Lake Level History

Electricity Commission

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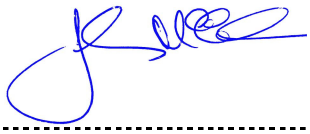

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Contents

1 Hydro Lakes

1.1 Introduction

This report provides a brief history of the fluctuations in the levels of the major lakes used for hydropower generation for New Zealand. The chronologies for each lake provide key information and dates relating to those factors that influence the level records.

The data provided with this report are the average daily lake levels for the entire length of record available. These data have been obtained from the Power Archive, which is maintained by Opus International Consultants under contract to the various power generation companies.

It should be noted that the average lake level recorded is a function of the interaction of a large number of 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. While the effect of some of these factors is minimised by using daily averages, all factors must be considered when analysing the various lake level records.

The data presented 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 heights. These changes to the data over time usually only affect the more recent record.

On some of the lakes there are multiple recorders maintained by different agencies. The data from these individual recorders are often treated in a different manner, and related to different datums. As a result it is possible to have multiple records for the same lake showing different heights. This issue, and the relationship between the various records, is discussed in more detail in the last chapter of this report. The data shown in the body of this report, however, are the average daily values from the Power Archive. When more detailed analysis is required, it is suggested that the power generation company that manages the lake levels be approached directly for higher resolution data.

1.2 Accuracy

As a result of changes in technology over time the accuracy of lake level data, both vertical and temporal, has increased. Increased accuracy in the lake level records will therefore be a response to changes in the methods by which lake levels have been recorded. For example, manual staff gauge readings are probably only accurate to ±10mm while modern shaft encoders in stilling wells are accurate to

±1mm. The accepted levels of accuracy of the various lake level recording methods that have been used throughout New Zealand are summarised in Table 1.1.

Table 1.1 Accuracy of various lake level measurement techniques

Level measurement technique	General accuracy
Staff gauge	±10mm
Littlejohn recorder	±20mm
Kent recorder	±20mm
Lea or Foxboro recorder	±20mm
Fischer and Porter	±3mm
Digital encoder	±1mm

Likewise, daily staff gauge readings have significantly lower temporal resolution than 15min encoder readings. The temporal resolution of the data in this report should not be a major consideration since only daily average lake levels have been used.

It is therefore important to consider the recording method when analysing trends in the lake level records if subtle changes are being investigated. When high resolution temporal data are required for analysis this should be requested directly from the current recording authority.

1.3 North Island

Lake Taupo and Lake Waikaremoana are both located in the North Island (Figure 1.1). Mighty River Power operates the Waikato hydro power scheme, which includes the Lake Taupo gates. Genesis Energy operate the Lake Waikaremoana scheme.

There are a number of 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 1-days storage, are totally managed, and are often artificial as opposed to natural water bodies e.g., impounded river valleys.

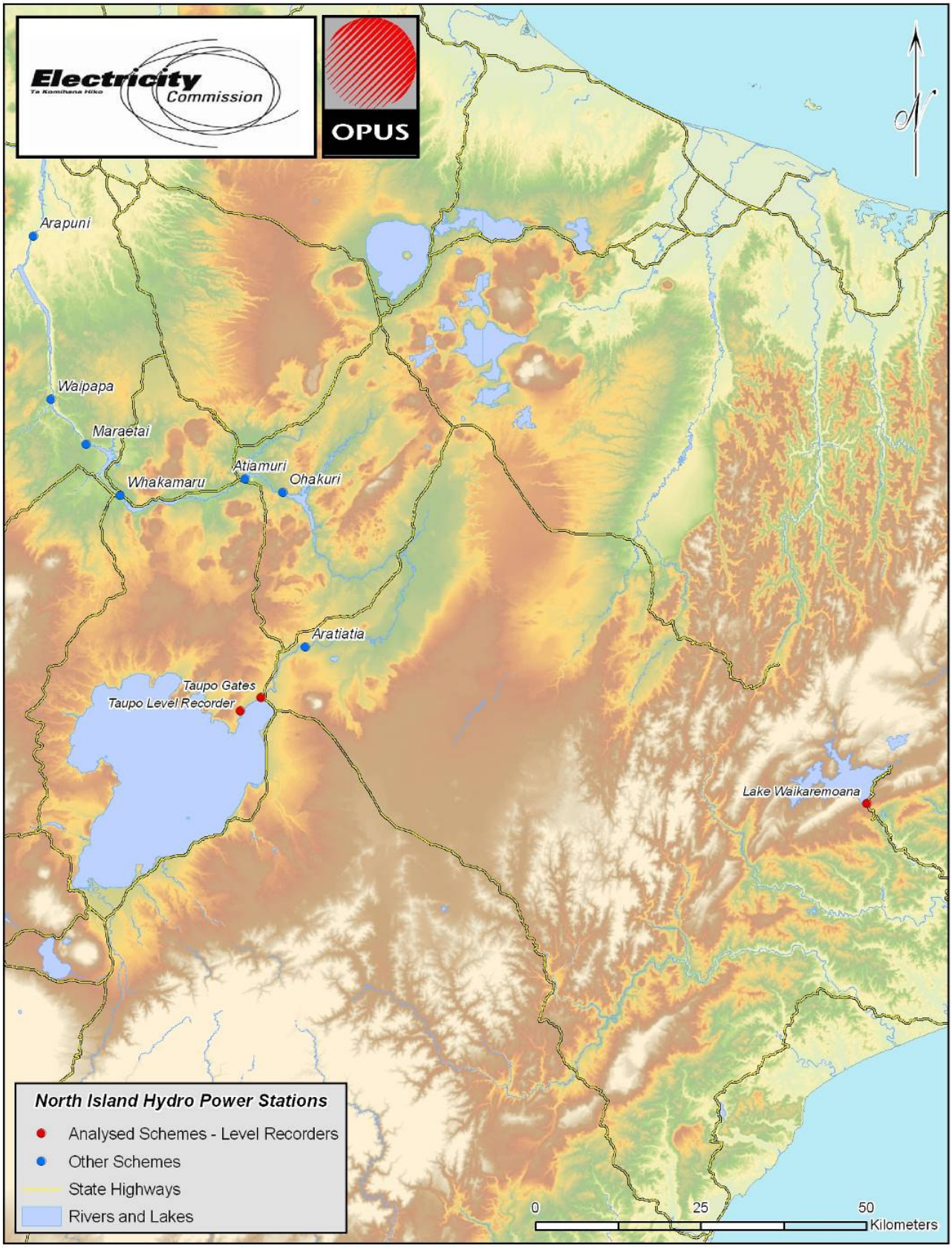

Figure 1.1 North Island Hydro Lakes Reviewed

1.4 South Island

A total of eight lakes were reviewed in the South Island. Lakes Ohau, Tekapo and Pukaki are part of the Waitaki scheme; and Te Anau and Manapouri make up the Waiau scheme; both scemes are operated by Meridian Energy. Lake Hawea, Operated by Contact Energy, and the natural Lakes Wanaka and Wakatipu were also studied. Figure 1.2 shows the locations of these lakes.

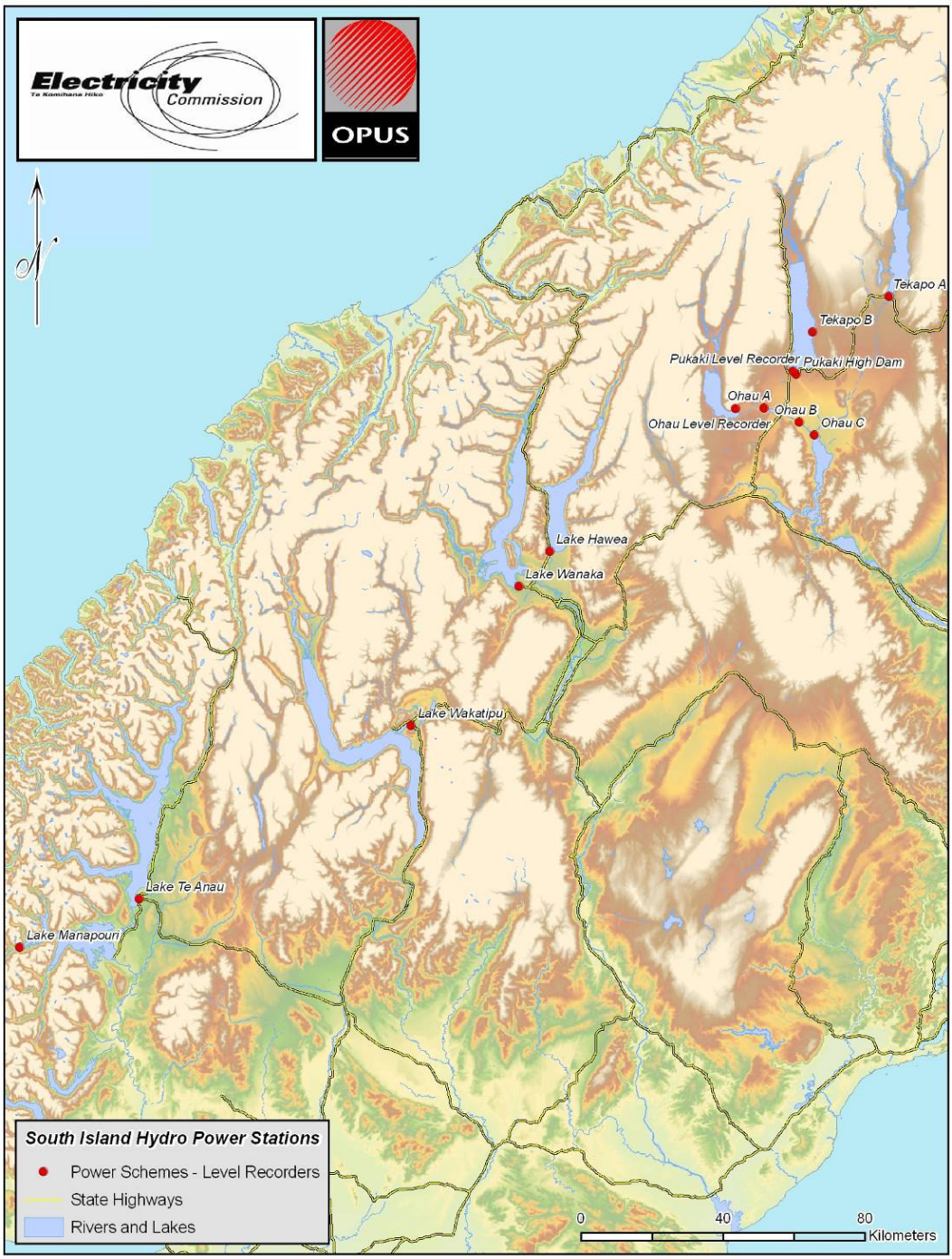

Figure 1.2 South Island Hydro Lakes Reviewed

2 North Island

2.1 Lake Taupo

2.1.1 History

Construction of the Lake Taupo Gates began in 1940 and they were completed and operational by September 1941. Since completion, the gates have been used to regulate the lake level, and to ensure that water is used efficiently and managed responsibly.

In times of extreme rainfall, the gates are used to retain water in the lake to reduce flooding downstream. In times of drought, the gates are used to conserve the water in the lake while still complying with the minimum flow conditions set for the Waikato River.

The Taupo outflow is recorded at the Taupo Gates. Lake level is currently recorded at a recorder in Acacia Bay; however it has been recorded at Lake Taupo Harbour, Waipahihi and Tokaanu previously. The lake is managed by Mighty River Power. The lake catchment is approximately 3300km^2 with the lake surface covering approximately 616km^2.

