded in Wells 1 and 2. Water levels in Well 1 are shown to remain at a consistent level throughout the entire monitoring period. The manual depth to water level measurements generally match the transducer data. The maximum manual depth to water level measurement recorded in Well 1 was -10.38 m below ground level (bgl) on 7 May 2013 which is the bottom of the piezometer. The data for this well suggests that it has essentially remained dry for the entire monitoring period as it was not installed to a deep enough depth during the drilling and installation of the well.

Based on manual depth to water measurements, water levels in Well 2 (Figure 9a) were initially measured at -8.2 m bgl but dropped to -10.4 m bgl on 6 December 2012 and generally remained at this level for the entire monitoring period. The transducer data for Well 2 shows an increase to -7.8 m bgl on 25 October 2012 immediately after the installation of the transducer, before dropping to -9.8 m bgl on 6 December 2012 and generally remained at this level for the entire monitoring period. The manual depth to water levels and the transducer data are offset by approximately 0.6 m. The depth of 9.8 m corresponds to the depth at which the transducer was set in Well 2. Table 1 shows that Well 2 is 10.8 m deep and the maximum recorded depth to water level for the

monitoring period based on the manual measurements was -10.7 m bgl on 11 January 2013. This water level suggests that the well was essentially dry during the time of this measurement. The consistent depth to water was only 0.2 m above this measurement. During the installation of wells, the gravel pack around the bottom of the screened section of the well can become clogged and disturbed as the casing is pulled back. While it appears that the manual water level measurements in Well 2 may be recording a true groundwater level, they may in fact be a false water level due to water being impounded in the bottom of the well. A small spike in water levels in the transducer data from Well 2 occurred on 6 February 2013 and may be related to a large rainfall event on 5 February 2013. However this spike in water level in this well was very brief and was not recorded in the manual measurements. Furthermore, other large rainfall events occur throughout the monitoring period and had no effect on the water level in the well. Due to short duration of the spike and quick recovery back to background levels, the spike maybe related to construction works interfering with the well and bumping the transducer.

The purpose of the groundwater level monitoring is to identify potential interactions between groundwater and surface water ways. While it appears that Wells 1 and 2 have gone dry throughout the monitoring period, both wells are expected to be deep enough so that they indicate that the water table is at a sufficient depth that there is no direct effect on the nearby surface water way. In terms of canal leakage having any impact on groundwater levels and interactions between groundwater and surface water there appears to be no direct effect from the fundamental water table on the nearby surface waterway at 8.17 km culvert based on the groundwater level information. It should also be noted that there is anecdotal knowledge that 8.17 km culvert has only had flowing water pass through it on a few occasions since the construction of the canal and typically remains dry.

Groundwater levels in both Wells 3 and 4 on the SH8 Canal section (Figure 9b) show influences from rainfall events with water levels increasing after a large rainfall, particularly in Well 3. Manual measurements plot relatively well with the transducer data in both wells. Well 3 displays an overall declining trend throughout the monitoring period, although the rate of decline is not markedly different to what was occurring before any canal de-watering activities occurred. In contrast, water levels in Well 4 have generally remained stable, although a slight decrease in levels has occurred after the canal was dewatered. A cluster of small rainfall events between 18 October and 7 December 2012 may have contributed to an increase in groundwater levels in Well 4. It seems likely that the more stable levels in Well 4 are sustained by the unnamed stream nearby, whereas Well 3 is more distant from that waterway. Based on the data from the monitoring period, groundwater levels in either Well 3 or 4 appear to have been relatively unaffected by dewatering of the canal and the installation of the liner.

Figure 9c shows water levels in Wells 5 and 6 on the Mary Burn Fill Canal section for the monitoring period. This section of canal did not undergo dewatering during construction. The manual depth to water level measurements generally plot well with the transducer data from both wells. Groundwater levels in both wells have remained relatively stable

throughout the monitoring period, although Well 5 displays a slight decreasing trend. A large rainfall event on 2 January 2013 may have caused a slight increase in water levels in Well 5. However, no other large rainfall events caused any increases in water levels in either well throughout the monitoring period. Well 6 does not appear to be affected by local rainfall. Water levels in neither Well 5 nor 6 appear to have been affected by the remedial works in the 8.17 km Culvert and SH8 Canal sections. Groundwater level data from Wells 5 and 6 for the next construction season (January 2014 to March 2014) will be of particular interest as remedial works will be concentrated on this section of the canal.

3.2 Surface water level monitoring

Figures 10a and 10b show the relative change in water levels measured using the pressure transducers and the manual staff gauge measurements in the ponds at the SH8 and Mary Burn Canal sections respectively.

The manual measurements from staff gauge 1 at SH8 in pond 1 (TKBSH8SG1) plot well against the transducer data (SH8SG1T). It should be noted that there are no manual measurements between 12 December 2012 and 18 March 2013 due to the staff gauge being stolen. The manual measurements after 18 March 2013 had to be adjusted to fit the transducer data after the staff gauge had been stolen as a new staff gauge was installed in a different location to the original staff gauge. However, the manual measurements after this date show a good fit with the relative change in water levels from the transducer data. Throughout the monitoring period, water levels in pond 1 appear to have steadily declined by 0.2 m. The steepening rate of decline from February to April 2013 may be related to the canal remedial works. Large rainfall events in the area appear to result in small increases in water level in pond 1. A particularly large rainfall event on 6 May 2013 caused water levels in the pond to increase by almost 0.1 m.

Manual water level measurements from staff gauge 2 in pond 2 at SH8 (TKBSH8SG2) show that the water level in the pond dropped rapidly between 14 November 2012 and 10 January 2013 before the water level dropped below the base of the staff gauge. According to anecdotal knowledge from Dave Jenkinson, this pond frequently dries up over the summer months and refills during the winter and spring months. Water levels have remained below the staff gauge (TKBSH8SG2) from 10 January 2013 for the rest of the duration of the monitoring period.

The transducer data for pond 1 at Mary Burn Fill Canal section (MBSG1T) is displayed in Figure 10b. While there is an offset of the manual measurements from the staff gauge (TKBMBSG1) and the transducer data (MBSG1T), both sets of data do follow a similar pattern. It should be noted that the transducer was moved to a deeper depth on 11 January 2013 as there was a risk of the water level dropping below the transducer. Both the manual staff gauge measurements and the transducer data show that water levels in the pond declined from when the instruments were installed to about 8 February 2013 where water levels began to increase. The maximum decrease in water levels based on

the transducer data is 0.42 m on 29 December 2012. The transducer data (MBSG1T) also shows that water levels in the pond increase after large rainfall events as surface water runoff will contribute to the pond levels. Water levels typically decline gradually after each large rainfall event.

The manual measurements from TKBMBSG2 in pond 2 show water levels declined from when the instrument was installed until 14 February 2013 before increasing back to levels initially measured in this pond. The overall pattern from the TKBMBSG2 measurements follow a similar pattern to the data from TKBMBSG1 and MBSG1T.

Water levels in neither of the Mary Burn Fill ponds appear to have been effected by the remedial works in the 8.17 km Culvert and SH8 Canal sections. Water level data from the Mary Burn Fill ponds for the next construction season (January 2014 to March 2014) will be of particular interest as remedial works will be concentrated on this section of the canal.

3.3 Surface water flow monitoring

3.3.1 Observations of seeps

Figures 11a and 11b display the inspection ratings of the seeps along the SH8 and the Mary Burn Fill Canal sections respectively. All seeps along the SH8 Canal section, with the exception of seeps TKB13150LS, TKB11518LS and TKB13185RS, show inspection ratings that fluctuated throughout the monitoring period. Seeps TKB11518LS and TKB13185RS remained at constant ratings throughout the monitoring period. The rating for seep TKB13150LS increased from wet to flowing after dewatering of the canal and remained at this rating for the duration of the monitoring period. Only four seeps were found to have ratings of flowing (TKB13150LS, TKB133335LS, TKB13150LS and TKB13185RS) along the SH8 Canal section. All other seeps generally fluctuated between wet and dry ratings. During the period where the flow in the canal stopped and was dewatered, seeps TKB12800LS, TKB1300LS, TKB1157RS and TKB13185RS had ratings that fluctuated between damp and wet between 10 and 20 January 2013. Generally, the ratings of all seeps stabilised after 20 January 2013, although the rating for seep TKB11575RS increased dramatically from dry on 10 March 2013 to flowing on 25 March 2013 and remained at flowing for the rest of the monitoring period. The rating for seep TKB12800LS also increased from dry to wet between 10 March 2013 and 18 March 2013 before dropping to damp and dry ratings for the rest of the monitoring period. From the seep observations collected for the SH8 Canal section, there appears to be no clear connection between the canal remediation or rainfall and the fluctuations in the seep observations.

Figure 11b shows the ratings for the seep observations for the Mary Burn Canal section. Generally, the inspection ratings of seeps along the Mary Burn Fill Canal section have remained relatively stable and appear to have been unaffected by the remedial works carried out on the 8.17 km Culvert and SH8 Canal sections. No construction work occurred along the Mary Burn Fill Canal section during the monitoring period. Seeps

TKB18725LS and TKB18750RS display the largest fluctuations in inspection ratings but neither seep had a rating that exceeded wet. Seep TKB18175LS was only seep to consistently remain at flowing for the duration of the monitoring period. Seeps TKB18081LS, TKB19600LS and TKB19644LS were initially observed to be flowing but dropped to a rating of wet or below. Rainfall events do not appear to have influenced the seeps along the Mary Burn Fill Canal section. Observations of seeps along the Mary Burn Fill Canal section for the next construction season (January 2014 to March 2014) will be of particular interest as remedial works will be concentrated on this section of the canal.

Care should be taken when interpreting the seep observations as they are qualitative measurements and can be subject to human error during the collection of the data.

3.3.2 Weir measurements

Figure 12 shows flow rates for the weirs monitored along 8.17 km Culvert, SH8 and Mary Burn Fill Canal sections. Figure 12 shows that with the exception of weir TKBD174 (Mary Burn Fill), flow rates in all weirs dropped to zero after the canal was dewatered. The flow rate in TKBD174 at the Mary Burn Fill Canal section shows a declining trend throughout the monitoring period and does not appear to be affected by large rainfall events although, this may be due to the measurements only being made monthly. All other weirs except TKBWELBM (8.17 Culvert) and TKBWELBM (SH8) show a decreasing trend prior to the start of the remedial works. A large rainfall event on 2 January 2013 and a second smaller event on 10 January 2013 appears to have resulted in an increase in the flow rate in weirs TKBWRRTM, TKBD118M and TKBDWRLBM. The increase in flow due to the larger rainfall event on 2 January 2013 is delayed as the maximum increase in flow was reached in each weir on 8 January 2013, six days after the rainfall event. The flow rate in each weir started to decrease rapidly after this increase in flow. This sudden drop in flow may be a combination of the flow in the canal stopping and the additional water from the rainfall event draining away. Based on the reduction in flow of all the monitored weirs along the 8.17 km Culvert and SH8 Canal sections during dewatering of the canal, it could be inferred that base flow in each of the weirs is supplied via seepage from the canal. This seepage would most likely create a mound beneath the invert of the canal down to the natural groundwater level. The effect of rainfall on the flow rate measured in weirs TKBWRRTM, TKBD118M and TKBDWRLBM may be due to rainfall contributing to the mound caused by seepage from the canal. The additional water from the rainfall would cause a localised increase in the water level of the mound and result in an increased flow rate at the weir. This may explain the delay between the rainfall event and the increase in flow rate experienced in weirs TKBWRRTM, TKBD118M and TKBDWRLBM. The weirs appear to be responding to a perched seepage system associated with the canal as no obvious decrease in groundwater levels was observed as a result of dewatering of the canal (i.e. Wells 3 and 4).

Monitoring of the flow rates from each of the weirs should continue and additional measurements could be made during large rainfall events to try and establish the relationship between rainfall and increased weir flow rates.

It should be noted that some of the weirs (TKBWR817L – 8.17 km Culvert, TKBD118M – SH8 and TKBWELBM – SH8) are no longer monitored as they have been destroyed during the construction works or removed from the monitoring list as they are now dry. If flows begin again in any of the weirs that have been removed from the monitoring list but are still in place, it is recommended that they are added back to the list of monitored sites.

3.3.3 Stream flow gauging

Table 2 below displays the stream gauging results carried out by PDP during the monitoring period.

Table 2: Stream flow gauging results (all flows in m^3/s)

Date	SH8EUS	SH8EDS	IRISHUS	IRISHDS	MBUS	MBDS
3/10/2012	0.204	0.153	2.345	2.531	-	-
15/10/2012	0.523*	0.546*	Too high*	Too high*	-	-
16/10/2012	-	-	Too high*	Too high*	1.881*	2.534*
4/12/2013	0.110	0.113	1.195	1.153	0.624	0.566
10/05/2013	0.019	0.009	0.742	0.812	0.289	0.242

Notes: * denotes stream in flood

Flows measured in the unnamed stream east of SH8 and the Mary Burn on 15 and 16 October 2013 were made when flows were high. These measurements should be treated with caution as they may have errors associated with them from the streams being gauged at such high flows. Irishman Creek was too high to safely gauge during this period as well. With the exception of the initial measurements made in the unnamed stream east of SH8, flow rates in all three streams declined over the monitoring period. This is likely to be related to flows reducing during the summer months. Figure 13 shows the downstream gauging site on the unnamed stream east of State Highway Eight (SH8) during each gauging and how the flow and water levels in the stream differed between visits. Figure 13 shows how water levels in this stream have dropped and flows have reduced throughout the monitoring period.

Flow rates between the upstream and downstream sites at each stream were not consistent in terms of having a greater flow on one particular side of the canal throughout the monitoring period. However at times of lower flow, flow rates were generally slightly larger on the upstream side of the canal in both the unnamed stream east of SH8 and the Mary Burn although, larger flows were measured on the downstream side. Flows in Irishman Creek were typically slightly larger on the downstream side of the canal.

Based on the flow gauging measurements carried out so far, there is no clear pattern that the three streams are gaining water from the canal across the culvert at each site.

The 8.17 km Culvert barrels remained dry for the entire monitoring period and therefore have not been discussed. However, it should be noted that during the monitoring period,

the 8.17 km culvert was excavated and replaced with a new, reinforced culvert prior to the canal liner being installed.

4.0 Environmental effects arising from Remedial works

The purpose of this report is to describe the monitoring carried out during the Tekapo Canal remedial works and determine if there have been any changes on groundwater and surface water due to the installation of the liner in 8.17 km Culvert and SH8 Canal sections. Overall, there appears to have been a general decreasing trend since the beginning of monitoring at the majority of both groundwater and surface water monitoring sites prior to the start of the remedial works and dewatering of the canal and continued to drop during construction. Some water levels also began to increase prior to the canal being refilled. No obvious increase in either groundwater levels or surface water levels and flows was observed from the refilling of the canal after construction. The majority groundwater and surface water monitoring sites along the canal also appear to be directly influenced by large rainfall events resulting in small increases in water level.

In terms of the effect of leakage from the canal altering the natural groundwater and surface water levels in proximity to the canal, it appears to be less than minor based on the data collected during the monitoring period from October 2012 to April 2013, with the exception of some shallow weirs that appear to be perched above the fundamental water table. It would be prudent to continue monitoring groundwater and surface water levels to determine if there are any longer term effects from the remedial works on the canal.

5.0 Update of monitoring programme

During the next construction period, remedial works will be focused on the Mary Burn Fill canal section. The frequency of monitoring over the following 12 months is outlined below:

<u>May 2013 to December 2013</u>

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for 8.17 Culvert, SH8 and Mary Burn Fill Canal sections. Monitoring during this period will be carried out by Paul Martin (Genesis Power Ltd)

<u>January 2014 to March 2014</u>

Weekly monitoring of weirs, seeps and pond staff gauges for Mary Burn Fill Canal section, changing to **Daily** for 1 week prior to dewatering/refilling, during dewatering/refilling and 1 week after dewatering/refilling has ceased at each particular canal section;

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for 8.17 Culvert and SH8 Canal sections. Also **Monthly** monitoring of groundwater levels in monitoring wells for Mary Burn Fill Canal section.

<u>March 2014 to March 2015</u>

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for 8.17 Culvert, SH8 and Mary Burn Fill Canal sections.

Flow gaugings of the unnamed stream east of SH8, Irishman Creek and the Mary Burn will be made in six months (October 2013) and twelve months (April 2014) time. Downloads of transducers in the six wells and two ponds at SH8 and Mary Burn Fill will be downloaded in July 2013, October 2013, January 2014 and again in April 2014.

No additional monitoring requirements or changes to the current monitoring programme are recommended at this time. A review of the monitoring programme should be made again in 12 month's time when the next annual environmental monitoring report is due.

6.0 References

Pattle Delamore Partners. 2012. Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works. Prepared for Genesis Energy Ltd.

Appendix A

Figures

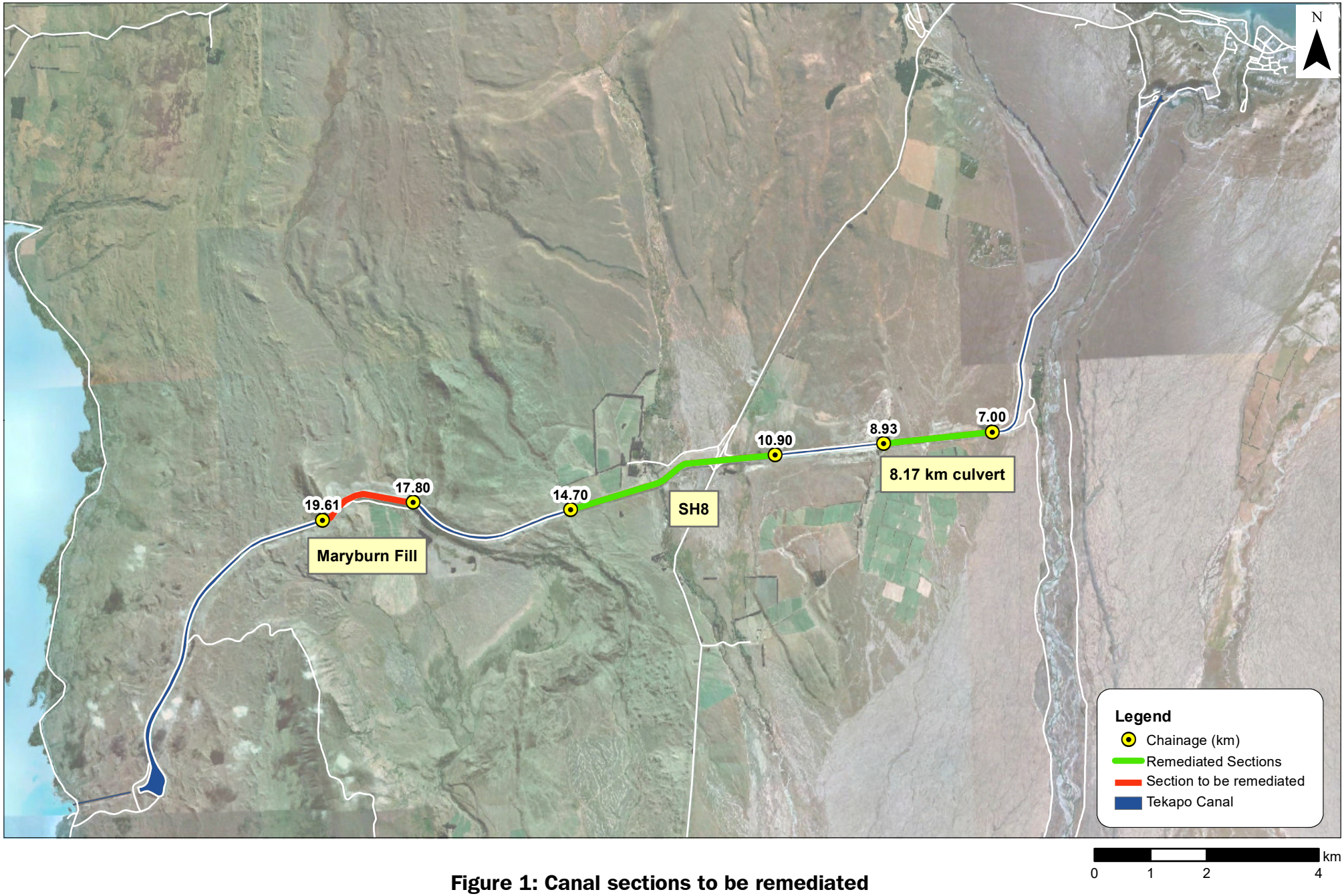


Figure 1: Canal sections to be remediated

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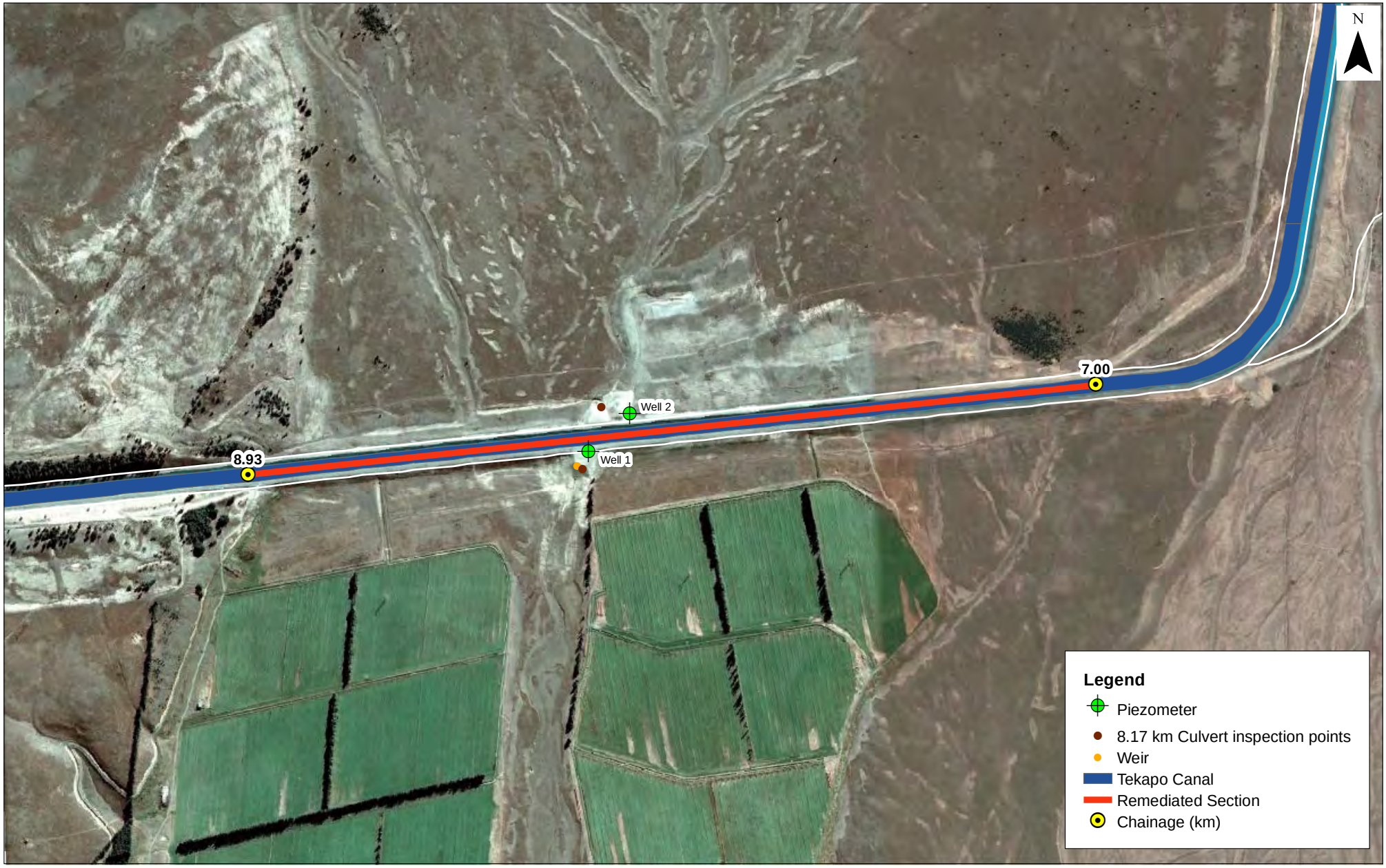


Figure 2a: Locations of monitoring points at 8.17 km culvert



Figure 2b: Locations of monitoring points along SH8 canal section

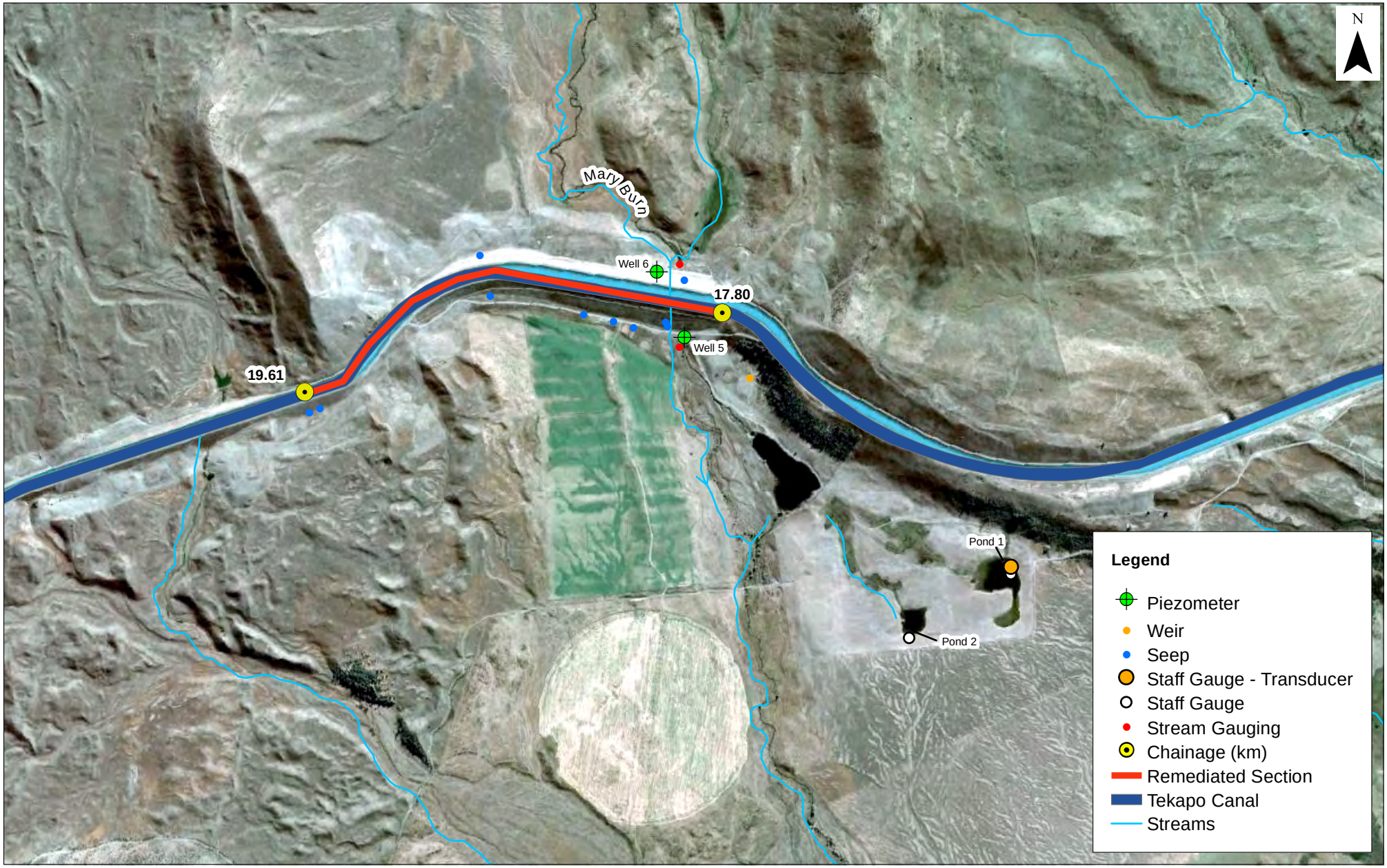


Figure 2c: Locations of monitoring points at Mary Burn Fill canal section

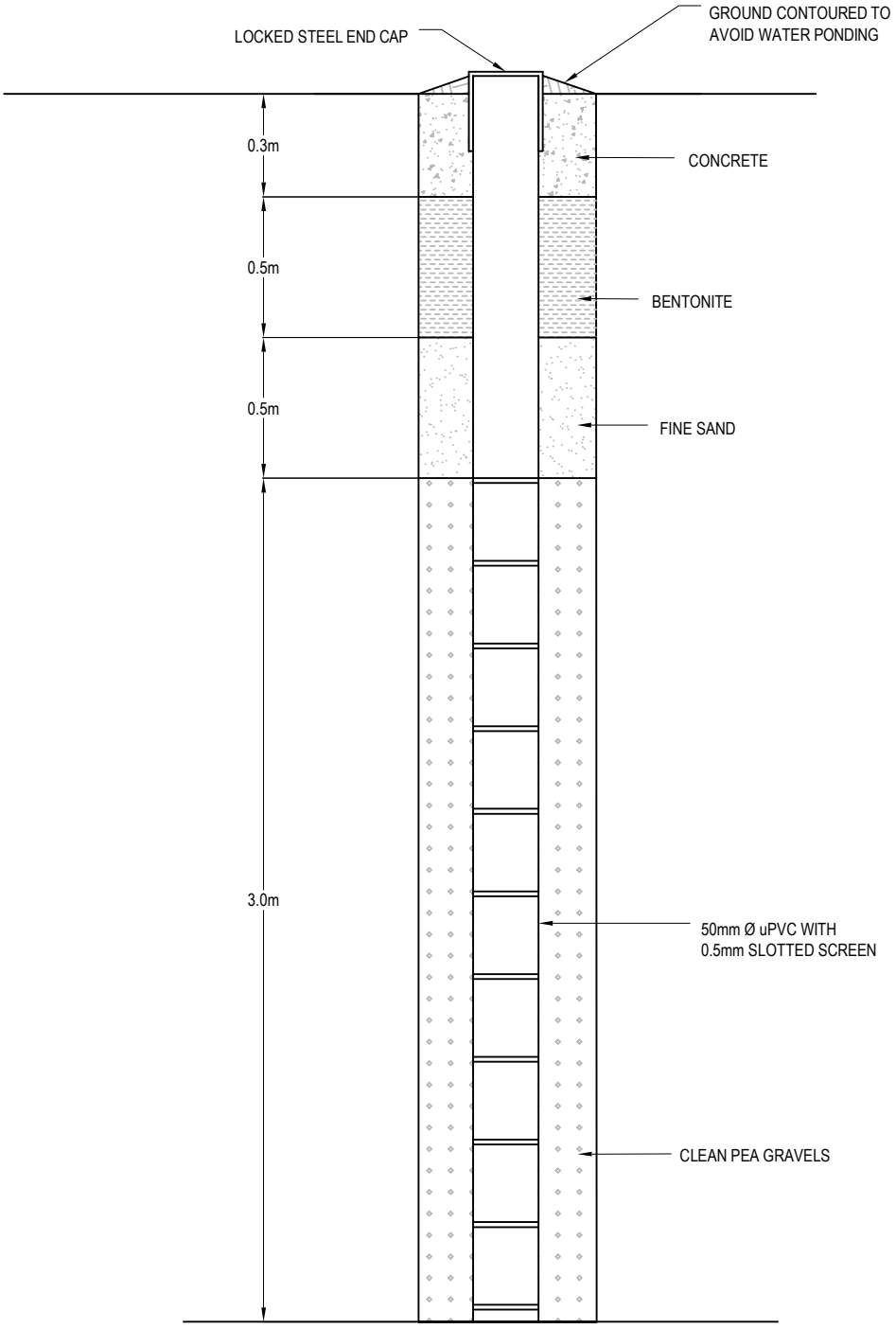


FIGURE 3 : SCHEMATIC DIAGRAM OF PIEZOMETER INSTALLATION (NOT TO SCALE)

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Figure 4a: Typical well head (Well 4) used for each the piezometers. Metal well cap is lockable and is set in concrete.



Figure 4b: Inside of well cap (Well 4). Top of PVC casing set in concrete to stop infiltration of surface water into annulus of well.

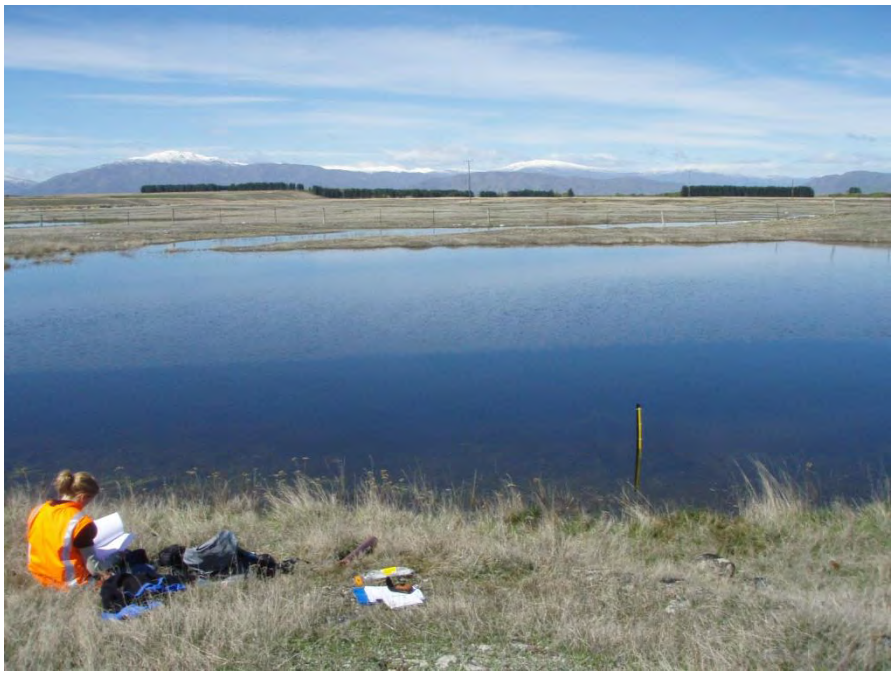


Figure 5a: Example of staff gauge installed in old borrow pit pond near SH8 (TKBSH8SG2). Photo taken on 15 October 2012.



Figure 5b: Example of transducer installed on submerged staff gauge in old borrow pit near SH8 (SH8SG1T). Staff gauge located in centre of photo. Photo taken on 4 December 2012.



Figure 6a: Example of seep on true left hand side of canal embankment, SH8 Canal section (Seep TKB12800LS). Seep rated as wet (2) at time of photo. Photo taken on 3 October 2012.



Figure 6b: Example of seep on true left hand side of canal embankment, Mary Burn Fill Canal section (Seep TKB18082LS). Seep rated as dry (0) at time of photo. Note increased vegetation growth. Photo taken on 3 October 2012.



Figure 7a: Example of weir on true right hand side of canal embankment next to the unnamed stream east of SH8, SH8 Canal section (Weir TKBWRRTM). Photo taken on 2 October 2012.



Figure 7b: Example of weir on true left hand side of canal embankment, Mary Burn Fill Canal section (Weir TKBWELBS). Photo taken on 3 October 2012.



Figure 8a: Example of stream flow gauging site in Irishman creek, up stream of canal (site IRISHUS). Photo taken on 3 October 2012.



Figure 8b: Downstream culvert barrels of 8.17 km culvert on true left hand side of 8.17 km Culvert Canal section. (site TKB08170LC). Photo taken on 2 October 2012.

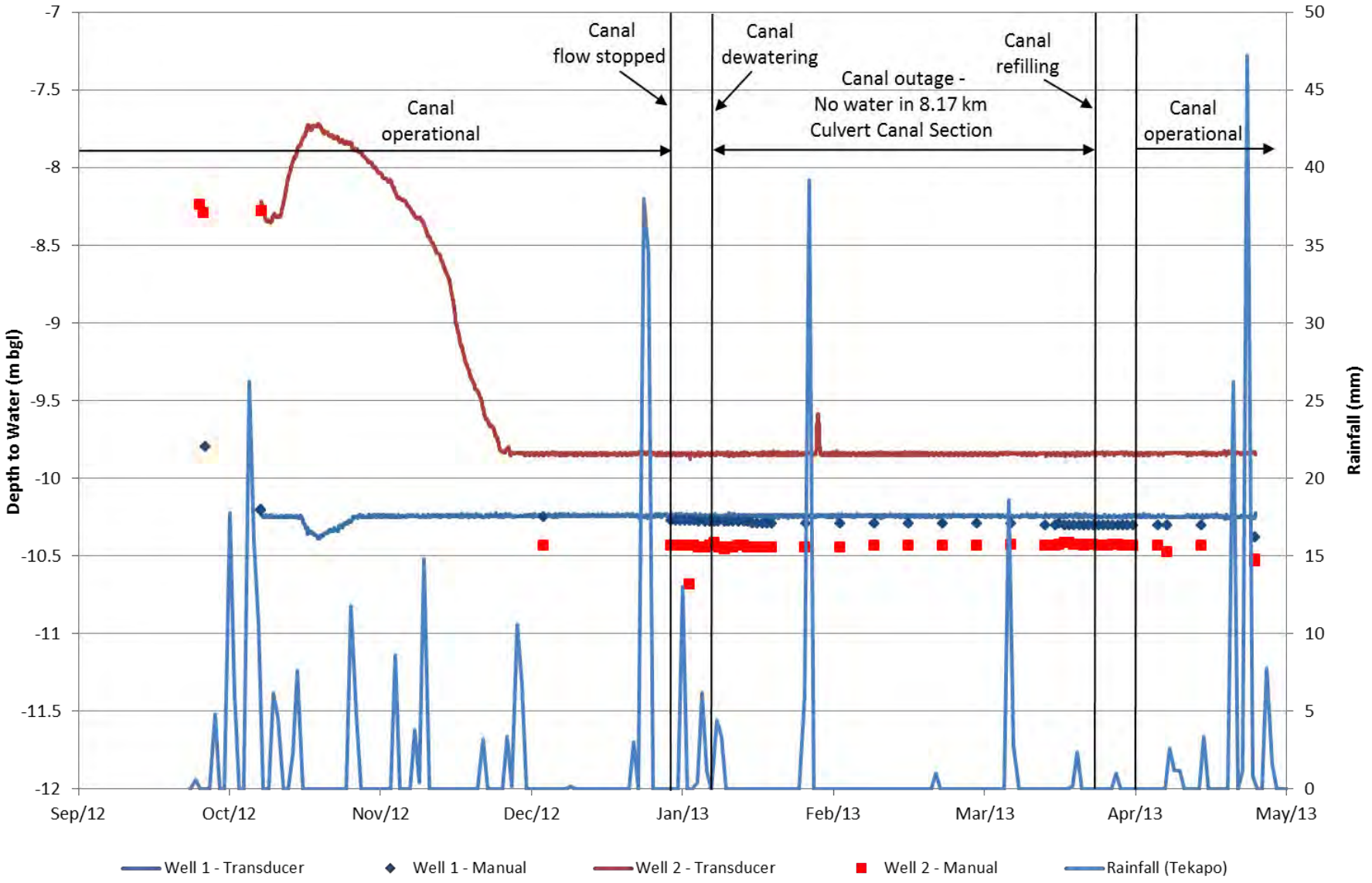


Figure 9a: Groundwater levels in wells 1 and 2 at 8.17 km Culvert and rainfall records

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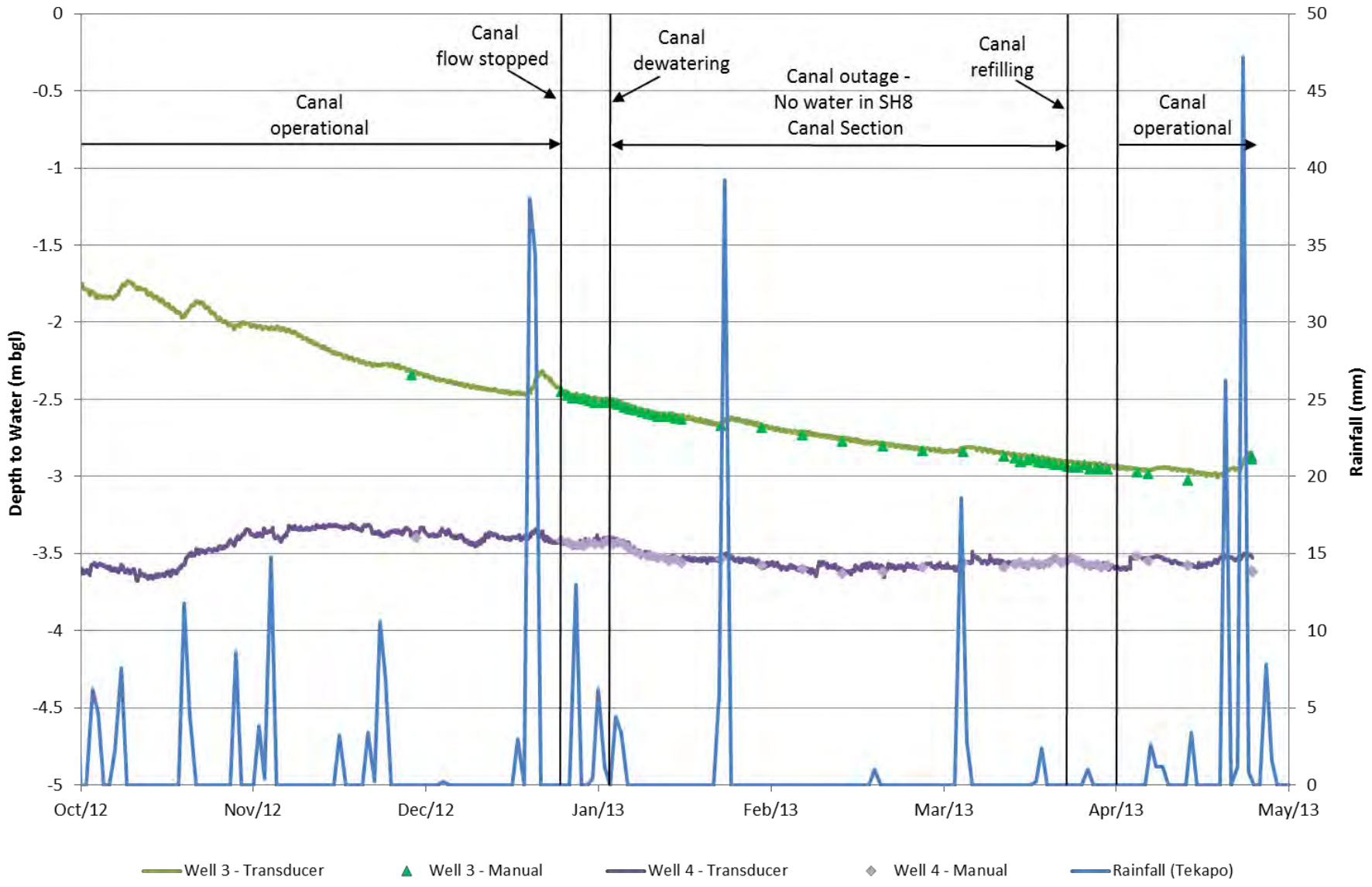


