Lake Generation Potential History

Electricity Commission

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Contents

1 Background

In February 2009 Opus International Consultants produced for the Electricity Commission a chronology and history of the 10 major lakes used for hydro generation in New Zealand. These lakes included: Taupo and Waikaremoana in the North Island; and Ohau, Tekapo, Pukaki, Wanaka, Hawea, Wakatipu, Te Anau and Manapouri 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.

It has been suggested that these lake level records might have considerable 'added value', and be of wider interest, if they could be related to their potential to generate electric power. That is, if these lake levels could first be 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.

The generation potential determined in this manner is essentially a 'hydrological index' which expresses the theoretical amount of energy that could be produced based on a number of assumptions. It does not represent the actual amount of power generated, or even the exact generation potential. To do this would involve considerable detail relating to the efficiency of individual power stations under different operating head, consent conditions, management decisions, flood events, and the national power supply situation etc. It is likely in fact that the precise determination of power generation potential is not possible from lake levels alone.

There have been a number of changes to the various control structures and resource consents relating to the management of lake levels over time. Therefore, this analysis of the potential generation only covers the period from 1 January 1990 to 1 July 2010. This 20 year period still provides an appropriate length of record, and a valid basis for review. The generation potential index, and the resulting time series, allow the water storage of the various lakes to be compared against a common index over time.

The lake level data were obtained from the Power Archive, which is maintained by Opus International Consultants under contract to the various power generation companies. The assistance of Genesis Energy, Mighty River Power, Meridian Energy, and Contact Energy in providing access to these data for this project is gratefully acknowledged. In some cases additional data were obtained from the National Hydrometric Archive administered by NIWA.

The lake level 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 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 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.

2 Methodology

The following process was used to convert the lake level records to a time series of the variability of lake storage generation potential over time. For each of the ten lakes:

1. The lake level data was obtained.

2. Using a lake level–storage volume rating the lake level record was transformed to 'usable storage' (millions of m^3). The usable 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, it will still be used to generate electricity in all 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. In some situations this water can be used to generate electricity but there are usually constraints that must be overcome. 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 Wanaka do not have operating ranges and thus the sill level and the base of the thalweg, respectively, were used as the level for no generation.

3. The usable storage was then converted to total generation potential (GWh) downstream. On rivers with multiple power stations downstream, the generation potential of each station was summed to provide the total generation potential of the water held in storage.

   The exact amount of electricity able to be generated by a fixed volume of water at a station depends on many factors, and is not constant over time. For example, it depends on: the plant, its age and maintenance; the effective head; management considerations; national electricity strategies etc. In the case of Manapouri, the second tail-race increased the station's efficiency. Despite this, the average efficiency (i.e., MW/cumec) of each power station over the normal operating range of the lake is considered a useful hydrological index for the analysis of longer term generation potential variability.

4. The generation potential time series for each lake since 1990 was then graphed, and a statistical summary of each provided. This summary includes the usual descriptive statistics such as mean, median, quartiles, frequency distribution, standard deviation etc.

3 Comparison with Comit Hydro

3.1 Summary

COMIT Hydro, maintained by NIWA, provides real-time estimates of the potential energy stored in various lakes used for hydro power generation. These data show how the energy stored in the lakes fluctuates with the weather, and with the management of outflows from the lakes. While those data, and those presented here are very similar, there are a number of differences in the assumptions and methodology of their derivation. These include:

- The data used in this study are those audited for accuracy and consistency, and then stored in the Power Archive. Comit Hydro uses real-time data which are subject to occasional error of unknown magnitude at the time;
- The average surface areas assumed for some of the lakes are different;
- The temporal resolution of the data. Comit Hydro is based on instantaneous data while this study uses daily average values;
- The normal operating ranges of some lakes differ, as do the maximum and minimum control levels. This is a result of changes in either consent conditions, or operating procedures;
- The methodology for estimating the volume of usable water stored in a particular lake is different. Comit Hydro uses the minimum lake area, the average beach slope, and measured water level to determine the volume of water stored. This analysis uses specific physical relationships that define how lake level affects lake area, and consequently lake volume; or in some cases, how lake level affects lake volume directly. These relationships have been developed from actual physical measurements; and
- This analysis uses the sum of the average generation potential (in cumecs/MW) at each dam downstream of the lakes. Comit Hydro converts the lake storage in

1000CMD (i.e., cubic metre days) directly to GWh. These two approaches should both produce essentially the same value of generation potential.

A full explanation as to how Comit Hydro estimates the amount of energy stored in the various hydro lakes is contained in the Comit Help documentation. Overall, the effect of the differences in the two approaches is expected to be relatively minor. While the differences may offset the average pattern of potential generation, they should have little effect on the relative differences presented in each record.

It is important that when comparing data or trends over time a consistent record is used. This consistency must apply to such things as the period of record, the temporal resolution of the data, and the statistics used for comparison. Changes in any of these variables may result in significant changes in the results produced making comparisons invalid.

4 North Island

4.1 Introduction

Lake Taupo and Lake Waikaremoana are both located in the North Island (Figure 4.1). Mighty River Power Ltd operates the Waikato hydro power scheme. This consists of eight dams and nine power stations with flows from Lake Taupo managed via the control gates. Genesis Energy Ltd operates the Lake Waikaremoana scheme which consists of three power stations.

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-day's storage, are totally managed, and are often artificial (i.e., impounded river valleys) as opposed to natural water bodies.

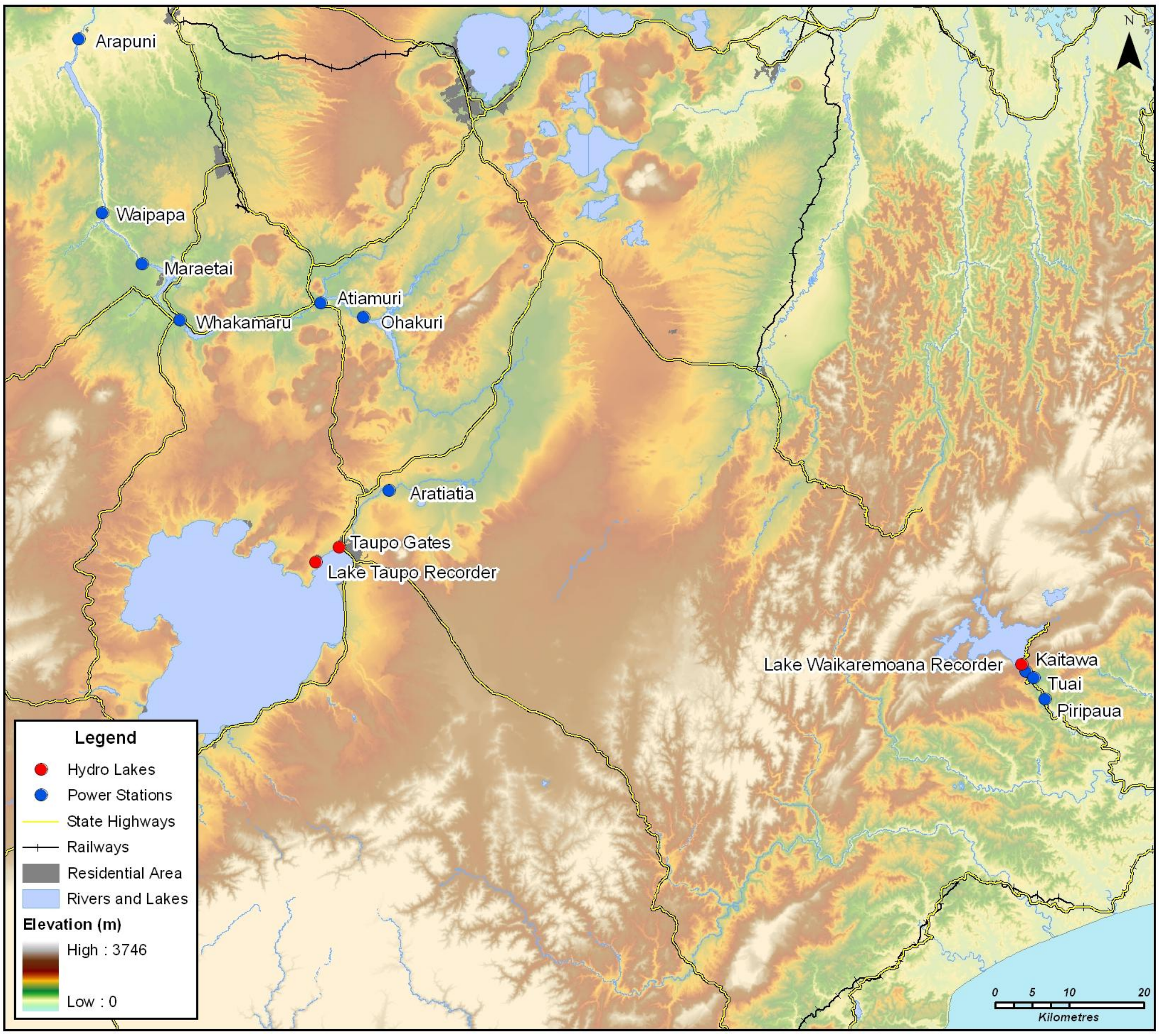

Figure 4.1 North Island hydro lakes reviewed.

4.2 Lake Taupo

4.2.1 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*

m^3/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.

4.2.2 Lake level and storage volumes

The Lake Taupo level record from 1-Jan-1990 to 1-Jul-2010 is shown in Figure 4.2. The level is relative to the Moturiki Datum 1956. Table 4.1 lists the characteristics of Lake Taupo including the maximum and minimum control levels and storage volumes. The large size of Lake Taupo means that a constant area was assumed for the lake storage rating.

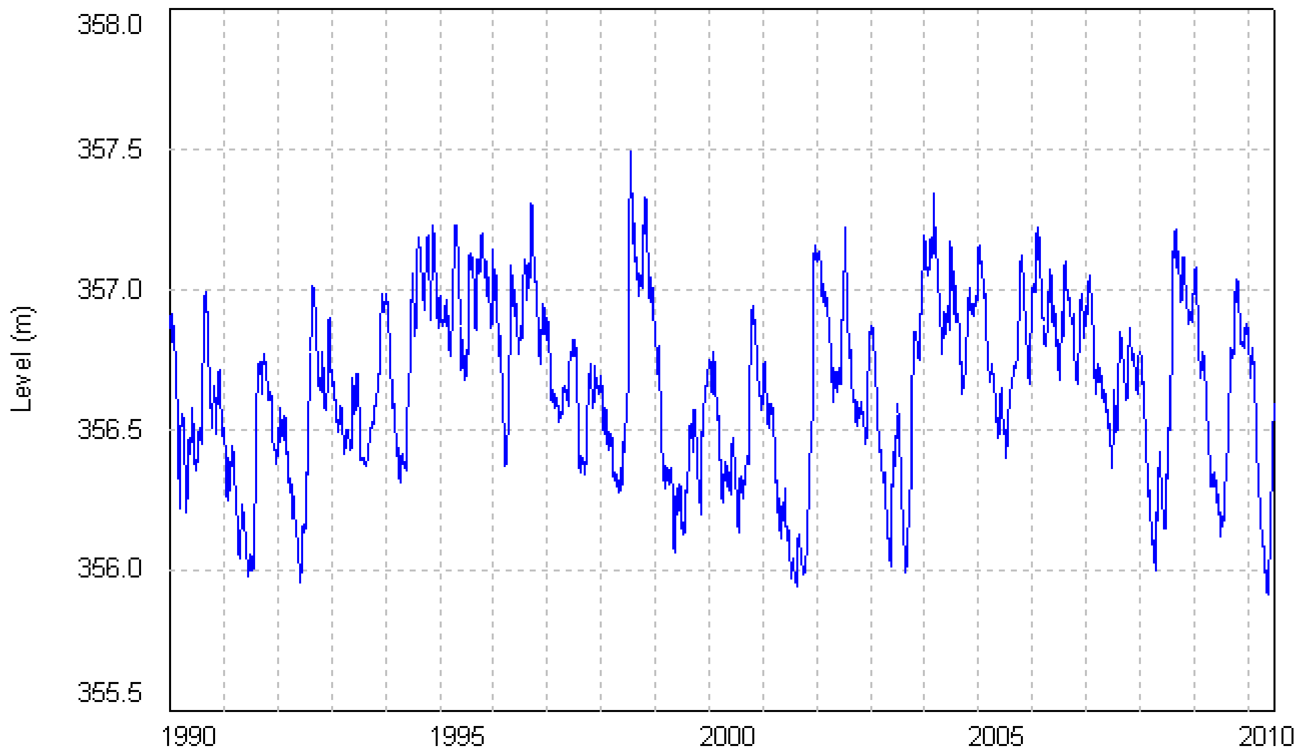

Figure 4.2 Lake Taupo water level record (masl) 1990 to 2010.

Table 4.1 Characteristics of Lake Taupo.

Lake Taupo	
Lake area (km²)	611.00
Maximum operating level (masl)	357.25
Minimum operating level (masl)	355.85
Maximum storage (million m³) – at maximum operating level	862.40
Minimum storage (million m³) – at minimum operating level	0.00
Downstream power stations	***Average efficiency** (m³/s/MW)*
Aratiatia	3.730
Ohakuri	3.596
Atiamuri	4.892
Whakamaru	3.170
Maraetai	2.009
Waipapa	7.003
Arapuni	2.160
Karapiro	3.767

4.2.3 Generation potential

The Waikato River has nine power stations through which the water from Lake Taupo passes; Aratiatia, Ohakuri, Atiamuri, Whakamaru, Maraetai 1&2, Waipapa, Arapuni and Karapiro. Each of these power stations has a different average efficiency. The total generation potential of Lake Taupo (GWh) was therefore calculated as the sum of the average individual efficiencies of all nine power stations over the normal lake operating range (Figure 4.3).

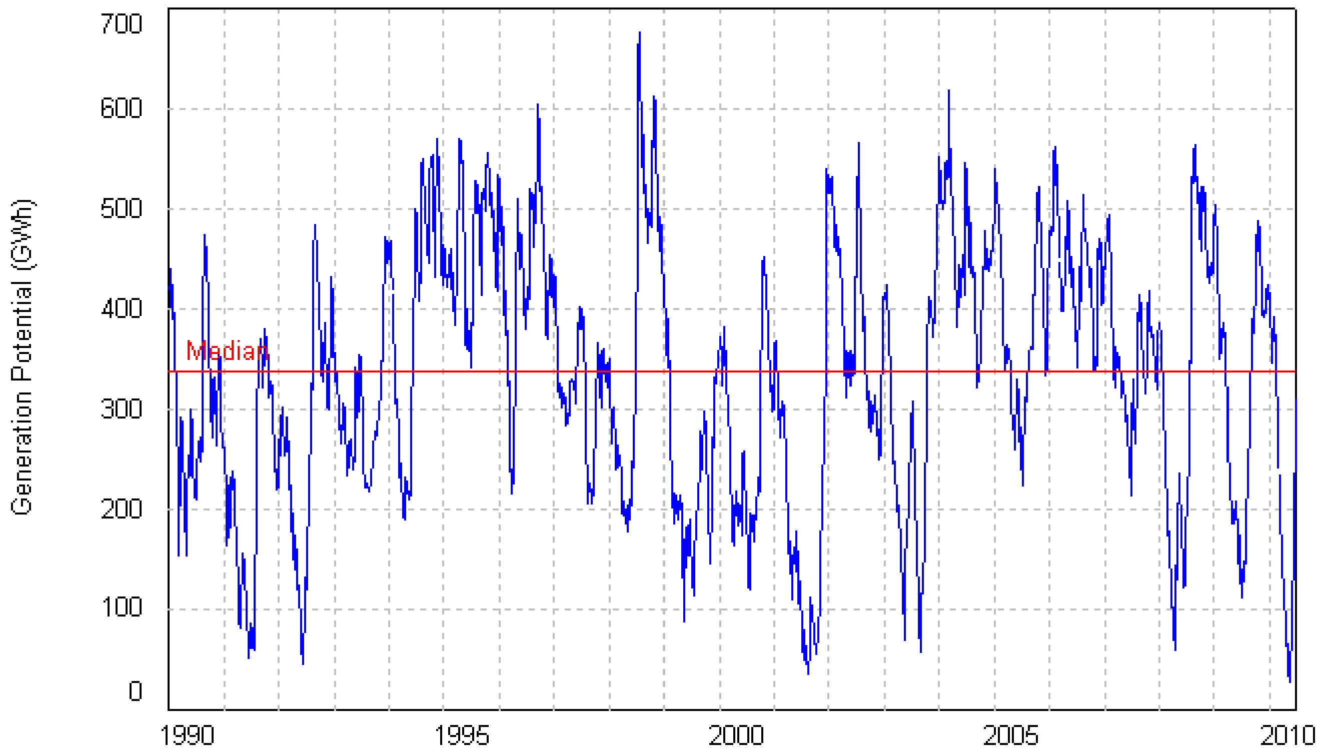

Figure 4.3 Generation potential of water stored in Lake Taupo (1-Jan-1990 to 1-Jul-2010).

Table 4.2 shows the summary statistics for the potential generation of Lake Taupo between 1990 and 2010.

Table 4.2 Lake Taupo generation potential statistics (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	28
Maximum	677
Mean	332
Median	337
10th percentile	158
Lower quartile	234
Upper quartile	434
90th percentile	498
Standard deviation	127

Figure 4.4 and Table 4.3 show the frequency distribution for the generation potential of water held in Lake Taupo.