Table 2.1 Timeline of Key Events

Period	Event
Jul 1905 - Nov 1932	Daily manual staff gauge readings taken in Lake Taupo Harbour. The BMs of this staff gauge were accurately levelled to MSL Moturiki with the gauge zero at 355.833m. The BMs are the origin of the Lake Datum (or Taupo Datum). Levels to Lake Datum are converted to Moturiki Datum by subtracting 1362mm. At times, the interval between readings was greater than a day.
24 Nov 1932	A Littlejohn recorder was established at Waipahihi and daily levels have been read from these charts. The recorder zero is the same as the original staff gauge RL Zero 355.833m Moturiki Datum until changed to the Lake Datum on 19 February 1940.
Sep 1941	Lake Taupo control structure was completed in September 1941 and daily lake level readings made by New Zealand Electricity Department (NZED) at 7:30 am on a new staff gauge in the harbour. The SG was in terms of Lake Datum. On 12 February 1975 it was found that the 1170.00ft mark was 1170.174ft Lake Datum. Basic readings have not been adjusted for this (53mm) but have been converted to Moturiki by subtracting 1362mm.
Sep 1941	Lake level control commenced.
1947	Lake Taupo Compensation Claims Act introduced which set maximum operational levels.
1 Jan 1953	Lake levels were read from the Littlejohn charts at 0hrs daily and converted to MSL Moturiki Datum by subtracting 1362mm.
1 May 1959	Kent monthly recorder installed at Waipahihi and processed manually to give daily levels at 0hrs. This recorder was calibrated in Lake Datum; and 1362mm has been subtracted to get MSL Moturiki. A check on 12 February 1975 showed that the 1170 ft mark was actually 1170.02ft Lake Datum. This correction has been applied.

Period	Event
1 Jan 1966	Kent charts digitised to an apparent datum of 1170ft Lake Datum. To convert to MSL Moturiki Datum, 355.254m has been added.
Nov 1968	Seasonal Maximum Control levels introduced.
1 Feb 1971	TPD Western Diversion began into Lake Taupo.
1 Sep 1973	Another recorder, a Lea recorder, was installed at the Tokaanu Wharf where 12 hourly values were extracted. This was in terms of Lake Datum, and when checked on 7 April 1976, it was found that 1170ft Lake Datum read 355.296m MSL Moturiki. W&S data has been altered accordingly to give an apparent zero of 350.00 m and Power Archive data is to MSL, Moturiki Datum.
3 Apr 1975	The Lea recorder at Tokaanu was changed to a 5 minute Fischer and Porter with SG as above. On 7 April, the SG was converted to metric with a zero of 350.00m MSL Moturiki.
Nov 1975	Waikato Flood Management Rules introduced (HDO 1080 A).
12 Dec 1978	An additional recorder was established at Acacia Bay. This recorder was levelled to Taupo Fundamental and its zero is 354.873m, assuming that Taupo Fundamental was 363.269m (i.e. level in terms of the Act). Levels given by this recorder differ from those at Tokaanu.
8 Oct 1979	TPD Eastern Diversion began into Lake Taupo.
1 Oct 1983	At Acacia Bay, the RL zero of the staff gauge is 354.873m based on Taupo Fundamental BM 1956 level of 363.269m. The adoption of this new level is based on recommendations in a MWD report (Freestone, 1986).
3 Aug 1988	Acacia Bay SG RL zero checked at 354.870m by transferring across lake from Taupo Fundamental 1956 level 363.269m. Tokaanu check on SG zero by transfer of levels from Taupo Fundamental (1956) revealed SG zero as 350.018m (nominal level was 350.00m).
8 Sep 1988	Staff gauge zero for Acacia Bay recorder reset to 354.876m based on Taupo Fundamental (1967 not 1956).
8 Jan 1989	From this date, Lake Taupo level has been from the recorder at Acacia Bay SG zero 354.876m.
26 Aug 1993	Lake level transferred across lake from Taupo Fundamental. New RL zero at Tokaanu was found to be 350.027m.
22 Jul 1999	A survey of water level recorder datum in terms of Taupo Fundamental was carried out. This established the Acacia Bay SG RL zero at 354.86m and Tokaanu at 350.004m in terms of Taupo Fundamental 1956 level.
2006	New consent conditions finalised. A single maximum control level introduced. A Water Level Recorder Datum Check Study highlighted the Acacia Bay SG RL zero changed to 354.857m ASL, Moturiki datum 1956; and Tokaanu Wharf 349.929m ASL, Moturiki datum 1956.

2.1.2 Current Operating Consents

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

Management of Lake Taupo

2.1 *The consent holder may at any time operate the Taupo gates to manage to level of Lake Taupo, 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 Taupo 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.*

Minimum Outflow

2.3 *The minimum outflow from the Taupo 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.*

Maximum Control Level

2.4 *The Taupo Gates may not be used to manage the level of Lake Taupo above 357.25 masl primarily for the purposes of generating electricity. If at any time the lake rises above this level the Taupo 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 Taupo gates according to a management regime designed to achieve the following objectives for the level of Lake Taupo:*

i. *A less than 20% annual exceedance probability of 357.25 masl (i.e., an average 1 in 5 year recurrence interval).*
ii. *A less than 5% annual exceedance probability of 375.39 masl (i.e., an average 1 in 20 year recurrence interval).*
iii. *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 Taupo 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 Taupo Gates in order to meet the objectives defined in condition 2.5 above.

Minimum Control Level

2.8 When the level of Lake Taupo is below 355.95 masl but above the minimum control level (355.85 masl), the Taupo 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 Taupo is below 355.85 masl, Taupo outflows shall not exceed Taupo inflows and when, in these circumstances, Taupo inflows are sufficient to exceed the minimum flow at Karapiro, any such excess inflow shall be managed to raise the level of Lake Taupo above 355.85 masl.

Exclusions

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.*

2.1.3 Lake Level

The entire record of Lake Taupo level is shown in Figure 2.1, and as a strip in Figure 2.2 for more detail. The level is relative to the Moturiki Datum 1956.

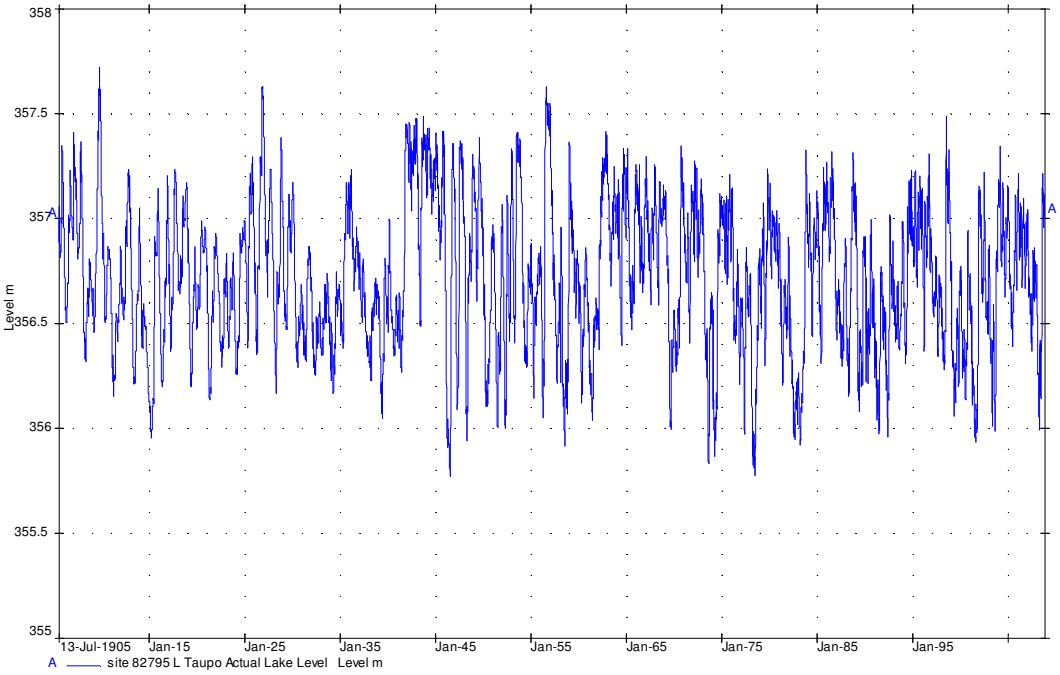

Figure 2.1 Lake Taupo Level Record (m) 1905 to 2008

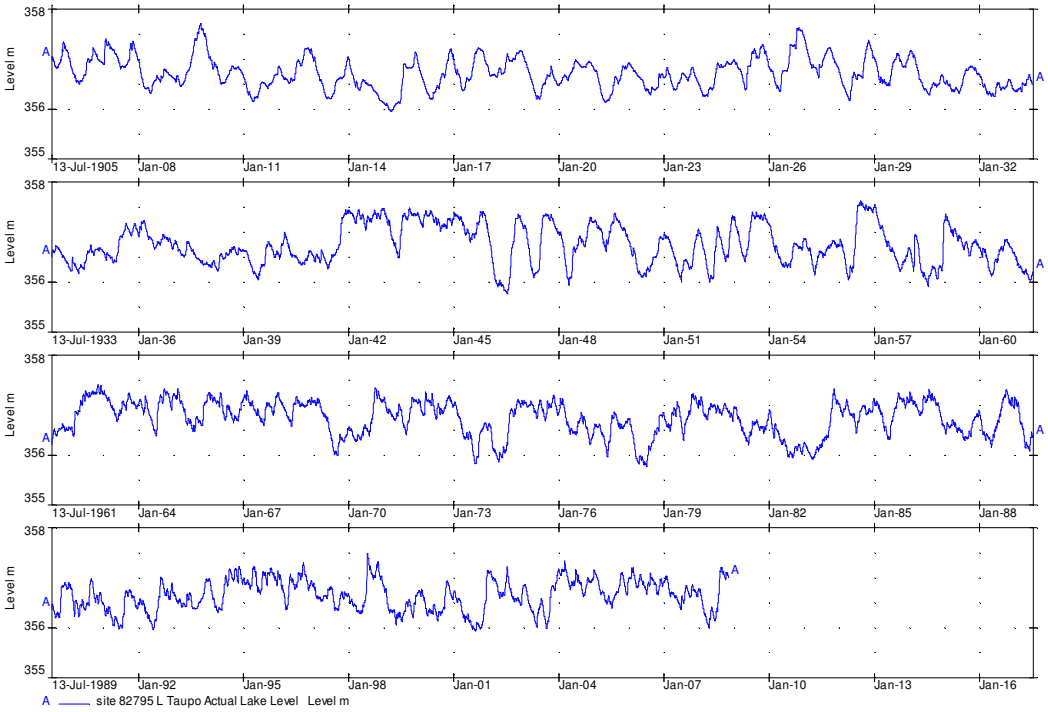

Figure 2.2 Lake Taupo Level (m) Strip 1905 to 2008

2.2 Lake Waikaremoana

2.2.1 History

The Waikaremoana Power Scheme is comprised of three power stations; Tuai, Piripaua, and Kaitawa. Tuai was commissioned in 1929 with two machines. A third machine was added in 1939. The station is located approximately 2.5km southeast of Lake Waikaremoana. Tuai discharges into Lake Whakamarino. The station has a total capacity of 60 MW. Piripaua was commissioned in 1943 and has a capacity of 42MW. The station is located a further 3.5km southeast of the Tuai station. Kaitawa power station, commissioned in 1948, has a capacity of 36MW and is located between Lake Waikaremoana and the Tuai power station.

Lake Waikaremoana operated under the influences of natural control until the introduction of siphons in the mid 1940's. The Lake was lowered by 5m in 1946 and the natural lake level range is 7m.

Waikaremoana is the North Island's deepest lake at 256m. It has a lake area of 54km² and catchment area of 373km². Lake level is managed by Genesis Energy.

Table 2.2 Timeline of Key Events

Period	Event
19th Century	Chief Mahaki's historic flood level 620.88 m (maximum natural level 1921-45 – 617.525 m).
1 Jun 1921 to 1923	Lake Waikaremoana level recorded on a staff gauge by construction staff working on the Tuai power station. Levels were natural.
1923 to 22 Apr 1981	Tuai Power Station commissioned and lake level recorded at the station by a staff gauge. Two machines in 1929, and a third in 1939.
3 Feb 1931	"Napier Earthquake" – main spring lake outflows affected. Possibly a 4% increase.
1943	Piripaua Power Station commissioned.
1945	Lake Waikaremoana Control Structures start to influence level record.
May 1946	Full control exerted. Lake is lowered by 5m.
Late 1940's early 1950's	Sealing of spring outlets reduced flows significantly.
1948	A third station, Kaitawa, was commissioned.
1955	Syphons installed at natural outlet.

