REVIEW OF THE BENEFITS OF THE OKERE GATES CONTROL STRUCTURE – LAKE ROTOITI

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ABSTRACT

Human intervention to our lakes and channels can take many turns and result in profound immediate and long term ecological, cultural, environmental and public safety implications. Similarly, modification to existing structures also needs full and considered assessment before physical works / changes to operating regimes are implemented. Such is the case at Lake Rotoiti and its interface with the Kaituna River.

Lake Rotoiti outflows are currently regulated via the Okere Channel radial gates to control lake levels within a target band. Lake levels in Rotoiti can also potentially impact on inflows from Lake Rotorua via the Ohau Channel and hence possibly also Lake Rotorua levels. As the resource consent for the Okere gates expire June 2010 it is imperative that EBOP fully understand the impacts any new operating regime will have.

Aurecon developed a hydraulic model of this two lake system. Alternative outlet structures were tested on the Okere channel for the period 1998 to 2007 and lake levels and outflows were compared with the 10 year historical record. Potential benefits / impacts for stakeholders including iwi, lake ecology, bach owners, fishing and white water rafting were examined. This modelling has provided a sound platform to inform the consultation process.

KEYWORDS

Lake level control, Lake Rotoiti, Ohau Channel, Okere gates, Radial gates, Kaituna River, Lake modeling.

PRESENTER PROFILE

Robert has expertise in hydraulic modelling using a range of software packages both one and two dimensional. He has applied these to analyse river systems in both Australia and NZ including the Hunter and Murrumbidgee Rivers in Australia and the Kopurererua and Raparapahoe in NZ. He has also completed detailed civil and stormwater design for both greenfield and brownfield sites including mitigation measures for complex stormwater and flooding issues.

1 INTRODUCTION

Lake levels in Lake Rotoiti are currently controlled via operation of the Okere radial gates which regulate the rate of discharge to the Kaituna River. The Okere radial gates are currently owned and operated by the Rivers & Drainage group of Environment Bay of Plenty (EBOP) in accordance with their resource consent. Te Arawa Lakes Trust are the new lakebed of lake Rotoiti which is a significant change from the situation in 1996 when the consent was first issued.

Resource consents for Okere gates and Ohau weir control structures are due to expire on 30 June 2010. Before applying to renew this consent EBOP wish to know what the positive and negative impacts of the current structure and its operating regime are, and what impacts there would be in removing the gates or replacing them with an alternative control structure.

Aurecon developed a hydraulic numerical model of this two lake system. Alternative outlet structures were tested using this model on the Okere channel for the period 1998 to 2007 and lake levels and outflows were compared with the 10 year historical record. Potential benefits / impacts for stakeholders including iwi, lake ecology, bach owners, fishing and white water rafting were examined. Rivers & Drainage have used this information to engage with Te Arawa Lakes Trust and other stakeholders to try to define an acceptable solution or solutions.

2 LITERATURE AND DATA REVIEW

2.1 LITERATURE

EBOP have provided a number of reports on both the Ohau Channel which discharges from Lake Rotorua into Lake Rotoiti, and the Okere gate structure which controls the discharge from Lake Rotoiti into the Kaituna River. These reports have been briefly reviewed for relevant information and are listed below. These reports (especially those by Titchmarsh (1995) and Surman (1998)) give a good background to the issues examined by this study. A repeat of that information is therefore not included in this paper.

Table 1 – Background reports and documents

Title	Author and Organisation	Date and File No
Draft report Hydraulic Modelling of Ohau Channel	Philip Wallace	February 2003
Report on the technical issues and effects to be considered in the application for resource consents	B R Titchmarsh, Manager Technical Services, EBOP	December 1995 Operations report 95/5
Okere Radial Control Gates Lake Rotoiti to Kaituna River Operation Report	Matthew Surman, Design Engineer, EBOP	November 1998 Operations report 98/4
Upper Kaituna Catchment Control Scheme	Bay of Plenty Catchment Commission	April 1975
Upper Kaituna River Major Scheme Lakes Rotorua & Rotoiti	A.P Griffiths, Bay of Plenty Catchment Commission	
Flood warning manual (pages 93 – 96 only)	EBOP	July 1998

2.1.1 EXISTING MIKE-11 HYDRAULIC MODEL

A Mike-11 hydraulic model of the Ohau Channel linking Lake Rotorua and Lake Rotoiti has already been developed, and is documented in the report "Draft Report – Hydraulic modelling of Ohau Channel - Phil Wallace February 2003". This model was supplied by EBOP for use in this study.

2.1.2 GAUGE DATA

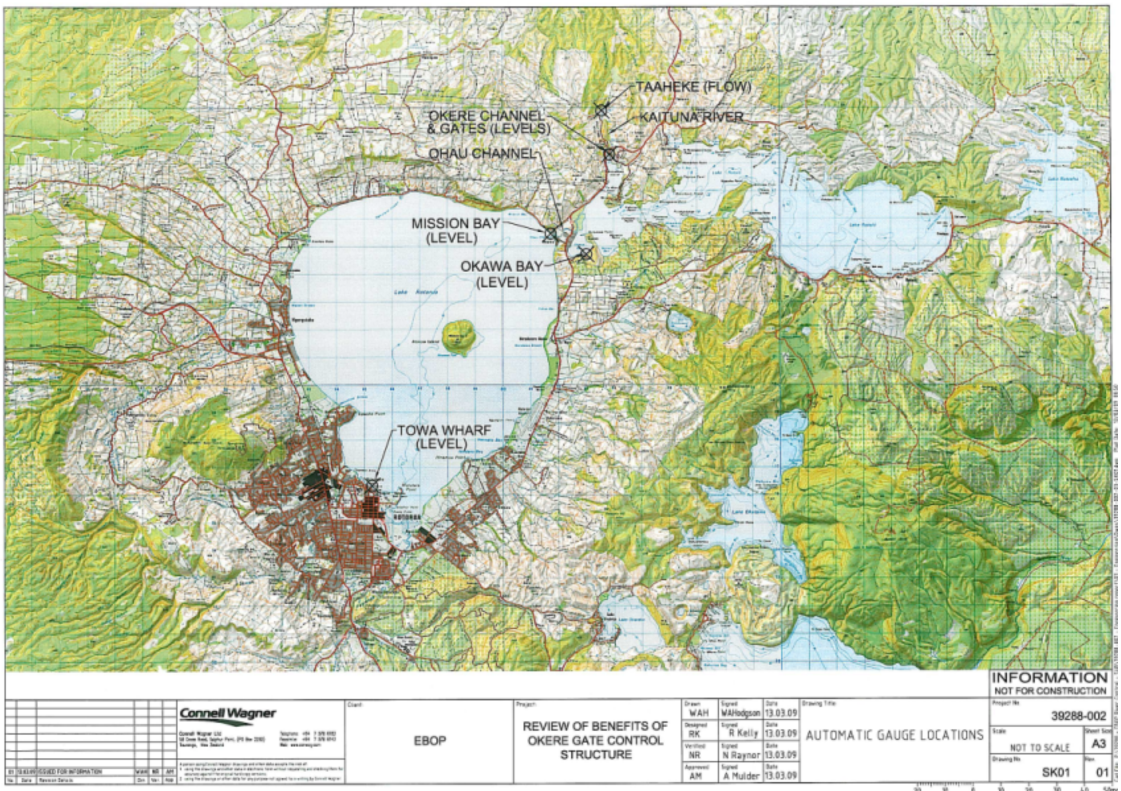
Automatic gauge data was provided by EBOP as detailed in Table 2 below;