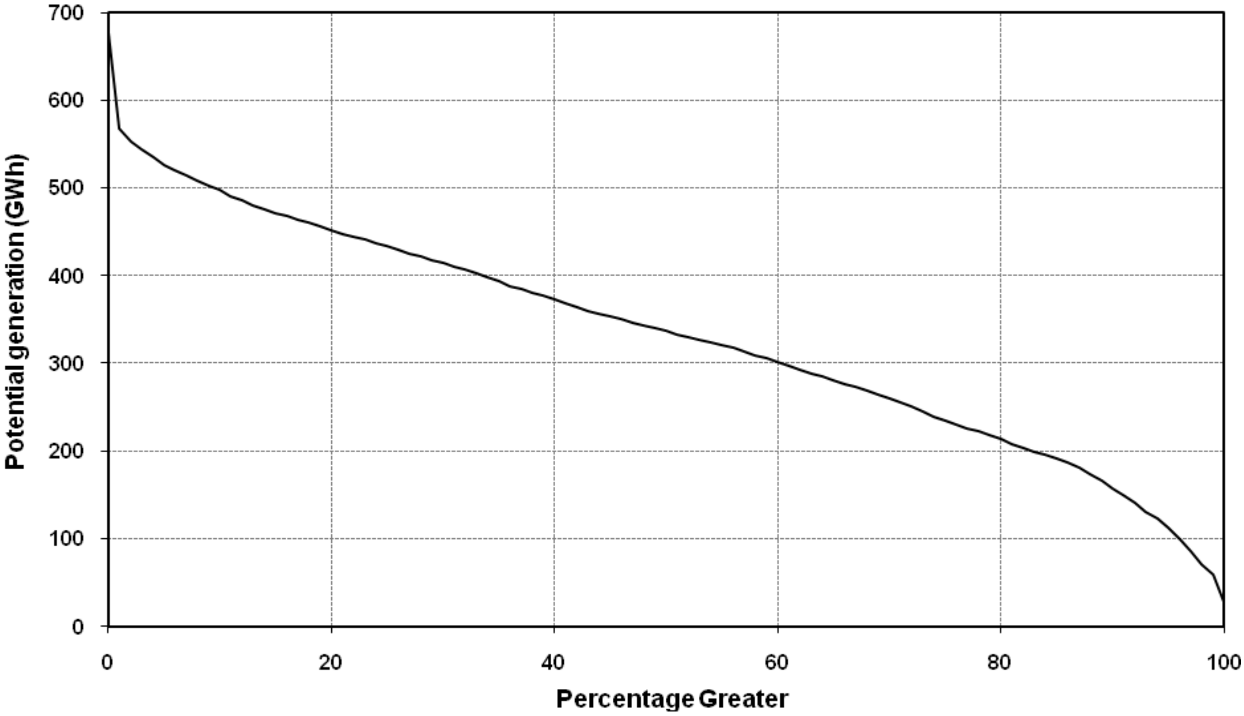

Figure 4.4 Frequency distribution of potential generation.

Table 4.3 Frequency distribution of the generation potential of water held in Lake Taupo.

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	677	567	553	544	535	527	519	514	509	503
10	498	491	485	481	476	472	467	463	460	456
20	452	448	444	441	437	434	430	426	422	418
30	414	411	407	403	398	393	388	384	380	377
40	372	368	363	360	356	353	350	347	344	341
50	337	333	330	327	324	321	317	313	309	305
60	302	297	293	289	285	281	277	273	268	264
70	260	255	250	245	239	234	230	226	222	218
80	214	207	203	199	195	191	187	181	173	166
90	158	150	140	131	122	113	99	85	70	59
100	28									

4.3 Lake Waikaremoana

4.3.1 Current operating consents

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

4.3.2 Lake level and storage volumes

The water level record for Lake Waikaremoana (1-Jan-1990 to 1-Jul-2010) relative to the Moturiki Datum is shown in Figure 4.5. Table 4.4 shows the characteristics of Lake Waikaremoana, including the maximum and minimum storage volumes. A lake level–lake area rating was used to calculate the lake storage volumes.

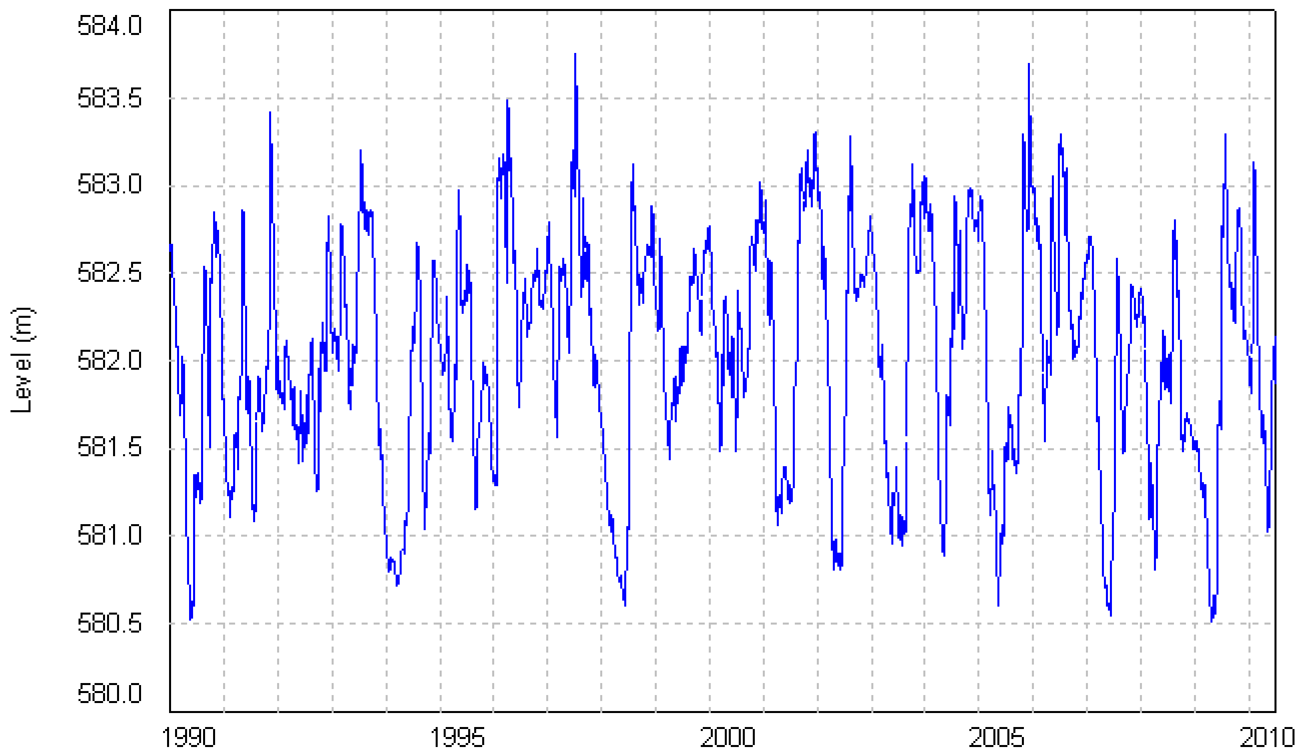

Figure 4.5 Lake Waikaremoana water level record (masl) 1990 to 2010.

Table 4.4 Characteristics of Lake Waikaremoana.

Lake Waikaremoana	
Lake area (km²)	54.00
Maximum operating level (masl)	583.29
Minimum operating level (masl)	580.29
Maximum storage (million m³) – at maximum operating level	157.16
Minimum storage (million m³) – at minimum operating level	0.00
Downstream power stations	***Average efficiency** (m³/s/MW)*
Kaitawa	0.994
Tuai	0.630
Piripaua	1.062

4.3.3 Generation potential

Water from Lake Waikaremoana flows into the Waikarataheke River where it potentially passes through three power stations: Kaitawa, Tuai, and Piripaua. Each of these power stations has a different generation efficiency. The total generation potential of the water held in Lake Waikaremoana was based on the sum of the average efficiency of each station over its normal operating range (Figure 4.6).

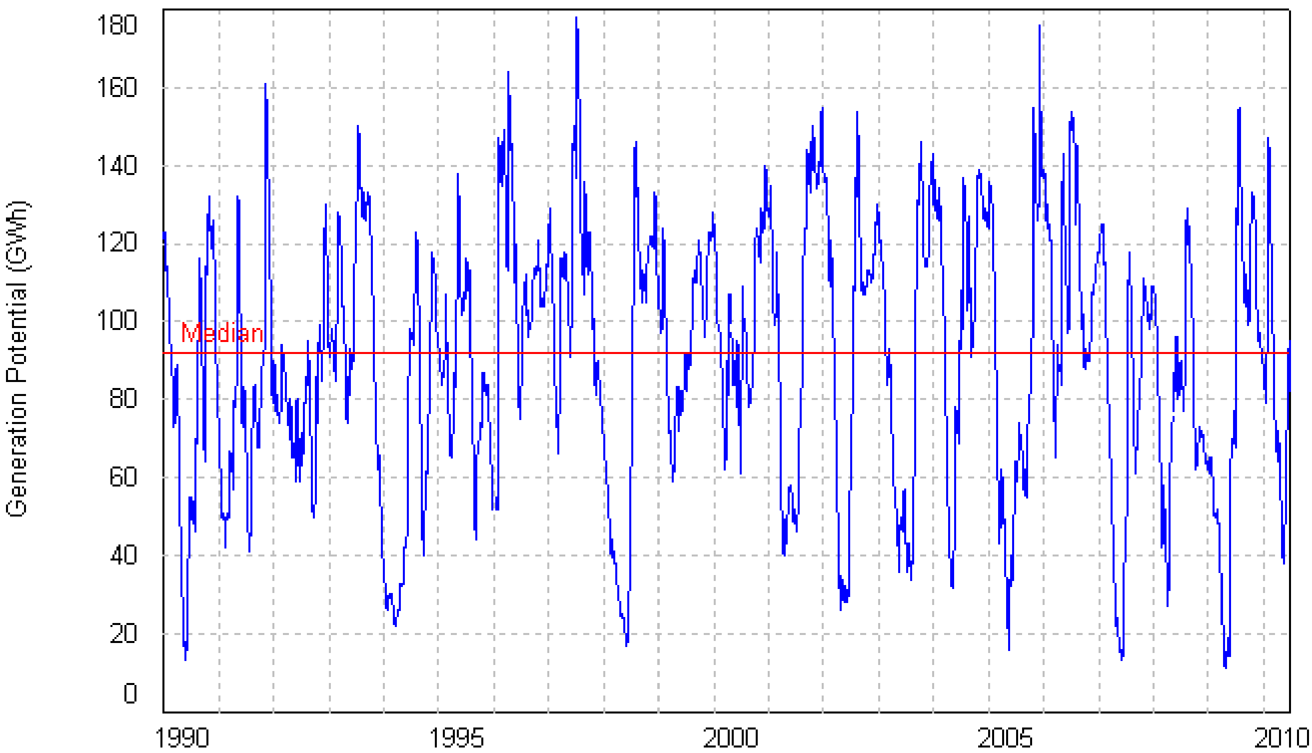

Figure 4.6 Generation potential of water stored in Lake Waikaremoana (1-Jan-1990 to 1-Jul-2010).

Table 4.5 shows the summary statistics for the potential generation of water held in Lake Waikaremoana between 1990 and 2010.

Table 4.5 Lake Waikaremoana generation potential statistics (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	11
Maximum	178
Mean	90
Median	92
10th percentile	42
Lower quartile	66
Upper quartile	116
90th percentile	132
Standard deviation	34

Figure 4.7 and Table 4.6 show the frequency distribution for the generation potential of the water held in Lake Waikaremoana.

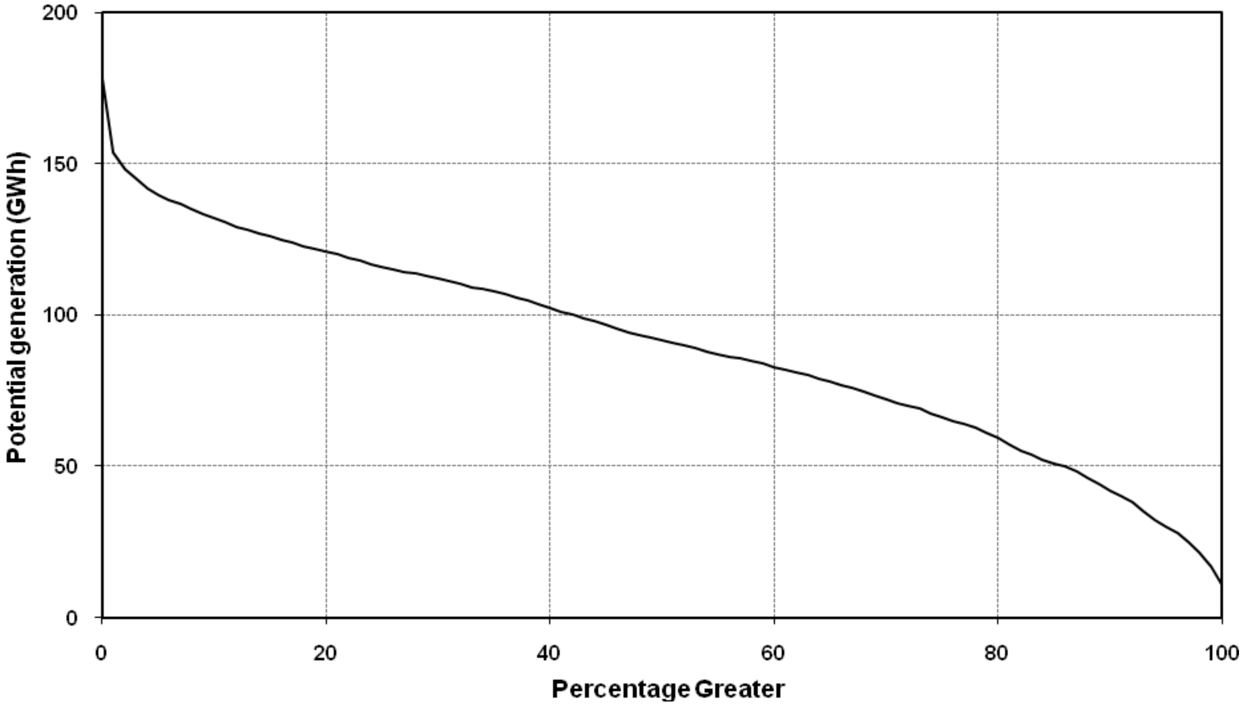

Figure 4.7 Frequency distribution of potential generation from water held in Lake Waikaremoana.

Table 4.6 Frequency distribution table of potential generation from water held in Lake Waikaremoana.

	0	1	2	3	4	5	6	7	8	9
0	178	154	148	145	142	140	138	137	135	133
10	132	131	129	128	127	126	125	124	123	122
20	121	120	119	118	117	116	115	114	114	113
30	112	111	110	109	109	108	107	106	105	104
40	102	101	100	99	98	97	95	94	93	93
50	92	91	90	89	88	87	86	86	85	84
60	83	82	81	80	79	78	77	76	75	73
70	72	71	70	69	67	66	65	64	63	61
80	59	57	55	54	52	51	50	48	46	44
90	42	40	38	35	32	30	28	25	22	17
100	11									

5 South Island

5.1 Introduction

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 schemes are operated by Meridian Energy. Lake Hawea, managed by Contact Energy, and the natural Lakes Wanaka and Wakatipu were also studied. Figure 5.1 shows the locations of these lakes.

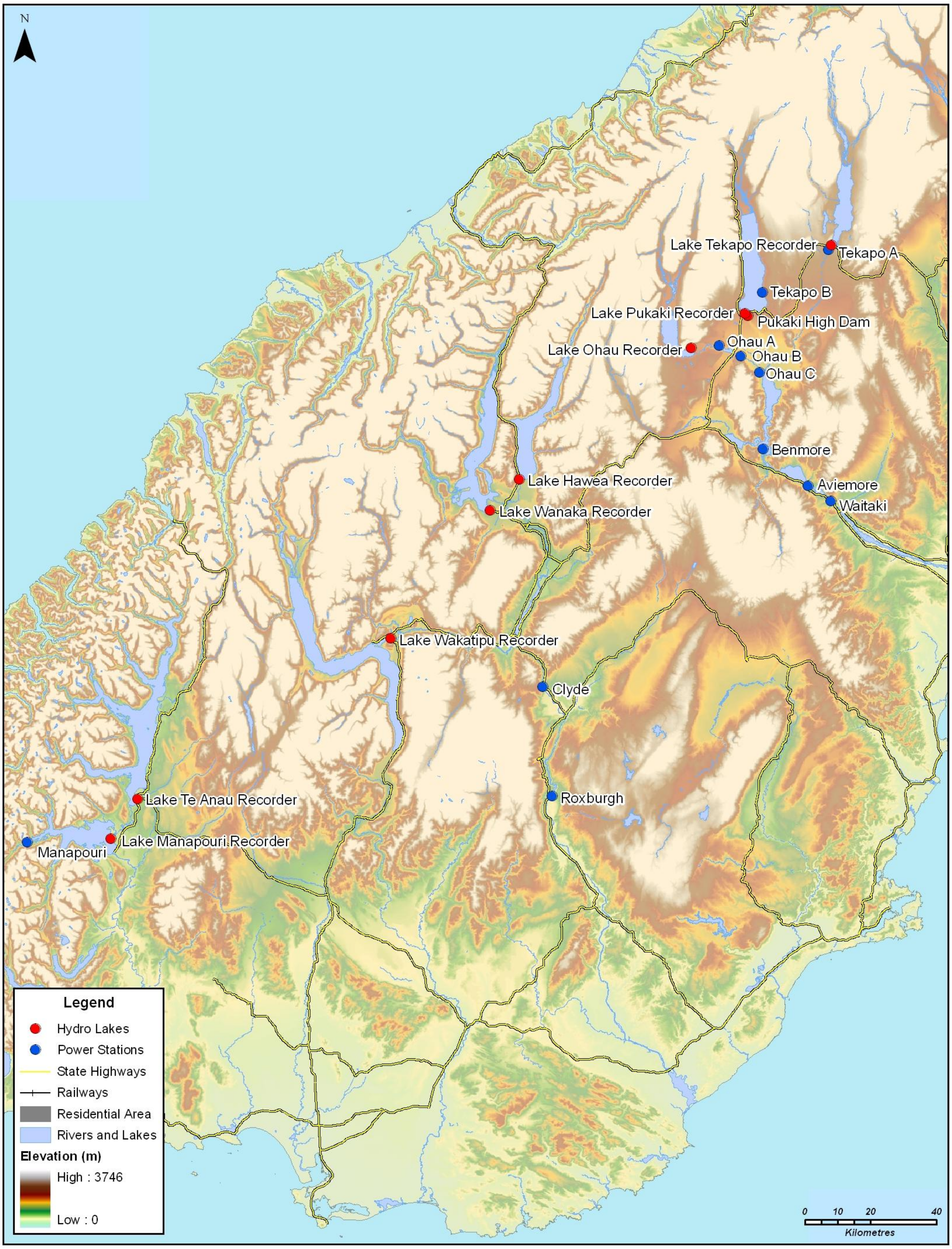

Figure 5.1 South Island hydro lakes reviewed.