Figure 9b: Groundwater levels in wells 3 and 4 at SH8 Canal section and rainfall records

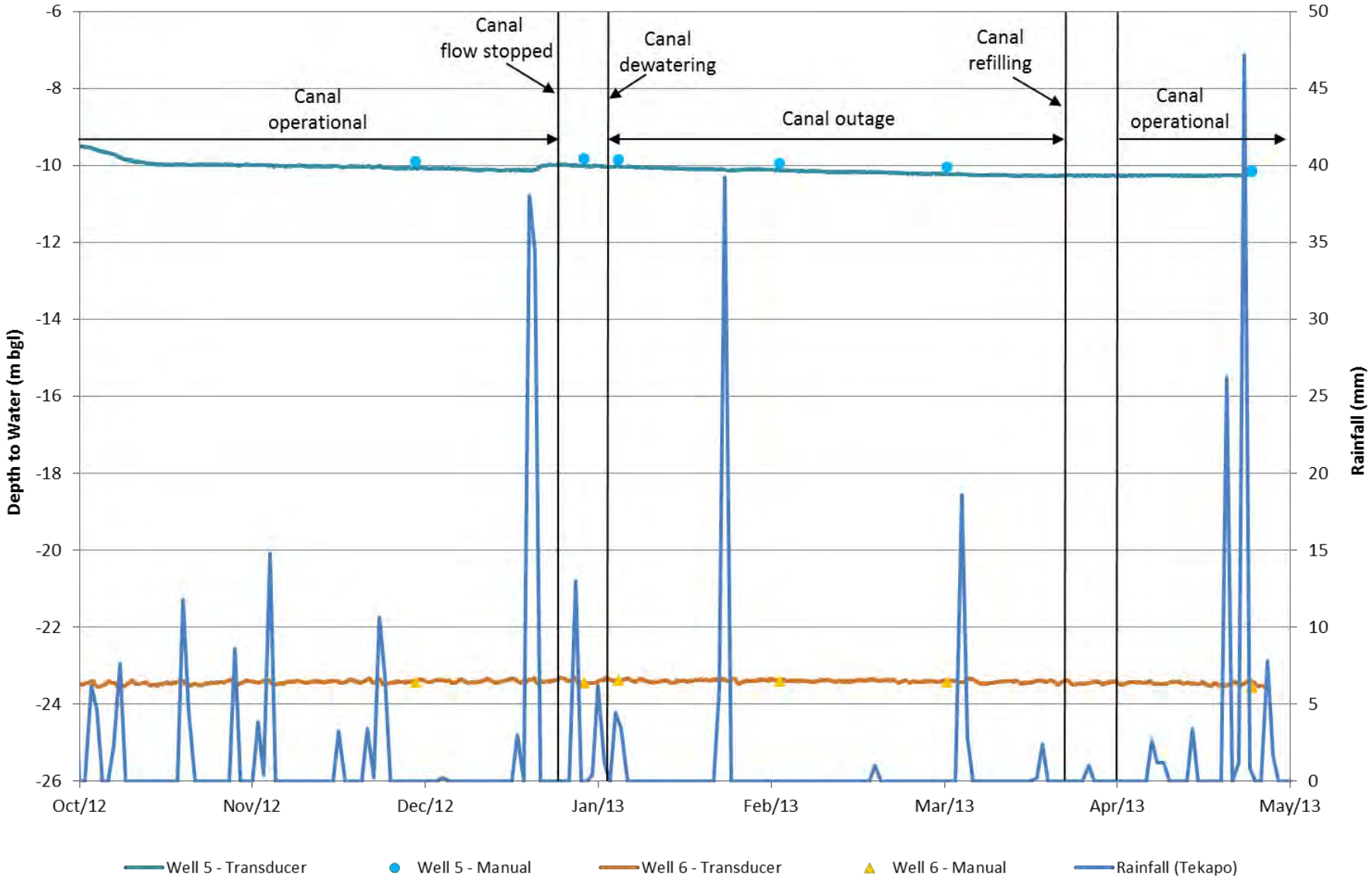


Figure 9c: Groundwater levels in wells 5 and 6 at Mary Burn Fill Canal section and rainfall records

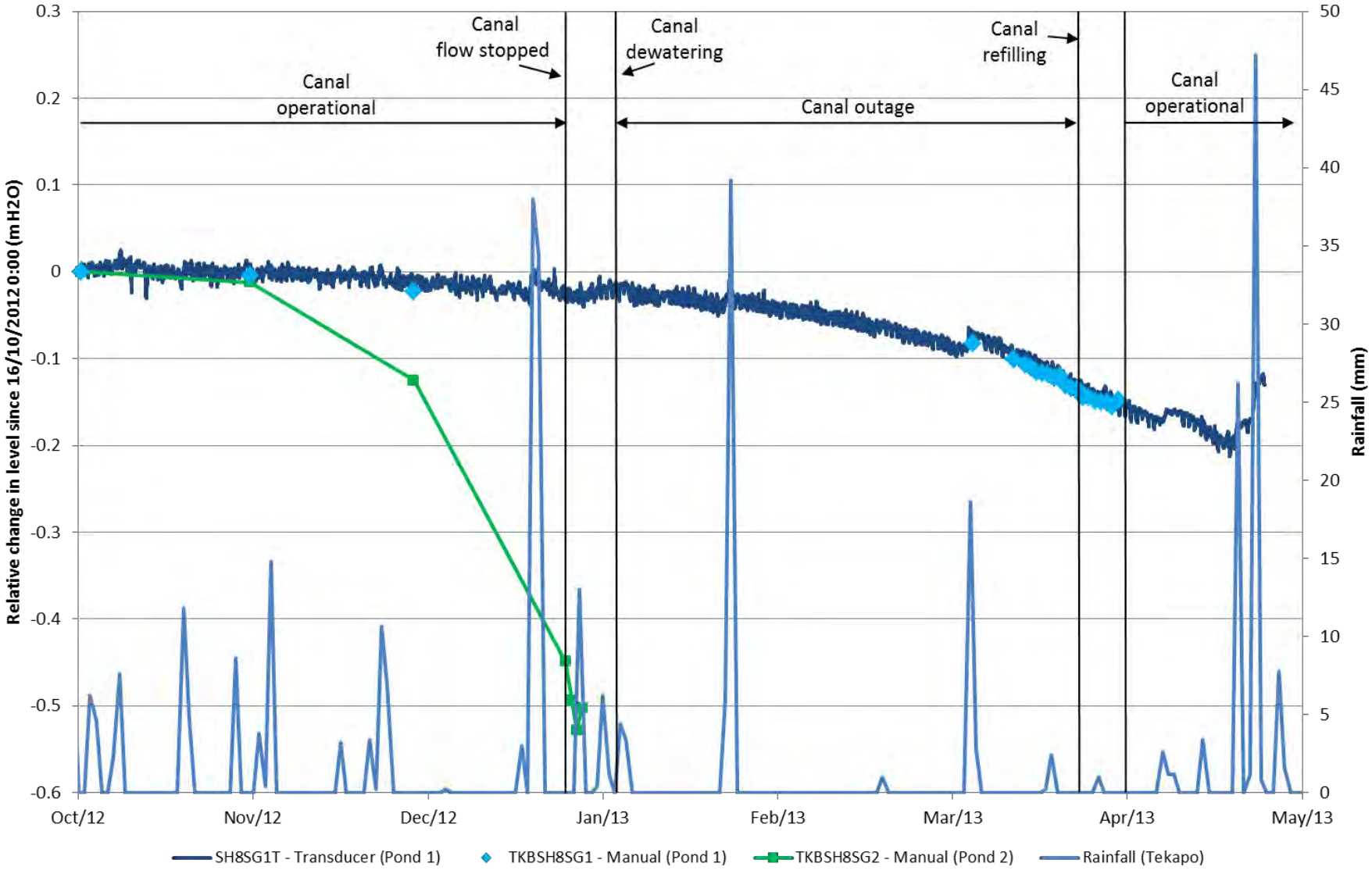


Figure 10a: Pond water levels in wells at SH8 Canal section and rainfall records

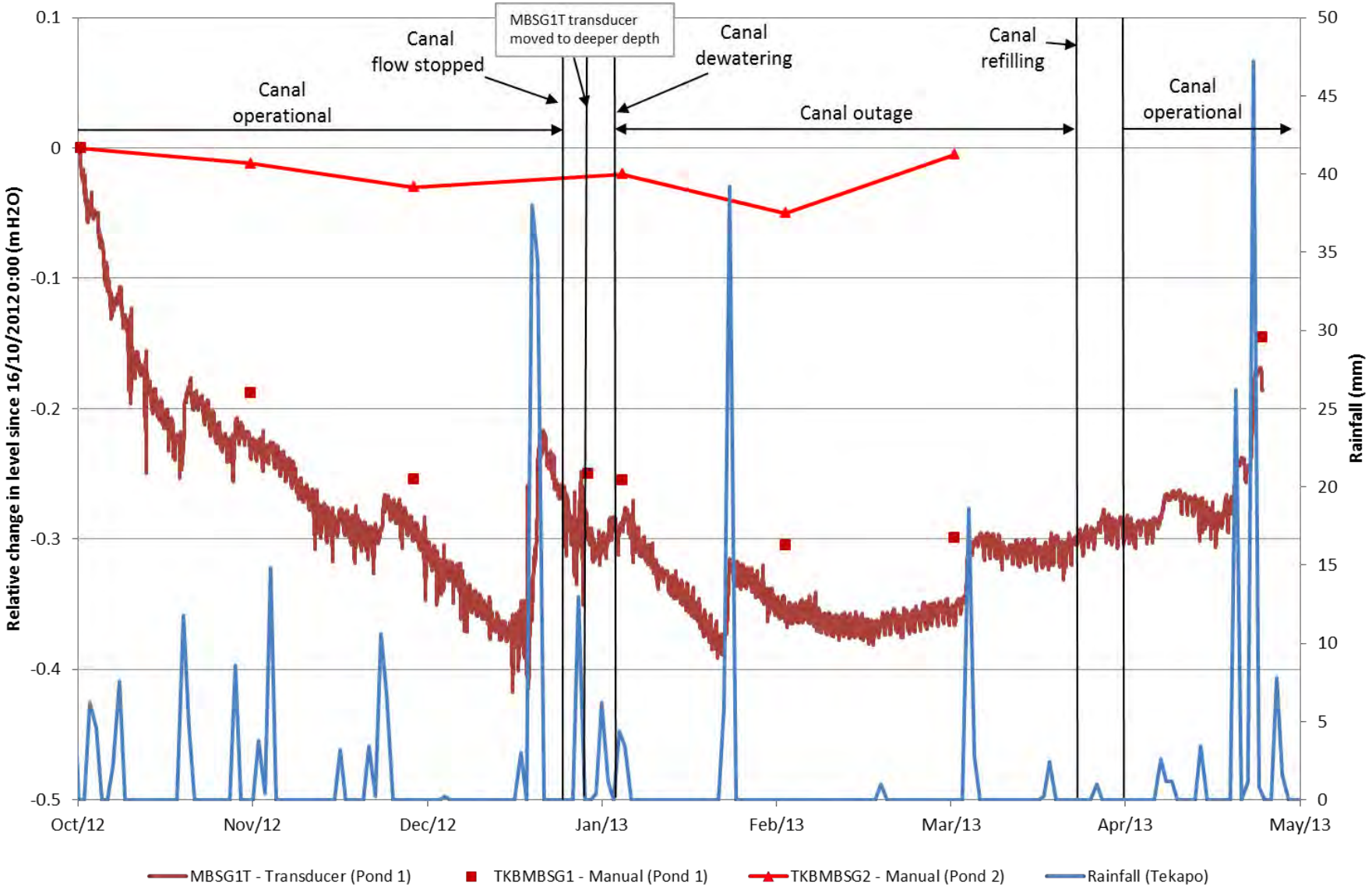


Figure 10b: Pond water levels in wells at Mary Burn Fill Canal section and rainfall records

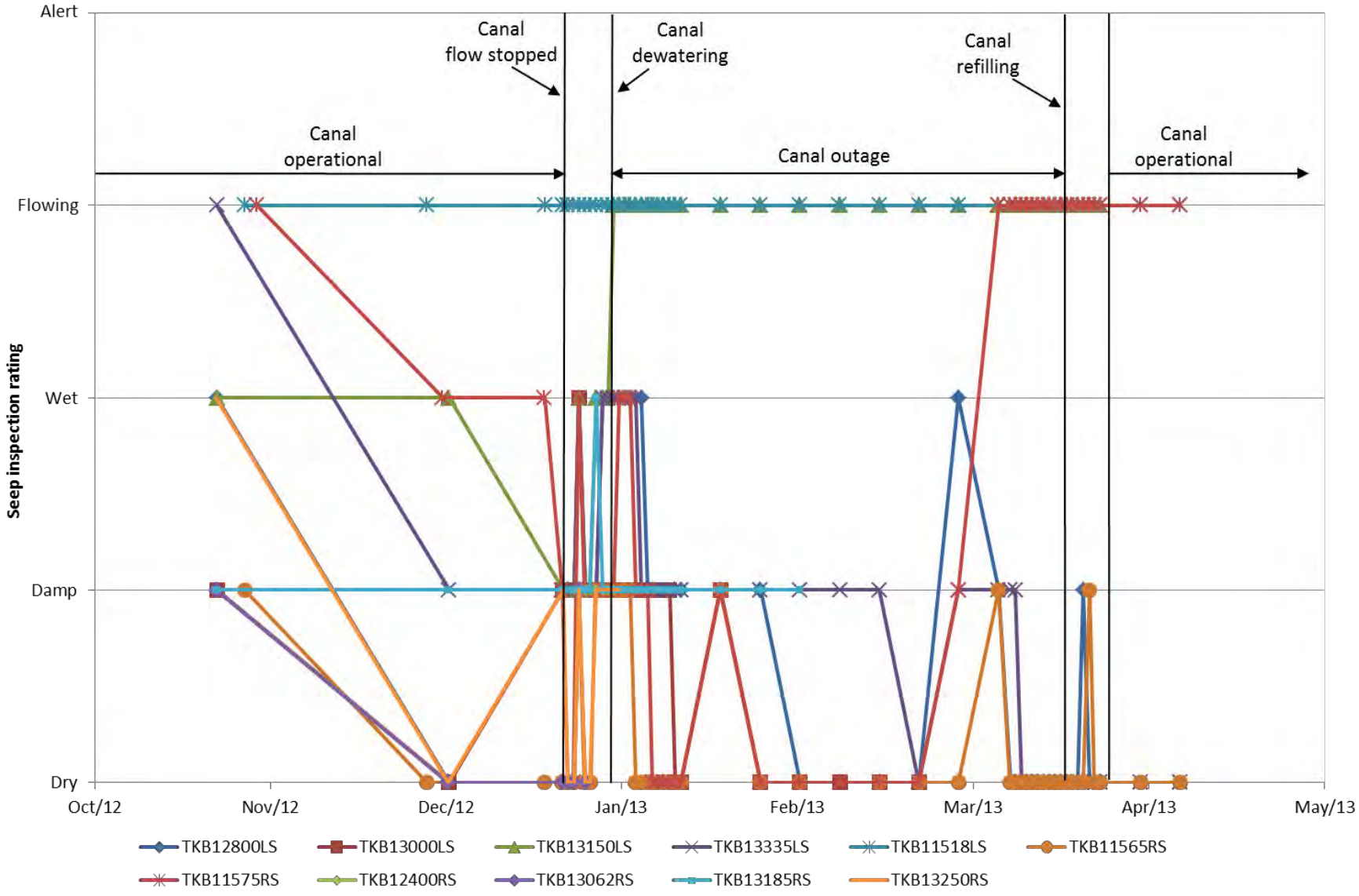


Figure 11a: Inspection ratings for seeps along the SH8 Canal section during the monitoring period

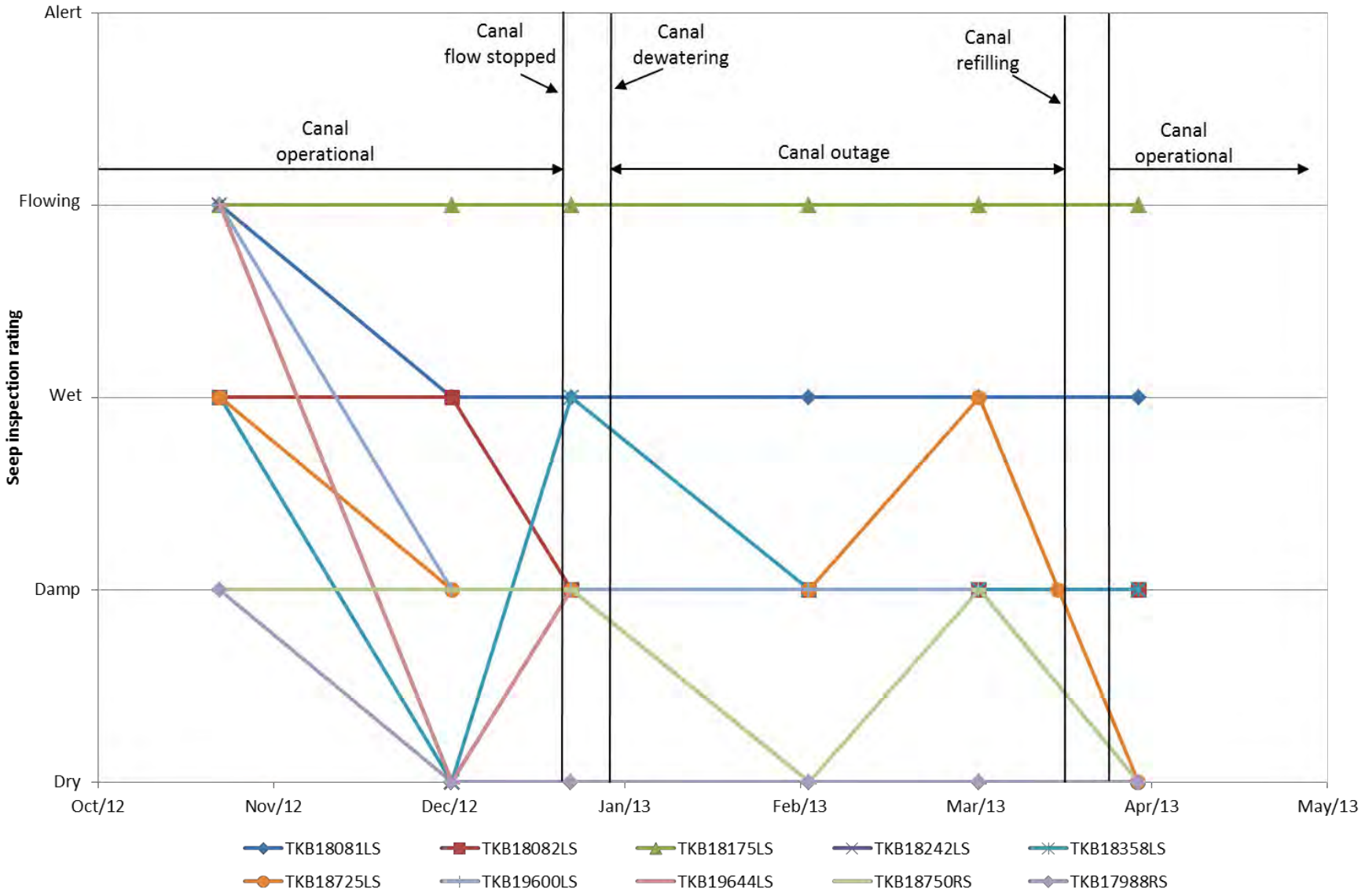


Figure 11b: Inspection ratings for seeps along the Mary Burn Fill Canal section during the monitoring period

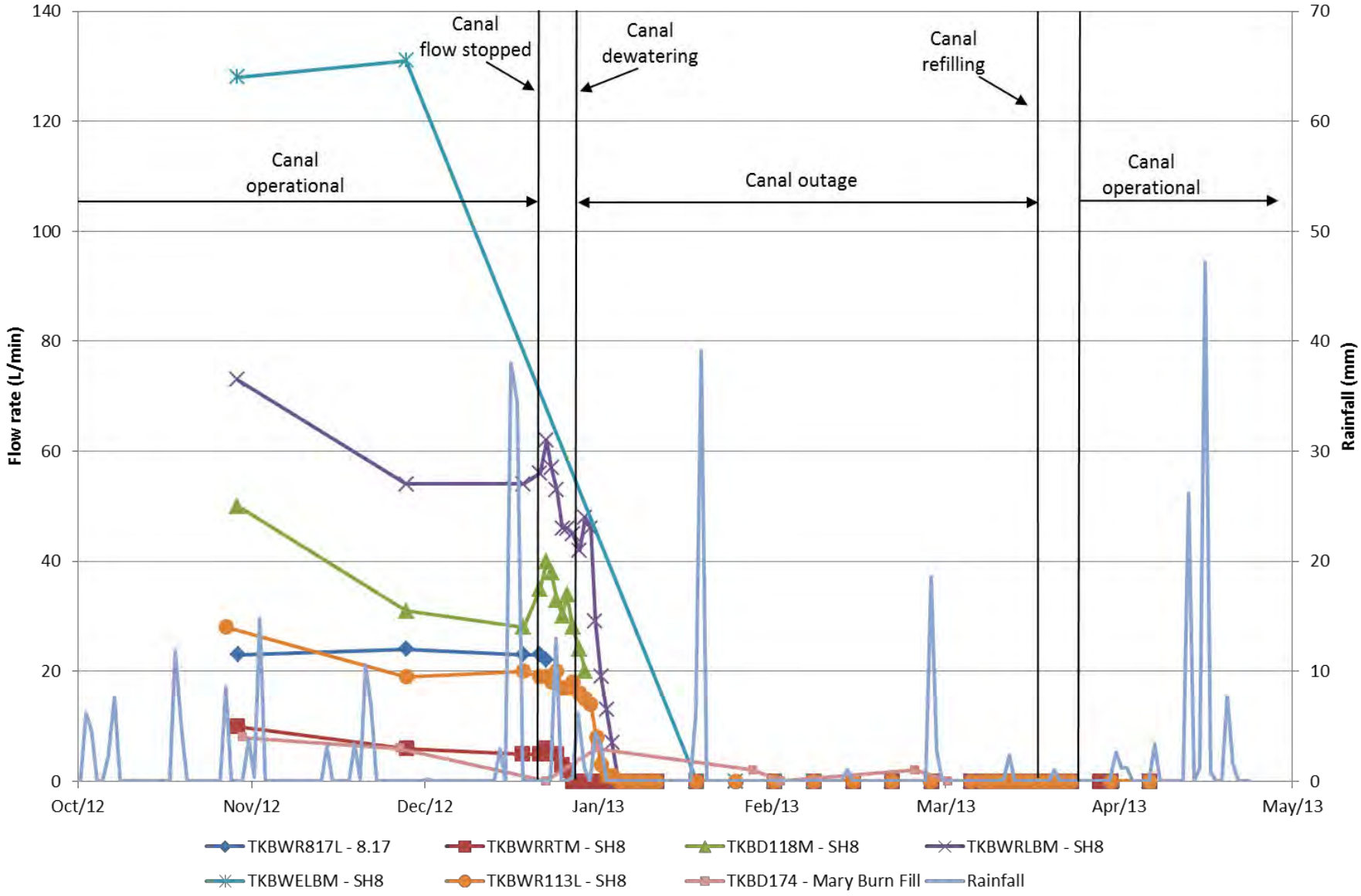


Figure 12: Flow rates of all weirs along 8.17 km Culvert, SH8 and Mary Burn Fill Canal sections along with rainfall









Figure 13: Photos of stream flow gauging site SH8EDS on true left hand side of SH8 Canal section. Photos taken at each flow gauging measurement at site.

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Appendix B

List of Monitoring Sites

Canal Section	Site Name	Easting (NZTM)	Northing (NZTM)	Type	Status (as of May 2013)
8.17	TKB08170LC	1392232	5117216	Culvert inspection (downstream)	Repaired
8.17	TKB08170RC	1392297	5117379	Culvert inspection (upstream)	Repaired
8.17	TKBWR817L	1392242	5117245	Weir	Removed
8.17	TKBOP401	1392307	5117272	Monitoring Well (Well 1)	Unaltered
8.17	TKBOP411	1392361	5117388	Monitoring Well (Well 2)	Unaltered
SH8	TKBSH8SG1	1388742	5116770	Staff Gauge	Unaltered
SH8	SH8SG1T	1388708	5116778	Transducer - Pond	Unaltered
SH8	TKBSH8SG2	1388548	5116726	Staff Gauge	Unaltered
SH8	TKB11518LS	1388951	5116880	Seep	Unaltered
SH8	TKB11565RS	1388931	5117011	Seep	Unaltered
SH8	TKB11575RS	1388879	5117012	Seep	Unaltered
SH8	TKB12400RS	1387960	5116899	Seep	No longer monitored
SH8	TKB12800LS	1387733	5116632	Seep	No longer monitored
SH8	TKB13000LS	1387594	5116502	Seep	No longer monitored
SH8	TKB13062RS	1387502	5116584	Seep	No longer monitored
SH8	TKB13150LS	1387422	5116423	Seep	No longer monitored
SH8	TKB13185RS	1387372	5116546	Seep	No longer monitored
SH8	TKB13250RS	1387298	5116547	Seep	No longer monitored
SH8	TKB13335LS	1387249	5116381	Seep	Unaltered
SH8	TKBD118M	1388898	5116881	Weir	Removed
SH8	TKBWELBM	1388909	5116886	Weir	Unaltered
SH8	TKBWELBS	1388914	5116880	Weir	Unaltered
SH8	TKBWR113L	1389170	5116878	Weir	Unaltered
SH8	TKBWRLBM	1388900	5116884	Weir	Unaltered
SH8	TKBWRRTM	1388893	5117018	Weir	Unaltered
SH8	TKBOP421	1388729	5116854	Monitoring Well (Well 3)	Unaltered
SH8	TKBOP431	1388961	5117010	Monitoring Well (Well 4)	Unaltered
SH8	SH8EUS	1388889	5117030	Flow Gauging site - Stream east of SH8	Unaltered
SH8	SH8EDS	1388924	5116860	Flow Gauging site - Stream east of SH8	Unaltered
SH8	IRISHDS	1387554	5116320	Flow Gauging site - Irishman Creek	Unaltered
SH8	IRISHUS	1387427	5116673	Flow Gauging site - Irishman Creek	Unaltered
Mary Burn Fill	TKBMBSG1	1384195	5115160	Staff Gauge	Unaltered
Mary Burn Fill	MBSG1T	1384195	5115160	Transducer - Pond	Unaltered
Mary Burn Fill	TKBMBSG2	1383805	5114914	Staff Gauge	Unaltered
Mary Burn Fill	TKB17988RS	1382940	5116288	Seep	Unaltered
Mary Burn Fill	TKB18081LS	1382870	5116127	Seep	Unaltered
Mary Burn Fill	TKB18082LS	1382875	5116113	Seep	Unaltered
Mary Burn Fill	TKB18175LS	1382746	5116106	Seep	Unaltered
Mary Burn Fill	TKB18242LS	1382669	5116131	Seep	Unaltered
Mary Burn Fill	TKB18358LS	1382554	5116156	Seep	Unaltered
Mary Burn Fill	TKB18725LS	1382196	5116227	Seep	Unaltered
Mary Burn Fill	TKB18750RS	1382156	5116384	Seep	Unaltered
Mary Burn Fill	TKB19600LS	1381542	5115795	Seep	Unaltered
Mary Burn Fill	TKB19644LS	1381502	5115781	Seep	Unaltered
Mary Burn Fill	TKBD174	1383192	5115912	Weir	Unaltered
Mary Burn Fill	TKBOP441	1382940	5116070	Monitoring Well (Well 5)	Unaltered
Mary Burn Fill	TKBOP451	1382834	5116321	Monitoring Well (Well 6)	Unaltered
Mary Burn Fill	MBUS	1382885	5116350	Flow Gauging Site - Mary Burn	Unaltered
Mary Burn Fill	MBDS	1382889	5116032	Flow Gauging Site - Mary Burn	Unaltered

Appendix C

Driller's Logs

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Camp / E2302272, N5678906

HOLE No. 1

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 10.38 | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 10.38 (m).

Driller: Neil / Simmons | SHIFT START DATE: 6/10/12 TIME: | SHIFT FINISH DATE: 6/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	2.2	Dual rotary 150mm	Brown Clay Bound Gravel			
			2.2	~~10.38~~	" "	Sandy Clay Bound Gravel			WL 9.8m
				10.38					
		0.5	0	0.5	-	Cement			1 Bag
		4.71	0.5	5.21		Backfill			
		0.73	5.21	5.94		Bentonite			1 Bag
		0.47	5.94	6.41		Fine Sand			
		3.97	6.41	10.38		Sand			7 Bags

INSTALLATIONS | CASING: from 0 to 7.38 (m). Diameter: 50mm pvc Comments:

SCREEN: from 7.38 to 10.38 (m). Diameter: 50mm pvc Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Cement E230230 N5679029

HOLE No. 2

Drill Rig Type: DR24

DRILLING LOG | Length of hole: | Inclination: | Bearing: 10-8 | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to ~~9.26~~ (m).

Driller: Neil Simmons | SHIFT START DATE: 3/10/12 TIME: | SHIFT FINISH DATE: 3/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	0.1	Down rotary 150mm	top Soil			
			0.1	10.8	"	Clay Bound Gravel	WS 3.24		
		3.46	7.33	10.79		Sand			8 1/2 Bags
		0.49	6.84	7.33		fine Sand			
		0.62	6.22	6.84		Betonite			1 Bag
		5.87	0.35	6.22		Back fill			
		0.35	0	0.35		Cement			1 Bag

INSTALLATIONS | CASING: from 0 to 7.79 (m). Diameter: 50mm pvc Comments:

SCREEN: from 7.79 to 10.79 (m). Diameter: 50mm pvc Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Canal
E2298695, N5678489

HOLE No. 3

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 5.67 | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 5.7 (m).

Driller: Neil | SHIFT START DATE: 3/10/12 TIME: | SHIFT FINISH DATE: 3/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
		5.67	0	5.67	Dual rotary 150mm	Clay Bound gravels	Swl 2.10m		
		0.4	0	.4		Cement			1 Bag
		0.72	0.4	1.12		Backfill			
		0.48	1.12	1.6		~~fine Sand~~ Bentonite			1 Bag
		0.52	1.6	2.12		~~Sand~~ fine Sand			
		3.55	2.12	5.67		Sand			6 1/2 Bag

INSTALLATIONS | CASING: from 0 to 2.67 (m). Diameter: 50mm Comments: pvc

SCREEN: from 2.67 to 5.67 (m). Diameter: 50mm Comments: pvc

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: E2298924, N5678648 Tekapo Canal

HOLE No. Hole 4

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 6.48m | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 6.5 (m).

Driller: Neil | SHIFT START DATE: 2/10/12 TIME: | SHIFT FINISH DATE: 2/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
		0.30	0	0.3	Dual rotary 6"	Top Soil			
		3.2	0.3	3.5	" "	Brown Silty Clay Bound Gravel			
		3.00	3.5	6.5	" "	Clay Bound Gravel yellow	SWL 3.54		
			0	.3	~~Geotube~~	Cement			1 Bag
			0.3	1.8		Backfill			
			1.8	2.5		Bentonite			1 Bag
			2.5	3.05		fine Sand			5 Bags
			3.05	6.48		Sand			

INSTALLATIONS | CASING: from 0 to 3.50 (m). Diameter: Comments: pvc

SCREEN: from 6.48 to 3.50 (m). Diameter: 50mm Comments: pvc

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: te Kapo corner
E2292907 N5677707

HOLE No. 5

Drill Rig Type: ORZ4

DRILLING LOG | Length of hole: 10.96m | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 10.96(m).

Driller: Neil Simmons | SHIFT START DATE: | TIME: | SHIFT FINISH DATE: | TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	10.96	Down Rotary 150mm	Clay Bound Gravel			WL 9.85m
		0.3	0	0.3		Cement			1 Bag
		6.08	0.3	6.38		Backfill			
		0.58	6.38	6.96		Bentonite			1 Bag
		0.45	6.96	7.41		Fine Sand			
		3.57	7.41	10.98		Sand			5½ Bags

INSTALLATIONS | CASING: from 0 to 7.96 (m). Diameter: 50mm PVC Comments:

SCREEN: from 7.96 to 10.96 (m). Diameter: 50mm PVC Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Corner E2292801 N5677958

HOLE No. 6

Drill Rig Type: DR24

DRILLING LOG

INSPECTOR

Driller: Neil / Simmons

Length of hole: 26.83 Inclination: Bearing:

TYPE: Open holing from 15 to 26.83 (m). Tubexing from to (m). Rotary from 0 to 15 (m).

Sheet 1 of 1

SHIFT START DATE: 5/10/12 TIME: SHIFT FINISH DATE: 5/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	8.5	Down / rotary 150mm	large fill (Boulders)			
			8.5	14	"	Clay Bound Gravel			
			14	17.1	"	Boulder			
			17.1	19.3	"	Clay Bound Gravel			
			19.3	24	"	Sand			
			24	26.9	"	Very Sand Gravel			
									WL 24.46m
			0	0.3		Cement			1 Bag
			0.3	22.4		Backfill			
			22.4	22.9		Bentonite			1 Bag
			22.9	23.38		fine Sand			
			23.38	26.83		Sand			6 1/2 Bag

INSTALLATIONS

CASING: from 0 to 23.83 (m). Diameter: 50mm pvc Comments:

SCREEN: from 23.83 to 26.83 (m). Diameter: 50mm pvc Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

Appendix D

Schedule One – General Conditions

SCHEDULE ONE – GENERAL CONDITIONS

CONDITIONS ATTACHED TO RESOURCE CONSENTS:
CRC122392, CRC122393, CRC122394, CRC122395, CRC122396, CRC122397, CRC122398, CRC122399, CRC122400, CRC122401, CRC122402, CRC122403, CRC122404, CRC122405, CRC122406, CRC122407, CRC122409, CRC122410 and CRC122411;
ISSUED BY THE CANTERBURY REGIONAL COUNCIL (CRC)

GENERAL

1) Unless otherwise stated where information is to be provided to CRC it shall be sent to the CRC Attention: Regional Manager RMA Monitoring and Compliance.

2) In each year these resource consents are exercised the consent holder shall provide CRC with an updated schedule of all construction activities at least every three months, and notify CRC if there are any changes.

3) Prior to the commencement of the construction season, in each year that these resource consents are to be exercised, the consent holder shall arrange and conduct a pre-construction site meeting between a CRC representative and all relevant parties, including the primary contractor. At a minimum, the following shall be covered at the meeting:

   a) Scheduling and staging of works;

   b) Responsibilities of all relevant parties;

   c) Contact details for all relevant parties;

   d) Expectations regarding communication between all relevant parties;

   e) Procedures for implementing any amendments;

   f) Site inspection;

   g) Maintenance of storm water, erosion and sediment control measures;

   h) Confirmation that all relevant parties have copies of the contents of this consent document and all associated management plans; and

   i) The management plans, or subsequent revisions allowed for in Condition 9.

4) Prior to the commencement of each construction season the consent holder shall provide written notification of the works commencing on the site to CRC, at least five working days prior to works commencing.

5) When undertaking the activities authorised by these resource consents, all practicable steps shall be undertaken to minimise adverse effects on property, wildlife, biodiversity values, aquatic ecosystems, vegetation, cultural and amenity values.

6) If the consent holder ceases work on-site for a period of seven consecutive or more days, they shall first take adequate preventive and remedial measures to control sediment discharges, and shall thereafter maintain those measures for as long as necessary to prevent sediment discharges from the site.

7) Notwithstanding Conditions 4, 11, 13, 14, 25 and 29 preliminary earthworks, vegetation clearance and the establishment of buildings associated with the development of the Construction Management Site may commence immediately following the commencement of these resource consents. These preliminary works shall be undertaken in accordance with all other relevant consent conditions. An Environmental Management Plan ("**EMP**") and supplementary environmental management plans ("**SEMP**") relevant to these preliminary works shall be submitted to CRC as soon as practicable after site preparation work commences, but no later than 15 working days thereafter.

MANAGEMENT PLANS

8) All management plans submitted in accordance with Schedule One shall address all the relevant matters identified within this schedule and demonstrate compliance with the relevant consent conditions.

9) The management plans may be amended at any time. Any amendments shall be:

   (a) Consistent with the conditions of these resource consents; and

   (b) Submitted in writing to CRC, as soon as practicable.

10) The preparation, and amendment, of a management plan shall be undertaken by a person or persons with a relevant tertiary qualification and at least five years relevant experience or a person who CRC deem to be appropriately qualified.

ENVIRONMENTAL MANAGEMENT PLAN

11) At least 20 working days prior to the commencement of any construction works, the consent holder shall submit an EMP to CRC.

12) The EMP shall be an umbrella document that identifies the management processes and techniques to ensure appropriate environmental management of the site and works.

SUPPLEMENTARY ENVIRONMENTAL MANAGEMENT PLANS

13) At least 20 working days prior to the commencement of construction works, the consent holder shall submit the following SEMP to CRC:

   (a) Canal Water Quality Management Plan

   (b) Storm Water, Sediment and Erosion Control Management Plan;

   (c) Dust Management Plan;

   (d) Rehabilitation Management Plan;

   (e) Contaminant Spill Contingency Plan; and

(f) Fish Salvage Management Plan.

14) All works shall be undertaken in accordance with the approved SEMP listed in Condition 13.

Canal Water Quality Management Plan

15)

a) At least 40 working days prior to the commencement of construction works, the consent holder shall undertake a one-off background monitoring of bed sediment quality at several sites in the canal to determine the proportion of organic material present in sediment upstream and downstream of the salmon farm operated by Mount Cook Alpine Salmon Limited and to assess the potential effect that organic material in the sediment will have on oxygen levels in the canal water when flows cease.

b) The results of the monitoring undertaken as part of Condition (15)(a) above shall be provided to the CRC within five working days of them becoming available.

c) The consent holder shall prepare, submit and implement a Canal Water Quality Management Plan ("**CWQMP**"). The frequency and location of the monitoring and the extent of the management responses required under the CWQMP shall be established based on the results of the monitoring undertaken as part of Condition (15)(a) above. In addition, the CWQMP shall address, but not necessarily be limited to, the following matters:

i) A water quality monitoring program which shall measure water temperature and dissolved oxygen levels in the Tekapo Canal while the flow in the canal is halted. Measurements shall be taken at a depth of 1 metre and a depth of 5 metres.

ii) The response the consent holder shall undertake to:

(a) Report on thermal stratification in the canal water if temperature monitoring shows a difference greater than 2°C between water at 1 metre depth and water at 5 metres depth; and / or;
(b) Increase dissolved oxygen levels in canal water to above 80 percent saturation.

iii) The management actions to be carried out when:

(a) The difference in water temperature between canal water at 1 metre depth and 5 metres depth exceeds 2°C, and/or:
(b) Dissolved oxygen levels in the canal water decrease to, or below, 50 percent saturation.

iv) The consent holder shall keep records of all water quality information recorded and shall submit the record annually to the CRC.

v) Should the actions detailed in Condition (15)(c)(iii) need to be carried out, the consent holder shall notify the CRC within 5 working days.

Storm Water, Sediment and Erosion Control Management Plan

16) The consent holder shall prepare, submit and implement a Storm Water, Sediment and Erosion Control Management Plan ("**SSECMP**"). The SSECMP shall be prepared in accordance with the Canterbury Regional Council's "Erosion and Sediment Control Guidelines for the Canterbury Region" Report No. CRC R06/23, February 2007 ("**ESCG**"). The SSECMP shall ensure that all discharges to water courses do not exceed total suspended solids of greater than 100 grams per cubic metre. The SSECMP shall address, but not necessarily be limited to, the following matters:

a) A map showing the location of all works;

b) Detailed plans showing the location of sediment control measures, on-site catchment boundaries, and sources of runoff;

c) Drawings and specifications of designated sediment control measures;

d) Details of any sediment Flocculent/Coagulant use including but not limited to:
   (i) Methodology for choosing a suitable flocculent/coagulant.
   (ii) Details of how the flocculent/coagulant will be applied including how the optimal dosage will be calculated, and manufactures instructions are complied with,
   (iii) Details of how it will be determined that the use of a flocculent/coagulant is necessary.
   (iv) Monitoring.

e) A programme of works, which includes but is not limited to, a proposed timeframe for the works; and

f) Details of the inspections and maintenance for the erosion and sediment control measures, including monitoring of total suspended solids in discharges to water.

g) Timing and methodology of decommissioning works.

