Supplement to Lake Rotoiti diversion wall modelling – refined wall designs and response to peer review

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Scott Stephens

Prepared for

Environment Bay of Plenty

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National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

Contents

Executive Summary			iv
1.	Introduction		1
2.	Response to the peer review		2
	2.1	Summary	2
	2.2	Calibration	3
	2.3	Ohau Channel Plume	4
	2.4	Channel diversions	4
3.	Quantitative evaluation of calibration		6
4.	Model verification		10
	4.1	Visual comparison	10
	4.2	Statistical comparison	12
5.	Ramifications for diversion wall results		15
6.	Additional diversion-wall simulation results		17
7.	References		21

Reviewed by:

Bob Spigel

Approved for release by:

John Oldman

Formatting checked

Executive Summary

This report provides a response to the peer review of the report titled “Modelling diversion walls for diverting the Ohau Channel inflow from Lake Rotoiti” (Stephens 2004) by Dr John List of Flow Science. As recommended in the review, this report presents a verification simulation, and provides a quantitative comparison between measured data for both the calibration and verification simulations. Results are also presented from some additional diversion-wall designs, requested subsequent to completion of the first report.

The primary aim of the 3-dimensional modelling was to assess the efficiency of various diversion-wall designs for preventing water from the Ohau Channel entering the main body of Lake Rotoiti. The criticisms within the review do not invalidate the diversion-wall results, which provide valuable guidance for decisions to be made about the placement of a diversion-wall.

The quantitative evaluation of the model calibration showed weaknesses in the calibration, with low (but not statistically insignificant) linear correlations. However, the linear correlations supported visual observations that the model was capturing the general pattern of flow reasonably well.

Linear correlations were low for the verification simulation. The verification highlighted the inability of the model to accurately represent the rapid plunge of the plume that occurs in the natural lake. Therefore, as configured, the model is not capable of accurately simulating the dynamics of the wider lake, because it is not exactly predicting the plunging plume jet in the near-field. However, the simulations do show qualitative agreement with measurements, indicating that an approximate representation was achieved. The comparison site was located in the highly dynamic “Narrows” area of the lake, which experiences large thermocline oscillations and strong currents, due to topographic amplification of internal waves. The modelling showed that the hydrodynamics in the Okere Arm, where the proposed diversion-wall would be located, were simpler than those occurring in the “Narrows”. With a diversion wall, the flow dynamics in the Okere Arm became more 2-dimensional. Thus the poor quantitative comparison obtained in the verification for the “Narrows” site does not invalidate the diversion wall results.

Improvements to the modelling process made the additional diversion-wall simulations more stable than described in the initial report, enabling higher confidence in the results. For any given diversion wall, more leakage (from the Okere Arm to the main body of Lake Rotoiti) was experienced during windy periods, and more leakage was experienced during underflow conditions than during overflow. The placement of the diversion wall had a bigger influence on leakage than the environmental conditions.

1. Introduction

This report provides a response to that portion of the peer review dated 21 February 2005 by Dr John List (List, 2005), that pertains to the 3-dimensional modelling report, Stephens, 2004. Section 2 responds directly to issues raised in the review. Sections 3 presents a quantitative comparison between the calibration simulation and measured data, as recommended in the review. Similarly, a verification simulation is discussed in Section 4 and a quantitative comparison is made. Section 5 discusses the ramifications of the additional work to the study outcomes. Section 6 is unrelated to the review; it includes the results of additional diversion wall simulations as requested by Rotorua District Council on behalf of Environment Bay of Plenty.

2. Response to the peer review

2.1 Summary

The primary aim of the 3-dimensional modelling was to assess the efficiency of various diversion-wall designs for preventing water from the Ohau Channel entering the main body of Lake Rotoiti. The review criticises several aspects of the 3-dimensional modelling that relate primarily to the dynamics of the plume as it interacts with the main body of the lake. As the review points out, predicting the Ohau Channel plume behaviour *as it enters the natural lake environment* is a very difficult modelling task. However, predicting the behavioural changes of the plume *in the presence of the diversion wall* is considerably more straightforward, as the plume flow structure is much more 2-dimensional and is not greatly influenced by lake stratification. Having developed a feel for the sensitivities within the model, it is my opinion that the acknowledged inaccuracies in the model simulations are not crucial to the diversion wall results. Instead, the model calibration and verification simulations show that the model is broadly reproducing the complex behaviour of the plume as it migrates through the "Narrows". This is also acknowledged in the review "… notwithstanding the foregoing criticisms, the model does appear to capture the essence of the sinking and floating plume process…" (List 2005).

Therefore, although the criticisms in the report are well-founded, the criticisms within the review do not invalidate the simulation results regarding the diversion-walls; these still provide valuable guidance for decisions to be made about the placement of a diversion-wall. The review suggested that a quantitative comparison be made between the calibration simulation and measured data, and that a verification simulation be undertaken. These suggestions have been actioned and are reported in Sections 3 and 4. Model stability and run-times have been improved during a number of additional diversion wall simulations, giving better confidence in the predictions (Section 6).