5.2 Lake Ohau

5.2.1 Current operating consents

The operating range for Lake Ohau is between 519.45m and 520.25m. Lake Ohau is essentially managed as a 'run of the river' scheme because it has a weir at the outflow instead of control gates.

5.2.2 Lake level and storage volumes

The Lake Ohau water level record is shown in Figure 5.2. A lake level–lake area rating was used to calculate the lake storage volumes. Table 5.1 shows the characteristics of Lake Ohau used in this analysis, including the maximum and minimum storage volumes.

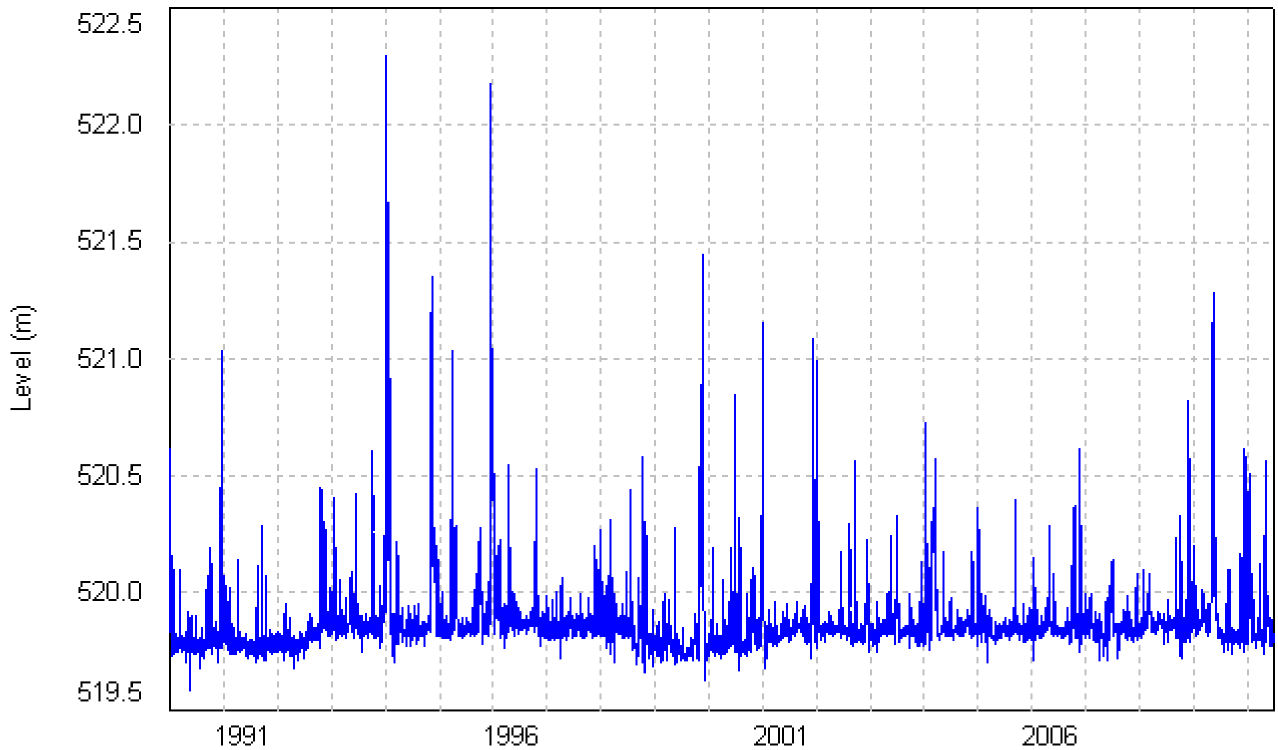

Figure 5.2 Lake Ohau water level record (masl) from 1990 to 2010.

Table 5.1 Characteristics of Lake Ohau.

Lake Ohau	
Lake area (km^2)	61.20
Normal operational maximum level (m)	520.25
Normal operational minimum level (m)	519.75
Consented minimum level (m)	519.45
Maximum storage (million m^3) – at normal operational maximum level	49.14
Minimum storage (million m^3) – at consented minimum level	0.00
Downstream power stations	***Average efficiency** (m^3/s/MW)*
Ohau A	1.998
Ohau B	2.400
Ohau C	2.400
Benmore	1.223
Aviemore	3.225
Waitaki	6.165

5.2.3 Generation potential

The Waitaki Scheme has six power stations through which the water from Lake Ohau can potentially pass. This includes: Ohau A, B and C; Benmore; Aviemore; and Waitaki. The total generation potential of the water stored in Lake Ohau was therefore derived from the sum of the average efficiency factor of each power station over the normal lake operating range (Figure 5.3). However, this assumes that all the water in Lake Ohau goes through each dam, and generates electricity at the average efficiency. This may not be the case all of the time. The generation potential may therefore be slightly different to the maximum actual generation based solely on the volume of water in the lake.

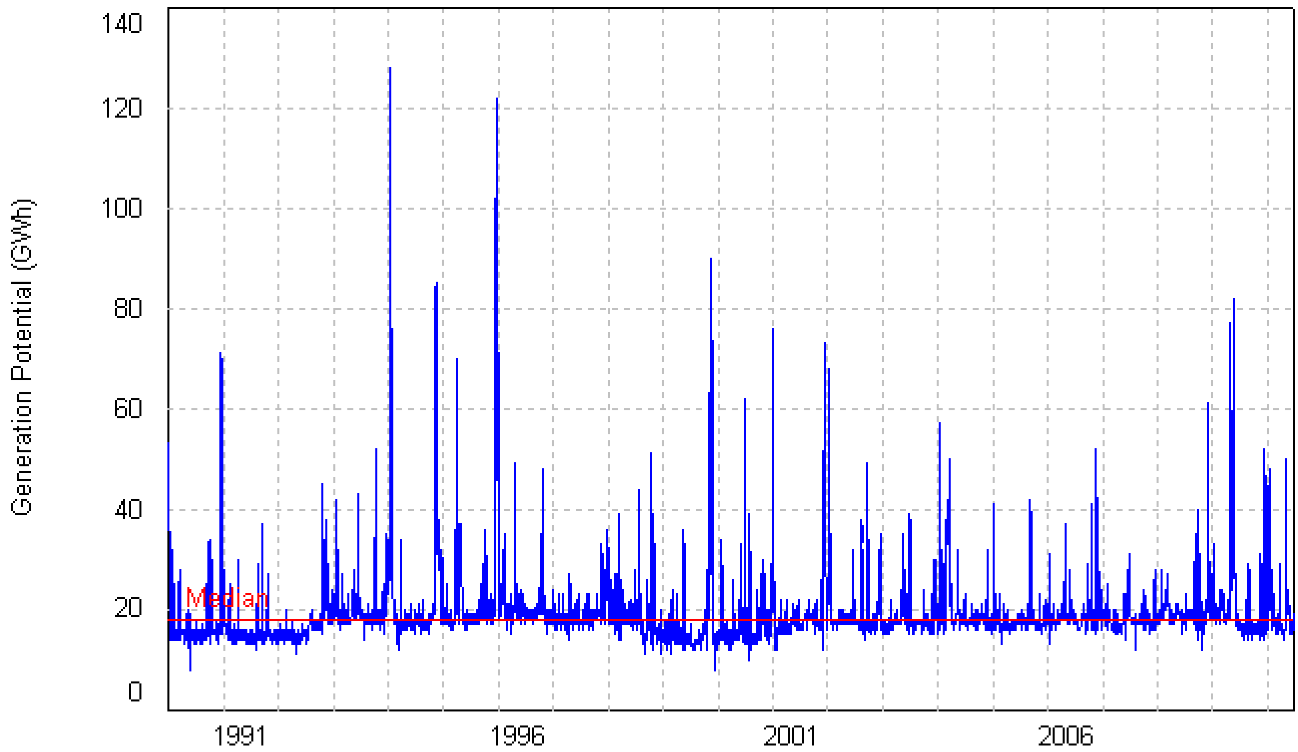

Figure 5.3 Total generation potential of Lake Ohau (1-Jan-1990 to 1-Jul-2010).

Table 5.2 summarises the variability in the total potential generation from the water held in Lake Ohau between 1990 and 2010.

Table 5.2 Variability in the generation potential of water held in Lake Ohau (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	8
Maximum	128
Mean	20
Median	18
10th percentile	15
Lower quartile	16
Upper quartile	20
90th percentile	26
Standard deviation	8

Figure 5.4 and Table 5.3 show the frequency distribution of the variability in generation potential of the water held in Lake Ohau.

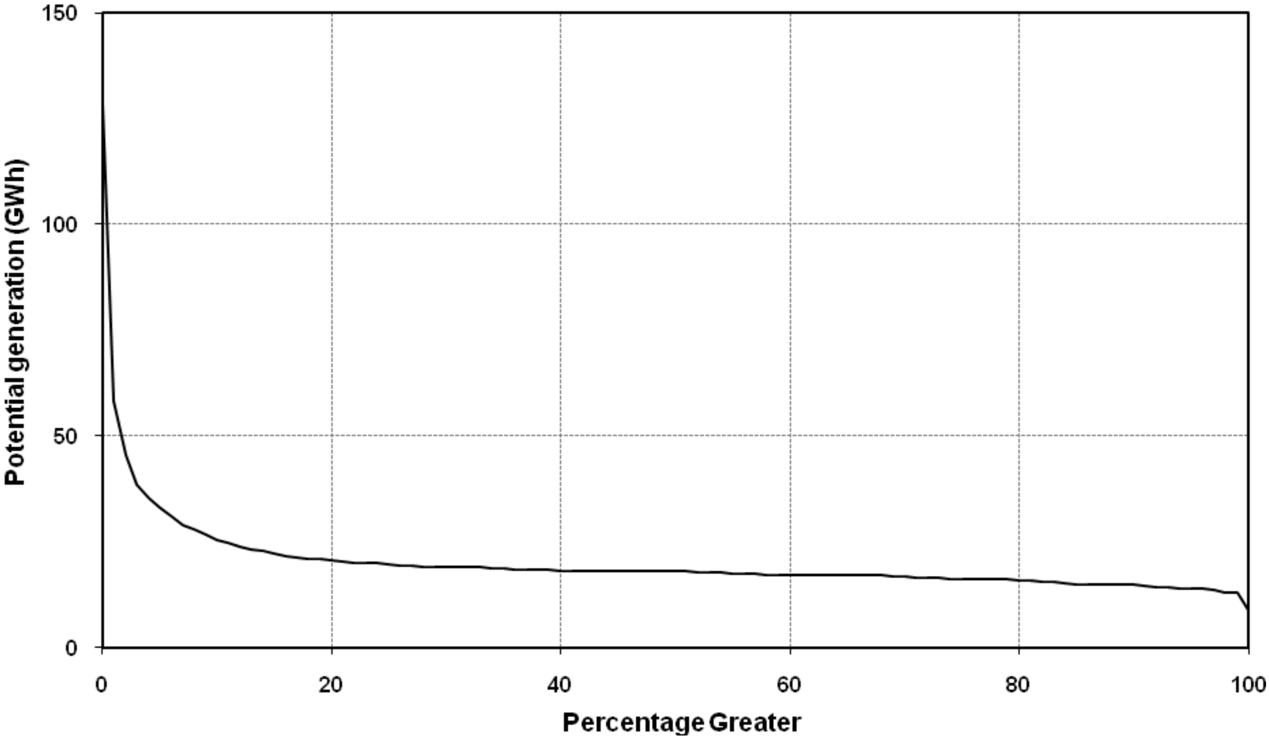

Figure 5.4 **Frequency distribution of the potential generation from water held in Lake Ohau.**

Table 5.3 **Frequency distribution table of the potential generation from water held in Lake Ohau.**

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	128	58	46	39	35	33	31	29	28	27
10	26	25	24	23	23	22	22	21	21	21
20	21	20	20	20	20	20	19	19	19	19
30	19	19	19	19	19	19	19	18	18	18
40	18	18	18	18	18	18	18	18	18	18
50	18	18	18	18	18	18	17	17	17	17
60	17	17	17	17	17	17	17	17	17	17
70	17	17	17	16	16	16	16	16	16	16
80	16	16	16	15	15	15	15	15	15	15
90	15	15	14	14	14	14	14	14	13	13
100	8									

5.3 Lake Tekapo

5.3.1 Current Operating Consents

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 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 of Lake Tekapo varies throughout the year as shown in Table 5.4.

Table 5.4 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

5.3.2 Lake level and storage volumes

The Lake Tekapo level record is shown in Figure 5.5. A lake level–lake area rating was used to calculate the lake storage volumes. Table 5.5 provides a summary of the variability in the storage of water held in Lake Tekapo, including the maximum and minimum storage volumes.

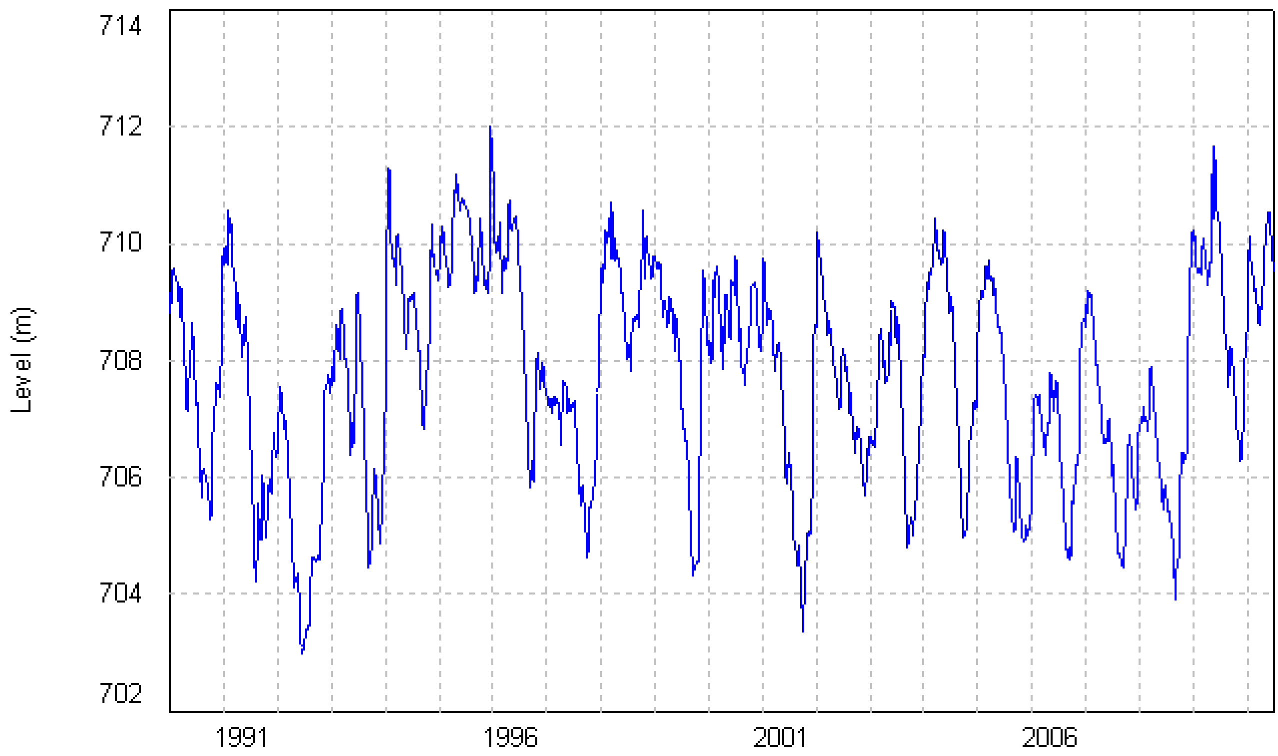

Figure 5.5 Lake Tekapo water level record (masl) from 1990 to 2010.

Table 5.5 Characteristics of Lake Tekapo.

Lake Tekapo	
Lake area (km²)	97.5
Normal operational maximum level (m)	709.7
Normal operational minimum levels (m) March – October October - March	702.1 701.8 704.1
Consented minimum level (m)	701.8
Maximum storage (million m³) - at normal operational maximum level	704.8
Minimum storage (million m³) - at consented minimum level	0.0
Downstream power stations	***Average efficiency** (m³/s/MW)*
Tekapo A	4.306
Tekapo B	0.780
Ohau A	1.998
Ohau B	2.400
Ohau C	2.400
Benmore	1.223
Aviemore	3.225
Waitaki	6.165

***Note:** Over the summer there is still additional generation potential stored in the lake but it cannot generally be accessed because of resource consent conditions.*

5.3.3 Generation potential

The Waitaki Scheme has eight power stations through which the water from Lake Tekapo can potentially pass. These include: Tekapo A and B, Ohau A, B and C; Benmore; Aviemore and Waitaki. The total generation potential of the water held in Lake Tekapo (GWh) is therefore the sum of the average efficiency of each power station over the normal operating range of the lake (Figure 5.6).