Dust Management Plan

17) The consent holder shall prepare, submit and implement a Dust Management Plan ("**DMP**"). The DMP shall, address, but not necessarily be limited to, the following matters:

a) A record of the dust control measures to be used, including where appropriate, the following:

   (i) Planning earthworks in advance so as to limit the amount of exposed surface area;

   (ii) Using water carts and / or irrigation sprays to pre-water the site of earthworks;

   (iii) Ceasing earthworks during periods of high winds;

(iv) Applying water via sprays to the aggregate crushing and screening facility;

(v) Limiting the height and slope of stockpiles of topsoil;

(vi) Applying water to the stockpiles using sprays;

(vii) Installing wind breaks near the stockpiles of topsoil;

(viii) Use of water carts on the unpaved roads;

(ix) Applying water to the feed hopper of the concrete batching plant; and

(x) Providing a bag filter unit to capture dust during filling operations at the cement silo.

b) Designated responsibilities for dust management, including sub-contractor management;

c) A record of maintenance requirements and contingency plans for dust control equipment;

d) Consultation with neighbouring property owners and occupiers if required; and

e) A complaints register, including a record of investigations carried out, the response action taken, and any reporting requirements. The register shall be provided to the CRC on request.

Rehabilitation Management Plan

18) The consent holder shall prepare, submit and implement a Rehabilitation Management Plan (**"RMP"**). The RMP shall address, but not necessarily be limited to, the following matters:

a) Identification of the soil resources to be used for rehabilitation;

b) Identification of the vegetation types to be used on a planting plan or schedule;

c) A programme for re-vegetation and maintenance activities;

d) The desired percentage of surface cover to be achieved to reduce the adverse effects from sediment-laden stormwater run-off; and

e) Identification of weed management activities to be undertaken.

Contaminant Spill Contingency Plan

19) The consent holder shall prepare and implement a Contaminant Spill Contingency Plan ("**CSCP**") for containment of any spill events. The CSCP shall address, but not be limited to, the following matters:

a) Identifying designated bulk fuel storage, contaminant storage facilities and re-fuelling locations;

b) Ensuring that all contaminant storage or designated re-fuelling areas are bunded or contained in such a manner so as to prevent the discharge of contaminants;

c) Requiring that all mobile fuel tankers carry spill kits, which are capable of absorbing the quantity of oil and petroleum products that may be spilt by a mobile fuel tanker on site at any one time, and that spill kits are also stored at bulk storage tank locations at all times;

d) Detailing the contents of the spill kits, including absorbent pads, booms, pillows and socks and appropriate pegs/rope to hold the absorbent material in place;

e) Recording the names of operators trained in spill response and remediation;

f) Ensuring that all machinery is regularly maintained in such a manner so as to minimise the potential for leakage of contaminants;

g) Ensuring that no machinery is cleaned, stored or refuelled within 20 metres of the bed of any water body (except in relation to the canal berms where a 20 metre setback is not possible);

h) Ensuring that all contaminants (e.g. fuel, hydraulic oils, lubricants etc) are removed from the site at the end of the construction period, except for those required for ongoing maintenance and operational activities;

i) Detailing an internal and external notification procedure in the event of a spill, including but not limited to providing emergency contact information for the Canterbury Regional Council Pollution Hotline, and emergency contact information for a waste management service provider with appropriate qualifications and equipment for cleaning up spills; and

j) Identifying measures to be undertaken to remediate a contaminant spill, including instructions for removing and disposing of contaminated material in a manner suitable to ensure no further contamination occurs.

k) Ensuring that when informing the Canterbury Regional Council of any spill, as specified in clause (i), the consent holder shall provide the following information:

(i) The date, time, location and estimated volume of the spill;

(ii) The cause of the spill;

(iii) The type of contaminant(s) spilt;

(iv) Clean up procedures undertaken;

(v) Details of the steps taken to control and remediate the effects of the spill on the receiving environment;

(vi) An assessment of any potential effects of the spill; and

(vii) Measures to be undertaken to prevent a recurrence.

Fish Salvage Management Plan

20) The consent holder shall prepare, submit and implement a Fish Salvage Management Plan ("**FSMP**"). The purpose of the FSMP shall be to minimise fish losses from dewatering sections of the Tekapo Canal. The FSMP shall address, but not necessarily be limited to, the following matters:

a) Details of a briefing to be held for all participants in the salvage operation prior to each salvage operation;

b) Details of the number of personnel required, their responsibilities, and required training (i.e. electric fishing, fish tanker, and boat operator certification);

c) Step by step information on the procedures to be undertaken to salvage the fish;

d) A list of all the fish handling equipment that will be required during the salvage operations;

e) A list of all support equipment required for the fish salvage operations;

f) Details of all fish handling activities including how to capture and handle fish within each canal section, specifics on the number of fish which can be transported in containers or transport tanks at varying water temperatures;

g) Details of how and where fish will be released, and whether any special structures will need to be created in order to release the fish;

h) Information on what to do with injured and dead fish, including tallying their numbers prior to disposal;

i) Reporting requirements that summarise each season's fish salvage operation and can be kept as a permanent record; and

j) Details of how tangata whenua can be involved in the design and implementation of fish salvage operations and monitoring.

GROUNDWATER AND SURFACE WATER MONITORING PROGRAMME

21) The consent holder shall design a Groundwater and Surface Water Monitoring Programme ("**GSWMP**"). The GSWMP shall include, but not necessarily be limited to:

a) Monitoring of groundwater levels in piezometers around the Tekapo Canal;

b) Monitoring of Mary Burn flows upstream and downstream of the Tekapo Canal and flows in springs that emerge downslope of the canal sections that are being relined; and

c) Monitoring of water levels in representative ponds and wetlands adjacent to the Tekapo Canal and works.

22) The consent holder shall implement the monitoring programme required in Condition 21 three months prior to the de-watering of the Tekapo Canal first occurring. The monitoring programme shall cease 12 months after the installation of the final section of the supplementary PVC liner in the Tekapo Canal.

23) The consent holder shall compile an annual monitoring report for each year that these resource consents are current addressing the monitoring undertaken in accordance with Condition 21. As a minimum the report shall:

a) Include a summary of all the data collected as required under Condition 22;

b) Critically analyse the information collected in terms of compliance and potential or actual adverse environmental effects;

c) Compare data with previously collected and reported results and identify and comment on any emerging trends; and

e) Make recommendations on alterations/additions to the monitoring programme, if required.

The annual monitoring report shall be submitted to CRC, by 30 June for each year these resource consents are exercised.

DIDYMO

24) To prevent the spread of pest species, including but not limited to Didymo (*Didymosphenia geminata*), the consent holder shall ensure that activities authorised by this resource consent are undertaken in accordance with the Biosecurity New Zealand's hygiene procedures, and that vehicles and machinery shall be free of plants and plant seeds prior to use in any water body.

Advice Note: You can access the most current version of these procedures from the Biosecurity New Zealand website http://www.biosecurity.govt.nz.

ACCIDENTAL DISCOVERY PROTOCOL

25) At least 20 working days prior to the proposed commencement date for construction, the consent holder shall submit an Archaeological Accidental Discovery Protocol to CRC. The Protocol shall be prepared in consultation with Upoko Runanga of Arowhenua, Waihao and Moeraki, or their representative(s).

In addition to the information and content proposed in the documentation accompanying the application and further information, the accidental discovery protocol shall include, but not be limited to, the following:

a) Preconstruction protocols that may be carried out;

b) Protocols for notification of relevant parties and site management procedures in the event any archaeological sites or taonga are uncovered at any time;

c) Contact details for all relevant parties; and

d) Training procedures for all contractors.

All works shall be exercised in accordance with the Archaeological Accidental Discovery Protocol.

26) In the event of any discovery of archaeological material:

(a) the consent holder shall immediately:

(i) Cease earthmoving operations in the affected area and mark off the affected area; and

(ii) Advise the CRC of the disturbance; and

(iii) Advise the New Zealand Historic Places Trust of the disturbance.

(b) If the archaeological material is determined to be Koiwi Tangata (human bones) or taonga (treasured artefacts) by the New Zealand Historic Places Trust, the consent holder shall immediately advise the office of the Upoko Runanga of Arowhenua, Waihao and Moeraki, of the discovery.

(c) If the archaeological material is determined to be Koiwi Tangata (human bones) by the New Zealand Historic Places Trust, the consent holder shall immediately advise the New Zealand Police of the disturbance.

(d) Work may recommence if the New Zealand Historic Places Trust (following consultation with rūnanga if the site is of Māori origin) provides a statement in writing to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager that appropriate action has been undertaken in relation to the archaeological material discovered. The Canterbury Regional Council shall advise the consent holder on written receipt from the New Zealand Historic Places Trust that work can recommence.

Advice Note:

Under the Historic Places Act 1993 an archaeological site is defined as any place associated with pre-1900 human activity, where there is material evidence relating to the history of New Zealand. For sites solely of Māori origin, this evidence may be in the form of accumulations of shell, bone, charcoal, burnt stones, etc. In later sites, artefacts such as bottles or broken glass, ceramics, metals, etc, may be found or evidence of old foundations,

wells, drains, tailings, races or other structures. Human remains/koiwi may date to any historic period.

It is unlawful for any person to destroy, damage, or modify the whole or any part of an archaeological site without the prior authority of the New Zealand Historic Places Trust. This is the case regardless of the legal status of the land on which the site is located, whether the activity is permitted under the District or Regional Plan or whether a resource or building consent has been granted. The Historic Places Act provides for substantial penalties for unauthorised damage or destruction

CERTIFICATION

27) The consent holder shall engage a Chartered Professional Engineer to certify that the design of the:

(a) Canal relining; and

(b) Culvert remediation

and their construction are in accordance with good engineering practice to ensure that the structure is safe and fit for purpose. This certificate shall be submitted to CRC, prior to the first filling of the canal.

ONGOING CONSULTATION

28) Within one month of the commencement of these resource consents, the consent holder shall invite representatives of the Department of Conservation, The Wolds Station Ltd, Irishman Creek Station Ltd, the Tekapo Community Board, Central South Island Fish and Game, Te Runanga o Ngai Tahu, Te Runanga o Arowhenua, Te Runanga o Waihao and Te Runanga o Moeraki to participate in a Tekapo Canal Remediation Project Consultation Group" ("**TCRPCG**").

a) The purpose of the TCRPCG, the meetings that will be held with the TCRPCG, and the consent holder's obligations to the TCRPCG shall be as follows:

i) To ensure stakeholder input is incorporated in the EMP and SEMPs;

ii) To ensure stakeholders are kept up to date with project implementation;

iii) To discuss the results of monitoring programmes; and

iv) To provide a mechanism for stakeholders to express any matters of concern and to address those concerns.

b) The consent holder shall initiate up to one meeting prior to, and one meeting during, any canal outage events with the TCRPCG and on an as required basis thereafter. The purpose of the meetings will be to:

i) Provide regular updates on progress with implementation of the resource consents;

ii) Advise of the activities and events related to the resource consents that have been completed and activities or events to be undertaken in the future, and likely effects on the local community;

iii) Identify the consultation to be undertaken with individual landowners;

iv) Advise what actions have been taken to comply with the conditions of consent;

v) Allow for community feedback on the EMP and SEMPs; and

vi) Provide an avenue by which people that may be affected by the consented activities are able to communicate any concerns they have to the consent holder.

c) The consent holder shall keep minutes of the meetings held in accordance with clause b) of this condition and shall forward them to all attendees within ten working days; and

d) The consent holder shall provide final copies of the reports prepared in accordance with the conditions of this resource consent to the TCRPCG concurrently with them being submitted to CRC.

29) The consent holder shall prepare a Communication Strategy, which shall set out procedures to deal with queries relating to the Tekapo Canal Remediation Works. The Communication Strategy shall be lodged with CRC, at least two months prior to any site works being undertaken. The Communication Strategy shall include, but not be limited to:

a) Advertising in local newspapers no later than three months prior to any canal outage events, explaining the general nature of the works to be undertaken in the following construction season and the extent to which these may affect traffic flows, angling and other recreational activities;

b) Advertising in local newspapers at least one month prior to construction works commencing in each construction season, providing details of the works proposed and a timetable for these;

c) A method of recording the time, date and the type of any complaint and the actions taken by the consent holder to resolve the complaint;

d) Establishing and publicising a toll-free project telephone number, so that any members of the public may raise matters or make an enquiry regarding the remediation works to the Tekapo Canal; and

(e) Detailing a mechanism whereby the consent holder undertakes reasonable endeavours to provide information on water levels in Lake Tekapo and flow rates and water levels in the Tekapo River to the public.

Annual Report on Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works

• Prepared for

Genesis Power Ltd

• June 2014

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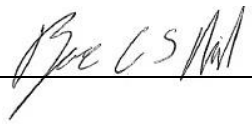
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Limitations:

This report has been prepared on the basis of information provided by Genesis Energy Ltd. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information. This report has been prepared by PDP on the specific instructions of Genesis Energy Ltd for the limited purposes described in the report. PDP accepts no liability if the report is used for a different purpose or if it is used or relied on by any other person. Any such use or reliance will be solely at their own risk.

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1.0 Introduction

Genesis Energy Ltd has completed remedial works along various sections of the 26 km long Tekapo Canal which extends from Tekapo A Power Station near Lake Tekapo through to the settling pond above the Tekapo B Power Station at Lake Pukaki. The remedial and construction works on the canal involved:

- De-watering sections of the canal using coffer dams;
- Excavation of the current canal liner;
- Placement and compaction of fill on the base and sides of the canal;
- Laying of a low permeability synthetic PVC liner; and
- Various temporary construction and ancillary works around the Tekapo Canal.

These works have taken place along the following three sections of canal:

- From chainage 7-8.93 km – a canal section referred to as the 8.17 km Culvert;
- From chainage 10.9-14.7 km – a canal section known to as SH8; and
- From chainage 17.8-19.61 km – a canal section referred to as the Mary Burn Fill.

These chainages are all measured from the Tekapo A Power station. Figure 1 displays the location of canal reach names and chainages along the Tekapo Canal.

Water in the Tekapo Canal (as originally constructed) interacts with the surrounding groundwater via seepage through the sides and base of the canal. Where the canal is located above groundwater, seepage from the canal will recharge the underlying groundwater. Where the canal is excavated below the water table, then seepage between the groundwater and canal will occur depending on the relative elevation of the groundwater level and the water level in the canal. During the remedial works, the water level in the canal was lowered by up to 1 m to minimise the stress on the coffer dams and the sections of canal between the coffer dams were dewatered completely. The change in water levels in the canal alters the interaction between the water in the Tekapo canal and the surrounding groundwater.

The rate of seepage between the canal and the groundwater is directly affected by the nature of the canal lining. Therefore, the liner material installed during the remedial works may have resulted in an alteration to the rate of seepage interaction with the natural groundwater resource around those areas that have been relined which will continue beyond the completion of the remedial works.

The shallow groundwater resource that is affected by the interaction with the canal will, in turn, interact with surface waterways in the area.

The purpose of this report is to describe the monitoring that has been undertaken since May 2013 as part of the Groundwater and Surface Water Monitoring Programme

(GSWMP) and follows on from the previous monitoring report prepared by PDP for Genesis Energy Ltd dated June 2013. This report will assess the changes in groundwater and surface water arising from the Tekapo Canal remedial works and provide any recommendations for the monitoring programme during the upcoming 12 month monitoring period.

This report is structured as follows:

- Section 2 provides a summary of the previous monitoring period between October 2012 through to April 2013;
- Section 3 outlines the monitoring programme undertaken by PDP for the period May 2013 through to April 2014;
- Section 4 discusses the results of the monitoring and any interpretations of the data;
- Section 5 describes any environmental effects arising from any changes related to the remedial works;
- Section 6 provides an outline of the monitoring period over the next 12 months and discusses any changes to the monitoring programme that may be required.

2.0 Summary of previous monitoring period

The previous monitoring report prepared by PDP dated June 2013 documented the environmental monitoring that was undertaken between October 2012 and April 2013. During this period, remediation works along 8.17 km Culvert and SH8 canal sections was carried out, with construction beginning in January 2013 and completed in April 2013.

During the October 2012 to April 2013 monitoring period, monitoring of groundwater levels, surface water levels, observations of seeps and flow gaugings of weirs and streams along the canal sections 8.17 km Culvert, SH8 and Mary Burn Fill was undertaken. More intensive frequency of monitoring at sites along canal sections 8.17 km Culvert and SH8 was carried out due to remediation of the these canal sections between January 2013 and April 2013. Observations and measurements at sites along the Mary Burn Fill canal section was undertaken to determine a baseline prior to construction of this section of Canal during 2014.

The data collected for the monitoring period between October 2012 and April 2013 identified that there had been a general decreasing trend since the beginning of monitoring at the majority of both groundwater and surface water monitoring sites prior to the start of construction works on canal sections 8.17 km Culvert and SH8. Immediately prior to and during construction on these two sections of canal, water levels typically continued to drop. No obvious increase in either groundwater levels or surface water levels and flows was observed from the refilling of the canal after the remedial works. Due to water levels beginning to drop prior to the start of remedial works it appeared that the reduction in leakage from the canal may not have adversely affected water levels in the shallow groundwater or nearby surface water ways. Water levels at the majority of

groundwater and surface water sites along all three canal sections appeared to be directly influenced by large rainfall events resulting in water levels increasing.

The effects of leakage from the canal altering natural groundwater and surface water levels adjacent to the canal where found to be less than minor, although continued monitoring was suggested to determine any longer term trends from the canal remedial works.

3.0 Monitoring data

For the period between May 2013 and April 2014, the monitoring programme concentrated on groundwater and surface water levels, observations of seeps and flow rates of weirs and surface water ways that flow beneath the sections of canal being remediated.

Construction work during the monitoring period focussed solely on the Mary Burn Fill Canal section. Maps showing the locations of the monitoring sites along each section of canal which underwent remediation are displayed in Figures 2a, 2b and 2c (Appendix A). Appendix B provides additional details of each monitoring site. It should be noted that some seep and weir monitoring sites have since been removed due to construction. These sites are noted in Appendix B, although their locations are still displayed in Figures 2a, 2b and 2c (Appendix A) for reference.

In addition to the monitoring data collected, daily rainfall data from the NIWA Lake Tekapo climate station (Agent Number: 24945) located at Tekapo Airfield was sourced from NIWA's CliFlo climate data for the monitoring period.

The sections below discuss the frequency of monitoring, locations of monitoring sites and the type of measurements made in more detail.

3.1 Frequency of monitoring

The frequency for environment monitoring during the remedial work on the Tekapo Canal between May 2013 and April 2014 is outlined below:

<u>May 2013 to December 2013</u>

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for 8.17 Culvert, SH8 and Mary Burn Fill Canal sections. Monitoring during this period was undertaken by Genesis Energy staff in conjunction with Damwatch services Ltd.

<u>January 2014 to March 2014</u>

Weekly monitoring of weirs, seeps, and pond staff gauges for Mary Burn Fill Canal section, changing to **Daily** for 1 week prior to dewatering/refilling, during

dewatering/refilling and 1 week after dewatering/refilling has ceased at each particular canal section.

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for 8.17 Culvert and SH8 Canal sections. Also **Monthly** monitoring of groundwater levels in monitoring wells for Mary Burn Fill Canal section.

Monitoring during this period was undertaken by Dave Jenkinson (employed by Genesis Energy Ltd) in conjunction with Damwatch Services Ltd

March 2014 to April 2014

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for 8.17 Culvert, SH8 and Mary Burn Fill Canal sections. Monitoring during this period was carried out by Genesis Energy staff in conjunction with Damwatch Services Ltd.

In addition to the monitoring undertaken by Dave Jenkinson, PDP downloaded nine electronic pressure transducers installed in each of the monitoring wells and two ponds at three monthly intervals. Each pressure transducer measured the relative change in pressure at 15 minute intervals. The transducers were installed on 15 October 2012 and have been recording continuously since installation.

Occasional flow gaugings were carried out in the Mary Burn, Irishman Creek and the unnamed stream immediately east (upstream) of the State Highway Eight (SH8) Bridge. Flow gaugings were only undertaken in all three streams once during the most recent monitoring period due to high flows in the streams during PDP's visit's to Tekapo to download the transducers.

3.2 Groundwater level monitoring

Six piezometers were installed along the 3 sections of canal undergoing remediation by McNeil Drilling Co Ltd between 2 October and 5 October 2012. The purpose of these monitoring wells is to measure the response of groundwater levels following the remedial works on the canal. The locations of the piezometers are shown in Figures 2a, 2b and 2c. At each canal section, two piezometers were installed with one located on the true right hand side and one on the true left hand side of the canal. The design of the piezometers is provided in Figure 3 and the details of each piezometer are outlined in Table 1 below.

Table 1: Environmental monitoring piezometers

Well number	ECan well number	Depth of well (m bgl)	Screened interval (m bgl)	Initial depth to water (m bgl)*	Easting (NZTM)	Northing (NZTM)	Canal section
Well 1	BZ16/0042	10.38	7.38 – 10.38	-9.80	1392307	5117272	8.17 km
Well 2	BZ16/0043	10.80	7.79 – 10.79	-8.24	1392361	5117388	8.17 km
Well 3	BZ16/0044	5.67	2.67 – 5.67	-2.10	1388729	5116854	SH8
Well 4	BZ16/0045	6.48	3.50 - 6.48	-3.50	1388961	5117010	SH8
Well 5	BZ16/0047	10.96	7.96 – 10.96	-9.85	1382940	5116070	Mary Burn Fill
Well 6	BZ16/0046	26.83	23.83 – 26.83	-24.46	1382834	5116321	Mary Burn Fill

* Initial depth to water measured by driller immediately after well was drilled

Borelogs of each piezometer is provided in Appendix C. The design of the piezometers required that the minimum depth be 4 m, and to a depth that is 3 m below the depth at which groundwater was encountered but no greater than 30 m deep. In other words the screened interval of the piezometer should be at least 3 m below the depth at which groundwater was encountered during drilling. The previous monitoring repot for the period between October 2012 and April 2013 identified that only Wells 3 and 4 adequately penetrate the groundwater table as specified in the design. The remaining four piezometers penetrate the groundwater table typically less than half of the screened interval due to being installed at a shallower depth during drilling. PDP were onsite to observe the installation of Well 4, but no other well installations were observed by PDP. However, it should be noted that the intention of the piezometers is to identify changes to interactions between groundwater and surface water ways. Based on this, it is expected that the piezometers are deep enough so that if they go dry during the monitoring period it indicates that there is no direct effect on any nearby surface water ways.

During the remediation of the 8.17 km culvert, an embankment was built above the well cap of Well 2. While the well cap of Well 2 was constructed to the specified design during its installation, material from the embankment has caused the surrounding land surface to be built up around the well cap and resulted in surface water ponding around the well cap on occasion. A small surface drain has been excavated around the well cap to allow surface water drain away and stop it ponding. The built up surface around the well cap is displayed in Figures 4a and 4b in Appendix A.

Pressure transducers were installed in each of the piezometers to measure the relative change in water pressure. An additional pressure transducer located inside the well cap of Well 4 was used to measure the change in atmospheric pressure. All the pressure transducers have been downloaded at three monthly intervals and manual depth to groundwater measurements were made during each download of the transducers. Additional manual depth to groundwater level measurements were made by Dave Jenkinson during the Mary Burn Fill canal section remediation. Outside of the Mary Burn

fill Canal section construction period, additional manual measurements were made by Genesis Energy staff. All measurements were recorded to monitor the relative change in groundwater level in each piezometer.

3.3 Surface water level monitoring

Staff gauges and pressure transducers were used to monitor changes in surface water levels in ponds on the true left hand side of the SH8 and the Mary Burn Fill canal section. Two ponds at each canal section were monitored with a staff gauge installed in each of the ponds. Figures 2b and 2c display the locations of the staff gauges and the names of the sites are as follows:

- TKBSH8SG1 – SH8 canal section, Pond 1;
- TKBSH8SG2 – SH8 canal section, Pond 2;
- TKBMBSG1 – Mary Burn Fill canal section, Pond 1; and
- TKBMBSG2 – Mary Burn Fill canal section, Pond 2.

The staff gauges consist of a plastic builder's ruler, 1 m in length with 1 mm gradations. The ruler was secured to a metal waratah fence post installed into the bed of the pond at a depth such that at least half of the ruler was submerged with the remaining length of the ruler above the pond surface. The staff gauge was installed close enough to the bank of the pond to ensure that the gradations could still be read but at a depth deep enough to measure any water changes in the pond. The water level was read off the staff gauge from the bank of the pond.

In addition to the four staff gauges, two pressure transducers were installed close to staff gauges TKBSH8SG1 and TKBMBSG1. The transducers are labelled as SH8SG1T and MBSG1T respectively. The transducers were submerged in the pond by mounting the transducers to a metal fence post installed into the base of the pond. The pressure transducers recorded changes in water pressure in the ponds and were downloaded at 3 monthly intervals by PDP.

The purpose of the staff gauges and pressure transducers is to measure the relative changes in water levels of the ponds from construction activities on the canal.

3.4 Surface water flow monitoring

Surface water flow monitoring includes observations of seeps and flow gaugings of weirs from seeps along canal embankments as well as flow gaugings and observations of major surface water ways that flow beneath the canal at the sections of the canal that underwent remedial works. The purpose of the seep observations and surface flow monitoring is to identify any changes in surface water bodies as a result of the remedial works.

It should be noted that during June and July 2013, some monitoring sites were not able to be accessed by Genesis Energy staff for regular monthly monitoring due to a large snow fall in the area during this period.

3.4.1 Observations of seeps

Damwatch currently undertake monitoring of seeps along the length of the Tekapo Canal. A number of these seeps occurred along the three sections of canal that underwent remediation. PDP identified eleven seeps along the SH8 canal section and ten along the Mary Burn Fill canal section that would be relevant to monitor during remediation. The locations of the monitored seeps are displayed in Figures 2b and 2c and details of the seep sites are listed in Appendix B.

Damwatch monitor these sites as part of their ongoing monitoring plan and provide PDP with data for each of the relevant sites identified by PDP. The monitoring of the seeps involves a qualitative assessment of each seep with observations categorised on a scale from 0 to 4. The scale (created by Damwatch) is as follows:

- 0 – Dry
- 1 – Damp
- 2 – Wet
- 3 – Flowing
- 4 – Alert (significant change, change in flow/turbidity)

The amount of water present at each seep during monitoring increases with the rating. During the construction period for the Mary Burn Fill canal section (January 2014 – February 2014) all observations of seeps were made by Dave Jenkinson in an effort to maintain consistency and reduce errors during the intensive collection of data throughout this period. Outside of the construction period, observations were made by Genesis staff.

Since the previous monitoring report (dated June 2013), a number of the seep monitoring sites are no longer monitored due to their removal during construction activities. Along the SH8 canal section, only 4 seep monitoring sites are still continuously monitored. These seeps are TKB11518LS, TKB11575RS, TKB11565RS and TKB13335LS. Seep TKB13150LS was monitored once on 9 July 2013 after the completion of the construction works at 8.17 km Culvert and SH8 canal sections but has not been monitored since due to its removal during minor ancillary works. No seep monitoring locations along the Mary Burn Fill canal section have been removed during the recent remedial works at this section of the canal. A full list of all seeps and their current status for all canal sections is provided in Appendix B.

3.4.2 Weir measurements and stream flow gaugings

Measurements of flow using weirs are also monitored by Damwatch as part of their ongoing monitoring program and were installed to monitor flows from seeps or springs that had consistent flow. During an initial site visit by PDP in October 2012, eight weirs

were identified by PDP as being relevant to the monitoring regime with one weir located at the 8.17 km Culvert canal section, five weirs along the SH8 canal section and one weir at the Mary Burn Fill canal section. These weirs are typically constructed of concrete and have a steel plate with a 45° angle v-notch through which water flows. The height of the water passing through the v-notch is recorded during monitoring and converted to a flow rate. Weir TKBWELBS at the Mary Burn Fill canal section is also constructed from concrete but has a single PVC pipe through which water flows. The flow rate is determined by measuring the time taken for the water flowing through the weir to fill a vessel of a known volume. All weir flow rate measurements were made by Dave Jenkinson during the Mary Burn Fill canal section construction period (January 2014 to February 2014) and by Genesis staff outside the construction period.

Weirs TKBWR817L and TKBD118 were removed during remedial works along 8.17 km Culvert and SH8 canal sections. No additional weirs have been removed since the construction along these two canal sections was completed. A full list of weirs and their current status is provided in Appendix B.

Stream flow gaugings were carried out by PDP in three major streams that flow beneath the SH8 and Mary Burn Fill canal sections. The three streams that flow in which gaugings measurements have been made are:

- Unnamed stream east of SH8 – SH8 canal section;
- Irishman Creek – SH8 canal section
- Mary Burn – Mary Burn Fill canal section

Flow gaugings were made in each stream both on the upstream and downstream side of the canal, as close to the culvert as possible to try and measure any change in flow across the canal. To provide a more meaningful measurement, flow gaugings have been made during periods when stream flows were low (e.g. < 600 L/s in the Mary Burn at SH8). Flow gauging measurements were made using a hand held Acoustic Doppler Velocimeter (Flow Tracker) across a transect of the stream where there was little turbulence and also parallel banks. In addition, the gauging sites were located as close as possible to the culvert both upstream and downstream of the canal to try and identify as much seepage from the canal and reduce errors from bank storage in the stream. Prior to each gauging, weed and any large rocks were removed from the stream bed to reduce turbulence and provide as accurate velocities as possible.

A fourth stream that flows through the 8.17 km culvert was also monitored. This stream is typically dry and therefore no flow gaugings were made in this stream. Qualitative observations of the 8.17 km culvert barrels were made as part of the ongoing monitoring by Damwatch in place of flow gauging. The qualitative observations of the culvert barrels use the same rating system as the system used for monitoring the seeps. During the Mary Burn Fill construction period between January 2014 to February 2014, observations of the 8.17 culvert were made by Dave Jenkinson. Outside of the construction period, observations were made by Genesis staff. Figures 5a and 5b show the upstream culvert barrels after the remediation of 8.17 km Culvert canal section in May 2013.

3.5 Compliance with monitoring programme (GSWMP)

Environmental monitoring of groundwater and surface water during the remedial works on the Tekapo Canal is described in conditions 21, 22 and 23 of Schedule One – General Conditions. Schedule One – General Conditions are a list of conditions attached to a number of resource consents related to the Tekapo Canal remediation works provided in Appendix D. The PDP report "Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works" (September 2012) also referred to as GSWMP, prepared for Genesis Energy Ltd prior to the beginning of the monitoring period, outlines the monitoring programme. Due to restrictions on access from adverse weather conditions and construction activities, some seep and weir monitoring sites were missed during the monthly monitoring outside of the construction period.

The GSWMP specifies that occasional flow gauging of the three streams is required but does not specify a required frequency for flow gauging the streams after remedial works have begun. Due to flows being too high (> 600 L/s in the Mary Burn at SH8) for the purposes of the monitoring required for this programme, flow gauging in the three streams were only carried out once during the most recent monitoring period on 17 January 2014.

Overall, the monitoring works and the frequency of monitoring as described in the previous sections are consistent with conditions 21, 22 and 23 of Schedule One – General Conditions and the GSWMP (2012) report.

4.0 Monitoring data

Plots of the data with the timing of major construction events occurring during the May 2013 through to April 2014 are provided in this section of the report. The major construction events during the monitoring period are:

- 7 January 2014 – canal flow stopped, water still in canal;
- 10 – 17 January 2014 – dewatering of Mary Burn Fill canal section;
- 13 – 15 February 2014 – refilling of Mary Burn Fill canal section; and
- 28 February 2014 – canal operational again.

The plots of data referenced in this section of the report also display the entire record of monitoring data from October 2012 through to April 2014 which has been included to determine any trends in the data. The timing of previous major construction events (i.e. remedial works on canal sections 8.17 km Culvert and SH8) are also displayed in the plots of data in this section for reference.

The sections below discuss the analysis of the data in more detail.

4.1 Groundwater level monitoring

Figures 6a, 6b, 6c and 6d (Appendix A) show groundwater level measurements measured using the pressure transducers along with the manual groundwater level measurements recorded by PDP, Dave Jenkinson and Genesis Energy staff.

Figure 6a shows groundwater levels recorded in Wells 1 and 2. Water levels in Well 1 have remained at a consistent level throughout the entire monitoring period. The manual depth to water level measurements generally match the transducer data. The maximum manual depth to water level measured during the most recent monitoring period was -10.36 m below ground level (m bgl) on 8 May 2014 which is essentially the bottom of the piezometer. The highest manual groundwater level measured in this well was -10.20 when the transducer was installed on 15 October 2012. The water level data for this well suggests that it has remained dry since being installed as it was not drilled deep enough. No long term trends are visible from the water level data in this well.

With the exception of the initial manual measurements when the transducer in Well 2 was installed, manual measurements have consistently remained approximately 0.6 to 1.0 m deeper than the transducer data. Table 1 shows that Well 2 is 10.8 m deep and the maximum manual water level measured in the well during the monitoring period was -10.73 m bgl on 8 May 2014. This water level indicates that the well was essentially dry during this measurement and has typically remained dry for the majority of the time since its installation. Manual measurements on 31 July and 2 August indicate a large increase in water levels which while offset by approximately 1.0 m, generally matches the transducer data. Two manual measurements recorded on 9 January and 27 January 2014 both recorded water levels of -8.17 m bgl and appear to be significantly different to the manual measurements preceding these measurements, as do the manual measurements after them. A water level at -8.17 m bgl would be recorded by the transducer however water levels remained below -9.8 m bgl during the period when these measurements were made. Based on this, it is likely that the two measurements of -8.17 m bgl on 9 January and 27 January 2014 are related to monitoring errors.

The transducer was initially installed at a depth of -9.8 m bgl on 15 October 2012 and water levels have generally remained below this level with the exception of 6 large increases in water level. The increases in water level generally appear to be related to large rainfall events recharging the groundwater in the area before dropping back below the depth of the transducer and bottom of the well, although the largest increases in water level do not appear to be directly related to rainfall events. A particularly large increase in Well 2 water levels was recorded by the transducer on 15 August 2013 with water levels reaching -7.0 m bgl which is the highest recorded water level in this well. Immediately prior to this large increase in water level, a number of large rain events had occurred between 6 May 2013 and 6 August 2013 which also resulted in increases in water level in Well 2 but on a smaller scale (the largest of these increases prior to the highest groundwater level was -8.4 m bgl on 3 June 2013). When the highest groundwater level was recorded on 15 August 2013, there had not been any significant

rain events and based on the abrupt increase in water level, the water level increase may be due to a groundwater pulse of water through the shallow aquifer. This pulse of groundwater may be related to the period of large rainfall events from between 6 May 2013 and 6 August 2013. In addition, a large snowfall event on 20 June 2013 may have also contributed to increasing groundwater levels in the area and resulted in the high groundwater level recorded on 15 August 2013. The shape of the water level increase on 15 July 2013 is similar in shape to the water level increase on 27 October 2012 and 16 November 2013 with all three water level increases displaying an abrupt increase in water level that rounds off before declining more gradually than water level increases directly related to large rainfall events. In contrast, the two sharp increases in water level (3 June and 18 June 2013) prior to the highest groundwater level in Well 2 being reached on 15 July 2013 appear to be directly related to rainfall infiltrating into the aquifer and drop off much quicker than the other three large increases in water level.

Alternatively, another explanation for some of the large increases in water level on 15 July and 16 November 2014 could be related to water spilling into the piezometer from the surface. As mentioned previously, construction works at 8.17 km Culvert created an embankment above Well 2 which has resulted in the land surface surrounding the well cap being higher than when the well was installed. Evidence of ponded water around the well head has been noted although a small drainage channel was excavated and has been maintained to allow water to drain away from the well head (Figures 4a and 4b). It is possible that ponded water around the well cap may have potentially inundated the well cap and flowed into the well causing the increases in water level. However, this would require a large volume of water to pond around the well cap for it to be inundated and it doesn't provide an explanation for all the large increases in water level occurred during periods where no significant rainfall fell. There are no obvious long term trends based on the water level data in Well2 with the exception that groundwater in the vicinity of this well may undergo large fluctuations.

During the most recent monitoring period, PDP attempted to lower the transducer to a deeper depth but decided to leave the transducer at its original depth of -9.8 m bgl after mud was encountered on the water dipper and transducer at deeper depths.

The purpose of the groundwater level monitoring is to identify potential interactions between groundwater and surface water ways. While it appears that Wells 1 and 2 have generally remained dry since their installation, both wells are expected to be deep enough to indicate that the water table is at a sufficient depth that there is no direct effect on the nearby surface water way (8.17 km culvert). In terms of canal leakage having any impact on groundwater levels and interactions between groundwater and surface water, there appears to be no direct effect from the fundamental water table on the nearby surface waterway at 8.17 km culvert based on the groundwater level information. Furthermore, it should be noted that 8.17 km culvert has remained dry since the environmental monitoring programme began in October 2012. Anecdotal information indicates that 8.17 km culvert has only had surface water flow through it on a few occasions since the construction of the canal and generally remains dry.

Based on this, continued monitoring of groundwater levels in Wells 1 and 2 as well as monitoring of flows through 8.17 km culvert for the environmental monitoring purposes of this report may not show any additional effects related to the remedial works on the 8.17 km Culvert canal section. Therefore, continued monitoring of these sites may not be necessary.

Groundwater levels in both Wells 3 and 4 on the SH8 canal section (Figure 6b) show that groundwater levels along this section of the canal are influenced by rainfall with water levels increasing after large rainfall events. This is particularly noticeable in Well 3. Manual measurements plot relatively well with the transducer data in both wells. Water levels in Well 3 increased after completion of the remedial works on the 8.17 km Culvert and SH8 canal sections. The period of large rainfall events between 6 May 2013 and 6 July 2013 appear to have caused in the increase water levels after the construction at 8.17 km Culvert and SH8 canal sections were competed. A large snowfall event also occurred on 20 June 2013 which also may have contributed to the increase in water levels in this well during this period. Water levels in Well 3 appear to display seasonal fluctuations with groundwater levels being highest during winter before declining gradually throughout summer and autumn. While water levels in Well 3 do display a longer term declining trend since monitoring in this well began in October 2012, this long term trend is not thought to be related to remedial works on the Tekapo Canal as water levels display a consistent and gradual decline prior to, during and after each construction period.

Groundwater levels in Well 4 have typically remained stable throughout the monitoring period although water levels in this well also appear display seasonal fluctuations although somewhat less pronounced than in Well 3, with water levels being slightly higher in winter and lower in summer. It is likely that water levels in Well 4 are more stable than water levels in Well 3 due to the proximity of Well 4 to the unnamed stream adjacent to this well whereas Well 3 is located further away from the unnamed stream and therefore may be more susceptible to rainfall infiltrating into the shallow aquifer. Based on the data from the most recent monitoring period as well as data from the previous monitoring period, groundwater levels in neither Well 3 nor 4 appear to have been affected by the installation of the liner in the SH8 canal section or the remedial works at Mary Burn Fill canal section. However, continued monitoring of water levels in both wells would be prudent to confirm whether the longer term declining trend in Well 3 is not related to the canal remediation works.

Water levels in Wells 5 and 6 at the Mary Burn Fill canal section are displayed in Figures 6c and 6 d respectively. During the most recent monitoring period (May 2013 to April 2014) construction activities including dewatering, were focussed on this section of the canal. The manual depth to water level measurements plot reasonably well against the transducer data from both wells. Water levels in Well 5 show a gradual decline, whereas Well 6 has typically remained stable during the most recent monitoring period. Well 5 appears to be affected by large rainfall events which result in small increases in water level. Well 6 does not appear to be directly affected by local rainfall which may be due to the large depth to groundwater from the ground surface (>23 m). Well 5 displays small

seasonal fluctuations, similar to Wells 3 and 4, with the highest water levels generally occurring during the winter months before declining gradually during late spring and summer. Well 6 displays a subtle seasonal fluctuation with water levels being higher during late winter and spring with water levels being lowest during late autumn. Water levels in both wells appear to have declined slightly during the remedial works at the Mary Burn Fill Canal section, however a declining trend is also apparent prior to construction works commencing. The groundwater levels in Well 5 increased to their pre-remedial works level in response to rainfall between 17 April and 8 May 2014. Based on the data collected during the most recent monitoring period between May 2013 to April 2014, dewatering and the installation of the PVC liner in the Mary Burn Fill canal section does not appear to have significantly affected the groundwater levels in either Well 5 or 6. Continued monitoring of water levels in these wells would be prudent to determine any longer term affects from the installation of the liner on groundwater levels along this section of the canal.

4.2 Surface water level monitoring

Figures 7a and 7b show the relative change in water levels measured using the manual staff gauges and pressure transducers installed in the ponds at the SH8 and Mary Burn Fill canal sections respectively.

The manual measurements from staff gauge 1 in pond 1 at SH8 (TKBSH8SG1) show a relatively good fit with the transducer data (SH8SG1T) although the manual measurements become slightly offset from the transducer data from 28 November 2013 onwards but both datasets still follow a similar pattern. Water levels in pond 1 increased rapidly by approximately 0.3 m after a large rainfall event on 6 May 2013. Water levels continued to increase until 2 August 2013 where water levels declined gradually through to April 2014 before stabilising. Water levels in the pond appear to directly influenced by rainfall, but also appear to display a seasonal fluctuation similar to that which was observed in the monitoring wells with the highest water levels observed during the winter months before water levels decline gradually during spring and summer. The installation of the PVC liner in the SH8 canal section does not appear to have affected water level in pond 1 at SH8. The previous monitoring report mentioned that the steepening decline in water levels during the remedial works on 8.17 km Culvert and SH8 canal sections may have been related to remedial works however, the decline in water levels during this period is more likely to be related to seasonal fluctuations. Generally speaking, the long term trend in water levels for pond 1 at SH8 appears to be stable and have even increased slightly since monitoring began in October 2012.

