Hydraulic Modelling of Ohau Channel

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Introduction

The Ohau Channel is the outlet for Lake Rotorua, and flows into Lake Rotoiti. The total length of the channel is approximately 2.3 km. In 1972 and 1973 the channel was enlarged to allow Lake Rotorua levels to drop, while in 1974 a gabion basket structure was installed to prevent lake levels falling too low in times of dry weather. In 1989 a permanent weir control structure was built so that the level of Lake Rotorua could be better regulated.

The weir consists of a central portion 6 m wide, and two flanking sections at a higher level. Within the central portion of the weir, stoplogs were built to allow a more refined regulation of lake level. The stoplogs consist of 3 parallel sets of 3 lengths of 100 x 100 RHS. Thus the stoplogs can raise the central invert by 300 mm. In practice, the stoplogs are either all in or all out.

There have been differing perceptions as to the actual effect of the stoplogs. This study aims to determine whether the stoplogs have any effect on the Lake Rotorua level.

Previous Studies

Murray-North carried out an investigation of the Ohau Channel as part of the Upper Kaituna Catchment Control Scheme studies in the mid 1970s (BOPCC, 1975). In 1988/89, Peter Blackwood further investigated the hydrology and hydraulics of the system, and designed the current control structure (Blackwood, 1989).

Further review work was undertaken in 1995 (Titchmarsh, 1995), which led to a refinement of the resource consent conditions, including the target lake level range (279.60 m – 280.11 m RL[1]).

In addition to these studies, Richard Croad of the then Ministry of Works' Central Laboratories carried out a physical model study of the channel.

Current Study – Method

In this current study, a MIKE 11 model of the channel has been built. The 1-dimensional model has Lake Rotorua as its upstream end and Lake Rotoiti as its downstream end, and includes a representation of the weir structure that can be altered to represent the addition or removal of the stoplogs. The effect of such changes on water levels and flows in the channel can then be predicted.

The layout of the model is shown in Figure 1. The model chainage is defined as 10000m at Lake Rotorua and increases downstream.

[1] All levels are in terms of Moturiki datum.

Figure 1 Model Layout

Model Cross-sections

Cross-sections were surveyed in 1975 by Murray-North (Plan K4234). The survey was repeated in June 2002 (although in some cases the later cross-sections were approximately rather than exactly in the same position as the original survey). In addition, sections of the upstream and downstream end of the model were derived from various other sources (Table 1).

A shallow delta exists at the downstream end of the channel. Depth soundings (taken during the June 2002 survey) over the delta range from 0.15m to 0.5m. There was a channel just deep enough for the survey boat with outboard motor to pass from the lake to the channel, indicating a depth of perhaps a little over 0.5m. As the Lake Rotoiti level at the time of survey was 279.218m, an invert of 278.7m has been assumed at the delta cross-section. Aerial photographs indicate that the delta is about 100m wide and the channel through it about 20m wide.

There is a possibility that some of the cross-section markers have sunk – no level run of the markers has been done recently.

Section	(MIKE 11 chainage)	Data Source
Lake Rotorua	10000	from 1990s model
u/s of weir	10025	old (preconstruction) survey
2	10052	2002 survey
6	10212	2002 survey
10	10352	2002 survey
13	10492	2002 survey
17	10662	2002 survey
21	10872	2002 survey
25	11042	2002 survey
SH Bridge (25A)	11082	2002 survey
25B	11140	2002 survey
75/34	11212	2002 survey
38A	11392	2002 survey
42B	11552	2002 survey
45A	11712	2002 survey
49A	11852	2002 survey
53A	11992	2002 survey
??56A??	12112	2002 survey
delta	12250	assumed delta (based on soundings 2002 & aerial photos)
Lake Rotoiti	12350	artificial section

Table 1 Model cross-sections *(To check against Level Book)*

Generally the 2002 cross-sections did not differ markedly from those of the previous survey (mid-1990s). The exception was at 10052, where the 2002 section was significantly larger – 4m deeper and with over double the section area at the water levels of June 2002. NIWA gaugings have been taken in approximately the same location, and the sections from those gaugings between October 2000 and March 2002 are all very similar and closer in shape to the previous survey rather than the later one. (See the file ohau.xns11). If all data are correct, this suggests that the channel bed returns to shallower depths only a short distance downstream of a large scour hole at the weir exit.

However preliminary model results from early stages of the calibration process proved insensitive to the shape of this section (10052). Results were also not very sensitive to the shape of the section upstream of the weir (10025). (Figure 2).