The review recognises the shortcomings of the modelling for making long-term hydrodynamic predictions in the lake. As completed, the modelling is therefore unsuitable for coupling with, or producing input for, an ecosystem model. Nor can it be reliably used to provide input for DYRESYM modelling, such as that undertaken by Hamilton and Uraoka, 2004.

2.2 Calibration

The main issues that Dr List found with the model calibration, together with my responses, can be summarised as follows:

C1. The model appears to have been cold-started, leading to start-up transient errors.

R1. The model was cold-started, and there will be start-up transient errors present in the simulations. This was unavoidable given the relatively short simulation run times. However, these errors will impact most upon predictions of internal waves in the main body of the lake, and will have far less impact on the diversion-wall results.

C2. The calibration was "eyeballed", so model was in qualitative agreement with data but there was no statistical measure of the "goodness of fit".

R2. A quantitative comparison has been made between the calibration simulation and measured data, this is presented in Section 3.

C3. No model verification was undertaken.

R3. A verification simulation has been undertaken, and a quantitative comparison has been made between the verification simulation and measured data. This is presented in Section 4.

C4. The model was terminated by a software crash without explanation as to why this occurred or any subsequent follow-up.

R4. The model crash occurred because the numerical dispersion was reduced as much as possible for the chosen model grid size and timestep. This left the model prone to instabilities, which was revealed in energetic events – the event that caused the model to crash was the most energetic event observed in the field study. This period was chosen for calibration to provide the most difficult test for the model. To have further reduced the model grid size and timestep would have made the simulation runtimes too large to meet the study deadlines. However, the model remained stable for long enough to undertake the calibration, and diversion-wall scenario runs, thus meeting the aims of the study despite experiencing instability late in the simulations.

2.3 Ohau Channel Plume

The main issues that Dr List found with the models description of the Ohau Channel plume, and my responses, can be summarised as follows:

C5. Tests on plume behaviour were conducted using idealised winds and plume-densities, but would have been better undertaken using real data sequences.

R5. Using real data sequences would have provided a truer test of the model's representation of plume behaviour, under historical conditions. But the purpose of the modelling was to test diversion-wall performance, and the idealised data sequences were used to provide tests of wall performance during extreme situations, e.g., strongly underflowing or overflowing. They were used to test plume within the time and resourcing constraints of the project.

C6. There is no discussion in the report of the effect of wind-induced seiching on plume behaviour, in particular on the plume injection depth. Yet this is a major control on plume behaviour.

R6. Wind-induced seiching influences thermocline depth, and therefore insertion depth of the plume when it is underflowing or interflowing in the Western Basin toward the narrows. But the area of interest is in much shallower water where the diversion-wall might be constructed. The diversion-wall site is well above most insertion depths, so the issue of plume insertion is not the main focus of the modelling. The main focus is plume leakage to the main lake body. To have fully investigated the effect of wind-induced seiching on plume dispersion would have required considerably more time than was available for the project.

2.4 Channel diversions

The main issues that Dr List found with the channel diversion simulations, and my responses, can be summarised as follows:

C7. Calculations should have used real data sequences rather than characteristic scenarios.

R7. The characteristic scenarios were designed to provide a challenging test for the diversion walls. Given the relatively short real data sequences available, the idealised data sequences were used to ensure the walls were tested under the most difficult conditions likely to be experienced.

C8. Longer simulations are required than the 5-7 days obtained. There is concern that the simulations ended with a model crash.

R8. This has been addressed to an extent (8–9 days) by the increased simulation run-times (increased model stability) obtained when producing the additional diversion-wall results in Section 6. The increased stability was achieved by using a better method for specifying the open boundary condition for the fine-grid tracer simulations.

C9. To fully assess the environmental effects of a diversion, 3-dimensional ecosystem coupled modelling should be undertaken for at least a 1-year period and preferably longer.

R9. This would be the best way to be certain about the long-term environmental effects of a diversion. But the resources required to undertake such a modelling study greatly exceed those allocated for this project. I feel that the modelling undertaken has adequately investigated the hydraulic efficiency of the diversion-wall designs, for preventing the Ohau Channel plume from entering the main body of Lake Rotoiti. This is a much simpler task than relating the wall efficiency to long-term biological changes in the Lake.

3. Quantitative evaluation of calibration

Figure 1 shows a feather plot of the currents measured in the Narrows between 26 April and 10 May 2004. Figure 2 shows a feather plot of the currents output from the calibrated model, which became unstable and crashed at 05:30 on 5 May. These figures have been reproduced from Stephens 2004 to provide a qualitative visual comparison alongside the quantitative comparison presented below (Table 1).