Manual water level measurements from staff gauge 2 in pond 2 at SH8 (TKBSH8SG2) show that water levels in this pond fluctuate greatly (Figure7a, Appendix A). Anecdotal information provided by Dave Jenkinson indicates that this pond typically dries up during the summer months before being recharged during the winter and spring months. Water levels dropped below the staff gauge in pond 2 (TKBSH8SG2) during the previous

monitoring period (October 2012 to April 2013), but during the most recent monitoring period (May 2013 to April 2014), water levels have remained above the base of the staff gauge. Water levels in this pond roughly follow a similar pattern to water levels in pond 1 at SH8, although pond 2 displays much larger fluctuations with the water level increasing by 0.6 m between 28 November 2013 and 7 January 2014. Based on the data collected for pond 2 during the previous and the most recent monitoring periods, water levels appear to have been relatively unaffected by the installation of the liner in the SH8 canal section or the remedial works on the Mary Burn Fill Canal section. However, it would be prudent to continue to monitor water levels in both ponds along the SH8 canal section to confirm the longer term trends.

Due to access restrictions, physical measurement of water levels in the SH8 ponds is no longer possible. Since it would be prudent to continue to monitor water levels in these ponds for any effects associated with the remedial works, it is proposed that visual observations of the SH8 ponds be undertaken for the next 12 month monitoring period.

Water level measurements for pond 1 at the Mary Burn Fill Canal section are displayed in Figure 7b. While there is an offset of the manual measurements from the staff gauge (TKBMBSG1) and the transducer data (MBSG1T) of approximately 0.02 m, both data sets do follow a similar pattern. Based on the transducer data, water levels in the pond appear to be directly affected by rainfall events as surface water runoff will cause water levels in the pond to increase. Water levels in the pond decline after each rainfall event. The transducer data for pond 1 suggest that water levels fluctuate seasonally by approximately 0.4 m with the highest water levels recorded during the winter months and before declining gradually during the spring and summer months. The lowest water levels are typically recorded during the summer months. Water levels in pond 1 during the remedial works on the Mary Burn Fill canal section appear to have increased slightly immediately prior to the start of dewatering before decreasing during the construction period. The decrease in water levels during the Mary Burn Fill construction period is not necessarily related to the remedial works as water levels in the pond display a seasonal declining trend well before construction at the Mary Burn Fill canal section began and show an increasing trend after the remedial works at the canal section were completed in response to rainfall and snowfall events. Overall, the long term water level trend in pond 1 at the Mary Burn Fill canal section appears to be stable.

The manual measurements from TKBMBSG2 in pond 2 at the Mary Burn Fill canal section show relatively stable water levels since monitoring began in the pond in October 2012. During dewatering and the subsequent remedial works on the Mary Burn Fill canal section between January 2014 and February 2014, water levels in pond 2 fluctuated slightly by approximately 0.02 m but remained relatively stable. Following construction on the Mary Burn Fill canal section, water levels in pond 2 increased to the highest water level recorded since monitoring in the pond began on 17 April 2014. This increase in water level is likely to be related to a combination of a rainfall event on 18 March 2014 and a general seasonal increase in surface water levels at this time. The increase in water

levels during the April 2014 monitoring round in pond 2 follows a similar increase in water levels in pond 1 at the same time.

While water levels in neither of the Mary Burn Fill ponds appear to have been affected by the remedial works on the Mary Burn Fill canal section, continued monitoring of water levels in both ponds for another 12 months would be prudent to determine the longer term effects of the remedial works on the Mary Burn Fill canal section on the downgradient ponds.

4.3 Surface water flow monitoring

4.3.1 Observations of seeps

Figures 8a and 8b display the inspection ratings of the seeps along the SH8 and Mary Burn Fill canal sections.

The 4 remaining seeps that are still monitored along the SH8 canal section (TKB11518LS, TKB11575RS, TKB11565RS and TKB13335LS) show that inspection ratings have generally decreased or remained consistent throughout the most recent monitoring period between May 2013 and April 2014. Seep TKB11518LS has generally remained at flowing with the exception of two occasions on 27 November and 16 December 2013 where the inspection rating for this site dropped to damp. Following this drop, the inspection rating increased back to flowing during the following monitoring round on 7 January 2014 when remedial works on the Mary Burn Fill canal section began and has remained at flowing since. Seep TKB11575RS was recorded at flowing following the completion of construction on SH8 canal section, but since 9 July 2013, has remained consistently at an inspection rating of either dry or damp. TKB11565RS was recorded at dry following the completion of the remedial works on the SH8 canal section before increasing to a maximum inspection rating of wet on 19 August 2013. Following this, the inspection rating has dropped back to damp before decreasing further to dry. The inspection rating for seep TKB13335LS has remained relatively consistent since monitoring of this seep began in November 2012 with an inspection rating of either damp or dry since construction on both the 8.17 km Culvert and SH8 canal sections was completed.

Seeps TKB11575RS, TKB11565RS and TKB13335LS were all recorded as being dry prior to, during and immediately after the remedial works at Mary Burn Fill canal section. Seep TKB11565RS has remained at dry since construction works at Mary Burn Fill canal section was completed, although seeps TKB11575RS and TKB13335LS have increased to damp during the most recent monitoring round on 14 April 2014.

Overall the seep inspection ratings for seeps TKB11575RS, TKB11565RS and TKB13335LS along the SH8 canal section appear to show inspection ratings that have generally decreased following the remedial works along this section of canal, although the

inspection ratings for seep TKB11518LS have generally remained consistent at flowing. Rainfall does not appear to have an obvious effect on the seep inspection ratings.

While it appears that the PVC liner that was installed in SH8 canal section may have reduced water flow to seeps TKB11575RS, TKB11565RS and TKB13335LS, based on the data from the neighbouring groundwater monitoring wells and ponds, the receiving groundwater and surface water ways do not appear to be affected by the reduction in water flow from the seeps. This may indicate that the amount of water leaking from the SH8 canal section through the seeps prior to remediation may have had a negligible effect on surrounding groundwater and surface water levels. However, it should be noted that the seep inspection ratings are qualitative measurements and care should be taken in their interpretation as they are subject to human error during the collection of the data.

Figure 8b displays the inspection ratings for seep observations along the Mary Burn Fill canal section and generally show that the majority of seeps along this canal section have fluctuated since the previous monitoring period (between October 2012 and April 2013). After the 8.17 km Culvert and SH8 remedial works ceased, all of the Mary Burn Fill canal section seeps remained consistently between inspection ratings of damp and flowing up to 26 November 2013. This may be related to seasonal surface water and groundwater fluctuations as the increase in the inspection ratings for all seeps appear to coincide with the winter months where groundwater and surface water levels were generally higher. However it is worth noting that groundwater levels at the Mary Burn Fill canal section are deep (typically between -10.0 m bgl and -23.5 m bgl), which may reduce the influence of groundwater levels on seep flow.

Dewatering and the associated remedial works on the Mary Burn Fill canal section do not appear to have had an obvious effect on the inspection ratings of the Mary Burn Fill seeps. The seep inspection ratings fluctuated during the remedial works and seeps TKB 18358LS and TKB18175LS even increased from wet and damp respectively to flowing immediately prior, during and after the remedial works at the Mary Burn Fill canal section. Seeps TKB18081LS and TKB 19644LS both recorded inspection ratings of flowing between the periods of construction on the canal, but both decreased to between dry and wet prior to, during and after the remedial works at the Mary Burn Fill canal section. There appears to have been no obvious influence from rainfall on the inspection ratings for the Mary Burn Fill canal section seeps. Continued monitoring of seeps along the Mary Burn Fill canal section seeps is required to determine any longer term effects on the inspection ratings of seeps from the remedial works on this section of the canal, although there does not appear to be any immediate short term effects.

4.3.2 Weir measurements

The flow rates of weirs monitored along canal sections SH8 and Mary Burn Fill are displayed in Figure 9 (Appendix A). Flow rates in all 5 monitored weirs have remained consistently below 14 litres per minutes (L/min) since the remedial works on the 8.17 km Culvert and SH8 canal sections. The flow rates in the weirs along the SH8 canal section appear to have been reduced significantly by the installation of the PVC liner in this

section of the canal. In particular, weir TKBWELBM recorded a maximum flow rate of 131 L/min prior to construction works on the SH8 canal section before being reduced to little to no flow during the remedial works. Since the SH8 remedial works, weir TKBWELBM has recorded a maximum flow rate of 9 L/min on 10 May 2013 and has typically remained less than 5 L/min since. Weirs TKBWR113L and TKBWRRTM recorded maximum flow rates of 28 and 10 L/min respectively prior to the start of the SH8 remedial works but since the remedial works on the SH8 canal section, they have had no recorded flow in them and remain dry. Figures 10a and 10b show photos of weir TKBWRRTM with flow prior to the remedial works on the SH8 canal section on (Figure 10a, dated 2 October 2012) and also after the remedial works were completed (Figure 10b, dated 8 May 2014). Weir TKBWRLBM had the highest recorded flow during the most recent monitoring period of 14 L/min on 28 November 2013 and 30 December 2013. During the remedial works at the Mary Burn Fill canal section, flows in the SH8 weirs were all consistently less than 2 L/min and remained below this flow since. Flow rates in weir TKB174 at the Mary Burn Fill canal section, does not appear to have been directly affected by any remedial works along any section of the canal. Flow rates in this weir did drop during the construction works on the 8.17 km Culvert and SH8 canal sections. However, flows fluctuated during this construction period before increasing to flows (3 L/min) similar to those recorded prior to the remedial works at 8.17 km culvert and SH8 canal sections. Weir TKBD174 recorded no flows during 30 September and 28 November 2013 but flows increased to flows consistent with those recorded previously and remained at this flow rate throughout the remedial works at the Mary Burn Fill canal section. Flows in this weir have remained consistently around 3 L/min since.

The previous monitoring report identified that rainfall events affected flows in weirs along the SH8 canal section. However, since the remedial works in the 8.17 km Culvert and SH8 canal sections, the influence of rainfall on the flows in these weirs is no longer obvious. This may potentially be related to manual measurements of flow in each weir only being recorded monthly since the remedial works finished and not daily during the dewatering of 8.17 km Culvert and SH8 canal sections.

Flow rates in the SH8 canal section weirs have been significantly reduced as a result of the remedial works in this section of the canal. However, adjacent groundwater and surface water levels which receive flow from the SH8 weirs do not appear to have been adversely affected by the reduction of flow from these weirs. The flow rate in weir TKBD174 on the Mary Burn Fill canal section does not appear to have been affected by any of the remedial works along the Tekapo Canal. It would be prudent to continue monitoring flows in the weirs along the SH8 and Mary burn Fill canal sections to determine if there are any further long term effects associated with the remedial works along Sh8 and Mary Burn Fill canal sections.

4.3.3 Stream flow gauging

Table 2 below displays the most recent gauging results made during the most recent monitoring period in January 2014 as well as previous flow measurements from the previous monitoring period between October 2012 and April 2013.

Table 2: Stream flow gauging results (all flows m³/s)

Date	SH8EUS	SH8EDS	IRISHUS	IRISHDS	MBUS	MBDS
3/10/2012	*0.204*	*0.153*	*2.345*	*2.531*	-	-
15/10/2012	*0.523**	*0.546**	*Too high**	*Too high**	-	-
16/10/2012	-	-	*Too high**	*Too high**	*1.881**	*2.534**
4/12/2013	*0.110*	*0.113*	*1.195*	*1.153*	*0.624*	*0.566*
10/05/2013	*0.019*	*0.009*	*0.742*	*0.812*	*0.289*	*0.242*
17/01/2014	0.039	0.038	0.736	0.789	0.350	0.391

Notes: Measurements in italics indicates flows measured during previous monitoring period (October 2012 and April 2013). * denotes stream in flood

Flow rate measurements during the most recent monitoring period between April 2013 and May 2014 were only undertaken once in all three streams on 17 January 2014 due to flows being too high (i.e. >600 L/s).

Generally speaking, the flow rates between the upstream and downstream gauging sites for each stream do not appear to be consistent in terms of having a greater flow on one particular side of the canal since gauging began in October 2012. Based on the flow gauging measurements undertaken so far, there does not appear to be a clear pattern that the three streams are gaining significant quantities of water from the canal across each culvert. Based on the data collected so far, continued monitoring over the next 12 month period would be prudent. However, due to access restrictions, flow gauging of the downstream sites on the unnamed stream east of SH8 and Irishman Creek can no longer be carried out. Therefore, it is proposed that flow gauging of the unnamed stream east of SH8 and Irishman Creek be ceased, but flow gauging of both the upstream and downstream sites on the Mary Burn continue over the next 12 month monitoring period.

The remediated 8.17 km culvert barrels remained dry for the entire monitoring period and have therefore not been discussed.

5.0 Environmental effects arising from remedial works

The purpose of this report is to describe the monitoring undertaken during and after the Tekapo Canal remedial works to determine if there have been any changes on

groundwater and surface water levels from the installation of the PVC liner in 8.17 km Culvert, SH8 and Mary Burn Fill canal sections.

Water levels in the majority of the monitoring wells and ponds appear to be influenced by large rainfall and snowfall events and display seasonal fluctuations with water levels generally higher during winter months and lowest during the summer months. The majority of the monitoring wells and ponds display stable long term trends. Seeps and weirs along the SH8 canal section appear to have been affected by the installation of the PVC liner on this section of canal as the flow of water to each of the monitored seeps and weirs has been reduced. Seeps and weirs along the Mary burn Fill canal section do not appear to have been affected by any remedial works along the Tekapo Canal.

In terms of the effect of leakage from the canal altering the natural groundwater and surface water levels in proximity to the remediated sections of the canal, any effect appears to be minor compared to the much larger natural variations. While it appears that leakage from the canal has potentially reduced water flow to some of the seeps and weirs along canal, the receiving environments (i.e. groundwater and surface water ways) do not appear to have been adversely affected. This suggests that the contribution canal leakage makes to groundwater and surface water levels are small compared to the natural variability that occurs. However, it would be prudent to continue monitoring groundwater and surface water levels along the Mary Burn Fill canal section to determine if there are any longer term effects from the remedial works on this section of the canal.

It is also recommended that monitoring of groundwater and surface water levels along the SH8 canal section continues for at least another 12 months to confirm that the installation of the PVC liner has not had an adverse effect on water levels along this section of canal. However, it should be noted that due to access restrictions, physical monitoring of the SH8 ponds and flow gauging at the downstream sites on both the unnamed stream east of SH8 and Irishman Creek is no longer possible. It is proposed that visual observations using photographs of water levels in the SH8 ponds be undertaken in place of physical monitoring to determine any major changes in water level in the ponds. Continued monitoring of groundwater and surface water levels along canal sections 8.17 km Culvert is unlikely to show any further potential effects arising from the installation of liner along this section. Therefore it is proposed that monitoring along 8.17 km Culvert canal section for the purposes outlined in the GWSMP (PDP, 2012) and Schedule One – General Conditions, is ceased. The following section provides the updated version of the monitoring programme for the next 12 months.

6.0 Update of monitoring programme

Condition 22 of Schedule One – General Conditions (Appendix D) states that:

"*The monitoring programme shall cease 12 months after the installation of the final section of the supplementary PVC liner in the Tekapo Canal*."

Construction works on the Tekapo Canal at all three sections have now been completed and monitoring of the 8.17 km Culvert and SH8 canal sections has been carried out for more than 12 months since the installation of the PVC liner at these 2 canal sections. Based on this and the monitoring data collected so far, it is proposed that monitoring of the 8.17 km Culvert canal section shall cease, but monitoring along the SH8 and Mary Burn Fill canal sections will continue for at least another 12 months. The frequency of monitoring over the following 12 months is listed below;

May 2014 to April 2015

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for the Mary Burn Fill canal section; and

Monthly monitoring of weirs, seeps and groundwater levels in monitoring wells for the SH8 canal section and monthly photographic surveys of SH8 canal section ponds.

Flow gaugings of the Mary Burn will be made in approximately six months (October 2013) and twelve months (April 2014) time or at periods where flow in the Mary Burn at SH8 is < 600 L/s.

Downloads of the transducers in Wells 3, 4, 5 and 6 as well as the transducer located in the Mary Burn Fill Canal section pond will be carried out in July 2014, October 2014, January 2015 and again in April 2015. It is proposed that the transducers located in Wells 1 and 2 located along the 8.17 km Culvert canal section as well as the transducer (SH8SG1T) and staff gauges (TKBSH8SG1 and TKBSH8SG2) in the SH8 canal section ponds will be removed during PDP's next scheduled site visit in July 2014.

Daily rainfall data from the NIWA Lake Tekapo climate station (Agent Number: 24945) located at Tekapo Airfield should be collected for the next 12 month monitoring period.

A final review of the monitoring programme should be made again in 12 months' time when the next annual environmental monitoring report is due to assess whether continued monitoring along the SH8 and Mary Burn Fill canal sections is required.

7.0 References

Pattle Delamore Partners. 2012. Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works. Prepared for Genesis Energy Ltd.

Pattle Delamore Partners. 2013. Annual Report on groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works. Prepared for Genesis Energy Ltd.

Appendix A

Figures



Figure 1: Remediated sections of the Tekapo Canal

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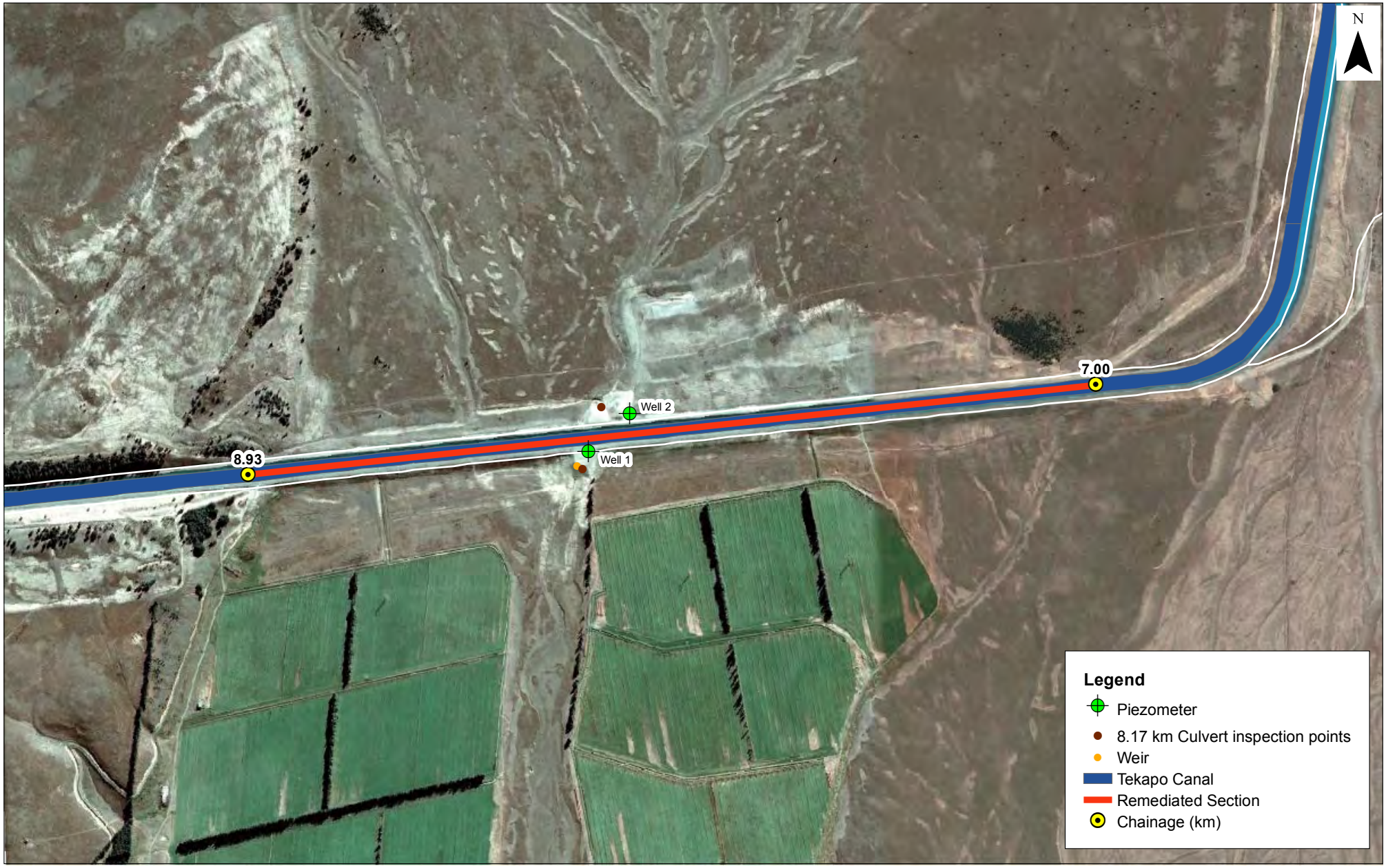


Figure 2a: Locations of monitoring points at 8.17 km culvert



Figure 2b: Locations of monitoring points along SH8 canal section

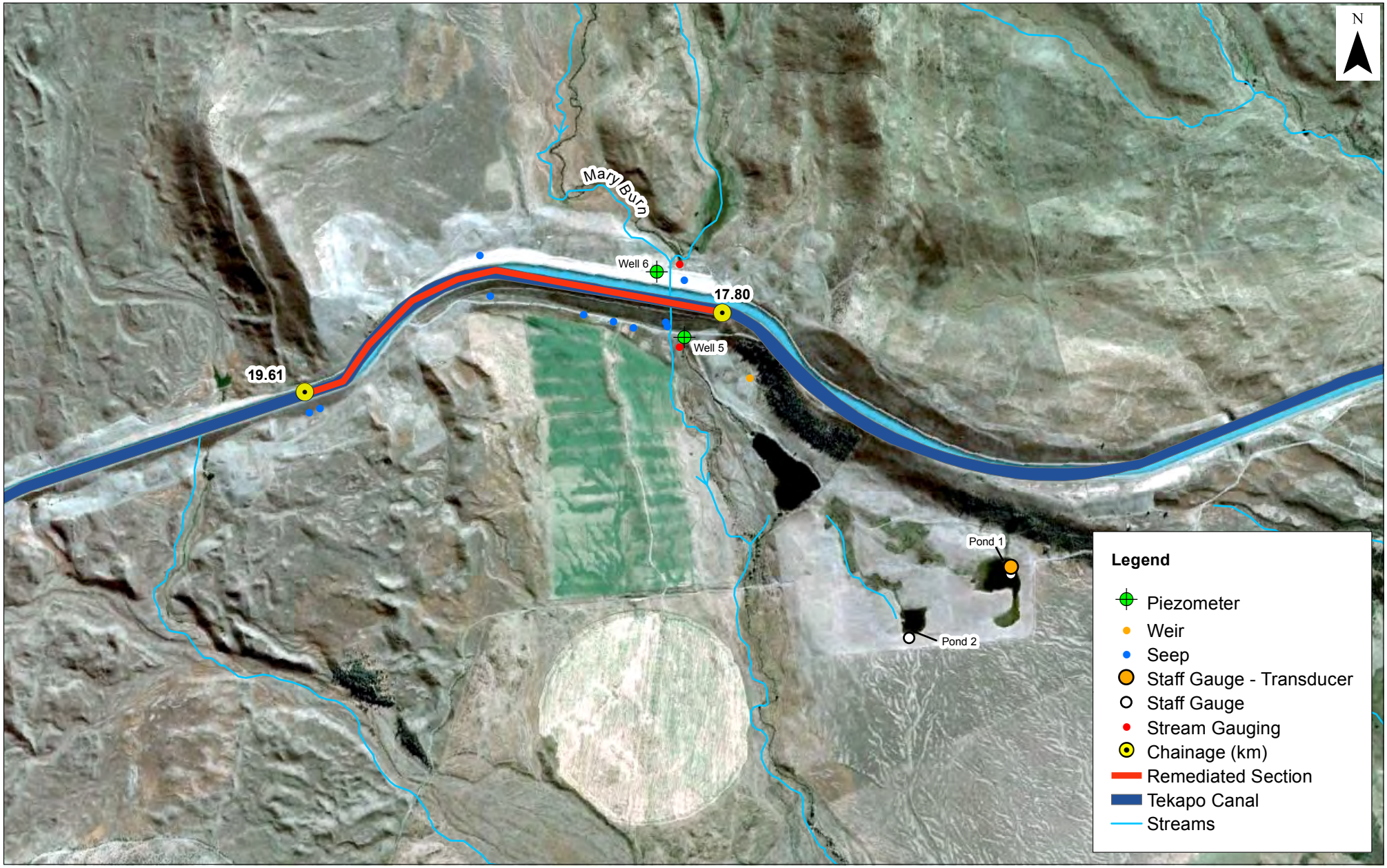


Figure 2c: Locations of monitoring points at Mary Burn Fill canal section

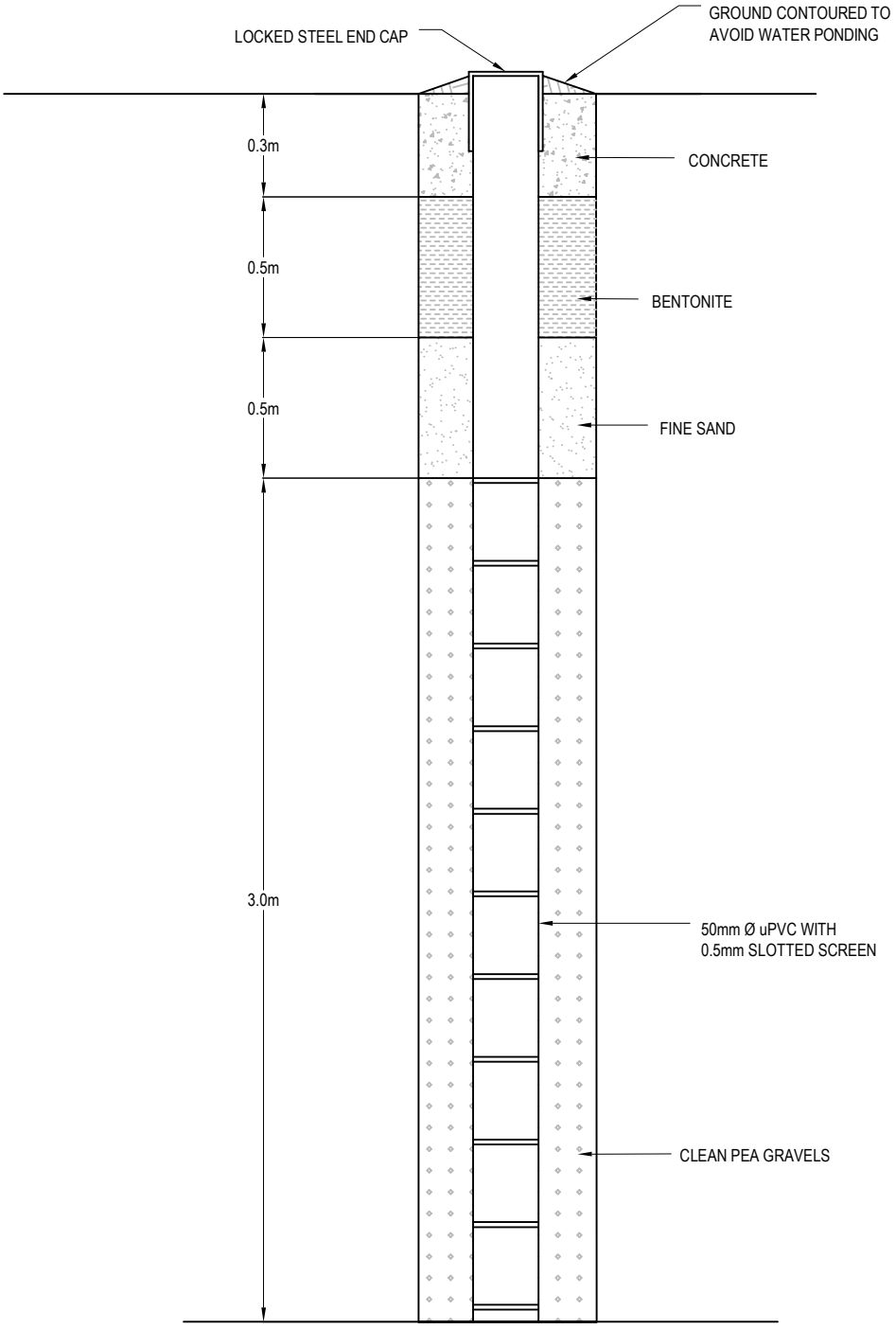


FIGURE 3 : SCHEMATIC DIAGRAM OF PIEZOMETER INSTALLATION (NOT TO SCALE)

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Figure 4a: Well 2 well head on 11 January 2013. Note silt ring surrounding the casing of the well head from ponded water.



Figure 4b: Well 2 well head on 8 May 2014. Note small drain has been excavated towards grass on right to allow ponded water to drain away from well head.



Figure 5a: Upstream culvert barrels at 8.17 km culvert on 7 May 2014 after remediation of canal section 8.17 km Culvert.

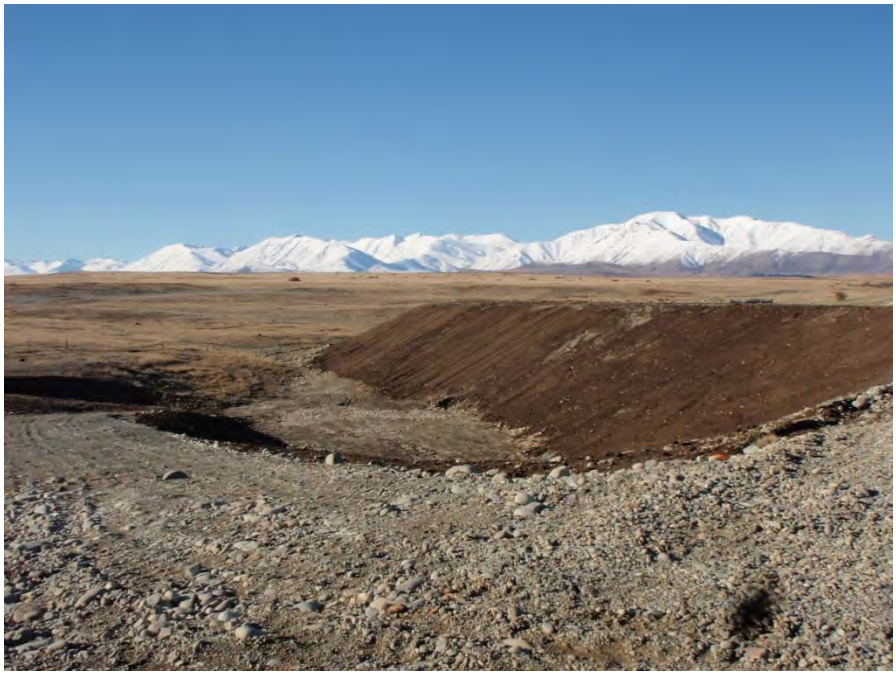


Figure 5b: Looking upstream from above the upstream culvert barrels at 8.17 km culvert on 7 May 2014 after remediation of canal section 8.17 km Culvert.

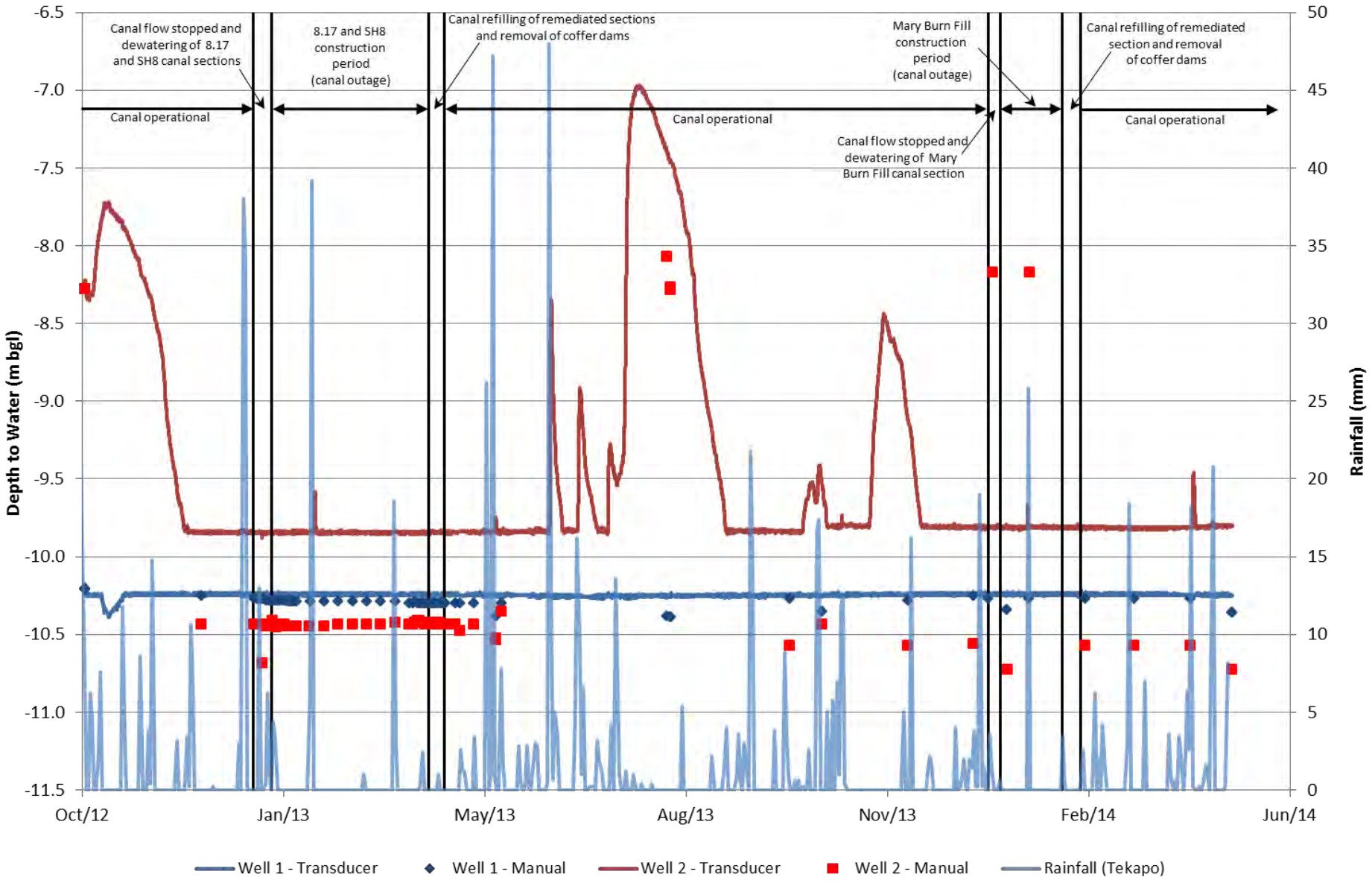


Figure 6a: Groundwater levels in Wells 1 and 2 at 8.17 km Culvert and rainfall records since monitoring began in October 2012

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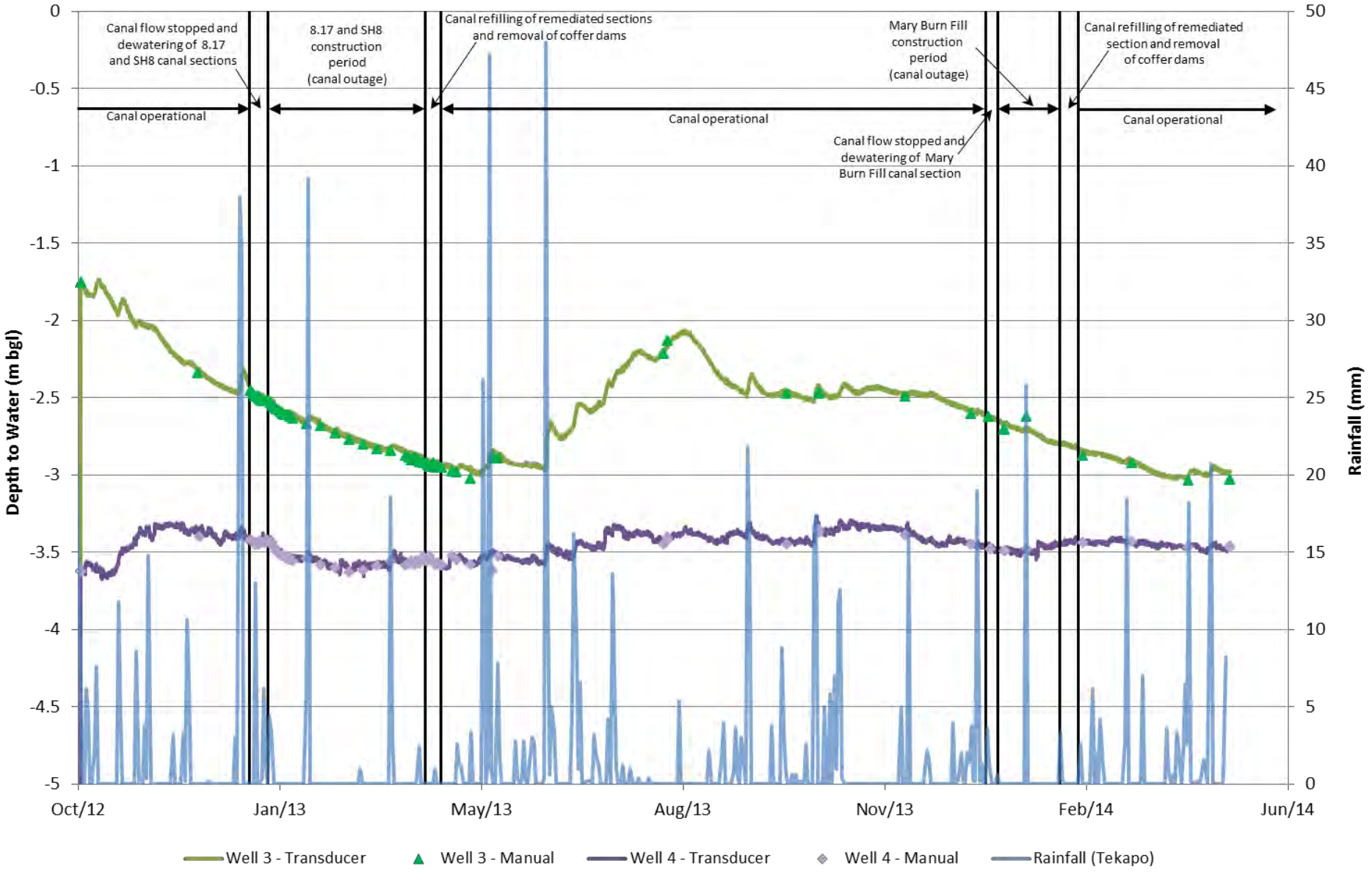


Figure 6b: Groundwater levels in Wells 3 and 4 at SH8 canal section and rainfall records since monitoring began in October 2012

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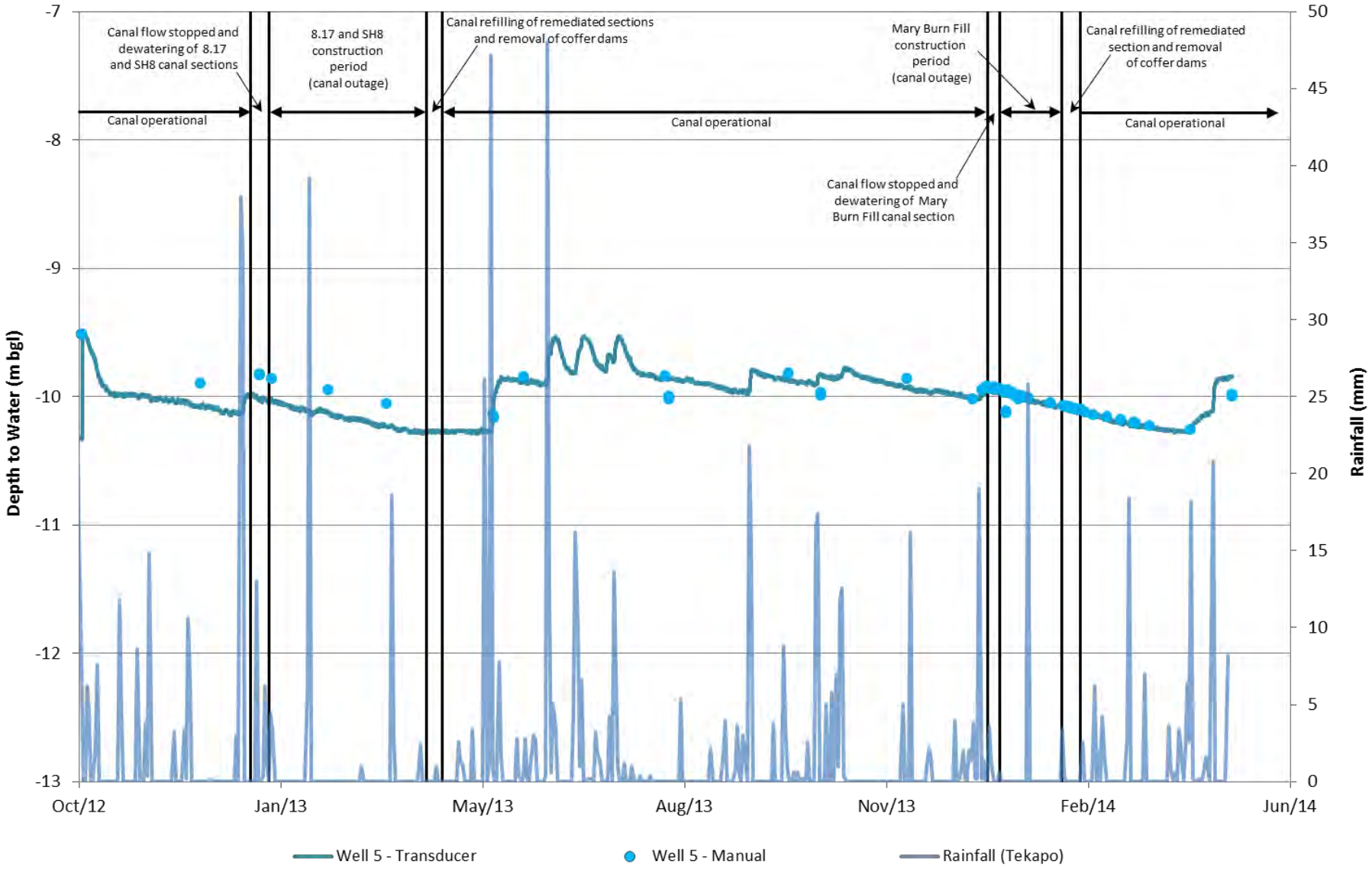