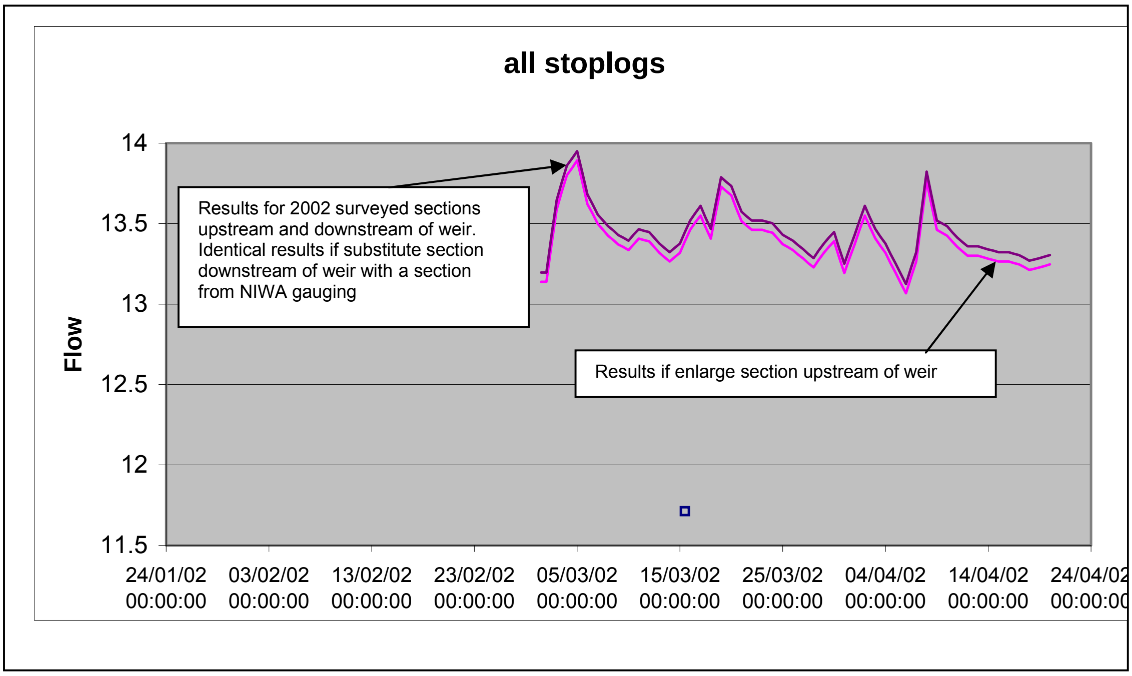

Figure 2 Model sensitivity to shape of cross-sections upstream and downstream of weir (early attempts at calibration of model)

Weir

After initial trials with a single weir structure in the model, 3 weir structures were inserted, representing the left, central and right portions of the weir. The 3 weir approach allows a better representation of the actual depth over each section of weir. The invert of the central portion was altered as appropriate to model the stoplog setting.

It was found that a 'single weir' formulation led to the 'no stoplogs' situation giving higher lake levels upstream than the 'all stoplogs' situation, for the prediction runs described below, which is counter-intuitive. The trends predicted by the 'three weir' formulation did however seem intuitively correct.

The weir shape (i.e that from which the 3 weirs in the modelled were later derived) used in this study was obtained from a June 2002 survey immediately downstream of the weir, supplemented with design information in the centre where it was not practical to survey. (Figure 3)

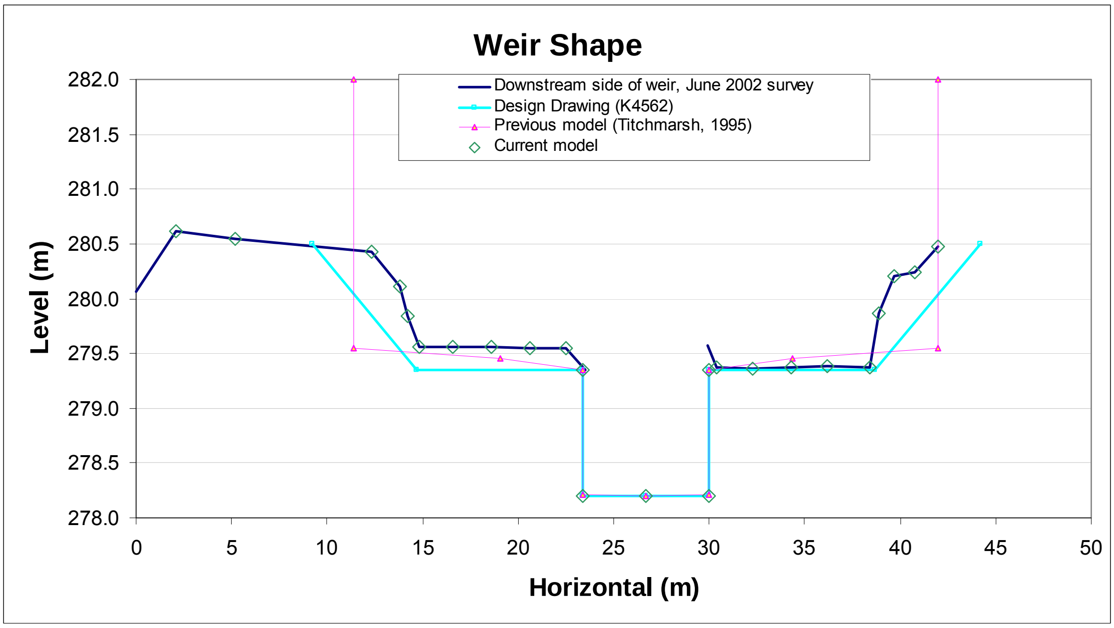

Figure 3 Weir shape

Model Calibration

The data available for calibration consists of lake level records for Rotorua and Rotoiti, flows as gauged occasionally by NIWA just downstream of the weir and water level profiles down the channel as measured during the most recent cross-section survey.

Lake Level Data

There were two sources for the water level recorder information. Automatic recorders located at Mission Bay (Lake Rotorua) and Okawa Bay (Lake Rotoiti) provide continuous lake level records, while, manually read lake level data are collated by the Technical Services Section of Environment Bay of Plenty. Those data are generally read each working day morning. There are however differences between the continuous data (as extracted daily) and the manual data.

The Rotorua lake levels according to the automatic data are higher than those from the manual readings for the period prior to 1 January 2001. A datum correction has been applied to the automatic recorder data after this date, and the two data sets then compare well. (Figure 4).

The Rotoiti levels according to the automatic data are generally lower than those from the manual readings, as the automatic recorder is in the drawdown zone at the lake outlet. (Figure 5).