Table 2- Gauge Data Details

Location	Data Type	Period
Lake Rotorua- Town Wharf	Lake Level	2003-2007
Lake Rotorua- Mission Bay	Lake Level	1998-2007
Lake Rotorua- Mission Bay	Flow into Ohau Channel	1998-2007
Lake Rotoiti- Okere Gates	Lake Level	1998-2007
Lake Rotoiti- Okawa Bay	Lake Level	June 2001-2007
Kaituna River- Taaheke	Flow	1998-2007

The location of the gauges is shown on Figure 1 below.

Figure 1: Gauge Locations



In addition, the Rivers and Drainage section of EBOP maintain a daily record of other useful information such as stoplog removal, gate settings and drawdown, and weather/rainfall.

2.1.3 SURVEY/DESIGN DATA

Design drawings from 1998 (not As-Builts) were provided for the stoplog structure in the Ohau Channel.

Survey of the Ohau Channel was undertaken by EBOP in 2002 and was provided in this study by way of the Mike-11 model from Phil Wallace. It should be noted that Phil Wallace had included levels of the stoplog structure from the 1998 design drawings in his Mike-11 model as As-Builts (post construction survey) of this structure are not available.

Design drawings (not As-Builts) for excavation of bed rock from the Okere Channel and construction of the Okere Gate structure were also provided (Murray North Partners Ltd-1978). A spot check by Graeme O'Rourke of EBOP in February 2009 confirmed the gate structure has been built to design levels.

Survey of the Okere Channel was included on the 1978 Murray North Ltd drawings. These drawings included only selected levels so other levels were scaled off by Aurecon's draughting team. It was assumed that the bed rock was excavated to the levels shown on the drawings. There are no as-builts to confirm this. This methodology was approved by EBOP for this phase of this study.

2.2 Data Processing

The automated average daily level and flows were graphed and compared with the manual daily records. In this way spurious data could be identified and cleaned.

2.2.1 DRAWDOWN CORRECTIONS

The lake level at the Okere Gates structure is subject to drawdown in the approach channel to the gate. The drawdown correction for each day is included in the comments of River and Drainage's daily record. This same factor was hence applied to the averaged automatic gauge data. From June 2001 automatic gauge data is available from the Okawa Bay site on Lake Rotoiti which is not subject to drawdown, due to its location and hence after June 2001 this data source was used in preference.

2.2.2 DATUM CORRECTIONS

Due to geological factors, among others, there have been several datum adjustments in the area. (Graeme O'Rourke of EBOP should be contacted for details on this). This has lead to some discontinuities in the lake level record.

2.3 LAKE TARGET LEVELS

EBOP's flood warning manual (July 2008) –refer Appendix A - states Lake Rotorua's medium level is RL 279.805 m, maximum is RL 280.11 m and minimum is RL 279.5 m. For Lake Rotoiti the target level is RL 279.116 m ± 75 mm, the maximum level is RL 279.406 m and minimum level RL 278.856 m.

It should be noted that prior to 30 November 2005 the target level for Lake Rotoiti was RL 279.15m. The change to RL 279.116 m was made due to datum adjustments.

2.4 STOPLOG REMOVAL RECORD

In 1989 a submerged weir structure was constructed at the upstream end of the Ohau Channel replacing the gabion baskets there at the time. The weir was designed to incorporate the insertion or removal of stoplogs allowing some control of Lake Rotorua levels. Table 3 below details the record of dates of stoplog removal in the Ohau Channel. This was taken from the comments sections of Rivers and Drainage daily lake levels record.

Table 3: Ohau Channel Stoplog Installation/Removal Dates.

Year	**Removed**	**Installed**
1998		
1999		
2000	30-August	24-October
2001	15-May	16-July
2001	19-December	
2002		28-February
2002	20-June	3-September
2003		
2004		
2005		
2006		
2007		
2008	12-August	19-November

3 METHODOLOGY

3.1 GENERAL APPROACH

The general approach was to use historical gauge data of lake levels and outflows to derive inflow hydrographs to Lakes Rotorua and Lake Rotoiti for the 10 year period 1998 to 2007. (This period includes significant floods and droughts.)

This approach is based on the equation: $S = I - O$ which says the change in storage of the lake (which can be measured by changes in lake level) is equal to the total inflow minus the total outflow.

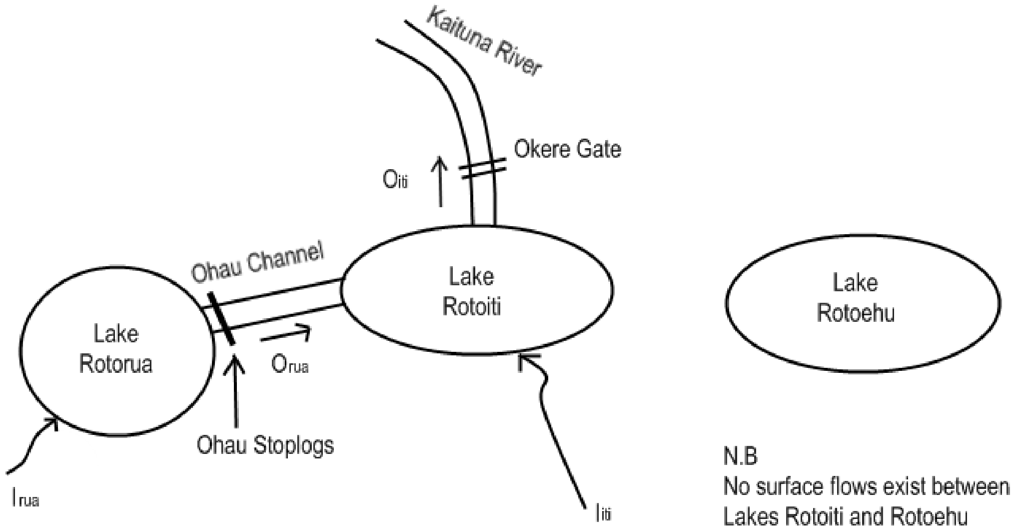
Having derived inflow hydrographs to both Lake Rotorua and Lake Rotoiti, a Mike-11 model was set up of the two lake system linked by the Ohau Channel.