Figure 6c: Groundwater levels in Well 5 at Mary Burn Fill canal section and rainfall records since monitoring began in October 2012

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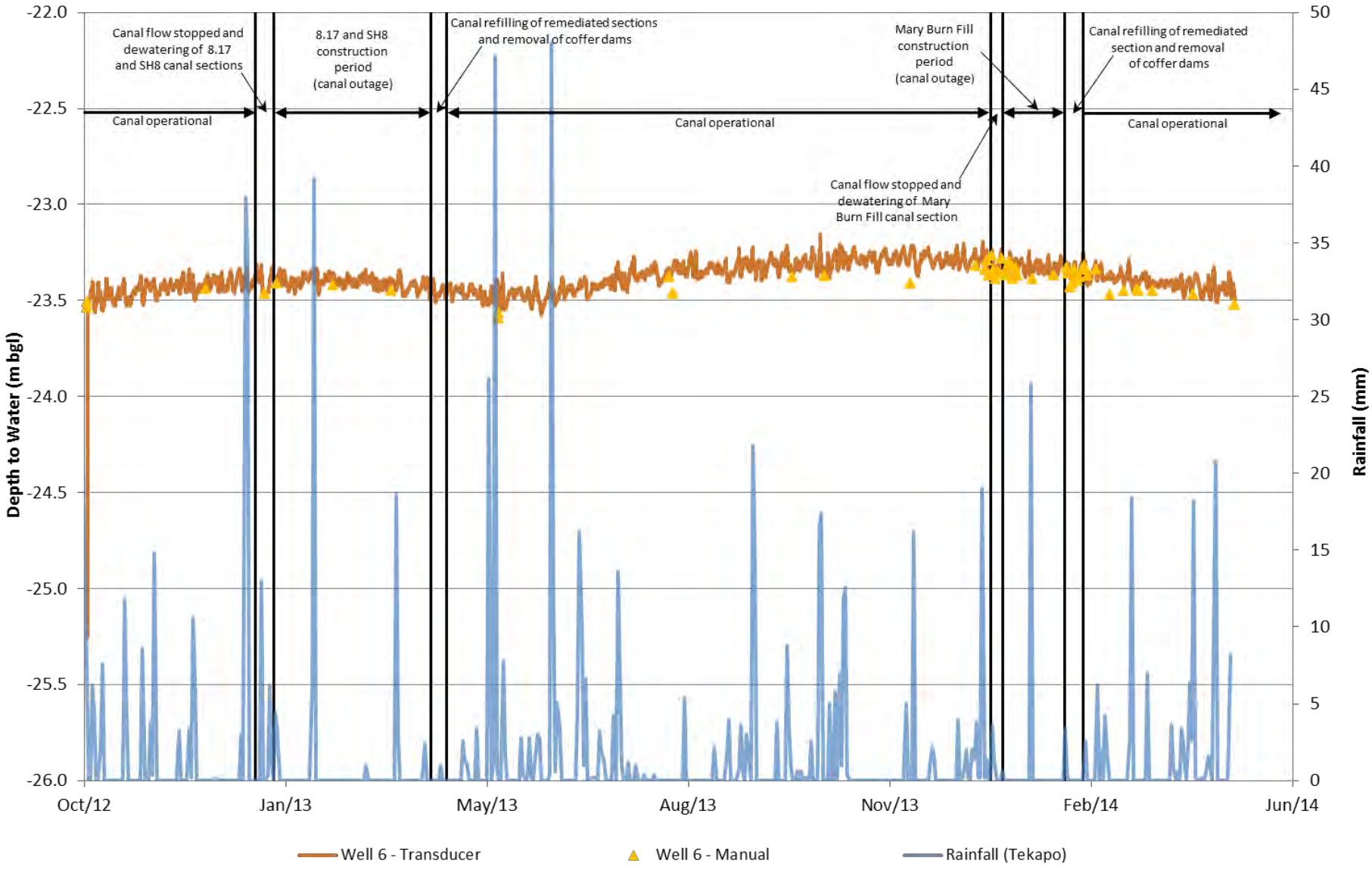


Figure 6d: Groundwater levels in Well 6 at Mary Burn Fill canal section and rainfall records since monitoring began in October 2012

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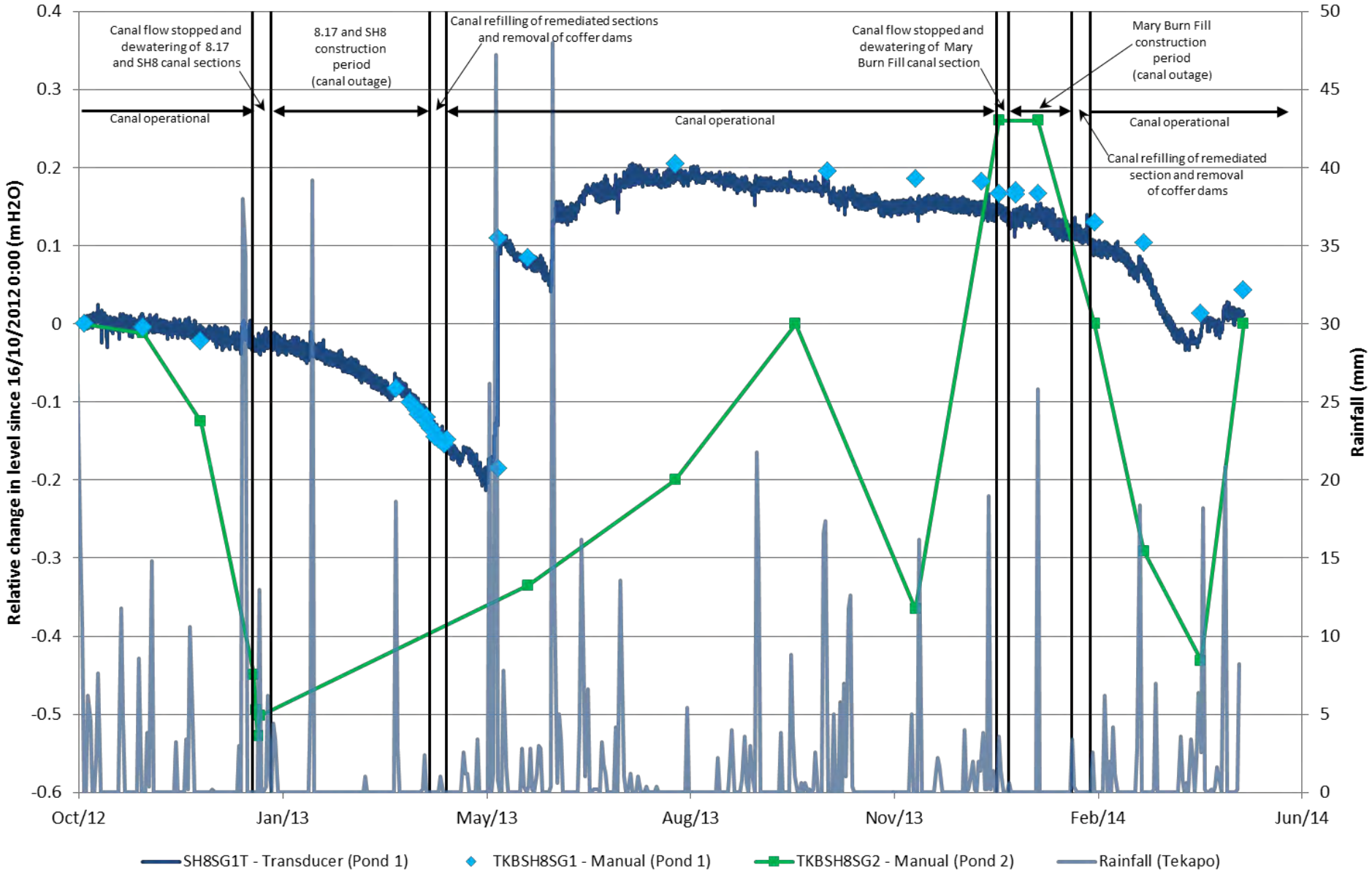


Figure 7a: Pond water levels in SH8 canal section ponds and rainfall records since monitoring began in October 2012

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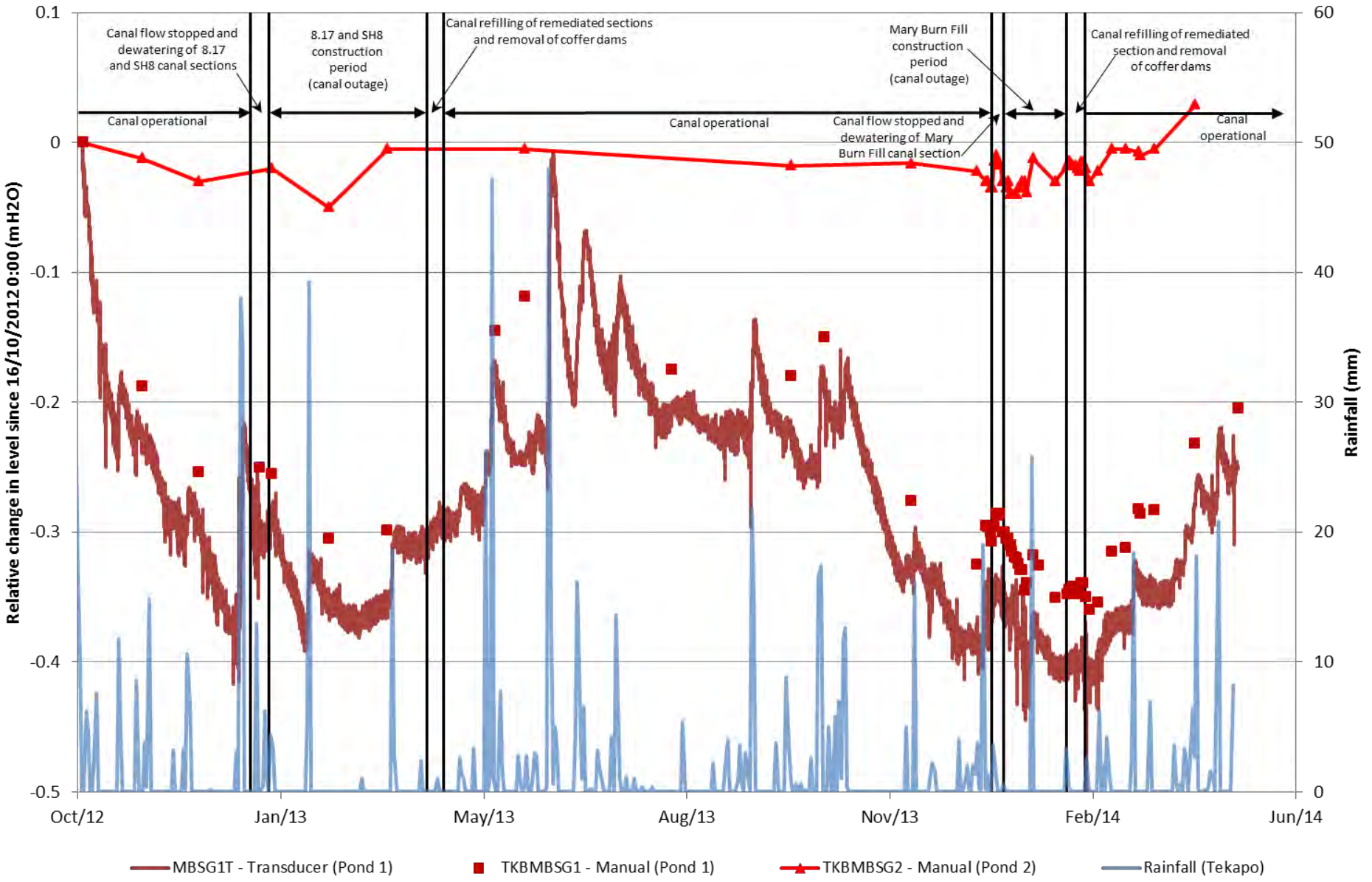


Figure 7b: Pond water levels in Mary Burn Fill canal section ponds and rainfall records since monitoring began in October 2012

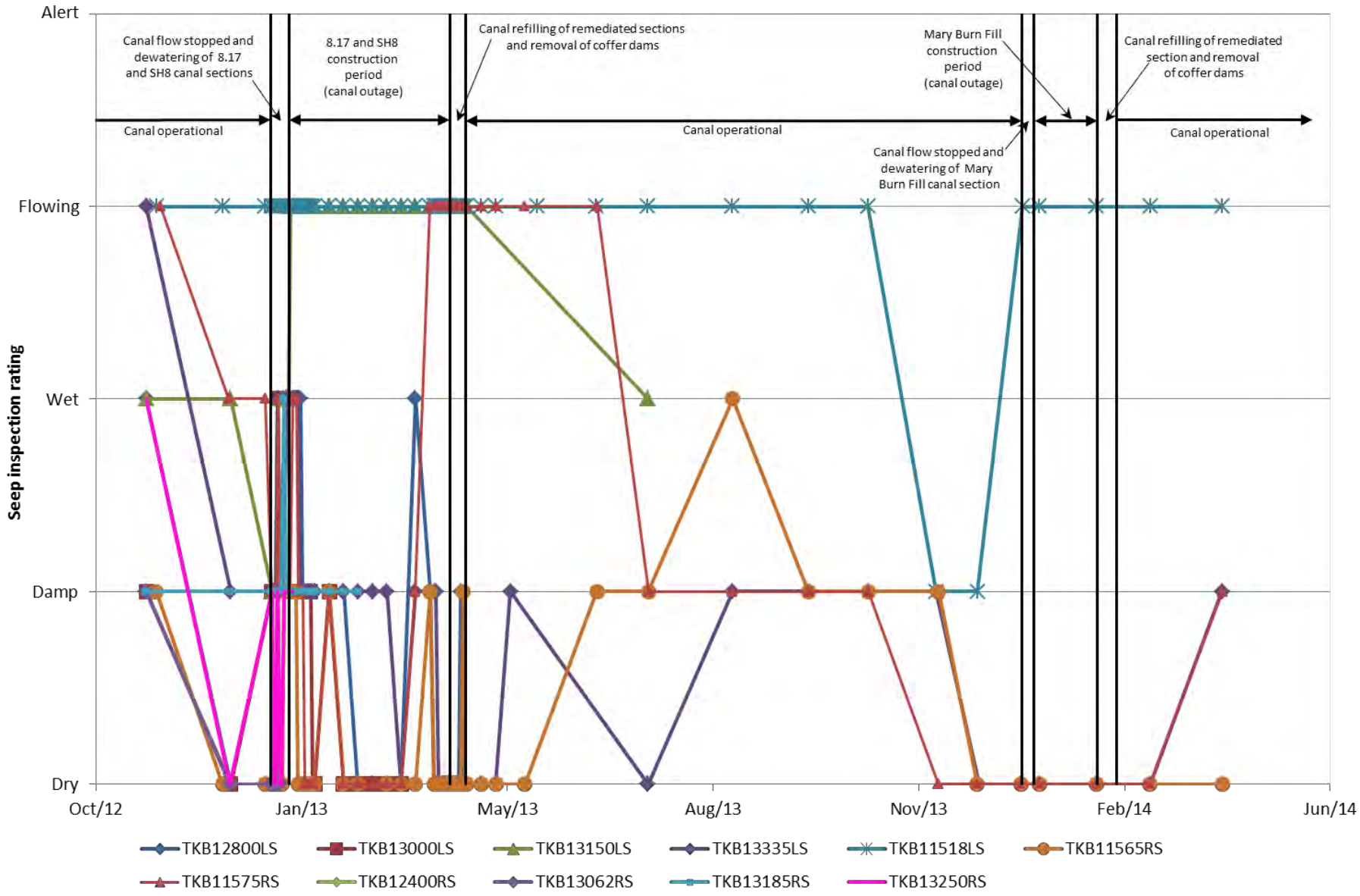


Figure 8a: Inspection ratings for seeps along the SH8 Canal section since monitoring of the seeps began in November 2012

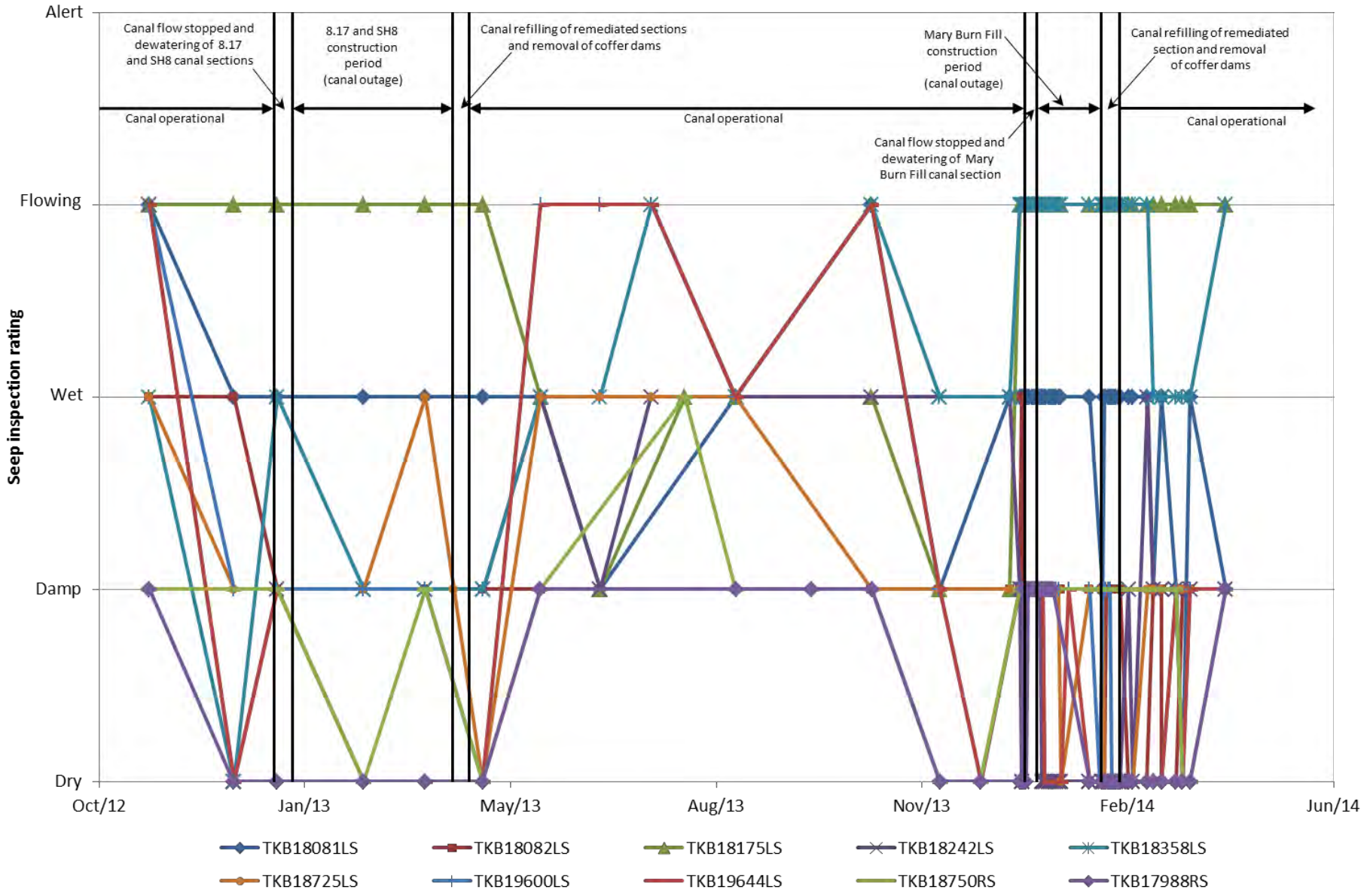


Figure 8b: Inspection ratings for seeps along the Mary Burn Fill canal section since monitoring of the seeps began in November 2012

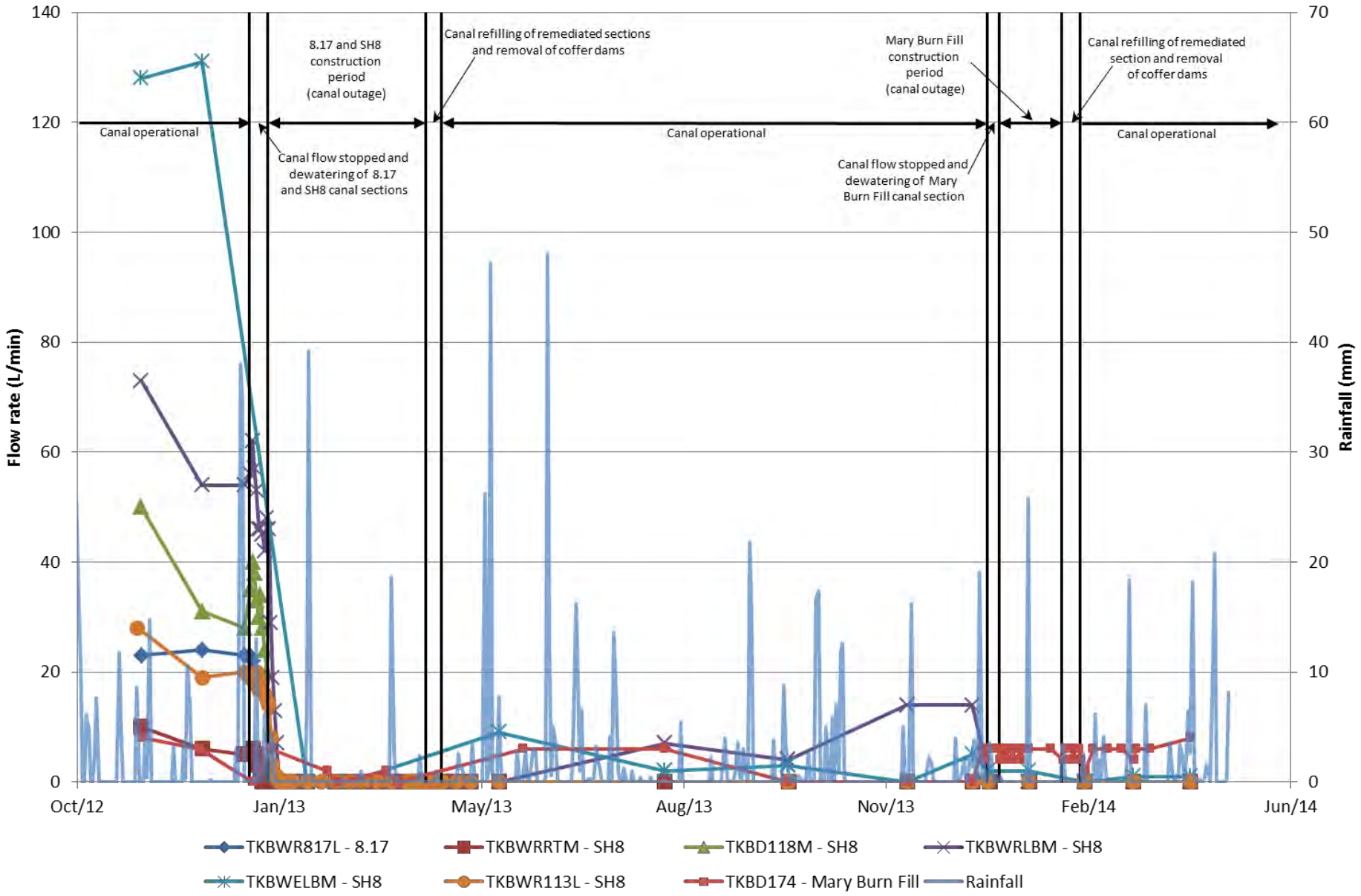


Figure 9: Flow rates of all weirs along 8.17 km Culvert, SH8 and Mary Burn Fill canal sections with rainfall since monitoring of the weirs began in November 2012



Figure 10a: Weir TKBWRRTM on true right hand side of canal embankment next to the unnamed stream east of SH8, SH8 Canal section prior to remedial works on SH8 canal section on 2 October 2012.



Figure 10b: Weir TKBWRRTM on true right hand side of canal embankment next to the unnamed stream east of SH8, SH8 Canal section after remedial works on 8 May 2014.

Appendix B

List of Monitoring Sites

Canal Section	Site Name	Easting (NZTM)	Northing (NZTM)	Type	Status as of June 2014
8.17	TKB08170LC	1392232	5117216	Culvert inspection (downstream)	Unaltered
8.17	TKB08170RC	1392297	5117379	Culvert inspection (upstream)	Unaltered
8.17	TKBWR817L	1392242	5117245	Weir	Removed
8.17	TKBOP401	1392307	5117272	Monitoring Well (Well 1)	Unaltered
8.17	TKBOP411	1392361	5117388	Monitoring Well (Well 2)	Unaltered
SH8	TKBSH8SG1	1388742	5116770	Staff Gauge	Unaltered
SH8	SH8SG1T	1388708	5116778	Transducer - Pond 1	Unaltered
SH8	TKBSH8SG2	1388548	5116726	Staff Gauge	Unaltered
SH8	TKB11518LS	1388951	5116880	Seep	Unaltered
SH8	TKB11565RS	1388931	5117011	Seep	Unaltered
SH8	TKB11575RS	1388879	5117012	Seep	Unaltered
SH8	TKB12400RS	1387960	5116899	Seep	No longer monitored
SH8	TKB12800LS	1387733	5116632	Seep	No longer monitored
SH8	TKB13000LS	1387594	5116502	Seep	No longer monitored
SH8	TKB13062RS	1387502	5116584	Seep	No longer monitored
SH8	TKB13150LS	1387422	5116423	Seep	No longer monitored
SH8	TKB13185RS	1387372	5116546	Seep	No longer monitored
SH8	TKB13250RS	1387298	5116547	Seep	No longer monitored
SH8	TKB13335LS	1387249	5116381	Seep	Unaltered
SH8	TKBD118	1388898	5116881	Weir	Removed
SH8	TKBWELB	1388909	5116886	Weir	Unaltered
SH8	TKBWR113L	1389170	5116878	Weir	Unaltered
SH8	TKBWRLBM	1388900	5116884	Weir	Unaltered
SH8	TKBWRRTM	1388893	5117018	Weir	Unaltered
SH8	TKBOP421	1388729	5116854	Monitoring Well (Well 3)	Unaltered
SH8	TKBOP431	1388961	5117010	Monitoring Well (Well 4)	Unaltered
SH8	SH8EUS	1388889	5117030	Flow Gauging Site - Stream East of SH8	Unaltered
SH8	SH8EDS	1388924	5116860	Flow Gauging Site - Stream East of SH8	Unaltered
SH8	IRISHUS	1387427	5116673	Flow Gauging Site - Irishman Creek	Unaltered
SH8	IRISHDS	1387554	5116320	Flow Gauging Site - Irishman Creek	Unaltered
Maryburn Fill	TKBMBSG1	1384195	5115160	Staff Gauge	Unaltered
Maryburn Fill	MBSG1T	1384195	5115160	Transducer - Pond 1	Unaltered
Maryburn Fill	TKBMBSG2	1383805	5114914	Staff Gauge	Unaltered
Maryburn Fill	TKB17988RS	1382940	5116288	Seep	Unaltered
Maryburn Fill	TKB18081LS	1382870	5116127	Seep	Unaltered
Maryburn Fill	TKB18082LS	1382875	5116113	Seep	Unaltered
Maryburn Fill	TKB18175LS	1382746	5116106	Seep	Unaltered
Maryburn Fill	TKB18242LS	1382669	5116131	Seep	Unaltered
Maryburn Fill	TKB18358LS	1382554	5116156	Seep	Unaltered
Maryburn Fill	TKB18725LS	1382196	5116227	Seep	Unaltered
Maryburn Fill	TKB18750RS	1382156	5116384	Seep	Unaltered
Maryburn Fill	TKB19600LS	1381542	5115795	Seep	Unaltered
Maryburn Fill	TKB19644LS	1381502	5115781	Seep	Unaltered
Maryburn Fill	TKBD174	1383192	5115912	Weir	Unaltered
Maryburn Fill	Well5	1382940	5116070	Monitoring Well (Well 5)	Unaltered
Maryburn Fill	Well6	1382834	5116321	Monitoring Well (Well 6)	Unaltered
Maryburn Fill	MBUS	1382885	5116350	Flow Gauging Site - Mary Burn	Unaltered
Maryburn Fill	MBDS	1382889	5116032	Flow Gauging Site - Mary Burn	Unaltered

Appendix C

Driller's Logs

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Camp / E2302272, N5678906

HOLE No. 1

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 10.38 | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 10.38 (m).

Driller: Neil / Simmons | SHIFT START DATE: 6/10/12 TIME: | SHIFT FINISH DATE: 6/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	2.2	Dual rotary 150mm	Brown Clay Bound Gravel			
			2.2	~~10.38~~	" "	Sandy Clay Bound Gravel			WL 9.8m
				10.38					
		0.5	0	0.5	-	Cement			1 Bag
		4.71	0.5	5.21		Backfill			
		0.73	5.21	5.94		Bentonite			1 Bag
		0.47	5.94	6.41		Fine Sand			
		3.97	6.41	10.38		Sand			7 Bags

INSTALLATIONS | CASING: from 0 to 7.38 (m). Diameter: 50mm pvc Comments:

SCREEN: from 7.38 to 10.38 (m). Diameter: 50mm pvc Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Cement E230230 N5679029

HOLE No. 2

Drill Rig Type: DR24

DRILLING LOG | Length of hole: | Inclination: | Bearing: 10-8 | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to ~~9.26~~ (m).

Driller: Neil Simmons | SHIFT START DATE: 3/10/12 TIME: | SHIFT FINISH DATE: 3/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	0.1	Down rotary 150mm	top Soil			
			0.1	10.8	"	Clay Bound Gravel	WS 3.24		
		3.46	7.33	10.79		Sand			8 1/2 Bags
		0.49	6.84	7.33		fine Sand			
		0.62	6.22	6.84		Betonite			1 Bag
		5.87	0.35	6.22		Back fill			
		0.35	0	0.35		Cement			1 Bag

INSTALLATIONS | CASING: from 0 to 7.79 (m). Diameter: 50mm pvc Comments:

SCREEN: from 7.79 to 10.79 (m). Diameter: 50mm pvc Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Canal
E2298695, N5678489

HOLE No. 3

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 5.67 | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 5.7 (m).

Driller: Neil | SHIFT START DATE: 3/10/12 TIME: | SHIFT FINISH DATE: 3/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
		5.67	0	5.67	Dual rotary 150mm	Clay Bound gravels	Swl 2.10m		
		0.4	0	.4		Cement			1 Bag
		0.72	0.4	1.12		Backfill			
		0.48	1.12	1.6		~~fine Sand~~ Bentonite			1 Bag
		0.52	1.6	2.12		~~Sand~~ fine Sand			
		3.55	2.12	5.67		Sand			6 1/2 Bag

INSTALLATIONS | CASING: from 0 to 2.67 (m). Diameter: 50mm Comments: pvc

SCREEN: from 2.67 to 5.67 (m). Diameter: 50mm Comments: pvc

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: E2298924, N5678648 Tekapo Canal

HOLE No. Hole 4

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 6.48m | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 6.5 (m).

Driller: Neil | SHIFT START DATE: 2/10/12 TIME: | SHIFT FINISH DATE: 2/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
		0.30	0	0.3	Dual rotary 6"	Top Soil			
		3.2	0.3	3.5	" "	Brown Silty Clay Bound Gravel			
		3.00	3.5	6.5	" "	Clay Bound Gravel yellow	SWL 3.54		
			0	.3	~~Geotube~~	Cement			1 Bag
			0.3	1.8		Backfill			
			1.8	2.5		Bentonite			1 Bag
			2.5	3.05		fine Sand			5 Bags
			3.05	6.48		Sand			

INSTALLATIONS | CASING: from 0 to 3.50 (m). Diameter: Comments: pvc

SCREEN: from 6.48 to 3.50 (m). Diameter: 50mm Comments: pvc

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: te Kapo corner
E2292907 N5677707

HOLE No. 5

Drill Rig Type: ORZ4

DRILLING LOG | Length of hole: 10.96m | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 10.96(m).

Driller: Neil Simmons | SHIFT START DATE: | TIME: | SHIFT FINISH DATE: | TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	10.96	Down Rotary 150mm	Clay Bound Gravel			WL 9.85m
		0.3	0	0.3		Cement			1 Bag
		6.08	0.3	6.38		Backfill			
		0.58	6.38	6.96		Bentonite			1 Bag
		0.45	6.96	7.41		Fine Sand			
		3.57	7.41	10.98		Sand			5½ Bags

INSTALLATIONS | CASING: from 0 to 7.96 (m). Diameter: 50mm PVC Comments:

SCREEN: from 7.96 to 10.96 (m). Diameter: 50mm PVC Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Corner E2292801 N5677958

HOLE No. 6

Drill Rig Type: DR24

DRILLING LOG

INSPECTOR

Driller: Neil / Simmons

Length of hole: 26.83 Inclination: Bearing:

TYPE: Open holing from 15 to 26.83 (m). Tubexing from to (m). Rotary from 0 to 15 (m).

Sheet 1 of 1

SHIFT START DATE: 5/10/12 TIME: SHIFT FINISH DATE: 5/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	8.5	Down / rotary 150mm	large fill (Boulders)			
			8.5	14	"	Clay Bound Gravel			
			14	17.1	"	Boulder			
			17.1	19.3	"	Clay Bound Gravel			
			19.3	24	"	Sand			
			24	26.9	"	Very Sand Gravel			
									WL 24.46m
			0	0.3		Cement			1 Bag
			0.3	22.4		Backfill			
			22.4	22.9		Bentonite			1 Bag
			22.9	23.38		fine Sand			
			23.38	26.83		Sand			6 1/2 Bag

INSTALLATIONS

CASING: from 0 to 23.83 (m). Diameter: 50mm pvc Comments:

SCREEN: from 23.83 to 26.83 (m). Diameter: 50mm pvc Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

Appendix D

Schedule One – General Conditions

SCHEDULE ONE – GENERAL CONDITIONS

CONDITIONS ATTACHED TO RESOURCE CONSENTS:
CRC122392, CRC122393, CRC122394, CRC122395, CRC122396, CRC122397, CRC122398, CRC122399, CRC122400, CRC122401, CRC122402, CRC122403, CRC122404, CRC122405, CRC122406, CRC122407, CRC122409, CRC122410 and CRC122411;
ISSUED BY THE CANTERBURY REGIONAL COUNCIL (CRC)

GENERAL

1) Unless otherwise stated where information is to be provided to CRC it shall be sent to the CRC Attention: Regional Manager RMA Monitoring and Compliance.

2) In each year these resource consents are exercised the consent holder shall provide CRC with an updated schedule of all construction activities at least every three months, and notify CRC if there are any changes.

3) Prior to the commencement of the construction season, in each year that these resource consents are to be exercised, the consent holder shall arrange and conduct a pre-construction site meeting between a CRC representative and all relevant parties, including the primary contractor. At a minimum, the following shall be covered at the meeting:

   a) Scheduling and staging of works;

   b) Responsibilities of all relevant parties;

   c) Contact details for all relevant parties;

   d) Expectations regarding communication between all relevant parties;

   e) Procedures for implementing any amendments;

   f) Site inspection;

   g) Maintenance of storm water, erosion and sediment control measures;

   h) Confirmation that all relevant parties have copies of the contents of this consent document and all associated management plans; and

   i) The management plans, or subsequent revisions allowed for in Condition 9.

4) Prior to the commencement of each construction season the consent holder shall provide written notification of the works commencing on the site to CRC, at least five working days prior to works commencing.

5) When undertaking the activities authorised by these resource consents, all practicable steps shall be undertaken to minimise adverse effects on property, wildlife, biodiversity values, aquatic ecosystems, vegetation, cultural and amenity values.

6) If the consent holder ceases work on-site for a period of seven consecutive or more days, they shall first take adequate preventive and remedial measures to control sediment discharges, and shall thereafter maintain those measures for as long as necessary to prevent sediment discharges from the site.

7) Notwithstanding Conditions 4, 11, 13, 14, 25 and 29 preliminary earthworks, vegetation clearance and the establishment of buildings associated with the development of the Construction Management Site may commence immediately following the commencement of these resource consents. These preliminary works shall be undertaken in accordance with all other relevant consent conditions. An Environmental Management Plan ("**EMP**") and supplementary environmental management plans ("**SEMP**") relevant to these preliminary works shall be submitted to CRC as soon as practicable after site preparation work commences, but no later than 15 working days thereafter.

MANAGEMENT PLANS

8) All management plans submitted in accordance with Schedule One shall address all the relevant matters identified within this schedule and demonstrate compliance with the relevant consent conditions.

9) The management plans may be amended at any time. Any amendments shall be:

   (a) Consistent with the conditions of these resource consents; and

   (b) Submitted in writing to CRC, as soon as practicable.

10) The preparation, and amendment, of a management plan shall be undertaken by a person or persons with a relevant tertiary qualification and at least five years relevant experience or a person who CRC deem to be appropriately qualified.

ENVIRONMENTAL MANAGEMENT PLAN

11) At least 20 working days prior to the commencement of any construction works, the consent holder shall submit an EMP to CRC.

12) The EMP shall be an umbrella document that identifies the management processes and techniques to ensure appropriate environmental management of the site and works.

SUPPLEMENTARY ENVIRONMENTAL MANAGEMENT PLANS

13) At least 20 working days prior to the commencement of construction works, the consent holder shall submit the following SEMP to CRC:

   (a) Canal Water Quality Management Plan

   (b) Storm Water, Sediment and Erosion Control Management Plan;

   (c) Dust Management Plan;

   (d) Rehabilitation Management Plan;

   (e) Contaminant Spill Contingency Plan; and

(f) Fish Salvage Management Plan.

14) All works shall be undertaken in accordance with the approved SEMP listed in Condition 13.

Canal Water Quality Management Plan

15)

a) At least 40 working days prior to the commencement of construction works, the consent holder shall undertake a one-off background monitoring of bed sediment quality at several sites in the canal to determine the proportion of organic material present in sediment upstream and downstream of the salmon farm operated by Mount Cook Alpine Salmon Limited and to assess the potential effect that organic material in the sediment will have on oxygen levels in the canal water when flows cease.

b) The results of the monitoring undertaken as part of Condition (15)(a) above shall be provided to the CRC within five working days of them becoming available.

c) The consent holder shall prepare, submit and implement a Canal Water Quality Management Plan ("**CWQMP**"). The frequency and location of the monitoring and the extent of the management responses required under the CWQMP shall be established based on the results of the monitoring undertaken as part of Condition (15)(a) above. In addition, the CWQMP shall address, but not necessarily be limited to, the following matters:

i) A water quality monitoring program which shall measure water temperature and dissolved oxygen levels in the Tekapo Canal while the flow in the canal is halted. Measurements shall be taken at a depth of 1 metre and a depth of 5 metres.

ii) The response the consent holder shall undertake to:

(a) Report on thermal stratification in the canal water if temperature monitoring shows a difference greater than 2°C between water at 1 metre depth and water at 5 metres depth; and / or;
(b) Increase dissolved oxygen levels in canal water to above 80 percent saturation.

iii) The management actions to be carried out when:

(a) The difference in water temperature between canal water at 1 metre depth and 5 metres depth exceeds 2°C, and/or:
(b) Dissolved oxygen levels in the canal water decrease to, or below, 50 percent saturation.

iv) The consent holder shall keep records of all water quality information recorded and shall submit the record annually to the CRC.

v) Should the actions detailed in Condition (15)(c)(iii) need to be carried out, the consent holder shall notify the CRC within 5 working days.

Storm Water, Sediment and Erosion Control Management Plan

16) The consent holder shall prepare, submit and implement a Storm Water, Sediment and Erosion Control Management Plan ("**SSECMP**"). The SSECMP shall be prepared in accordance with the Canterbury Regional Council's "Erosion and Sediment Control Guidelines for the Canterbury Region" Report No. CRC R06/23, February 2007 ("**ESCG**"). The SSECMP shall ensure that all discharges to water courses do not exceed total suspended solids of greater than 100 grams per cubic metre. The SSECMP shall address, but not necessarily be limited to, the following matters:

a) A map showing the location of all works;

b) Detailed plans showing the location of sediment control measures, on-site catchment boundaries, and sources of runoff;

c) Drawings and specifications of designated sediment control measures;

d) Details of any sediment Flocculent/Coagulant use including but not limited to:
   (i) Methodology for choosing a suitable flocculent/coagulant.
   (ii) Details of how the flocculent/coagulant will be applied including how the optimal dosage will be calculated, and manufactures instructions are complied with,
   (iii) Details of how it will be determined that the use of a flocculent/coagulant is necessary.
   (iv) Monitoring.

e) A programme of works, which includes but is not limited to, a proposed timeframe for the works; and

f) Details of the inspections and maintenance for the erosion and sediment control measures, including monitoring of total suspended solids in discharges to water.

g) Timing and methodology of decommissioning works.

