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Hydrological Modelling Dataset

Report 3: Storage and Spill Series Descriptions

28 September 2026



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PREFACE

A large proportion of New Zealand's electricity needs are met by generation from hydro power. Information about the distribution of inflows and the capability of the various hydro systems is necessary to ensure a reliable, competitive, and efficient market and electricity system.

The hydrological modelling dataset (HMD) is a dataset of hydrological information made available by the Electricity Authority. The dataset was known as the SPECTRA update until 2010. In 2015 the dataset was revised to become the HMD, a comprehensive dataset that can be relied upon by modellers and analysts to test scenarios, provide commentary and inform decisions.

The HMD is comprised of data provided by hydro generators and supplemented with data from other sources. These parties are acknowledged for their contribution and for making this data available.

The HMD consists of three main components:

1. **Infrastructure and hydrological constraint attributes:**
    - This dataset records standing information about the capability of the main hydro schemes.
2. **Flows:**
    - This time series dataset records data for inflows for reservoirs and flows at various existing or potential hydro generating sites.
3. **Storage and spill:**
    - This time series dataset records storage for the main hydro schemes.

This report describes the third component of the HMD, the storage and spill series.

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1 INTRODUCTION

This Hydrological Modelling Dataset (HMD) full update was requested by the Electricity Authority and includes data to 31 December 2025.

An interim update simply adds one year of data to the end of the previous full HMD update, whereas the full update from 2024 recalculated all data back to July 1931. This interim update includes data from 1 July 1931 to 31 December 2025.

The HMD consists of six datasets:

- Infrastructure attributes:

  Lists the changes over time to the 'plant factors' or 'average efficiency factors' for each of the power stations associated with the 10 largest reservoirs.

- Hydrological constraints:

  Lists the constraints put on hydrological parts of schemes usually via consent conditions. This was completed for the power stations associated with the 10 largest reservoirs in New Zealand.

- Actual flows:

  a) 'Actual' inflows or outflows to or from several reservoirs in New Zealand. The inflows are modelled data, the outflows are generally measured data;
  b) Tributary flows or local inflows into various reservoirs;
  c) Hypothetical 'actual' flows, i.e., flows which could occur under certain regimes; and
  d) Actual river flows at gauging stations which could be possible hydro-power schemes in the future; and
  e) Average daily outflows from daily derived flow records.

  Many of these are also part of the natural flow dataset.

- Natural flows:

  a) 'Natural' uncontrolled inflows to several reservoirs in New Zealand;
  b) Modelled natural inflows or tributary inflows to reservoirs, as though they are uncontrolled; and
  c) River flows at gauging stations which could be possible hydro-power schemes in the future.

  Many of these are also part of the actual flow dataset.

- Lake storage:

  Daily active storage volumes from 1980 to 2025 for the 10 largest hydro lakes in NZ.

- Spill volume:

  Average daily spill flow data for 25 sites in New Zealand including the 10 largest hydro-lakes and each of the structures downstream.

  Daily spill data is from 24:00 to 24:00 filed at the end of the day i.e. 23:59, identical to the daily actual and natural flow datasets.

The lake storage, spill volumes, infrastructure attributes, and hydrological attributes datasets were produced for the first time in 2015. Daily spill volumes were produced for the first time in 2020.

The average outflows of the reservoirs that are a part of the Waikato and Waitaki schemes were produced for the first time in 2017.

Flow routines for actual and natural flows are re-run for each update and new datasets created. These datasets are then compared with previous data to ensure continuity and accuracy. Explanations of any differences between successive full update datasets are provided in a separate report – “Hydrological Modelling Dataset: HMD Flow Series Comparison”.

The following Power Companies have provided data for this update for storage and spill:

- Contact Energy Ltd
- Genesis Energy Ltd
- Meridian Energy Ltd
- Mercury NZ Ltd

All input data records have been checked for gaps and, where necessary, these have been filled to provide continuous time series.

1.1 CLIMATE CHANGE

The HMD is based on recorded flows, and the interaction of these flows with both hydro-electric power infrastructure and the consenting framework. No specific consideration is given to the future potential effects of climate change on the flow regimes of the various rivers.

The raw data, however, contain all the inherent climatic effects on the recorded flow regimes of the various rivers. Consequently, the data include seasonality, persistence, and any climatic trends or cycles which have affected the flow regimes.

Where data have been synthesised, to fill gaps in the records, this has been based on correlation with the most appropriate ‘donor’ site, over the longest period of concurrent data. Consequently, the synthetic records include any effects of climatic variability inherent in the ‘donor’ record. Since the flow regimes for the two records have similar characteristics, hence their correlation, the transference of any climate signature is appropriate. However, since the longest period of concurrent record is used to derive the synthetic series, the correlation will include the average effect of any climatic variability over that time. Shorter-term climatic effects will not be apparent in the synthetic data. Such an approach is the best possible to synthesise periods of missing record, and results in the least error while still including any longer-term climate signature.

It should be noted that the use of daily average flows in the HMD provides significant smoothing of any minor effects of climate variability and change, especially the potential impact of short duration – high intensity flood events.

The HMD therefore contains all those actual longer-term climatic signatures which have affected the various rainfall-runoff relationships. Any shorter or more subtle trends are smoothed over periods of synthetic flow data. HMD does not provide any quantitative consideration of the potential effects of climate change in the future.

1.2 THE POWER ARCHIVE

A significant amount of input data for the HMD series are from the Power Archive. In the mid-late 1970s the Power Division of the Ministry of Works and Development commenced development of the ‘Power Archive’, a repository for all hydrometric data relating to the various hydro systems, reservoirs and dams throughout New Zealand. Over time the Power Archive evolved to include not only the hydrometric data but also various additional outputs such as machine flows, generation, spills, inflows, gate openings, and natural inflows and lake levels.

Management of the Power Archive has also moved over time from the Ministry of Works and Development to the Works and Development Services Corporation NZ, to Works Consultancy Services, Opus International Consultants Ltd and currently WSP Ltd.

With the break-up of the Electricity Corporation of New Zealand into several separate companies the Power Archive was also partitioned. While the majority of the original Power Archive is still maintained by WSP, several of the power companies have taken these services in-house, e.g., Manawa Energy and Genesis Energy. Ongoing maintenance of the Power Archive by WSP has ensured continuity and consistency of independently quality assured data for use in analysis and modelling.

Despite this partitioning of the Power Archive the various hydrometric and generation set are still generally collectively referred to as the Power Archive'.

1.3 QUALITY CODES

The National Environmental Monitoring Standards steering group (NEMS) has prepared a series of environmental monitoring standards on authority from the Regional Chief Executive Officers (RCEO) and the Ministry for the Environment (MFE) (NEMS, 2013).

These standards describe how to collect, process, retain and archive environmental data, using best practice methodologies. The NEMS incorporates a common National Quality Code Schema (NQCS) across all measured environmental parameters, which assigns a final Quality Code to the data. This code describes how the data meets the various requirements required under each environmental standard; the degree of rigour in which the standard is applied affects the final quality of the data.

It was recommended that these standards be adopted throughout New Zealand and all data be collected, processed and quality coded appropriately.

The National Quality Code Schema is divided into six 'Zones of Quality' within a numeric index which describes how the collected and processed environmental data meets the relevant standard. These six zones have a parent code summarising the overarching quality of the data; 100 represents Missing Record; 200 is Unverified or Cautionary Data; 300 is Synthetic; 400 is Poor Quality; 500 is Fair Quality; and 600 is Good Quality. To achieve 'Good Quality' data requires each component of the standard to be practised; from the data collection stage to archiving.

The NQCS can be introduced in its basic parent form or it can be expanded upon to provide more data quality detail by agencies where a greater level of detail is required; detail relating to data quality and operational requirements and standards. This expansion to the NQCS is called 'child coding'. These 'child codes' are currently allocated in-house and have therefore been developed to differentiate between data quality in the HMD.

Table 1-1 shows the quality codes used for the HMD. In the event that no measured data was recorded and replacement data could not be reasonably calculated, a missing record is filled with a quality code of 100 assigned to the null time period. The direct measurement of flow and the spill flow volumes were both coded as 200, because the quality of this data is non-verified. This number is a 'parent code' and has been outlined by the NQCS. All of the rest of the quality codes used for the HMD are child codes that were created under the parent code of synthetic data (300). A 301 code denotes that the data was created via simple arithmetic, for example, Site 1 + Site 2. The 310 code is used when data is made via a correlation with another dataset, for example, when there is no available data for a site so a relationship is established with an adjacent station to correlate the data. The codes 320 and 325 represent data that has been manufactured, usually with calculations or models. The 330 code denotes that the data has been entered as the median flow, for example, for gap filling where other methods were not deemed appropriate. The 335 code describes data used to fill small gaps using a combination of correlation, visual interpolation and site-specific information from the recording authority to provide the most likely flow. The 340 code is used when the data has been replicated for larger periods of data. This may occur when whole or parts of years were replicated and entered to fill a piece of missing record, using

a combination of correlation, calculation and modelling. This occurred often between 1931 and 1934 when there were a limited number of sites operating at this time. The last code is 350 indicates where the data is synthetic but is of an unknown origin, with no new suitable data or reliable methodology to derive that period of data that would be more representative.