To achieve the objectives of this study, alternative outlet structures from Lake Rotoiti were tested on the Okere outlet channel for this 10 year period and lake levels modelled and compared with the 10 year historical record.

3.2 METHODOLOGY DETAILS

The sketch below shows schematically the relationship between the lakes:

Figure 2 – Model setup



I_{rua} – Inflows to Lake Rotorua
O_{rua} – Outflows from Lake Rotorua to Lake Rotoiti via Ohau Channel
I_{iti} – Inflows to Lake Rotoiti (excluding those from Ohau Channel)
O_{iti} – Outflows from Lake Rotoiti to Kaituna River via Okere Gate

Step 1 – Flows in Ohau Channel

The Ohau Channel Mike-11 model set up by Phil Wallace was used to generate a 10 year record of O_{rua}. The model was set up with the averaged daily Lake Rotorua levels measured at Mission Bay at the upstream end, and the averaged daily Lake Rotoiti levels measured at Okawa Bay (Okere corrected for drawdown prior to June 2001) at the downstream end. The Mike-11 model was run in two different states – stoplogs in or stoplogs out – according to the dates in Table 3.

Step 2 – Flows into Lake Rotorua

Daily values of I_{rua} were calculated from $S_{rua} = I_{rua} – O_{rua}$ where O_{rua} was calculated in step 1 and

$S_{rua} = Z_{rua} . A_{rua}$

Z_{rua} = daily change in Lake Level at Mission Bay

A_{rua} = Area of Lake Rotorua = 8047 ha (from www.envbop.govt.nz/water/Lakes/Lakes - Statistical - Information.asp). Changes in the area of the lake due to water level variations are minor and considered negligible.

Step 3 – Flows into Lake Rotoiti

Daily values of I_{iti} were calculated from $S_{iti} = I_{iti} + O_{rua} – O_{iti}$ where O_{rua} was calculated in step 1.

O_{iti} was taken from daily averaged values at the Taaheke gauge.

$S_{iti} = Z_{iti} . A_{iti}$

Z_{iti} = daily changes in Lake Level at Okawa Bay (or Okere corrected for drawdown prior to June 2001)

A_{iti} = Area of Lake Rotoiti = 3370ha (from www.envbop.govt.nz/water/Lakes/Lakes - Statistical - Information.asp). Changes in the area of the lake due to water level variations are minor and considered negligible.

Step 4 – Setting up 2 Lake Mike-11 model

The Mike-11 model of the Ohau Channel was extended upstream with dummy sections to represent Lake Rotorua. To correctly represent the area of Lake Rotorua a channel was made in the Mike-11 model 8.047 km long by 10km wide.

Similarly the model was extended downstream with dummy sections representing Lake Rotoiti by a channel 3.370 km long with sections 10 km wide.

Step 5 – Modelling the Okere Channel

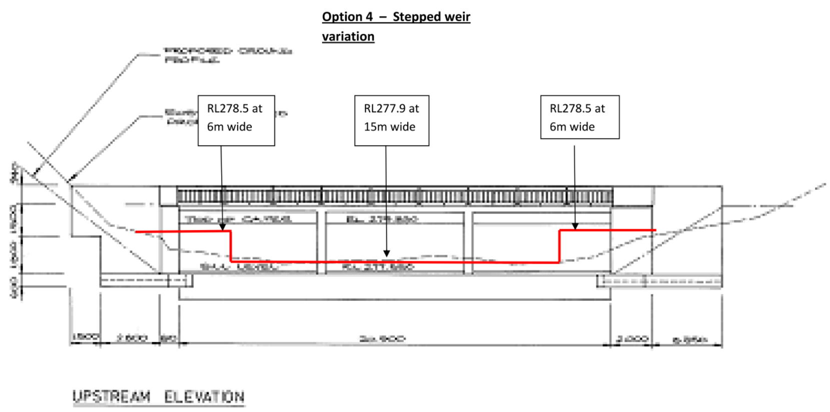
Downstream of Lake Rotoiti an Okere Channel branch was added to the Mike-11 model. Cross-sections were taken from the bedrock excavation design levels shown on the Murray North 1978 survey. Several options were tested with different weirs inserted into the Mike 11 Okere channel branch in place of the radial gates

The cross-sections in the lower portion of the Okere Channel are not consistent in their cross-sectional area or conveyance and result in rapidly varying flow. Mike-11 is not designed to model rapidly varying flow leading to model instabilities. Initially to improve model stability the more restrictive sections were therefore removed. This was done on the assumption that the weir would provide the main 'control' on flows within the channel and that downstream impacts are negligible.

While this assumption was probably OK for the preliminary investigations and broad comparisons required by EBOP (especially for higher level weirs) it was discussed with EBOP that actual survey and calibration of the channel/weir combination would be required before any detailed design or construction of a new structure was undertaken.

A stepped weir option favoured by Dr Kepa Morgan of the University of Auckland (representing Te Arawa) is shown schematically below.

Figure 3: Stepped weir variation



As this is one of the options being taken forward in the resource consent application, calibration of the Okere channel was recommended by the peer reviewer (Dr Grant Webby – Principal Hydraulic Engineer at Opus). The high flows and velocities in the Okere channel meant EBOP did not wish to undertake cross-sectional hydro-survey. However a longitudinal profile of water levels were taken along the Okere channel for low flow (19.6m3/s) and high flow (35.3m3/s) from around 100m upstream of the gates to 130m downstream of the gates.