Dust Management Plan

17) The consent holder shall prepare, submit and implement a Dust Management Plan ("**DMP**"). The DMP shall, address, but not necessarily be limited to, the following matters:

a) A record of the dust control measures to be used, including where appropriate, the following:

   (i) Planning earthworks in advance so as to limit the amount of exposed surface area;

   (ii) Using water carts and / or irrigation sprays to pre-water the site of earthworks;

   (iii) Ceasing earthworks during periods of high winds;

(iv) Applying water via sprays to the aggregate crushing and screening facility;

(v) Limiting the height and slope of stockpiles of topsoil;

(vi) Applying water to the stockpiles using sprays;

(vii) Installing wind breaks near the stockpiles of topsoil;

(viii) Use of water carts on the unpaved roads;

(ix) Applying water to the feed hopper of the concrete batching plant; and

(x) Providing a bag filter unit to capture dust during filling operations at the cement silo.

b) Designated responsibilities for dust management, including sub-contractor management;

c) A record of maintenance requirements and contingency plans for dust control equipment;

d) Consultation with neighbouring property owners and occupiers if required; and

e) A complaints register, including a record of investigations carried out, the response action taken, and any reporting requirements. The register shall be provided to the CRC on request.

Rehabilitation Management Plan

18) The consent holder shall prepare, submit and implement a Rehabilitation Management Plan (**"RMP"**). The RMP shall address, but not necessarily be limited to, the following matters:

a) Identification of the soil resources to be used for rehabilitation;

b) Identification of the vegetation types to be used on a planting plan or schedule;

c) A programme for re-vegetation and maintenance activities;

d) The desired percentage of surface cover to be achieved to reduce the adverse effects from sediment-laden stormwater run-off; and

e) Identification of weed management activities to be undertaken.

Contaminant Spill Contingency Plan

19) The consent holder shall prepare and implement a Contaminant Spill Contingency Plan ("**CSCP**") for containment of any spill events. The CSCP shall address, but not be limited to, the following matters:

a) Identifying designated bulk fuel storage, contaminant storage facilities and re-fuelling locations;

b) Ensuring that all contaminant storage or designated re-fuelling areas are bunded or contained in such a manner so as to prevent the discharge of contaminants;

c) Requiring that all mobile fuel tankers carry spill kits, which are capable of absorbing the quantity of oil and petroleum products that may be spilt by a mobile fuel tanker on site at any one time, and that spill kits are also stored at bulk storage tank locations at all times;

d) Detailing the contents of the spill kits, including absorbent pads, booms, pillows and socks and appropriate pegs/rope to hold the absorbent material in place;

e) Recording the names of operators trained in spill response and remediation;

f) Ensuring that all machinery is regularly maintained in such a manner so as to minimise the potential for leakage of contaminants;

g) Ensuring that no machinery is cleaned, stored or refuelled within 20 metres of the bed of any water body (except in relation to the canal berms where a 20 metre setback is not possible);

h) Ensuring that all contaminants (e.g. fuel, hydraulic oils, lubricants etc) are removed from the site at the end of the construction period, except for those required for ongoing maintenance and operational activities;

i) Detailing an internal and external notification procedure in the event of a spill, including but not limited to providing emergency contact information for the Canterbury Regional Council Pollution Hotline, and emergency contact information for a waste management service provider with appropriate qualifications and equipment for cleaning up spills; and

j) Identifying measures to be undertaken to remediate a contaminant spill, including instructions for removing and disposing of contaminated material in a manner suitable to ensure no further contamination occurs.

k) Ensuring that when informing the Canterbury Regional Council of any spill, as specified in clause (i), the consent holder shall provide the following information:

(i) The date, time, location and estimated volume of the spill;

(ii) The cause of the spill;

(iii) The type of contaminant(s) spilt;

(iv) Clean up procedures undertaken;

(v) Details of the steps taken to control and remediate the effects of the spill on the receiving environment;

(vi) An assessment of any potential effects of the spill; and

(vii) Measures to be undertaken to prevent a recurrence.

Fish Salvage Management Plan

20) The consent holder shall prepare, submit and implement a Fish Salvage Management Plan ("**FSMP**"). The purpose of the FSMP shall be to minimise fish losses from dewatering sections of the Tekapo Canal. The FSMP shall address, but not necessarily be limited to, the following matters:

a) Details of a briefing to be held for all participants in the salvage operation prior to each salvage operation;

b) Details of the number of personnel required, their responsibilities, and required training (i.e. electric fishing, fish tanker, and boat operator certification);

c) Step by step information on the procedures to be undertaken to salvage the fish;

d) A list of all the fish handling equipment that will be required during the salvage operations;

e) A list of all support equipment required for the fish salvage operations;

f) Details of all fish handling activities including how to capture and handle fish within each canal section, specifics on the number of fish which can be transported in containers or transport tanks at varying water temperatures;

g) Details of how and where fish will be released, and whether any special structures will need to be created in order to release the fish;

h) Information on what to do with injured and dead fish, including tallying their numbers prior to disposal;

i) Reporting requirements that summarise each season's fish salvage operation and can be kept as a permanent record; and

j) Details of how tangata whenua can be involved in the design and implementation of fish salvage operations and monitoring.

GROUNDWATER AND SURFACE WATER MONITORING PROGRAMME

21) The consent holder shall design a Groundwater and Surface Water Monitoring Programme ("**GSWMP**"). The GSWMP shall include, but not necessarily be limited to:

a) Monitoring of groundwater levels in piezometers around the Tekapo Canal;

b) Monitoring of Mary Burn flows upstream and downstream of the Tekapo Canal and flows in springs that emerge downslope of the canal sections that are being relined; and

c) Monitoring of water levels in representative ponds and wetlands adjacent to the Tekapo Canal and works.

22) The consent holder shall implement the monitoring programme required in Condition 21 three months prior to the de-watering of the Tekapo Canal first occurring. The monitoring programme shall cease 12 months after the installation of the final section of the supplementary PVC liner in the Tekapo Canal.

23) The consent holder shall compile an annual monitoring report for each year that these resource consents are current addressing the monitoring undertaken in accordance with Condition 21. As a minimum the report shall:

a) Include a summary of all the data collected as required under Condition 22;

b) Critically analyse the information collected in terms of compliance and potential or actual adverse environmental effects;

c) Compare data with previously collected and reported results and identify and comment on any emerging trends; and

e) Make recommendations on alterations/additions to the monitoring programme, if required.

The annual monitoring report shall be submitted to CRC, by 30 June for each year these resource consents are exercised.

DIDYMO

24) To prevent the spread of pest species, including but not limited to Didymo (*Didymosphenia geminata*), the consent holder shall ensure that activities authorised by this resource consent are undertaken in accordance with the Biosecurity New Zealand's hygiene procedures, and that vehicles and machinery shall be free of plants and plant seeds prior to use in any water body.

Advice Note: You can access the most current version of these procedures from the Biosecurity New Zealand website http://www.biosecurity.govt.nz.

ACCIDENTAL DISCOVERY PROTOCOL

25) At least 20 working days prior to the proposed commencement date for construction, the consent holder shall submit an Archaeological Accidental Discovery Protocol to CRC. The Protocol shall be prepared in consultation with Upoko Runanga of Arowhenua, Waihao and Moeraki, or their representative(s).

In addition to the information and content proposed in the documentation accompanying the application and further information, the accidental discovery protocol shall include, but not be limited to, the following:

a) Preconstruction protocols that may be carried out;

b) Protocols for notification of relevant parties and site management procedures in the event any archaeological sites or taonga are uncovered at any time;

c) Contact details for all relevant parties; and

d) Training procedures for all contractors.

All works shall be exercised in accordance with the Archaeological Accidental Discovery Protocol.

26) In the event of any discovery of archaeological material:

(a) the consent holder shall immediately:

(i) Cease earthmoving operations in the affected area and mark off the affected area; and

(ii) Advise the CRC of the disturbance; and

(iii) Advise the New Zealand Historic Places Trust of the disturbance.

(b) If the archaeological material is determined to be Koiwi Tangata (human bones) or taonga (treasured artefacts) by the New Zealand Historic Places Trust, the consent holder shall immediately advise the office of the Upoko Runanga of Arowhenua, Waihao and Moeraki, of the discovery.

(c) If the archaeological material is determined to be Koiwi Tangata (human bones) by the New Zealand Historic Places Trust, the consent holder shall immediately advise the New Zealand Police of the disturbance.

(d) Work may recommence if the New Zealand Historic Places Trust (following consultation with rūnanga if the site is of Māori origin) provides a statement in writing to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager that appropriate action has been undertaken in relation to the archaeological material discovered. The Canterbury Regional Council shall advise the consent holder on written receipt from the New Zealand Historic Places Trust that work can recommence.

Advice Note:

Under the Historic Places Act 1993 an archaeological site is defined as any place associated with pre-1900 human activity, where there is material evidence relating to the history of New Zealand. For sites solely of Māori origin, this evidence may be in the form of accumulations of shell, bone, charcoal, burnt stones, etc. In later sites, artefacts such as bottles or broken glass, ceramics, metals, etc, may be found or evidence of old foundations,

wells, drains, tailings, races or other structures. Human remains/koiwi may date to any historic period.

It is unlawful for any person to destroy, damage, or modify the whole or any part of an archaeological site without the prior authority of the New Zealand Historic Places Trust. This is the case regardless of the legal status of the land on which the site is located, whether the activity is permitted under the District or Regional Plan or whether a resource or building consent has been granted. The Historic Places Act provides for substantial penalties for unauthorised damage or destruction

CERTIFICATION

27) The consent holder shall engage a Chartered Professional Engineer to certify that the design of the:

(a) Canal relining; and

(b) Culvert remediation

and their construction are in accordance with good engineering practice to ensure that the structure is safe and fit for purpose. This certificate shall be submitted to CRC, prior to the first filling of the canal.

ONGOING CONSULTATION

28) Within one month of the commencement of these resource consents, the consent holder shall invite representatives of the Department of Conservation, The Wolds Station Ltd, Irishman Creek Station Ltd, the Tekapo Community Board, Central South Island Fish and Game, Te Runanga o Ngai Tahu, Te Runanga o Arowhenua, Te Runanga o Waihao and Te Runanga o Moeraki to participate in a Tekapo Canal Remediation Project Consultation Group" ("**TCRPCG**").

a) The purpose of the TCRPCG, the meetings that will be held with the TCRPCG, and the consent holder's obligations to the TCRPCG shall be as follows:

i) To ensure stakeholder input is incorporated in the EMP and SEMPs;

ii) To ensure stakeholders are kept up to date with project implementation;

iii) To discuss the results of monitoring programmes; and

iv) To provide a mechanism for stakeholders to express any matters of concern and to address those concerns.

b) The consent holder shall initiate up to one meeting prior to, and one meeting during, any canal outage events with the TCRPCG and on an as required basis thereafter. The purpose of the meetings will be to:

i) Provide regular updates on progress with implementation of the resource consents;

ii) Advise of the activities and events related to the resource consents that have been completed and activities or events to be undertaken in the future, and likely effects on the local community;

iii) Identify the consultation to be undertaken with individual landowners;

iv) Advise what actions have been taken to comply with the conditions of consent;

v) Allow for community feedback on the EMP and SEMPs; and

vi) Provide an avenue by which people that may be affected by the consented activities are able to communicate any concerns they have to the consent holder.

c) The consent holder shall keep minutes of the meetings held in accordance with clause b) of this condition and shall forward them to all attendees within ten working days; and

d) The consent holder shall provide final copies of the reports prepared in accordance with the conditions of this resource consent to the TCRPCG concurrently with them being submitted to CRC.

29) The consent holder shall prepare a Communication Strategy, which shall set out procedures to deal with queries relating to the Tekapo Canal Remediation Works. The Communication Strategy shall be lodged with CRC, at least two months prior to any site works being undertaken. The Communication Strategy shall include, but not be limited to:

a) Advertising in local newspapers no later than three months prior to any canal outage events, explaining the general nature of the works to be undertaken in the following construction season and the extent to which these may affect traffic flows, angling and other recreational activities;

b) Advertising in local newspapers at least one month prior to construction works commencing in each construction season, providing details of the works proposed and a timetable for these;

c) A method of recording the time, date and the type of any complaint and the actions taken by the consent holder to resolve the complaint;

d) Establishing and publicising a toll-free project telephone number, so that any members of the public may raise matters or make an enquiry regarding the remediation works to the Tekapo Canal; and

(e) Detailing a mechanism whereby the consent holder undertakes reasonable endeavours to provide information on water levels in Lake Tekapo and flow rates and water levels in the Tekapo River to the public.

Annual Report on Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works

Prepared for

Genesis Energy

June 2015

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Limitations:

This report has been prepared on the basis of information provided by Genesis Energy. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

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1.0 Introduction

Genesis Energy Ltd began remedial works along various sections of the 26 km long Tekapo Canal which extends from Tekapo A Power Station near Lake Tekapo through to the settling pond above the Tekapo B Power Station at Lake Pukaki in October 2012 and completed the works in February 2014. The remedial and construction works along the canal involved:

- De-watering sections of the canal using coffer dams;
- Excavation of the current canal liner;
- Placement and compaction of fill on the base and sides of the canal;
- Laying of a low permeability synthetic PVC liner; and
- Various temporary construction and ancillary works around the Tekapo Canal.

These works took place along the following three sections of canal:

- From chainage 7-8.93 km – a canal section referred to as the 8.17 km Culvert;
- From chainage 10.9-14.7 km – a canal section referred to as SH8; and
- From chainage 17.8-19.61 km – a canal section known as the Mary Burn Fill.

These chainages are all measured from the Tekapo A Power station. Figure 1 displays the location of canal reach names and chainages along the Tekapo Canal.

Water in the Tekapo Canal (as originally constructed) interacts with the surrounding groundwater via seepage through the sides and base of the canal. Where the canal is located above groundwater, seepage from the canal will recharge the underlying groundwater. Where the canal is excavated below the water table, then seepage between the groundwater and canal will occur depending on the relative elevation of the groundwater level and the water level in the canal. During the remedial works, the water level in the canal was lowered by up to 1 m to minimise the stress on the coffer dams and the sections of canal between the coffer dams were dewatered completely. The change in water levels in the canal alters the interaction between the water in the Tekapo canal and the surrounding groundwater.

The rate of seepage between the canal and the groundwater is directly affected by the nature of the canal lining. Therefore, the liner material installed during the remedial works may result in an alteration to the rate of seepage interaction with the natural groundwater resource around those areas that have been relined which will continue beyond the completion of the remedial works.

The shallow groundwater resource that is affected by the interaction with the canal will, in turn, interact with surface waterways and water bodies in the area.

The purpose of this report is to describe the monitoring that has been undertaken since May 2014 as part of the Groundwater and Surface Water Monitoring Programme (GSWMP) and follows on from the previous monitoring report prepared by PDP for Genesis Energy Ltd dated June 2014. This report will assess the changes in groundwater and surface water arising from the Tekapo Canal remedial works.

This report is structured as follows:

- Section 2 provides a summary of the previous monitoring period between April 2013 through to May 2014;
- Section 3 outlines the monitoring programme undertaken by PDP for the period May 2014 through to April 2015;
- Section 4 discusses the results of the monitoring and any interpretations of the data; and
- Section 5 describes any environmental effects arising from any changes related to the remedial work and whether any additional monitoring will be required proceeding into the future.

2.0 Summary of previous monitoring round

The previous monitoring report prepared by PDP dated June 2014 documented the environmental monitoring that was carried out between April 2013 and May 2014. During this period, remediation works along the Mary Burn Fill canal section was undertaken, with construction beginning in January 2014 and being completed in February 2014. The remediation works at the 8.17 Culvert and SH8 had already been completed.

During the April 2013 to May 2014 monitoring period, monitoring of groundwater levels, surface water levels, observations of seeps and flow gaugings of the weirs and streams along the canal sections 8.17 Culvert, SH8 and Mary Burn fill was undertaken. More intensive frequency of monitoring at sites along the Mary Burn Fill canal section was undertaken during the remedial works along this section of canal between January 2014 and February 2014. Outside of this period, monthly observations and measurements were made at all monitoring sites along the three canal sections.

The data collected for the monitoring period between April 2013 and May 2014 indicated that shallow groundwater and surface water bodies are influenced by precipitation and appear to display seasonal fluctuations. Water levels are generally higher during the winter months and lowest during the summer months when precipitation in the area is lowest. The majority of the monitoring wells and ponds generally displayed stable long term trends with the exception of

Well 3 (SH8 canal section) which showed a long term declining trend beginning prior to the start of any construction works on the Tekapo Canal and continued throughout both construction seasons. Construction works and the installation of the liner along the Mary Burn Fill canal section did not appear to have an effect on adjacent groundwater and surface water levels. The effect of any leakage from the 8.17 Km Culvert and SH8 canal sections altering natural groundwater and surface water was found to be minor compared to the larger natural variations.

As of May 2014, twelve months of environmental monitoring along 8.17 Km Culvert and SH8 canal after construction had finished along these sections was completed. Based on the monitoring results for the 8.17 km Culvert canal section, it was decided that environmental monitoring for this section of canal be ceased. However, due to the observed declining trend in Well 3 along the SH8 canal section, it was decided that environmental monitoring along this section of canal should continue for a further twelve months. Due to access restrictions, physical monitoring of the SH8 ponds and flow gauging of the downstream locations on both the unnamed stream east of SH8 and Irishman Creek was no longer possible, although continued monitoring of all other accessible sites along the SH8 canal section was recommended.

3.0 Monitoring data from May 2014 to April 2015

For the period between May 2014 and April 2015, the monitoring programme focussed on groundwater and surface water levels, observations of seeps and flow rates of weirs along the SH8 and Mary Burn Fill canal sections, as well as flow rates of the Mary Burn that flows beneath the Mary Burn Fill canal section. As sufficient monitoring along the 8.17 km Culvert canal section was completed by May 2014, no monitoring of this section of canal was undertaken during the May 2014 to April 2015 period, and as such is not discussed any further in this report. Monitoring along the SH8 canal section continued, although due to access restrictions (as mentioned previously) physical monitoring of the SH8 ponds and flow gauging of the downstream locations on both the unnamed stream east of SH8 and Irishman Creek could no longer be undertaken. In place of the physical monitoring of water levels in the ponds adjacent to SH8, photographic surveys of the two ponds were taken at two locations on the canal road immediately north of the ponds. The purpose of the photos of the ponds was to assess any significant changes in water level in the ponds during the monitoring period.

Prior to this monitoring period, all remedial works on the Tekapo Canal were completed with the final works on the Mary Burn Fill canal section being completed on 26 February 2014. As a result, no construction works took place during the most recent monitoring period between May 2014 and April2015.

Maps showing the locations of monitoring sites along the two canal sections monitored during the May 2014 to April 2015 monitoring period are displayed in Figures 2a and 2b (Appendix A). A list of all the environmental monitoring sites along the Tekapo Canal is provided in Appendix B. The status of the monitoring sites during the May 2014 and April 2015 monitoring period is provided also.

In addition to the monitoring data collected along the canal sections, daily rainfall data from the NIWA Lake Tekapo climate station (Agent number: 24945) located at the Tekapo Airfield was sourced from NIWA's CliFlo climate data for the monitoring period.

The sections below discuss the frequency of monitoring, locations of monitoring sites and the type of measurements made in more detail.

3.1 Frequency of monitoring

The frequency of the environmental monitoring along the Tekapo Canal between May 2014 and April 2015 is outlined below:

May 2014 to April 2015

Monthly monitoring of weirs, seeps, pond staff gauges and groundwater levels in monitoring wells for the Mary Burn Fill canal section; and

Monthly monitoring of weirs, seeps and groundwater levels in monitoring wells for the SH8 canal section and monthly photographic surveys of SH8 canal section ponds.

Monitoring during this period was carried out by Genesis Energy Ltd staff in conjunction with Damwatch Services Ltd.

In addition to the monitoring undertaken by Genesis Energy Ltd staff and Damwatch Lt, PDP downloaded six electronic pressure transducers installed in each of the monitoring wells along the SH8 and Mary Burn canal sections and a single pond adjacent to the Mary Burn Fill canal section at three monthly intervals. Each pressure transducer measured the relative change in pressure at 15 minute intervals.

Occasional flow gaugings of the Mary Burn were undertaken in October 2013 and April 2015 when flows in the Mary Burn at SH8 were less than 600 L/s.

3.2 Groundwater level monitoring

Four piezometers were installed along the SH8 (Wells 3 and 4) and Mary Burn Fill (Wells 5 and 6) canal sections between 2 October and 5 October 2012. The purpose of these monitoring wells was to measure the response of groundwater levels prior to, during and following the remedial works on the canal. The locations of the piezometers are displayed in Figures 2a and 2b. At each canal section, two piezometers were installed with one located on the true right hand

side and one on the true left hand side of the canal. The design of the piezometers is displayed in Figure 3 and the details of the piezometers are summarised in Table 1 below.

Table 1: Environmental monitoring piezometers

Well number	ECan well number	Depth of well (m bgl)	Screened interval (m bgl)	Initial depth to water (m bgl)*	Easting (NZTM)	Northing (NZTM)	Canal section
Well 3	BZ16/0044	5.67	2.67 – 5.67	-2.10	1388729	5116854	SH8
Well 4	BZ16/0045	6.48	3.5 – 6.48	-3.50	1388961	5117010	SH8
Well 5	BZ16/0047	10.96	7.96 – 10.96	-9.85	1382940	5116070	Mary Burn Fill
Well 6	BZ16/0046	26.83	23.83 – 26.83	-24.46	1382834	5116321	Mary Burn Fill

Notes: Initial depth to groundwater measured by driller immediately after the well was drilled

Borelogs of the four piezometers are provided in Appendix C. The design of the piezometers required that the minimum depth be 4 m and to a depth that is 3 m below the depth at which groundwater is encountered but no greater than 30 m deep. In simpler terms, the screened section of the piezometer should be at least 3 m below the depth at which groundwater was encountered during drilling.

The previous two monitoring reports identified that only Wells 3 and 4 were installed correctly and adequately penetrate the groundwater table as per the specified well design. Wells 5 and 6 are not as deep as they should be. However, the intention of the piezometers is to identify changes in the interactions between groundwater and surface water ways and despite the shallower depth, Wells 5 and 6 have provided adequate and useful groundwater level data since monitoring began in October 2012 and throughout the most recent monitoring period between May 2014 and April 2015.

Pressure transducers were installed in each of the piezometers to measure the relative change in water pressure. An additional pressure transducer located inside the well cap of Well 4 was used to measure the change in atmospheric pressure. All the pressure transducers were downloaded at three monthly intervals and manual depth to groundwater measurements were made during each download of the transducers. Additional manual depth to water level measurements were collected by Genesis Energy staff. All measurements were recorded to monitor the relative change in groundwater level in each piezometer.

3.3 Surface water level monitoring

Staff gauges and pressure transducers were used to monitor changes in surface water levels in ponds on the true left hand side of the Mary Burn fill canal section. The two ponds at this canal section were monitored with a staff gauge installed in each of the ponds. Figure 2b shows the location of the two staff gauges and the names of the two sites are listed below:

- TKBMBSG1 – Mary Burn Fill canal section, Pond 1; and
- TKBMBSG2 – Mary Burn Fill canal section, Pond 2.

The staff gauges consisted of a plastic builder's ruler 1 m in length with 1 mm gradations. The ruler was secured to a metal waratah fence post installed into the bed of the pond at a depth such that at least half of the ruler was submerged with the remaining length of the ruler above the pond surface. Both staff gauges were installed close enough to the bank of each pond to ensure that the gradations could be read but at a depth deep enough to measure any changes in water level. Water levels were read off the staff gauges from the bank of the pond.

In addition to the two staff gauges, a pressure transducer was installed immediately adjacent to staff gauge TKBMBSG1. The transducer was labelled MBSG1T and was submerged in the pond by being mounted to a metal waratah installed into the base of the pond. The pressure transducer recorded changes in water pressure in the pond and were downloaded at three monthly intervals by PDP.

The purpose of the staff gauges and pressure transducers was to measure the relative changes in water levels of the ponds as a result of construction activities on the canal.

Photographic surveys of the ponds on the true left hand side of the SH8 canal section were collected to monitor qualitative changes in level in these ponds. Since physical measurements of the water levels within the two ponds on the left hand side of the canal at SH8 were no longer possible during the monitoring period between May 2014 and April 2015, photographic surveys of the ponds were undertaken to monitor any larger scale qualitative changes in water levels within the ponds. The photographic surveys were undertaken by Genesis Energy staff. Due to staffing changes, no photos of the ponds were taken in December 2014or February 2015 but an additional round of photographic surveys were also taken in May 2015. The locations from where the photographic surveys were taken from are displayed in Figure 2a.

3.4 Surface water flow monitoring

Surface flow monitoring includes observations of seeps and flow gaugings for weirs from seeps along canal embankments of both canal sections that

underwent remedial works, as well as flow gaugings of the Mary Burn that flows beneath the Mary Burn Fill canal section. The purpose of the seep and surface flow monitoring was to identify any changes in local surface water bodies as a result of the remedial works.

3.4.1 Observations of seeps

Damwatch currently undertake monitoring of seeps along the length of the Tekapo canal. A number of these seeps occur along the sections of canal that underwent remediation. PDP originally identified eleven seeps along the SH8 canal section and ten seeps along the Mary Burn Fill canal section that were considered to be relevant to monitor during remediation. The locations of the monitored seeps are shown in Figures 2a and 2b.

Damwatch monitored these sites as part of their ongoing monitoring plan and provided PDP with data for each of the relevant sites identified by PDP. The monitoring of the seeps involved a qualitative assessment of each seep with observations categorised on a scale from 0 to 4. The scale (created by Damwatch) is as follows:

- 0 – Dry
- 1 – Damp
- 2 – Wet
- 3 – Flowing
- 4 – Alert (significant change, change in flow/turbidity)

The quantity of water present at each seep during monitoring increases with the rating. During the May 2014 to April 2015 monitoring period, all observations of seeps were made by Genesis Energy staff.

Since the previous monitoring report (dated June 2014), a number of seep monitoring sites along the SH8 canal section were removed during construction activities and therefore could not be monitored. Along the SH8 canal section, five seep monitoring sites remain and were monitored during the most recent monitoring period. These seeps are:

- TKB11518LS;
- TKB11565RS;
- TKB11575RS;
- TKB13150LS; and
- TKB13335LS.

Seep TKB13150LS was only monitored once during the previous monitoring period (between April 2013 and May 2014) as it was removed from the monitoring programme as the site was covered up during remedial works not long after the final observation was recorded. However, during the most recent monitoring period (May 2014 to April 2015), this seep monitoring site was

reinstated with observations beginning again on 28 July 2014 and continuing through to April 2015.

All ten seep monitoring sites along the Mary Burn Fill canal section were monitored throughout the May 2014 to April 2015 monitoring period. No sites were removed during the previous construction activities along this section of canal.

A full list of the seeps and their status during the May 2014 to April 2015 monitoring period is provided in Appendix B.

3.4.2 Weir measurements and stream flow gaugings

Measurements of flow using weirs are also monitored by Damwatch as part of their ongoing monitoring program for Genesis Energy Ltd and were installed to monitor flows from seeps or springs that had consistent flow. During PDP's initial site visit in October 2012, five weirs along the SH8 canal section and one weir along the Mary Burn Fill canal section were considered to be relevant to the environmental monitoring program. These weirs are typically constructed of concrete and have a steel plate with a 45° angle v-notch through which water flows. The height of the water passing through the notch is recorded during monitoring and converted to a flow rate. Weir TKBWELBS at the Mary Burn Fill canal section is also constructed of concrete but has a single PVC pipe through which water flows. The flow rate for this weir is determined by measuring the time taken for the water flowing through the weir to fill a vessel of a known volume. All weir flow measurements were made by Genesis Staff during the monitoring period.

Weir TKBD118M along the SH8 canal section was removed during construction works and therefore was not monitored during the most recent monitoring period between May 2014 and April 2015. Monitoring of weir TKBWR113 along the SH8 canal section ceased in June 2014 as the weir was unable to be monitored due to access restrictions.

A full list of weirs and their status during the most recent monitoring period is shown in Appendix B.

During the May 2014 to April 2015 monitoring period, flow gaugings of the Mary Burn that flows beneath the Mary Burn Fill canal section were undertaken by PDP in October 2014 and April 2015. No flow gaugings were made in the unnamed stream east of SH8 and Irishman Creek (SH8 canal section) as access to the downstream gauging sites of these streams was restricted.

Flow gaugings in the Mary Burn were carried out on both the upstream and downstream side of the canal to try and measure any change in flow across the canal. To provide a more meaningful measurement, flow gaugings were undertaken during periods when stream flows were low (e.g. < 600 L/s in the

Mary Burn at State Highway 8). Flow gauging measurements were made using a hand held Acoustic Doppler Velocimeter (Sontek Flow Tracker) across a transect of the stream where there was little turbulence and also parallel banks. In addition, flow gauging measurements were made as close to the inlet and outlet of the culvert on both sides of the canal to try and identify as much seepage from the canal and reduce errors from bank storage in the stream. Prior to each gauging, weed and any large rocks were removed from the stream bed to reduce turbulence and provide as accurate velocities as possible.

3.5 Compliance with monitoring programme (GSWMP)

Environmental monitoring of groundwater and surface water during the remedial works on the Tekapo canal is described in conditions 21, 22 and 23 of Schedule One – General Conditions. Schedule One – General Conditions are a list of conditions attached to a number of resource consents related to the Tekapo Canal remediation works. A copy of Schedule One – General Conditions is provided in Appendix D. The PDP report "Groundwater and Surface water Monitoring Programme for Tekapo Canal Remedial works" (September 2012) also referred to as the GWSMP, prepared for Genesis Energy Ltd prior to the start of monitoring along the canal in October 2012, outlines the monitoring programme.

Minor changes to the monitoring programme during the May 2014 to April 2015 monitoring period were made due to access restrictions and therefore a number of sites along SH8 could not be accessed. In addition, photographs of the SH8 ponds were not measured during December 2014 and February 2015 due to Genesis Energy staffing changes at Tekapo. Manual groundwater levels in the four monitoring bores and surface water levels in the Mary Burn Fill ponds were not measured during February 2015 due to changes in the monitoring software used by Damwatch not being updated to include these sites.

The GSWMP specifies that occasional flow gauging of the Mary Burn is required but does not specify a required frequency. During the May 2014 to April 2015 monitoring period, the Mary Burn was gauged twice (on 8 October 2014 and 30 April 2015).

Overall, the monitoring works and the frequency of monitoring as described in the previous sections are consistent with conditions 21, 22 and 23 of Schedule One – General Conditions and the GSWMP (2012) report.

4.0 Data Analysis

Plots of the monitoring data for the monitoring period between May 2014 and April 2015 are provided in this section of the report. No major construction events took place during the most recent monitoring period but the complete record of monitoring data since monitoring began in October 2012 along with the

timing of major construction events are also provided to determine any trends in the data.

The sections below discuss the analysis of the data in further detail.

4.1 Groundwater level monitoring

Figures 4a, 4b and 4c (Appendix A) show groundwater level measurements in the monitoring bores using the pressure transducers along with the manual groundwater level measurements recorded by Genesis Energy staff and PDP.

Figure 4a shows groundwater levels measured in Wells 3 and 4 on the SH8 canal section. Figure 4a shows that groundwater levels along this section of the canal are influenced by rainfall with water levels increasing after large rainfall events. This effect is most obvious in Well 3. Manual measurements in both wells plot relatively well with the transducer data from both wells.

Water levels in Well 3 declined during the monitoring period between May 2014 and April 2015 with the lowest water level in the bore of -3.837 m bgl since monitoring began being recorded on 20 March 2015. However by 30 March 2015, water levels in the bore had increased slightly to -3.778 m bgl. Water levels in Well 3 appear to experience seasonal fluctuations with the higher levels recorded during the wetter winter months and the lowest levels recorded during the drier summer months. Water levels in Well 3 appear to decline more sharply during December 2014. During the 2014-2015 summer, the central South Island experienced drought conditions and subsequently there was lower than usual rainfall in the Tekapo area. This is evident in the rainfall records also displayed in Figure 4a as daily rainfall totals in the Tekapo area were lowest between September 2014 and April 2015 since monitoring began in October 2012. The low rainfall appears to have resulted in the decline in the water levels in Well 3 during this period.

Since monitoring in Well 3 began, there has been a steady overall declining trend in water levels in Well 3 with water levels dropping to the lowest recorded level in March 2015. However, due to the long term declining trend in water levels prior to, during and after construction on the Tekapo canal, the declining trend is not thought to be directly related to the remediation works undertaken along the canal, although the loss of canal seepage may contribute to the decline to some degree.

Groundwater levels in Well 4 have remained relatively stable throughout the most recent monitoring period. Water levels in this well also appear to display seasonal fluctuations (although somewhat less pronounced than in Well 3) with levels being slightly higher during the winter/spring months and lowest during late summer/early autumn. Water levels in Well 4 may potentially be more stable due to the proximity of the well to an unnamed stream (with permanent flow) adjacent to the well than Well 3 which is located further away from the

stream and therefore maybe more susceptible to rainfall infiltrating the shallow aquifer.

Based on the data from the most recent monitoring period as well as data from the previous monitoring periods, groundwater levels in neither Well 3 nor 4 appear to have been significantly affected by the remediation works along the Tekapo canal.

Water levels in Wells 5 and 6 at the Mary Burn Fill canal section are shown in Figures 4b and 4c respectively. The manual depth to water level measurements generally plot relatively well against the transducer data for both wells and both follow a similar pattern.

During the most recent monitoring period (May 2014 to April 2014) water levels in Well 5 display a gradual decline, reaching the lowest level (-10.421 m bgl on 12 March 2015) recorded in Well 5 since monitoring began in October 2012 before increasing to back to levels (-9.918 on 28 March 2015) similar to the start of the monitoring period. The low water level recorded in this bore occurred near the end of the summer/early autumn and correlates with a period of low rainfall associated with the dry 2014/2015 summer. Water levels in Well 5 appear to decline slightly more sharply during November 2014 than in previous years and continue to decline throughout the summer months until a large rainfall event on 28 March 2015 where water levels appear to start recovering. Water levels in Well 5 appear to be affected directly by large rainfall events and periods of low rainfall. Water levels in Well 5 also appear to display seasonal fluctuations with water levels being highest during the wetter winter months before gradually declining during the spring and summer months. The overall trend in water levels in Well 5 is a relatively stable pattern with seasonal fluctuations of around 0.5 m.

Water levels in Well 6 have remained relatively stable during the most recent monitoring period, following a similar pattern to water levels recorded in the bore during the previous monitoring rounds. During the most recent monitoring period, water levels started to decline around December 2014 slightly more sharply than previous monitoring rounds for this time of year. Water levels continued to decline through to the end of the monitoring period recording a minimum water level of -23.663 m bgl (30 March 2015) which is the lowest water level recorded in this bore since monitoring began in October 2012. This decline appears to occur each summer although, during the most recent monitoring period, it appears to have started slightly earlier (December 2014) than previous years (typically January) and continued to decline through to March 2015 to the minimum water level recorded in this well. The reason for this decline in water levels during the most recent monitoring period is likely due to low rainfall in the Tekapo area throughout the 2014/2015 summer. The overall trend of water levels in Well 6 since monitoring began in October 2012 is relatively consistent and stable with smaller, more gradual seasonal fluctuations (higher water levels

during late winter and spring before gradually declining to lowest water levels during late autumn) than in Well 5. Water levels in Well 6 do not appear to be as directly affected by local rainfall as levels in Well 5 which may be due to the relatively large depth to groundwater level (>23 m) in Well 6.

Water levels in both Wells 5 and 6 on the Mary Burn Fill canal section appear to have remained relatively stable since monitoring began in October 2012. Both bores display seasonal fluctuations in water levels with Well 5 being more directly affected by large rainfall events than Well 6 which displays more subtle fluctuations in water level. Water levels in both bores do not appear to have affected by the remediation works along the Mary Burn Fill canal section as water levels in both bores have remained relatively stable, prior to, during and after the works were completed.

4.2 Surface water level monitoring

Figure 5a shows the relative change in water levels measured using the manual staff gauges and pressure transducer installed in the Mary Burn Fill ponds.

The manual measurements from staff gauge 1 in pond 1 at the Mary Burn Fill canal (TKBMBSG1) display an offset from the transducer data (MBSG1T) by approximately 0.02 – 0.04 m although, both data sets do follow a similar pattern. The Mary Burn Fill ponds are exposed to frequent prevailing winds in the area and as such, there is likely to be a small amount of uncertainty when the manual measurements were made by reading the water level off the staff gauge. Based on the transducer data, water levels in pond 1 appear to be directly affected by rainfall events such as surface water run off which result in water levels in the pond to increase. Following each rainfall event, water levels in the pond generally decline. Based on the transducer data for pond 1, water levels fluctuate seasonally by approximately 0.4 m with higher levels recorded during the wetter autumn and winter months before declining gradually during the spring and summer months. During the most recent monitoring period, water levels increased over the winter months following the completion of the remedial works along the Mary Burn Fill canal section before declining to a seasonal low near the beginning of January 2015 and gradually increasing during the autumn months. While water levels during the 2014/2015 summer did decline (during the period of low rainfall in the area), they did not drop to levels as low as previous years and started to increase near the end of January 2015. While water levels in pond 1 at the Mary Burn Fill canal section have never quite reached similar peak levels since the start of monitoring in the pond in October 2012, the overall trend is relatively stable. The general pattern of water level fluctuations follows a similar pattern to groundwater levels in Well 5 as shown in Figure 5b.

The manual measurements from TKBMBSG2 in pond 2 at the Mary Burn Fill canal section show relatively stable water levels. Water levels in pond 2 also display

subtle seasonal fluctuations with higher water levels generally occurring during the autumn and winter months and the lower levels during the spring and summer months although the fluctuations are much smaller than in pond 1.

The long term trend in water levels for both of the ponds at the Mary Burn Fill canal section have remained relatively stable and consistent since monitoring began in October 2012. Water levels in the ponds are affected by large rainfall events and surface runoff and experience seasonal fluctuations. Remediation works along the Mary Burn Fill canal section do not appear to have significantly affected water levels in either pond. It is interesting to note that groundwater levels in the majority of the monitoring bores along the Tekapo canal recorded minimum water levels since monitoring began during the 2014/2015 summer, but water levels in both of the Mary Burn Fill ponds remained relatively stable and consistent. This is likely due to the catchment of the Mary Burn (which feeds the ponds) being relatively large and mountainous at the northern extreme of the catchment.

Water levels in the SH8 ponds along the SH8 canal section were monitored during the most recent monitoring period by photographic surveys. Physical measurements of the ponds were no longer possible due to access restrictions.

Figure 5c shows the physical measurements recorded in both SH8 ponds between October 2012 (when monitoring started) and June 2014 when physical monitoring equipment was removed. Based on this data, water levels in both ponds appear to directly influenced by rainfall and also display seasonal fluctuations similar to that which was observed in the monitoring wells with the highest water levels observed during the winter months before water levels decline gradually during spring and summer. Based on this data, the previous monitoring report concluded that water levels in both ponds were relatively unaffected by the remedial works along the SH8 canal section and are largely influenced by rainfall and seasonal fluctuations.

Figure 5d shows a summary of the photographic surveys for pond 1 for the monitoring period. The photos for pond 1 show that water levels in the pond remained relatively stable for the majority of the monitoring period until late summer/early autumn when water levels appear to decline. This decline is first visible in the March 2015 photo as a small gravel bar is now visible in the pond as well as the exposed bank edge that normally be submerged. The low water level in the pond continued through into April although water levels appear to have recovered slightly as the size of the gravel bar has been reduced in this photo. Additional photographic surveys were taken in May 2015 to check the water level in the pond and show that while pond levels are still low, water levels are slowly increasing again. As previously mentioned, the majority of the monitoring bores along the Tekapo canal were affected by the period of low rainfall in the area over the 2014/2015 summer, in particular Well 3 which is located approximately 80 north of pond 1. It is likely that the ponds at SH8 were also affected by the

low rainfall in the Tekapo area during this period. Anecdotal information provided by Colin Stevens (Tekapo A Station Manager, Genesis Energy) suggests that pond 1 typically declines in water level throughout the drier summer months before being recharged during the wetter autumn and winter months.

Pond 2 also had occasional photographic surveys taken of it and showed that by January it had dried up. However, as mentioned in previous monitoring reports, anecdotal information provided by Dave Jenkinson (retired contact engineer for Genesis Energy) indicates that this pond typically dries up during the summer months before being recharged during the winter and spring months and is therefore not an unusual occurrence.

The decline in water levels in the SH8 ponds coincides with the decline in water levels observed in the groundwater monitoring wells along the Tekapo canal which have been interpreted to be due to the period of low rainfall in the area over the 2014/2015 summer. Based on the data and photographic surveys collected during the monitoring programme, water levels in the SH8 ponds are affected by large rainfall events and periods of low rainfall as well as seasonal fluctuations. The remediation works along the SH8 canal section appear to have had relatively little effect on water levels in the ponds as the natural variations in water level appear to be much greater.

4.3 Surface water flow monitoring

4.3.1 Observations of seeps

Figures 6a and 6b display the inspection ratings of the seeps along the SH8 and Mary Burn Fill canal sections.

The five seeps that are monitored along the SH8 canal section (TKB11518LS, TKB11565RS, TKB11575RS, TKB13150LS and TKB13335LS) show that inspection ratings have fluctuated during the monitoring period between May 2014 and April 2015. Seep TKB11518LS consistently remained at a rating of flowing for the entire monitoring period. The remaining seeps appear to be affected by seasonal variations in precipitation. Seep TKB13150LS was recorded at a rating of flowing between 28 July 2014 and 9 December 2014 before dropping to dry in January 2015. The rating for TKB13150LS remained at dry until 14 March 2015 where the rating increased to damp. Seeps TKB11565RS and TKB11575RS typically appear to be dry between November and March (summer months) and increase progressively to wet and flowing respectively between July and September (winter/spring months) before gradually decreasing to dry. TKB13335LS also appears to display a seasonal trend as the rating for this site is typically dry between November and March before increasing to damp for the remainder of the year. Based on the long term seep monitoring data for the SH8 canal section, the remediation works on the SH8 canal section appear to have reduced the ratings for the majority of the remaining seeps. However, the remaining seeps

appear to be affected by seasonal fluctuations with higher ratings during the wetter autumn and winter months and decreasing ratings during the spring and summer months.

