BAY OF PLENTY REGIONAL COUNCIL
TOI MOANA

Ohau Diversion Wall 7-year review - March 2024

Bay of Plenty Regional Council
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1 Introduction

Bay of Plenty Regional Council (BOPRC) hold resource consent RM 10-0527-AP which authorises the occupation and operation of the Ohau Diversion Wall. A review of the performance of the diversion wall is required as Condition 10.1:

> **10 Reporting**
>
> 10.1 The consent holder shall, at seven (7) yearly intervals, prepare, publish and make available to the public, a review of the performance of the structure in improving water quality in Lake Rotoiti including whether the structure is still needed to divert water from Lake Rotorua away from Lake Rotoiti.

The 7-year period ends in March 2024. The condition specifically refers to review of *"…the performance of the structure in improving water quality in Lake Rotoiti…"*. Water quality monitoring is only part of the total environmental monitoring undertaken, as part of the programme to monitor the impact of the wall, and consequently the Technical Group has agreed to bring together a more comprehensive review that provides a review of water quality, comparison with earlier expectations for water quality changes, as well as review wider ecological impacts of the diversion wall. Much of the ecological data is available on the Bay of Plenty Regional Council websites, however, the aim is to bring a summary together in this review report.

As part of the review, the group has consulted with the main groups that are interested in the impact of the diversion wall. This includes Ngāti Pikiao Environmental Society, Tapuika Iwi Authority, Lake Rotoiti Community Association and Lakes Water Quality Society. A Terms of Reference for the review has been developed with our review team - this is attached as Appendix 1. The following people have been co-opted from our Water Quality Technical Advisory Group (TAG) to undertake the necessary review work:

- Andy Bruere, BOPRC Review leader
- Associate Professor Deniz Özkundakci, University of Waikato (UoW)
- Matthew Prentice, University of Waikato
- Ian Kusabs, Ian Kusabs and Associates Ltd
- Matt Osborne, Fish and Game New Zealand
- Soweeta Fort-D'ath, Te Arawa Lakes Trust
- Justine Randall, BOPRC

2 Review scope

The main components for the review are divided into the following sections. A more detailed description of each component is presented in Appendix 1.

(a) **Water quality modelling**

This will be led by Matthew Prentice working for the UoW. The aim is to set up the hydrological, water quality and ecological model to test scenarios of the Ōhau Wall. See ERI Report Number 169 for detailed commentary on the modelling work.

(b) **Water quality review**

Bay of Plenty Regional Council has a water quality monitoring programme that has been monitoring many lake and river locations continuously on a monthly basis since as early as 1990. This monitoring has progressed through the commissioning of the diversion wall in 2008 period. The aim of this work is to review this water quality data and investigate the impact of the wall on water monitoring data. Associate Professor Deniz Özkundakci has led this part of the review.

See ERI Report Number 169 for detailed commentary on the water quality analysis.

(c) **Cyanobacterial analysis**

Cyanobacterial analysis was undertaken for all monitored sites during the Plan Change 10 review, by Dr Susie Wood of Cawthron. This review is available on the BOPRC website and will be summarised by Andy Bruere to present for this project. The summary will include Lake Rotoiti and Kaituna River commentary from the PC 10 report.

See Cawthron Report No. 3803 Rotorua Lakes Cyanobacterial Data Analysis - 2022 for a detailed commentary on the cyanobacteria analysis.

(d) **Fisheries monitoring**

As part of the wall consent, Council monitors a range of fishery parameters. These are reported to the appointed fishery panel at an annual meeting. They provide recommendations on ongoing monitoring and assess the impact of the wall on these parameters.

While the fishery monitoring has been included within this report, it is not strictly required by the Reporting Condition of the consent. Consequently, the reporting is mainly limited to a summary of the work undertaken as part of the consent monitoring and the general findings of the monitoring work on the ecological fishery.

3 Result summaries

(a) **Water quality review and b) Water quality modelling**

The water quality review and water quality modelling are a key part of this report as identified in the resource consent condition. ERI Report Number 169 is summarised into the following Technical Summary: Ōhau Channel Diversion Wall: 7-year review - Water quality review and modelling, by Matthew J. Prentice and Deniz Ozkundakci.

Introduction

Lake Rotoiti is a large-monomictic mesotrophic lake (Trophic Level Index (TLI); 3.8) located in the central North Island of New Zealand. Lake Rotoiti experienced considerable degradation in water quality from the 1960s to the early 2000s, primarily due to nutrient-laden waters flowing from Lake Rotorua via the Ōhau Channel. Consequently, in the mid-2000s an in-lake diversion wall was designed and constructed, with construction completed in mid-2008, to prevent the nutrient-laden Ōhau Channel flow from entering the main basin of the lake and instead short-circuiting the water down the Kaituna River. However, improvements in water quality in Lake Rotorua during this period, attributed to enhanced catchment management practices and alum dosing, raise questions about the continued necessity of the diversion wall for preventing water quality decline in Lake Rotoiti, with respect to both its current TLI of 3.8 and target TLI of 3.5.

This report presents the findings and implications of a comprehensive study commissioned by BOPRC, to evaluate the impact of the Ōhau Channel Diversion Wall on the water quality of Lake Rotoiti, New Zealand. The study, guided by specific research questions outlined in the "Terms of Reference: Ōhau wall: 7-year review", aimed to assess the effectiveness of the wall in improving water quality, its influence on achieving TLI targets, and its impact on the quality of the Kaituna River. Additionally, the study investigated the potential consequences of removing the diversion wall, considering the altered water residence time and its effects on bottom water dissolved oxygen (DO) levels. To address these aims, a multifaceted approach was employed, including: 1) a water quality review, which included a comprehensive analysis of observed data, and 2) water quality modelling, which included the configuration and calibration of a 3-D model for pointed scenario testing. In addition, an assessment of the holes in the diversion wall was also carried out to understand the amount of water leaking through the wall into Lake Rotoiti, and the potential implications for water quality.

Methods

To address the above research questions, the study consisted of three main components: 1) water quality data analysis, 2) lake system modelling, and 3) assessment of holes in the diversion wall.

1 This study utilised a combination of statistical and analytical techniques to investigate the impact of the Ōhau Channel Diversion Wall on water quality in Lake Rotoiti. Descriptive statistics and graphical aids were employed to explore long-term changes in water quality parameters, including trends and patterns. Correlation analysis was conducted to examine the relationship between Lake Rotorua and Lake Rotoiti, as well as between Lake Rotoiti and the Kaituna River, using Pearson correlation coefficients and least square linear regression. This analysis aimed to identify any changes in the association between the water quality of these systems, before and after the diversion construction of the diversion wall. Intervention analysis using generalised least squares regression models was used to detect changes in water quality variables, including Total Nitrogen (TN), Total Phosphorus (TP), chlorophyll a, and Secchi depth. The models incorporated terms for time, intervention, and post-intervention time, enabling the detection of both immediate (step changes) and gradual (change in trend direction and slope) changes in water quality.