Using the steady state, energy equation mode of Mike-11, calibration runs were undertaken both upstream and downstream of the gates. Downstream of the gates a critical depth boundary condition was used where the Froude number first exceeded 1. Upstream of the gates the water level on the upstream side of the gates was used as the boundary condition. A good calibration downstream of the gates was obtained but there were difficulties calibrating a section of channel around 50 to 70m upstream of the gates. It is thought that perhaps the design excavation was never actually extended this far upstream. By replacing the cross-sections in this area with the pre-existing levels rather than the design excavation levels a much better calibration fit was achieved. (No survey has been undertaken to confirm if this is the case).

The weir proposed by Dr Kepa Morgan was inserted into the calibrated model of the Okere Channel (with the two upstream sections using pre-existing levels). This was run using the energy equation for a series of steady state in increments of 5m3/s from 5 m3/s to 50m3/s. In this way a rating curve was developed at the top end of the Okere Channel. This rating curve was inserted as the downstream boundary condition of the two lake level. (Thanks to Grant Webby for his assistance and guidance in this).

Methodology uncertainties

The results of the modelling are discussed in the following sections. However it is prudent first to discuss inherent uncertainties in the assumptions and methodology that was employed.

i) Lake levels used to calculate the inflows to the lakes are subject to the following factors:
   a) Wind waves and run-up
   b) Drawdown assumptions at the Okere Gates gauge
   c) Datum level changes
ii) Outflows from Lake Rotorua via the Ohau Channel are dependent on:
   a) Lake levels (see above)
   b) Survey of cross-sections (dates from 2002)
   c) Stoplog weir was input to model from design drawings not as-built survey

d) Calibration factors in model for weir and cross-sections (refer Phil Wallace's report)

iii) Historic outflows from Lake Rotoiti were taken from Taaheke which is about 1 km downstream of Okere and includes an extra 2 km^2 of catchment, and will hence tend to overestimate flow from Lake Rotoiti. These outflows are also dependent on the accuracy of NIWA's rating curve at Taaheke.

iv) Modelled outflows over alternative structures at Okere have the following uncertainties
 a) They are theoretical flows and not calibrated.
 b) No reliable survey of post-excavated channel upstream or downstream of gate structure is available.

v) The Ohau Channel diversion wall has only just been recently constructed (2007/2008 – completed July 2008) and was therefore not included in the modelling of the period 1998 to 2007 analysed in this study. (Impacts from this wall however are likely to be minor).

Despite all of the above factors, many of them apply to both the options and the historic record. Any relative differences will be consistent between the existing gate and alternative outlet models. Hence there can be some reasonable confidence in the results, especially in the broad trends and relative differences.

4 RESULTS

The objective of this study was to model alternative structures to the current Okere gates and compare their impacts on:

i) Lake levels of Lake Rotoiti
ii) Lake levels of Lake Rotorua
iii) Outflows into the Kaituna River

Results for the above levels and flows are compared for the 10 year period 1998 to 2007 inclusive for the h istoric recorded values for the current gate operating regime and the weir proposed by Dr Kepa Morgan

4.1 Impacts on Lake Rotoiti lake levels

Figure 4 shows the lake levels in Lake Rotoiti. This shows that the weir gives a much wider range of lake levels than the current gate operating regime which has effectively kept lake levels between around RL 279.0 to 279.4 m for the 10 year period 1998 to 2007. In contrast the levels for the weir option range approximately from RL 278.7 to 279.4 m.

Table 4 shows the percentage of time that each the weir option keeps the lake level within different height bands. EBOP's flood warning manual (July 2008) gives a minimum and maximum level for Lake Rotoiti of RL 278.856 and RL 279.406 m respectively. It can be seen that between 1998 and 2007 the actual level was kept between RL 278.9 m and 279.4 m 100% of the time, but for the weir options this figure is reduced to 64%.

Figure 4: Lake Rotoiti Levels

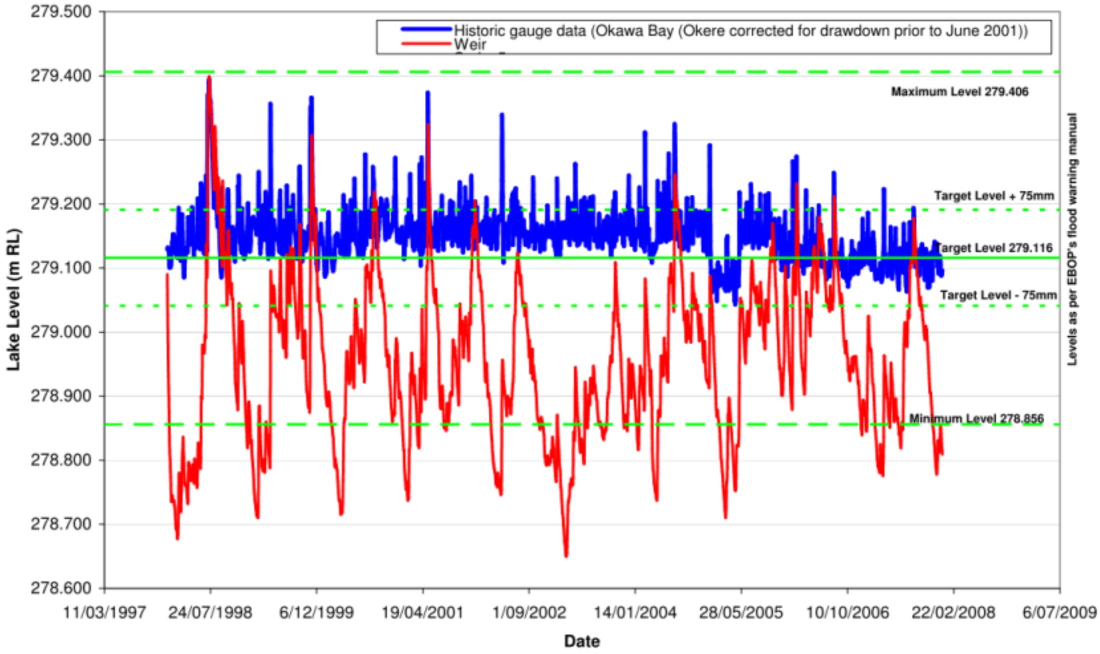


Table 4: – Lake Rotoiti levels

Percentage of days at different lake levels for 10 year period 1998 to 2007**		
Level Band (m RL)	Historic gauged data*	Weir
Level < 278.2	0	0
278.2 < Level < 278.3	0	0
278.3 < Level < 278.4	0	0
278.4 < Level < 278.5	0	0
278.5 < Level < 278.6	0	0
278.6 < Level < 278.7	0	1
278.7 < Level < 278.8	0	12
278.8 < Level < 278.9	0	23
278.9 < Level < 279.0	0	27
279.0 < Level < 279.1	9	25
279.1 < Level < 279.2	83	9
279.2 < Level < 279.3	7	2
279.3 < Level < 279.4	1	1
279.4 < Level < 279.5	0	0
279.5 < Level < 279.6	0	0
279.6 < Level < 279.7	0	0
279.7 < Level < 279.8	0	0
Level >= 279.8	0	0