2.2.2 Lake Level

The entire level record for Lake Waikaremoana is shown in Figure 2.3, and as a strip in Figure 2.4 for more detail. The level is relative to the Moturiki Datum 1956.

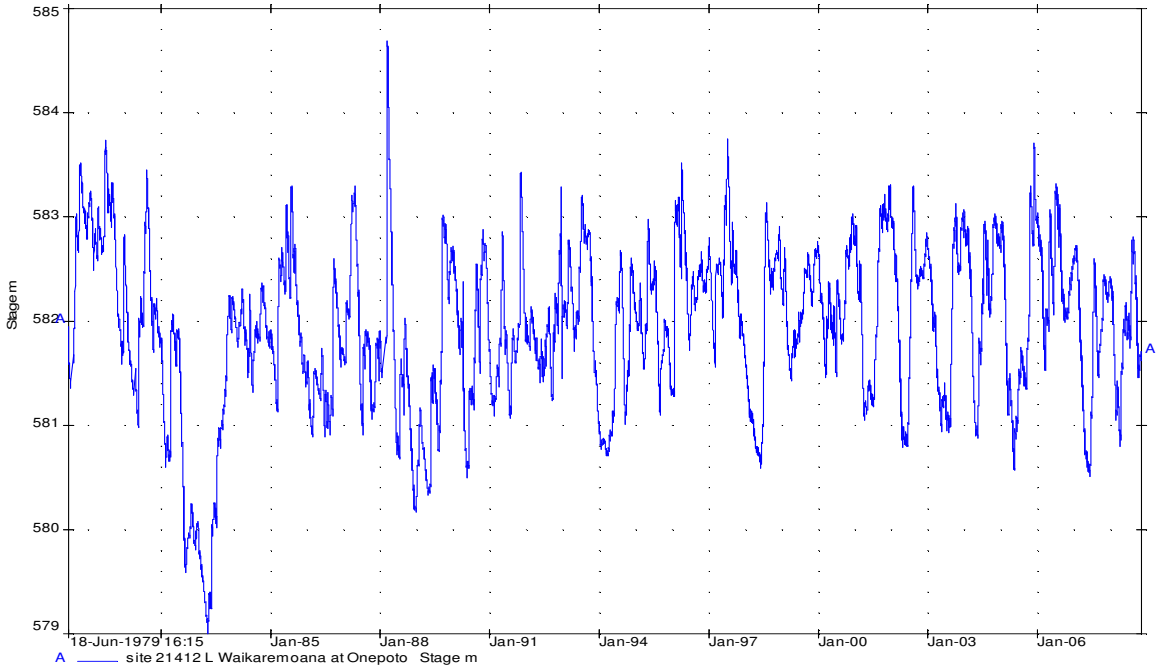

Figure 2.3 Lake Waikaremoana Level Record (m) 1979 to 2008

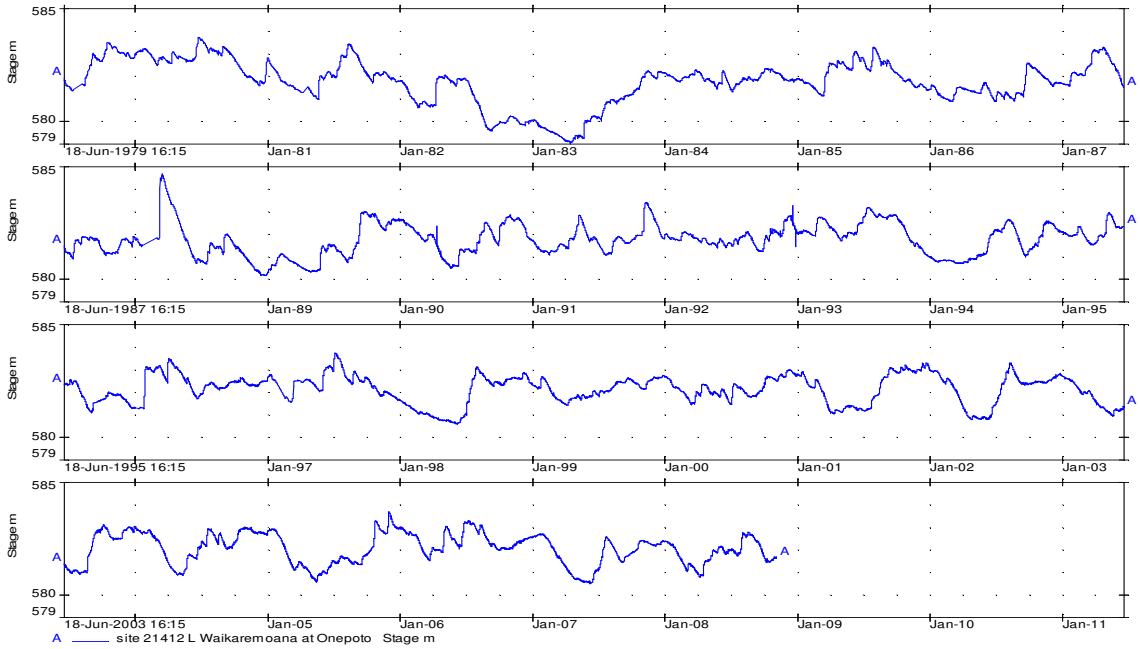

Figure 2.4 Lake Waikaremoana Level (m) Strip 1979 to 2008

2.2.3 Current Operating Consents

Lake Waikaremoana currently has an operating regime of three metres, 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. For example, the maximum lake level can be exceeded when Genesis Energy is releasing a controlled discharge from Lake Waikaremoana (Table 2.3). Lake Waikaremoana is also managed to reflect natural lake level cycling. That is, high lake levels heading into summer, reducing levels during summer and autumn, and increasing levels during winter and spring.

Table 2.3 Controlled discharge rates from Lake Waikaremoana when Lake level exceeds 583.29 masl

Lake Level	Controlled discharge (m^3/s)
<583.29	No controlled release
≥583.29	43
≥583.49	47
≥583.69	51
≥584.09	55

3 South Island

3.1 Lake Ohau

3.1.1 History

The Ohau hydro scheme, now operated by Meridian Energy, consists of three power stations; Ohau A, Ohau B and Ohau C. Ohau A is located approximately 7.5km downstream of the Lake Ohau Outlet and at the inlet to Lake Ruataniwha. Ohau B is located approximately 5km downstream of Lake Ruataniwha; and Ohau C power station is a further 5km downstream at the inlet to Lake Benmore (Figure 1.2).

The Ohau A power station was commissioned in June 1979 and has a generation capacity of 248MW. The outflow record prior to the commissioning of Ohau A is therefore uncontrolled. Ohau B, commissioned in 1983, has a capacity of 212MW. Ohau C also has a capacity of 212MW and was commissioned in 1985.

Lake level records for Ohau began on 8 October 1926 with daily measurements until 1966 when digitised Kent chart records were used. In 1977, the current gauge at Moose Lodge replaced the Kent chart recording. Prior to 1986, data for Ohau A was received on manual sheets before the WESDAC automated recording system was introduced.

Lake Ohau is at an elevation of 520 m and reaches a depth of 129m. The lake has a catchment area of 1135km² and a lake area of 61.2km² (at normal maximum level).

Table 3.1 Timeline of Key Events

Period	Event
8 Oct 1926	Daily lake level measurements began from staff gauge.
17 Dec 1931	Littlejohn recorder installed at Lake Middleton.
1966	Lake level started to be measured by Kent charts. (Kent recorder installed 15/5/59 – not digitised at that time).
1977 to present	Lake level measurement was changed to be measured at Moose Lodge.
6 May 1979	Spill weir commissioned.
29 May 1979	Ohau A power station was commissioned with a 248MW capacity. Ohau Canal commissioned.
1983	Ohau B power station was commissioned with a 212MW capacity.
1985	Ohau C power station was commissioned with a 212MW capacity.
1986 to present	Ohau A data switched from manual sheet recordings to the digital WESDAC system.
Mar 1991	Consents issued. New control levels for Lake Ohau operation.

3.1.2 Current Operating Consents

The consented operating range is 519.45m to 520.40m.

3.1.3 Lake Level

The Lake Ohau level record is shown in Figure 3.1, and as a strip in Figure 3.2 for further detail.