Table 1-1: A description of the quality codes used for the HMD.

Code	Description
100	Missing Record
200	Unknown or non-verified quality
301	Simple arithmetic
310	Correlation
320	Manufactured via calculations or models (WSP)
325	Manufactured by the recording authority
330	Median flow
335	Small gap filling via correlation, calculation and interpolation
340	Replicated data
350	Unknown origin

1.4 DATASET SUMMARY

1.4.1 DATA SOURCES

The HMD data record for any of the flow series are often a composite record derived using different methods for different periods, however for the storage and spill series, the records have been derived using a single method in each case. Table 1-2 and Table 1-3 list the source of the record for each series and period for the storage and spill datasets, respectively. The quality code for the data record is listed along with the definition of the quality code in Table 1-1. Note the 'overarching' quality code is shown, not the individual periods where the data is missing, due to the number of gaps that some sites have.

Table 1-2: Quality of HMD Storage series - North and South Island.

Dataset	Period	Quality Code	Code Definition
Lake Taupō Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Waikaremoana Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Ōhau Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Tekapo Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Pūkaki Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Wānaka Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Hāwea Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Wakatipu Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Te Anau Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)
Lake Manapōuri Storage	01/01/80 - 31/12/25	320	Synthetic – Manufactured (WSP)

From 2020, the spill data was presented as 'daily spill', filed at 23:59 as at 20254, identical to the daily flow datasets.

Note spill data cannot be filled or synthesised if missing; therefore some datasets do not start in 1980 and where there are significant gaps, the data is filed as ‘0’ and quality coded ‘100’ for missing data.

Table 1-3: Quality of HMD Spill series - North and South Island.

Lake	Dataset	Period	Quality Code	Code Definition
Lake Waikaremoana	Onepoto	02/11/98 - 31/12/25	200	Non verified data
	Waikaretaheke River at Piripaua	17/04/02 - 31/12/25	200	Non verified data
	Waikaretaheke River at Upstream Mangaone	27/06/97 - 31/12/25	200	Non verified data
Lake Tekapo	Lake Tekapo at Gate 17	31/12/79 - 31/12/25	200	Non verified data
	Lake George Scott to Tekapo River	31/12/79 - 31/12/25	200	Non verified data
Lake Pūkaki	Lake Pūkaki	31/12/79 - 31/12/25	200	Non verified data
Lake Ruataniwha	Lake Ruataniwha	02/12/86 - 31/12/25	200	Non verified data
Lake Ōhau	Lake Ohau	31/12/79 - 31/12/25	200	Non verified data
Lake Benmore	Lake Benmore	31/12/79 - 31/12/25	200	Non verified data
Lake Aviemore	Lake Aviemore	31/12/79 - 31/12/25	200	Non verified data
Lake Waitaki	Lake Waitaki	31/12/79 - 31/12/25	200	Non verified data
Lake Te Anau	Lake Te Anau	31/12/79 - 31/12/25	200	Non verified data
Lake Manapōuri	Lake Manapouri	31/12/79 - 31/12/25	200	Non verified data
Lake Hāwea	Lake Hawea	31/12/79 - 31/12/25	200	Non verified data
Lake Dunstan	Clyde Dam	20/04/92 - 31/12/25	200	Non verified data
Lake Roxburgh	Lake Roxburgh	31/12/79 - 31/12/25	200	Non verified data
Lake Taupō	Lake Taupo	31/12/79 - 31/12/25	200	Non verified data
Lake Aratiatia	Lake Aratiatia	31/12/79 - 31/12/25	200	Non verified data
Lake Ōhakuri	Lake Ohakuri	31/12/79 - 31/12/25	200	Non verified data
Lake Ātiamuri	Lake Atiamuri	31/12/79 - 31/12/25	200	Non verified data
Lake Whakamaru	Lake Whakamaru	31/12/79 - 31/12/25	200	Non verified data
Lake Maraetai	Lake Maraetai	31/12/79 - 31/12/25	200	Non verified data
Lake Waipapa	Lake Waipapa	31/12/79 - 31/12/25	200	Non verified data
Lake Arapuni	Lake Arapuni	31/12/79 - 31/12/25	200	Non verified data
Lake Karapiro	Lake Karapiro	31/12/79 - 31/12/25	200	Non verified data

1.5 UPDATE TO HILLTOP SOFTWARE

As of June 2022, all scripts used as part of the HMD update, whether for a full update or an interim update, have been converted from Tideda scripts into Hilltop Manager using the vimsim scripting language (commonly

referred to as creating virtual measurements). This means none of the calculations are derived in Tideda software, with all data analysis, scripting and graphing carried out in Hilltop and packages associated with this software.

This software has increased accuracy as it stores the entire number, rather than rounding to a whole number. This will result in differences due to rounding when comparing HMD outputs pre 2022 and this has been addressed in the previous full update comparison analysis and reports.

2 LAKE STORAGE

In February 2009, Opus produced (for the Electricity Commission) a chronology and history of the 10 major lakes used for hydro generation in New Zealand (Knight & McConchie, 2009). These lakes included: Taupō and Waikaremoana in the North Island; and Ōhau, Tekapo, Pūkaki, Wānaka, Hāwea, Wakatipu, Te Anau and Manapōuri in the South Island. That report discussed the changes in water level over time and provided an explanation for the significant changes caused by alterations to control structures and consent conditions. All the water levels were, however, presented relative to the local level datum at each lake.

Following this, in October 2010 Opus produced a Lake Generation Potential History report (Paine, 2010) of data series for the 10 largest hydro lakes. Lake levels were related to the amount of water stored in the lake, and then to potential power generation as this water is conveyed downstream through the various hydro stations. The total generation potential of water held in a particular lake is considered to be the sum of the energy generated as the water passes through all the dams downstream, and not just the one at the lake outlet. While the above analysis provides an index of the generation potential at any point in time, the total generation capacity in any given year is the sum of how many times water from the lake is drained and then refilled.

For the 2025 HMD update, the storage capacity history of the 10 largest hydro lakes has been recalculated from 1 January 1980 to 31 December 2025 i.e. using raw data input data from 1980 to the end of 2025 to recalculate the overall storage. This could then be used to calculate potential generation from the capacity of the system using data from the infrastructure attributes HMD series. This differs from an Interim update where only the most recent year is appended to the dataset.

There have been several changes to the various control structures and resource consents relating to the management of lake levels over time. This changes the capacity of the system. Therefore, this analysis of the potential generation only covers the period from 1 January 1980 to 31 December 2025. This 46-year period provides an appropriate length of record, and a valid basis for review.

With permission from Meridian Energy Ltd, Mercury NZ Ltd, and Contact Energy Ltd, lake level data have been retrieved from the Power Archive held by WSP.

The lake level data used are those that have been edited and audited to ensure consistency and quality control before being appended to the Power Archive. However, it is periodically necessary to review and update these data when checking instrument calibrations and adjusting datums to account for subsidence and other factors that affect relative water levels. These changes to the data over time usually only affect the more recent period of record.

It should be noted that the lake level recorded is a function of the interaction of many variables. These variables include: rainfall, runoff, inflows, outflows, evaporation, lake level management (for hydro power generation and flood mitigation), seiching (both natural and that caused by seismic activity), tectonic deformation and subsidence, wind build up, and wave action (both wind and boat generated). Lake levels, therefore, rather than being a simple measure, actually reflect the integrated effect of a diverse range of controls.

2.1 LAKE STORAGE VOLUME MODEL

The following process was used to convert the lake level records to a time series of the variability of active lake storage volumes, i.e., the capacity of the system, over time. For each of the ten lakes:

1) The lake level data was obtained.
2) Using a lake level–storage volume rating curve provided by the generators, the lake level record was transformed to active storage (millions of m^3).

The active storage was defined as that volume of water held above the minimum control level. Although the lakes also have maximum control levels, it was assumed that water above this level was still available to generate electricity. While there may be increased controls over the use of this water, in most situations the water is still used to generate electricity. Furthermore, even in the situation where this water may by-pass the first power station via spill flow, it may still be used to generate electricity in other structures downstream.