278.9 < Level < 279.4	100	64

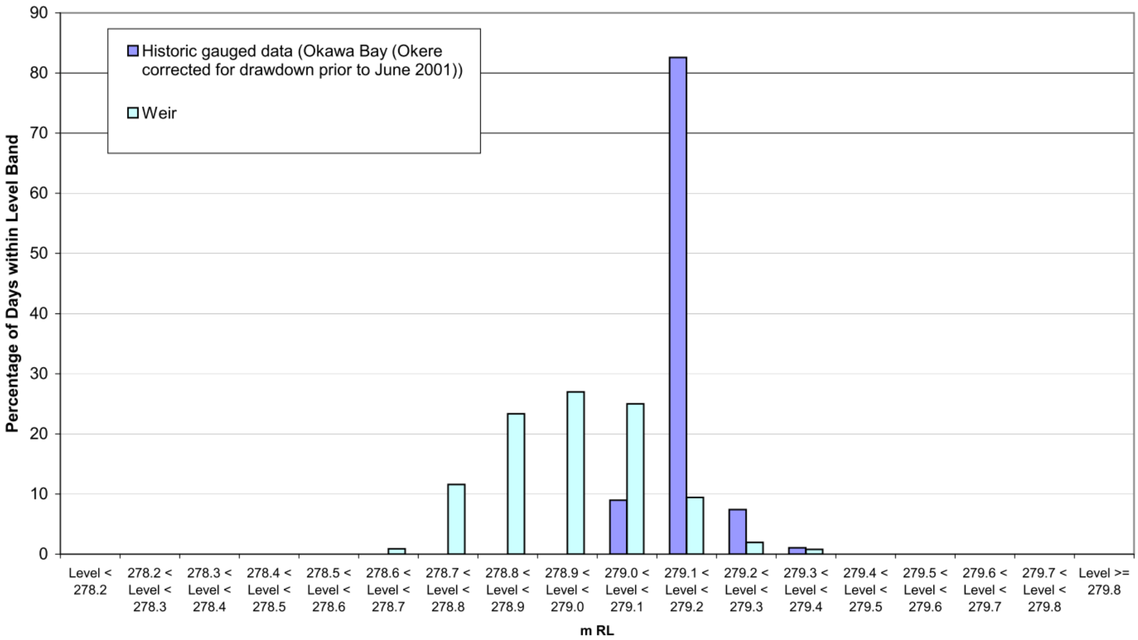
Minimum Level	279.0	278.7
Maximum Level	279.4	279.4
Average level	279.15	278.95

* Historic gauged data from Okawa Bay (and from Okere corrected for drawdown prior to June 2001)

** Excludes January 1998 as results for this month affected by change in gate condition

The Bar Chart in Figure 5 presents this table more visually and shows how the weir option has levels spread over a much wider range of values.

Figure 5: Bar Chart – Lake Rotoiti Level Bands



The aim of Dr Kepa Morgan's weir option was to provide a weir that approximately replicated pre-gate and pre-channel excavation conditions. Figures from a report by NIWA (Water Level Fluctuations in Lake Rotoiti and their Ecological Implications – 2003) show the Lake Rotoiti water level since 1905 and are included in Appendix A. This shows that prior to the gate operation fluctuations of lake levels were much greater than at present. It also shows that the lake levels were generally higher than the current target level. While the increased range in levels shown for the weir option in Figure 4 is consistent with the pre-gate NIWA data, levels are generally lower than the current target levels. There has been no marked decrease in catchment rainfall in the period 1998 to 2007.

In order for a weir structure to provide a narrower range of lake levels, similar to that maintained with the current gate operating regime, the weir structure would need to be considerably longer than 20 m. This would require locating the weir upstream from the present gate structure to where the Okere Channel is wider.. Alternatively a longer weir at the current gate location could be obtained by zig-zagging it across the channel.

4.2 IMPACTS ON OUTFLOWS TO THE KAITUNA RIVER

Figure 6 shows the outflows to the Kaituna River and shows marked differences between the weir option and the historic gauged flows at Taaheke. In general the outflows for the weir option is less extreme.