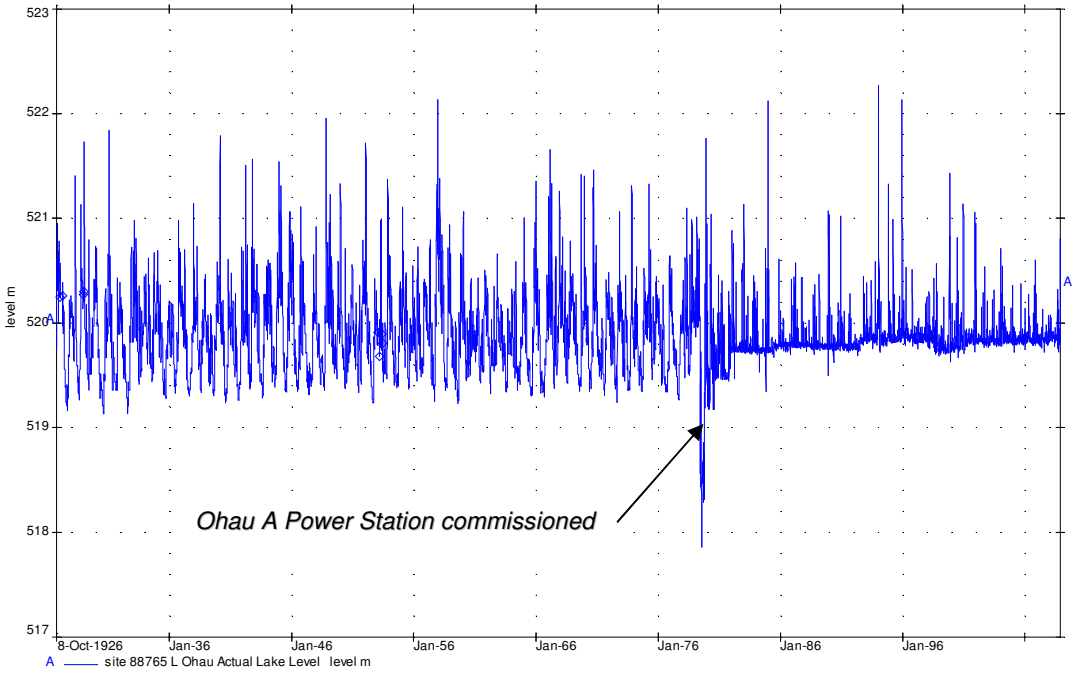

Figure 3.1 Lake Ohau Level Record (m) 1926 to 2008

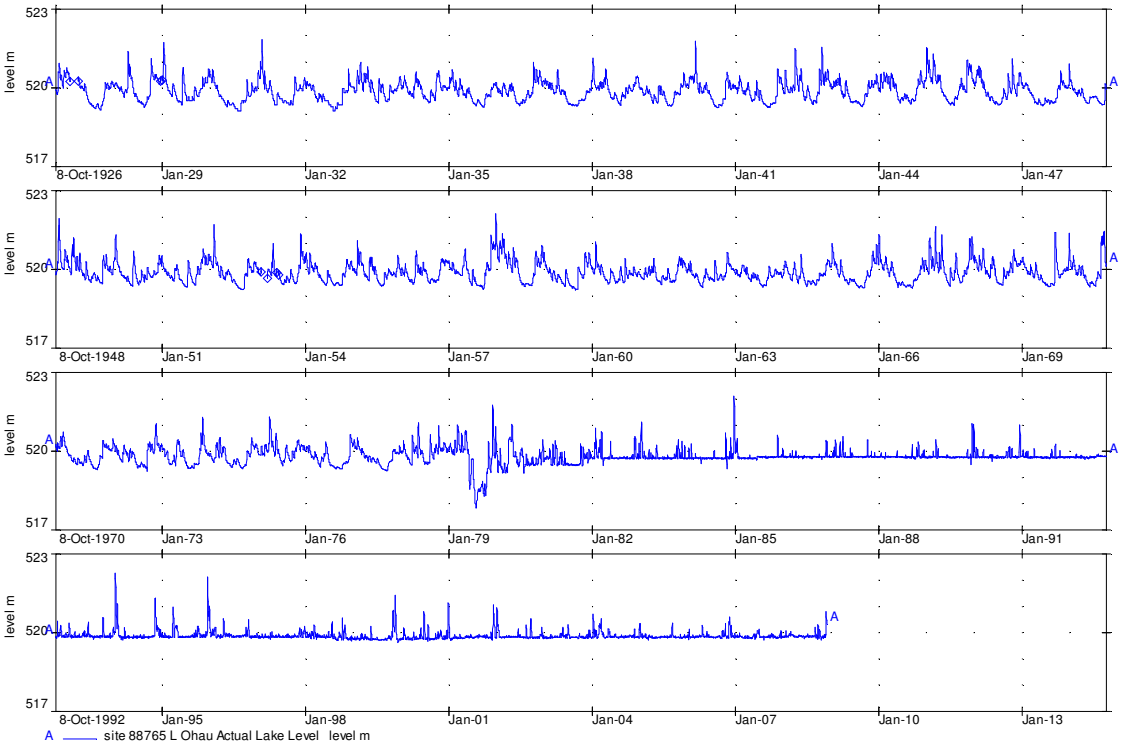

Figure 3.2 Lake Ohau Level (m) Strip 1926 to 2008

3.2 Lake Tekapo

3.2.1 History

The Lake Tekapo hydro scheme was built between 1938 and 1951. In 1942, construction was halted because of the war; work recommenced in 1944. The scheme, now operated by Meridian Energy, consists of two power stations: Tekapo A, commissioned in 1951; and Tekapo B, commissioned in 1978. The generation capacity of Tekapo A is 25MW while the Tekapo B station has a much larger generation capacity of 160MW.

Tekapo A power station was the second to be constructed as part of the larger Waitaki Power Scheme. The influence of the power station on the lake level of Tekapo is clear following its commissioning in 1951. Tekapo A power station records commenced in August 1965.

Flows were originally passed into the Tekapo River below the Tekapo A station, at the southern end of the lake. Since August 1978, and the commissioning of a 26km intake tunnel joining to a second power station, Tekapo B, flows have been passed into Lake Pukaki. Tekapo B power station is located on the eastern shores of Lake Pukaki (Figure 1.2).

Lake Tekapo has a surface area of 97.5km² (at normal maximum level) and a catchment area of 1440km². The lake is at an altitude of 700m above sea level.

Table 3.2 Timeline of Key Events

Period	Event
3 Mar 1925 to 1951	Natural lake level recorded manually by staff gauge.
29 Sep 1931	Littlejohn recorder installed at the bridge.
Jun 1951	Tekapo A power station commissioned with a maximum generation capacity of 25MW.
24 Jun 1951	Lake Tekapo Control Structure commissioned to regulate outflow to Tekapo River and into Lake Scott.
Feb 1952	Control Dam first operated.
Aug 1965	Tekapo A power station records began.
Feb 1978	Tekapo B power station commissioned with a maximum generation capacity of 160MW. The power station is located at the end of a 1.6 km intake tunnel running from Tekapo A. The station is located on the eastern shore of Lake Pukaki.

3.2.2 Current Operating Consents

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

"*(a) From 1 October to the following 31 March the minimum operating level for Lake Tekapo shall not decrease below 704.1m amsl 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 min 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

The maximum control level varies throughout the year as shown in Table 3.3.

Table 3.3 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

3.2.3 Lake Level

The Lake Tekapo level record is shown in Figure 3.3, and as a strip in Figure 3.4 for more detail.

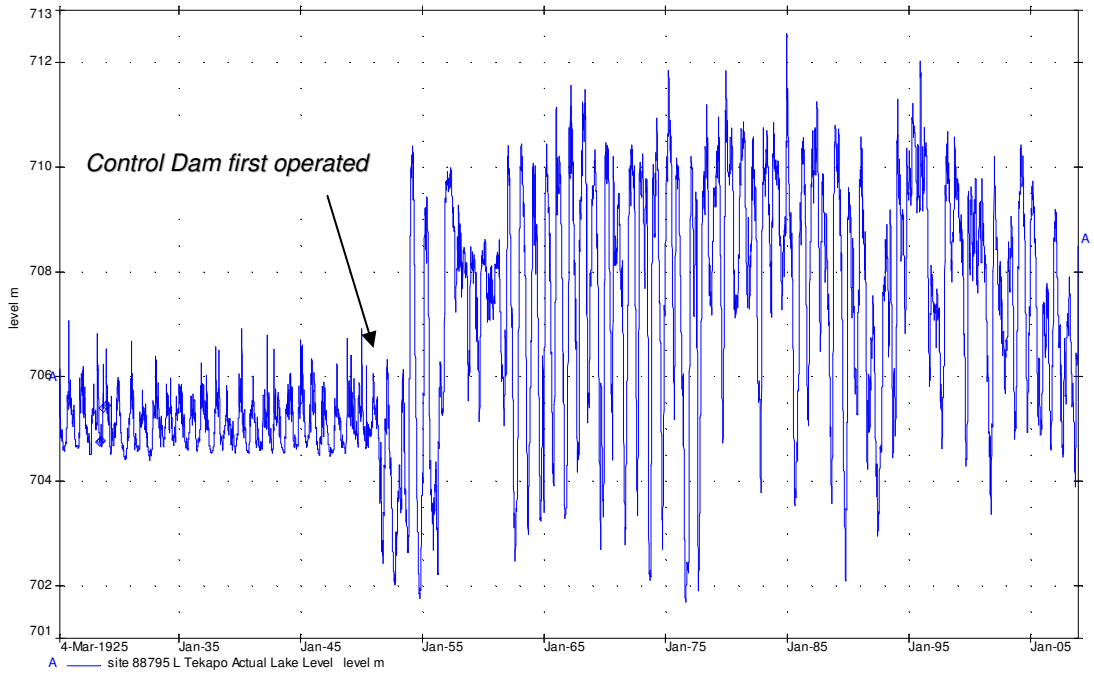

Figure 3.3 Lake Tekapo Level Record (m) 1925 to 2008

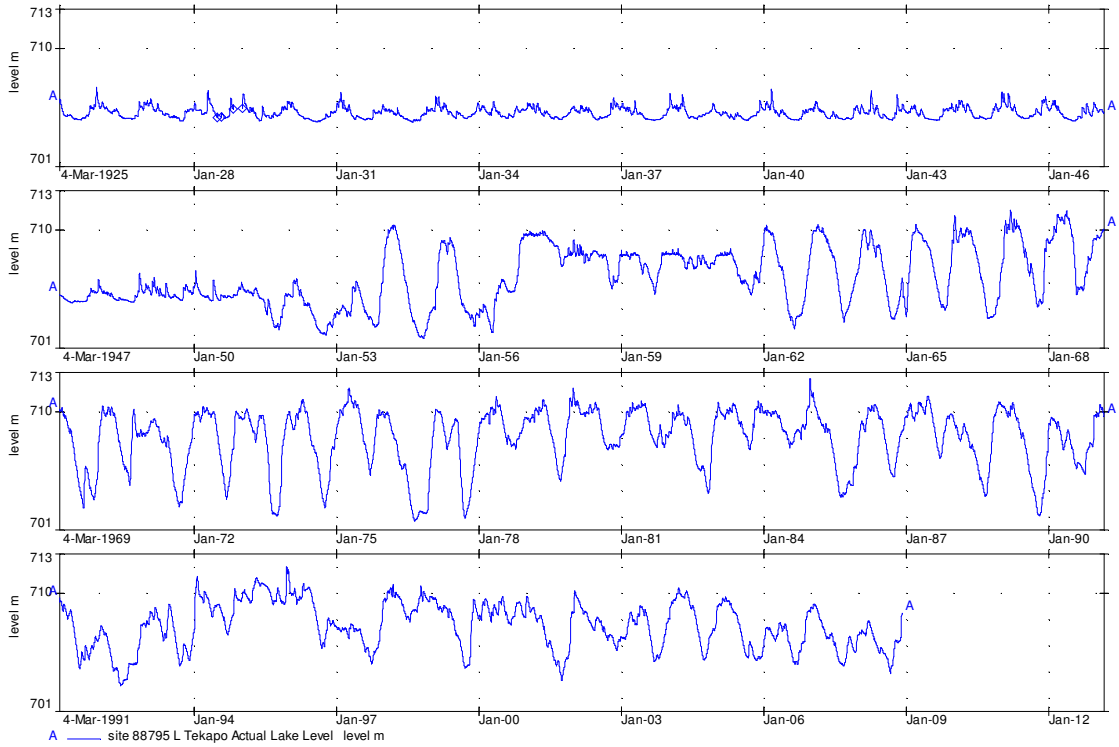

Figure 3.4 Lake Tekapo Level (m) Strip 1925 to 2008

3.3 Lake Pukaki

3.3.1 History

The first Pukaki dam was commissioned in 1952 to provide storage and flow control for the Waitaki hydro scheme. With increasing development in the upper Waitaki catchment, further storage capacity for the lake was needed to achieve a higher utilization of the available water. The Lake Pukaki (High) Dam was therefore constructed from 1971 to 1976; approximately 150m downstream of the original structure. The new dam raised the lake a further 37m, doubling the lake's storage capacity. This raising of the lake is clearly evident in Figure 3.5.

Prior to the filling of the lake, levels were recorded by daily S.G readings, daily values from chart records, and digitised chart records. Once the lake was completely filled on 16 January 1979, automatic recording of the level started. The lake level is managed by Meridian Energy.

Lake Pukaki has a catchment area of 1420km² and a lake area of 178.7km² (at normal maximum level). The lake is situated at an elevation of approximately 520 m above sea level.

Table 3.4 Timeline of Key Events

Period	Recorder
27 Jul 1925 to 17 Oct 1931	Manual readings.
1 Apr 1931 to 13 Dec 1946	Littlejohn chart recorder.
13 Dec 1946 to 22 Sep 1964	Manual readings.
1952	Pukaki Dam commissioned to provide storage and flow control.
22 Sep 1964 to 27 May 1975	Lea chart recorder.
27 May 1975 to 16 Jan 1979	Foxboro chart recorder.
1971 to 1976	Pukaki (High) Dam constructed. Lake began filling.
16 Jan 1979 to present	Lake Pukaki completely filled behind the new (high) dam. Digital recordings have occurred from this date.
16 Jan 1979	Lake Pukaki raised by 37 m after slow lake filling and then diversion of Tekapo Canal flows into lake.
17 Jul 1979	Pukaki Canal commenced operation diverting water to Ohau A Power Station.

3.3.2 Current Operating Consents

The consented minimum control level for Lake Pukaki is 518.0m. The Maximum control level varies throughout the year as detailed in Table 3.5.

Table 3.5 Maximum Control Levels for Lake Pukaki

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

3.3.3 Lake Level

The Lake Pukaki level record is shown in Figure 3.5 below and as a strip in Figure 3.6 for further detail.