While the manual data is therefore more representative of the lake levels that should be used for boundary conditions, the calibration runs when the flow gaugings were taken were made with the automatic data. This was because the automatic data record does not have the gaps (e.g. during weekends) that the manual data records do. A sensitivity test showed that using the manual data instead made little difference to the results of interest.

The calibration runs for the periods in June 2002 (when water level profiles were measured) used the manual records for the boundary conditions.

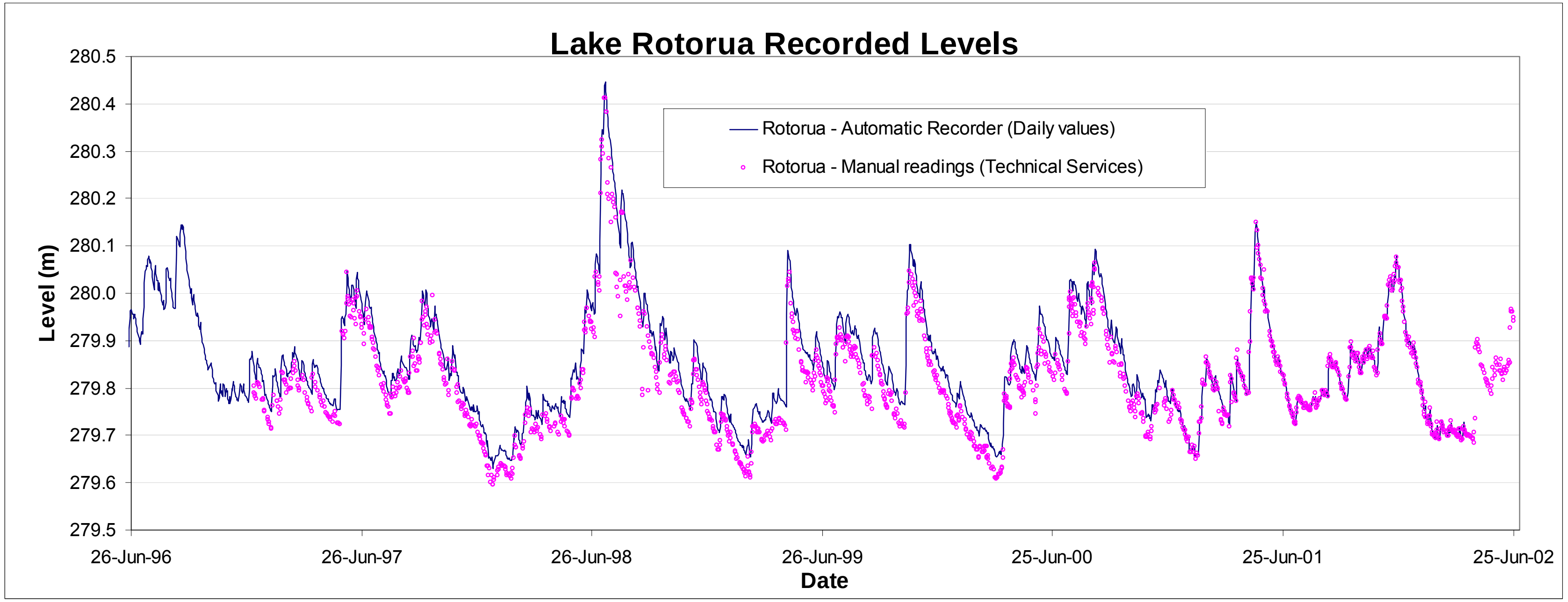

Figure 4 Lake Rotorua Level

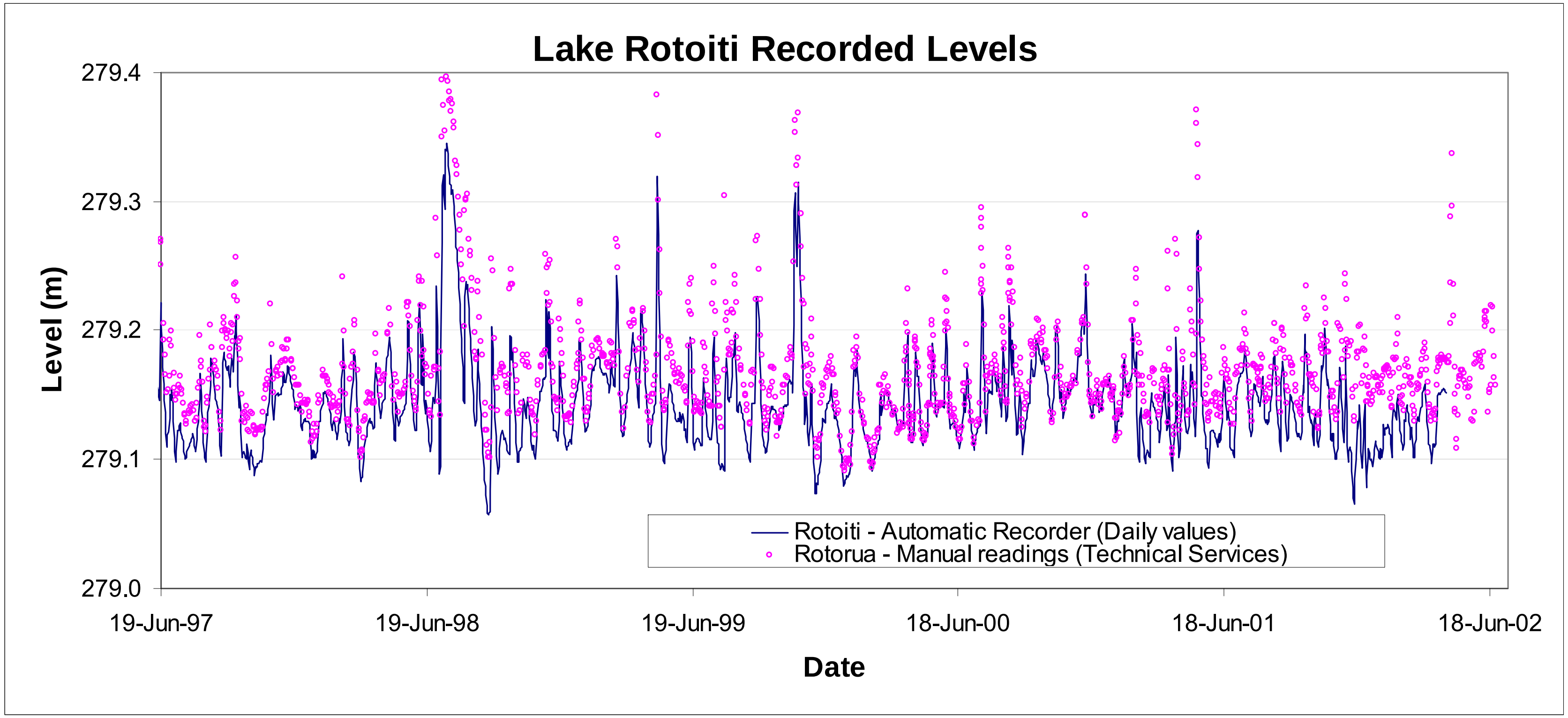

Figure 5 Lake Rotoiti Level

Calibration Process

The continuous water level records were used as upstream and downstream boundary conditions. Two broad types of comparisons were then made between predicted and observed data. Firstly, predicted flows downstream of the weir were compared to NIWA gaugings. Secondly, the predicted water level profiles were compared to those recorded during the June 2002 survey.

Channel resistance, weir head loss factors and the shape of the cross-section at the downstream delta were the parameters adjusted to improve calibration. Sensitivity to sections either side of the weir was also tested during the calibration process (see below).

Calibration results are generally satisfactory, but further observed data (particularly for the "no-stoplogs" situation) are needed to have greater confidence in the model. (Figures 6-9).

The inflow headloss factors for the "all stoplogs" and "no stoplogs" cases have been set at 0.6 and 0.5 respectively, to improve calibration (default valve is 0.5). Given that the flow has to pass over 3 parallel sets of stoplogs in the "all stoplogs" case, the higher head loss factor is not unreasonable.

The inflow headloss factor for the side weirs has been set to 0.75 in both cases. Outflow and free overflow head loss factors have been set to the default in all cases. Some simulations better predicted observations if these were adjusted, but others did not and on balance the default values seemed appropriate.

The final bed resistance profile down the channel is as shown in Figure 10. Some consideration of the channel bends was had in the final selection. Note that Blackwood (1989) used resistance values that were a function of flow in the lower reaches of the channel. In this study a more simple approach of a constant resistance is taken, as data are limited.