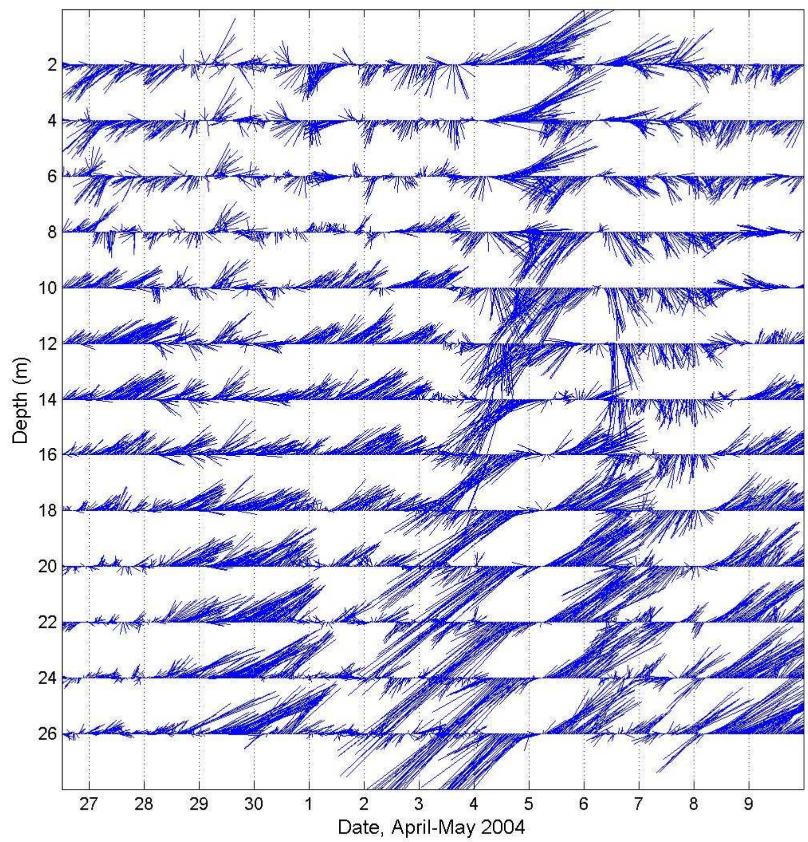

Figure 1: Currents measured by ADCP current-meter between 26 April and 10 May 2004. Scale: 1 day on the x-axis equals 0.05 m s^{-1}. True north corresponds with the vertical axis, depths are relative to the water surface, and "feathers" are in the direction toward which the current is flowing. Currents were recorded every 5 minutes, but are plotted at half-hour intervals after smoothing with a half-hour running-average.

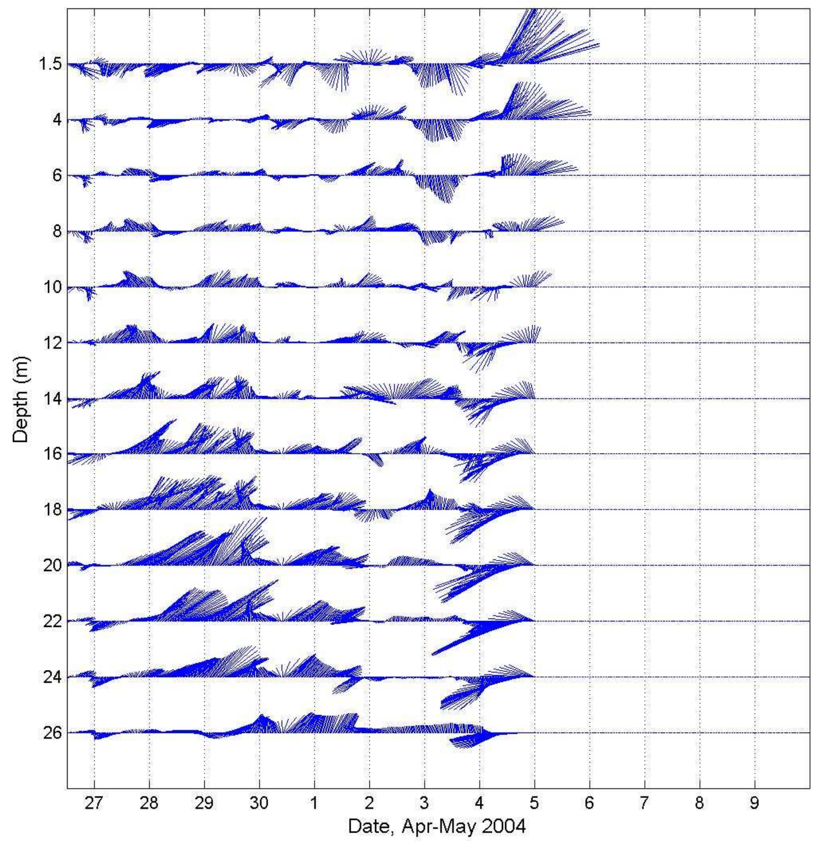

Figure 2: Currents predicted by the calibrated model between 26 April and 5 May 2004. Scale: 1 day on the x-axis equals 0.05 m s^{-1}. True north corresponds with the vertical axis, depths are relative to the water surface, and "feathers" are in the direction toward which the current is flowing. Feathers are time-averaged over the preceding half-hour and are plotted at half-hour intervals.