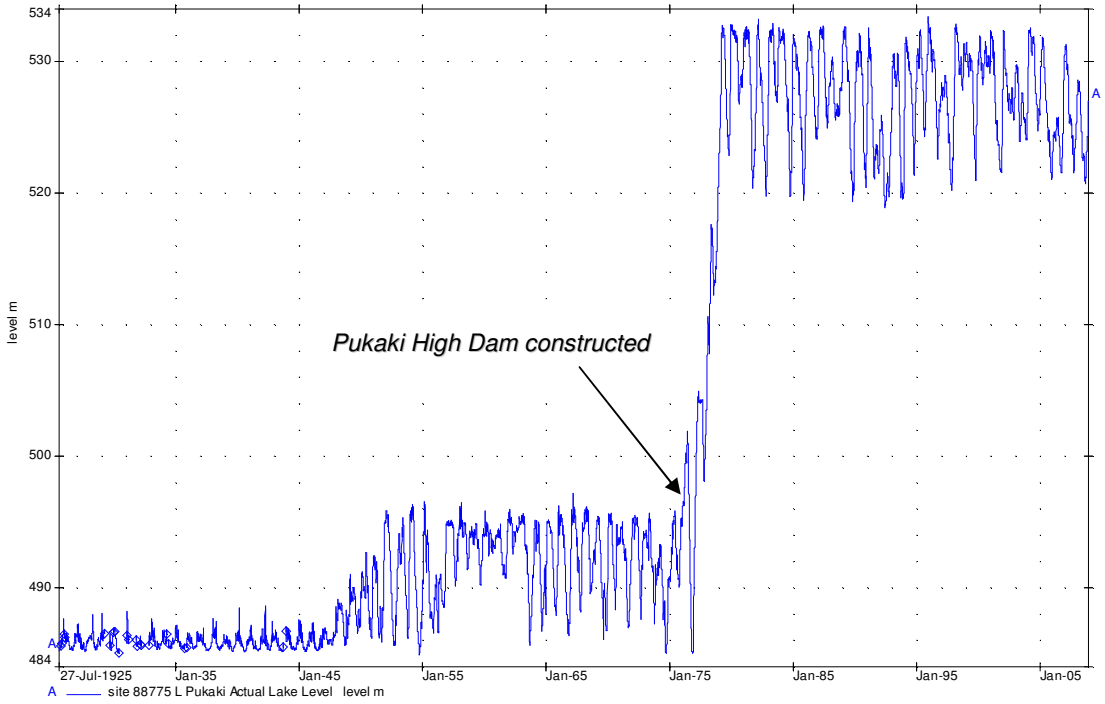

Figure 3.5 Lake Pukaki Level Record (m) 1925 to 2008

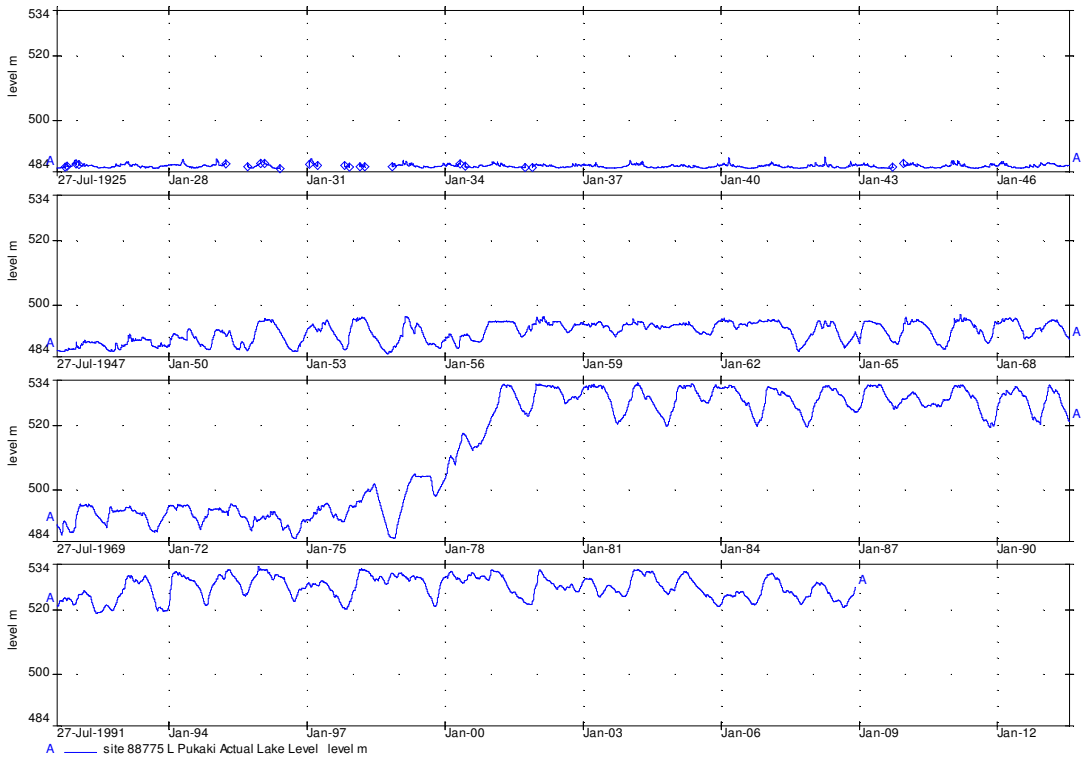

Figure 3.6 Lake Pukaki Level (m) Strip 1925 to 2008

3.4 Lake Wanaka

3.4.1 History

Lake Wanaka, the country's fourth largest lake, is more than 300m deep and an altitude of approximately 300m. The surface area of the lake is 192km² with a catchment area of 2576km². The level of this 'natural' is not managed currently. The lake level data are, however, used by Contact Energy to manage the hydro scheme on the Clutha River.

The lake level recorder is located at the Wanaka Township. The earlier lake level records (1929 to 1933) were from a staff gauge installed on the wharf in Roy's Bay (Pembroke Wharf). This gave poor readings as the wharf gradually subsided. A monthly Kent chart recorder was installed near the wharf on 1 February 1933, using the wharf staff gauge as the external staff gauge. This gauge was replaced in 1952 by a new installation approximately 250m northwest of the wharf. This new site began recording in October 1952 with another monthly Kent chart recorder. This continued operating until it was replaced with a Fisher and Porter punched tape recorder in May 1975.

In February 1994, an encoder replaced the tape record and the data are currently telemetered. Outflow is recorded at the south eastern end of the lake which flows into the Clutha River.

Table 3.6 Timeline of Key Events

Period	Recorder
1 Dec 1929	Record commenced. Natural lake – no controls. Possibly backwater effects from high flows in the Hawea River.
7 Dec 1929 to 1 Feb 1933	Staff gauge on Roy's Bay Wharf recorded lake level.
1 Feb 1933 to 2 Oct 1952	Installed a monthly Kent chart recorder on wharf.
2 Oct 1952 to 21 May 1975	Kent chart recorder replaced by another Kent recorder 250m northwest of the wharf as the wharf was sinking and producing poor data.
21 May 1975 to 11 Feb 1994	Kent recorder replaced by a Fischer and Porter digital recorder.
11 Feb 1994 to present	Digital recorder replaced with an Aquitel encoder and telemetry.

3.4.2 Lake Level

The Lake Wanaka level record is shown in Figure 3.7, and as a strip in Figure 3.8 for more detail.

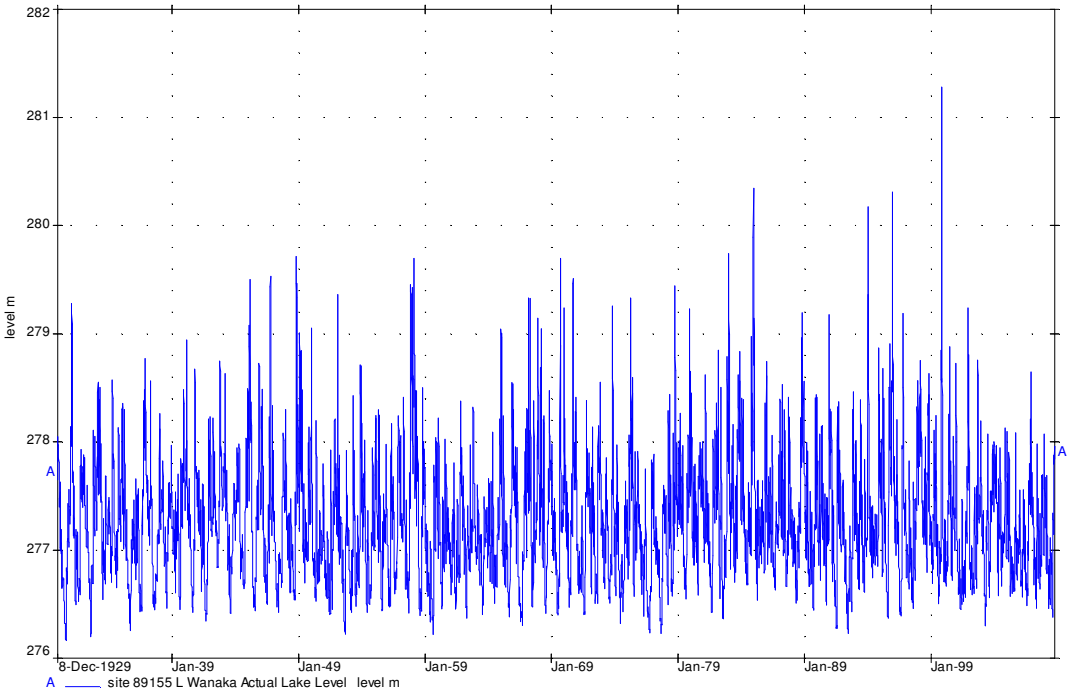

Figure 3.7 Lake Wanaka Level Record (m) 1929 to 2008

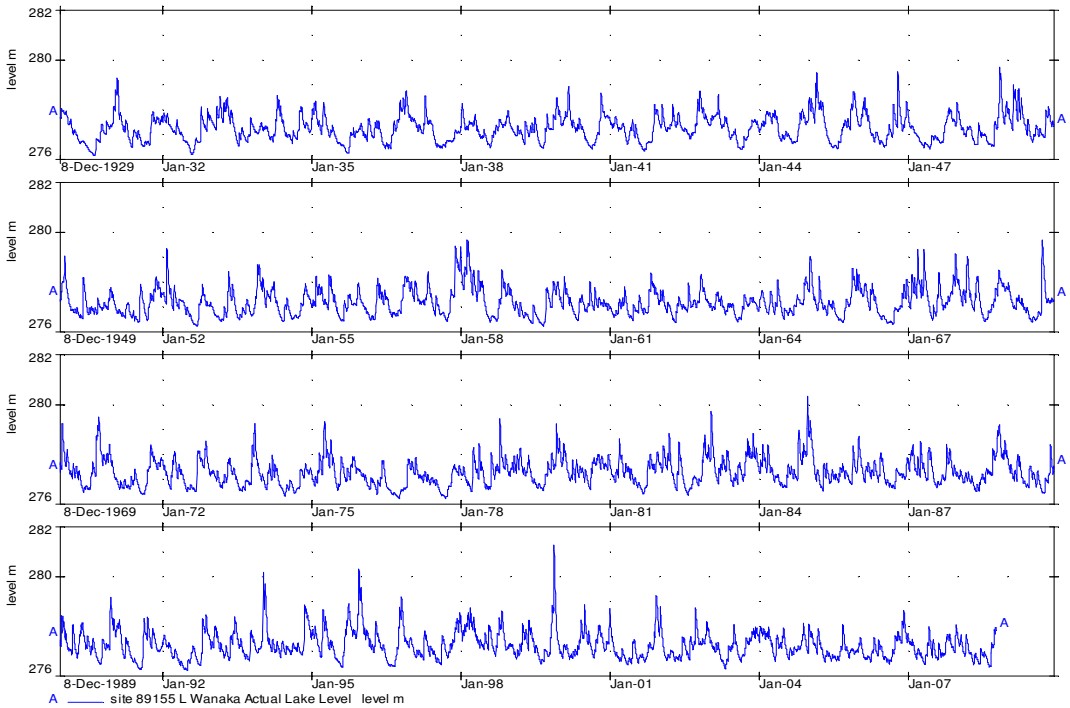

Figure 3.8 Lake Wanaka Level (m) Strip 1929 to 2008

3.5 Lake Hawea

3.5.1 History

The Hawea Dam was constructed from 1955 to 1958. Lake Hawea is at an altitude of 348m; a lake area of 141km², and a catchment area of 1390km². The lake is 392m deep. On 5 Dec 1955, a diversion channel was opened and the old river channel finally closed off. The lake is formed in a post-glacial depression that is dammed to the south by a terminal moraine. Once the dam was completed in 1958, the artificial lake level rose by approximately 20m. This is clearly seen in Figure 3.9 and Figure 3.10. Lake levels are managed by Contact Energy.