2 Lake system modelling was carried out using the Aquatic Ecosystem Model (AEM3D), a 3-D hydrodynamic–ecological model, which allowed the temporal and spatial behaviour of Lake Rotoiti to be well captured. The model was configured to run at a 100-m^2 horizontal grid and uniform 1-m vertical layer, on a 2-min timestep, in trade-off between model resolution and runtime. The hydrodynamic-ecological model was configured to include two phytoplankton groups, cyanobacteria (summer-adapted; buoyant) and diatoms (and other; winter-adapted; non-buoyant). Hydrodynamic model simulations were applied to investigate changes in the accumulation, retention, and behaviour of Ōhau Channel inflow-derived water within the lake and the removal of the existing water in the lake, with and without the wall in place. Correspondingly, two scenarios were tested, including: 1) wall-out, 2) and wall-in. Hydrodynamic-ecological model simulations were applied to investigate changes in TLI with and without the wall in place, and without the wall in place under three Ōhau Channel inflow water quality regimes. Correspondingly, four scenarios were tested, including: 1) wall-in (with Ōhau Channel water quality parameters as measured), 2) wall-out (with Ōhau Channel water quality parameters as measured); 3) wall-out, with Ōhau Channel water quality measures scaled to a maximum TLI of 4.2 (equivalent to a 15.5% reduction in nitrogen, phosphorus, and chlorophyll a); and 4) wall-out, with Ōhau Channel water quality measures scaled to a maximum TLI of 3.8 (equivalent to a 39.0% reduction in nitrogen, phosphorus, and

chlorophyll a). As simulations are initialised with measured data, wall-out scenarios for the hydrodynamic-ecological model (which was initialised in 2014; seven-eight years post-wall construction) represent the removal of the Ōhau Channel Diversion Wall. Hydrodynamic simulations were run across 19 limnological years from 1 July 2003 through 30 June 2022, whereas coupled-hydrodynamic-ecological simulations were run across eight limnological years from 1 October 2014 through 30 June 2022.

3 Assessment of wall holes involved data analysis and hydrodynamic model scenario testing to evaluate their impact on Lake Rotoiti. To facilitate a quantitative estimation of the water flow through the holes in the diversion wall, BOPRC commissioned Greenfield Diving Services & Maintenance Engineering to assess the condition of the wall, which included measuring the size of the holes, using a 100 × 100 mm square welded wire mesh. Thirty-two holes were assessed, yielding a total measured hole area of 1.13 m² and an average hole size of 0.035 m². Flow velocity measurements were taken at 100 m intervals along the wall in February 2024. The distance-weighted average velocity was 0.156 m s-1, with a maximum velocity of 0.456 m s-1, and a minimum velocity of -0.074 m s-1. Notably, measurements from 900 m downstream from the Ōhau Channel delta onwards were all negative, indicating water flowing from Lake Rotoiti into the Ōhau Channel through the holes. The total number of holes was estimated to calculate the volume of water flowing through the holes, which was compared to the average discharge in the Ōhau Channel during February 2024. Hydrodynamic modelling was based on the same calibrated and configured hydrodynamic model, used to quantify changes in hydrodynamics with and without the wall, except for the addition of a single 1 × 100 m hole (the finest scale hole possible within our model grid). To account for the simplified representation of the holes, six different configurations of the single 1 × 100 m hole were simulated to provide a range of potential values, which included holes at 300 m-400 m, 600 m-700 m, and 1,000-1,100 m along the wall, at 1 m and 2 m below the surface. To investigate whether and to what extent a 1 × 100-m hole affects the rate of accumulation, rate of retention, and wall efficiency, the six scenarios with a 100 m hole, and the regular wall-in and wall-out scenarios were run for one limnological year from July 2003 through June 2004.

Findings

The data analysis of existing water quality data for Lake Rotoiti, employing a three-step approach (in increasing levels of complexity and inference), revealed nuanced insights into the impacts of the Ōhau Channel Diversion Wall. While descriptive statistics (i.e., approach 1) indicated an overall improvement in water quality post-wall construction in Lake Rotoiti, correlation analysis (i.e., approach 2) between water quality in Lake Rotorua and Rotoiti suggested limited statistical significance in observed differences, except for Secchi depth, indicating altered connectivity between Lake Rotorua and Rotoiti. An intervention analysis (i.e., approach 3), employing interrupted time series analysis, detected significant step changes in TN, Secchi depth, and TLI post-wall construction, suggesting immediate positive effects on lake water quality persisting throughout the study period. The estimated improvements due to the diversion wall were a decrease in TN by 203 mg m-3, an increase in Secchi depth by 2.5 m, and a decrease in TLI by 0.59 units. The data analysis supports the long-held observations of the Lake Rotoiti community, who have noticed a visible improvement in water quality immediately following the construction of the diversion wall. The data analysis revealed that the diversion wall has had no significant impact on bottom water DO demand in Lake Rotoiti, as measured by volumetric hypolimnetic oxygen demand, which remained largely unchanged. Any year-to-year variations are likely attributed to changes in prevailing in-lake and meteorological conditions.

Table 1: Summary of findings for the water quality data analysis

Approach	Outcome					
	TLI	**TN**	**TP**	**Chlorophyll *a***	**Secchi depth (SD)**	**Overall impact in Rotoiti WQ**
Descriptive statistics	N/A	Improvement	Improvement	Improvement	Improvement	Improvement in all variables post-wall.
Correlation analysis	N/A	No improvement	No improvement	No improvement	Significant improvement	Significant change post-wall in SD only.
Intervention analysis	Significant improvement (down 0.59 units)	Significant improvement (down 203 ppb)	No improvement	No improvement	Significant improvement (up 2.5 m)	Significant step change post-wall in TLI, TN, & SD.

Note: Green font = improving water quality, orange font = indeterminate.

Hydrodynamic model simulations illustrated that the wall was effective in reducing the accumulation of Ōhau Channel inflow in the system, increasing the fraction of Ōhau Channel inflow short-circuited down the Kaituna River, and consequently, increasing the residence time of Lake Rotoiti. In terms of accumulation of Ōhau Channel-derived water in Lake Rotoiti, the wall resulted in a substantial reduction as evidenced by an annual cumulative contribution of Ōhau Channel water to Lake Rotoiti of 22.0% without a wall in place, but 0.3% with a wall in place. Concerning the fraction of Ōhau Channel-derived water short-circuited down the Kaituna River, the wall resulted in a substantial increase, as evidenced by the proportion of Ōhau Channel water being diverted down the Kaituna River being 55.2% without a wall in place, but 99.3% with a wall in place. Regarding the residence time in Lake Rotoiti, the wall resulted in a substantial increase, i.e., a factor of 3.3, as evidenced by a residence time of 8.2 years without a wall in place, but 26.9 years with a wall place.

Table 2: Summary of findings for the hydrodynamics lake system modelling

Scenario	Outcome		
	Fraction of Lake Rotoiti water derived from Ohau Channel in an average year	**Fraction of Ohau Channel water diverted down the Kaituna River**	**Residence time in Lake Rotoiti**
Wall-in	0.3%	99.3%	26.9 years
Wall-out	22.0%	55.2%	8.2 years

Coupled hydrodynamic-ecological model simulations revealed the removal of the wall (c.f., wall-in, base scenario) would lead to a small deterioration of water quality in Lake Rotoiti. However, this deterioration could be mitigated with improvements in water quality in the Ōhau Channel inflow. Specifically, removal of the wall with Ōhau Channel water quality parameters as measured, i.e., maximum TLI of 4.41, resulted in a small deterioration to water quality (i.e. increase in TLI of 0.02 units) in Lake Rotoiti due to small increases to Trophic Level nitrogen (TLn; 0.08), Trophic Level chlorophyll a (TLc; 0.07), but a slight decrease in Trophic Level phosphorus (TLp; 0.09). Removal of the wall with

Ōhau Channel water quality measures scaled to a maximum TLI of 4.2 (equivalent to a 15.5% reduction in nitrogen, phosphorus, and chlorophyll a), resulted in an improvement to water quality (i.e. decrease in TLI of 0.02 units) in Lake Rotoiti, due to slight increases to TLn (0.02), TLc (0.04), but a decrease in TLp (0.12). Removal of the wall with Ōhau Channel water quality measures scaled to a maximum TLI of 3.8 (equivalent to a 39.0% reduction in nitrogen, phosphorus, and chlorophyll a), resulted in an improvement to water quality (i.e., decrease in TLI of 0.08 units) in Lake Rotoiti, due to decreases to TLn (0.07), TLp (0.16), TLc (0.02). Consequently, removing the wall alongside maintaining a maximum TLI in Lake Rotorua of ~4.3 would likely be required to maintain the current TLI in Lake Rotoiti. However, removing the wall alongside maintaining a maximum TLI in Lake Rotorua of ~4.0 would likely be required to maintain the current TLI as well as TLn, TLp, and TLc in Lake Rotoiti. Furthermore, even with the most ambitious reduction in maximum TLI in Lake Rotorua (i.e., 3.8), additional water quality management in Lake Rotoiti would be required to achieve the target TLI of 3.5.