Table 1 contains the results of a quantitative comparison (linear regression) between the currents predicted in the calibration simulation and those measured by the current-meter placed in the "Narrows". The water depth here was approximately 28 m. For each depth below the water surface represented in Table 1, a linear regression has been undertaken between the nearest output depth in the model and the closest current-meter reading. Linear regressions were undertaken separately for each of the current components in the east-west and north-south directions as:

$$Simulated = slope \times Measured + c,$$

where *slope* is the regression-line slope (value given in Table 1) and *c* is the y-intercept (the regressions produced y-intercept values close to 0 and they are not shown). Table 1 also presents the r^2 regression fits for currents. Similar results are presented in Table 2 for water temperature. Most of the slope values in Table 1 are less than 1, indicating that the model under-predicted the current speeds, which agrees with a visual comparison between Figure 1 and Figure 2. This is a manifestation of high dispersion coefficients in the model (necessary for stability) causing smoothing of velocity gradients, as discussed in Stephens 2004. The r^2 values are low, indicating a low degree of agreement between measured and modelled currents. However, the standard two-tail significance test for the linear correlation suggests that only the N–S currents at 8 m depth are statistically unrelated within a significance level of 5% (Zar 1984). The fits are highest below the thermocline where currents were strongest, the strong currents being caused by the downwelling Ohau Channel plume (at depths of 12–22 m). The fits were low from 6–10 m depth, where weak currents occurred above the thermocline but below the surface wind-driven layer. The fits improved near the surface as the model responded to wind-driven currents. The fits decreased toward the bottom below 22 m, most likely due to the inexact representation of the lakebed in the model. Although the statistical fits are not high, the trends of higher fits in the upper 4 m and between 12–22 m depth are encouraging. They indicate that the model is responding directly to forcing by the wind, and that it is capturing the downwelling of the Ohau Channel plume to an extent. Thus the statistical calibration fit supports the qualitative interpretation of Figure 1 and Figure 2, that the model is capturing the general pattern of flow reasonably well.

Table 1: Quantitative comparison between measured currents and those simulated in the *calibration* simulation. E–W and N–S refer to currents in the east-west and north-south directions respectively. Slope values are the values of the linear regression slopes between measured and modelled currents (e.g., Modelled = slope × Measured + c). r^2 values are the linear regression r^2 fits between measured and modelled currents.

Depth (m)	E-W slope	E-W r^2	N-S Slope	N-S r^2
2	0.47	0.27	0.51	0.29
4	0.35	0.16	0.35	0.20
6	0.18	0.05	0.15	0.05
8	0.1	0.02	-0.03	0.00
10	0.21	0.14	0.07	0.04
12	0.58	0.46	0.36	0.42
14	0.71	0.43	0.48	0.42
16	0.68	0.42	0.52	0.39
18	0.57	0.40	0.54	0.37
20	0.63	0.49	0.50	0.44
22	0.44	0.49	0.27	0.37
24	0.23	0.34	0.09	0.20
26	0.18	0.32	0.05	0.21

Table 2: Quantitative comparison between measured temperatures and those simulated in the *calibration* simulation. Slope values are the values of the linear regression slopes between measured and modelled currents (e.g., Modelled = slope × Measured + c). r^2 values are the linear regression r^2 fits between measured and modelled currents.

Measured depth (m)	Modelled depth (m)	Linear fit slope	r^2
0	1.5	0.49	0.21
2.5	4	0.91	0.4
7.5	8	1.13	0.71
10	10	0.67	0.69
12.5	12	0.4	0.69
15	15	0.38	0.68
17.5	18	0.33	0.54
20	20	0.33	0.57
25	25	0.13	0.28

4. Model verification

A simulation was undertaken to verify that the parameters selected during the model calibration were correct, and that the model could reliably reproduce the lake hydrodynamics for a period other than that which it was calibrated for. The verification simulation was undertaken for the period 19–25 May 2004, a time when measured current and temperature data were available for comparison. During this period the Ohau Channel was consistently cooler than the surface lake water (ranging between 0.5–4°C cooler with an average difference of about 1.5°C), so the plume formed an underflow current that flowed along the lakebed, past the monitoring site in the Narrows toward the Eastern Basin.

4.1 Visual comparison

Figure 3 shows currents measured in the Narrows during this period, and Figure 4 shows the model's predictions for the same period. A visual comparison yields the following observations.

- The "cold-started' model takes about 1-day to begin responding in a manner consistent with the measurements.

- An underflow current was measured between 16–26 m depth, but was strongest along the lakebed from 22–26 m depth. The model under-predicted the underflow speed, and the predicted underflow appears too high in the water column, mainly between 16–24 m. The predicted underflow did reach the lakebed 3-days after start-up, and got stronger toward the end of the simulation.

- The under-predicted underflow speeds, and the delay in the downward travel-time of the plume demonstrate the inability of the model to accurately represent the rapid plunge of the plume that occurs in the natural lake. The vertically-layered computational scheme in the model is simply not capable of accurately representing the near-vertical plunge of the plume that occurs naturally (Vincent et al. 1986). Therefore the plume becomes somewhat more horizontally dispersed and diluted in the model than actually occurs. This was exacerbated by the high horizontal dispersion used in the model (necessary for stability given the grid size and timestep used).

- Surface return-flows toward the southwest occurred in response to the northeast-directed underflow. These occurred to greater depths in the model (strong down to 8–10 m) than measured (present down to 10 m, but strong from only 2–6 m). This indicates that the limits of vertical dispersion were set slightly too high in the model, although the high limits did assist the plunging of the plume. Therefore, the dispersion parameters used in the model represented the best achievable balance under the constraints of grid size and timestep.