The first staff gauge was installed in October 1919 at Lagoon Creek (the Neck). On 18 July 1932, a Littlejohn level recorder located approximately 18km north of the lake outlet. A series of staff gauges were then introduced at the outlet from 8 September 1953. Lake level was controlled by the dam from 1 October 1958. A Lea recorder was installed to replace the staff gauge measurements on 11 April 1967. This was subsequently replaced by the more modern Fischer and Porter recorder on 20 May 1975.

A generating plant is expected to be installed at the dam to produce up to 17MW of power for the surrounding region by 2012.

Table 3.7 Timeline of Key Events

Period	Recorder
Oct 1919	First staff gauge installed to record lake level at Lagoon Creek (the Neck). Referred to as the “old gauge”.
8 Jul 1930 to 18 Jul 1932	Manual staff gauge recordings from the “old lake gauge”. Unmodified conditions.
18 Jul 1932 to 1 Feb 1956	Littlejohn water level recorder installed 18km north of the lake outlet to take over manual staff gauge readings.
1956	Gladstone Gap emergency spillway built (fuse plug).
8 Sep 1953 to 11 Apr 1967	A set of eight staff gauges were installed from Wilson’s Rock and around the outlet of the proposed dam. Measurement of level was now taken from the “new lake gauge”.
3 Aug 1954 to 1 Oct 1958	Lake Hawea Dam constructed. Lake Hawea level from 1 Oct 1958.
11 Apr 1967 to 20 May 1975	Lea recorder installed in the control structure at the dam to replace staff gauge measurements.
20 May 1975	The Lea recorder was replaced with a Fischer and Porter recorder.
1 Apr 1985	The National Water and Soil Conservation Authority set a new operating range for Lake Hawea.
2007	Consent conditions set.

3.5.2 Current Operating Consents

The consented minimum control level for Lake Hawea is 338m, although this can be lowered to 336m as an absolute minimum (previously 330m) when the Electricity Commission determines that reserve generation should be used. The maximum control level is 346m. This can, however, be exceeded under the Flood Management Plan.

3.5.3 Lake Level

The Lake Hawea level record is shown in Figure 3.9, and as a strip in Figure 3.10 for more detail.

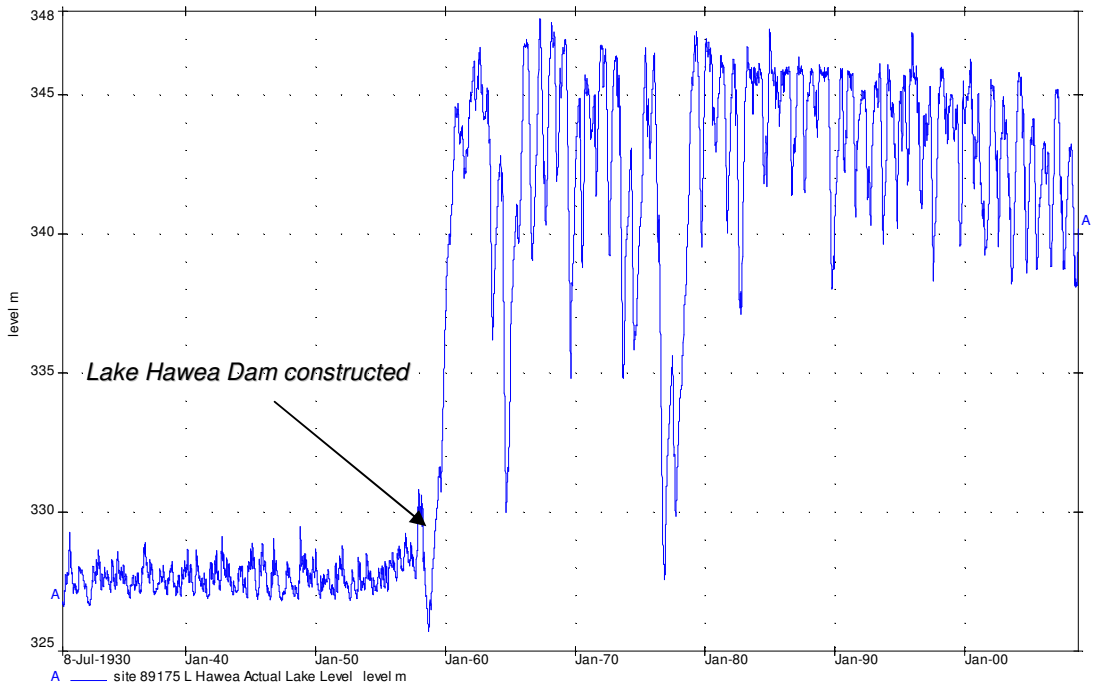

Figure 3.9 Lake Hawea Level Record (m) 1930 to 2008

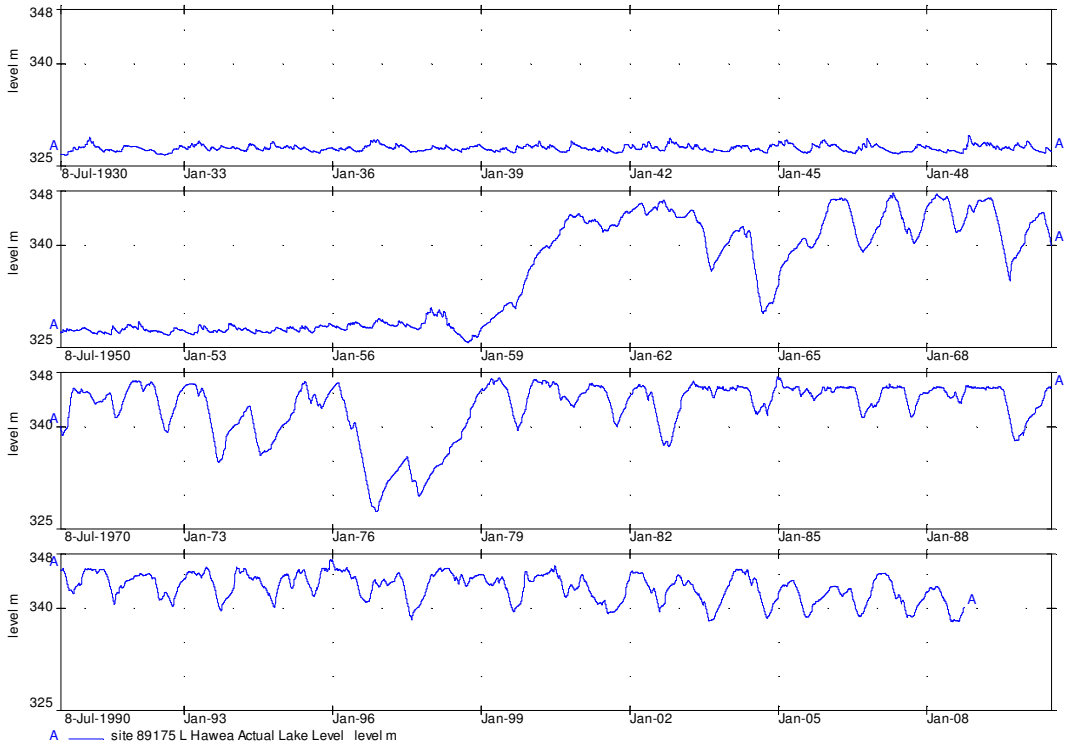

Figure 3.10 Lake Hawea Level (m) Strip 1930 to 2008

3.6 Lake Wakatipu

3.6.1 History

Lake Wakatipu is New Zealand's third largest lake with a surface area of 291km² and a catchment area of 3041km². It is situated at an altitude of 310m and is drained by the Kawarau River approximately 8km east of Queenstown. The lake reaches depths of 420m; approximately 100m below sea level. The Wakatipu lake level recorder is located at the outflow to the Kawarau River. The recordings are maintained by Contact Energy.

In the 1920's, a control structure was built on the outlet of the lake, initially to close the outlet and allow access to gold deposits in the river bed. Construction began on 22 November 1924 and was finished on 30 August 1926. The gates were used until 1938. In 1941, gate operation commenced to assist in the construction of the Roxburgh Dam.

After wharf repairs in 1962, the staff gauge was replaced without being levelled. When the gauge was levelled in 1965, it was found to be 2.41ft lower than when initially installed in 1945. In 1950, four staff gauges were installed at the outlet to replace measurements at the wharf. A fifth gauge was introduced at the end on 1957, 300m above the outlet. This fifth gauge was measured daily from 1 January 1957 to 28 November 1962 before being replaced by a Lea recorder on the Frankton Arm.

The Lea recorder was replaced with a Fischer and Porter recorder on 22 October 1975.

Table 3.8 Timeline of Key Events

Period	Recorder
25 Mar 1924 to 30 Jun 1959	A staff gauge was installed on the Queenstown Wharf and read daily, except Sundays.
22 Nov 1924 to 30 Aug 1926	Construction of the Lake Wakatipu Control Structure.
30 Aug 1926	Control Structure gates first close, remaining shut for ten days. Use of the structure continued until 1938.
1941-1956	Use of Lake Wakatipu Gates to assist with construction of Roxburgh Power Project.
1950	Four staff gauges installed at the outlet to measure level.
1 Jan 1957 to 28 Nov 1962	A fifth gauge was used to measure level, located approximately 300 m north of the outlet.
28 Nov 1962 to 22 Oct 1975	A Lea recorder was installed in the Frankton Arm of the lake.
22 Oct 1975	A Fischer and Porter recorder replaced the Lea recorder.

3.6.2 Lake Level

The Lake Wakatipu level record is shown in Figure 3.11, and as a strip in Figure 3.12 for more detail.