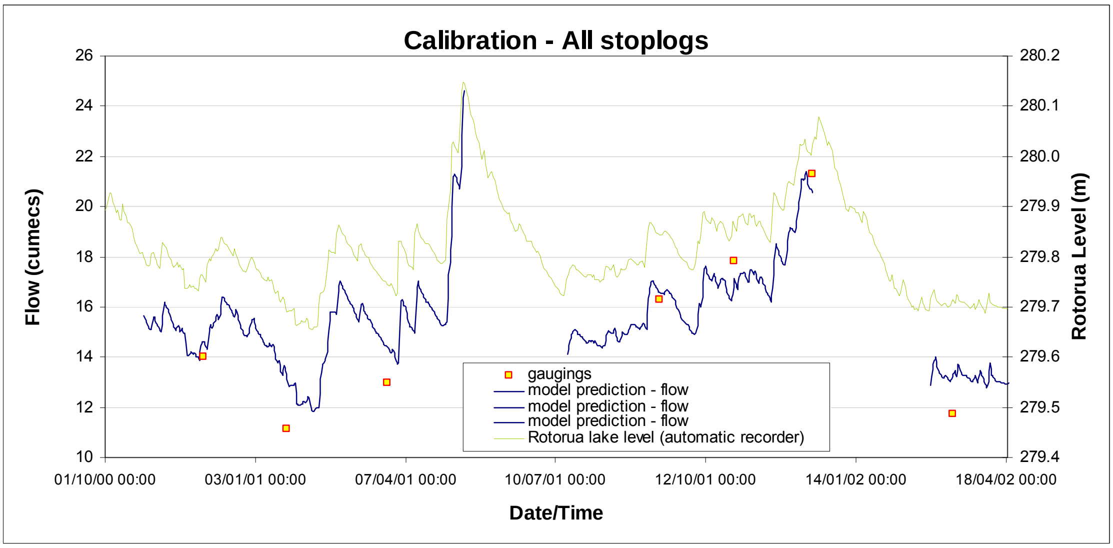

Figure 6 Calibration against flow, all stoplogs in place

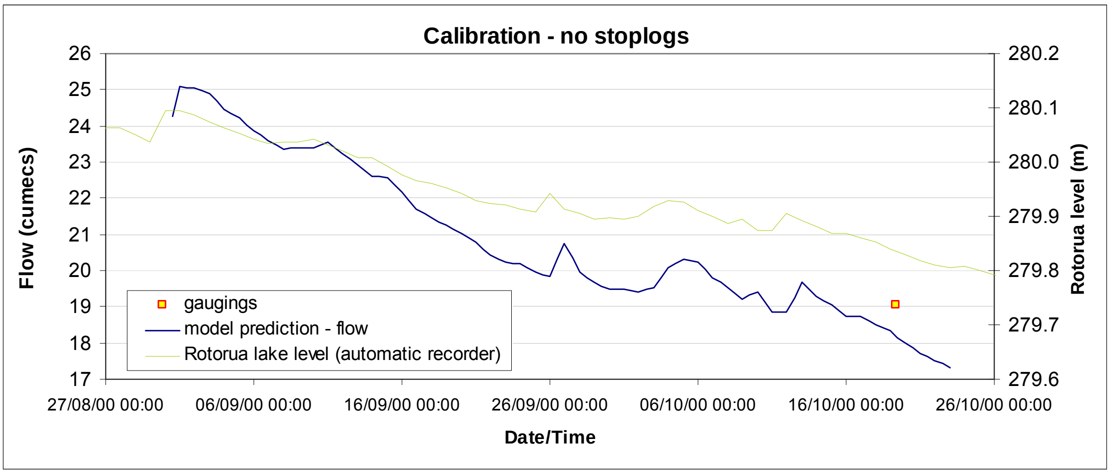

Figure 7 Calibration against flow, no stoplogs in place

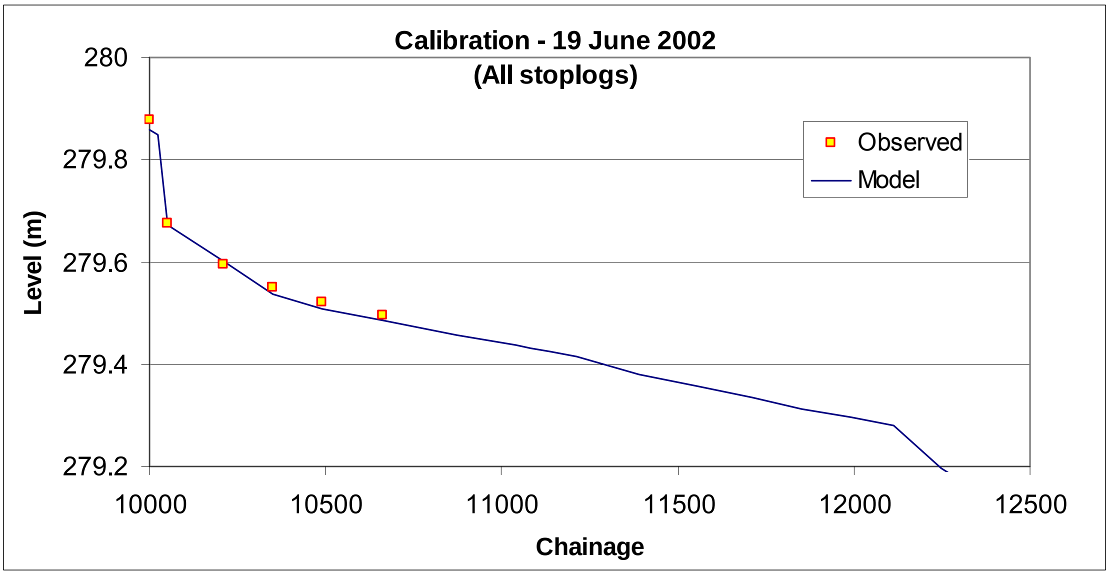

Figure 8 Calibration against level, all stoplogs in place

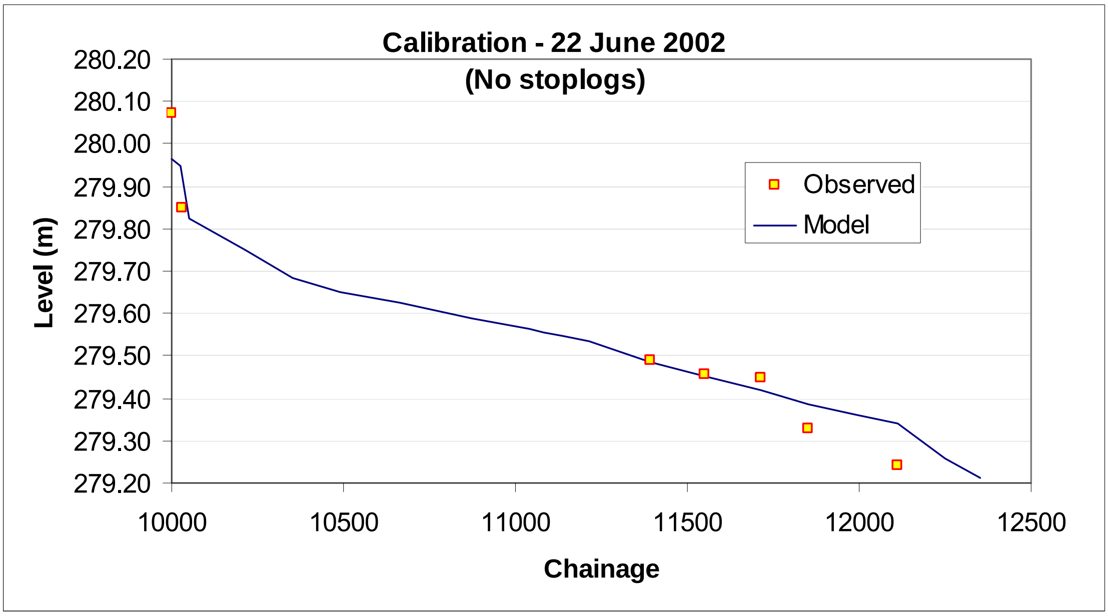

Figure 9 Calibration against level, no stoplogs in place

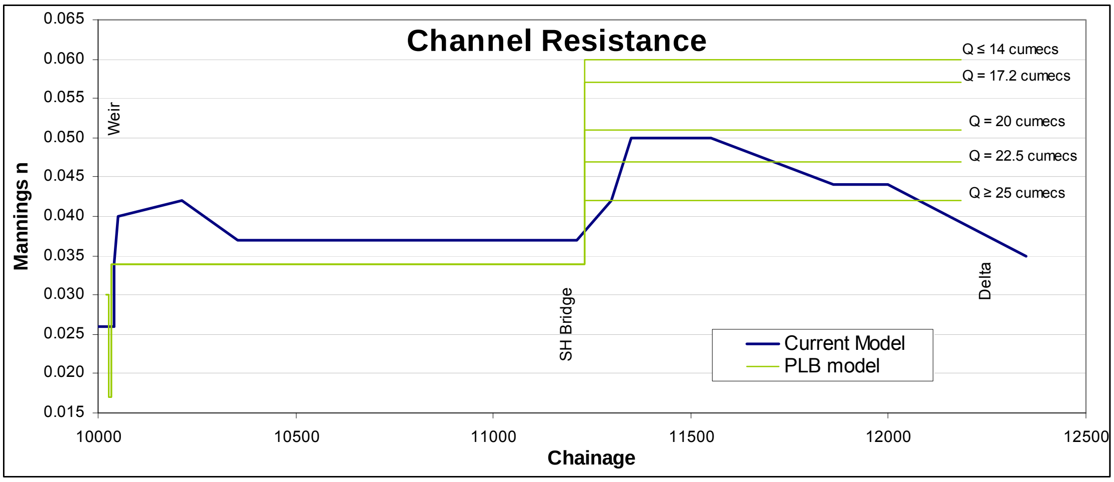

Figure 10   Channel Resistance

Predicted Effect of Stoplogs

The aim of the model study is to predict the effect of the stoplogs on Lake Rotorua levels. However, because Lake Rotorua level is a boundary condition, and therefore has to be defined prior to a simulation, the effect cannot be directly predicted. Instead, the effect can be inferred from graphs of lake level versus weir flow, as follows.