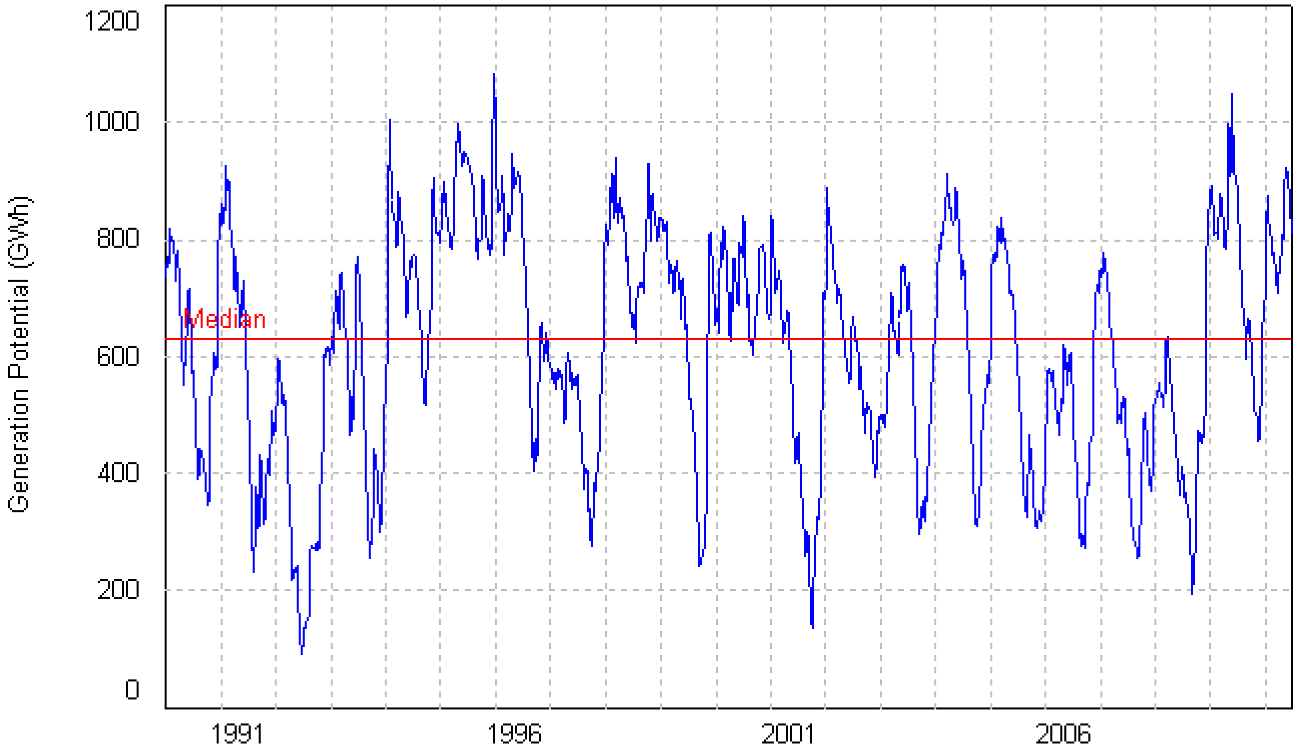

Figure 5.6 Total generation potential of water held in Lake Tekapo (1-Jan-1990 to 1-Jul-2010).

Table 5.6 summarises the variability in the potential generation of the water held in Lake Tekapo between 1990 and 2010.

Table 5.6 Variability in the generation potential of water held in Lake Tekapo (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	92
Maximum	1086
Mean	614
Median	630
10th percentile	331
Lower quartile	466
Upper quartile	778
90th percentile	852
Standard deviation	196

Figure 5.7 and Table 5.7 show the frequency distribution for the variability in total generation potential of the water held in Lake Tekapo.

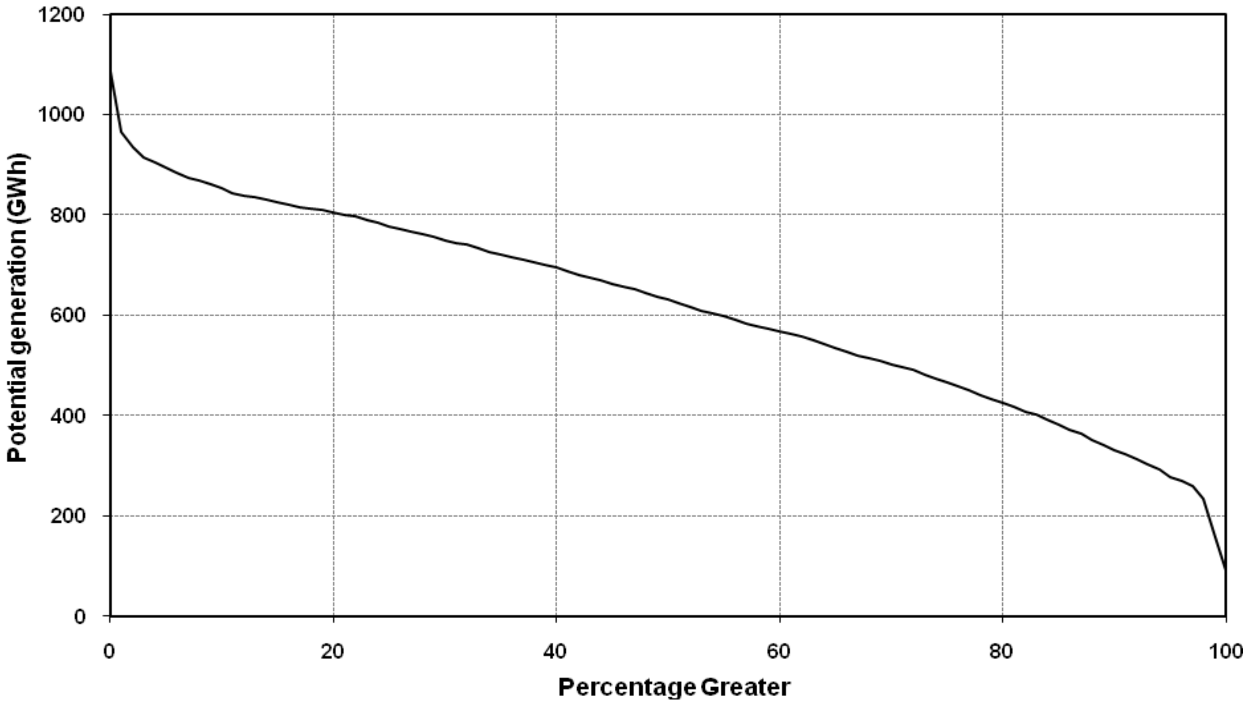

Figure 5.7 Frequency distribution of the total potential generation from water held in Lake Tekapo.

Table 5.7 Frequency distribution table of the total potential generation from water held in Lake Tekapo.

	0	1	2	3	4	5	6	7	8	9
0	1086	965	935	915	905	895	884	875	868	860
10	852	844	839	835	830	825	821	816	812	809
20	804	800	796	790	784	778	773	768	762	756
30	750	745	740	733	727	721	715	711	707	701
40	694	688	681	674	669	663	657	652	645	638
50	630	623	616	609	604	597	591	583	577	572
60	567	562	557	551	543	533	527	520	515	509
70	502	497	491	482	473	466	458	450	441	433
80	424	416	408	402	392	381	372	363	351	340
90	331	323	314	303	291	278	270	258	235	156
100	92									

5.4 Lake Pukaki

5.4.1 Current operating consents

The consented minimum control level for Lake Pukaki is 518.0 masl. The maximum control level varies throughout the year as detailed in Table 5.8.

Table 5.8 Maximum control levels for Lake Pukaki.

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

5.4.2 Lake levels and storage volumes

The Lake Pukaki water level record is shown in Figure 5.8. A lake level–lake area rating was used to calculate the lake storage volumes. Table 5.9 shows the characteristics of Lake Pukaki used in the analysis, including the maximum and minimum storage volumes.

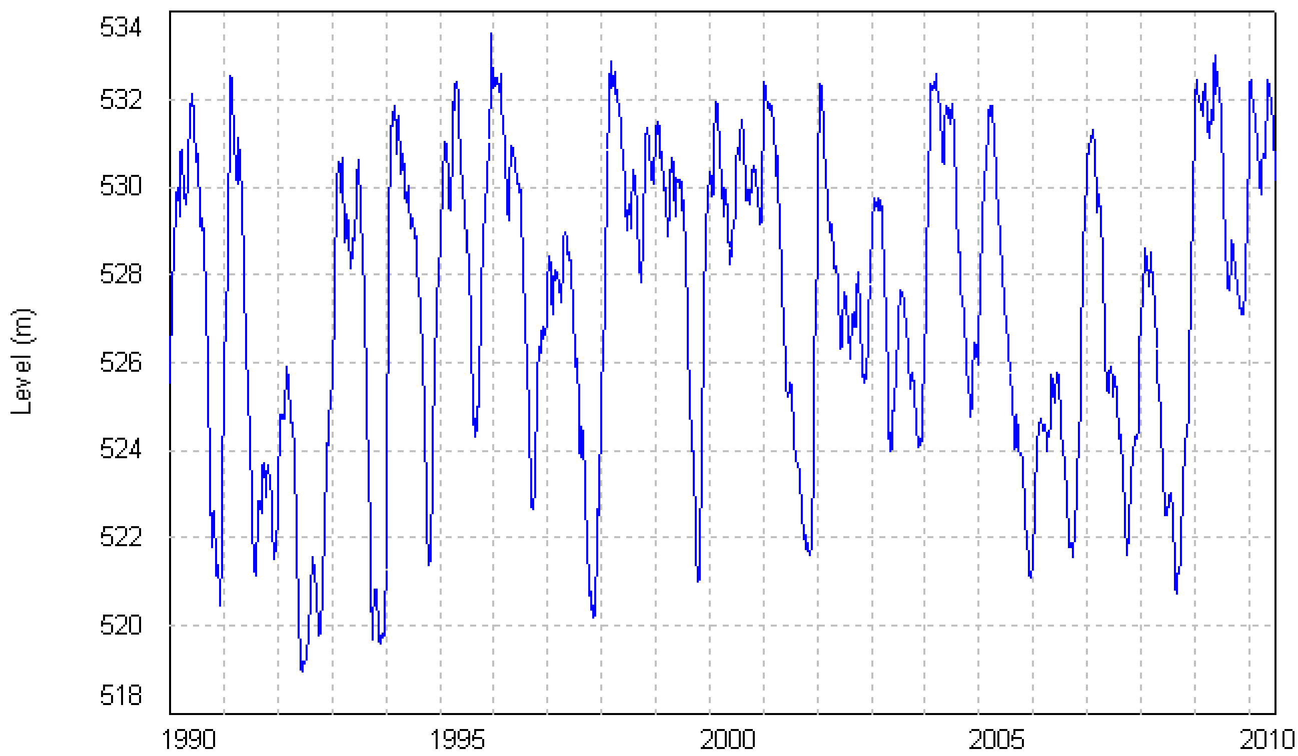

Figure 5.8 Lake Pukaki water level record (masl) from 1990 to 2010.

Table 5.9 Characteristics of Lake Pukaki.

Lake Pukaki	
Lake area (km²)	178.70
Normal operational maximum level (m)	532.00
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
Downstream power stations	***Average efficiency** (m³/s/MW)*
Tekapo A	4.306
Tekapo B	0.780
Ohau A	1.998
Ohau B	2.400
Ohau C	2.400
Benmore	1.223
Aviemore	3.225
Waitaki	6.165

5.4.3 Generation potential

The Waitaki Scheme has six power stations through which the water from Lake Pukaki can potentially pass. This includes: Ohau A, B and C; Benmore; Aviemore; and Waitaki. The total generation potential of the water stored in Lake Pukaki was therefore derived from the sum of the average efficiency factor of each power station over the normal lake operating range (Figure 5.9).

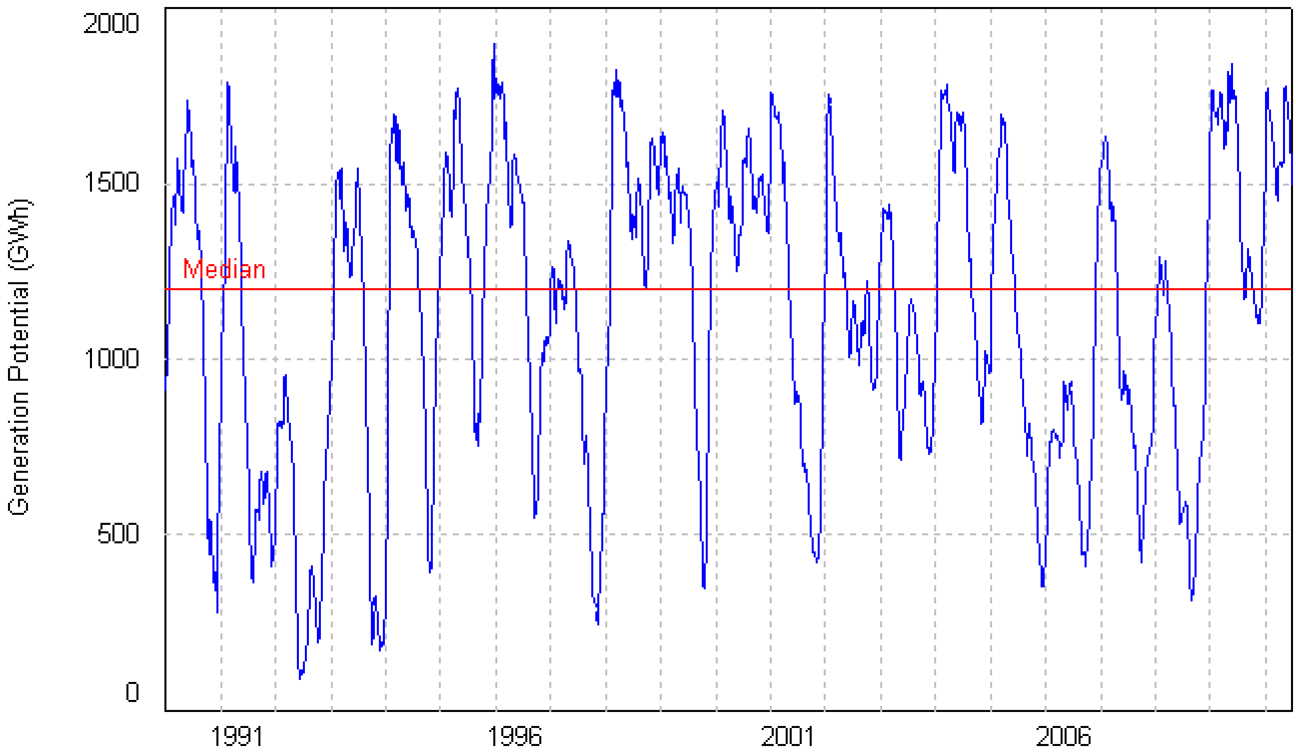

Figure 5.9 Total generation potential of Lake Pukaki (1-Jan-1990 to 1-Jul-2010).

Table 5.10 summarises the variability in the total potential generation from water held in Lake Pukaki between 1990 and 2010.

Table 5.10 Variability in the total generation potential from water held in Lake Pukaki (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	85
Maximum	1896
Mean	1130
Median	1197
10^{th} percentile	480
Lower quartile	790
Upper quartile	1495
90^{th} percentile	1664
Standard deviation	433

Figure 5.10 and Table 5.11 show the frequency distribution for the variability in generation potential from the water held in Lake Pukaki.

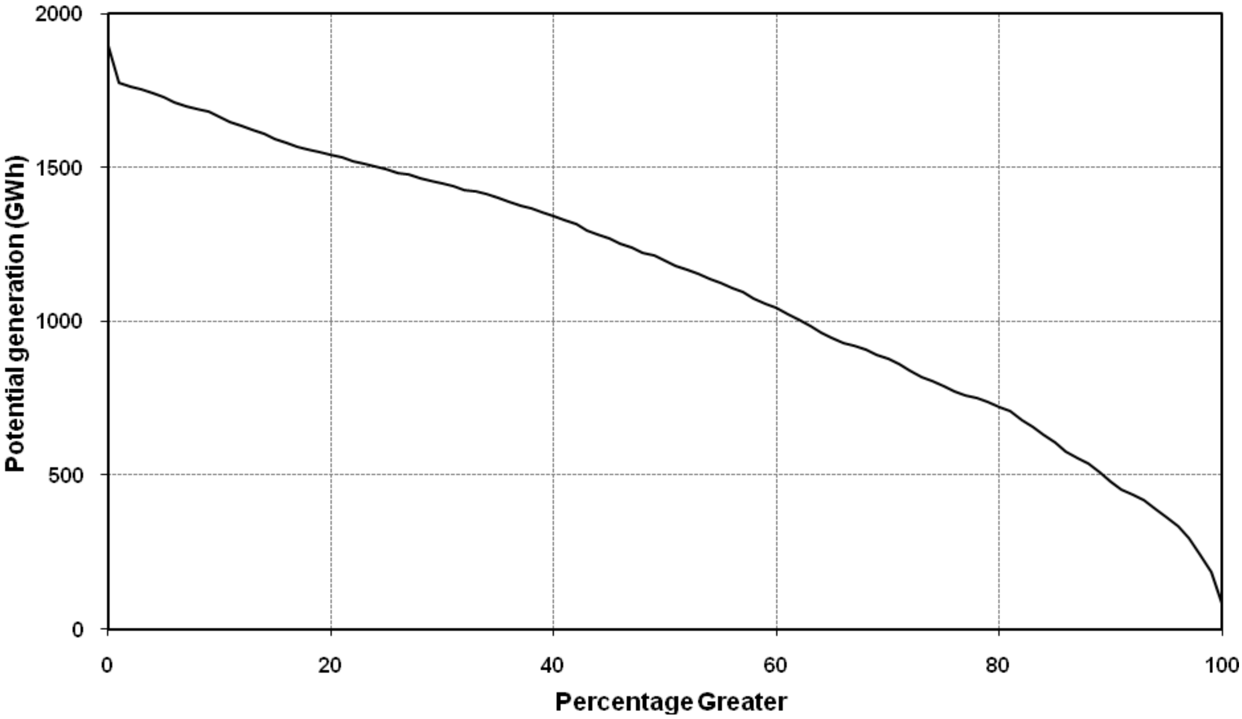

Figure 5.10 Frequency distribution of the total potential generation from water held in Lake Pukaki.