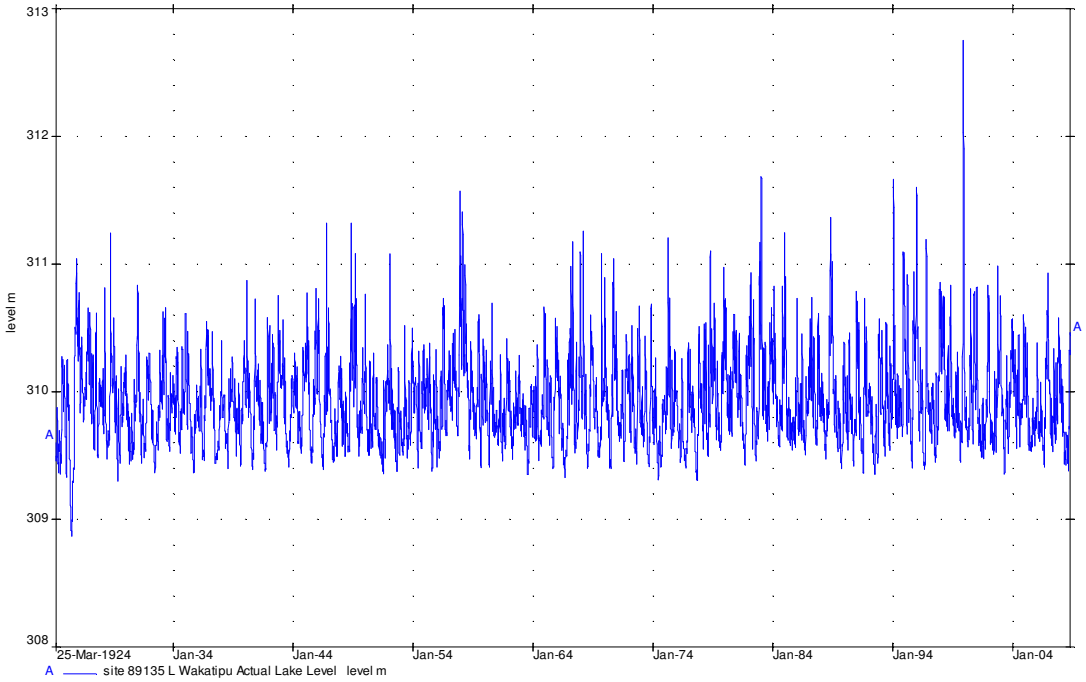

Figure 3.11 Lake Wakatipu Level Record (m) 1924 to 2008

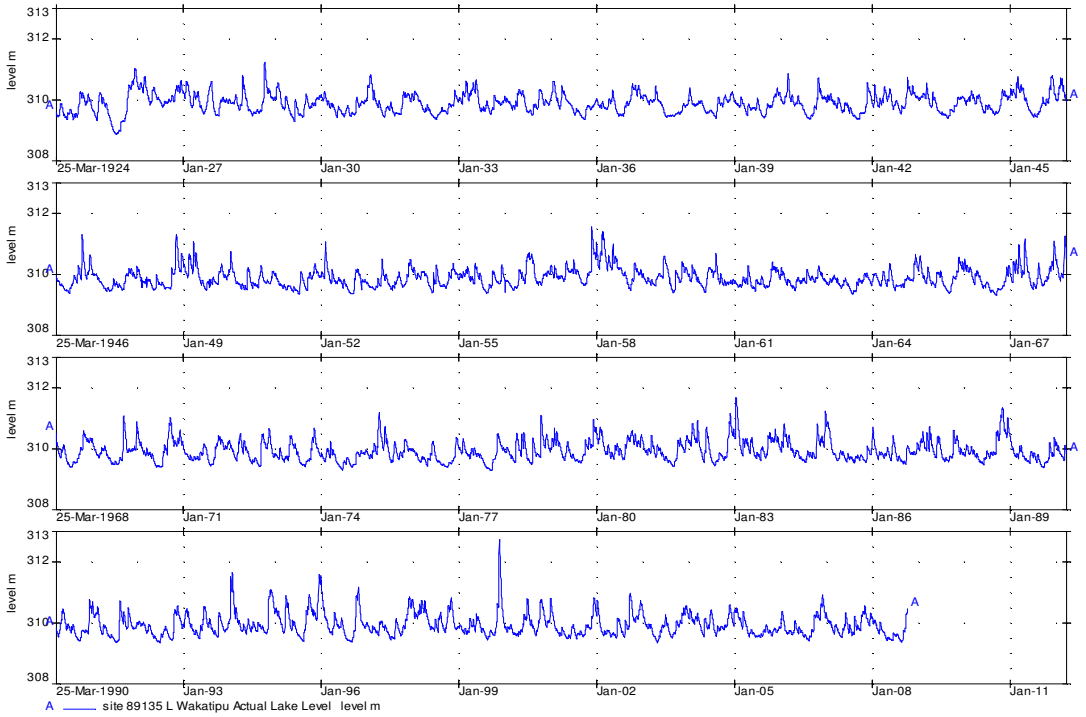

Figure 3.12 Lake Wakatipu Level (m) Strip 1924 to 2008

3.7 Lake Te Anau

3.7.1 History

Lake Te Anau is New Zealand's second largest lake, with a surface area of 352km² (at normal maximum level) and a catchment area of 3095km². The lake lies at an altitude of 210m and reaches 417m in depth. Much of the lake bed is therefore effectively below sea level. The lake level recorder is located approximately 3km northeast of the outflow down the Waiau River. The Waiau River flows several kilometres into Lake Manapouri. The records of lake level are maintained by Meridian Energy.

Daily staff gauge readings on Lake Te Anau began in January 1926 on the Te Anau Wharf. A Littlejohn recorder was installed on 22 June 1932 and took over the manual measurements. A Kent recorder then replaced the Littlejohn recorder in March 1959. A Lea recorder then, subsequently, replaced this in May 1962. This recorder was used until November 1975 when it was replaced by the more modern Fischer and Porter recorder.

Table 3.9 Timeline of Key Events

Period	Recorder
14 Jan 1926 to 22 Jun 1932	Daily staff gauge readings of level from Te Anau Wharf.
22 Jun 1926 to 19 Mar 1959	Littlejohn recorder replaced the staff gauge.
19 Mar 1959 to 3 May 1962	Kent Recorder replaced the Littlejohn recorder.
3 May 1962 to 27 Nov 1975	A Lea recorder replaced the Kent recorder. The recorder was reconstructed in 1965.
17 Nov 1973	Construction of control structure interfered with the outlet.
1974	Control structure completed and lake control began.
27 Nov 1975 to present	A Fischer and Porter recorder was installed to replace the Lea recorder.

3.7.2 Current Operating Consents

The guidelines governing the management of Lake Te Anau stipulate the minimum control level to be 201.5m and the maximum control level of 202.7m.

3.7.3 Lake Level

The Lake Te Anau level record is shown in Figure 3.13, and as a strip in Figure 3.14 for more detail.

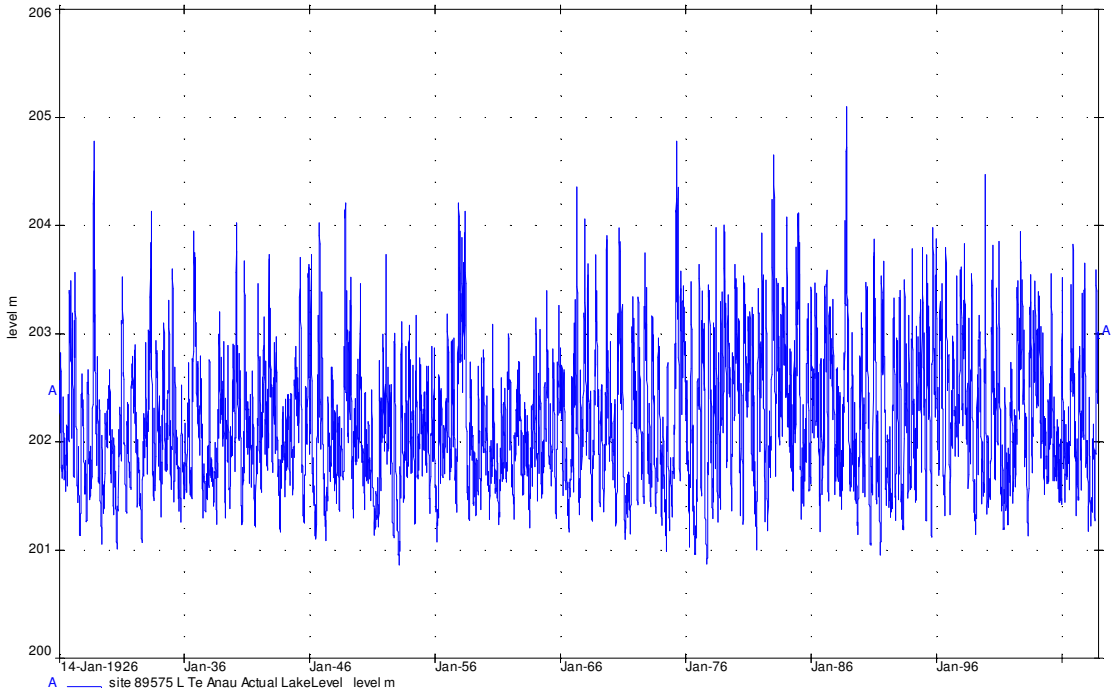

Figure 3.13 Lake Te Anau Level Record (m) 1926 to 2008

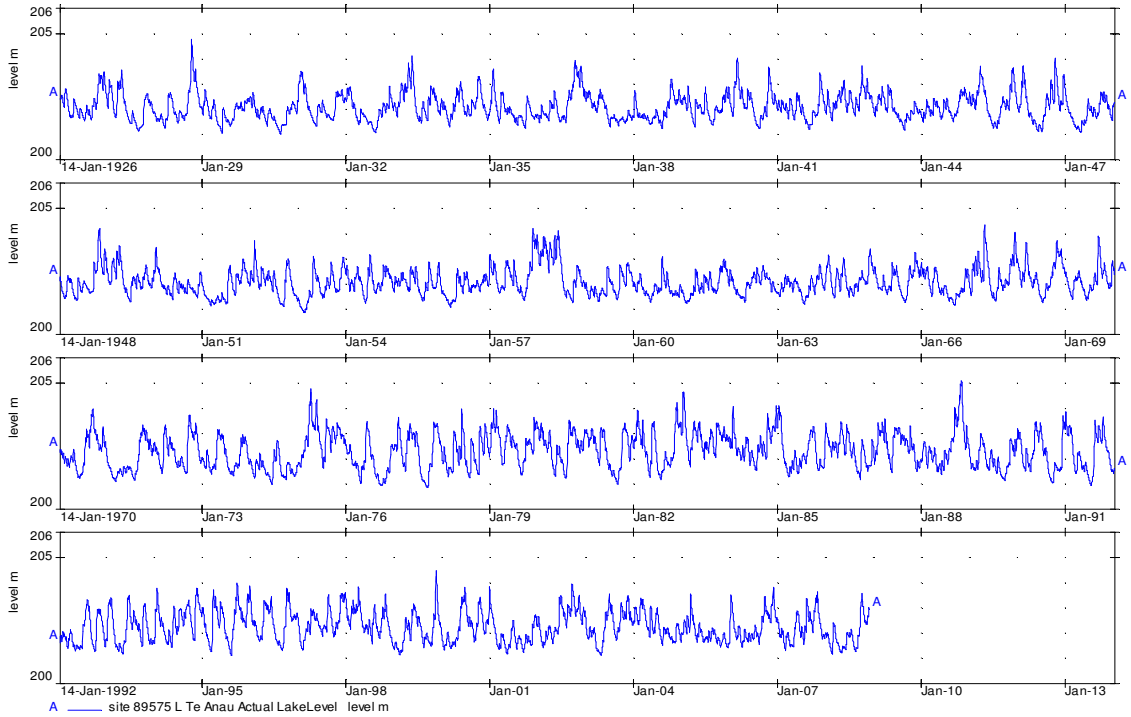

Figure 3.14 Lake Te Anau Level (m) Strip 1926 to 2008

3.8 Lake Manapouri

3.8.1 History

Lake Manapouri lies at an elevation of 178m and has a post-control catchment area of 5880km². This includes Te Anau, the natural catchment (4540km²), Mararoa, and Home Creek. The lake surface area is 141km² (at normal maximum level). The lake has an underground power station located in its western arm which is operated by Meridian Energy. The power station was commissioned in October 1969, with construction beginning in the early 1960's. A second tailrace tunnel was commissioned in 2002 to increase generation capacity.

Two 10km tailrace tunnels discharge water into Doubtful Sound and the sea. The lake level was proposed to be raised approximately 30m in 1959 but this proposal elicited large public opposition. The lake is now controlled to replicate natural conditions. The maximum capacity of Manapouri is 850MW. The majority of this capacity (approximately 610MW) is currently used by an aluminium smelter near Bluff.

Staff gauge recordings began on Lake Manapouri in January 1926 until manual measurements were replaced by a Littlejohn recorder in April 1932. The Littlejohn was replaced by a Kent recorder in March 1959. A Foxboro recorder was installed in January 1973 and this was replaced by a Fischer and Porter recorder, located at the Supply Bay in 1976. A digital recorder has been used to measure lake level since March 1990. The recorder is located on the West Arm of the lake.

Table 3.10 Timeline of Key Events

Period	Recorder
11 Jan 1926 to 26 Apr 1932	Staff gauge readings from Pearl Harbour.
26 Apr 1932 to 9 Mar 1959	Littlejohn recorder replaced staff gauge recording.
9 Mar 1934 to 9 Nov 1936	Missing record. Can be filled with synthetic data based on Te Anau lake level.
9 Mar 1959 to 4 Jan 1973	Kent recorder replaced Littlejohn recorder.
8 Aug 1969	First power generated at Manapouri Power Station – discharge to Deep cove.
10 Feb 1970	Rock weir – significantly affected levels and flows (weir completed Apr 1970).
4 Jan 1973 to 19 Feb 1976	Foxboro recorder replaced Kent recorder.
19 Feb 1976 to 12 Mar 1990	Fischer and Porter recorder replaces Foxboro recorder. Measurements at the Supply Bay.
Nov 1976	Manapouri Lake Control structure completed at confluence with Mararoa River.
12 Mar 1990 to present	Recorder replaced with a digital recorder located at West Arm.
1996	Residual flow introduced at the Manapouri Lake Control.
5 May 2002	A second tunnel to Deep Cove commissioned.

3.8.2 Current Operating Consents

The guidelines governing the management of Lake Manapouri stipulate the minimum control level to be 176.8 m and the maximum control level 178.6 m.