Any water in the lakes below the minimum control or operating level is treated as if it is not available for generation and therefore not 'active storage'. In some situations, this water can be used to generate electricity but there are usually constraints that must be overcome. An example of this is 'active contingent storage' which is available for some reservoirs if they meet specific conditions. These constraints may relate to consent conditions, dam infrastructure and design, and environmental considerations. Because of the complexity of lake level management and power generation at low lake levels, it is simpler to assume no generation. This, however, results in the total generation potential provided by this analysis being conservative for a small percentage of time, i.e., when the lake level is below the normal operating range. Lakes Wakatipu and Wānaka do not have operating ranges and thus the sill level and the base of the thalweg, respectively, were used as the level for zero generation.

2.2 NORTH ISLAND

Lake Taupō and Lake Waikaremoana are both located in the North Island (Figure 2-1). As of July 2016, Mercury Energy Ltd operates the Waikato hydro power scheme; they supersede Mighty River Power Ltd prior to this date. This consists of eight dams and nine power stations with flows from Lake Taupō managed via the control gates. Genesis Energy Ltd operates the Lake Waikaremoana scheme which consists of three power stations.

There are several other lakes that form part of various hydro schemes around the North Island. These, however, have not been included in this national overview and summary. This is because these lakes are small, usually contain only about one day of storage, are totally managed, and are often artificial (i.e., impounded river valleys) as opposed to natural water bodies.

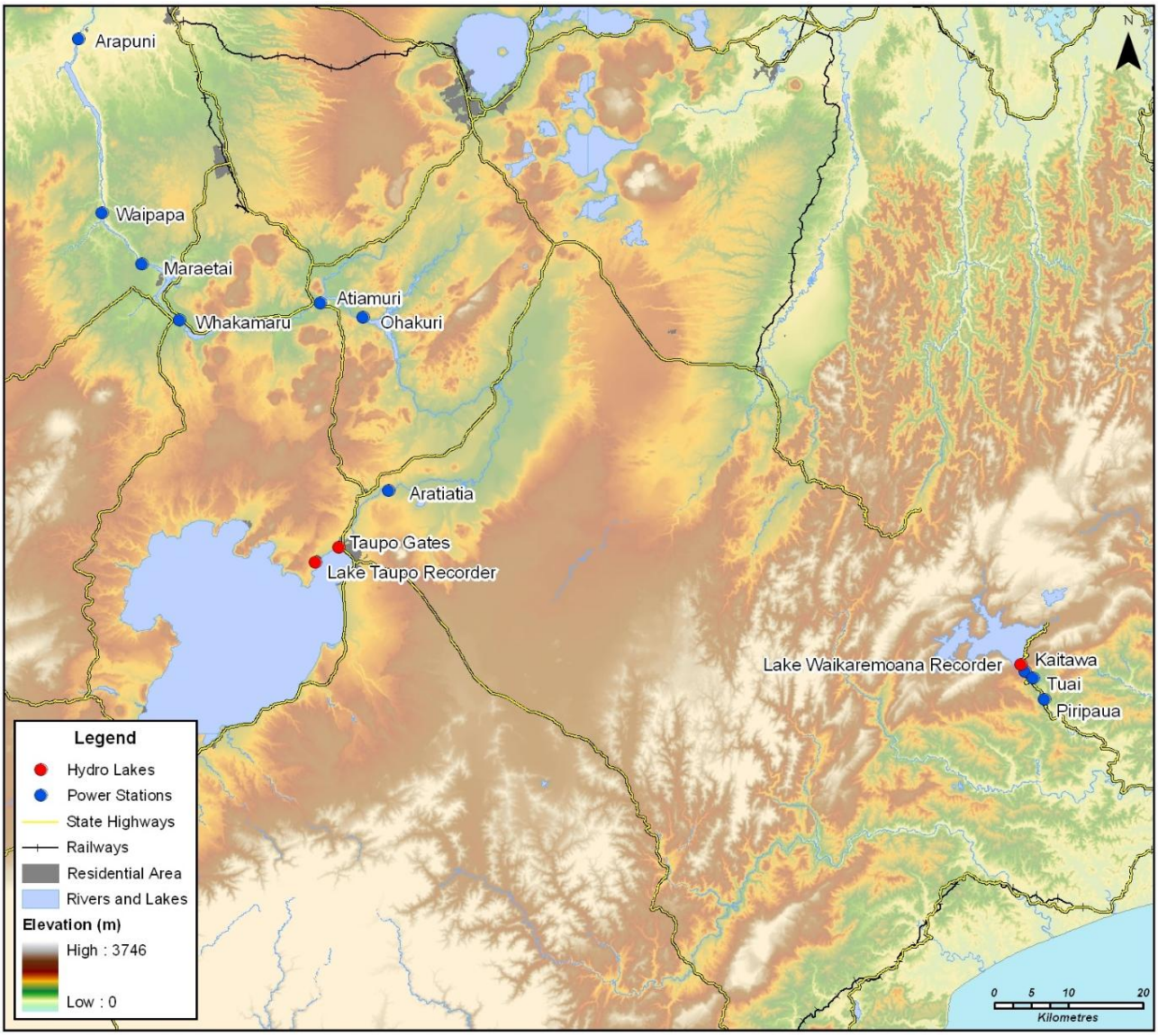


Figure 2-1: North Island hydro lakes part of the HMD storage and spill series.

2.2.1 LAKE TAUPŌ

The conditions for the management of levels in Lake Taupō are set out in Environment Waikato's Resource Consent 105226 section 2:

2.2.1.1 MANAGEMENT OF LAKE TAUPŌ

Condition number	Condition description
2.1	The consent holder may at any time operate the Taupō gates to manage the level of Lake Taupō, for the purpose of water storage for hydro electricity generation, between the following control levels: *357.25 masl (maximum control level), and* *355.85 masl (minimum control level)*

2.2	The consent holder shall keep records of the levels of Lake Taupō and make them available to the Waikato Regional Council upon request. These levels shall be measured at the NIWA Acacia Bay lake level recording site, or at some alternative location approved in advance by Waikato Regional Council and determined as a rolling average of levels taken over a 24-hour period.

2.2.1.2 MINIMUM OUTFLOW

Condition number	Condition description
2.3	The minimum outflow from the Taupō Gates shall be 50m³/s determined as a rolling average of total gate flows taken over 30 minutes unless one of the Minimum Control Level conditions 2.8 or 2.9 applies.

2.2.1.3 MAXIMUM CONTROL LEVEL

Condition number	Condition description
2.4	The Taupō Gates may not be used to manage the level of Lake Taupō above 357.25 masl primarily for the purposes of generating electricity. If at any time the lake rises above this level the Taupō gates shall be operated in such a way as to return the level of the lake to 375.25 masl as soon as is practicable.
2.5	The consent holder shall operate the Taupō gates according to a management regime designed to achieve the following objectives for the level of Lake Taupō: *A less than 20% annual exceedance probability of 357.25 masl (i.e., an average 1 in 5-year recurrence interval).* *A less than 5% annual exceedance probability of 375.39 masl (i.e., an average 1 in 20-year recurrence interval).* *A less than 1% annual exceedance probability of 375.50 masl (i.e., an average 1 in 100-year recurrence interval).*
2.6	Within six months of the commencement of this consent the consent holder shall prepare a management plan that describes how Lake Taupō will be operated in order to meet the requirements of these consents. This plan shall incorporate all predictive and operational tools and methods that are employed to attain compliance with the objectives listed in condition 2.5 of these consents. This plan shall form part of the High Flow Management Plan by condition 5.2 of these consents.
2.7	The consent holder shall report annually to the Waikato Regional Council on its performance in managing the Taupō Gates in order to meet the objectives defined in condition 2.5 above.

2.2.1.4 MINIMUM CONTROL LEVEL

Condition number	Condition description
2.8	When the level of Lake Taupō is below 355.95 masl but above the minimum control level (355.85 masl), the Taupō gates will be operated so as to provide a flow sufficient to maintain an average flow at Karapiro that is between 140 m³/s and 150 m³/s, (determined as a rolling average of total station outflows taken over 30 minutes).
2.9	When the level of Lake Taupō is below 355.85 masl, Taupō outflows shall not exceed Taupō inflows and when, in these circumstances, Taupō inflows are sufficient to exceed the minimum flow at Karapiro, any such excess inflow shall be managed to raise the level of Lake Taupō above 355.85 masl.