Figure 6: Okere Outflows to Kaituna River

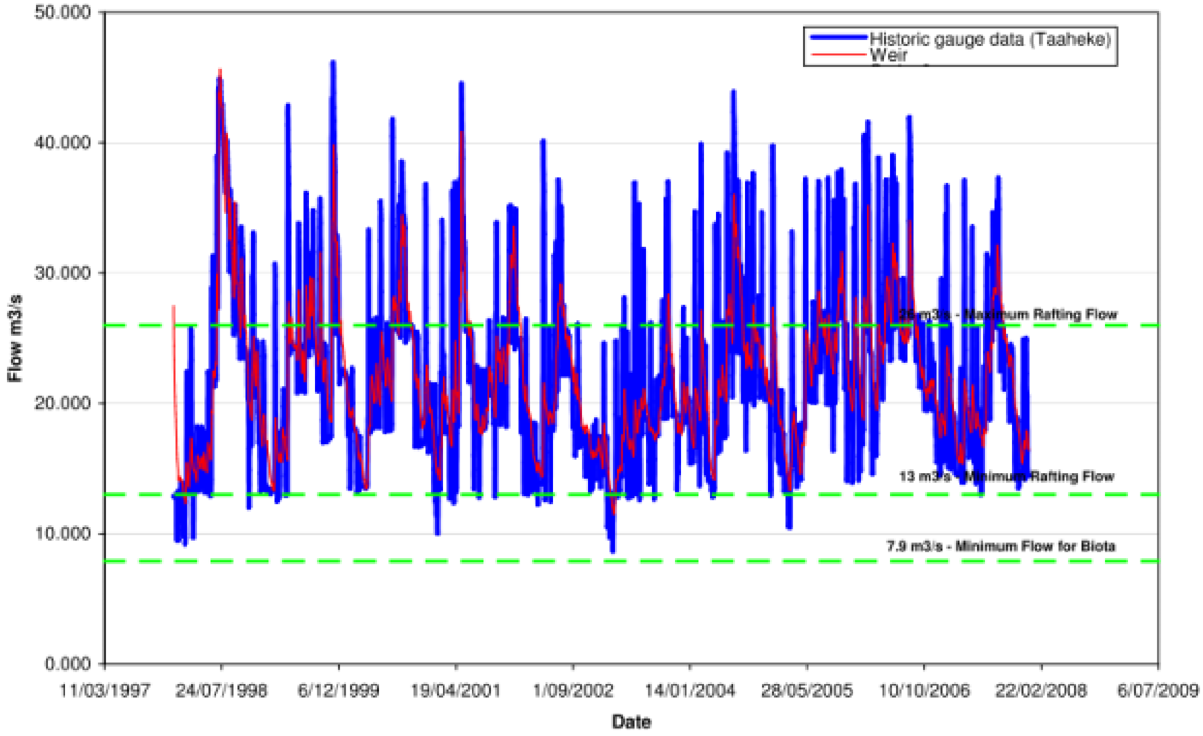


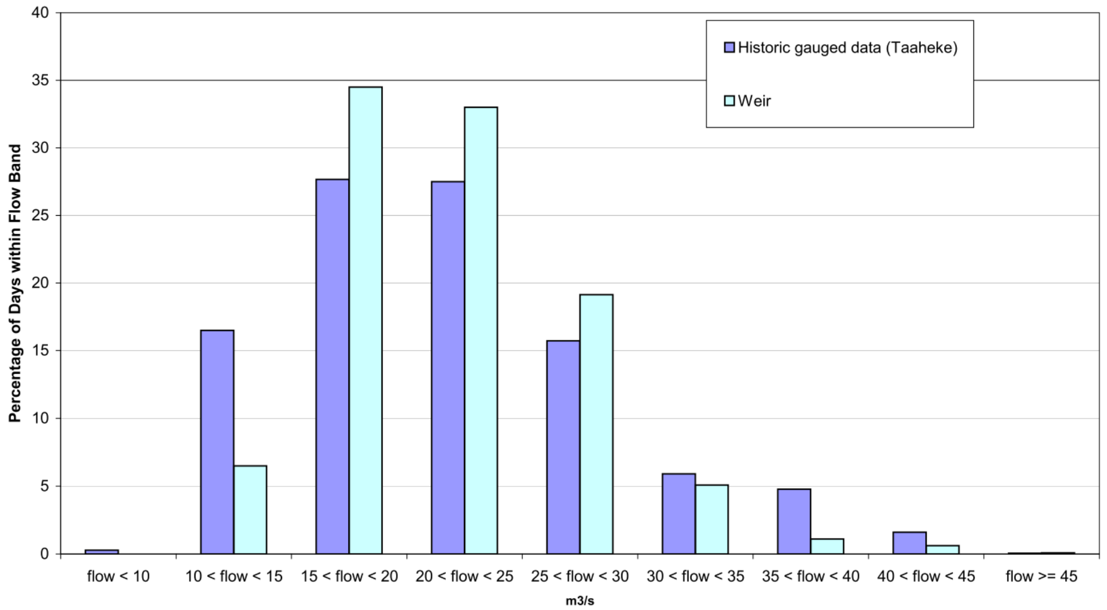
Table 5 shows the percentage time that different flow bands are achieved for each option. It can be seen that the range 13 to 26 m³/s, which is suitable for rafting on the Kaituna River downstream of Okere, was obtained 75% of the time under the current radial gate structure and 79% of the time for the weir option. This table is presented visually in Figure 7.

Table 5: Okere outflows to the Kaituna River (1998 to 2007)

Percentage of days at different lake outflows for 10 year period 1998 to 2007**		
Flow Band (m3/s)	**Historic gauged data***	**Weir**
flow < 10	0	0
10 < flow < 15	16	6
15 < flow < 20	28	34
20 < flow < 25	28	33
25 < flow < 30	16	19
30 < flow < 35	6	5
35 < flow < 40	5	1
40 < flow < 45	2	1
flow >= 45	0	0
13 < flow < 26	75	79
Minimum Flow	9	12
Maximum Flow	46	46
Average Flow	22	22

* Historic gauged data from Taaheke
** Excludes January 1998 as results for this month affected by change in gate condition

Figure 7: Okere Outflow Bands to Kaituna River



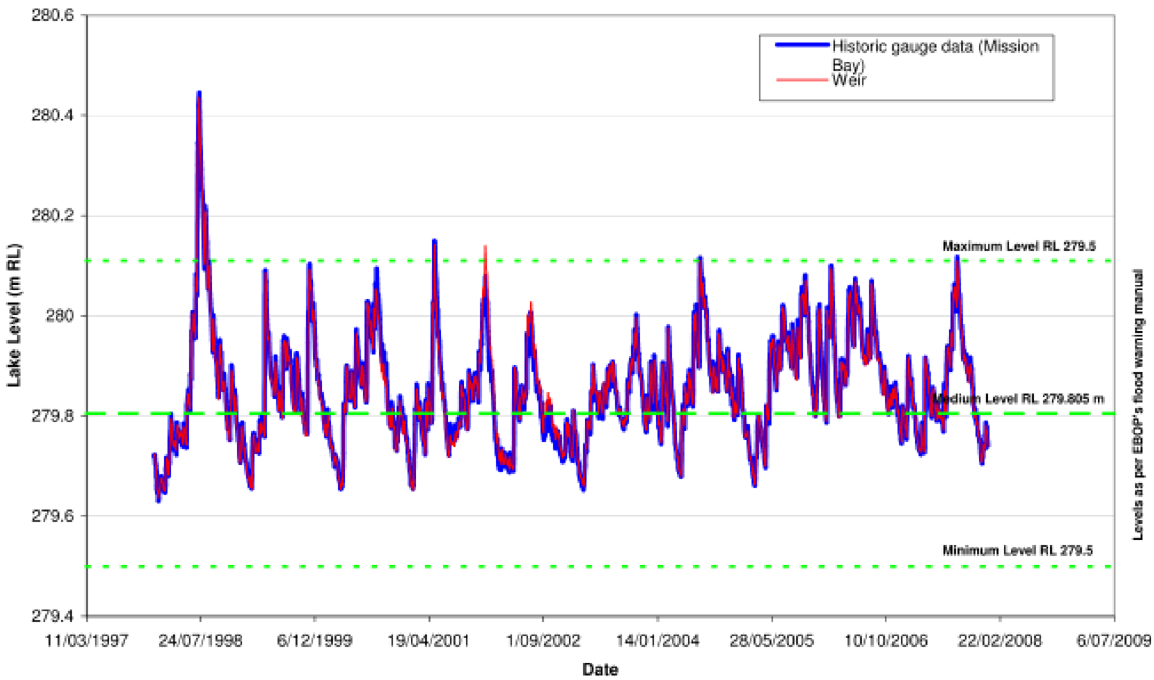
The reason that flows are more peaked with the current operating regime is related to lake level control. With the current narrow operating regime of levels there is little scope for storage within the lake and hence attenuation. The radial gate openings are modified frequently (sometimes daily) to control level by modifying flow.