Once best estimates of the calibration parameters (channel resistance and weir representation) i.e. to give the best overall match to observed flows and water levels, were obtained as in the previous section, simulations over a range of lake levels and inflows were run.

Firstly, the level of Lake Rotorua was gradually stepped up and down to cover a wide range of levels. Each level was held steady for a time to allow a steady flow at the weir to be reached. (Figure 11). The July 1998[2] recorded levels (automatic) for Lake Rotoiti were used for the downstream boundary condition, although results of interest are not sensitive to the Rotoiti level.

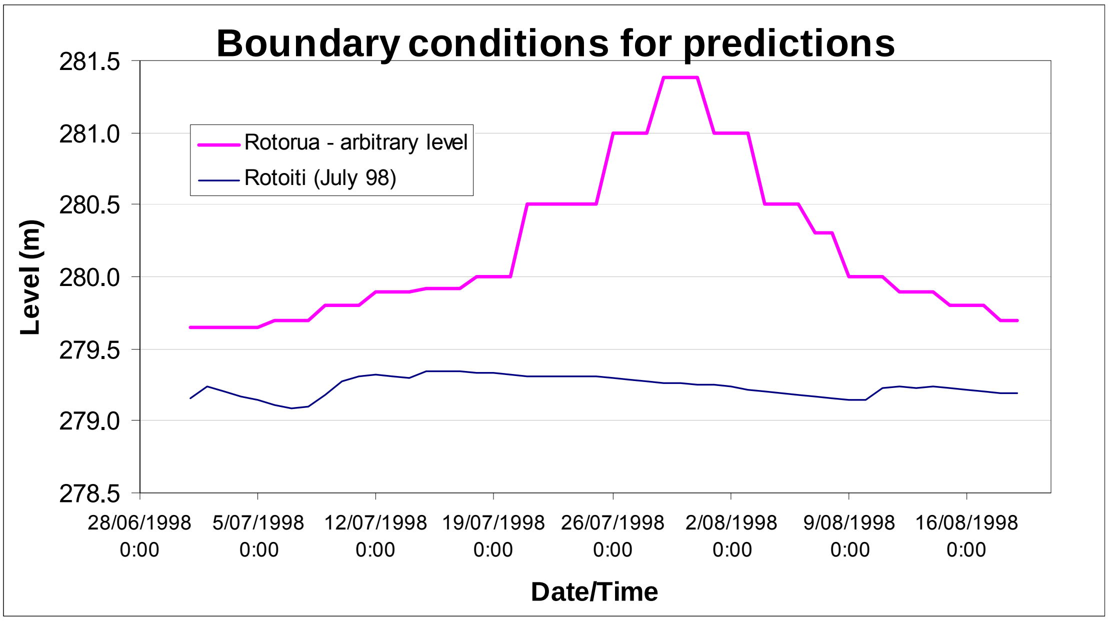

Figure 11 Boundary conditions for predictions, with Rotorua lake level stepped up and down

As a check, a discharge-time relationship was used as an upstream boundary condition. Flows were gradually stepped up and down, with each flow held steady for a period. Again, the July 1998 automatic recorded levels in Lake Rotoiti were used for the downstream boundary conditions.