2.2.1.5 EXCLUSIONS

Condition number	Condition description
2.10	The requirements of conditions 2.1, 2.3, 2.4, 2.5, 2.8, 2.9 and 3.20 shall not apply at any time when one or more of the following circumstances apply: i. *When the High Flow Management Plan described in condition 5.2 of this consent requires otherwise; or until that plan is operational, where the Waikato River Power Development Flood Management Rules dated November 2000 (or agreed amendment version) require otherwise;'* ii. *When there is a threat to the structural integrity of the structures of the Waikato hydro system;* iii. *When otherwise lawfully directed in writing by the Waikato Regional Council for flood management or Civil Defence purposes;* iv. *When requested by the police, army, fire or other emergency service provider;* v. *When necessary to respond to the uncontrolled release and spread of contaminants;* vi. *Any force majeure event.*
2.11	Where any of the circumstances listed in condition 2.10 occur (or there is a reasonable expectation that one may occur) the consent holder shall, as soon as practicably possible, advise the Waikato Regional Council and other parties who may reasonably be expected to be directly affected by the excursion from the normal operating regime, of the circumstances, the action being taken and its likely duration.
2.12	Where an excursion from the defined operating regime occurs due to any of the circumstances described in condition 2.10, the consent holder shall return the system to normal operating regime as soon as practicably possible.
2.13	Within four weeks of the system being returned to normal operation a report shall be provided to the Waikato Regional Council describing the nature and duration of the excursion event and the ways in which the hydro system was operated outside the normal requirements of this consent.

Table 2-1 lists characteristics of Lake Taupō including the maximum and minimum control levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. The large size of Lake Taupō means that a constant area was assumed for the lake storage rating and are listed in Table 2-2. A linear lake level–lake area rating was used to calculate the lake storage volumes which is also listed in Table 2-2.

Table 2-1: Characteristics of Lake Taupō.

Lake Taupō	
Lake area (km²)	611.00
Maximum operating level (masl)	357.25
Minimum operating level (masl)	355.85
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{611}) - \mathbf{217424}$	

Table 2-2: Lake Taupō Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
355.85	611	0.00
356.00	611	91.65
356.20	611	213.85
356.40	611	336.05
356.60	611	458.25
356.80	611	580.45
357.00	611	702.65
357.25	611	855.40

2.2.2 LAKE WAIKAREMOANA

Lake Waikaremoana currently has an operating regime of 3m, from 580.29 to 583.29 masl (Moturiki Datum). Genesis Energy operates to specific consent conditions that control discharges from Lake Waikaremoana above and below this operating range.

Table 2-3 shows the characteristics of Lake Waikaremoana, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-4.

There are several gaps in the lake level dataset and therefore also in the storage volume dataset. Any gaps less than 24-hours were removed but any greater than 24-hours were left.

Table 2-3: Characteristics of Lake Waikaremoana.

Lake Waikaremoana	
Lake area (km²)	54.00
Maximum operating level (masl)	583.29
Minimum operating level (masl)	580.29
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{52.407}) - \mathbf{30411}$	

Table 2-4: Lake Waikaremoana Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
580.29	51.85	0.00
580.60	51.96	16.11
580.80	52.02	26.51
581.00	52.09	36.93
581.20	52.16	47.36
581.40	52.22	57.81
581.60	52.29	68.26
581.80	52.36	78.73
582.00	52.42	89.22
582.20	52.49	99.72
582.40	52.56	110.23
582.60	52.62	120.75
582.80	52.69	131.29
583.00	52.75	141.84
583.20	52.82	152.40
583.29	52.85	157.16

2.2.3 LAKE ARATIATIA

Lake Aratiatia currently has an operating regime of 1.83 m, from 335.99 to 337.82 masl. Mercury Energy operates to specific consent conditions that control discharges from Lake Aratiatia above and below this operating range.

Table 2-5 shows the characteristics of Lake Aratiatia, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-6.

There are several gaps in the lake level dataset and therefore also in the storage volume dataset. Any gaps less than 24-hours were removed but any greater than 24-hours were left.

Table 2-5: Characteristics of Lake Aratiatia.

Lake Aratiatia	
Lake area (km²)	0.45
Maximum operating level (masl)	337.82
Minimum operating level (masl)	335.99
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{0.5124}) - \mathbf{172.36}$	

Table 2-6: Lake Aratiatia Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
336.4	0.45	0.00
336.6	0.45	0.11
336.8	0.45	0.22
337	0.45	0.32
337.2	0.45	0.42
337.4	0.45	0.52
337.6	0.45	0.63
337.8	0.45	0.73

2.2.4 LAKE OHAKURI

Lake Ohakuri currently has an operating regime of 2.43 m, from 285.1 to 287.53 masl. Mercury Energy operates to specific consent conditions that control discharges from Lake Ohakuri above and below this operating range.

Table 2-7 shows the characteristics of Lake Ohakuri, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-8.

Table 2-7: Characteristics of Lake Ohakuri.

Lake Ohakuri	
Lake area (km²)	9.39
Maximum operating level (masl)	287.53
Minimum operating level (masl)	285.1
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{12.277}) - \mathbf{3507.4}$	

Table 2-8: Lake Ohakuri Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
285.7	9.39	0.00
285.9	9.39	2.59
286.1	9.39	5.05
286.3	9.39	7.51
286.5	9.39	9.96
286.7	9.39	12.42
286.9	9.39	14.87
287.1	9.39	17.33

2.2.5 LAKE ATIAMURI

Lake Atiamuri currently has an operating regime of 4.02 m, from 249.07 to 253.09 mas. Mercury Energy operates to specific consent conditions that control discharges from Lake Atiamuri above and below this operating range.

Table 2-9 shows the characteristics of Lake Atiamuri, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-10.

Table 2-9: Characteristics of Lake Atiamuri.

Lake Atiamuri	
Lake area (km²)	2.03
Maximum operating level (masl)	253.09
Minimum operating level (masl)	249.07
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{2.1315}) - \mathbf{535}$	

Table 2-10: Lake Atiamuri Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
251	2.03	0.00
251.3	2.03	0.65
251.6	2.03	1.29
251.9	2.03	1.92
252.2	2.03	2.56
252.5	2.03	3.20
252.8	2.03	3.84
253.1	2.03	4.48

2.2.6 LAKE WHAKAMARU

Lake Whakamaru currently has an operating regime of 2.40 m, from 224.35 to 226.75 masl. Mercury Energy operates to specific consent conditions that control discharges from Lake Whakamaru above and below this operating range.

Table 2-11 shows the characteristics of Lake Whakamaru, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-12.

Table 2-11: Characteristics of Lake Whakamaru.

Lake Whakamaru	
Lake area (km²)	5.39
Maximum operating level (masl)	226.75
Minimum operating level (masl)	224.35
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{6.8057}) - \mathbf{1531.3}$	

Table 2-12: Lake Whakamaru Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
225	5.39	0.00
225.3	5.39	2.02
225.5	5.39	3.39
225.7	5.39	4.75
225.9	5.39	6.11
226.1	5.39	7.47
226.3	5.39	8.83
226.5	5.39	10.19

2.2.7 LAKE MARAETAI

Lake Maraetai currently has an operating regime of 4.49 m, from 184.98 to 189.47 masl. Mercury Energy operates to specific consent conditions that control discharges from Lake Maraetai above and below this operating range.

Table 2-13 shows the characteristics of Lake Maraetai, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-14.

There are several gaps in the lake level dataset and therefore also in the storage volume dataset. Any gaps less than 24-hours were removed but any greater than 24-hours were left.

Table 2-13: Characteristics of Lake Maraetai.

Lake Maraetai	
Lake area (km²)	4.00
Maximum operating level (masl)	189.47
Minimum operating level (masl)	184.98
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{4.9749}) - \mathbf{932.05}$	

Table 2-14: Lake Maraetai Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
187.3	4.00	0.00
187.7	4.00	1.74
188.1	4.00	3.73
188.5	4.00	5.72
188.9	4.00	7.71
189.3	4.00	9.70
189.7	4.00	11.69
190.1	4.00	13.68

2.2.8 LAKE WAIPAPA

Lake Waipapa currently has an operating regime of 4.62 m, from 124.27 to 128.89 masl. Mercury Energy operates to specific consent conditions that control discharges from Lake Waipapa above and below this operating range.

Table 2-15 shows the characteristics of Lake Waipapa, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-16.

Table 2-15: Characteristics of Lake Waipapa.