Based on the hydrodynamic-ecological model scenario testing, water quality improvements in Lake Rotoiti expected from improved the Ōhau Channel inflow water quality appear to be buffered against by internal processes (e.g., internal loading of N and P). This was demonstrated by a reduction to TLn, TLp, and TLc, as well as TN, TP, and chlorophyll a concentrations in the Ōhau Channel inflow, not directly correlating with changes in Lake Rotoiti. Moreover, even accounting for the Ōhau-derived contribution of water in the lake, realised improvements in water quality were less than what would be expected based on concentration of the Ōhau Channel inflow and dilution, and dispersion of the Ōhau Channel inflow within Lake Rotoiti. It is likely that this buffering is attributed to nitrogen (N) and phosphorus (P) legacies in the system released from the sediments during anoxia, and/or N and P derived from a substantive unquantified groundwater-based geothermal flux. Consequently, future improvement to the water quality in Lake Rotoiti may require additional water quality management measures in Lake Rotorua, and within Lake Rotoiti itself.

Table 3: Summary of findings for the water quality lake system modelling wall-out scenarios

Wall-out scenario (c.f. wall-in scenario), as Ōhau Channel inflow water quality	Outcome (8-years post wall removal)					
	TLI	TLn	TLp	TLc	Overall impact in Rotoiti WQ*	Does Rotoiti meet TLI target of 3.5
Simulated scenario						
Wall-out with max TLI of 4.41 (i.e., as measured)	Increase of 0.02	Increase of 0.08	Decrease of 0.09	Increase of 0.07	Small decline (TLI = 3.96)	No
Wall-out with max TLI of 4.2 (i.e., as a 15.5% reduction in WQ parameters)	Decrease of 0.02	Increase of 0.02	Decrease of 0.12	Increase of 0.04	Small improvement (TLI = 3.92)	No
Wall-out with max TLI of 3.8 (i.e., as a 39% reduction in WQ parameters)	Decrease of 0.08	Decrease of 0.07	Decrease of 0.16	Decrease of 0.02	Improvement (TLI = 3.86)	No

Table 3 cont

Wall-out scenario (c.f. wall-in scenario), as Ōhau Channel inflow water quality	Outcome (8-years post wall removal)					
	TLI	TLn	TLp	TLc	Overall impact in Rotoiti WQ*	Does Rotoiti meet TLI target of 3.5
Inferred scenario						
Wall-out with max TLI of 4.3	Expected hold	Expected hold	Expected decrease	Expected increase	Expected hold in TLI, but not all of TLn, TLp, & TLc	No
Wall-out with max TLI of 4.0	Expected decrease	Expected decrease	Expected decrease	Expected hold	Expected hold in TLI, & each of TLn, TLp, & TLc	No

* Modelled TLI, thus to be interpreted relative to equivalent modelled 'wall-in' scenario TLI of 3.94.

Note 1: Key conclusion: To meet Rotoiti TLI target 3.5 without the wall, more interventions are required in Rotorua and Rotoiti. Rotorua may need to reach a TLI of 3.8, quite a substantial improvement on current water quality and target.

Note 2: Green font = positive impact while red font = negative impact on water quality WRT target TLI.

The analysis of available data of the holes in the diversion wall indicated that despite a relatively small number of estimated holes in the wall, the leakage of Ōhau Channel water into Lake Rotoiti is appreciable, i.e., assuming a total of 100 holes along the length of the diversion wall, approximately 3.3% of the Ōhau Channel water was estimated to leak through the holes into Lake Rotoiti. This percentage increased to 9.8% of the Ōhau Channel water when the total number of holes was assumed to be 300. These discharge rates compare well with the hydrodynamic modelled output, where a single 1 × 100 m hole (the finest scale hole possible within our model grid) in the Ōhau Channel Diversion Wall was shown to reduce the effectiveness of the wall, in preventing the accumulation of Ōhau-derived water within the lake by 29.3-55.0%. Although the study's estimates are conservative and limited by the model resolution, the corroboration of the measured and modelled data provides sufficient evidence that all holes in the wall collectively, although small individually, can result in a substantial flux of Ōhau Channel-derived water and ultimately accumulation within the lake. Given uncertainties in the number of holes, the focus was on estimating water discharge rather than assessing nutrient load or water quality impacts.

This research, as with Priscu et al. (1986) and Hamilton et al. (2005), demonstrated nutrient dynamics in Lake Rotoiti are complex and not well understood. Nutrient-related dynamics in Lake Rotoiti that would benefit from a further understanding are primarily related to: 1) processes driving the NH4-NO3-NH4 succession in the hypolimnion of Lake Rotoiti; 2) geothermal fluxes relating to temperature, pH, and most notably P and N, and their constituents; and 3) atmospheric deposition of P and N, and their constituents. This research, although ambitious, was limited by the current state of computing, modelling capabilities, and understanding of certain scientific processes (e.g., the unique N succession in the hypolimnion of Lake Rotoiti). Despite this, continued advancement in computational power and lake model capabilities, and breakthrough and advancement of critical scientific processes will enable more ambitious scenario testing and more advanced simulations in the coming years. Finally, this research also highlights that future

work might endeavour to explore the impact of a greater variety of Ōhau Channel inflow scenarios, the impact of future climate scenarios, and the interplay of these two factors.

4 Conclusions

A comprehensive evaluation of water quality in Lake Rotoiti involved a systematic analysis of long-term datasets and detailed 3-D hydrodynamic-ecological modelling, to better understand the impacts of the Ōhau Channel Diversion Wall and the potential effects of its removal on the lake. Data analysis revealed clear improvements in water quality in Lake Rotoiti, with TN, Secchi depth, and the TLI exhibiting a significant change following the wall's construction. This underscores the critical role of the Ōhau Channel Diversion Wall in preventing degradation in Lake Rotoiti. Hydrodynamic modelling illustrated that the wall was effective in reducing accumulation of Ōhau Channel inflow in the system, increasing the fraction of Ōhau Channel inflow short-circuited down the Kaituna River, and consequently, increasing the residence time of Lake Rotoiti. Hydrodynamic-ecological simulations illustrated that removal of the wall (c.f., wall-in, base scenario) would lead to a small deterioration of water quality in Lake Rotoiti, which could be mitigated with improved water quality in the Ōhau Channel inflow. An assessment of the effects of holes in the diversion wall using the best available data and hydrodynamic modelling, suggested that a significant amount of Ōhau Channel water is leaking into Lake Rotoiti. However, considerable uncertainty remains in this assessment as the total number of holes remains unknown.

Answers to research questions outlined in the “Terms of Reference: Ōhau wall: 7-year review”

Water quality review

Has the wall achieved its objective of improving water quality?