- Despite the aforementioned disagreements in the visual comparison, the model did approximate the broad pattern of flow.

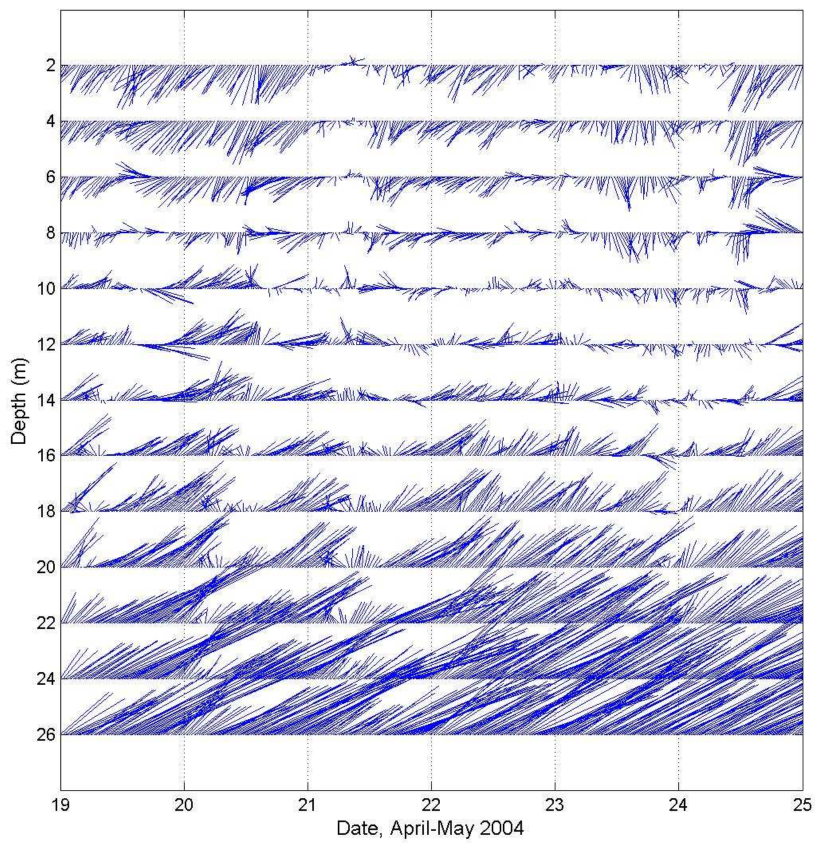

Figure 3: Currents measured by ADCP current-meter between 19 and 25 May 2004. Scale: 1 day on the x-axis equals 0.05 m s^{-1}. True north corresponds with the vertical axis, depths are relative to the water surface, and "feathers" are in the direction toward

which the current is flowing. Currents were recorded every 5 minutes, but are plotted at half-hour intervals after smoothing with a half-hour running-average.

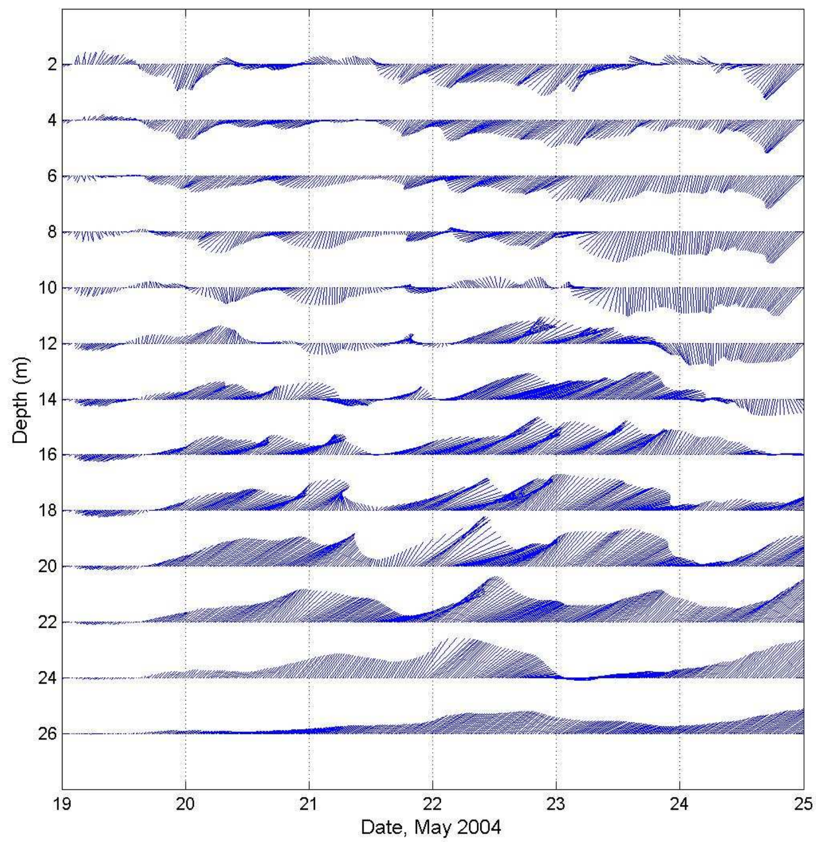

Figure 4: Currents predicted by the calibrated model between 19 and 25 May 2004. Scale: 1 day on the x-axis equals 0.05 m s^{-1}. True north corresponds with the vertical axis, depths are relative to the water surface, and "feathers" are in the direction toward which the current is flowing. Feathers are time-averaged over the preceding half-hour and are plotted at half-hour intervals.