Table 5.11 Frequency distribution table of the total potential generation from water held in Lake Pukaki.

	0	1	2	3	4	5	6	7	8	9
0	1896	1774	1763	1755	1743	1730	1712	1699	1690	1680
10	1664	1649	1637	1622	1608	1594	1581	1568	1560	1552
20	1543	1532	1522	1512	1504	1495	1484	1476	1466	1455
30	1446	1438	1428	1420	1413	1402	1390	1376	1365	1354
40	1342	1327	1315	1296	1281	1268	1253	1238	1225	1214
50	1197	1180	1166	1153	1139	1125	1110	1094	1075	1058
60	1042	1021	1004	984	965	945	929	919	906	892
70	878	859	839	817	804	790	773	760	750	737
80	722	706	680	658	633	604	576	556	537	509
90	480	453	436	418	391	366	336	297	245	184
100	85									

5.5 Lake Wanaka

5.5.1 Current operating consents

Lake Wanaka 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 800m³/s except when flood emergency conditions prevail. Contact Energy treat the 'normal operating range' of Lake Wanaka as 276.35m to 278.00m (Table 5.12).

Table 5.12 'Operating' levels Lake Wanaka.

Lake Wanaka	
Minimum	276.35
Maximum	278.00

5.5.2 Lake levels and storage volumes

The Lake Wanaka water level record is shown in Figure 5.11. At the 'minimum operating level', water is still being discharged and can be used for generation. Therefore, the thalweg level (275.40m) at the lake outlet was taken to have storage of 0m³. At the 'minimum operating level' there is still estimated to be 183.35 million m³ of storage. Table 5.13 shows the characteristics of Lake Wanaka used in this analysis, including the maximum and minimum storage volumes. The large size of Lake Wanaka means that a constant area was assumed for the lake storage rating.

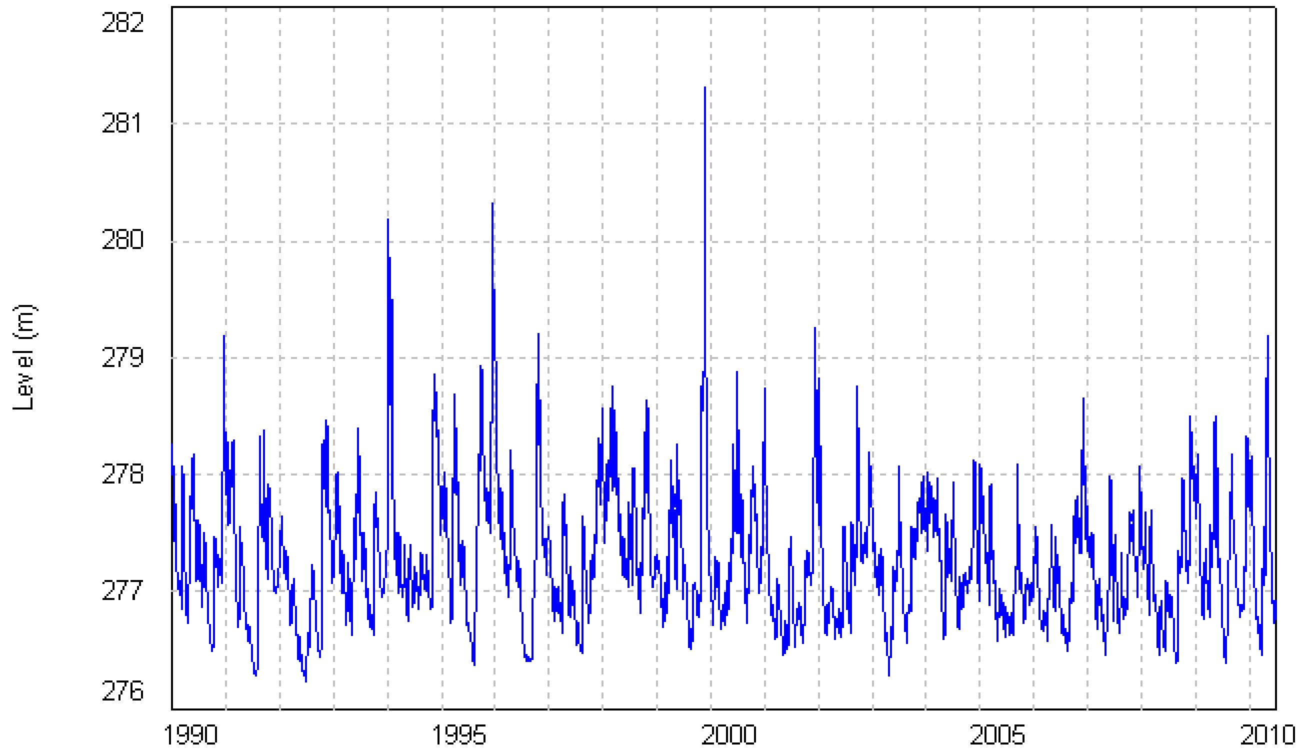

Figure 5.11 Lake Wanaka water level record (masl) from 1990 to 2010.

Table 5.13 Characteristics of Lake Wanaka.

Lake Wanaka	
Lake area (km²)	193.00
Maximum 'operating level' (m)	278.00
Minimum 'operating level' (m)	276.35
Maximum storage (million m³) - at 'maximum operating level'	501.80
Minimum storage (million m³) - at 'minimum operating level'	183.35
Downstream power stations	***Average efficiency** (m³/s/MW)*
Clyde	1.93
Roxburgh	2.54

5.5.3 Generation potential

The Clutha and Kawarau rivers flow into Lake Dunstan which supplies both the Clyde and Roxburgh dams. The total generation potential of water stored in Lake Wanaka was therefore derived from the sum of the average efficiency factor of each power station (Figure 5.12).

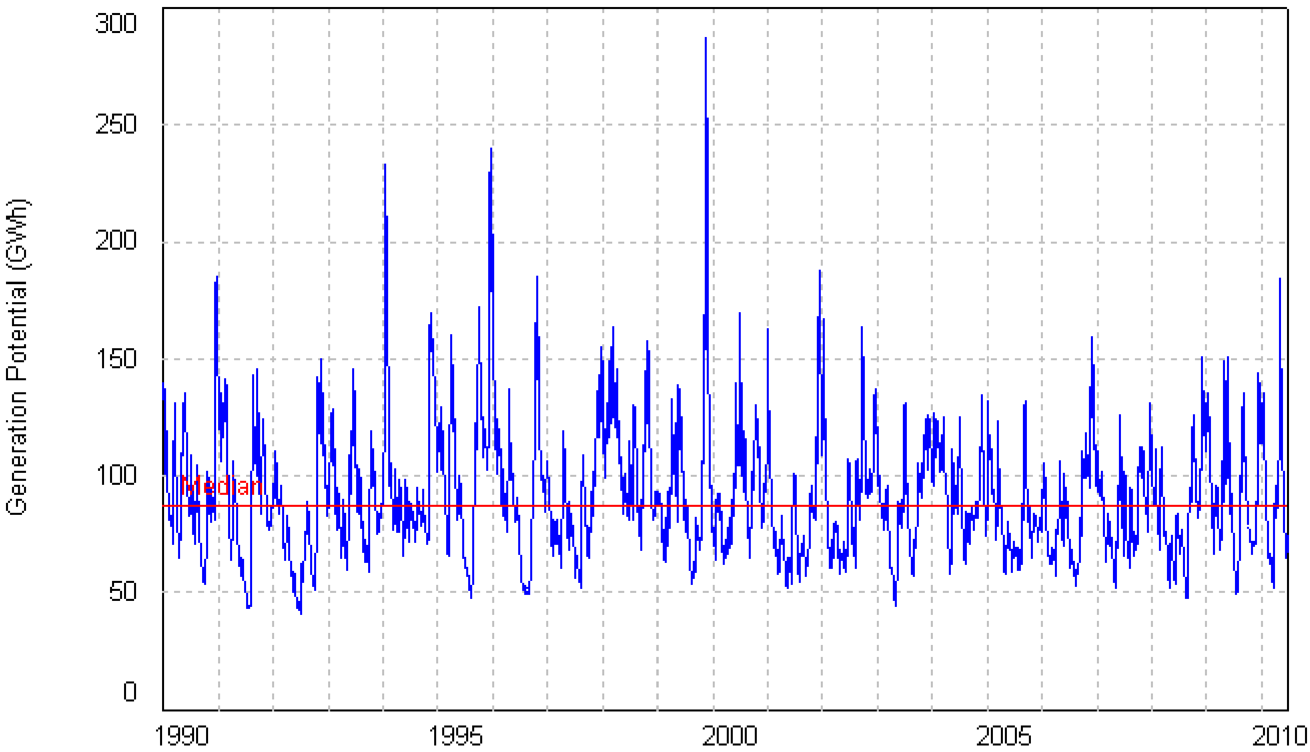

Figure 5.12 Total generation potential of Lake Wanaka (1-Jan-1990 to 1-Jul-2010).

Table 5.14 summarises the variability in the total potential generation from water held in Lake Wanaka between 1990 and 2010, based on the previous assumptions.

Table 5.14 Variability in the total generation potential from water held in Lake Wanaka (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	41
Maximum	287
Mean	91
Median	87
10th percentile	62
Lower quartile	72
Upper quartile	106
90th percentile	126
Standard deviation	27

Figure 5.13 and Table 5.15 show the frequency distribution of the total generation potential from water held in Lake Wanaka.

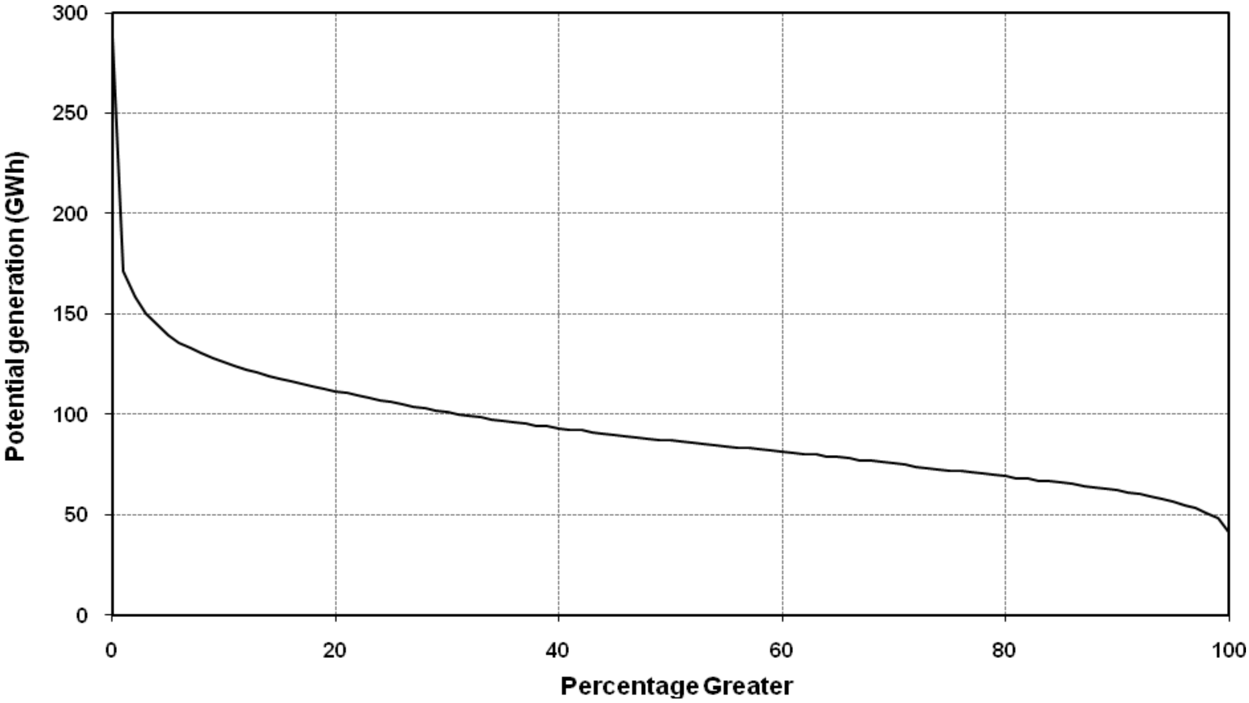

Figure 5.13 Frequency distribution of the total potential generation from water held in Lake Wanaka.

Table 5.15 Frequency distribution table of the total potential generation from water held in Lake Wanaka.

	0	1	2	3	4	5	6	7	8	9
0	287	171	159	150	144	139	136	133	130	128
10	126	124	122	121	119	118	117	115	114	113
20	112	111	109	108	107	106	105	104	103	102
30	101	100	99	98	98	97	96	95	94	94
40	93	93	92	91	90	90	89	89	88	87
50	87	86	86	85	85	84	84	83	82	82
60	81	81	80	80	79	79	78	77	77	76
70	75	75	74	73	73	72	72	71	70	70
80	69	68	68	67	66	66	65	64	64	63
90	62	61	60	59	58	56	55	53	51	48
100	41									

5.6 Lake Hawea

5.6.1 Current operating consents

The consented minimum control level for Lake Hawea is 338m. However, this can be lowered to 336m (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.

5.6.2 Lake levels and storage volumes

The Lake Hawea water level record is shown in Figure 5.14. A lake level–lake area rating was used to calculate the lake storage volumes. Table 5.16 shows the characteristics of Lake Hawea used in the analysis, including the maximum and minimum storage volumes.

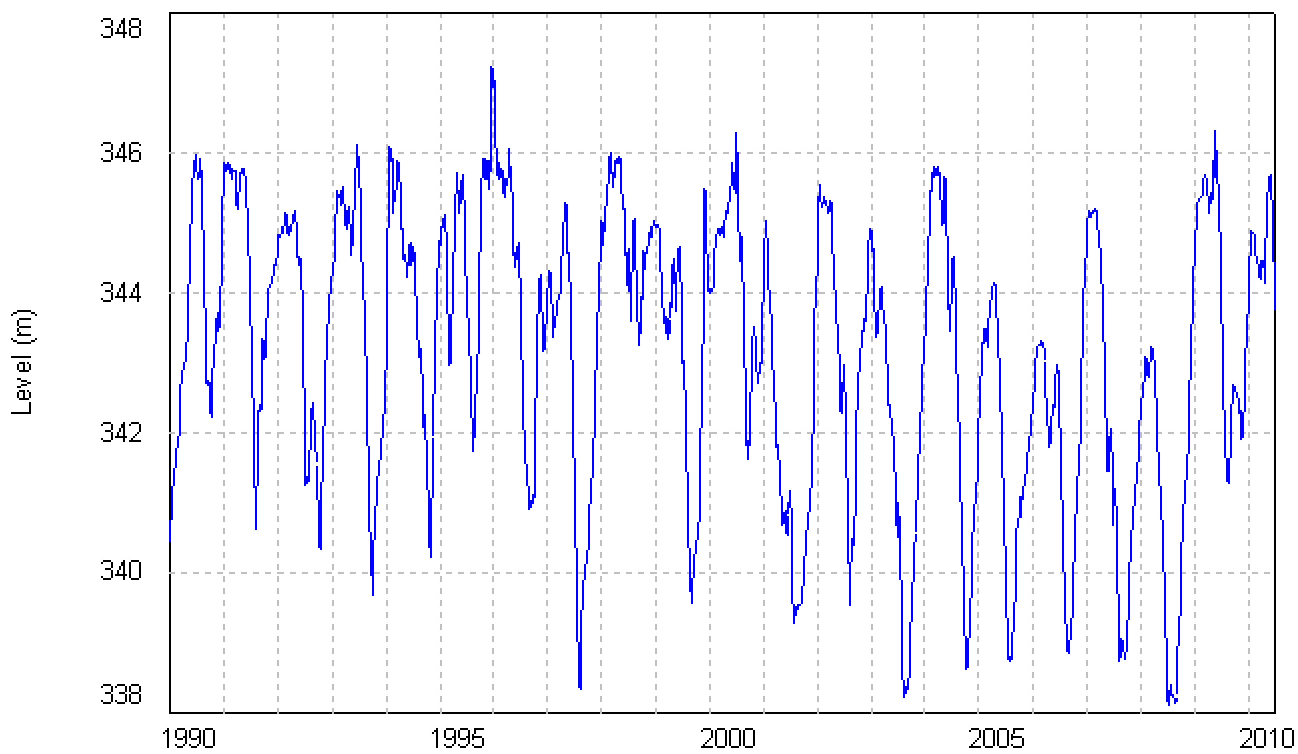

Figure 5.14 Lake Hawea water level record (masl) from 1990 to 2010.