The weir options by contrast have a much wider range of lake levels, giving more additional storage in the lake and more attenuation of flows, resulting in less variation in flows.

4.3 IMPACTS ON LAKE ROTORUA LAKE LEVELS

Figure 8 shows that lake levels for Rotorua are similar for both the historic data and and the weir option.

Figure 8: Lake Rotorua Levels



4.4 SUMMARY OF RESULTS

i) The range and variability of lake levels in Lake Rotoiti increase significantly if the current gate operating regime is replaced with a weir – Refer Figure 4.

ii) The average level of Lake Rotoiti with a weir outlet is dependent on the level the weir is set at. Dr Kepa Morgan's weir option gives a significantly lower average Lake Rotoiti level than the current gate operating range.

iii) The range and variability of outflows from Lake Rotoiti to the Kaituna River decrease significantly if the existing control gate is replaced with a weir structure. Refer Figure 6 and 7.

iv) Lake levels in Lake Rotorua (refer Figure 8) show no significant difference between the weir option and the current Okere gate operating regime

5 DISCUSSION OF IMPACTS

5.1 POSITIVE AND NEGATIVE IMPACTS

The potential positive and negative impacts of both the current gate operating regime and the weir option are discussed below. Bearing in mind the scope and objectives of this study and the early stages of consultation this discussion is mainly of a qualitative nature. It may need to be refined when further consultation has been undertaken. Further modelling or separate studies may also be required if particular issues/concerns need a more definitive discussion.

Stakeholder – Bay of Plenty Energy (BOPE) - Future hydro generation		
	Benefits	Negative Impacts
Status Quo	• Flow can be controlled • Flows could be discharged at peak demand periods • Gates potentially give BOPE the ability to control storage volume in Lake Rotoiti (although this is limited by the current narrow target range for levels)	• Greater fluctuation of flows from day to day
Weir Option	• More uniform flow from day to day	• No ability to control flow or storage in Lake Rotoiti

Stakeholder – Cultural Values		
	Benefits	Negative Impacts
Status Quo	• More able to maintain minimum flows in Kaituna River in drought times	• Manmade controls preventing nature taking its course • Ecological impacts • Lack of depth range at edges result in greater weed growth and lack of beaches
Weir	• More natural regime for	• Unable to maintain minimum flows

Option	Lake Rotoiti and Kaituna River	in Kaituna River in drought times

Stakeholder – EBOP Flood Management of Lakes Rotoiti and Rotorua		
	Benefits	Negative Impacts
Status Quo	• Ability to control Kaituna River flows in flood emergencies • Ability to control Lake Rotoiti levels	• Cost of maintenance of structure • Cost of monitoring lake levels and adjusting gates to suit. • Political pressure. Trying to reconcile demands from different groups that are in conflict with each other.
Option 1	• Greatly reduced operating/maintenance or monitoring expenses • No political pressure or perception that EBOP is favouring one group over another. Letting nature take its course • No ability to close gate and restrict Kaituna flows in flooding or drowning emergencies	• No ability to control day to day Kaituna River flows • No ability to control Lake Rotoiti levels

Stakeholder – Ecological Factors		
	Benefits	Negative Impacts
Status Quo	• Can maintain a legal minimum flow of at least 7.9 m^3/s in Kaituna River that is required by biota (Water right 76C)	• Refer Niwa Report “Water Level fluctuations in Lake Rotoiti and their ecological implications (2003) – This states that “A very stable level regime is likely to result in a narrower and less diverse band of lake margin wetlands than an unstable one with corresponding impacts on the invertebrates, fish and birds that exploit the zone”. • Larger range of flows in upper Kaituna River may continue any erosion problems that currently occur
Weir Option	• Larger range of Lake Rotoiti levels should result in “a wider and more diverse band of lake margin wetland”	• Cannot maintain minimum flow of 7.9 m^3/s in Kaituna River as required by biota (however in 10 year simulation flow was always >10 m^3/s anyway)

Stakeholder – Kaituna River Scheme (managed by EBOP’s Rivers and Drainage

Group)		
	Benefits	Negative Impacts
Status Quo	• Potential control of Kaituna flows in flood emergencies	• Increased daily variation in flows increasing erosion. (Flow from Okere as % of total flow in Kaituna in lower catchment is small however)
Weir Option	• Reduced daily variation in discharges reduces erosion along downstream banks of Kaituna River.	• No potential control of Kaituna in flood flows. As discussed by Titchmarsh (p42) the Okere Falls contributed only 55 mζ/s of the 376 mζ/s 1962 flood at Te Matai on the Lower Kaituna. However this may still be enough to be the difference between stopbank overtopping or not

Stakeholder – Lake users		
	Benefits	Negative Impacts
Status Quo	• Boat ramps are accessible at all times • Less unsightly mudflats	• Lack of depth range at edges result in greater weed growth and lack of beaches
Weir Option	• Less weed growth and more beaches • More beaches will provide smelt spawning areas which is beneficial to Trout fishery	• Boat ramps may not be accessible when lake levels are low

Stakeholder – Property owners adjacent to Lake Rotoiti		
	Benefits	Negative Impacts
Status Quo	• Narrow range of lake levels means boat sheds can be used most days. • Less unsightly mudflats.	• Lack of depth range at edges result in greater weed growth and lack of beaches.
Weir Option	• Less weed growth and more beaches.	• Variable lake levels means private boat ramps may not always be usable. • More unsightly mudflats at times of low lake levels

Stakeholder – Property owners adjacent to Lake Rotorua		
	Benefits	Negative Impacts
Status Quo	• Nil	• Nil
Weir Option	• Nil	• Nil.