A further check was made by using the July 1998 lake level records as boundary conditions at both lakes. The relationship between Lake Rotorua level and weir flow is

[2] July 1998 was a time of heavy rainfall and flooding in the central North Island and Bay of Plenty hence lake levels also rose to high levels.

plotted in Figure 12 for all three cases, for both the "no stoplogs" and "all stoplogs" options. Results from Table 4 of Titchmarsh (1995) are also plotted.

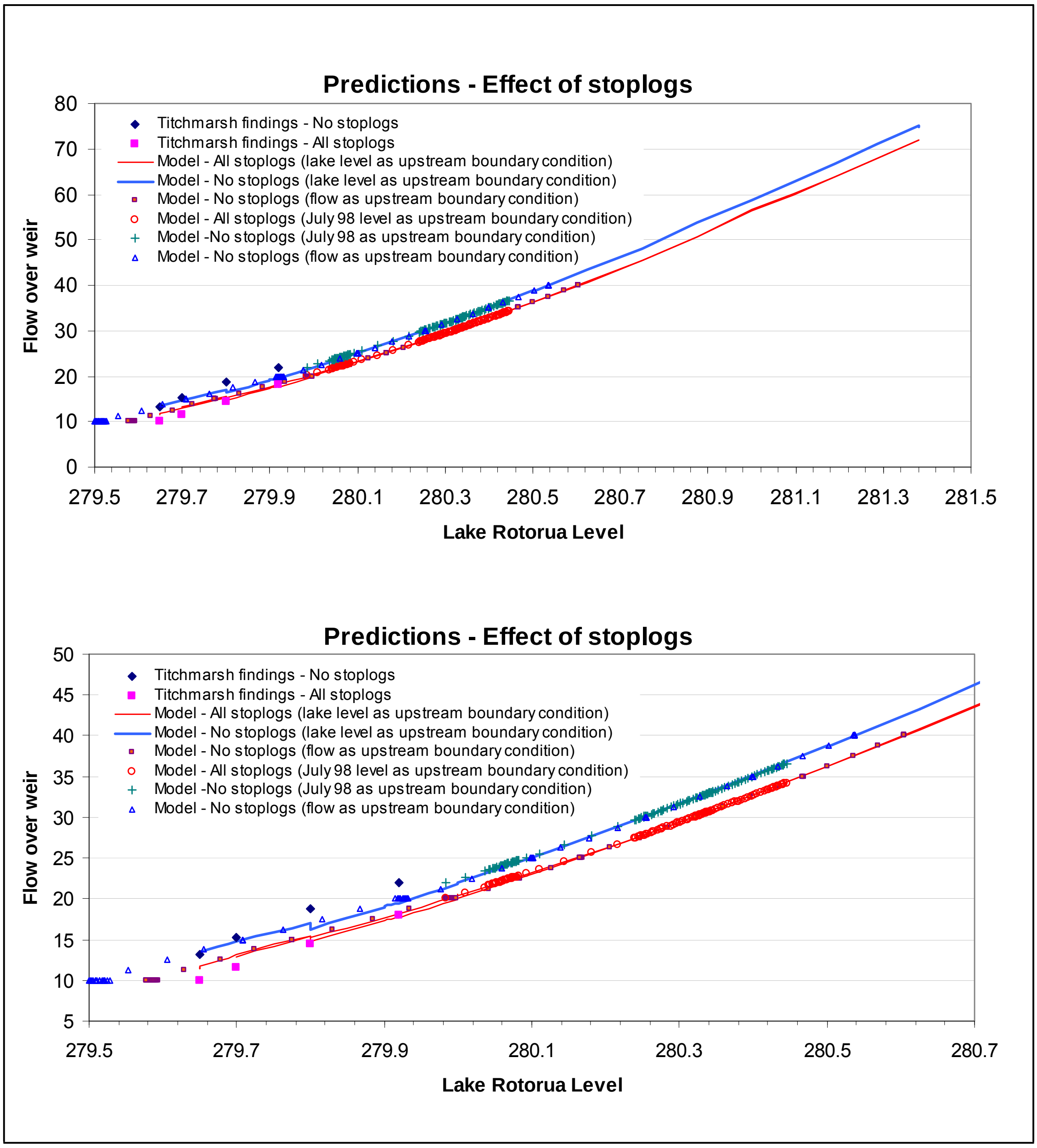

Figure 12 Predicted Effect of Stoplogs

Model results show that Lake Rotorua levels are slightly higher for the same flow in the all-stoplogs case compared to the no-stoplogs case. For the same lake level, the all-stoplogs case results in a lesser-flow across the weir than for the no-stoplogs case. These results are similar to the findings of the Titchmarsh study.

A Q-H relationship at the weir has also been plotted for the all- and no- stoplogs cases (Figure 13). Results from all the simulations show the same relationship.