Table 5.16 Characteristics of Lake Hawea.

Lake Hawea	
Lake area (km²)	141.7
Maximum operating level (m)	346.0
Minimum operating level (m)	338.0
Maximum storage (million m³) - at maximum operating level	1139.0
Minimum storage (million m³) - at minimum operating level	0.0
Downstream power stations	***Average efficiency** (m^3/s/MW)*
Clyde	1.93
Roxburgh	2.54

Note: ***The minimum operating level has been assumed to be 338m and not 336m which is only available under special circumstances.***

5.6.3 Generation potential

Lake Hawea flows into the Clutha River, via the Hawea River, and then into Lake Dunstan which feeds two power stations; Clyde and Roxburgh. The total generation potential of the water stored in Lake Hawea (GWh) was therefore derived from the sum of the average efficiency factor of each power station over the normal lake operating range (Figure 5.15).

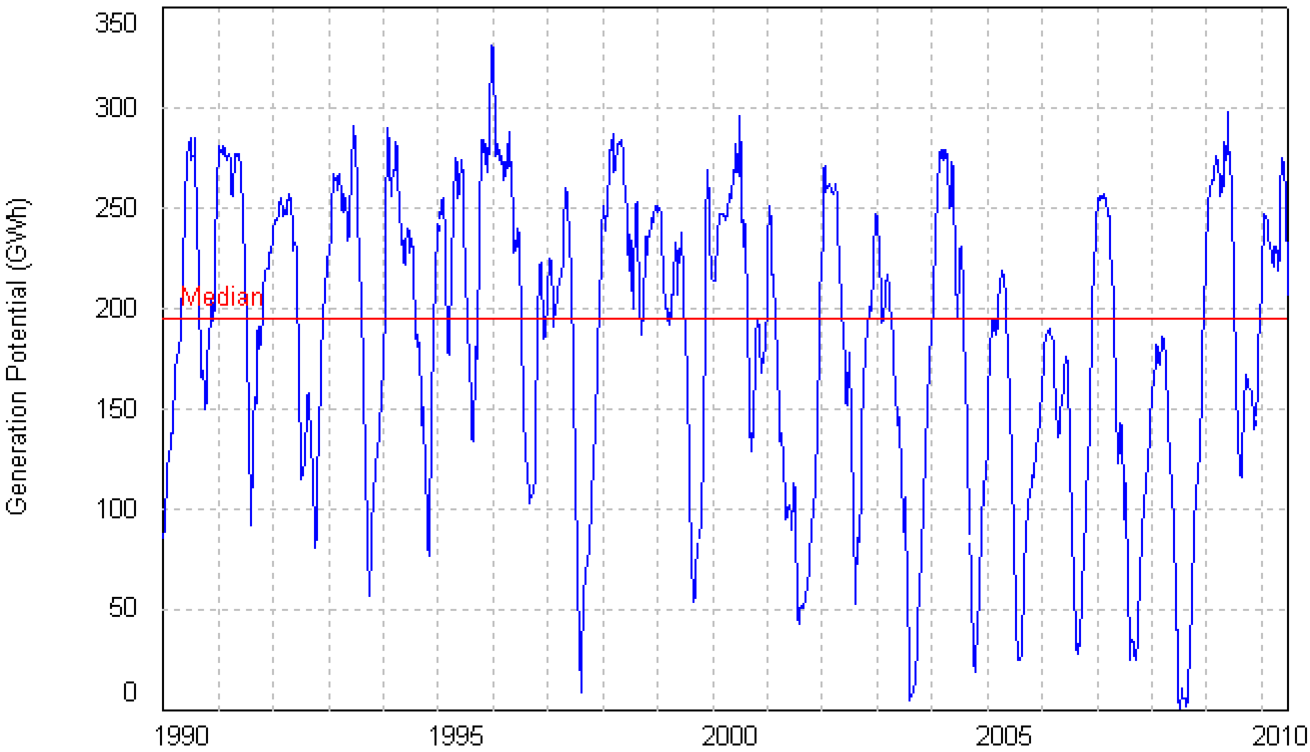

Figure 5.15 Total generation potential of Lake Hawea (1-Jan-1990 to 1-Jul-2010).

Table 5.17 summarises the variability in the total potential generation from water held in Lake Hawea between 1990 and 2010.

Table 5.17 Variability in the total generation potential from water held in Lake Hawea (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	1
Maximum	331
Mean	184
Median	195
10th percentile	77
Lower quartile	131
Upper quartile	246
90th percentile	270
Standard deviation	73

Figure 5.16 and Table 5.18 show the frequency distribution of the variability in total generation potential from the water held in Lake Hawea.

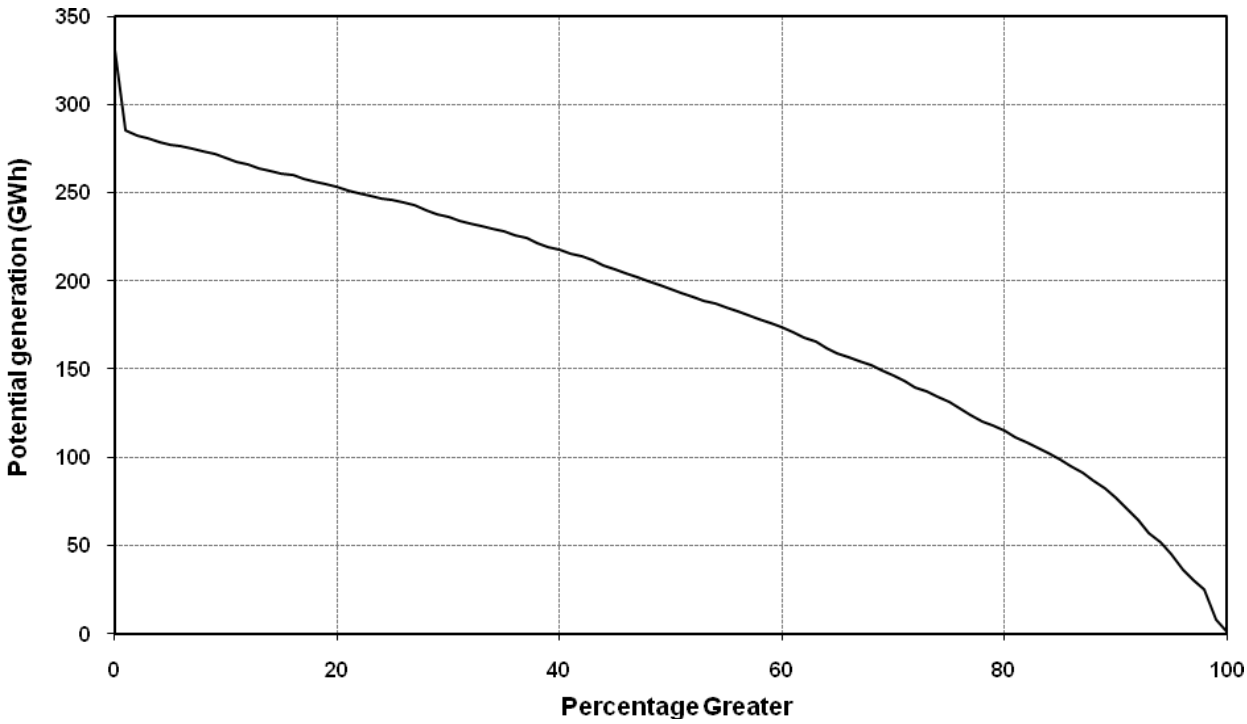

Figure 5.16 Frequency distribution of the total potential generation from water held in Lake Hawea.

Table 5.18 Frequency distribution of the total potential generation from water held in Lake Hawea.

	0	1	2	3	4	5	6	7	8	9
0	331	285	282	281	279	277	276	275	274	272
10	270	268	266	264	262	261	260	258	256	255
20	253	251	250	248	247	246	244	243	240	238
30	236	234	233	231	230	228	226	224	221	219
40	217	216	214	212	209	207	204	202	200	197
50	195	193	191	189	187	185	183	181	178	176
60	174	171	168	165	162	159	157	154	152	149
70	146	143	140	137	134	131	128	124	120	118
80	115	112	109	105	102	99	95	92	87	82
90	77	71	65	57	52	45	36	30	25	8
100	1									

5.7 Lake Wakatipu

5.7.1 Current operating consents

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

5.7.2 Lake level and storage volumes

The Lake Wakatipu water level record is shown in Figure 5.17. Table 5.19 shows the characteristics of Lake Wakatipu used in the analysis, including the maximum and minimum storage volumes. The large size of Lake Wakatipu means that a constant area was assumed for the lake storage rating.

At the minimum ‘operating’ level, water is still being discharged and can be used for generation. Therefore, a lake level equal to the sill elevation (308.83m) at the lake outlet was taken to imply a storage capacity of 0m³. At the minimum ‘operating’ level there is 225.61 million m³ of storage.

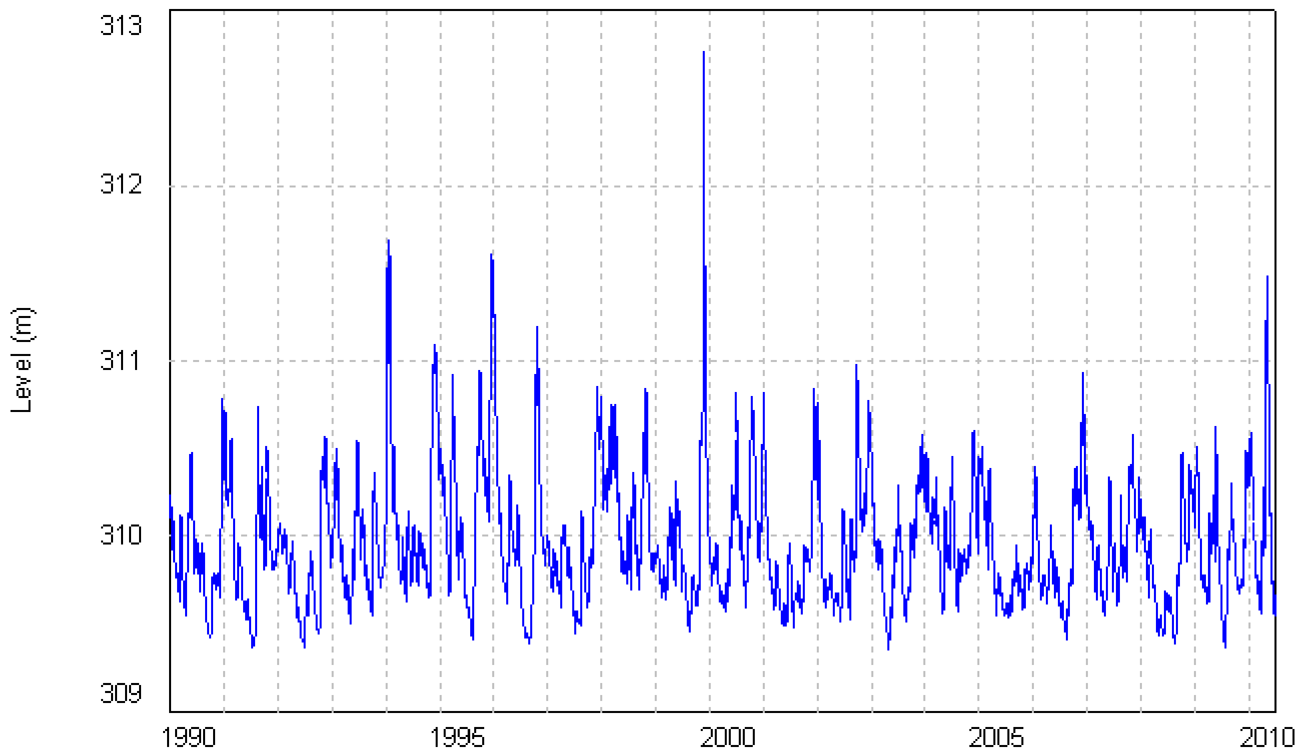

Figure 5.17 Lake Wakatipu water level record (masl) from 1990 to 2010.

Table 5.19 Characteristics of Lake Wakatipu.

Lake Wakatipu	
Lake area (km²)	293.00
Maximum 'operating' level (m)	310.80
Minimum 'operating level' (m)	309.60
Maximum storage (million m³) - at the maximum 'operating' level	577.21
Minimum storage (million m³) - at the minimum 'operating' level	225.61
Downstream power stations	***Average efficiency** (m³/s/MW)*
Clyde	1.93
Roxburgh	2.54

5.7.3 Generation potential

The Kawarau River from Lake Wakatipu flows into the Clutha River and then Lake Dunstan which feeds two power stations; Clyde and Roxburgh. The total generation potential of the water in Lake Wakatipu (GWh) was therefore derived from the sum of the average efficiency factor of each power station (Figure 5.18).

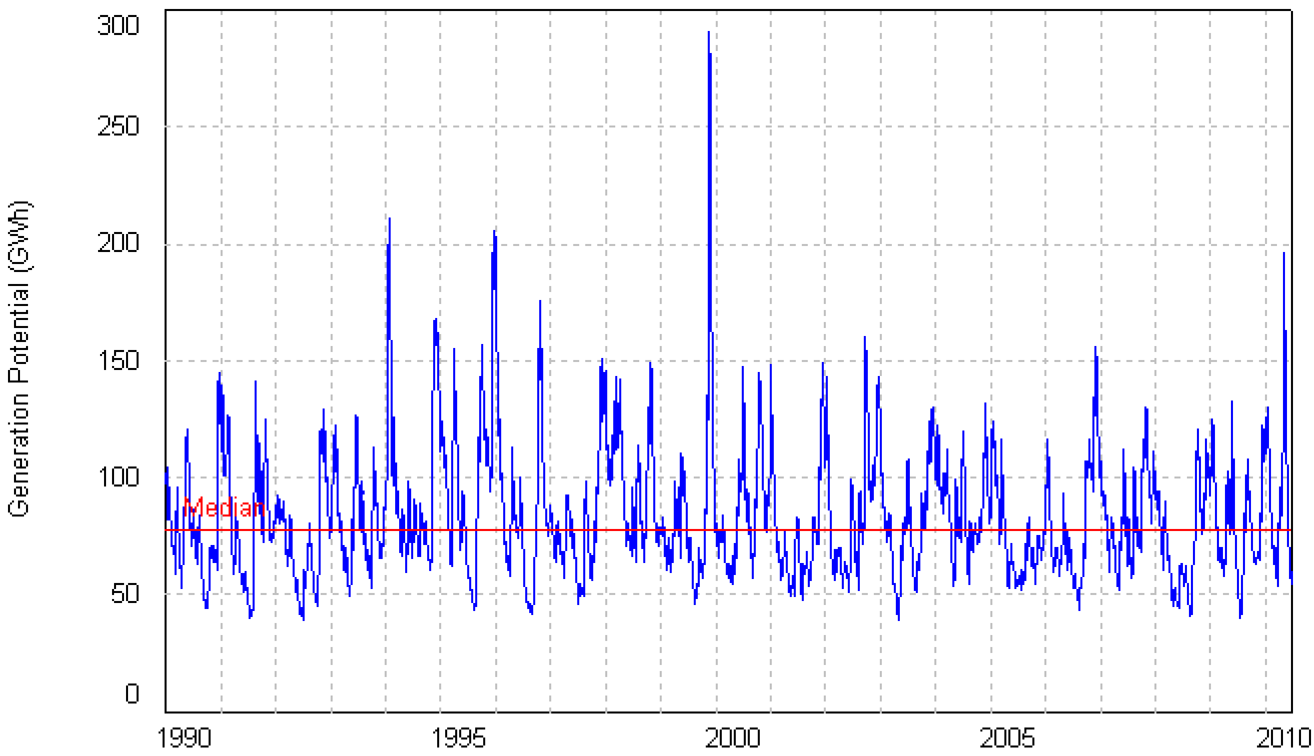

Figure 5.18 Total generation potential of Lake Wakatipu (1-Jan-1990 to 1-Jul-2010).

Table 5.20 summarises the variability in the total potential generation from water held in Lake Wakatipu from 1990 to 2010.

Table 5.20 Variability in the generation potential from water held in Lake Wakatipu (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	39
Maximum	291
Mean	84
Median	78
10^{th} percentile	55
Lower quartile	65
Upper quartile	98
90^{th} percentile	120
Standard deviation	27

Figure 5.19 and Table 5.21 show the frequency distribution of the variability in total generation potential from water held in Lake Wakatipu.