Lake Waipapa	
Lake area (km²)	1.16
Maximum operating level (masl)	128.89
Minimum operating level (masl)	124.27
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{1.5803}) - \mathbf{197.53}$	

Table 2-16: Lake Waipapa Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
125	1.16	0.00
125.4	1.16	0.64
125.8	1.16	1.27
126.2	1.16	1.90
126.6	1.16	2.54
127	1.16	3.17
127.4	1.16	3.80
127.8	1.16	4.43

2.2.9 LAKE ARAPUNI

Lake Arapuni currently has an operating regime of 3.16 m, from 109.02 to 112.18 masl. Mercury Energy operates to specific consent conditions that control discharges from Lake Arapuni above and below this operating range.

Table 2-17 shows the characteristics of Lake Arapuni, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-18.

There are several gaps in the lake level dataset and therefore also in the storage volume dataset. Any gaps less than 24-hours were removed but any greater than 24-hours were left.

Table 2-17: Characteristics of Lake Arapuni.

Lake Arapuni	
Lake area (km²)	8.27
Maximum operating level (masl)	112.18
Minimum operating level (masl)	109.02
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{9.0927}) - \mathbf{1000.2}$	

Table 2-18: Lake Arapuni Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
110	8.27	0.00
110.2	8.27	1.82
110.4	8.27	3.63
110.6	8.27	5.45
110.8	8.27	7.27
111	8.27	9.09
111.2	8.27	10.91
111.4	8.27	12.73

2.2.10 LAKE KARAPIRO

Lake Karapiro currently has an operating regime of 2.83 m, from 50.62 to 53.45 masl. Mercury Energy operates to specific consent conditions that control discharges from Lake Karapiro above and below this operating range.

Table 2-19 shows the characteristics of Lake Karapiro, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-20.

There are several gaps in the lake level dataset and therefore also in the storage volume dataset. Any gaps less than 24-hours were removed but any greater than 24-hours were left.

Table 2-19: Characteristics of Lake Karapiro.

Lake Karapiro	
Lake area (km²)	7.70
Maximum operating level (masl)	53.45
Minimum operating level (masl)	50.62
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{7.3345}) - \mathbf{337.73}$	

Table 2-20: Lake Karapiro Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
51.5	7.70	0.00
51.7	7.70	1.46
51.9	7.70	2.93
52.1	7.70	4.40
52.3	7.70	5.86
52.5	7.70	7.33
52.7	7.70	8.80
52.9	7.70	10.27

2.3 SOUTH ISLAND

A total of fourteen lakes were reviewed in the South Island. Lakes Ōhau, Tekapo, Pūkaki Ruataniwha, Waitaki, Aviemore and Benmore are part of the Waitaki scheme and Lakes Te Anau and Manapōuri make up the Waiau scheme; both schemes are operated by Meridian Energy except for Lake Tekapo which is managed by Genesis Energy. Lake Hāwea, Dunstan and Roxburgh are managed by Contact Energy, and the natural Lakes Wānaka and Wakatipu were also studied. Figure 2-2 shows the locations of these lakes.

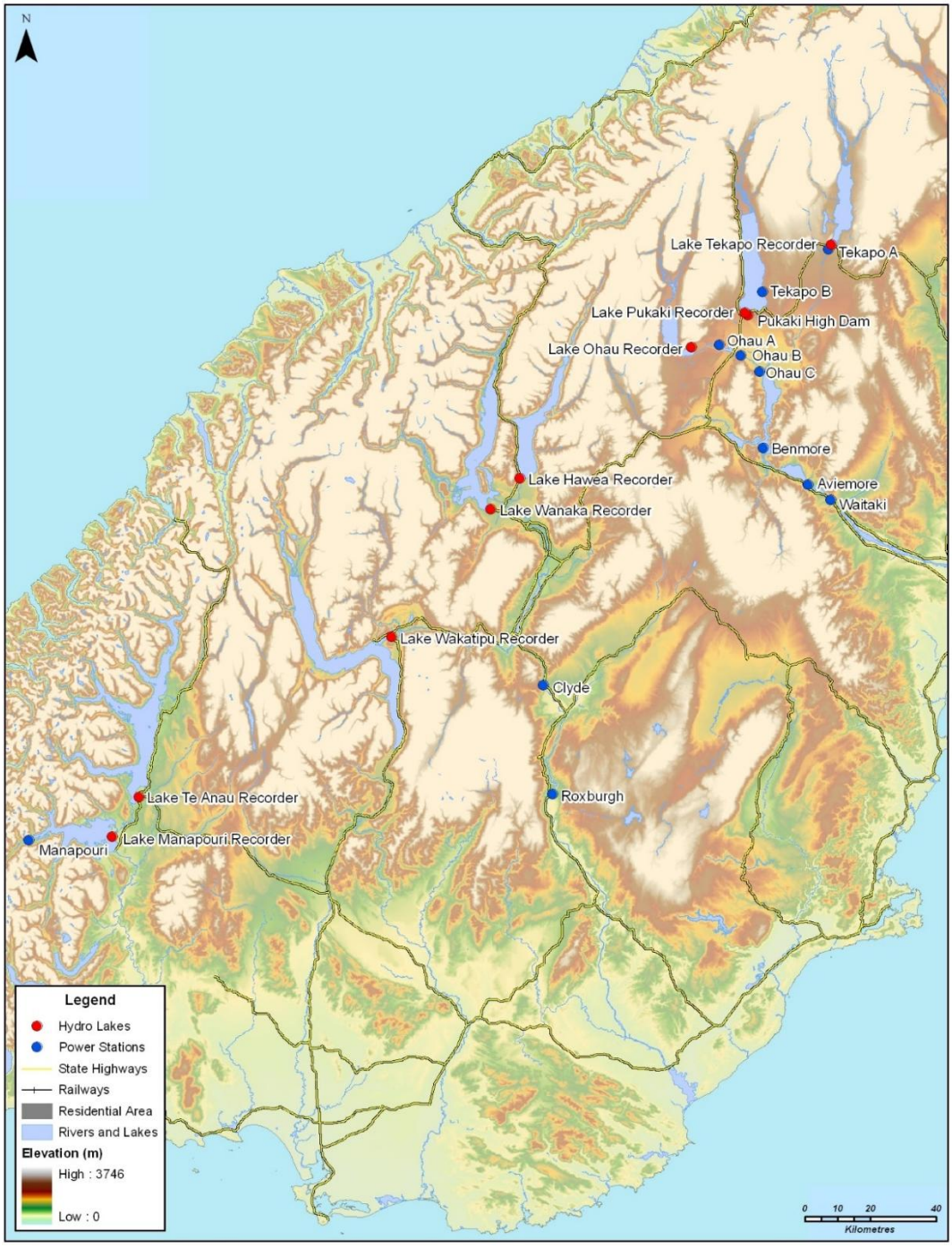


Figure 2-2. South Island hydro lakes part of the HMD storage and flow series.

2.3.1 LAKE TEKAPO

The consented minimum control level for Lake Tekapo is 701.8 masl. However, from 1 October to the following 31 March the effective minimum control level is 704.1 masl. Water below 704.1 masl can be used, however, only according to condition 14 Resource Consent number CRC905302.0 (Canterbury Regional Council):

The consented minimum control level for Lake Tekapo is 701.8 masl. However, from 1 October to the following 31 March the effective minimum control level is 704.1 masl. Water below 704.1 masl can be used, however, only according to condition 14 Resource Consent number CRC905302.0 (Canterbury Regional Council):

(a) From 1 October to the following 31 March the minimum operating level for Lake Tekapo shall not decrease below 704.1m masl except during any period during which the Electricity Commission (or any statutory body exercising like powers and functions to the Electricity Commission) determines:

(i) That reserve generation capacity (such as Whirinaki Power Station) is required to generate electricity; or

(ii) The National or South Island minimum zones (or their future equivalents) have been breached.

(b) The Grantee shall restore the level of Lake Tekapo to above 704.1m as soon as practicable and shall advise the Water Resources Manager, Canterbury Regional Council, weekly of strategies adopted until the lake level is restored to above 704.1m.

(c) The Grantee shall provide evidence that the circumstances set out in (i) exist to the Canterbury Regional Councils RMA Compliance and Enforcement Manager

This means that Tekapo has 'active contingent storage' available, if the above requirements are met. Therefore, some years this is available for generation, and is calculated separately in the dataset from the 'active' storage.

The maximum control level of Lake Tekapo varies throughout the year as shown in Table 2-21.

Table 2-21: Maximum control levels for Lake Tekapo.

Maximum Control Level (m)	Months
710.9	June to July
710.6	May
710.3	April and August
710.0	March
709.7	September to February

Table 2-22 provides a summary of the variability in the storage of water held in Lake Tekapo, including the consented and operating levels as well as the lake area. The associated active storage volumes are listed in the hydrological constraints dataset. A polynomial lake level–lake area rating was used to calculate the lake storage volumes, key values including both summer and winter equations are listed in

Table 2-23.