Evidence suggests that the diversion wall has led to enhanced water quality in Lake Rotoiti independent of water quality improvement in Lake Rotorua. Total Nitrogen, Secchi depth, and TLI showed a step change after the wall's construction, although there were no shifts in long-term trend slopes.

Has the wall resulted in the lake reaching its TLI target in advance of improvements to Lake Rotorua water quality impacting Lake Rotoiti?

There is some evidence suggesting that water quality in Lake Rotoiti improved before the construction of the wall. Total Nitrogen and chlorophyll *a* concentrations, as well as Secchi depth, showed improvement prior to the wall's construction. However, drawing strong conclusions from the data is challenging, as the observed patterns in the long-term dataset may or may not be fluctuating cyclically.

Does current monitoring support the continued placement of the wall, diverting Ōhau Channel water?

The TLI in Lake Rotoiti is still above its target. There is also no clear evidence that water quality in the lake is still improving. However, there is some evidence that the TN and TP concentrations are going through a period of increase. This suggests that (together with conclusions drawn from this study’s water quality modelling work; see below), the continued placement of the wall is still warranted.

What impact has the diversion wall had on the quality of the Kaituna River?

There is no evidence to suggest that the diversion wall has had an impact on the water quality dynamics in the Kaituna River.

Water quality modelling

What is the modelled impact of the diversion wall on water quality and ecology?

Modelling showed that the implementation of the diversion wall has resulted in small reductions to TN and chlorophyll a, but increases in TP. Taken together, the wall has resulted in a reduction in TLI in Lake Rotoiti.

Does this align with the water quality and ecological monitoring of Lake Rotoiti?

Simulated TLI and its constituents over longer-term periods (i.e. eight years) agree well with the data analysis of even longer-term data sets carried out in this study's water quality review work (see above). Further, the effects of the observed reduction in TLp in Lake Rotorua (because of catchment management practices and alum dosing in Lake Rotorua), and thus the Ōhau Channel inflow entering Lake Rotoiti, were well captured by model simulations through simulating a decrease in TLp in Lake Rotoiti as the Lake Rotorua-derived water accumulated within the lake.

The diversion wall is expected to be in place for 50-100 years. Once it has been removed, what is the likely water quality expectation for Lake Rotoiti if Lake Rotorua meets the TLI of 4.2 +, when Lake Rotoiti is expected to meet a TLI of 3.5?

Simulations run from 2014-2022 in which the Ōhau Diversion Wall was removed in conjunction with water quality in Lake Rotorua, equivalent to a maximum annual TLI of 4.2, resulted in a TLI in Lake Rotoiti after eight years of 4.2. Although eight years is ample time for the lake to reach a new equilibrium, this assumes all other inputs are at baseline, and thus no concomitant in-lake or catchment management practices implemented in Lake Rotoiti. Therefore, removal of the wall alongside a maximum annual TLI in Lake Rotorua of 4.2, without additional measures, will be insufficient to have Lake Rotoiti meet its TLI target of 3.5.

The diversion wall has effectively changed the water residence time in Lake Rotoiti from about 1.5 years to 5+ years. How does this impact Lake Rotoiti water quality, potentially having an impact on bottom water dissolved oxygen levels and especially the western arm of the lake?

Simulations suggest residence times (determined as the time to clear 95% of existing water) are substantially longer than 1.5 and 5+ years for wall-out and wall-in scenarios, respectively. Simulations instead indicated residence times of 8.2 and 26.9 years for wall-out and wall-in scenarios. Nevertheless, model simulations in the eastern (i.e. Narrows) and western (i.e. Crater) basins demonstrated the wall-in scenario, compared to the wall-out scenario, maintains a small increase of <0.1-0.2 mg DO L^{-1} in the bottom waters during the stratified period, which is well within the range of uncertainty of the model simulations. There was no clear evidence of any changes in bottom water DO levels in the monitoring data in Lake Rotoiti at sites 3 and 4.

(b) **Cyanobacterial analysis**

A comprehensive report was undertaken by Dr Suzie Woods of the Cawthron Institute for BOPRC on Rotorua Lakes Cyanobacterial Data Analysis – 2022. The report covered all cyanobacterial data for a number of lakes and the Kaituna River. Not all lakes are regularly monitored for cyanobacteria, with the focus of monitoring on lakes known to have regular seasonal algal blooms. Lake Rotoiti and the Kaituna River are monitored for cyanobacteria. Their results are included in the report located here: https://www.rotorualakes.co.nz/vdb/document/1906.

The summary for this report has been taken directly from Wood 2022 and is focussed specifically on results for Lake Rotoiti and the Kaituna River only, with some results for Lake Rotorua included as it impacts the Kaituna River water quality. All of the statements below are directly quoted and only reference where there is an impact on cyanobacterial results.

Report Summary

Statistical results indicated that cyanobacterial biovolumes had very likely decreased over the last approximately 20 years (data from March 1997 to April 2022, but the timeframes vary among lakes) for Lakes Rotoiti and Rotorua and the Kaituna River site.

We also analysed trends in the data before and after two interventions aimed at improving water quality: alum dosing in Lake Rotorua and the construction of the Ōhau Channel Diversion Wall. The before and after analysis of the application of alum indicates that this may have had a positive impact on Lake Rotorua and the Kaituna River site. However, it is less clear whether the building of the diversion wall has had a positive impact on cyanobacterial abundance in Lake Rotoiti with biovolumes increasing post installation at all sites except Okere Arm.

The long-term trends need to be interpreted with some caution as analysis of the data with generalised additive models highlights variability, with significant periods of increasing and decreasing cyanobacterial biovolume identified. Without corresponding physicochemical data, it is difficult to explore the drivers of these shifts. However, the sinusoidal and almost synchronous fluctuation in total cyanobacterial biovolume prompted us to undertake a very preliminary investigation into whether global climate patterns may explain some of the observed shifts. Alignment of the cyanobacterial biovolume data with the Southern Oscillation Index indicates that climate patterns could be involved, but further investigation is recommended.

Note: references to tables and figures have been left in the text, to see these refer to the original report referenced.

5 Results

5.1 Assessment of long-term trends in total cyanobacterial biovolume

Kendall's Tau Test

When data across all sites were combined, the Kendall's Tau results indicated that it was highly likely that cyanobacterial biovolume is decreasing in Lake Rotoiti, although this pattern is not clear when the data are analysed pre- and post-July 2008 (installation of the diversion wall). Pre-2008, the combined data analysis suggests there was little change in cyanobacterial biovolume over the study period. Post-2008, the analysis of the combined data indicated that total cyanobacterial biovolume was increasing, with an increasing trend also observed at three of the five sites (Table 5).

Generalised additive models

The GAMs analysis shows periods of significant increasing and decreasing biovolumes in all lakes and at the Kaituna River site over the study period (Figure 1). In general, the oscillations in cyanobacterial biovolume in Lakes Rotoiti, Rotorua, Rotoehu and the Kaituna River follow the same timing.

5.2 Assessment of long-term trends – relative abundance of potential toxin producers versus non-producers

Kendall's Tau Test

The results of the Kendall's Tau Test indicate that the portion of the cyanobacteria community that are potentially toxin producers, was likely or highly likely increasing in lakes… Rotoiti and Rotorua and highly likely decreasing in … the Kaituna River (Table 6).

Generalised additive models

Of note was the decrease in the five and one-year trends in lakes Rotoiti and Rotorua and the Kaituna River site (Figure 2).