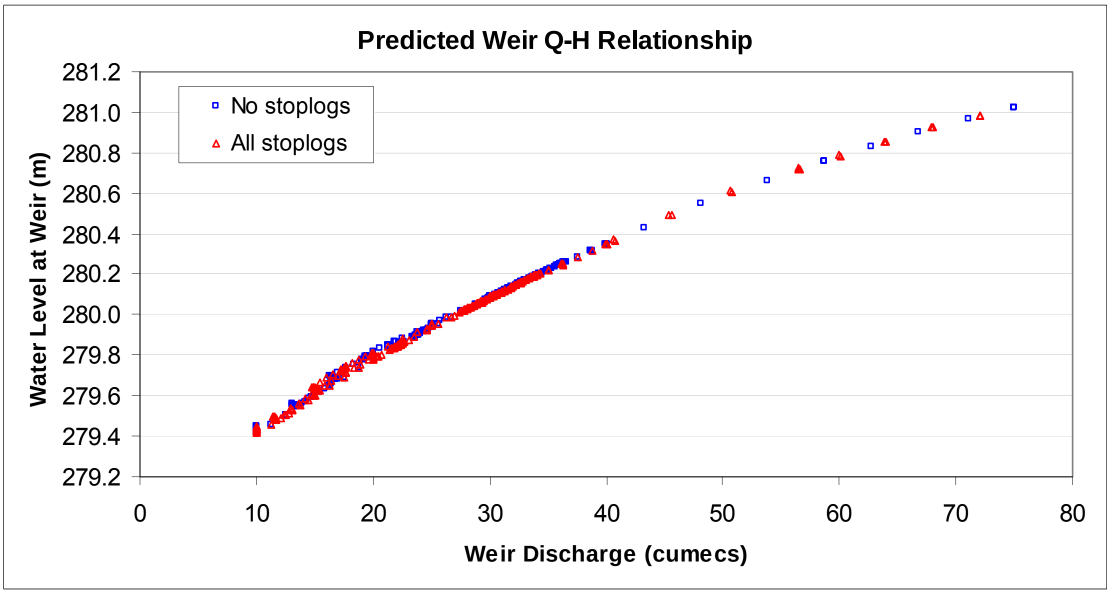

Figure 13 Predicted Q-H Relationship at Weir

Conclusions and Recommendations

The modelling indicates that the stoplogs do have an effect. A higher Rotorua Lake level than the "no-stoplogs" case is required to maintain the same outflow. Across the weir itself, no difference is predicted in water level.

However, calibration is limited, particularly for the "no-stoplogs" case. Further observations would allow the model to be refined, to give greater confidence in the predictions.

It is recommended that a stage board be installed downstream of the weir, so that the position of the NIWA gauging is consistent and accurately fixed, and so that the water level can be read at the time of each gauging. Having a water level reading downstream of the weir, as well as upstream – i.e. the lake level – will provide more information for future calibration of any model. Environment Bay of Plenty should liaise with NIWA regarding this.

It is also recommended that some consideration be given to developing a lake balance model for Rotorua, linked with the Ohau Channel model developed here. With the upstream boundary condition of such a model then being catchment rainfall, the effect of the stoplogs on lake level could then be directly predicted, although many assumptions (e.g. average runoff coefficients and evaporation) would need to be made. The model could also be used with forecast rainfalls for the management of the stoplog settings.

References

Blackwood, P. (1989); Lake Rotorua Control Structure: Hydrology and Hydraulic Design Report. Bay of Plenty Catchment Board.

Titchmarsh, B.R. (1995); Lake Rotorua and Lake Rotoiti: Report on the Technical Issues and Effects to be Considered in the Application for Resource Consent. Environment BOP, Operations Report 95/5.

Appendix 1 MIKE 11 Files Used

Scenario	sim11	nwk11	xns11	bnd11	HD11	RES11
calibration						
Uses Automatic level records	ohauOct00-May01	ohau2002-all_stoplogs-3weirs	ohau	shanes levels	ohau	SHANES LEVELS-ALLSTOPLOGS_OCT00-MAY01-3weirs
Uses Automatic level records	ohauSep-Oct00	ohau2002-no_stoplogs-3weirs	ohau	shanes levels	ohau	SHANES LEVELS-NOSTOPLOGS_SEP-OCT00-3weirs
Uses Automatic level records	ohauJul-Dec01	ohau2002-all_stoplogs-3weirs	ohau	shanes levels	ohau	SHANES LEVELS-ALLSTOPLOGS_jul-dec01-3weirs.
Uses Automatic level records	ohauMar-Apr02	ohau2002-all_stoplogs-3weirs	ohau	shanes levels	ohau	SHANES LEVELS-ALLSTOPLOGS_mar-apr02-3weirs
Uses Manual level records	ohauTSno	ohau2002-no_stoplogs-3weirs	ohau	TechServ levels June02	ohau	TECHSERV- LEVELS-noSTOPLOGS_JUN02-3weirs
Uses Manual level records	ohauTSall	ohau2002-all_stoplogs-3weirs	ohau	TechServ levels June02	ohau	TECHSERV- LEVELS-ALLSTOPLOGS_JUN02-3weirs
predictive						
L Rotorua levels stepped up/down	ohau-allstoplogs-flows	ohau2002-all_stoplogs-3weirs	ohau	assess2 - flow us bc	ohau	WL-allstoplogs-3weirs
L Rotorua levels stepped up/down	ohau-nostoplogs-flows	ohau2002-no_stoplogs-3weirs	ohau	assess2 - flow us bc	ohau	WL-nostoplogs-3weirs
July 98 lake levels both bound. conds.	ohau-allstoplogsJul98levels	ohau2002-all_stoplogs-3weirs	ohau	Jul98levels	ohau	July98levels-allstoplogs-3weirs
July 98 lake levels both bound. conds.	ohau-nostoplogsJul98levels	ohau2002-no_stoplogs-3weirs	ohau	Jul98levels	ohau	July98levels-nostoplogs-3weirs
Inflows stepped up/down	ohau-allstoplogs-arbitraryinflows	ohau2002-all_stoplogs-3weirs	ohau	Jul98levels&arbitraryinflow	ohau	FLOWS-allSTOPLOGS-3weirs
Inflows stepped up/down	ohau-nostoplogs-arbitraryinflows	ohau2002-no_stoplogs-3weirs	ohau	Jul98levels&arbitraryinflow	ohau	FLOWS-noSTOPLOGS-3weirs