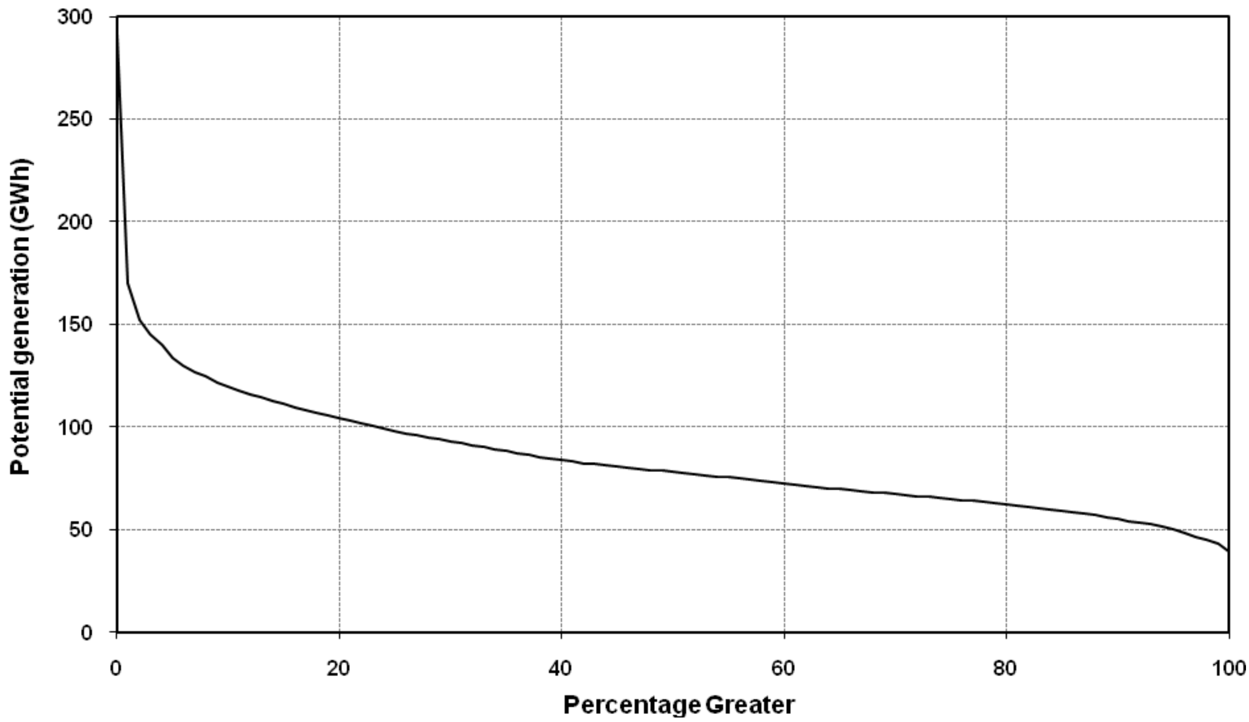

Figure 5.19 Frequency distribution of the total potential generation from water held in Lake Wakatipu.

Table 5.21 Frequency distribution table of the total potential generation from water held in Lake Wakatipu.

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	291	170	152	145	140	134	130	127	124	122
10	120	118	116	114	113	111	110	108	107	105
20	104	103	102	100	99	98	97	96	95	94
30	93	92	91	90	89	88	87	86	85	85
40	84	83	82	82	81	81	80	80	79	79
50	78	78	77	76	76	75	75	74	74	73
60	73	72	71	71	70	70	69	69	68	68
70	67	67	66	66	65	65	64	64	63	63
80	62	62	61	60	60	59	58	58	57	56
90	55	54	53	53	51	50	48	46	45	43
100	39									

5.8 Lake Te Anau

5.8.1 Current operating consents

Lake Te Anau is a storage component in the Manapouri 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 202.7 m and 201.5 m

Low Range: below 201.5 m

The top of the Main Range (202.7m) is also known as the maximum control level and the bottom of the Main Range (201.5m) 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 203.3m, which is 0.6m into the high range. There are also further complications in relation to the high and low ranges as set out in the Manapouri-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 particular lake level can remain stable.

For this report, the maximum operating level is 202.7m, and the minimum operating level is 201.5m, in accordance with the Main Range set out in the Act. However, the absolute minimum level of 200.86m 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.

5.8.2 Lake levels and storage volumes

The Lake Te Anau water level record is shown in Figure 5.20. Table 5.22 shows the characteristics of Lake Te Anau used in the analysis, including the maximum and extreme minimum storage volumes. 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.

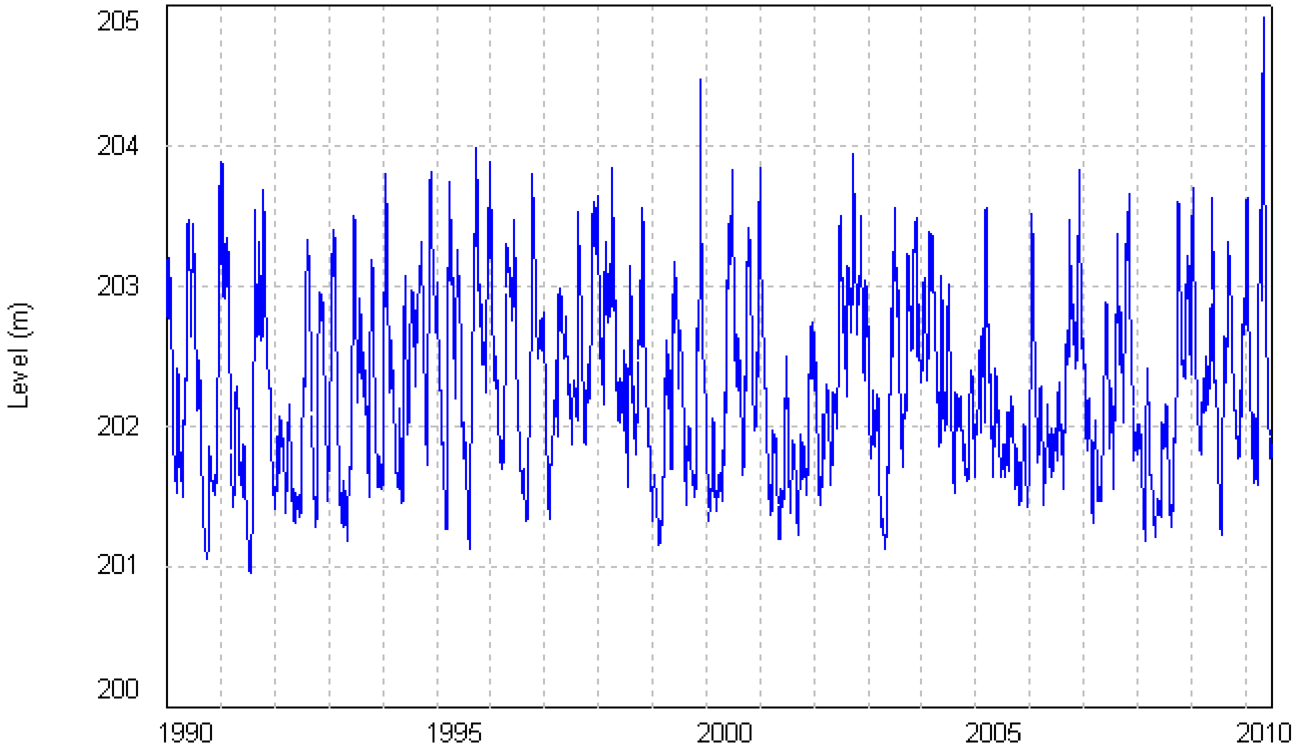

Figure 5.20 Lake Te Anau water level record (masl) from 1990 to 2010.

Table 5.22 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
Maximum storage (million m³) – at maximum operating level	647.68
Minimum storage (million m³) – at absolute minimum level	0.00
Downstream power stations	***Average efficiency** (m³/s/MW)*
Manapouri	0.653

5.8.3 Generation potential

The Waiau Scheme has one power station (i.e., Manapouri) through which the water from Lake Te Anau may pass. The generation potential of Lake Te Anau (GWh) was therefore assumed to be the average efficiency of the Manapouri station from the maximum normal lake level down to the extreme minimum (Figure 5.21). The average station efficiency since the construction of the second tailrace has been used over the entire length of the record for consistency.

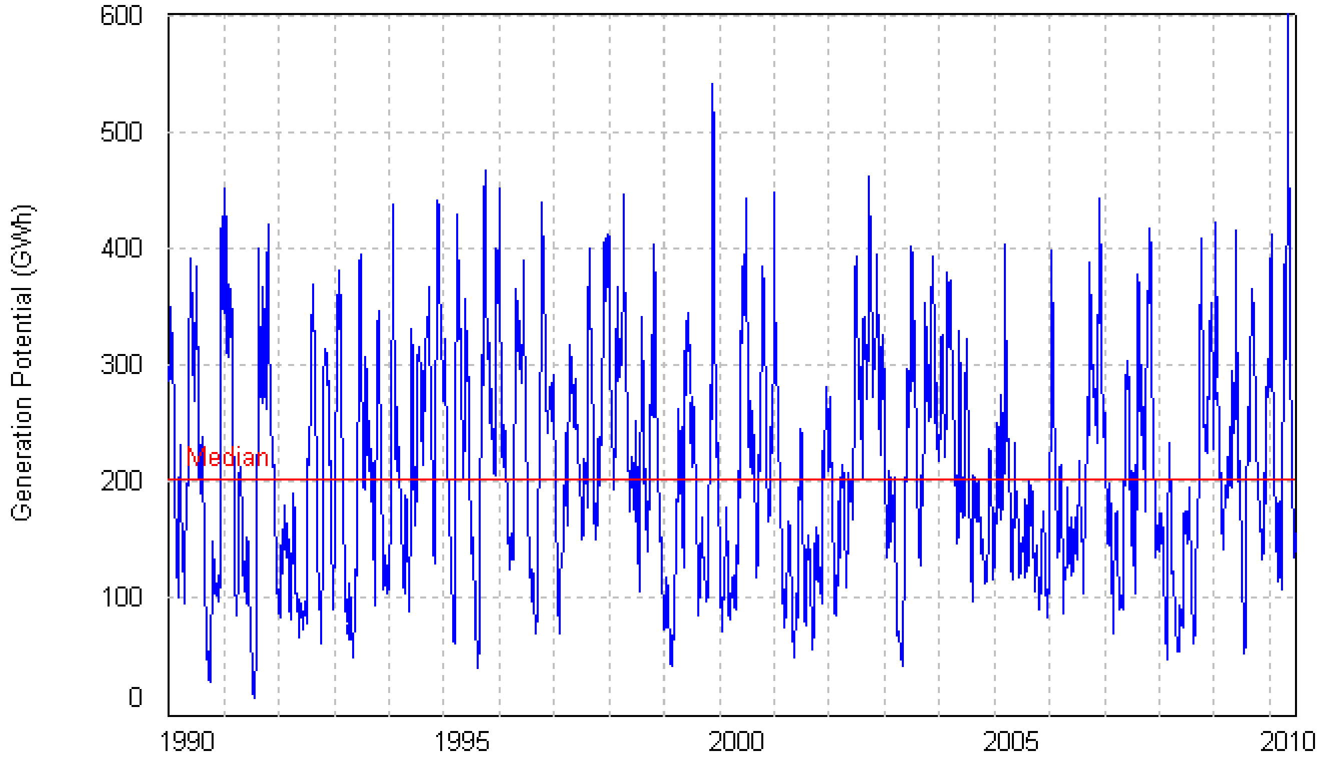

Figure 5.21 Total generation potential of Lake Te Anau (1-Jan-1990 to 1-Jul-2010).

Table 5.23 summarises the variability in the total potential generation from water held in Lake Te Anau between 1990 and 2010.

Table 5.23 Variability in the total generation potential from water held in Lake Te Anau (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	14
Maximum	601
Mean	213
Median	203
10th percentile	98
Lower quartile	138
Upper quartile	284
90th percentile	344
Standard deviation	93

Figure 5.22 and Table 5.24 show the frequency distribution of the variability in generation potential of the water held in Lake Te Anau.

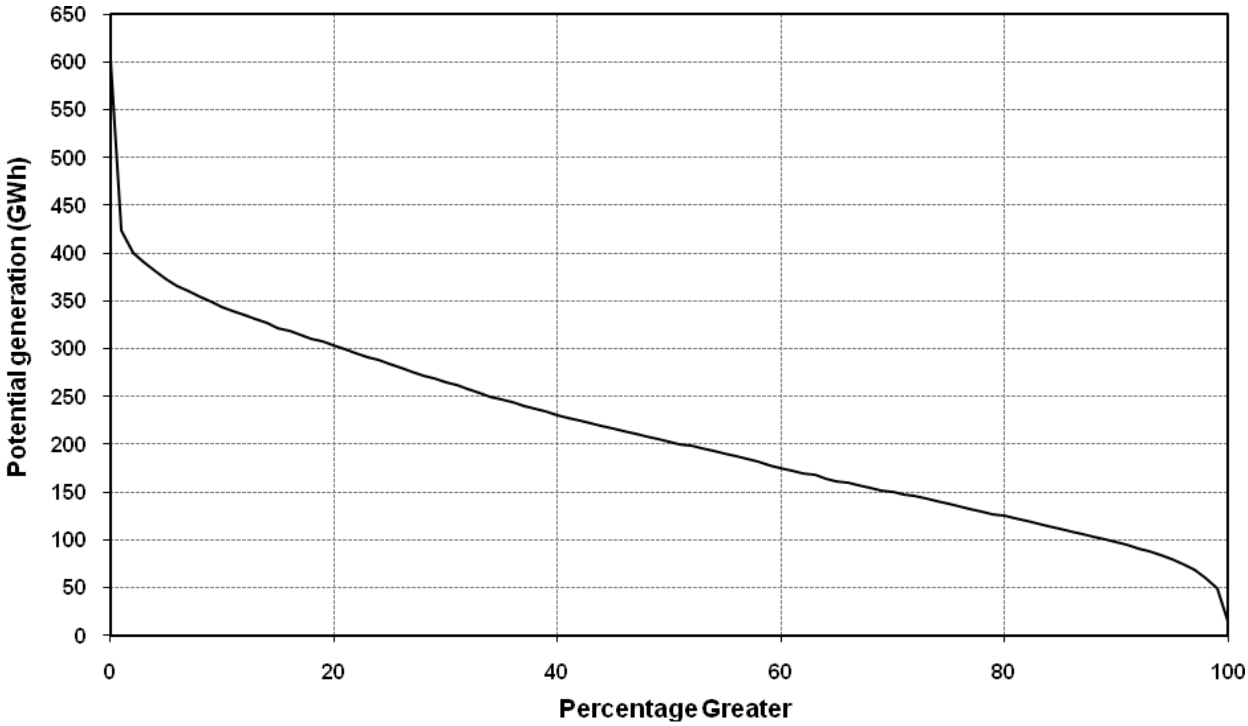

Figure 5.22 Frequency distribution of the potential generation from water held in Lake Te Anau.

Table 5.24 Frequency distribution of the potential generation from water held in Lake Te Anau.

	0	1	2	3	4	5	6	7	8	9
0	601	423	401	390	381	373	366	360	354	349
10	344	339	335	331	326	322	318	314	311	307
20	303	299	295	291	288	284	280	276	272	269
30	265	262	258	254	250	247	243	240	237	234
40	231	228	225	221	219	216	213	211	208	205
50	203	200	198	195	192	190	187	184	181	178
60	175	173	170	167	165	162	159	157	154	152
70	150	148	145	143	140	138	135	132	130	127
80	125	122	120	117	115	112	109	106	103	101
90	98	95	91	88	84	79	74	68	61	50
100	14									

5.9 Lake Manapouri

5.9.1 Current operating consents

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

High Range: above 178.6m

Main Range: between 176.8m and 178.6m

Low Range: below 178.6

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

Like Lake Te Anau, Lake Manapouri has a complicated system governing the control levels (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 particular lake level can remain stable.

For this report, the maximum operating level is 178.6m and the minimum operating level is 176.8m. This is consistent with the Main Range set out in the Manapouri-Te Anau Development Act (Operating Guidelines) (Appendix A). However, the absolute minimum level of 175.86 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.

5.9.2 Lake levels and storage volumes

The Lake Manapouri water level record is shown in Figure 5.23. Table 5.25 shows the characteristics of Lake Manapouri used in this analysis; including the maximum and extreme minimum storage volumes. A lake-level area rating was used to calculate the lake storage volumes.

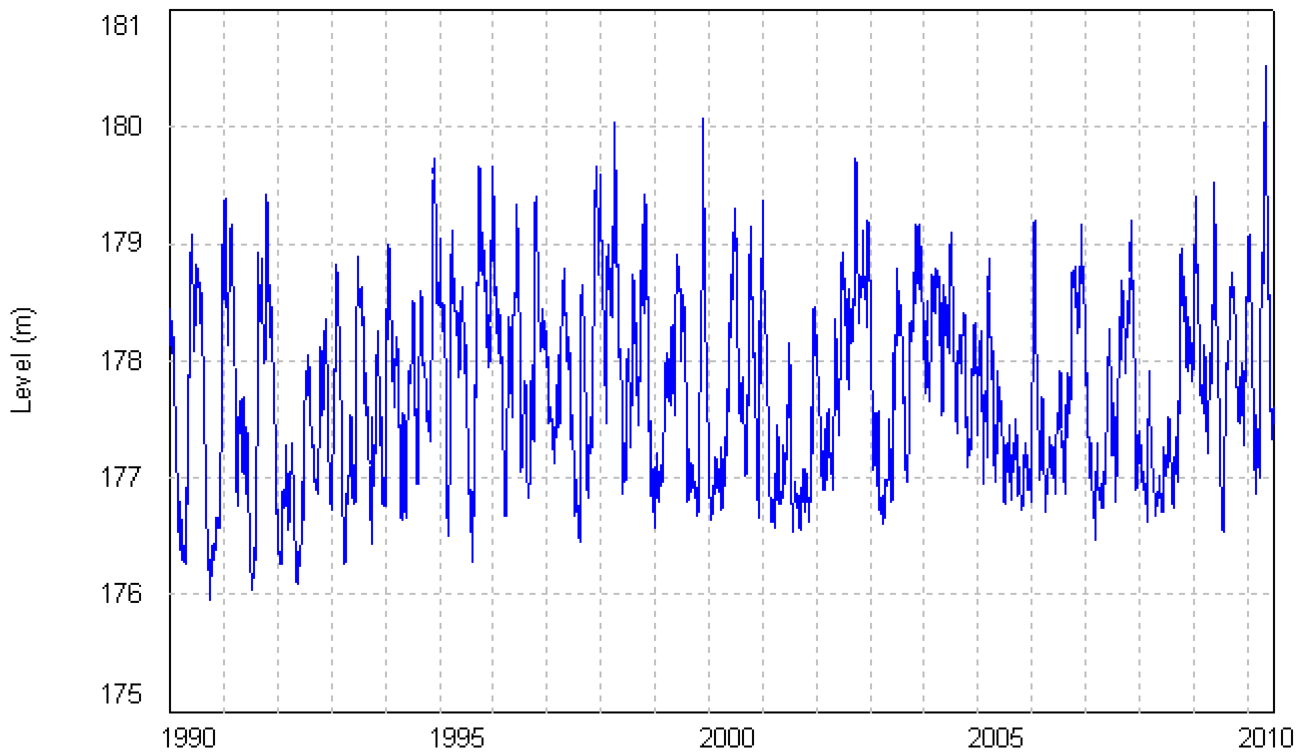

Figure 5.23 Lake Manapouri water level record (masl) from 1990 to 2010.