4.2 Statistical comparison

Table 3 contains the results of a quantitative comparison (linear regression) between the currents predicted in the verification simulation and those measured by the current-meter placed in the "Narrows". Table 4 contains similar regression results, but for water temperature. The slopes for water temperature indicate that the model is holding more heat in the upper water column and less below the thermocline than occurred in reality but the relationships are otherwise reasonable. The squared correlation coefficients (r^2) show a poor fit, particularly for the currents, and the regression slopes for currents are inconsistent and indicate very little statistical agreement between the model and measurements.

Therefore, the quantitative comparison indicates that the model is representing the hydrodynamics of the lake poorly at the comparison site in the "Narrows".

Table 3: Quantitative comparison between measured currents (Figure 3) and those simulated in the *verification* simulation (Figure 4). The first 24-hours are omitted from the comparison to avoid cold-start transients. E–W and N–S refer to currents in the east-west and north-south directions respectively. Slope values are the values of the linear regression slopes between measured and modelled currents (e.g., Modelled = slope × Measured + c). r^2 values are the linear regression squared-correlation fits between measured and modelled currents. Highlighted r^2 values are statistically uncorrelated at a 95% significance level.

Depth (m)	E-W slope	E-W r^2	N-S Slope	N-S r^2
2	0.36	0.23	0.17	0.03
4	0.41	0.25	0.01	0
6	0.38	0.25	-0.03	0
8	0.36	0.22	0.11	0.02
10	0.12	0.01	0.73	0.19
12	-0.02	0	0.83	0.18
14	-0.25	0.03	-0.19	0.02
16	-0.15	0.02	-0.4	0.19
18	0.16	0.04	0.28	0.13
20	0.31	0.24	0.51	0.26
22	0.24	0.36	0.28	0.07
24	0.07	0.08	0.2	0.03
26	0.09	0.12	0.18	0.13

Table 4: Quantitative comparison between measured temperatures and those simulated in the *verification* simulation. The first 24-hours are omitted from the comparison to avoid cold-start transients. Slope values are the values of the linear regression slopes between measured and modelled currents (e.g., Modelled = slope × Measured + c). r^2 values are the linear regression r^2 fits between measured and modelled currents.

Measured depth (m)	Modelled depth (m)	Linear fit slope	r^2
0	1.5	1.48	0.73
2.5	4	1.54	0.51
7.5	8	1.25	0.3
10	10	1.21	0.36
12.5	12	0.81	0.25
15	15	0.8	0.22
17.5	18	0.83	0.14
20	20	0.74	0.2
25	25	0.08	0.03

5. Ramifications for diversion wall results

What do the poor verification correlations imply for the 3-dimensional modelling as a whole? In particular, does this place the diversion-wall results in doubt?

Firstly, why is the comparison poor? It is an extremely challenging 3-dimensional modelling task to simulate the dynamics of a plume with changing density as it inserts into a lake system with an oscillating thermocline. As mentioned above, the verification highlights the inability of the model to accurately represent the rapid plunge of the plume that occurs in the natural lake (Vincent et al. 1986). The verification occurred during a period of strong underflow where the hydrodynamics will be strongly influenced by the plunging process. The multiple-horizontally-layered grid scheme in the model is simply not capable of accurately representing the near-vertical plunge of the plume that occurs naturally. Consequentially the plume becomes somewhat more horizontally dispersed and diluted in the model than actually occurs, as it works its way more slowly downward through the model layers. To account for plunging, model formulations may have to be tailored to meet the specific complexity of the task e.g., the near-field turbulent mixing of the momentum-dominated plume (e.g., Spigel et al. 2005), followed by the density-current phase of the underflow (e.g., Dallimore et al. 2004).

Therefore, as configured, the model is not capable of accurately simulating the dynamics of the wider lake, because it is not exactly predicting the plunging plume jet in the near-field. The model is capable of accurately predicting the wider lake dynamics if the plunging plume could better be represented in the model. It possible to do better if the model resolution is improved by decreasing both the grid size and timestep but this would require considerable computer and operator time.

However, the simulations do show qualitative agreement with measurements, indicating that an approximate representation was achieved. It should be remembered that the comparison site was located in the highly dynamic “Narrows” area of the lake, which experiences the largest thermocline oscillations and strongest currents, due to topographic amplification of internal waves.

The modelling showed that the hydrodynamics in the Okere Arm was greatly simplified to that occurring in the “Narrows”, particularly in the presence of a diversion wall that effectively separates the Okere Arm into a separate water body from the main lake. The shallow water in this area means there is little vertical plunging of the plume and the flow dynamics become much more 2-dimensional.