While it appears that the remediation works undertaken on the SH8 canal section may have reduced water flow to some seeps, based on the data from the neighbouring groundwater monitoring wells and ponds, the receiving groundwater and surface water ways do not appear to be affected by the reduction in water flow from the seeps. This may indicate that the amount of water leaking from the SH8 canal section through the seeps prior to the remediation works only had a small effect on surrounding groundwater and surface water levels relative to the natural variations in the surrounding groundwater and surface water are larger than the effect that the seepage from the canal had on the surrounding groundwater and surface water. However, it should be noted that the seep inspection ratings are qualitative measurements and care should be taken in their interpretation as they are subject to human error during the collection of the data.

Figure 6b displays the inspection ratings for seep observations along the Mary Burn Fill canal section and generally show that the majority of seeps along this canal section appear to fluctuate seasonally similarly to the seeps along the SH8 canal section. The increase in ratings generally appears to occur between March and November where ratings range between damp and flowing. Between November and March, ratings typically decrease for the majority of the seep sites, ranging between dry and wet, correlating roughly with the drier summer months. These fluctuations may be attributed to seasonal rainfall variations and perched. Direct inputs from the groundwater table monitored by Wells 5 and 6 may be limited because groundwater levels at the Mary Burn Fill canal section are deep (typically between -10.0 m bgl and -23.5 m bgl. A number of seeps appear to have increased to a rating of flowing during the winter months and even started flowing just prior to and during the Mary Burn Fill canal remediation works. While there appears to be no direct obvious effect on seep ratings from specific rainfall events, the seep ratings do display seasonal fluctuations suggesting an indirect effect. The remediation works along the Mary Burn Fill canal section do not appear to have had an obvious effect on the inspection ratings of the Mary Burn Fill seeps.

4.3.1 Weir measurements

The flow rates of weirs monitored along the SH8 and Mary Burn Fill canal sections are shown in Figure 7, Appendix A. During the most recent monitoring period, flow rates in all five monitored weirs remained consistently below 5 litres per minute (L/min) with the exception of TKBWRLBM which had a maximum flow rate of 10 L/min on 18 July 2014. A spike in flow at weir TKBWELBM on the SH8 canal section of 5 L/min occurred on 17 December 2014.

The June 2013 monitoring report identified that rainfall events affected flows in weirs along the SH8 canal section. However, since the remedial works in the 8.17 km Culvert and SH8 canal sections, the influence of rainfall on the flows in these weirs is not as obvious, although some small spikes in flow in both TKBWRLBM and TKBWELBM may potentially be related to rainfall events. This also may be related to manual measurements of flow in each weir only being recorded monthly since the remediation works were completed and not daily as during the periods of remediation works on each canal section. Weir TKBWRRTM on the SH8 canal section had no flow throughout the entire monitoring period. Flow at weir TKBD174 on the Mary Burn Fill canal section remained relatively stable around 3 L/min during the most recent monitoring period. Flow in this weir does not appear to be directly affected by large rainfall events, although during the period of low rainfall over the 2014/2015 summer, flow at this weir declined to 1 L/min on 20 February 2015 before increasing back to its base flow of around 3 L/min for the remainder of the monitoring period.

Flow rates in the SH8 canal section weirs have been significantly reduced as a result of the remedial works in this section of the canal. However, adjacent groundwater and surface water levels which received flow from the SH8 weirs prior to the remediation works do not appear to have been adversely affected by the reduction of flow from these weirs. The flow rate in weir TKBD174 on the Mary Burn Fill canal section does not appear to have been affected by any of the remedial works along the Tekapo Canal, and based on the drop in flow during the period of low rainfall over the 2014/2015 summer flow in this weir may be influenced by precipitation in the area.

4.3.1 Stream flow gauging

Table 2 below displays the most recent gauging results made during the most recent monitoring period in October 2014 and March 2015 as well as previous flow measurements since monitoring along the Tekapo Canal began in October 2012. Photos of flow gauging the Mary Burn downstream site during October 2014 and March 2015 are provided in Appendix A.

Table 2: Stream flow gauging results (all flows m^3/s)

Date	SH8EUS	SH8EDS	IRISHUS	IRISHDS	MBUS	MBDS
3/10/2012	*0.204*	*0.153*	*2.345*	*2.531*	-	-
15/10/2012	*0.523**	*0.546**	*Too high**	*Too high**	-	-
16/10/2012	-	-	*Too high**	*Too high**	*1.881**	*2.534**
4/12/2013	*0.110*	*0.113*	*1.195*	*1.153*	*0.624*	*0.566*
10/05/2013	*0.019*	*0.009*	*0.742*	*0.812*	*0.289*	*0.242*
17/01/2014	*0.039*	*0.038*	*0.736*	*0.789*	*0.350*	*0.391*
8/10/2014	-	-	-	-	0.529	0.596
30/04/2015	-	-	-	-	0.237	0.276

Notes: Measurements in italics indicates flows measured during previous monitoring periods (October 2012 through to May 2014). * denotes stream in flood

Flow rate measurements during the most recent monitoring period between May 2014 and April 2015 were only undertaken in the Mary Burn as the downstream sites on the unnamed stream east of SH8 and Irishman Creek were unable to be accessed during the most recent monitoring period.

Generally speaking, the flow rates between the upstream and downstream gauging sites for each stream do not appear to be consistent in terms of having a greater flow on one particular side of the canal since gauging began in October 2012. Based on the flow gauging measurements undertaken so far, there does not appear to be a clear pattern that the three streams are gaining significant quantities of water from the canal across each culvert. Any changes in flow across the canal appear to be small and based on the continued variations in flow between the upstream and downstream gauging sites, any effect related to leakage from the canal is assumed to be negligible.

5.0 Environmental effects arising from remedial works

The purpose of this monitoring report is to describe the monitoring undertaken after the Tekapo Canal remediation works to determine if there have been any

changes on groundwater and surface water levels from the remediation works along the SH8 and Mary Burn Fill canal sections.

Water levels in the majority of the monitoring wells and ponds appear to be predominantly influenced by large rainfall events and display seasonal fluctuations with water levels generally being higher during the winter months and lowest during the summer months. The majority of the monitoring wells and ponds display stable long term trends. Seeps and weirs along the SH8 canal section appear to have been affected by the remedial works on this section of canal as the flow of water to each of the monitored seeps and weirs has been reduced. Seeps and weirs along the Mary Burn Fill canal section do not appear to have been affected by any remedial works along the Tekapo Canal. Seeps along both the SH8 and Mary Burn Fill canal sections appear to display seasonal fluctuations with higher ratings during the wetter winter months and lower ratings during the drier summer months. A period of low rainfall during the 2014/2015 summer appears to have caused water levels in a number of monitoring bores, surface water bodies and flows in weirs to be reduced.

In regard to the effect of leakage from the canal altering the natural groundwater and surface water levels in proximity to the remediated sections of the canal, any effect appears to be minor compared to the much larger natural variations. From the monitoring data, it appears that leakage from the canal has potentially reduced water flow to some of the seeps and weirs along canal. However, the receiving environments (i.e. surface water ways and the groundwater table) do not appear to have been affected. This suggests that the contribution that the canal leakage makes to groundwater and surface water levels are small compared to the much larger natural variability that occurs (i.e. declining water levels due to low rainfall over the 2014/2015 summer).

Schedule One – General Conditions states that groundwater and surface water monitoring of the Tekapo canal shall:

"*cease 12 months after the installation of the final section of the supplementary PVC liner in the Tekapo Canal.*"

As the remediation works and installation of the final section of PVC liner in the Tekapo Canal was completed along the Mary Burn Fill canal section on 26 February 2014, more than 12 months of monitoring has been completed. In addition to this monitoring along the SH8 canal section was continued for a further 24 months after the remediation works and liner installation was completed along this section of canal. Therefore it is proposed that monitoring along the SH8 canal section and Mary Burn Fill canal sections for the purposes outlined in the GWSMP (PDP, 2012) and Schedule One - General Conditions should cease.

6.0 References

Pattle Delamore Partners. 2012. *Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works*. Prepared for Genesis Energy Ltd.

Pattle Delamore Partners. 2013. *Annual Report on Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works*. Prepared for Genesis Energy Ltd.

Pattle Delamore Partners. 2014. *Annual Report on Groundwater and Surface Water Monitoring Programme for Tekapo Canal Remedial Works*. Prepared for Genesis Energy Ltd.

Appendix A: Figures



Figure 1: Remediated sections of the Tekapo Canal

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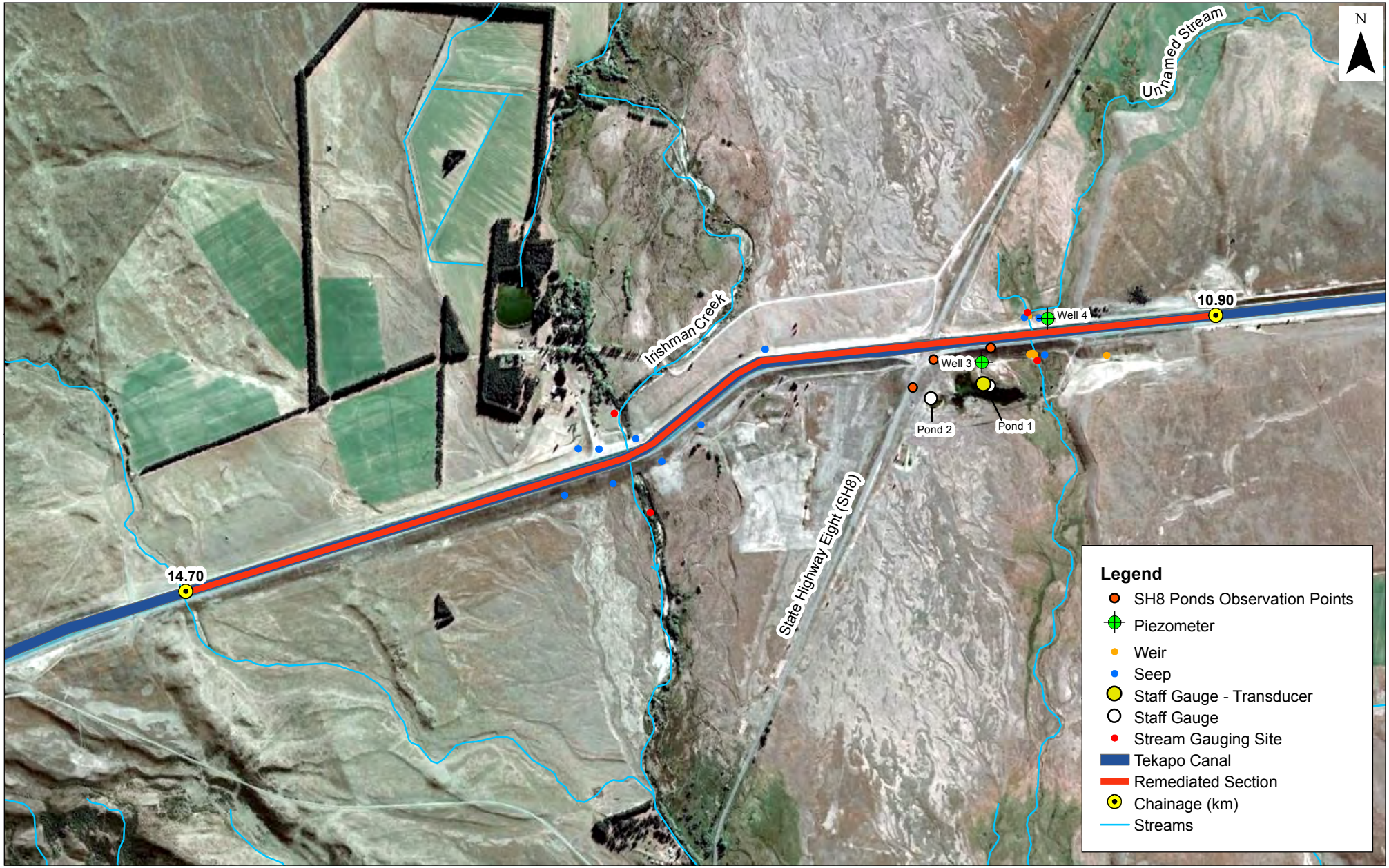


Figure 2a: Locations of monitoring points along SH8 canal section

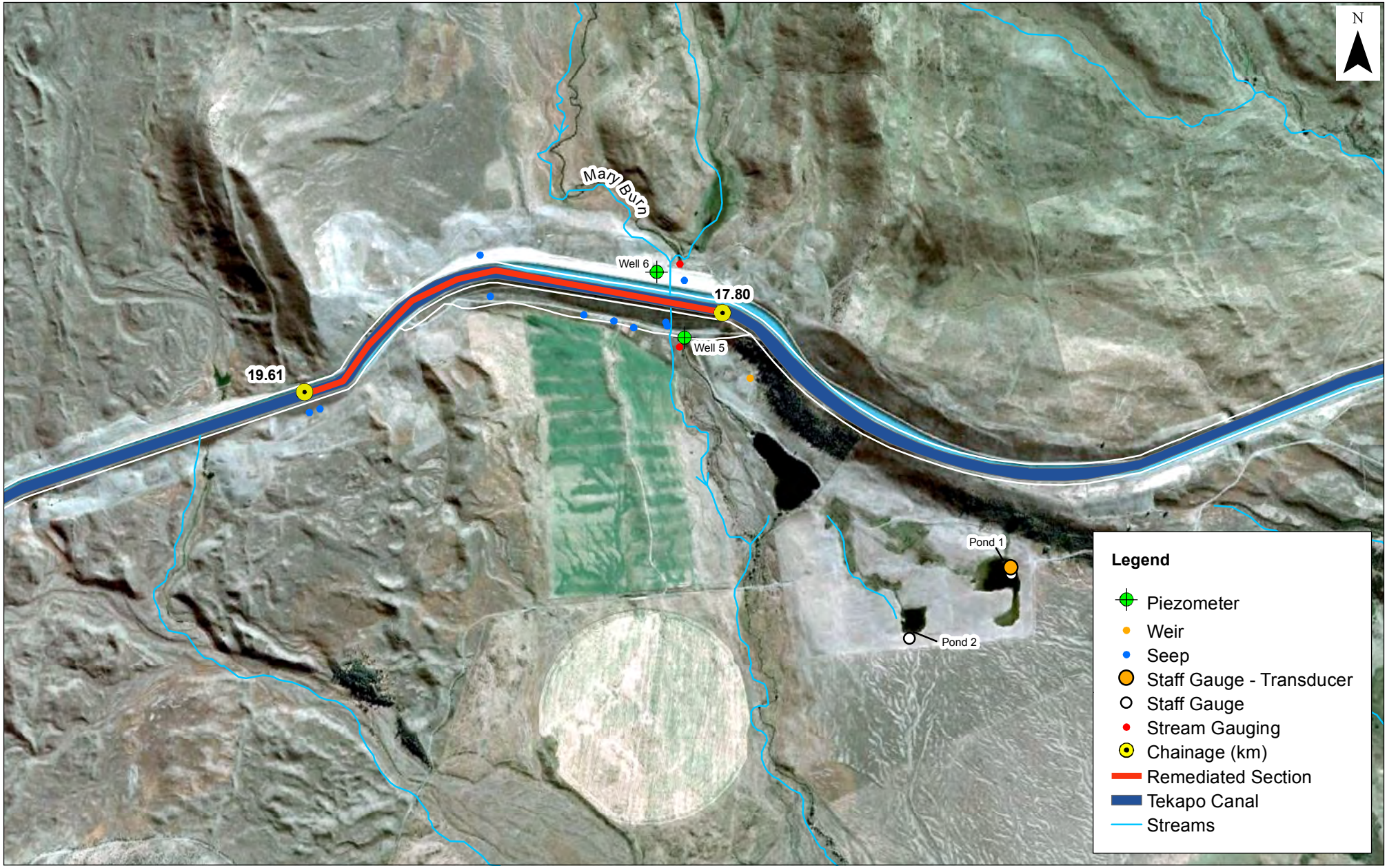


Figure 2b: Locations of monitoring points at Mary Burn Fill canal section

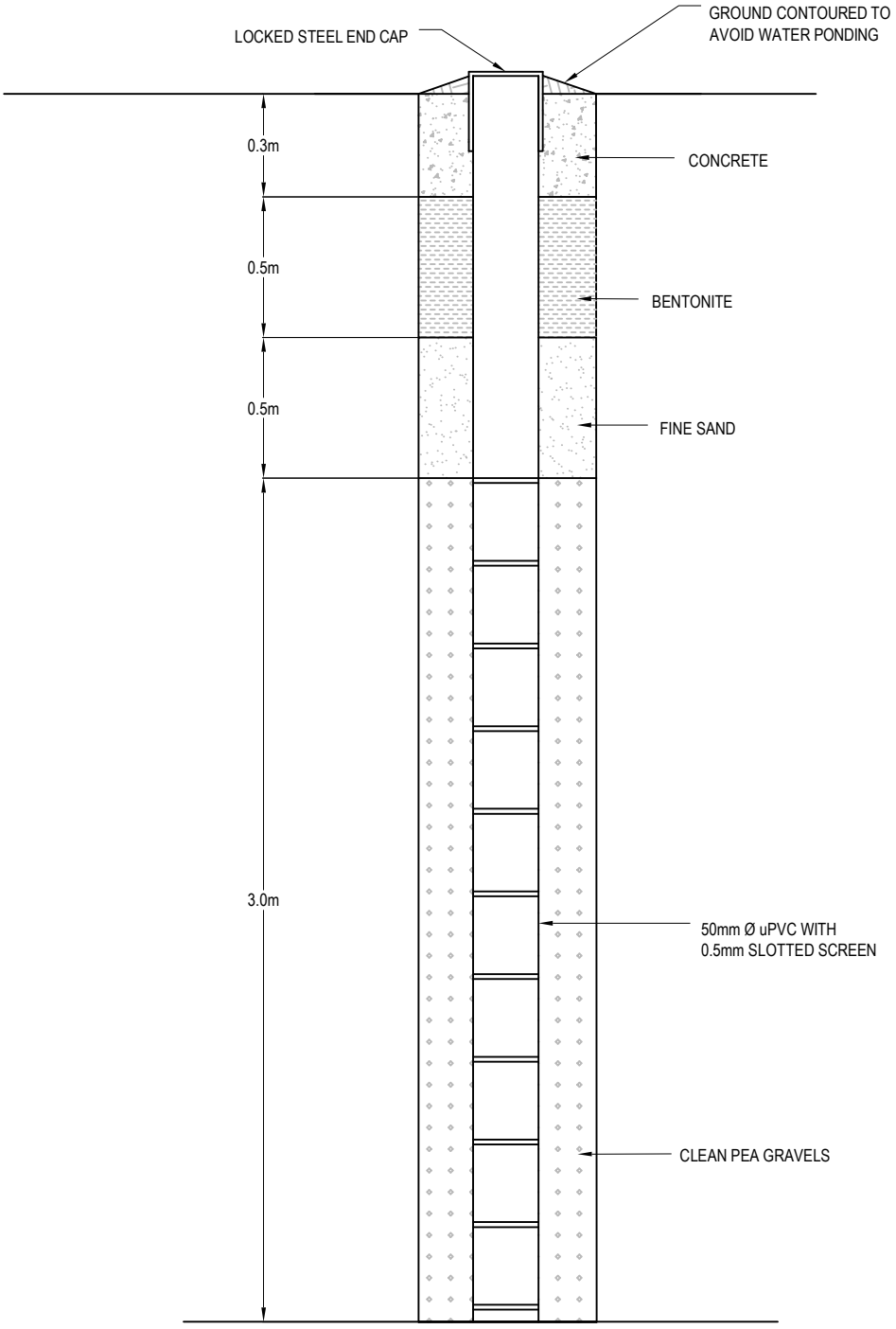


FIGURE 3 : SCHEMATIC DIAGRAM OF PIEZOMETER INSTALLATION (NOT TO SCALE)

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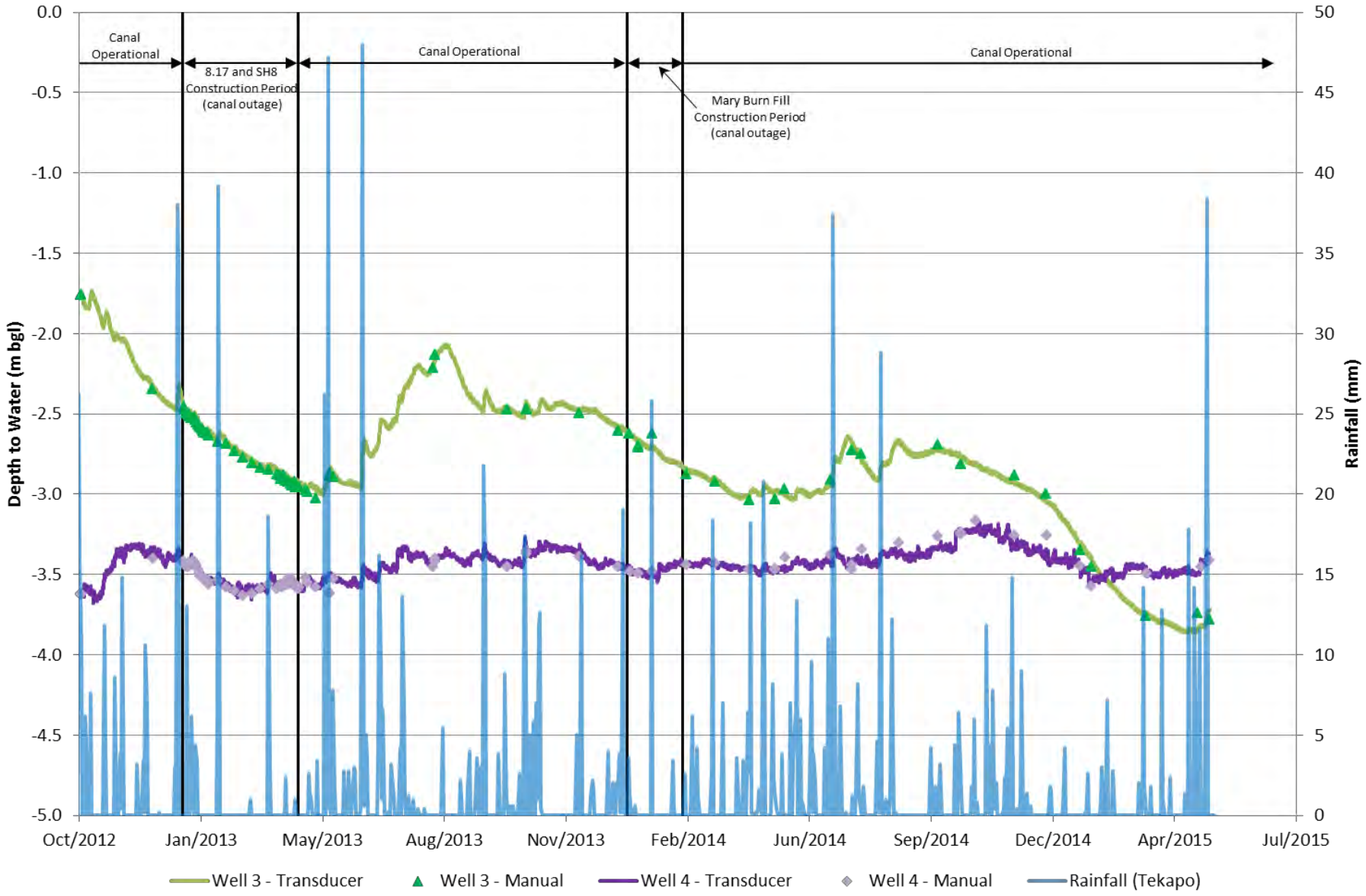


Figure 4a: Groundwater levels in Wells 3 and 4 at SH8 canal section and rainfall records since monitoring began in October 2012

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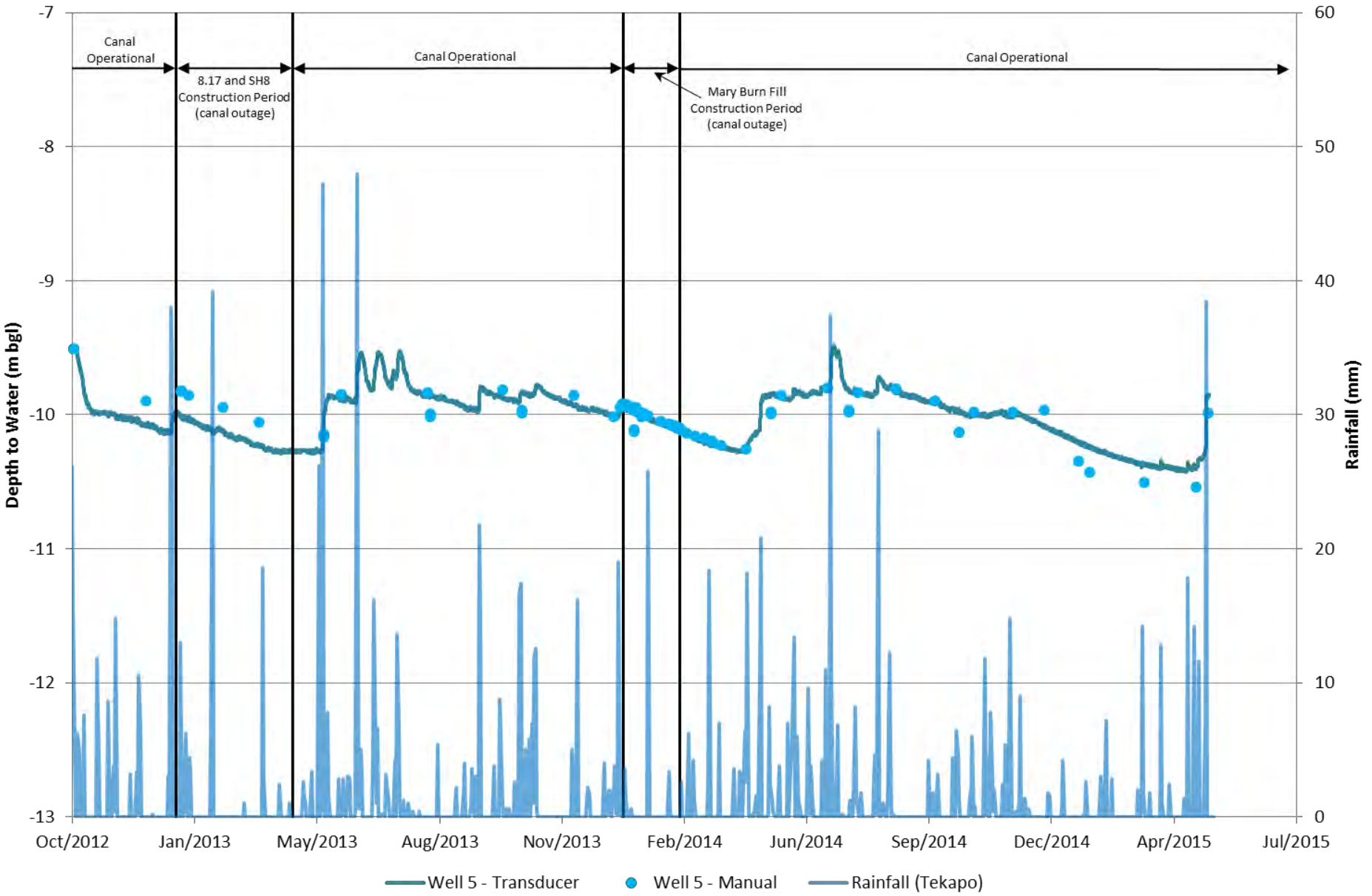


Figure 4b: Groundwater levels in Well 5 at Mary Burn Fill canal section and rainfall records since monitoring began in October 2012

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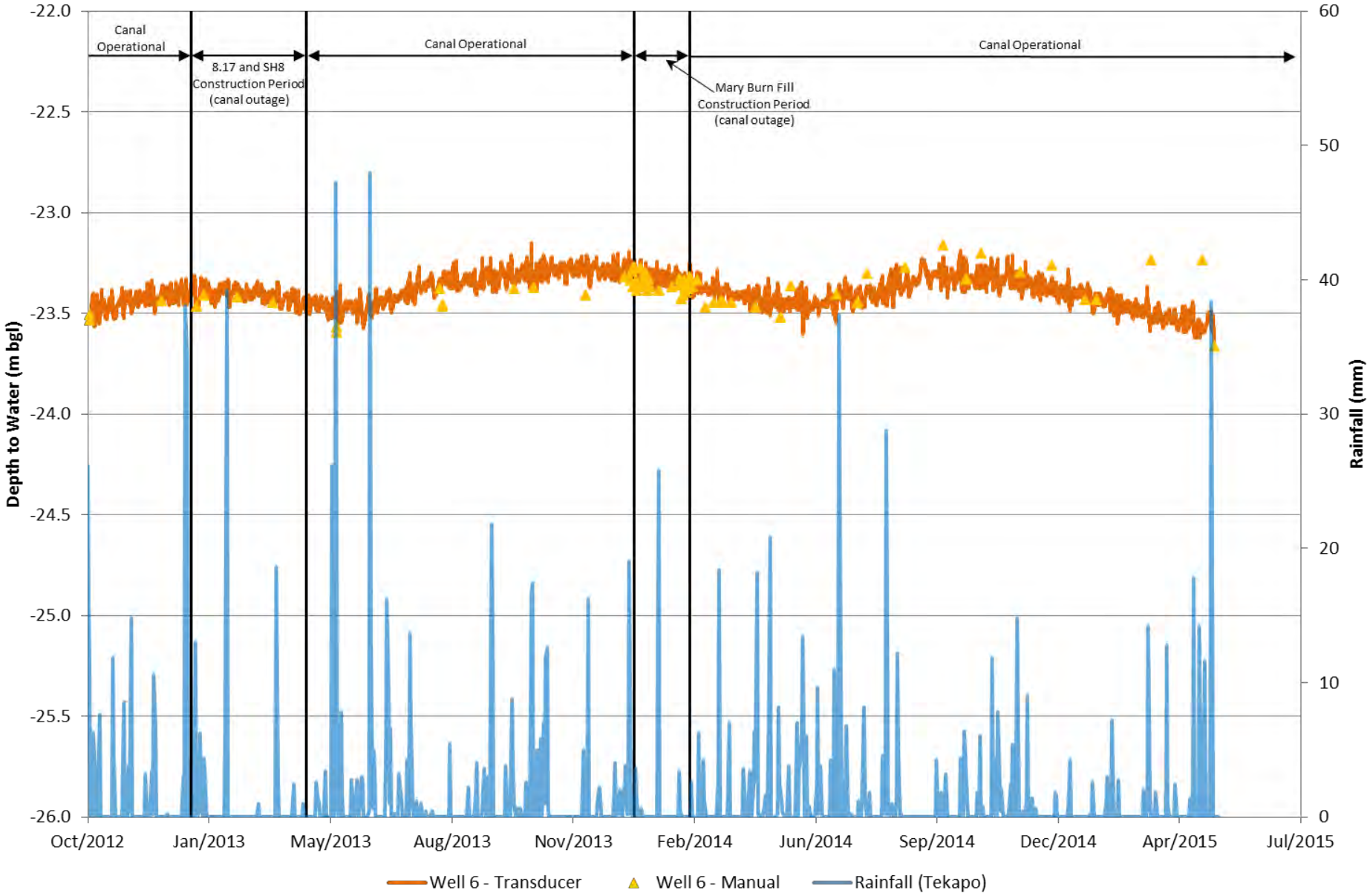


Figure 4c: Groundwater levels in Well 6 at Mary Burn Fill canal section and rainfall records since monitoring began in October 2012

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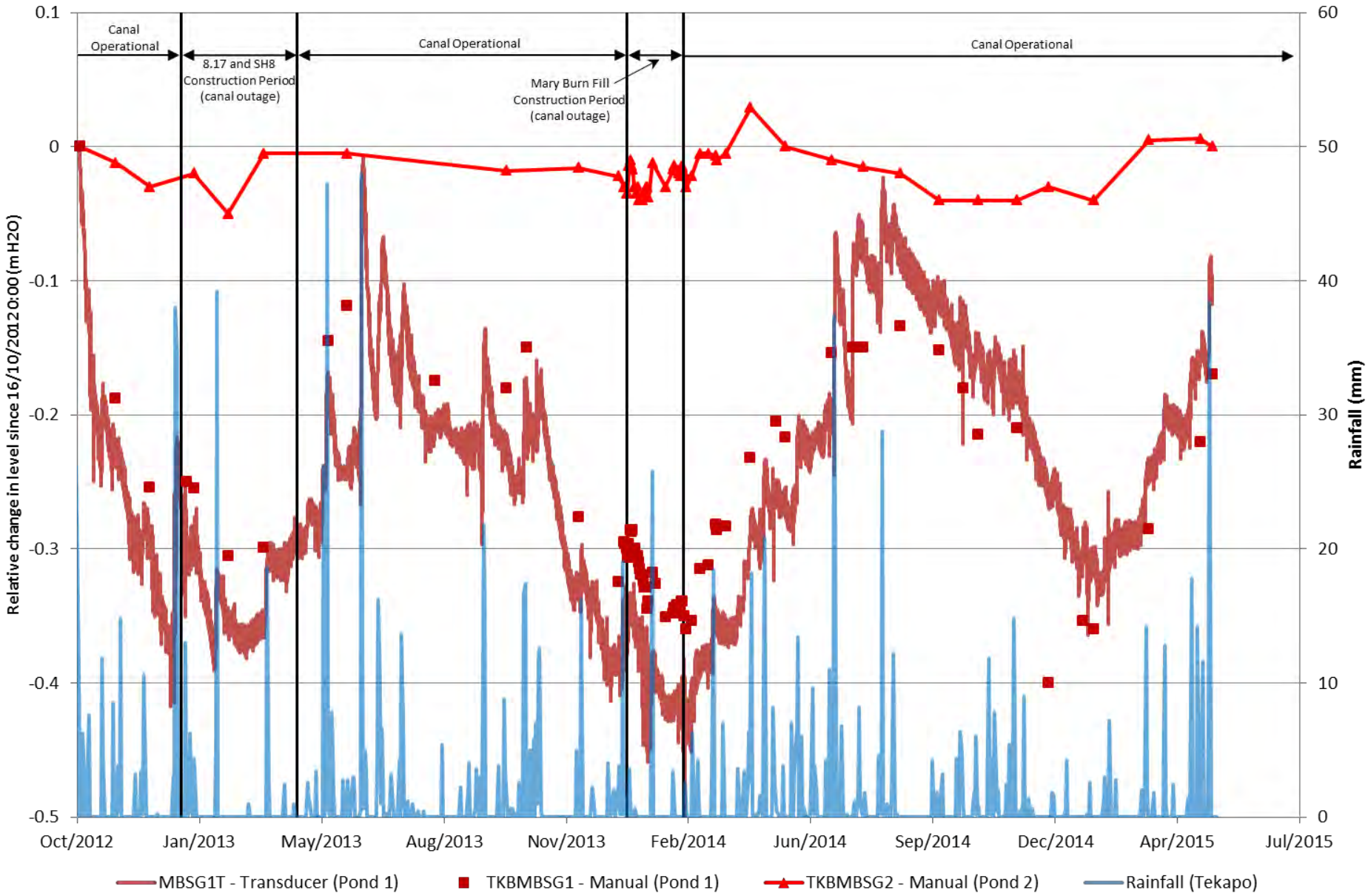


Figure 5a: Pond water levels in Mary Burn Fill canal section ponds and rainfall records since monitoring began in October 2012

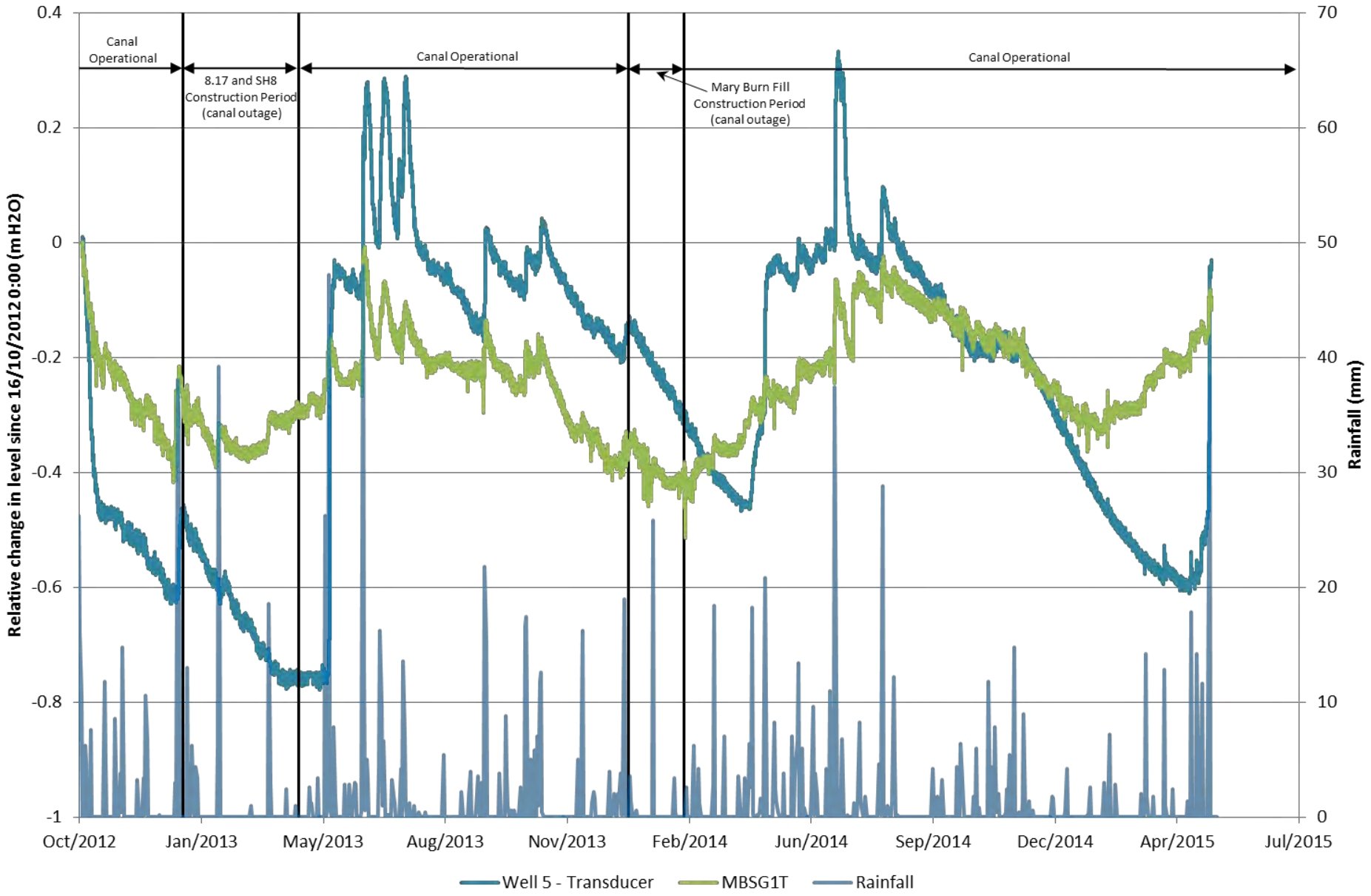


Figure 5b: Change in water levels in Well 5 and pond 1 along the Mary Burn Fill canal section and rainfall records since monitoring began in October 2012

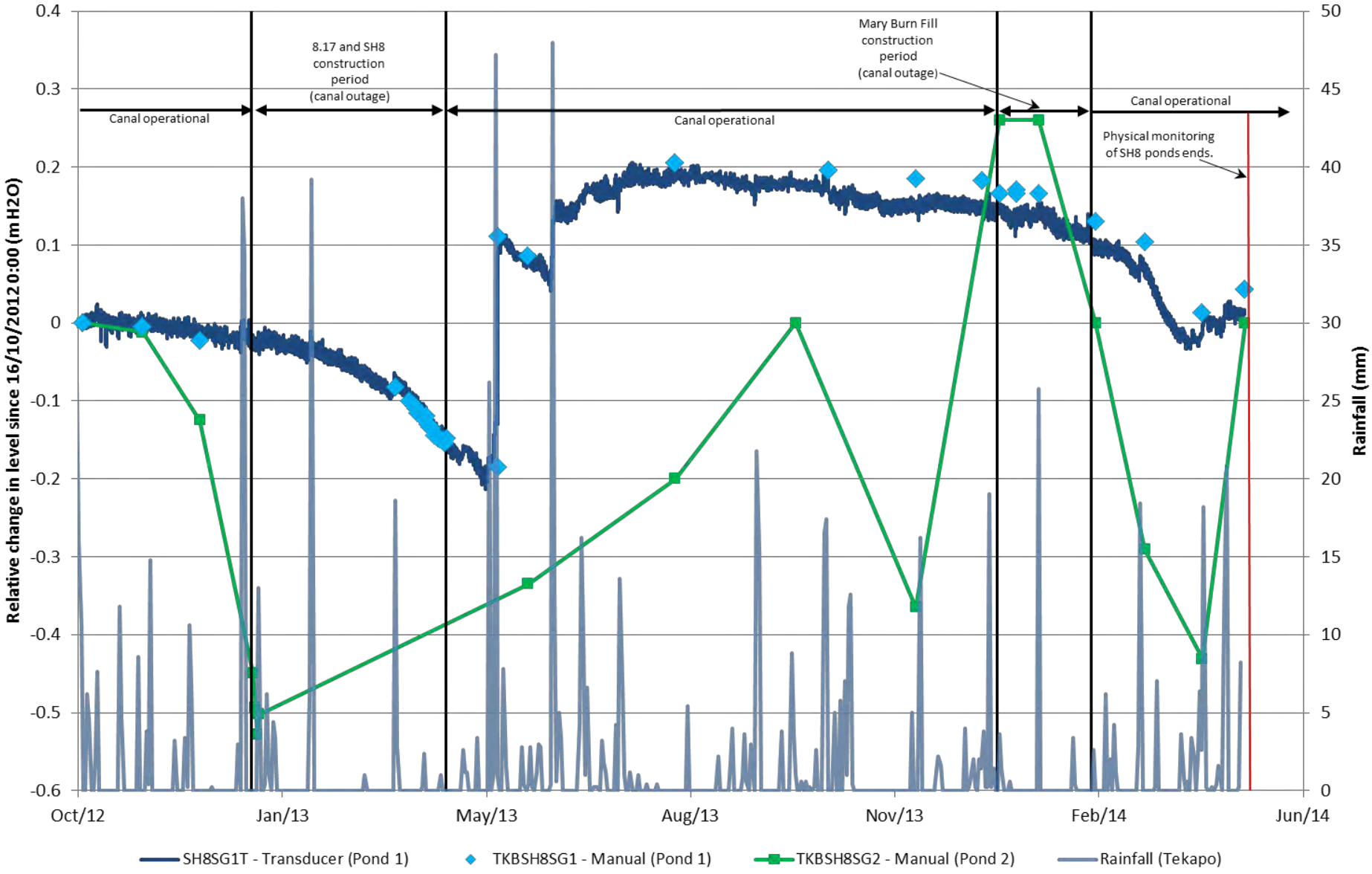


Figure 5c: Pond water levels in SH8 canal section ponds and rainfall records between monitoring October 2012 and June 2014 before physical monitoring in the SH8 ponds ceased