5.3 Assessment of long-term trends - relative abundance of taxa capable of nitrogen fixing, versus those with no nitrogen fixing capacity

Kendall's Tau Test

Analysis using the Kendall's Tau Test of the long-term trend in the proportion of the cyanobacterial community, that was comprised of species capable of nitrogen fixation, demonstrated that there has highly likely been a decrease in their relative abundance in lakes Ōkaro, Rotoiti and Rotorua and no change in either Lake Rotoehu or the Kaituna River site (Table 7).

Generalised additive models

All the study lakes and the Kaituna River site have at times, had a high proportion of their cyanobacterial community having the ability to fix atmospheric nitrogen (Figure 3). Although there were significant periods of increasing and decreasing trends, there were no consistent patterns across lakes or the Kaituna River site (Figure 3). A general pattern of decreases in cyanobacteria with the ability to fix atmospheric nitrogen between the start of monitoring and c. 2012 was apparent in lakes … Rotoiti and Rotorua, although this has been more variable over the last ten years. The one and five-year trends in … and Rotoiti suggest the proportion of cyanobacterial taxa with the ability to fix nitrogen is declining, whereas the five-year trend is increasing in … the Kaituna River site (Figure 3).

6 Discussion

A positive outcome of the long-term trend analysis was, that for lakes Rotoiti and Rotorua and the Kaituna River, the analysis indicates that cyanobacterial biovolumes are highly likely decreasing over the c. 20-year period (although see below regarding Lake Rotoiti).

The before and after analysis of the application of alum to the inflows of Lake Rotorua indicate that this may have had a positive impact on this lake and the Kaituna River site, with the trend switching in Lake Rotorua from one of increasing total cyanobacterial biovolume prior to dosing, followed by a decreasing trend post dosing. However, it is less clear whether the building of the Ōhau Channel Diversion Wall has had a positive impact

on total cyanobacterial biovolumes in Lake Rotoiti, with biovolumes increasing post installation at all sites except for the Okere Arm site.

The long-term trend analysis needs to be interpreted with some caution as the GAMs analysis highlights variability in the data, with significant periods of increasing and decreasing biovolume in all lakes and the Kaituna River site. These changes do not necessarily align with interventions: for example, immediately following the initiation of alum dosing, there is an increase in total cyanobacterial biovolume in Lake Rotorua and the Kaituna River site. In contrast, following the construction of the diversion wall there is a decrease in cyanobacterial biovolume as might be expected but this is then followed by an increase about five years later. We acknowledge that the effects of mitigation actions are likely to have an impact over multiple years and we wouldn't necessarily expect to see immediate impacts, but the natural cyclic variation in the cyanobacterial data demonstrates why long-term data are required to understand the impacts of mitigation actions. Without corresponding physicochemical data and a carefully planned sampling strategy (e.g., not biased by seasonality and shoreline sampling) we do not believe it is appropriate to draw any further conclusions of the impact of these interventions of cyanobacterial biovolumes.

The analysis of the potential toxin producers in the Rotorua lakes showed no obvious patterns.

Similarly, the change in cyanobacterial taxa with the ability to fix atmospheric nitrogen was somewhat inconclusive.

(c) Fisheries monitoring

(i) Koura and Kakahi

A key concern to iwi prior to the installation of the Ohau Wall, was the potential effect on native freshwater species koura and kakahi. A monitoring programme has been in place since 2005, pre-wall to determine any negative impacts on these species. Annual reports on this monitoring have been prepared for BOPRC by Dr Ian Kusabs. One of the significant challenges with long term monitoring of this nature, is that there are often multiple stressors that complicate understanding of the causes of changes in koura and kakahi populations. The summary presented below is taken from Ohau Diversion Wall, Lake Rotoiti-Koura and Kakahi Monitoring Programme, Report Number 16, 2022.

Executive Summary

In July 2008, a wall (the Ohau River Diversion Wall) was installed in Lake Rotoiti to divert nutrient-rich water from Lake Rotorua down the Kaituna River, preventing it from entering Lake Rotoiti. Two major concerns to iwi were the potential impacts of the wall on koura (freshwater crayfish) and kākahi (freshwater mussels). Initially, the aim of this study was to monitor long term trends in the kōura and kākahi populations, in order to determine the effects of the diversion wall. However, since 2005, the kōura and kākahi populations in Lake Rotoiti have been subjected to multiple stressors including, increased predation of kōura by invasive brown bullhead catfish, reduced lake productivity, and increased aquatic macrophyte growth. These stressors make it impossible to distinguish the impact of the diversion wall on kōura and, to a lesser extent, kākahi populations in the Ōkere Arm. The principal aim of this study now is to monitor long term trends in the kōura and kākahi populations in Lake Rotoiti.

Seasonal monitoring surveys of kākahi commenced in 2005, while seasonal kōura monitoring surveys began at Ōkere in 2005, Te Ākau in 2007 and Manupirua in 2009. This report provides an in-depth analysis of Lake Rotoiti kōura and kākahi monitoring data for 2021/2022 and a comparison with previous surveys carried out since 2005.

The Lake Rotoiti kōura population was sampled using the Tau kōura a traditional Māori method of harvesting kōura in the Rotorua Te Arawa lakes. Tau kōura were located at Ōkere, Te Ākau and Manupirua in Lake Rotoiti with each Tau kōura composed of approximately ten whakaweku (bracken fern bundles). The kākahi monitoring methodology developed by National Institute of Water and Atmospheric Research (NIWA) specifically for community and iwi groups (Nuri et al. 2020) was used to determine kākahi densities at five sites (40 m x 0.5 m transects) around Lake Rotoiti.

The 2021/22 kōura monitoring surveys were similar to previous years which show a drastic reduction in kōura abundance and biomass in Lake Rotoiti and the Ōkere Arm. In 2021/22, a total of 256 kōura were collected, a decrease of -65.3%% compared to the previous year (2020/21). Kōura are far less abundant in Lake Rotoiti now than they were when surveys commenced in 2005. Mean CPUE has declined significantly at all three sites with a decrease of -99% at Te Ākau, -98% at Ōkere and -85% at Manupirua. There has also been a correspondingly decline in mean BPUE, at Te Ākau (-95%), Ōkere (- 95%), and Manupirua (-87%).

The decline in kōura abundance and biomass has coincided with the widespread establishment of brown bullhead catfish (Ameiurus nebulosus) and an improvement in water quality. In addition, prolonged periods of deoxygenation in the summer and early autumn at Te Ākau and Manupirua, Ōhau River Diversion Wall Report Number 16, 2021 -2022 have also reduced available kōura habitat and increased the vulnerability of kōura to catfish predation. Reduced productivity and aquatic weed proliferation are additional stressors on the kōura population.

In contrast, kākahi remain abundant in the Ōkere Arm and Lake Rotoiti with high densities recorded in and outside of the wall. Kākahi abundance has remained relatively stable at most monitoring sites except at the Ditch (treatment), where there has been a five-fold increase in silt and at the Ōkawa Bay site where counts are sometimes affected by heavy growths of turf species and filamentous algae.

It is recommended that the existing kōura monitoring programme be reviewed due to the low numbers of kōura being captured in Lake Rotoiti. Subsequently, a decision was made at the Ōhau Diversion Wall Fisheries Panel Meeting held on 15 March 2023 to reduce the frequency of kōura monitoring to spring sampling only.

Ongoing monitoring for the 2022/23 season was reported in Ohau River Diversion Wall Report Number 17 (2022/2023). This monitoring showed a continued trend of declining koura numbers. This declining trend has coincided with the widespread establishment of brown bullhead catfish. In contrast, kākahi remain abundant in the Okere Arm and Lake Rotoiti with high densities recorded in and outside the wall.