The model was somewhat overly-dispersive in the horizontal direction. In the tracer-simulations used to trace the advection of the plume, this would err on the side of increased mixing and leakage past the diversion wall – therefore the leakage results are conservative.

Thus the poor quantitative comparison obtained for the "Narrows" site does not invalidate the diversion wall results; these still provide valuable guidance for decisions to be made about the placement of a diversion-wall.

6. Additional diversion-wall simulation results

Nine diversion-wall designs were tested in the initial modelling study, with leakage into the main body of Lake Rotoiti ranging between 0 and 32% during underflow-favourable conditions (Stephens 2004, Table 1). Subsequent to completion of the initial modelling report, it was decided that diversion-wall options C and F (Stephens 2004, Figure 23, Table 1) were preferred alignments. It was requested that additional simulations be conducted using variations to these alignments, shown in Figure 5 below. Diversion-wall options C and F have similar lengths and alignments, but vary in distance offshore. The horizontal grid cells were 30 m wide, therefore option C is positioned approximately 120 m offshore, and option F is 60 m offshore. Geotechnical considerations mean that a diversion-wall would probably be positioned 75 m offshore, in between the two wall alignments (Peter Dine, *pers. comms.*).

The diversion-wall variations were simulated for conditions measured between 26 April and 6 May 2004 (i.e., the original calibration period), which included periods of mild underflow-favourable conditions interspersed with a period of overflow-favourable conditions. Further tests were then undertaken using idealised extreme conditions that included strong winds and strongly underflow/overflow-favourable conditions. The idealised underflow/overflow-favourable conditions included inflowing Ohau Channel temperatures set 2.5°C colder/warmer than surface lake water to promote downwelling/overflow, respectively. For both of the idealised underflow and overflow simulations, a wind velocity sequence was used that blew winds along the northeast–southwest axis, alternating between the northeast and southwest directions. The wind speed remained at 0 m s^{-1} for the first 48-hours, then followed a sinusoidal velocity pattern with 48-hour period and speed-amplitude of 7.7 m s^{-1}, beginning blowing from the northeast[1]. The results are shown in Table 5.

Simulations undertaken without a diversion wall showed that only 21–24% percent of the Ohau Channel water exited through the Kaituna River (for the simulated conditions), with the remainder accumulating in the main body of the lake (Table 5 shows tracer in the Western Basin, but much tracer also found its way to the Eastern Basin in the “no wall” simulations). Compared to the simulations without a wall, all the diversion walls substantially reduced leakage to the main body of the lake, and increased the amount of Ohau Channel water exiting through the Kaituna River.

[1] In other words, after an initial 48-hour calm period, the wind blew from the northeast, smoothly increasing in speed from 0 up to 7.7 m s^{-1}, then dropping back to zero, all in 24-hours. In the next 24 hours the pattern was repeated, but with the wind blowing from the southwest. The pattern then continued to repeat, beginning again from the northeast.

The simulations showed that for any given diversion wall, more leakage was experienced during windy periods (wind-driven currents and water-level changes transport plume water through the gap in the wall), and more leakage was experienced during underflow conditions than during overflow (plume water that enters the main lake body during *underflow* conditions will sink and move quickly downward, away from the wall, but during *overflow* conditions it may remain at the water surface near the wall, where it can be re-entrained toward the Kaituna River). The placement of the diversion wall had a bigger influence on leakage than the environmental conditions.

Table 5 shows that the original diversion wall option C was 100% effective at preventing tracer from entering the main body of Lake Rotoiti, during the 8–9 day long simulations. As the length of the wall was progressively shortened, the gap between the wall end and the Te Akau headland widened, and the amount of Ohau Channel water leaking into the Western Basin grew progressively larger.

Wall option F was positioned 60 m off the shoreline for much of its length. The original wall alignment showed substantial leakage (up to 25%), but the extended wall was 100% efficient for the simulated conditions.