Table 2-22: Characteristics of Lake Tekapo.

Lake Tekapo	
Lake area (km²)	97.5
Normal operational maximum level (m)	709.7
Normal operational minimum levels (m)	702.1
March – October	701.8
October - March	704.1
Consented minimum level (m)	701.8
Winter Storage = $(-\mathbf{0.0120654091} \times \boldsymbol{LakeLevel}^{\mathbf{3}}) + (\mathbf{26.6378593716} \times \boldsymbol{LakeLevel}^{\mathbf{2}}) - (\boldsymbol{LakeLevel} \times \mathbf{19481.175113337}) + \mathbf{4722566.45591556}$	
Summary Storage = $((-\mathbf{0.0120654091} \times \boldsymbol{LakeLevel}^{\mathbf{3}}) + (\mathbf{26.6378593716} \times \boldsymbol{LakeLevel}^{\mathbf{2}}) - (\boldsymbol{LakeLevel} \times \mathbf{19481.175113337}) + \mathbf{4722566.45591556}) - \mathbf{191}$	

Table 2-23: Lake Tekapo Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
701.80	80.25	0.00
702.10	80.98	24.19
702.33	81.55	42.96
702.50	81.96	56.77
703.00	83.16	98.05
703.50	84.34	139.92
704.00	85.50	182.38
704.50	86.65	225.42
705.00	87.78	269.03
705.50	88.89	313.20
706.00	89.98	357.91
706.50	91.05	403.17
707.00	92.11	448.96
707.50	93.15	495.28
708.00	94.17	542.11
708.50	95.17	589.44
709.00	96.15	637.28
709.50	97.12	685.60
709.70	97.50	705.06
710.00	98.07	734.39
710.50	99.00	783.66

Level (m)	Area (km²)	Storage (Mm³)
711.00	99.91	833.39
711.50	100.80	883.56
712.00	101.68	934.18
712.50	102.54	985.24
712.88	103.17	1023.91
712.94	110.59	1030.31
713.36	111.61	1074.45
714.28	114.10	1170.26
715.25	116.72	1273.79
715.80	118.02	1332.72

2.3.2 LAKE PŪKAKI

The consented minimum control level for Lake Pūkaki is 518.0 masl, with a recent consent provision to allow to drawdown to 513.0 masl during dry seasonal conditions until 2028 The maximum control level varied throughout the year until 11 Sep 2012 as detailed in Table 2-24. Since 11 Sep 2012 the maximum control level is now 532.5 m year-round.

Table 2-24: Maximum control levels for Lake Pūkaki until 11 Sep 2012.

Maximum Control Level (m)	Months
532.5	May to August
532.0	September to April

Lake Pūkaki also has a separate consented contingent storage, where the lake can be lowered further and the available storage used for generation. This is the 'active contingent storage' available. Therefore, some years this is available for generation, and is calculated separately in the dataset from the 'active' storage.

Table 2-25 shows the characteristics of Lake Pūkaki, including the levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. A polynomial lake level–lake area rating was used to calculate the lake storage volumes. Key values are listed in Table 2-26.

Table 2-25: Characteristics of Lake Pūkaki.

Lake Pūkaki	
Lake area (km²)	178.70
Normal operational maximum level (m)	532.50
Normal operational minimum level (m)	518.20
Consented minimum level (m)	518.00
Maximum storage (million m³) - at normal operational maximum level	2335.92
Minimum storage (million m³) - at consented minimum level	0.00
Storage = $(\mathbf{0.8383} \times \boldsymbol{LakeLevel}^{\mathbf{2}}) - (\boldsymbol{LakeLevel} \times \mathbf{713.36}) + \mathbf{144584}$	

Table 2-26: Lake Pūkaki Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
518.00	154.47	0.00
518.20	154.84	30.93
520.00	158.14	312.62
522.00	161.74	632.51
524.00	165.27	959.52
526.00	168.72	1293.51
528.00	172.10	1634.34
530.00	175.41	1981.85
532.00	178.66	2335.92
532.50	179.46	2425.45
534.00	181.83	2696.42
536.00	184.94	3063.18
538.00	187.98	3436.10

2.3.3 LAKE ŌHAU

The operating range for Lake Ōhau is between 519.45 m and 520.25 m. Lake Ōhau is essentially managed as a 'run of the river' scheme because it has a weir at the outflow instead of control gates. Though Lake Ōhau is consented for contingent storage, because of the weir at the outflow this 'active contingent storage' is not used as such and is therefore not separated like other lakes with this type of consented contingent storage.

Table 2-27 shows the characteristics of Lake Ōhau, including the levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-28.

Table 2-27: Characteristics of Lake Ōhau.

Lake Ōhau	
Lake area (km²)	61.20
Normal operational maximum level (m)	520.25
Normal operational minimum level (m)	519.75
Consented minimum level (m)	519.45
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{62.181}) - \mathbf{32300}$	

Table 2-28: Lake Ōhau Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
519.45	60.23	0.00
519.60	60.51	9.80
519.75	60.78	18.92
519.90	61.06	28.08
520.05	61.33	37.28
520.20	61.61	46.52
520.25	61.70	49.60
520.35	61.89	55.79
520.50	62.16	65.15
520.65	62.44	74.48
520.80	62.71	83.89
520.95	62.99	93.34
521.10	63.27	102.83
521.25	63.54	112.36

2.3.4 LAKE TE ANAU

Lake Te Anau is a storage component in the Manapōuri Power Scheme (MPS) water balance, although the rapid turnover of water through the lake means that the total volume of water that can be stored for later electricity generation purposes is small.

Lake Te Anau fluctuates because of natural variations in inflow, and the controlled outflow via the Te Anau Lake Control Structure (TLC) to the Upper Waiau River. Under the Lake Operating Guidelines, the duration, rate, and return period of fluctuations is controlled to mimic, as far as possible, the natural lake level variations that occurred prior to the development of the power scheme. Operating ranges defined in the Guidelines for Lake Te Anau are as follows:

- *High Range*: above 202.7 m
- *Main Range*: between 201.5 m and 202.7 m
- *Low Range*: below 201.5 m

The top of the Main Range (202.7 m) is also known as the maximum control level and the bottom of the Main Range (201.5 m) is the minimum control level (Meridian, 2009).

However, the flood rules do not start to be applied at the maximum control level (top of the Main Range). They come into effect at a level of 203.3 m, which is 0.6 m into the high range. There are also further complications in relation to the high and low ranges as set out in the Manapōuri-Te Anau Development Act (Operating Guidelines, Appendix A). Within the high range (above the ‘maximum control level’) there are certain ranges which the lake level can reside. However, the lake cannot be static at any of these ranges, and there are maximum durations over which any lake level can remain stable.

For this report, the maximum operating level is 202.7 m, and the minimum operating level is 201.5 m, in accordance with the Main Range set out in the Act. However, the absolute minimum level of 200.86 m is used by Meridian Energy as the lower limit in their calculations. At this level they are only able to release a volume of water equal to the inflow to the lake.

Table 2-29 shows the characteristics of Lake Te Anau used in the analysis, including the levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. A large part of Lake Te Anau has vertical walls which produce a near-straight line; thus, a constant area was assumed for the lake storage rating. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-30.

Table 2-29: Characteristics of Lake Te Anau.

Lake Te Anau	
Lake area (km²)	352.00
Maximum operating level (m)	202.70
Minimum operating level (m)	201.50
Absolute minimum (m)	200.86
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{352}) - \mathbf{70703}$	

Table 2-30: Lake Te Anau Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
200.86	352.00	0
201.00	352.00	49.28
201.50	352.00	225.28
202.00	352.00	401.28
202.50	352.00	577.28
202.70	352.00	647.68
203.00	352.00	753.28

2.3.5 LAKE MANAPŌURI

Lake Manapōuri fluctuates because of natural variations in inflow, and the controlled outflow via the Manapōuri Lake Control Structure (MLC), just downstream of the confluence of the Mararoa and Lower Waiau Rivers. The Manapōuri Power Scheme (MPS) has operated under Lake Operating Guidelines developed by the Lakes Guardians since 1977. These Guidelines were incorporated into the Manapōuri-Te Anau Development Act 1963 (MTADA) in 1981. The first version of these Guidelines was published in the *New Zealand Gazette* on 3 December 1981. The guidelines have been amended several times subsequently.