(ii) **Trout fishery**

The Ohau Channel trout fishery was surveyed by Eastern Region Fish & Game during the 2005-2006 season. Monitoring was not undertaken during the 2006-2007 season, prior to a standardised creel survey being implemented under the Water Quality Diversion Wall Consent from 1 October of the 2007-2008 angling season. The diversion wall was completed in June 2008, resulting in two creel surveys being carried out pre-wall and 15 creel surveys post wall.

Prior to the diversion wall being constructed, anglers could choose from two key publicly accessible areas of the channel with a high probability of success. The first area at the head of the channel by the Lake Rotorua Outlet Weir from Ramada Resort. The second area where the channel entered Lake Rotoiti known as the Ohau Channel Delta. Both areas provided deep water drop-offs where trout would congregate and hold. The remainder of the channel flows through private riparian property where general public are not guaranteed access. Since the diversion wall was constructed, the area known previously as the 'Delta' has shallowed, due to silt deposition and become a poor angling area. The wall has effectively blocked shore-based anglers from accessing the deep water below the Ohau Delta into Lake Rotoiti. This has exacerbated angling pressure on the Lake Rotorua end of the channel.

The trout creel survey is constructed to measure and compare between surveys three main facets of angling metrics. These are angler catch rate (legal sized fish caught per hour), fish size and condition (exhibiting changes in growing conditions/habitat) along with how anglers perceive their satisfaction.

Has catch rate altered over the course of surveys?

The average individual catch rates recorded between seasons have fluctuated highly over the course of the 17 completed surveys. Angler experience may account for differences seen in catch rates. as inexperienced anglers generally have lower catch rates. Angler visitation frequency has changed over recent years with higher numbers of 'one time' visitors, and few, if any, anglers recorded as fishing on greater than 20 occasions per season.

Has surveyed fish size altered over surveys?

The condition factor of trout caught within the Ohau Channel has declined compared with pre-wall measurements following the wall being built. Unfortunately, just two surveys were conducted prior to the Ohau Wall's construction. Pre-wall brown trout averaged 53.30cf points compared to 45.93cf post-wall. Rainbow's pre-wall averaged 50.54cf compared to 43.44cf post-wall. The summer creel undertaken annually on Lake Rotorua also recorded a decline in fish condition around and following 2007-08 when the wall was constructed. This may be a consequence of elevated summer lake temperatures, lack of smelt in Lake Rotorua and/or algal blooms affecting lake productivity from this period. Lake Rotorua is a shallow polymictic environment. When hot summers occur with little wind to mix the waters, lake temperatures become too warm for trout (25°C at surface) that are forced into cool water refuge at the tributary inflows. Trout drop condition through this period as they are focussed on survival rather than actively feeding. When these warm-water, still conditions prevail over long periods of the summer, deoxygenation and nutrient release occurs in the bottom waters below the thermocline and when the lake flips - which can occur a number of times in a

polymictic lake, nutrient is released and becomes available for autumnal algal growth. Trout being largely sight feeders may struggle to locate numerous prey when turbid conditions exist, such as in heavy bloom areas.

Trout monitoring in Lake Rotorua indicated an improvement in rainbow trout size and condition during the 2012-13 and 2013-14 seasons, along with anecdotal reports of smelt appearing in high numbers. A subsequent decline in condition was then noted in Rotorua catch from the 2014-15 season, with very warm summer water temperatures. This indicates a high likelihood that Lake Rotorua fish condition is a key driver of what is occurring within the Ohau Channel catch and therefore angler perceptions of fish quality.

How have anglers perceived the fishery since the wall has been in place?

In the two seasons surveyed prior to the wall being in place, angler perceptions of catch rate, fish size and satisfaction were rated acceptable to good/satisfied.

Since the diversion wall was constructed, eight of the fifteen angling seasons surveyed have resulted in anglers rating their catch rate as being below average. Four seasons out of the fifteen surveyed, post-wall were rated as poor to terrible in terms of catch rate. These seasons were 2008-2009 and 2010-2011 to 2012-2013.

For fish size, six of the fifteen seasons post-wall were considered below average by anglers, with five of them being rated as poor to terrible. These were (as for catch rate) 2008-2009, 2010-2011 to 2012-2013 along with the 2014-2015 season.

Anglers have rated their level of satisfaction in fishing the Ohau Channel as being ‘Dissatisfied’ to ‘Strongly dissatisfied’ for these same five seasons (2008-2009, 2010-2011 to 2012-2013 and 2014-2015). However, the past eight seasons 2015-2016 to 2022-2023 have consistently produced better than average satisfaction ratings. These are similar to the ratings of angler satisfaction from the 2007-2008 season, immediately prior to the wall’s construction.

In response to what detracts from their angling experience, fishers over the course of the surveys have identified three main sources of detractions. The quality of the water (which also encompasses the water level), the number of fish caught, and the quality of the fish caught. These are all immediately within the anglers’ vision and the first things that come to mind, such as ‘I haven’t caught any fish’, ‘my fish are terrible’ or ‘the water level is low and dirty looking’.

The Ohau Channel fishery still provides an angling experience through October, November and April–June when water temperatures are conducive to trout being present. Outside of these times, temperatures can be too warm. The opening period (October) is particularly important in setting the tone for seasons angling. If smelt runs are occurring in the leadup to the opening on 1 October, trout will follow smelt into the channel and be present for anglers to catch. The loss of the delta end of the fishery cannot be understated as trout would have continued to be available for anglers beyond the drop off in Lake Rotoiti.

Conclusions

- Just two years data from pre-wall monitoring has made comparison of before and after conditions difficult.
- Placement of the Water Quality Diversion Wall has resulted in the loss of the Ohau Delta drop-off for shore-based anglers into Lake Rotoiti, which formed a large part of the Ohau Channel fishery. This will not be reinstated until the wall is removed.
- The Ohau Channel continues to attract trout fishers. The main area anglers access the Ohau fishery from, is at the upstream end of the channel, downstream of the Rotorua Outlet Weir.
- Angling success is variable from season to season and dependent upon time of year. The best angling is encountered in absence of elevated summer lake temperatures and when angling sessions align with timing of smelt runs.
- Lake Rotorua trout appear to contribute highly to the Ohau anglers' catch.

(iii) **Smelt monitoring**

Smelt are a key food source for the trout fishery. A monitoring programme has been in place since pre-wall, to determine any negative impacts on this fishery. This programme has been altered on the advice of the fishery panel. The impact of the wall on this fishery is summarised below from NIWA Report: Smelt Monitoring in the Ohau Channel 2021/2022. This summary is the executive summary taken directly from the report, and it provides a succinct review of the smelt monitoring programme since prior to the construction of the wall.

Executive Summary

In 2008, a diversion wall was installed in Lake Rotoiti to channel the nutrient-laden water flowing out of Lake Rotorua, around the edge of Lake Rotoiti and down the Kaituna River. This flow diversion was designed to reduce the nutrient loads entering Lake Rotoiti from Lake Rotorua, thereby assisting in the restoration of water quality in the lake. Concerns were raised that this diversion wall could adversely affect the migrations of smelt and trout up the Ohau Channel, which connects Lake Rotoiti to Lake Rotorua. Consequently, monitoring of runs of smelt and bullies was carried out before and after construction of the diversion wall, to identify any significant adverse impacts of the wall on these fish. In this report, we present the results of the smelt monitoring for the 2021/22 season, the fourteenth year of monitoring since the diversion wall was constructed.