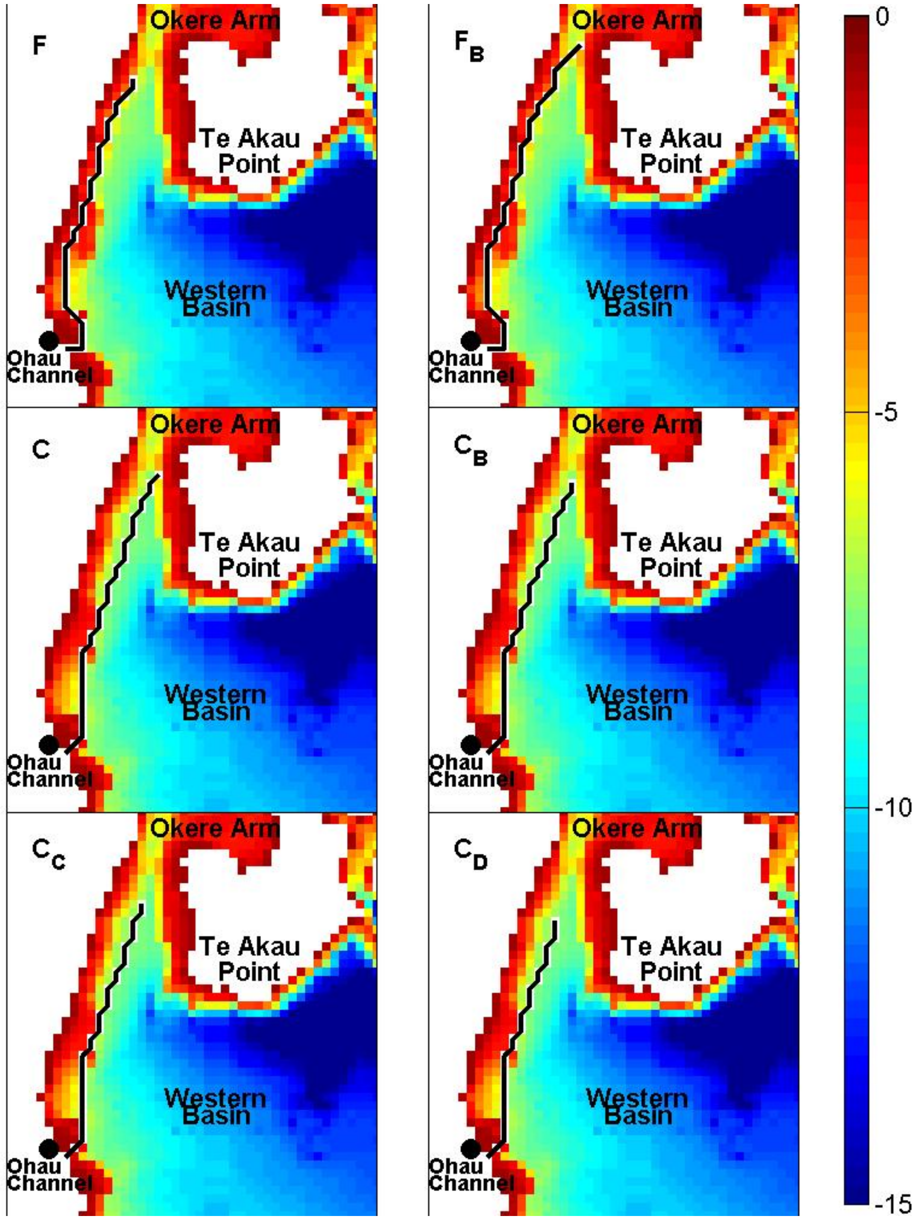

Figure 5: Depth-shaded bathymetry maps showing simulated wall locations; walls are variations on Options C and F (Stephens, 2004, Table 1, Figure 23). Option F_B has been extended from the original, whereas options C_B, C_C and C_D become progressively shorter than the original. Dry areas are shaded white.

Table 5: Percentage of tracer (Ohau Channel plume) entering the main body of Lake Rotoiti, or exiting through the Kaituna River, for simulations with no diversion wall and with variations of Wall Option C and F (Stephens, 2004, Table 1). Wall alignments are shown in Figure 5. For each wall variation, simulations were run using three different “Conditions”. “Measured conditions” use measured wind and plume density timeseries from 26 April to 6 May 2004; “Underflow/Overflow conditions” include inflowing Ohau Channel temperatures set 2.5°C colder/warmer than surface lake water to promote downwelling/overflow. For both the Underflow and Overflow simulations, an idealised wind velocity sequence was used, which remained at 0 m s^{-1} for the first 48-hours, then following a sinusoidal velocity pattern with 24-hour period and amplitude of 7.7 m s^{-1} along the northeast–southwest axis, beginning blowing from the northeast. WB Max (%) = maximum percent leakage to the Western Basin side of the wall at any time during the simulation; WB (%) = accumulated percent leakage into the Western Basin at simulation end; KR (%) = accumulated percent loss down the Kaituna River at simulation end. Percentages are calculated relative to the total tracer mass released into the model domain. WB (%) and KR (%) do not sum to 100% due to residual tracer remaining in the Okere Arm, and that exiting through the “narrows” (entering the Eastern Basin).

Wall	Conditions	Western Basin Maximum (%)	Western Basin (%)	Kaituna River (%)	Run time (days)
No wall	Measured	100	36	24	8.7
No wall	Underflow	100	45	21	7.9
No wall	Overflow	100	54	21	7.6
C	Measured	0	0	86	9.4
C	Underflow	0	0	82	8.1
C	Overflow	0	0	82	8.1
C_B	Measured	5	4	83	9.5
C_B	Underflow	14	9	73	8.0
C_B	Overflow	7	6	77	8.1
C_C	Measured	13	11	73	9.4
C_C	Underflow	25	16	66	8.0
C_C	Overflow	25	17	66	8.1
C_D	Measured	22	18	60	9.4
C_D	Underflow	44	22	55	7.9
C_D	Overflow	30	21	62	8.0
F	Measured	7	7	82	9.5
F	Underflow	19	13	72	8.0
F	Overflow	25	16	70	8.1
F_B	Measured	0	0	89	9.4
F_B	Underflow	0	0	85	8.0
F_B	Overflow	0	0	85	8.0

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