Stakeholder – Rafting companies		
	Benefits	Negative Impacts
Status Quo	• Have potential to control flows to required limits (13 to 26 m^3/s) to suit rafting days (e.g Sundays) and times (e.g. 9am to 5pm). • EBOP can warn rafting companies prior to any changes in flow.	• Current regime leads to fewer days within required flow range than weir option.
Weir Option	• More days within required range of flows (13 to 26 mζ/s).	• No potential to control flows on required days/times - at nature's mercy. • No potential to stop flows in case of accidents/drownings. • No warnings about changes in flow (although with lake storage changes in flow over weir will tend to be gradual)

Stakeholder – Rotorua District Council		
	Benefits	Negative Impacts
Status Quo	• Narrow range of Lake Rotoiti levels means boat ramps do not need to extend into lake for dry periods	• Lack of depth range at edges result in greater weed growth and lack of beaches.
Weir Option	• Less weed growth and more beaches on Lake Rotoiti.	• Boat ramps may need to be extended to cover periods of low levels in Lake Rotoiti.

Stakeholder – Western Bay of Plenty District Council		
	Benefits	Negative Impacts
Status Quo	• Potential control of Kaituna flows in flood emergencies	• Greater daily variation in flows and and statistically higher peak flows with associated increased bank erosion potential
Weir Option	• More uniform day to day flow and less bank erosion	• No control of Kaituna flows in flood emergences

6 FURTHER ALTERNATIVE OPTIONS

This study has considered a fixed weir option with the average level of lake Rotoiti determined by the level(s) this weir is set at. Regardless of the height of the weir the weir option will always result in a larger range of Lake Rotoiti levels than the current consented gate operating regime, with a corresponding decrease in range of flows in the Kaituna River (refer section 4).

Other alternatives that may wish to be considered are:

i) Maintain the manual operating regime of the gates but with a larger target lake level range.

ii) Maintain the manual operating regime of the gates but with another stakeholder such as EBOP's Lakes Management group or some other agency such as Bay of Plenty Energy (for their proposed hydropower scheme) or river rafting companies taking control. (However very careful consultation and rules would need to be put into place to make sure other stakeholders were not disadvantaged)

iii) Optimise gate operations by developing a flow forecasting model that provides early warnings on expected flows and required gate operations. (This could be incorporated into either a manual or automated algorithm operating regime).

iv) If the wish is to replace the gates with a weir, but to maintain a narrow range of Lake levels then a weir considerably wider than 27 m is required. This would require either zig-zagging the weir or for it to be possibly placed further upstream in the Okere arm.

7 CONCLUSIONS / RECOMMENDATIONS

This report has quantitatively described the impacts of replacing the current radial gates with a fixed weir structure on Lake Rotoiti and Lake Rotorua levels and Kaituna River flows. It has also qualitatively described potential impacts this may have on various factors/groups (eg ecology, boat users etc).

It is recommended that the results of this study be used to help inform the consultation process between EBOP and other stakeholders.

It is suggested that if an alternative to the current gate operation is the preferred outcome from the consultation process then the gate structure should not be removed but instead retained, with the gates fully open. In this way there is still the ability to close the gates in the event of a flooding or drowning type emergency.

If the preferred outcome from consultation is an alternative structure to the current gate operation, accurate survey of the Okere Channel and the Ohau Diversion Channel within Lake Rotoiti will be required to refine the modelling and calibration.

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NIWA for lake level and flow data
Opus – Dr Grant Webby - For assistance in model calibration

REFERENCES

References given in Table 1.

APPENDIX A

NIWA GRAPHS OF LAKE LEVELS OF LAKE ROTOITI SINCE 1906

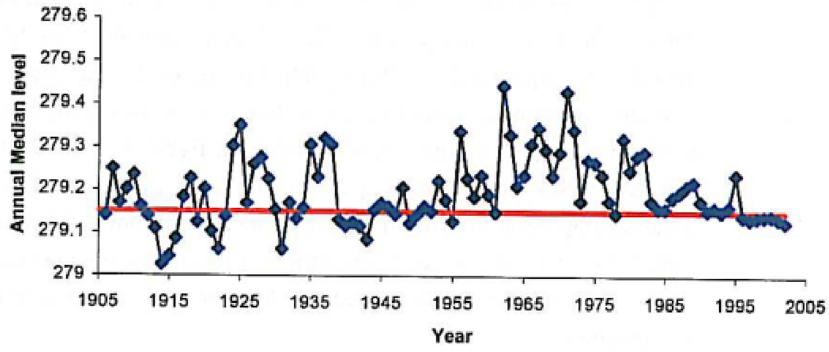

Figure 3: Annual median water levels in Lake Rotoiti. The red line indicates centre of the current target level range.

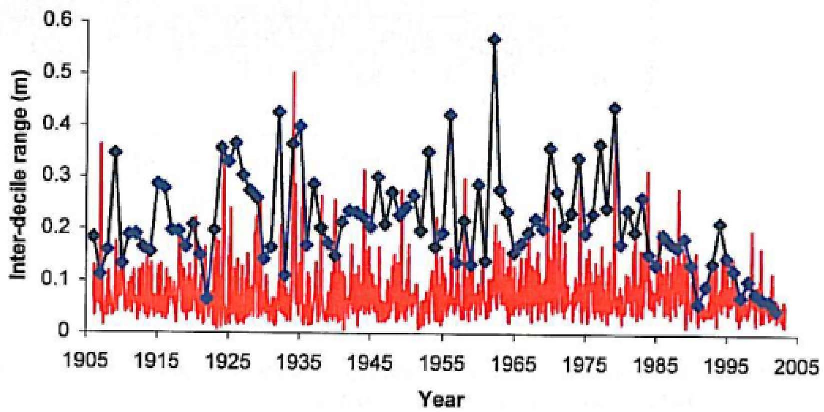

Figure 4: Inter-decile range of water levels by year (blue) and by month (red).

In summary, prior to outflow control, water level changes of 20-50 cm range occurred between years in Lake Rotoiti, sometimes as part of near decadal cycles and sometimes as a steady directional change, and a seasonal pattern of approximately 20 cm average range was overlaid on these long term fluctuations. These patterns have disappeared since regulation. The short term (within month) variability of 5-10 cm is, however, only slightly less than that that seen without regulation.