Overall, the results for 2021/22 complement and add to those obtained in previous years and indicate that:

(a) *The diversion wall does not prevent the movement of either adult or juvenile smelt into and up the Ohau Channel, because migrations of both have continued after the wall was constructed. Common bully migrations also appear unaffected, although small catches of bullies were observed in 2021/22, these show signs of increasing as part of an ebb and flow cycle.*

(b) *Regressions indicated that the size of smelt migrations tended to increase with increasing flow at the time of sampling and seven-day mean flow, while adult run size tended to decrease slightly with increasing temperatures, beyond 14°C. These findings suggest a link between flow and temperature and the size of smelt runs.*

Given the daily variation in runs detected by both trapping and observations over the past decade, it is apparent that runs do not occur every day, and that the daily occurrence of runs is sporadic, with high temporal variability. Given such variability, detecting changes in the smelt run up the channel before and after the diversion wall was constructed, would require near daily monitoring over five years, both before and after the installation of the wall. Thus, the continued monitoring of the smelt run, given these limitations, would not provide any additional insight into any potential impacts that the diversion wall may have on smelt or bully migrations. Instead, ecological monitoring of smelt migrations would be more appropriate to identify and quantify the impact of other anthropogenic factors, such as climate change, which may play an important role in the long-term persistence of smelt within the Lake Rotoiti/Rotorua ecosystem. To meet future needs, additional monitoring should include robust ecological monitoring technique (e.g., acoustic cameras) that enable smelt migrations to be monitored continuously with limited effort. Information derived from these advanced monitoring techniques, will fill key knowledge gaps related to smelt migrations through the Ohau Channel (e.g. the size, timing, and frequency of smelt runs), needed to effectively manage the Lake Rotorua and Lake Rotoiti smelt population.

While this report identifies a need to undertake additional monitoring to quantify the more detailed (daily) estimates of smelt migration, staff supported by Dr Ian Kusabs have more recently undertaken visual observations of smelt movement through the wall and conclude:

1 The sheet piles have numerous regular holes near the lake surface, generally about 200 mm-300 mm wide by 75 mm–120 mm high.

2 These holes that would allow fish passage, in particular, passage for smelt are present at regular intervals along the wall length,

3 Smelt were observed swimming in small schools in a number of locations on the Rotoiti side of the wall, and

4 A very large school of smelt were observed swimming around the area of the Delta boat ramp and jetty (on the Rotorua side of the wall),

5 We also observed juvenile bullies in some locations amongst the wall sheet piles at the Okere Arm end of the wall.

At this stage, due to the unlimited “holes” in the wall in the top 500 mm from the surface, there is currently no impediment to smelt access through the wall. The Council is trialling a method to repair these corrosion holes. If this work leads to all of the holes being repaired and blocked, Council need to give consideration of the effect on smelt migration. There are, however, three holes in the wall that were designed to enable smelt migration.

(iv) Catfish

Drs Frank Burdon and Ian Kusabs are investigating the impact of catfish establishment in lakes Rotorua and Rotoiti and their impact on koura. This work involves analysis of catfish and koura monitoring data since the catfish were first discovered in Lake Rotoiti in 2014, building on the koura reporting in Section i. above. At the time of writing, this analysis was not available but a preliminary review of the catfish and koura data indicates that there is a strong inverse relationship between the two species, which supports the conclusions reported in Section i. Pers comm, F. Burdon 2023.

The analysis is expected to be completed later in 2024 and reported in a refereed scientific journal.

(v) Fish Panel

The Fishery Panel is appointed as a requirement of the resource consent to make recommendations on the ongoing monitoring plan and to annually assess any changes to the impact of the diversion wall on the local fishery. The following are the fish panel recommendations for action from its recent meeting in March 2023:

Action No.	Action	Status update
1	Ask Deniz Özkundakci (UoW) to factor the holes in the lake modelling.	Completed in this report
2	Ian to pass data to Michel to review and compare it to his Taupo catfish monitoring and look for trends. Also to liaise with Ian re effects on koura.	Under progress
3	Keep the trout creel survey going.	On going
4	Develop the TALT monitoring programme requirements	Developing
5	After AP3, Ian to meet with the new TALT monitoring team to train surveyors to ensure accuracy and consistence of data collection.	Done
6	To plot 'Relative Condition Factor' against Lake TLI, particularly against chlorophyl-A as an indicator of lake productivity.	Under action with UoW
7	Reduce kōura monitoring to once per year (date to be confirmed). but keep the current kākahi monitoring unchanged.	Done
8	Train the catfish killas to measure more parameters of captured kōura.	Done
Action No.	**Action**	**Status update**
9	Send all kōura and Kākahi background data and reports to TALT.	Done
10	Cancel NIWA smelt monitoring.	Done
11	Ensure that smelt observation is specifically covered in the creel survey and operational TALT staff asked to record observations of smelt locations and movement.	Done

7 References

Prentice M.J., Özkundakci D. 2024. Ōhau Channel diversion wall: 7-year review — Water quality review and modelling. ERI Report 169, a client report prepared for Bay of Plenty Regional Council. Environmental Research Institute – Te Tumu Whakaora Taiao, Division of Health, Engineering, Computing & Science, University of Waikato, Hamilton, New Zealand. 89 pp. DOI: 10.15663/ERI.Report.169 ISSN 2463-6029 (Print) & ISSN 2350-3432 (Online)

Wood S, Goodwin E, Kelly L, Puddick J 2022. Rotorua Lakes cyanobacterial data analysis - 2022. Prepared for Bay of Plenty Regional Council. Cawthron Report No. 3803. 45 p. plus appendices

Kusabs, I.A. (2022). Ōhau River Diversion Wall Lake Rotoiti - kōura and kākahi monitoring programme 2020/2021. Report number 16 prepared for Bay of Plenty Regional Council. Kusabs and Associates Ltd, Rotorua, New Zealand

Appendices

Appendix 1:
Terms of Reference: Ohau Wall – 7 year review

27 April 2023

1 Introduction

A meeting was held with key experts on 27 April to discuss the preparation for the Ohau Diversion Wall: 7-year review. The review is required as part of the Resource Consent RM 10-0527-AP. See Appendix 1 Email re the 7-year review.

A review of the performance of the diversion wall is required as condition 10.1:

> **10 Reporting**
>
> 10.1 The consent holder shall, at seven (7) yearly intervals, prepare, publish and make available to the public, a review of the performance of the structure in improving water quality in Lake Rotoiti including whether the structure is still needed to divert water from Lake Rotorua away from Lake Rotoiti.

The seven-year period ends in March 2024, so this review is planned to be completed by March 2024. The condition specifically refers to review of "…the performance of the structure in improving water quality in Lake Rotoiti…". Water quality monitoring is only part of the total environmental monitoring undertaken as part of the programme to monitor the impact of the wall, and consequently the Technical Group has agreed to bring together a more comprehensive review that provides a review of water quality, comparison with earlier expectations for water quality changes as well as review wider ecological impacts of the diversion wall. Much of the ecological data is available on the Bay of Plenty Regional Council websites, however, the aim is to bring a summary together in this review report.

As part of the review, the group will consult with the main groups that are interested in the impact of the diversion wall. This includes Ngāti Pikiao Environmental Society, Tapuika Iwi Authority, Lake Rotoiti Community Association and Lakes Water Quality Society. It is proposed that consultation commences with the Terms of Reference (ToR) and follow up with the final reports.

2 Team members

The following key people have been co-opted from our Water Quality TAG and other specialists necessary for the review. Other experts may also be called upon as necessary to advise.

- Andy Bruere BOPRC Review leader
- Associate Professor Deniz Özkundakci, University of Waikato (UoW)
- Matthew Prentice, University of Waikato
- Ian Kusabs, Ian Kusabs and Associates Ltd.