The aim of the Lake Operating Guidelines is to protect the existing patterns, ecological stability, and recreational values of their 'vulnerable shorelines, and to optimise the energy output of the Manapōuri power station'. The Guidelines set out limits on the frequency, duration, and return period for the lake levels by describing low, main, and high ranges. The Guidelines also outline 'Gate Opening and Closing Procedures' that are applicable to the MLC and TLC structures.

Operating ranges defined in the Guidelines for Lake Manapōuri are:

- *High Range*: above 178.6 m
- *Main Range*: between 176.8 m and 178.6 m
- *Low Range*: below 178.6 m

The top of the Main Range (178.6 m) is also known as the maximum control level and the bottom of the Main Range (176.8 m) as the minimum control level (Meridian, 2009).

Like Lake Te Anau, Lake Manapōuri has a complicated system governing the control levels (Operating Guidelines, Appendix A). Within the high range (above the 'maximum control level') there are certain ranges within which the lake level can reside. However, the lake cannot be static at any of these ranges, and there are maximum durations over which any lake level can remain stable.

For this report, the maximum operating level is 178.6 m and the minimum operating level is 176.8 m. This is consistent with the Main Range set out in the Manapōuri-Te Anau Development Act (Operating Guidelines, Appendix A). However, the absolute minimum level of 175.86 m is used by Meridian Energy as the lower limit in their calculations. At this level they are only able to generate using a volume of water equal to lake inflow.

Table 2-31 shows the characteristics of Lake Manapōuri used in this analysis; including the levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake-level area rating was used to calculate the lake storage volumes; key values are listed in Table 2-32.

Table 2-31: Characteristics of Lake Manapōuri.

Lake Manapōuri	
Lake area (km²)	141.00
Maximum operating level (m)	178.60
Minimum operating level (m)	176.80
Absolute minimum level (m)	175.86
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{139.34}) - \mathbf{24506}$	

Table 2-32: Lake Manapōuri Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
175.86	141.00	0.00
176.80	141.00	129.79
177.00	141.00	157.55
177.20	141.00	185.37
177.40	141.00	213.24
177.60	141.00	241.16
177.80	141.00	269.13
178.00	141.00	297.16
178.20	141.00	325.24
178.40	141.00	353.37
178.60	141.00	381.55

2.3.6 LAKE HĀWEA

The consented minimum control level for Lake Hāwea is 338 m. However, this can be lowered to 336 m (previously 330 m) when the Electricity Authority determines that reserve generation should be used, i.e., it has a consented 'contingent storage'. This is calculated separately from the 'active storage' that is available in the storage dataset. The maximum control level is 346 m. This can, however, be exceeded under the Flood Management Plan.

Table 2-33 shows the characteristics of Lake Hāwea including the levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. A polynomial lake level–lake area rating was used to calculate the lake storage volumes. Key values are listed in Table 2-34.

Table 2-33: Characteristics of Lake Hāwea.

Lake Hāwea	
Lake area (km²)	141.7
Maximum operating level (m)	346.0
Minimum operating level (m)	338.0
Storage = $(\mathbf{0.939500} \times \boldsymbol{LakeLevel}^{\mathbf{2}}) - (\boldsymbol{LakeLevel} \times \mathbf{500.21}) + \mathbf{62758.0}$	

Table 2-34: Lake Hāwea Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
338.00	134.42	0
338.50	135.36	67.49
339.00	136.30	135.46
339.50	137.24	203.89
340.00	138.18	272.79
340.50	139.12	342.16
341.00	140.06	412.00
341.50	141.00	482.31
342.00	141.94	553.10
342.50	142.88	624.35
343.00	143.82	696.07
343.50	144.76	768.26
344.00	145.70	840.92
344.50	146.64	914.05
345.00	147.58	987.65
345.50	148.51	1061.72
346.00	149.45	1136.26

2.3.7 LAKE WĀNAKA

Lake Wānaka is a natural lake, with no control structure. It therefore does not have any consent conditions that manage water levels. It does, however, impact on the Clutha at Cardrona Confluence consent (Permit No. 2001.392 8c) where the flow cannot exceed 800 m³/s except when flood emergency conditions prevail. Contact Energy treat the normal operating range of Lake Wānaka as 276.35 m to 278.00 m (Table 2-35).

Table 2-35: 'Operating' levels Lake Wānaka.

Lake Wānaka	
Minimum operating level (m)	276.35
Maximum operating level (m)	278.00

At the minimum operating level, water is still being discharged and can be used for generation. Therefore, the thalweg level (275.40 m) at the lake outlet was taken to have storage of 0 m³. At the minimum operating level there is still estimated to be 183.35 million m³ of storage.

Table 2-36 shows the characteristics of Lake Wānaka used in this analysis, including the levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. The large size of Lake Wānaka means that a constant area was assumed for the lake storage rating. A linear lake level–lake area rating was used to calculate the lake storage volumes. Key values are listed in

Table 2-37.

Table 2-36: Characteristics of Lake Wānaka.

Lake Wānaka	
Lake Area (km²)	193.00
Maximum 'operating level' (m)	278.00
Minimum 'operating level' (m)	276.35
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{193}) - \mathbf{53152}$	

Table 2-37: Lake Wānaka Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
275.40	193.00	0.00
275.60	193.00	38.60
275.80	193.00	77.20
276.00	193.00	115.80
276.20	193.00	154.40
276.35	193.00	183.35
276.40	193.00	193.00
276.60	193.00	231.60
276.80	193.00	270.20
277.00	193.00	308.80
277.20	193.00	347.40
277.40	193.00	386.00
277.60	193.00	424.60
277.80	193.00	463.20
278.00	193.00	501.80

2.3.8 LAKE WAKATIPU

Lake Wakatipu is an uncontrolled lake, with no operating levels. Contact Energy use levels 309.60 m and 310.80 m for internal reporting regarding active storage. These numbers are adopted here as the minimum and maximum operating levels for consistency with information from Contact Energy.

Table 2-38 shows the characteristics of Lake Wakatipu used in the analysis, including the levels and lake area. The associated storage volumes are listed in the hydrological constraints dataset. The large size of Lake

Wakatipu means that a constant area was assumed for the lake storage rating. A linear lake level–lake area rating was used to calculate the lake. Key values are listed in Table 2-39.

Table 2-38: Characteristics of Lake Wakatipu.

Lake Wakatipu	
Lake area (km²)	293.00
Maximum 'operating' level (m)	310.80
Minimum 'operating' level (m)	309.60
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{289}) - \mathbf{89252}$	

Table 2-39: Lake Wakatipu Level-Area-Storage rating.

Level (m)	**Area (km²)**	**Storage (Mm³)**
308.83	293.00	0.00
309.00	293.00	49.13
309.20	293.00	106.93
309.40	293.00	164.73
309.60	293.00	222.53
309.80	293.00	280.33
310.00	293.00	338.13
310.20	293.00	395.93
310.40	293.00	453.73
310.60	293.00	511.53
310.80	293.00	569.33

2.3.9 LAKE DUNSTAN

Lake Dunstan currently has an operating regime of 1.0 m, from 193.5 to 194.5 masl. Contact Energy operates to specific consent conditions that control discharges from Lake Dunstan above and below this operating range.

Table 2-40 shows the characteristics of Lake Dunstan, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-41.

Table 2-40: Characteristics of Lake Dunstan.

Lake Dunstan	
Lake area (km²)	26.73
Maximum operating level (masl)	194.5
Minimum operating level (masl)	193.5
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{25.985}) - \mathbf{5028.2}$	

Table 2-41: Lake Dunstan Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
193.5	26.73	0.00
193.7	26.73	5.09
193.9	26.73	10.29
194.1	26.73	15.49
194.3	26.73	20.69
194.5	26.73	25.88
194.7	26.73	31.08
194.9	26.73	36.28

2.3.10 LAKE ROXBURGH

Lake Roxburgh currently has an operating regime of 2.45 m, from 130.15 to 132.60 masl. Contact Energy operates to specific consent conditions that control discharges from Lake Roxburgh above and below this operating range.

Table 2-42 shows the characteristics of Lake Roxburgh, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-43.

Table 2-42: Characteristics of Lake Roxburgh.

Lake Roxburgh	
Lake area (km²)	5.9
Maximum operating level (masl)	132.60
Minimum operating level (masl)	130.15
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{5.9993}) - \mathbf{780.81}$	

Table 2-43: Lake Roxburgh Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
130.15	5.9	0.00
130.35	5.9	1.20
130.55	5.9	2.40
130.75	5.9	3.60
130.95	5.9	4.80
131.15	5.9	6.00
131.35	5.9	7.20
131.55	5.9	8.40

2.3.11 LAKE RUATANIWHA

Lake Ruataniwha has a very small 0.8 m operating range and is considered operationally part of the Ohau B Canal by Meridian Energy as it is more similar to a slow moving river than a lake. As it also typically fluctuates twice per day an appropriate way to estimate storage is to use the target storage of 0.72 Mm^3.