Table 5.25 Characteristics of Lake Manapouri.

Lake Manapouri	
Lake area (km²)	141.00
Maximum operating level (m)	178.60
Minimum operating level (m)	176.80
Absolute minimum level (m)	175.86
Maximum storage (million m³) – at maximum operating level	359.49
Minimum storage (million m³) – at absolute minimum level	0.00
Downstream power stations	***Average efficiency** (m³/s/MW)*
Manapouri	0.653

5.9.3 Generation potential

The Waiau Scheme has one power station (i.e., Manapouri) through which the water from Lake Manapouri may pass. The generation potential of Lake Manapouri (GWh) was therefore assumed to be the average efficiency of the Manapouri station from the maximum normal lake level down to the extreme minimum since the construction of the second tail race (Figure 5.24). This ensures consistency over the entire period of record.

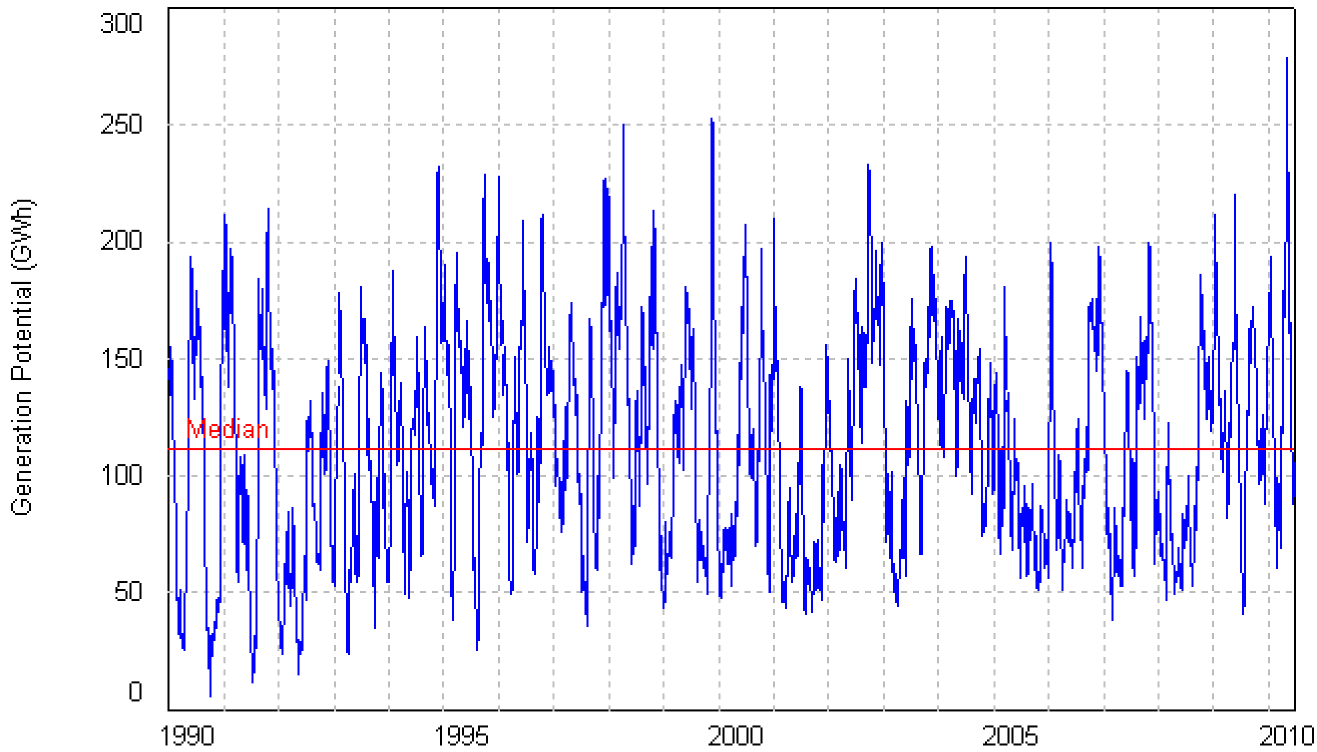

Figure 5.24 Generation potential of Lake Manapouri (1-Jan-1990 to 1-Jul-2010).

Table 5.26 summarises the variability in the potential generation from water held in Lake Manapouri between 1990 and 2010.

Table 5.26 Variability in the generation potential of water held in Lake Manapouri (1-Jan-1990 to 1-Jul-2010).

Generation potential (GWh)	
Minimum	6
Maximum	279
Mean	113
Median	111
10th percentile	56
Lower quartile	73
Upper quartile	150
90th percentile	172
Standard deviation	46

Figure 5.25 and Table 5.27 show the frequency distribution of the variability in generation potential from water held in Lake Manapouri.

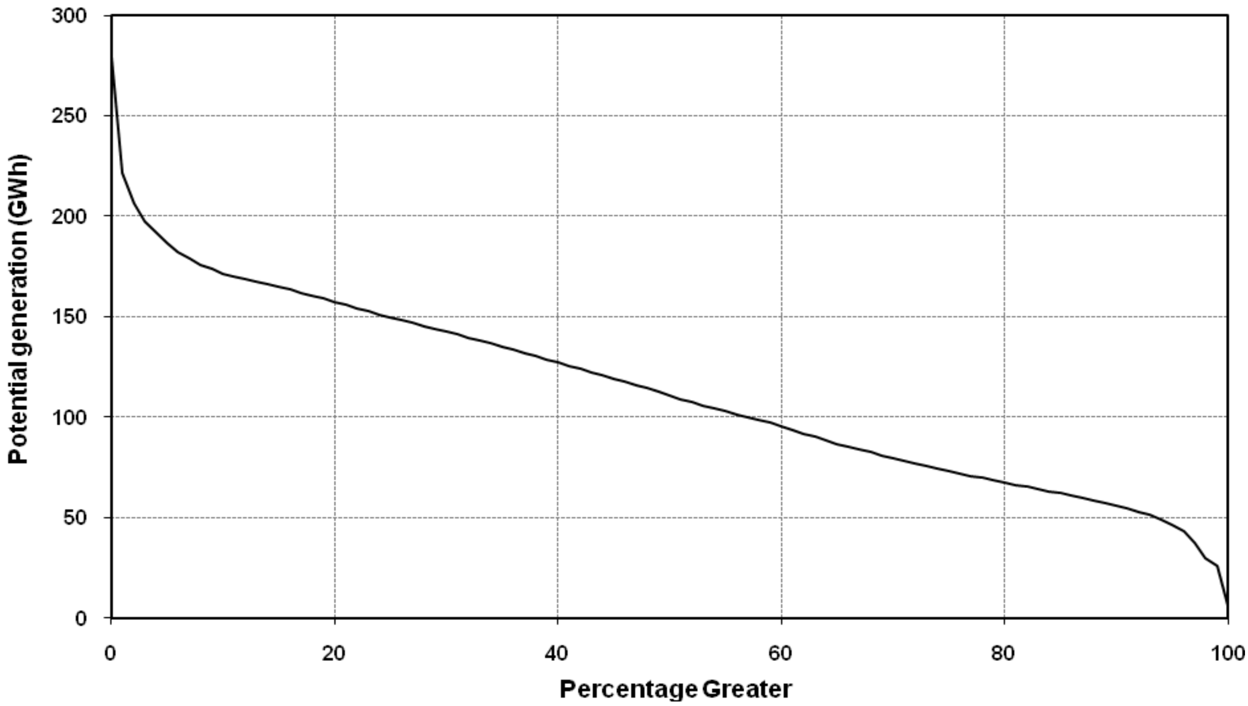

Figure 5.25 **Frequency distribution of the potential generation from water held in Lake Manapouri.**

Table 5.27 **Frequency distribution table of the potential generation from water held in Lake Manapouri.**

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	279	222	207	197	192	187	182	179	176	174
10	172	170	169	167	166	165	163	162	161	159
20	158	156	154	153	151	150	148	147	145	144
30	143	141	140	138	137	135	133	132	130	129
40	127	125	124	122	121	119	118	116	114	112
50	111	109	107	106	104	103	101	100	98	97
60	95	94	92	90	88	87	85	84	82	81
70	80	78	77	76	74	73	72	71	70	68
80	67	66	65	64	63	62	61	60	58	57
90	56	55	53	51	49	47	43	37	30	26
100	6									

6 Acknowledgments

The support of the following power generation companies for this project, and in providing data, is gratefully acknowledged:

Genesis Energy Ltd

Mighty River Power Ltd

Meridian Energy Ltd

Contact Energy Ltd

We also acknowledge the use of data from the National Hydrometric Archive administered by NIWA (National Institute of Water and Atmospheric Research).

Appendix A

Operating Guidelines for Lakes Manapouri and Te Anau

FROM: *NEW ZEALAND GAZETTE*,
No. 168. pp. 4227 – 4229

Manapouri-Te Anau Development Act 1963

Operating Guidelines for Levels of Lakes Manapouri and Te Anau

Pursuant to section 4A of the Manapouri-Te Anau Development Act 1963, I, Pete Hodgson, Minister of Energy, based upon the recommendations of the Guardians of Lakes Manapouri and Te Anau and of Meridian Energy Limited, hereby give the following notice of the operating guidelines for the levels of Lakes Manapouri and Te Anau aimed to protect the existing patterns, ecological stability, and recreational values of their vulnerable shorelines and to optimise the energy output of Manapouri power station.

Notice

1. Title and commencement—(1) This notice may be cited as the Manapouri-Te Anau Development Act (Operating Guidelines) Notice 2002.

(2) This notice shall come into force on its publication in the *New Zealand Gazette*.

2. Application and interpretation—(1) This notice applies to Lakes Manapouri and Te Anau.

(2) In this notice, unless the context otherwise requires:

"Duration" means the number of continuous days any of the Lakes were within a particular range of level specified within the High or Low Operating Ranges.

"High Operating Ranges" are those set out in clause 5 of this notice.

"Interval" means, in relation to either of the Lakes, the number of continuous days that a Lake was below a particular range of level specified for the High Operating Ranges for that Lake.

"Lakes" means Lakes Manapouri and Te Anau. "Level" means height, in metres, above mean sea level.

"Low Operating Ranges" are those set out in clause 6 of this notice.

"Main Operating Ranges" are those set out in clause 4 of this notice.

"Maximum duration" means, in relation to any of the Lakes, the number of continuous days that a Lake may be within a particular range of level specified for the High or Low Operating Ranges, and in relation to the High Operating Ranges, subject to the specified minimum interval.

"Minimum interval" means the number of continuous days that should elapse from either of the Lakes moving below a particular range of level, until that Lake returns within that range of level.

"Parties" means the Guardians of the Lakes and Meridian Energy Limited.

"Specified ratio" means the ratio derived from dividing the minimum interval by the maximum duration, and applies only to the High Operating Ranges.

3. Lakes management—The parties recognise three separate operating ranges of levels for each of the Lakes within which Meridian Energy Limited may operate, being Main, High and Low, as set out in clauses 4, 5 and 6 of this notice.

4. The Main Operating Ranges—(1) The Main Operating Ranges, within which Meridian Energy Limited shall endeavour to maintain continuous variation, are:

(a) for Lake Manapouri, levels from 176.8m to 178.6m; and

(b) for Lake Te Anau, levels from 201.5m to 202.7m.

(2) Meridian Energy Limited shall, for each of the lakes, aim to achieve annual mean levels within the applicable Main Operating Ranges as specified in this notice.

5. The High Operating Ranges—(1) Meridian Energy Limited shall use its best endeavours to:

(a) not exceed the maximum durations; and

(b) achieve the specified ratio in relation to the ranges of level set out in subclause (2) of this clause, where the actual interval (in days) between the Lake moving below a particular range of level and returning to within that range of level is divided by the actual duration (in days) that the Lake was originally within that range of level.

(2) Subject to subclause (3) of this clause, the High Operating Ranges are:

(a) for Lake Manapouri, above 178.6m, in accordance with the following maximum durations, minimum intervals, and specified ratios for the ranges of level set out:

Level (m)	*Maximum Duration*	*Minimum Interval*	*Specified Ratio*

At 180.5	1	100	100.00
Above 180.4	3	100	33.33
Above 180.1	9	100	11.11
Above 179.8	22	80	3.64
Above 179.5	35	40	1.15
Above 179.2	44	40	0.91
Above 178.9	99	20	0.20
Above 178.6	119	20	0.17

(b) for Lake Te Anau, above 202.7m, in accordance with the following maximum durations, minimum intervals, and specified ratios for the ranges of levels set out:

Level (m)	*Maximum Duration*	*Minimum Interval*	*Specified Ratio*
At 204.3	7	100	14.29
Above 204.2	10	100	10.00
Above 203.9	15	60	4.00
Above 203.6	22	30	1.36
Above 203.3	39	30	0.77
Above 203.0	65	30	0.46
Above 202.7	125	20	0.16

(3) Where the ratio derived from dividing the interval between the lake level moving below a particular range of level and returning to that range of level by the duration that the lake was in that range of level immediately prior to the interval:

(a) results in a ratio greater than or equal to the specified ratio, then the guidelines are deemed to be complied with.

(b) results in a ratio less than the specified ratio, then subject to subclause (4) of this clause, the interval occurring after a particular duration shall be added to that duration along with the duration occurring after that interval, in order to determine the duration for which the specified ratio must be achieved.

(4) The period of duration within any range of level, including accumulations as provided for in paragraph (b) of subclause (3) of this clause, shall not exceed the relevant maximum duration.

(5) The parties record that:

a) High Operating Range guidelines were reviewed in 2001 and are based on the mean of the three extreme events during the period of natural and synthetic record from 1933 to 2000.

b) the 1988 flood was excluded from this review because of its damaging high levels and extended duration. Extreme natural floods have occurred historically, e.g. 1988: Lake Te Anau 205.41m, Lake Manapouri 182.15m. It is accepted that guideline breaches may occur on rare occasions despite the best endeavours of the power station operator.

6. The Low Operating Ranges—(1) Subject to subclause (2) of this clause, the Low Operating Ranges are:

(a) for Lake Manapouri levels from 175.86m to 176.8m, with an absolute minimum level of 175.86:

Level (m)	*Maximum Duration*
Below 176.8	107
Below 176.5	66
Below 176.2	22
At or below 175.9	5

(b) for Lake Te Anau from 200.86m to 201.5m, with an absolute minimum level of 200.86m:

Level (m)	*Maximum Duration*
Below 201.5	88
Below 201.3	46
Below 201.1	21

(2) For the purposes of the Low Operating Ranges outlined in subclause (1) of this clause, Meridian Energy Limited shall use its best endeavours to:

(a) not exceed the maximum durations for the individual ranges of levels specified;

(b) avoid lake levels below 201.1m for Lake Te Anau and below 176.2m for Lake Manapouri during the equinoxial periods (March, April, October and November);

(c) not exceed, in any continuous period of 365 days, twice the maximum duration specified for any particular range of level; and

(d) ensure the rates of drawdown do not exceed the natural rates of drawdown averaged over four days, being 0.05m per day for Lake Manapouri and 0.03m per day for Lake Te Anau.

(3) The parties record that:

(a) in the period of natural record, the level of Lake Manapouri has been below the absolute minimum level of 175.86m; and

c) these guidelines are based on the mean of three extreme events during the period of natural record and may result in low ranges of level being experienced more often than would have occurred naturally

7. Gate opening and closing procedures—(1) The Parties have agreed upon and adopted gate opening and closing procedures which are designed amongst other things:

(a) in the case of the Lake Te Anau Control structure, to reduce or eliminate scour action on the upper Waiau River banks, to facilitate repair following periods of extremely high flow, and to facilitate the successful spawning of salmonids; and

(b) in the case of the Lake Manapouri Control structure, to reduce potentially dangerous increases in river flow downstream of the gates, and to bypass flood flows from the Mararoa River in such a manner as to prevent dirty debris-laden water from entering Lake Manapouri.

(2) It should be noted that the procedures referred to in subclause (1) of this clause are modified from time to time by agreement between the Parties.

8. Benchmarks—For the purposes of this notice:

(a) the level of Lake Te Anau at any time shall be determined by reference to the Land Information New Zealand Benchmark Z58, New Zealand map grid co-ordinates (5518335) metres north (2096815) metres east, which is adjacent to the lake water level recorder and staff gauge, which benchmark shall be deemed to represent a height 205.161 metres above mean sea level; and

(b) the level of Lake Manapouri at any time shall be determined by reference to the Land Information New Zealand Benchmark Z47, New Zealand map grid co-ordinates (5506094) metres north (2091334) metres east which benchmark shall be deemed to represent a height of 208.910 metres above mean sea level.

9. Consequential revocation—The notice entitled "Manapouri-Te Anau Development Act 1963" dated 14 April 1993 and published in the *New Zealand Gazette*, 29 April 1993, page 1084, is hereby consequentially revoked.

igned at Wellington this 12th day of November 2002.

P. HODGSON, Minister of Energy.

Note: The Guardians and Meridian Energy Limited may review these guidelines from time to time with a view to recommending that the Minister promulgate new guidelines.

OPUS