July 2014



November 2014



January 2015



March 2015



April 2015



May 2015

Figure 5d: Summary of photographic surveys of the SH8 ponds between May 2014 and May 2015

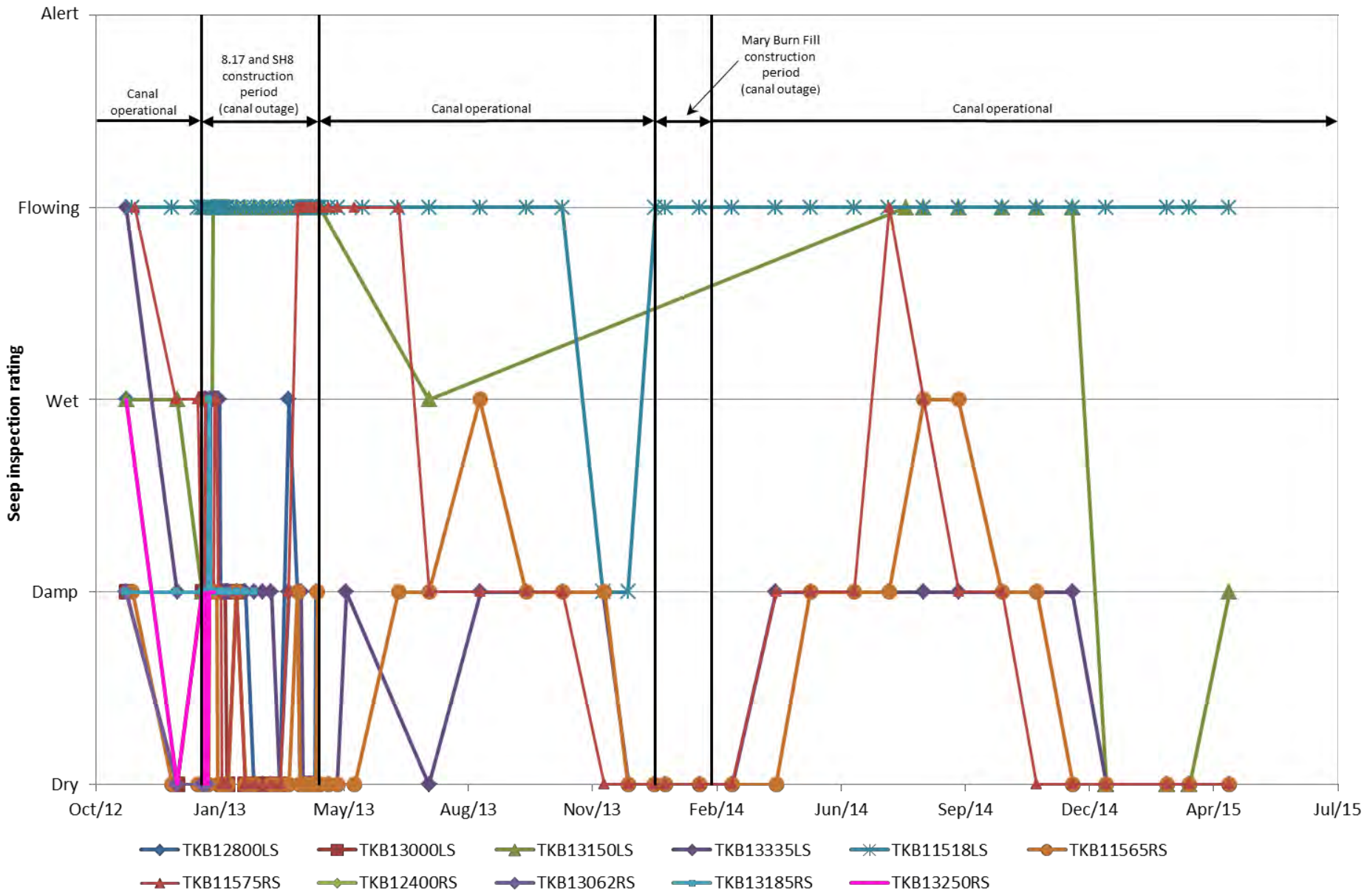


Figure 6a: Inspection ratings for seeps along the SH8 Canal section since monitoring of the seeps began in November 2012

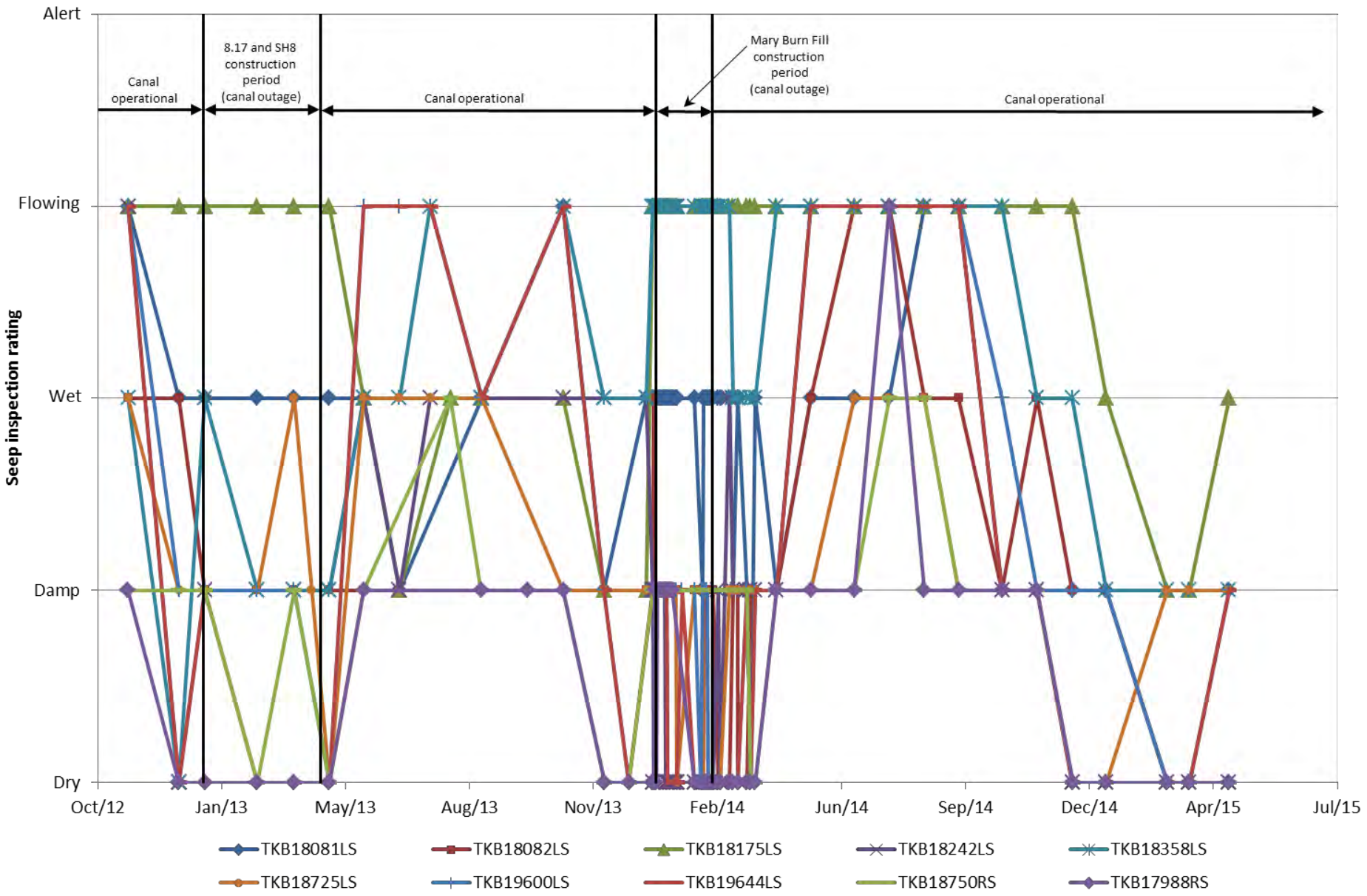


Figure 6b: Inspection ratings for seeps along the Mary Burn Fill canal section since monitoring of the seeps began in November 2012

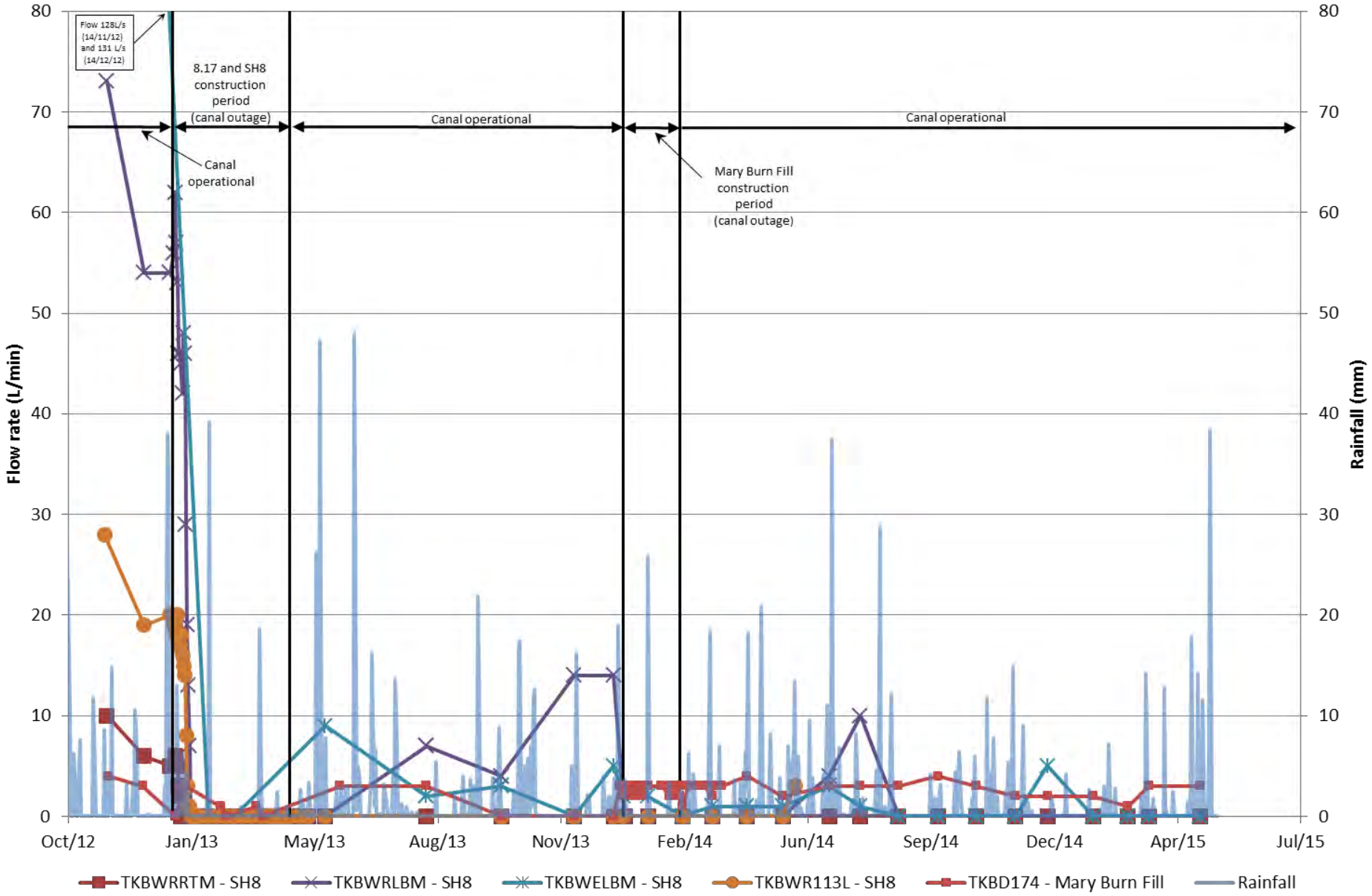


Figure 7: Flow rates of all weirs along SH8 and Mary Burn Fill canal sections with rainfall since monitoring of the weirs began in November 2012



8 October 2014



30 March 2015

Figure 8: Photos of the downstream flow gauging site on the Mary Burn for the monitoring period between May 2014 and April 2015

Appendix B: List of Monitoring Sites

Canal section	Site name	Easting (NZTM)	Northing (NZTM)	Type	Status during monitoring period May 2014 - April 2015
8.17	TKB08170LC	1392232	5117216	Culvert inspection (downstream)	Not monitored
8.17	TKB08170RC	1392297	5117379	Culvert inspection (upstream)	Not monitored
8.17	TKBWR817L	1392242	5117245	Weir	Removed
8.17	TKBOP401	1392307	5117272	Monitoring Well (Well 1)	Not monitored
8.17	TKBOP411	1392361	5117388	Monitoring Well (Well 2)	Not monitored
SH8	TKBSH8SG1	1388742	5116770	Staff Gauge	Removed
SH8	SH8SG1T	1388708	5116778	Transducer - Pond 1	Removed
SH8	TKBSH8SG2	1388548	5116726	Staff Gauge	Removed
SH8	Point 1	1388760	5116904	Visual Observation of SH8 ponds (photograph)	Unaltered
SH8	Point 2	1388552	5116870	Visual Observation of SH8 ponds (photograph)	Unaltered
SH8	Point 3	1388473	5116769	Visual Observation of SH8 ponds (photograph)	Unaltered
SH8	TKB11518LS	1388951	5116880	Seep	Unaltered
SH8	TKB11565RS	1388931	5117011	Seep	Unaltered
SH8	TKB11575RS	1388879	5117012	Seep	Unaltered
SH8	TKB12400RS	1387960	5116899	Seep	Not monitored
SH8	TKB12800LS	1387733	5116632	Seep	Not monitored
SH8	TKB13000LS	1387594	5116502	Seep	Not monitored
SH8	TKB13062RS	1387502	5116584	Seep	Not monitored
SH8	TKB13150LS	1387422	5116423	Seep	Reinstated
SH8	TKB13185RS	1387372	5116546	Seep	Not monitored
SH8	TKB13250RS	1387298	5116547	Seep	Not monitored
SH8	TKB13335LS	1387249	5116381	Seep	Unaltered
SH8	TKBD118	1388898	5116881	Weir	Removed
SH8	TKBWELB	1388909	5116886	Weir	Unaltered
SH8	TKBWR113L	1389170	5116878	Weir	Not Monitored after June 2014
SH8	TKBWRLBM	1388900	5116884	Weir	Unaltered
SH8	TKBWRRTM	1388893	5117018	Weir	Unaltered
SH8	TKBOP421	1388729	5116854	Monitoring Well (Well 3)	Unaltered
SH8	TKBOP431	1388961	5117010	Monitoring Well (Well 4)	Unaltered
SH8	SH8EUS	1388889	5117030	Flow Gauging Site - Stream East of SH8	Not monitored
SH8	SH8EDS	1388924	5116860	Flow Gauging Site - Stream East of SH8	Not monitored
SH8	IRISHUS	1387427	5116673	Flow Gauging Site - Irishman Creek	Not monitored
SH8	IRISHDS	1387554	5116320	Flow Gauging Site - Irishman Creek	Not monitored
Maryburn Fill	TKBMBSG1	1384195	5115160	Staff Gauge	Unaltered
Maryburn Fill	MBSG1T	1384195	5115160	Transducer - Pond 1	Unaltered
Maryburn Fill	TKBMBSG2	1383805	5114914	Staff Gauge	Unaltered
Maryburn Fill	TKB17988RS	1382940	5116288	Seep	Unaltered
Maryburn Fill	TKB18081LS	1382870	5116127	Seep	Unaltered
Maryburn Fill	TKB18082LS	1382875	5116113	Seep	Unaltered
Maryburn Fill	TKB18175LS	1382746	5116106	Seep	Unaltered
Maryburn Fill	TKB18242LS	1382669	5116131	Seep	Unaltered
Maryburn Fill	TKB18358LS	1382554	5116156	Seep	Unaltered
Maryburn Fill	TKB18725LS	1382196	5116227	Seep	Unaltered
Maryburn Fill	TKB18750RS	1382156	5116384	Seep	Unaltered
Maryburn Fill	TKB19600LS	1381542	5115795	Seep	Unaltered
Maryburn Fill	TKB19644LS	1381502	5115781	Seep	Unaltered
Maryburn Fill	TKBD174	1383192	5115912	Weir	Unaltered
Maryburn Fill	Well5	1382940	5116070	Monitoring Well (Well 5)	Unaltered
Maryburn Fill	Well6	1382834	5116321	Monitoring Well (Well 6)	Unaltered
Maryburn Fill	MBUS	1382885	5116350	Flow Gauging Site - Mary Burn	Unaltered
Maryburn Fill	MBDS	1382889	5116032	Flow Gauging Site - Mary Burn	Unaltered

Appendix C: Borelogs

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Canal
E2298695, N5678489

HOLE No. 3

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 5.67 | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 5.7 (m).

Driller: Neil | SHIFT START DATE: 3/10/12 TIME: | SHIFT FINISH DATE: 3/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
		5.67	0	5.67	Dual rotary 150mm	Clay Bound gravels	Swl 2.10m		
		0.4	0	.4		Cement			1 Bag
		0.72	0.4	1.12		Backfill			
		0.48	1.12	1.6		~~fine Sand~~ Bentonite			1 Bag
		0.52	1.6	2.12		~~Sand~~ fine Sand			
		3.55	2.12	5.67		Sand			6 1/2 Bag

INSTALLATIONS | CASING: from 0 to 2.67 (m). Diameter: 50mm Comments: pvc

SCREEN: from 2.67 to 5.67 (m). Diameter: 50mm Comments: pvc

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: E2298924, N5678648 Tekapo Canal

HOLE No. Hole 4

Drill Rig Type: DR24

DRILLING LOG | Length of hole: 6.48m | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 6.5 (m).

Driller: Neil | SHIFT START DATE: 2/10/12 TIME: | SHIFT FINISH DATE: 2/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
		0.30	0	0.3	Dual rotary 6"	Top Soil			
		3.2	0.3	3.5	" "	Brown Silty Clay Bound Gravel			
		3.00	3.5	6.5	" "	Clay Bound Gravel yellow	SWL 3.54		
			0	.3	~~Geotube~~	Cement			1 Bag
			0.3	1.8		Backfill			
			1.8	2.5		Bentonite			1 Bag
			2.5	3.05		fine Sand			5 Bags
			3.05	6.48		Sand			

INSTALLATIONS | CASING: from 0 to 3.50 (m). Diameter: Comments: pvc

SCREEN: from 6.48 to 3.50 (m). Diameter: 50mm Comments: pvc

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: te Kapo corner
E2292907 N5677707

HOLE No. 5

Drill Rig Type: ORZ4

DRILLING LOG | Length of hole: 10.96m | Inclination: | Bearing: | Sheet 1 of 1

INSPECTOR | TYPE: Open holing from to (m). Tubexing from to (m). Rotary from 0 to 10.96(m).

Driller: Neil Simmons | SHIFT START DATE: | TIME: | SHIFT FINISH DATE: | TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	10.96	Down Rotary 150mm	Clay Bound Gravel			WL 9.85m
		0.3	0	0.3		Cement			1 Bag
		6.08	0.3	6.38		Backfill			
		0.58	6.38	6.96		Bentonite			1 Bag
		0.45	6.96	7.41		Fine Sand			
		3.57	7.41	10.98		Sand			5½ Bags

INSTALLATIONS | CASING: from 0 to 7.96 (m). Diameter: 50mm PVC Comments:

SCREEN: from 7.96 to 10.96 (m). Diameter: 50mm PVC Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

McNEILL DRILLING CO. LTD

LOCATION: Tekapo Corner E2292801 N5677958

HOLE No. 6

Drill Rig Type: DR24

DRILLING LOG

INSPECTOR

Driller: Neil / Simmons

Length of hole: 26.83 Inclination: Bearing:

TYPE: Open holing from 15 to 26.83 (m). Tubexing from to (m). Rotary from 0 to 15 (m).

Sheet 1 of 1

SHIFT START DATE: 5/10/12 TIME: SHIFT FINISH DATE: 5/10/12 TIME:

TIME Start	TIME Finish	RUN LENGTH	INTERVAL From	INTERVAL To	Drilling Method/ Hole Diameter	DESCRIPTION: Hardness, material, colour	Water Pressure (kPa)	Water Flow (l/time)	COMMENTS Breakdowns etc
			0	8.5	Down / rotary 150mm	large fill (Boulders)			
			8.5	14	"	Clay Bound Gravel			
			14	17.1	"	Boulder			
			17.1	19.3	"	Clay Bound Gravel			
			19.3	24	"	Sand			
			24	26.9	"	Very Sand Gravel			
									WL 24.46m
			0	0.3		Cement			1 Bag
			0.3	22.4		Backfill			
			22.4	22.9		Bentonite			1 Bag
			22.9	23.38		fine Sand			
			23.38	26.83		Sand			6 1/2 Bag

INSTALLATIONS

CASING: from 0 to 23.83 (m). Diameter: 50mm pvc Comments:

SCREEN: from 23.83 to 26.83 (m). Diameter: 50mm pvc Comments:

TESTING (packer/permeability/flow rate): see test sheets for data

Appendix D: Schedule One – General Conditions

SCHEDULE ONE – GENERAL CONDITIONS

CONDITIONS ATTACHED TO RESOURCE CONSENTS:
CRC122392, CRC122393, CRC122394, CRC122395, CRC122396, CRC122397, CRC122398, CRC122399, CRC122400, CRC122401, CRC122402, CRC122403, CRC122404, CRC122405, CRC122406, CRC122407, CRC122409, CRC122410 and CRC122411;
ISSUED BY THE CANTERBURY REGIONAL COUNCIL (CRC)

GENERAL

1) Unless otherwise stated where information is to be provided to CRC it shall be sent to the CRC Attention: Regional Manager RMA Monitoring and Compliance.

2) In each year these resource consents are exercised the consent holder shall provide CRC with an updated schedule of all construction activities at least every three months, and notify CRC if there are any changes.

3) Prior to the commencement of the construction season, in each year that these resource consents are to be exercised, the consent holder shall arrange and conduct a pre-construction site meeting between a CRC representative and all relevant parties, including the primary contractor. At a minimum, the following shall be covered at the meeting:

   a) Scheduling and staging of works;

   b) Responsibilities of all relevant parties;

   c) Contact details for all relevant parties;

   d) Expectations regarding communication between all relevant parties;

   e) Procedures for implementing any amendments;

   f) Site inspection;

   g) Maintenance of storm water, erosion and sediment control measures;

   h) Confirmation that all relevant parties have copies of the contents of this consent document and all associated management plans; and

   i) The management plans, or subsequent revisions allowed for in Condition 9.

4) Prior to the commencement of each construction season the consent holder shall provide written notification of the works commencing on the site to CRC, at least five working days prior to works commencing.

5) When undertaking the activities authorised by these resource consents, all practicable steps shall be undertaken to minimise adverse effects on property, wildlife, biodiversity values, aquatic ecosystems, vegetation, cultural and amenity values.

6) If the consent holder ceases work on-site for a period of seven consecutive or more days, they shall first take adequate preventive and remedial measures to control sediment discharges, and shall thereafter maintain those measures for as long as necessary to prevent sediment discharges from the site.

7) Notwithstanding Conditions 4, 11, 13, 14, 25 and 29 preliminary earthworks, vegetation clearance and the establishment of buildings associated with the development of the Construction Management Site may commence immediately following the commencement of these resource consents. These preliminary works shall be undertaken in accordance with all other relevant consent conditions. An Environmental Management Plan ("**EMP**") and supplementary environmental management plans ("**SEMP**") relevant to these preliminary works shall be submitted to CRC as soon as practicable after site preparation work commences, but no later than 15 working days thereafter.

MANAGEMENT PLANS

8) All management plans submitted in accordance with Schedule One shall address all the relevant matters identified within this schedule and demonstrate compliance with the relevant consent conditions.

9) The management plans may be amended at any time. Any amendments shall be:

   (a) Consistent with the conditions of these resource consents; and

   (b) Submitted in writing to CRC, as soon as practicable.

10) The preparation, and amendment, of a management plan shall be undertaken by a person or persons with a relevant tertiary qualification and at least five years relevant experience or a person who CRC deem to be appropriately qualified.

ENVIRONMENTAL MANAGEMENT PLAN

11) At least 20 working days prior to the commencement of any construction works, the consent holder shall submit an EMP to CRC.

12) The EMP shall be an umbrella document that identifies the management processes and techniques to ensure appropriate environmental management of the site and works.

SUPPLEMENTARY ENVIRONMENTAL MANAGEMENT PLANS

13) At least 20 working days prior to the commencement of construction works, the consent holder shall submit the following SEMP to CRC:

   (a) Canal Water Quality Management Plan

   (b) Storm Water, Sediment and Erosion Control Management Plan;

   (c) Dust Management Plan;

   (d) Rehabilitation Management Plan;

   (e) Contaminant Spill Contingency Plan; and

(f) Fish Salvage Management Plan.

14) All works shall be undertaken in accordance with the approved SEMP listed in Condition 13.

Canal Water Quality Management Plan

15)

a) At least 40 working days prior to the commencement of construction works, the consent holder shall undertake a one-off background monitoring of bed sediment quality at several sites in the canal to determine the proportion of organic material present in sediment upstream and downstream of the salmon farm operated by Mount Cook Alpine Salmon Limited and to assess the potential effect that organic material in the sediment will have on oxygen levels in the canal water when flows cease.

b) The results of the monitoring undertaken as part of Condition (15)(a) above shall be provided to the CRC within five working days of them becoming available.

c) The consent holder shall prepare, submit and implement a Canal Water Quality Management Plan ("**CWQMP**"). The frequency and location of the monitoring and the extent of the management responses required under the CWQMP shall be established based on the results of the monitoring undertaken as part of Condition (15)(a) above. In addition, the CWQMP shall address, but not necessarily be limited to, the following matters:

i) A water quality monitoring program which shall measure water temperature and dissolved oxygen levels in the Tekapo Canal while the flow in the canal is halted. Measurements shall be taken at a depth of 1 metre and a depth of 5 metres.

ii) The response the consent holder shall undertake to:

(a) Report on thermal stratification in the canal water if temperature monitoring shows a difference greater than 2°C between water at 1 metre depth and water at 5 metres depth; and / or;
(b) Increase dissolved oxygen levels in canal water to above 80 percent saturation.

iii) The management actions to be carried out when:

(a) The difference in water temperature between canal water at 1 metre depth and 5 metres depth exceeds 2°C, and/or:
(b) Dissolved oxygen levels in the canal water decrease to, or below, 50 percent saturation.

iv) The consent holder shall keep records of all water quality information recorded and shall submit the record annually to the CRC.

v) Should the actions detailed in Condition (15)(c)(iii) need to be carried out, the consent holder shall notify the CRC within 5 working days.

Storm Water, Sediment and Erosion Control Management Plan

16) The consent holder shall prepare, submit and implement a Storm Water, Sediment and Erosion Control Management Plan ("**SSECMP**"). The SSECMP shall be prepared in accordance with the Canterbury Regional Council's "Erosion and Sediment Control Guidelines for the Canterbury Region" Report No. CRC R06/23, February 2007 ("**ESCG**"). The SSECMP shall ensure that all discharges to water courses do not exceed total suspended solids of greater than 100 grams per cubic metre. The SSECMP shall address, but not necessarily be limited to, the following matters:

a) A map showing the location of all works;

b) Detailed plans showing the location of sediment control measures, on-site catchment boundaries, and sources of runoff;

c) Drawings and specifications of designated sediment control measures;

d) Details of any sediment Flocculent/Coagulant use including but not limited to:
   (i) Methodology for choosing a suitable flocculent/coagulant.
   (ii) Details of how the flocculent/coagulant will be applied including how the optimal dosage will be calculated, and manufactures instructions are complied with,
   (iii) Details of how it will be determined that the use of a flocculent/coagulant is necessary.
   (iv) Monitoring.

e) A programme of works, which includes but is not limited to, a proposed timeframe for the works; and

f) Details of the inspections and maintenance for the erosion and sediment control measures, including monitoring of total suspended solids in discharges to water.

g) Timing and methodology of decommissioning works.

Dust Management Plan

17) The consent holder shall prepare, submit and implement a Dust Management Plan ("**DMP**"). The DMP shall, address, but not necessarily be limited to, the following matters:

a) A record of the dust control measures to be used, including where appropriate, the following:

   (i) Planning earthworks in advance so as to limit the amount of exposed surface area;

   (ii) Using water carts and / or irrigation sprays to pre-water the site of earthworks;

   (iii) Ceasing earthworks during periods of high winds;

(iv) Applying water via sprays to the aggregate crushing and screening facility;

(v) Limiting the height and slope of stockpiles of topsoil;

(vi) Applying water to the stockpiles using sprays;

(vii) Installing wind breaks near the stockpiles of topsoil;

(viii) Use of water carts on the unpaved roads;

(ix) Applying water to the feed hopper of the concrete batching plant; and

(x) Providing a bag filter unit to capture dust during filling operations at the cement silo.

b) Designated responsibilities for dust management, including sub-contractor management;

c) A record of maintenance requirements and contingency plans for dust control equipment;

d) Consultation with neighbouring property owners and occupiers if required; and

e) A complaints register, including a record of investigations carried out, the response action taken, and any reporting requirements. The register shall be provided to the CRC on request.

Rehabilitation Management Plan

18) The consent holder shall prepare, submit and implement a Rehabilitation Management Plan (**"RMP"**). The RMP shall address, but not necessarily be limited to, the following matters:

a) Identification of the soil resources to be used for rehabilitation;

b) Identification of the vegetation types to be used on a planting plan or schedule;

c) A programme for re-vegetation and maintenance activities;

d) The desired percentage of surface cover to be achieved to reduce the adverse effects from sediment-laden stormwater run-off; and

e) Identification of weed management activities to be undertaken.

Contaminant Spill Contingency Plan

19) The consent holder shall prepare and implement a Contaminant Spill Contingency Plan ("**CSCP**") for containment of any spill events. The CSCP shall address, but not be limited to, the following matters:

a) Identifying designated bulk fuel storage, contaminant storage facilities and re-fuelling locations;

b) Ensuring that all contaminant storage or designated re-fuelling areas are bunded or contained in such a manner so as to prevent the discharge of contaminants;

c) Requiring that all mobile fuel tankers carry spill kits, which are capable of absorbing the quantity of oil and petroleum products that may be spilt by a mobile fuel tanker on site at any one time, and that spill kits are also stored at bulk storage tank locations at all times;

d) Detailing the contents of the spill kits, including absorbent pads, booms, pillows and socks and appropriate pegs/rope to hold the absorbent material in place;

e) Recording the names of operators trained in spill response and remediation;

f) Ensuring that all machinery is regularly maintained in such a manner so as to minimise the potential for leakage of contaminants;

g) Ensuring that no machinery is cleaned, stored or refuelled within 20 metres of the bed of any water body (except in relation to the canal berms where a 20 metre setback is not possible);

h) Ensuring that all contaminants (e.g. fuel, hydraulic oils, lubricants etc) are removed from the site at the end of the construction period, except for those required for ongoing maintenance and operational activities;

i) Detailing an internal and external notification procedure in the event of a spill, including but not limited to providing emergency contact information for the Canterbury Regional Council Pollution Hotline, and emergency contact information for a waste management service provider with appropriate qualifications and equipment for cleaning up spills; and

j) Identifying measures to be undertaken to remediate a contaminant spill, including instructions for removing and disposing of contaminated material in a manner suitable to ensure no further contamination occurs.

k) Ensuring that when informing the Canterbury Regional Council of any spill, as specified in clause (i), the consent holder shall provide the following information:

(i) The date, time, location and estimated volume of the spill;

(ii) The cause of the spill;

(iii) The type of contaminant(s) spilt;

(iv) Clean up procedures undertaken;

(v) Details of the steps taken to control and remediate the effects of the spill on the receiving environment;

(vi) An assessment of any potential effects of the spill; and

(vii) Measures to be undertaken to prevent a recurrence.

Fish Salvage Management Plan

20) The consent holder shall prepare, submit and implement a Fish Salvage Management Plan ("**FSMP**"). The purpose of the FSMP shall be to minimise fish losses from dewatering sections of the Tekapo Canal. The FSMP shall address, but not necessarily be limited to, the following matters:

a) Details of a briefing to be held for all participants in the salvage operation prior to each salvage operation;

b) Details of the number of personnel required, their responsibilities, and required training (i.e. electric fishing, fish tanker, and boat operator certification);

c) Step by step information on the procedures to be undertaken to salvage the fish;

d) A list of all the fish handling equipment that will be required during the salvage operations;

e) A list of all support equipment required for the fish salvage operations;

f) Details of all fish handling activities including how to capture and handle fish within each canal section, specifics on the number of fish which can be transported in containers or transport tanks at varying water temperatures;

g) Details of how and where fish will be released, and whether any special structures will need to be created in order to release the fish;

h) Information on what to do with injured and dead fish, including tallying their numbers prior to disposal;

i) Reporting requirements that summarise each season's fish salvage operation and can be kept as a permanent record; and

j) Details of how tangata whenua can be involved in the design and implementation of fish salvage operations and monitoring.

GROUNDWATER AND SURFACE WATER MONITORING PROGRAMME

21) The consent holder shall design a Groundwater and Surface Water Monitoring Programme ("**GSWMP**"). The GSWMP shall include, but not necessarily be limited to:

a) Monitoring of groundwater levels in piezometers around the Tekapo Canal;

b) Monitoring of Mary Burn flows upstream and downstream of the Tekapo Canal and flows in springs that emerge downslope of the canal sections that are being relined; and

c) Monitoring of water levels in representative ponds and wetlands adjacent to the Tekapo Canal and works.

22) The consent holder shall implement the monitoring programme required in Condition 21 three months prior to the de-watering of the Tekapo Canal first occurring. The monitoring programme shall cease 12 months after the installation of the final section of the supplementary PVC liner in the Tekapo Canal.

23) The consent holder shall compile an annual monitoring report for each year that these resource consents are current addressing the monitoring undertaken in accordance with Condition 21. As a minimum the report shall:

a) Include a summary of all the data collected as required under Condition 22;

b) Critically analyse the information collected in terms of compliance and potential or actual adverse environmental effects;

c) Compare data with previously collected and reported results and identify and comment on any emerging trends; and

e) Make recommendations on alterations/additions to the monitoring programme, if required.

The annual monitoring report shall be submitted to CRC, by 30 June for each year these resource consents are exercised.

DIDYMO

24) To prevent the spread of pest species, including but not limited to Didymo (*Didymosphenia geminata*), the consent holder shall ensure that activities authorised by this resource consent are undertaken in accordance with the Biosecurity New Zealand's hygiene procedures, and that vehicles and machinery shall be free of plants and plant seeds prior to use in any water body.

Advice Note: You can access the most current version of these procedures from the Biosecurity New Zealand website http://www.biosecurity.govt.nz.

ACCIDENTAL DISCOVERY PROTOCOL

25) At least 20 working days prior to the proposed commencement date for construction, the consent holder shall submit an Archaeological Accidental Discovery Protocol to CRC. The Protocol shall be prepared in consultation with Upoko Runanga of Arowhenua, Waihao and Moeraki, or their representative(s).

In addition to the information and content proposed in the documentation accompanying the application and further information, the accidental discovery protocol shall include, but not be limited to, the following:

a) Preconstruction protocols that may be carried out;

b) Protocols for notification of relevant parties and site management procedures in the event any archaeological sites or taonga are uncovered at any time;

c) Contact details for all relevant parties; and

d) Training procedures for all contractors.

All works shall be exercised in accordance with the Archaeological Accidental Discovery Protocol.

26) In the event of any discovery of archaeological material:

(a) the consent holder shall immediately:

(i) Cease earthmoving operations in the affected area and mark off the affected area; and

(ii) Advise the CRC of the disturbance; and

(iii) Advise the New Zealand Historic Places Trust of the disturbance.

(b) If the archaeological material is determined to be Koiwi Tangata (human bones) or taonga (treasured artefacts) by the New Zealand Historic Places Trust, the consent holder shall immediately advise the office of the Upoko Runanga of Arowhenua, Waihao and Moeraki, of the discovery.

(c) If the archaeological material is determined to be Koiwi Tangata (human bones) by the New Zealand Historic Places Trust, the consent holder shall immediately advise the New Zealand Police of the disturbance.

(d) Work may recommence if the New Zealand Historic Places Trust (following consultation with rūnanga if the site is of Māori origin) provides a statement in writing to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager that appropriate action has been undertaken in relation to the archaeological material discovered. The Canterbury Regional Council shall advise the consent holder on written receipt from the New Zealand Historic Places Trust that work can recommence.

Advice Note:

Under the Historic Places Act 1993 an archaeological site is defined as any place associated with pre-1900 human activity, where there is material evidence relating to the history of New Zealand. For sites solely of Māori origin, this evidence may be in the form of accumulations of shell, bone, charcoal, burnt stones, etc. In later sites, artefacts such as bottles or broken glass, ceramics, metals, etc, may be found or evidence of old foundations,

wells, drains, tailings, races or other structures. Human remains/koiwi may date to any historic period.

It is unlawful for any person to destroy, damage, or modify the whole or any part of an archaeological site without the prior authority of the New Zealand Historic Places Trust. This is the case regardless of the legal status of the land on which the site is located, whether the activity is permitted under the District or Regional Plan or whether a resource or building consent has been granted. The Historic Places Act provides for substantial penalties for unauthorised damage or destruction

CERTIFICATION

27) The consent holder shall engage a Chartered Professional Engineer to certify that the design of the:

(a) Canal relining; and

(b) Culvert remediation

and their construction are in accordance with good engineering practice to ensure that the structure is safe and fit for purpose. This certificate shall be submitted to CRC, prior to the first filling of the canal.

ONGOING CONSULTATION

28) Within one month of the commencement of these resource consents, the consent holder shall invite representatives of the Department of Conservation, The Wolds Station Ltd, Irishman Creek Station Ltd, the Tekapo Community Board, Central South Island Fish and Game, Te Runanga o Ngai Tahu, Te Runanga o Arowhenua, Te Runanga o Waihao and Te Runanga o Moeraki to participate in a Tekapo Canal Remediation Project Consultation Group" ("**TCRPCG**").

a) The purpose of the TCRPCG, the meetings that will be held with the TCRPCG, and the consent holder's obligations to the TCRPCG shall be as follows:

i) To ensure stakeholder input is incorporated in the EMP and SEMPs;

ii) To ensure stakeholders are kept up to date with project implementation;

iii) To discuss the results of monitoring programmes; and

iv) To provide a mechanism for stakeholders to express any matters of concern and to address those concerns.

b) The consent holder shall initiate up to one meeting prior to, and one meeting during, any canal outage events with the TCRPCG and on an as required basis thereafter. The purpose of the meetings will be to:

i) Provide regular updates on progress with implementation of the resource consents;

ii) Advise of the activities and events related to the resource consents that have been completed and activities or events to be undertaken in the future, and likely effects on the local community;

iii) Identify the consultation to be undertaken with individual landowners;

iv) Advise what actions have been taken to comply with the conditions of consent;

v) Allow for community feedback on the EMP and SEMPs; and

vi) Provide an avenue by which people that may be affected by the consented activities are able to communicate any concerns they have to the consent holder.

c) The consent holder shall keep minutes of the meetings held in accordance with clause b) of this condition and shall forward them to all attendees within ten working days; and

d) The consent holder shall provide final copies of the reports prepared in accordance with the conditions of this resource consent to the TCRPCG concurrently with them being submitted to CRC.

29) The consent holder shall prepare a Communication Strategy, which shall set out procedures to deal with queries relating to the Tekapo Canal Remediation Works. The Communication Strategy shall be lodged with CRC, at least two months prior to any site works being undertaken. The Communication Strategy shall include, but not be limited to:

a) Advertising in local newspapers no later than three months prior to any canal outage events, explaining the general nature of the works to be undertaken in the following construction season and the extent to which these may affect traffic flows, angling and other recreational activities;

b) Advertising in local newspapers at least one month prior to construction works commencing in each construction season, providing details of the works proposed and a timetable for these;

c) A method of recording the time, date and the type of any complaint and the actions taken by the consent holder to resolve the complaint;

d) Establishing and publicising a toll-free project telephone number, so that any members of the public may raise matters or make an enquiry regarding the remediation works to the Tekapo Canal; and

(e) Detailing a mechanism whereby the consent holder undertakes reasonable endeavours to provide information on water levels in Lake Tekapo and flow rates and water levels in the Tekapo River to the public.