Table 2-44 shows the characteristics of Lake Ruataniwha, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-45.

Table 2-44: Characteristics of Lake Ruataniwha.

Lake Ruataniwha	
Lake area (km²)	3.49
Maximum operating level (masl)	458.8
Minimum operating level (masl)	458.0
Storage Mm^3 = $\mathbf{0.72}$	

Table 2-45: Lake Ruataniwha Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
458.25	3.49	0.72

2.3.12 LAKE WAITAKI

Lake Waitaki currently has an operating regime of 3.8 m, from 227.0 to 230.8 masl. Meridian Energy operates to specific consent conditions that control discharges from Lake Waitaki above and below this operating range.

Table 2-46 shows the characteristics of Lake Waitaki, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A non-linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-47.

Table 2-46: Characteristics of Lake Waitaki.

Lake Waitaki	
Lake area (km²)	5.67

Maximum operating level (masl)	230.80
Minimum operating level (masl)	227.0
Storage = $(\boldsymbol{LakeLevel^2 \times 0.2958}) - (\boldsymbol{LakeLevel \times 130.27}) - \boldsymbol{14320}$	

Table 2-47: Lake Waitaki Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
228.7	5.67	0.00
229.2	5.67	1.27
229.7	5.67	4.01
230.2	5.67	6.89
230.7	5.67	9.92
231.2	5.67	13.10
231.7	5.67	16.43
232.2	5.67	19.91
232.7	5.67	23.53

2.3.13 LAKE AVIEMORE

Lake Aviemore currently has an operating regime of 2.8 m, from 265.5 to 268.3 masl. Meridian Energy operates to specific consent conditions that control discharges from Lake Aviemore above and below this operating range

Table 2-48 shows the characteristics of Lake Aviemore, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-49.

Table 2-48: Characteristics of Lake Aviemore.

Lake Aviemore	
Lake area (km²)	28.34
Maximum operating level (masl)	268.3
Minimum operating level (masl)	265.5
Storage = $(\boldsymbol{LakeLevel \times 27.51}) - \boldsymbol{7364.54}$	

Table 2-49: Lake Aviemore Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
267.7	28.34	0.00
267.9	28.34	5.89
268.1	28.34	11.32
268.3	28.34	16.76
268.5	28.34	22.19
268.7	28.34	27.63
268.9	28.34	33.06
269.1	28.34	38.50

2.3.14 LAKE BENMORE

Lake Benmore currently has an operating regime of 6.2 m, from 355.25 to 361.45. Meridian Energy operates to specific consent conditions that control discharges from Lake Benmore above and below this operating range

Table 2-50 shows the characteristics of Lake Benmore, including the maximum and minimum storage volumes. The associated storage volumes are listed in the hydrological constraints dataset. A linear lake level–lake area rating was used to calculate the lake storage volumes; key values are listed in Table 2-51.

Table 2-50: Characteristics of Lake Benmore.

Lake Benmore	
Lake area (km²)	75.85
Maximum operating level (masl)	361.45
Minimum operating level (masl)	355.25
Storage = $(\boldsymbol{LakeLevel} \times \mathbf{68.465}) - \mathbf{24680}$	

Table 2-51: Lake Benmore Level-Area-Storage rating.

Level (m)	Area (km²)	Storage (Mm³)
360.5	75.85	0.00
360.8	75.85	22.17
361.1	75.85	42.71
361.4	75.85	63.25
361.7	75.85	83.79
362	75.85	104.33
362.3	75.85	124.87
362.6	75.85	145.41

3 SPILL VOLUMES

To calculate potential generation, spill volumes from each of the major infrastructure are required. Spill flows that bypass generators do not generate power and therefore should not be included in potential generation.

There are many reasons for hydrological spill flow, Meridian Energy have split these into 11 categories:

1. Plant
2. Obstruction
3. High flow
4. Regulatory
5. Contractual
6. Recreation
7. Cost
8. Economic
9. Transmission constraint
10. Hydraulic constraint
11. Other

Meridian and other generators may also publish spill information regarding their respective schemes and the reasons for this.

Average daily spill volumes from 1 January 1980 to 31 December 2025 are included as part of this HMD update. With permission from Meridian Energy Ltd, Mercury Ltd, and Contact Energy Ltd, spill data was retrieved from the Power Archive held by WSP. The spill volumes for Lake Tekapo and Lake Waikaremoana have been received from Genesis Energy.

From 2020, the spill data is presented as ‘daily spill’, filed at 23:59, identical to the average daily flow datasets.

There were several gaps in these datasets. Gaps that were smaller than 24-hours were removed but longer gaps were kept in the datasets. These gaps have a ‘null’ value filed for the time step and a quality code of 100 applied to the period of missing record. This is because spill data cannot be reliably synthesised and is therefore more appropriate to be filed as ‘missing’.

3.1 NORTH ISLAND

3.1.1 WAIKATO POWER SCHEME

Daily spill volumes for each of the major dams in the Waikato Power Scheme are included in the HMD: Lake Taupō; Lake Aratiatia; Lake Ōhakuri; Lake Ātiamuri; Lake Whakamaru; Lake Maraetai; Lake Waipapa; Lake Arapuni; and Lake Karapiro. Lake Taupō outflows have also been included as all outflows from Lake Taupō through the control gates are technically spill flows.

This spill data, collected by Mercury, is the best data available at this time. The quality of this data is not guaranteed and therefore should be used accordingly.

3.1.2 WAIKAREMOANA POWER SCHEME

Daily average ‘spill’ volumes for each of the major dams in the Waikaremoana Scheme are included in the HMD: Lake Waikaremoana – Onepoto; Waikaretaheke River at Piripaua; and Waikaretaheke River at Upstream Mangaone.

Lake Waikaremoana – Onepoto is the spill from Lake Waikaremoana which can be either operational or regulatory. The lake level (maximum control level) could be used to determine whether the spill is regulatory or not.

The Waikaretaheke River at Piripaua and Waikaretaheke River at U/S Mangaone flow records can be used to determine the spill flows from Lake Kaitawa and Lake Whakamarino. Waikaretaheke River at Piripaua shows the spill from either Lake Kaitawa or Lake Whakamarino, as it is situated below the Waikaretaheke Diversion and the Whakamarino spillway. Waikaretaheke at U/S Mangaone shows the natural and spill flow from Lake Kaitawa. Any flows above ~6 m^3/s at the Waikaremoana River at U/S Mangaone flow site is most likely spill from Lake Kaitawa; it has a baseflow of approximately 0.8-0.9 m^3/s. The flows can be separated from the U/S Mangaone site from the Piripaua site to determine when there is spill at Lake Kaitawa, and when the spill is from Lake Whakamarino. The exception is under high rainfall conditions, which will cause natural inflow below the Waikaretaheke diversion, resulting in flow measured at the Piripaua site.

This spill data, collected by Genesis Energy Ltd, is the best data available at this time. The quality of this data is not guaranteed and therefore should be used accordingly. Not all datasets begin in 1980 and consequently have different start dates to some other datasets.

3.2 SOUTH ISLAND

3.2.1 WAITAKI POWER SCHEME

Daily average spill volumes for each of the major dams in the Waitaki Power Scheme are included in the HMD: Lake Tekapo Gate 17; Lake George Scott – Tekapo River; Lake Pūkaki; Lake Ōhau; Lake Ruataniwha; Lake Benmore; Lake Aviemore; and Lake Waitaki.

Lake Tekapo Gate 17 data is the spill data from Lake Tekapo that bypasses only Tekapo A Power Station. Lake George Scott – Tekapo River is the spill data from Lake Tekapo that bypasses Tekapo A and B Power Stations and well as Ōhau A, B and C Power Stations.

3.2.2 MANAPŌURI POWER SCHEME

Daily average spill volumes for each of the major dams in the Manapōuri Power Scheme are included in the HMD: Lake Te Anau; and Lake Manapōuri. Lake Te Anau outflows have been included as all outflows from Lake Te Anau through the control gates are technically spill flows.

3.2.3 CLUTHA POWER SCHEME

Daily average spill volumes for each of the major dams in the Clutha Power Development are included in the HMD: Lake Hāwea; Lake Dunstan; and Lake Roxburgh. Lake Hāwea outflows have been included as all outflows from Hāwea through the control gates are technically spill flows.

4 REFERENCES

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