3.8.3 Lake Level

The Lake Manapouri level record is shown in Figure 3.15, and as a strip in Figure 3.16 for more detail.

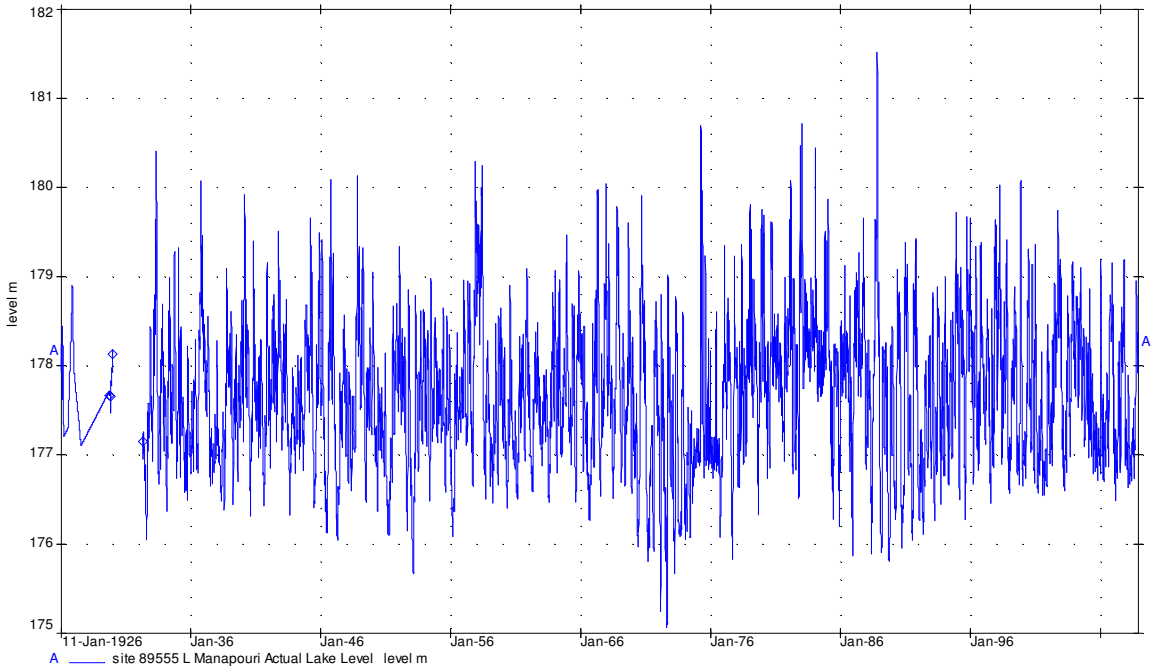

Figure 3.15 Lake Manapouri Level Record (m) 1926 to 2008

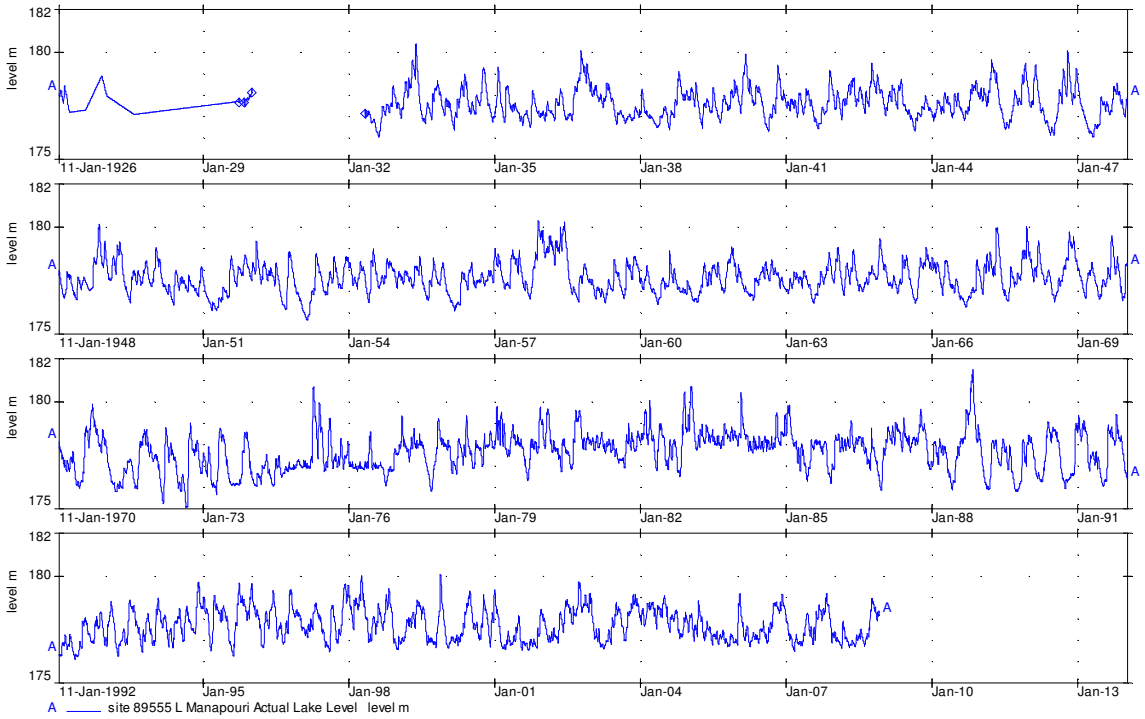

Figure 3.16 Lake Manapouri Level (m) Strip 1926 to 2008

4 Other Lake Level Recorders

4.1 The National Institute of Water and Atmospheric Research (NIWA)

In addition to the various power companies' data, NIWA also have lake level recorders on some of the lakes mentioned in this report. Multiple recorders, maintained by separate agencies, with differing treatment of the lake level data can result in disparate apparent water levels for the same lake. Table 4.1 outlines the details of the most recently installed lake level recorders at each sites and the method of correcting the data to their chosen datum.

Table 4.1 Details of the NIWA Lake level recorders

Lake	Site	Most recent recorder	Period	Accuracy	Datum	Manipulation	Notes
Taupo	**Tokaanu 1143420** Primary	Unidata Hydrologger 2000	13/11/2001 - Present	+/-1mm	RL Zero Taupo Fundamental 1956	349.929m is added to stage data to make all data relative to the Moturiki 1956 Datum (MSL). Site 1143450 is the same data as site 2532 (Lake Taupo at Tokaanu).	Site re-opened in 2001. The Tokaanu logger is situated in an area experiencing subsidence which results in higher lake level readings (such as those seen when compared to Braxmere Lodge recordings during a brief data overlap in 2002). This is regularly resurveyed and the data adjusted accordingly.
	Braxmere 3043467 Primary	Sutron Acubar Gas Purge Transducer with Hydrologger	07/06/2000 - 03/01/2002	+/-1mm	RL Zero Taupo Fundamental 1956	No record as to what was added to make it relative to Moturiki 1956 Datum (MSL).	
	Acacia Bay 1543478 Primary	Kainga Shaft Encoder with Aquitel Logger	16/03/1995 - Present	+/-1mm	RL Zero Taupo Fundamental 1967	354.857m is added to stage data to make it relative to the Moturiki 1956 Datum (MSL). 354857mm is currently added to site 1543478 (Opus site 2531) to make the same data as site 82795 (L. Taupo Actual Level)	
	Backup	Unidata Encoder with DAA Logger	?	+/-1mm			

Lake	Site	Most recent recorder	Period	Accuracy	Datum	Manipulation	Notes
Waikaremoana	**Onepoto 21412**						
	Primary	Hydrologger 2001	15/06/2004 - Present	not stated	Moturiki 1956	580.000m added to stage data to make it relative to Moturiki 1956.	
	Backup	Hydrologger 2002	15/06/2004 - Present				
Ohau	**Moose Lodge 71168**						
	Primary	Kainga Shaft Encoder with Aquitel Logger	08/12/1992 - Present	+/-1mm	Lyttleton MSL	517.000m added to stage data to make it relative to Lyttleton MSL. 517000mm is added to site 71168 (Opus site 8605) to make the same data as site 88765 (L. Ohau Actual Lake Level).	
	Backup	Meridian Site					200mm out due to a leak in the tower. Meridian accepts NIWA data as being correct.
	Lk Middleton 71120						
	Primary	Leopold and Stevens	? – 05/12/1977		Possibly Lyttleton MSL	Unknown	
	Wetheralls 71171						
	Primary	Leopold and Stevens	09/12/1991 - 01/07/1996		Assumed level		

Lake	Site	Most recent recorder	Period	Accuracy	Datum	Manipulation	Notes
Pukaki	**Canal Inlet Gate 71123**						
	Primary	Kainga Encoder and Logger	27/01/1993 -present	+/-1mm	Lyttleton MSL	500.00m added to stage data to make it relative to Lyttleton MSL. Site 71132 is the same data as Opus site 88775 (Actual Lake Level).	
	Backup	Aquatel Logger with shared encoder	04/02/1993 - present	+/-1mm			
Tekapo	**Power Station 71132**						
	Primary	Kainga Encoder and Logger	10/03/1992	+/-1mm	Lyttleton MSL	700.00m added to stage data to make it relative to Lyttleton MSL. 700000mm is added to site 71132 to make the same data as site 88795 (L. Tekapo Actual Lake Level).	
	Backup	Aquatel Logger with shared encoder	15/12/92	+/-1mm			
Wanaka	**Roys Bay 75292**						
	Primary	Kainga Shaft Encoder with Aquitel Logger	11/02/2004 - Present	+/-3mm	Dunedin MSL	276.082m added to stage data to make it relative to Dunedin MSL. 276082mm is added to site 75292 (Opus site 9004) to make the same data as site 89155 (L. Wanaka Actual Lake Level).	
	Backup	Unidata Hydrologger	16/05/2000 - Present	+/-3mm			

Lake	Site	Most recent recorder	Period	Accuracy	Datum	Manipulation	Notes
Hawea	**Dam 75288** Primary	DAA H331 Encoder with DAA Logger	20/10/2005 - Present	+/-3mm	Dunedin MSL	320.000m added to stage data to make it relative to Dunedin MSL. 320000mm is added to site 75288 (Opus site 89175) to make it the same data as site 89175 (L. Hawea Actual Lake Level.	
	Backup	DAA H331 Encoder with DAA Logger	24/11/2005 - Present	+/-3mm			
Wakatipu	**Willow Place 75277** Primary	Kainga Shaft Encoder with Aquitel Logger	12/09/1996 - Present	+/-3mm	Dunedin MSL	309.083m added to stage data to make it relative to Dunedin MSL. 309083mm is added to 75277 (Opus site 9002) to make it the same data as site 89135 (L. Wakatipu Actual Lake Level).	
	Backup	Unidata Hydrologger	12/02/2002 - Present	+/-3mm			
Te Anau	**Park HQ 79704**						
	Primary	Hydrologger	22/08/2002 - Present	+/-1mm	Bluff MSL	190.000m added to stage data to make it relative to Bluff MSL	
	Backup	Unidata Encoder with DAA Logger	February 2009	+/-1mm			

Lake	Site	Most recent recorder	Period	Accuracy	Datum	Manipulation	Notes
	Glade House 79709						
	Primary	Kainga Encoder and Logger	08/04/1998 – 06/08/1999		Bluff MSL		
Manapouri	**West Arm 79706**						
	Primary	Hydrologger	?	+/-1mm	Bluff MSL	170.000m added to stage data to make it relative to Bluff MSL. Site 79706 (Opus site 9568) is the same data as site 89555 (L. Manapouri Actual Level).	
	Backup	Kainga Encoder with Aquatell Logger	?	+/-3mm			To be upgraded to Unidata Encoder with DAA Logger in late Feb 2009 accuracy +/- 1mm
	Supply Bay 79707						
	Primary	Hydrologger	13/09/2004 - Present	+/-1mm	Bluff MSL	170.000m added to stage data to make it relative to Bluff MSL.	
	Backup	Hydrologger	08/10/1999 - Present	+/-1mm			

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Mighty River Power Ltd

Meridian Energy Ltd

Contact Energy Ltd

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