- Matt Osborne, Fish and Game New Zealand
- Soweeta Fort-D'ath, Te Arawa Lakes Trust
- Justine Randall, BOPRC

3 Review scope

The main components for the review are divided into the following sections:

(a) Water quality modelling

This will be led by Matthew Prentice working for the UoW. The aim is to set up the hydrological, water quality and ecological model to test scenarios of the Ōhau Wall. These will include:

(i) Model with and without the wall to address part of the investigation for the ongoing need for the wall, (under historic and current water quality),

(ii) Model future impact of the wall on Lake Rotoiti water quality with future climate change expectations (possibly 2050 and 2090 expectations),

(iii) Possibly model the impact of the current leakage due to the corrosion holes in the wall.

Other scenarios may be developed as the model becomes available.

Some key questions to help are:

- What is the modelled impact of the diversion wall on water quality and ecology?
- Does this align with the water quality and ecological monitoring of Lake Rotoiti?
- The diversion wall is expected to be in place for 50 years-100 years. Once it has been removed, what is the likely water quality expectation for Lake Rotoiti if Lake Rotorua meets the TLI of 4.2 +_ , when Lake Rotoiti is expected to meet a TLI of 3.5 units?
- The diversion wall has effectively changed the water residence time in Lake Rotoiti from about 1.5 years to 5+ years. How does this impact Lake Rotoiti water quality, potentially having an impact on bottom water dissolved oxygen levels and especially the western arm of the lake?

(b) Water quality review

Bay of Plenty Regional Council has a water quality monitoring programme that has been monitoring many lake and river locations continuously on a monthly basis since as early as 1990. This monitoring has progressed through the commissioning of the diversion wall in 2008 period. The aim of this work is to review this water quality data and investigate the impact of the wall on water monitoring data. Associate Professor Deniz Özkundakci will lead this part of the review. The review will include:

(i) An update of the C. 2010 review undertaken by Moritz Lehmann, to test impact of the diversion wall on Lake Rotoiti water quality,

(ii) Undertake a statistical "intervention analysis" on Regional Council data, from the PC 10 review,

(iii) Review impact of the diversion wall on Kaituna River water quality.

Some key questions are:

- Has the wall achieved its objective of improving water quality?
- Has the wall resulted in the lake reaching its TLI target in advance of improvements to Lake Rotorua water quality impacting Lake Rotoiti?
- Does current monitoring support continued placement of the wall diverting Ōhau Channel water?
- What impact has the diversion wall had on the quality of the Kaituna River?

(c) Cyanobacterial analysis

Cyanobacterial analysis was undertaken for all monitored sites during the Plan Change 10 review, by Dr Susie Wood of Cawthron. This review is available on the BOPRC website and will be summarised by Andy Bruere to present for this project. The summary will include Lake Rotoiti and Kaituna River commentary form the PC 10 report.

At times and especially during periods when Lake Rotorua is having algal blooms, BOPRC is required to undertake additional cyanobacterial monitoring downstream in the Kaituna River. Due to the current heavy workload of the staff involved with the current monitoring programme, BOPRC staff are addressing how future monitoring will be implemented to add the necessary monitoring when triggered.

(d) Fisheries monitoring

As part of the wall consent, Council monitors a range of fishery parameters. These are reported to the appointed fishery panel at an annual meeting. They provide recommendations on ongoing monitoring and assess the impact of the wall on these parameters.

(i) Kōura and kākahi

Kōura and kākahi have been monitored since 2006, pre wall. Kōura abundance has declined significantly since catfish establishment circa 2016, kākahi abundance has remained relatively stable since wall construction.

Current reports will be summarised to provide an overview of the monitoring and conclusions (Andy Bruere).

(ii) Trout fishery

Fish and Game have reported annually on opening day surveys of anglers as well as summer creel surveys, since 2005. No major impact has been detected on the trout fishery in the Ōhau Channel since wall completion, however, the delta (the drop-off into Lake Rotoiti) is no longer popular for fishing.

Matt Osborne to summarise trout fishery reports. The review should refer to current reports and identify any impacts of the diversion wall on the trout fishery.

(iii) Smelt

Smelt are a key food source for the trout fishery. A monitoring programme has been in place since pre-wall to determine any negative impacts on this fishery. This programme has been altered on the advice of the fishery panel. The impact of the wall on this fishery will be summarised from existing reports.

(iv) Catfish

Catfish monitoring has been undertaken since the first incursion in about 2016. It appears that catfish have had a major impact on the kōura population in lakes Rotorua and Rotoiti. Locate monitoring data and undertake analysis of the number and size range. Dr Francis Burden (UoW) may be able to assist in the review of the data. Also impact of catfish work led by Brendon Hicks and Shane Grayling.

(v) Fishery Panel

The appointed Fishery Panel meets annually to review fishery monitoring data. It would be useful to provide a summary of the fishery panel discussion and recommendations with respect to the impact of the diversion wall on the Lake Rotorua and Lake Rotoiti fisheries. This will be a high level overview bringing up to date conclusions from the panel. (Andy Bruere to summarise this work).

4 Timing and report format

The review is expected to be submitted by March 2024.

Consultation with interested parties will take place over May 2023, outlining the ToR and discussion if requested. Final reports will also be presented to the interested parties near the end of 2023.

Draft reports should be completed for review with the team by 15 October 2023.

Reports will be presented to cover off each of the four main areas listed above (Water Quality Modelling, Water Quality Monitoring, Cyanobacterial Analysis and Fisheries Monitoring).

Final report will be presented to Council regulators by March 2024.

Email re the 7 Year review.

Ohau diversion wall: 7 year review.

Andy Bruere
To Deniz Ozkundakci; Chris McBride; Ian Kusabs; Soweeta Fort-D'ath; Matt Osborne; James Dare

Reply | Reply All | Forward
Mon 7/11/2022 3:29

RM16-0527 Consent Conditions FINAL.pdf
.pdf File

Kia ora team,

It may come as a surprise but we have had the second resource consent for the Ohau diversion wall for nearly 6 years. The consent was issued for 35 years which is great but comes with some extra requirements to ensure that any untoward effects are addressed as the consent proceeds.

I have attached the consent conditions for your info, and bring to your attention condition 10.1 that requires:

10 Reporting

10.1 The consent holder shall, at seven (7) yearly intervals, prepare, publish and make available to the public, a review of the performance of the structure in improving water quality in Lake Rotoiti including whether the structure is still needed to divert water from Lake Rotorua away from Lake Rotoiti.

The seven year period ends in March 2024, so I would like to aim for completing the review in the next 12 months. To add value I think it would be useful to also engage with parties who are likely to be interested in the review. I think these would be iwi, Lakes Water Quality Society, The Rotoiti Community Association and submitters to the application back in 2017.

What I'm thinking right now is that we have a TAG workshop to formulate the ToR for the review. We inform the various groups we are doing the review, and then by the end of 2023, we invite them to a hui before we finalise the reports and overview.

An overview of what I'm thinking to cover would be the following:

1. Water quality modelling to assess wall performance now and also to review what will happen to Rotoiti as the wall is removed (also consider the impact of the wall on the lake HRT),
2. Review of water quality data and impact on the Kaituna River (We have regional council NERMN data plus the monitoring buoys),
3. Fishery data, this should include native species (Ian Kusabs), Catfish incursions (TALT) and trout fishery (Matt Osbourne F&G),
4. Cyanobacteria data. This was analysed by Cawthron for the PC10 Review, but we also have the Kaituna River data DS of the Trout Pools. (It seems the Trout Pools is decreasing so it could be interesting to just find the trend for the River and estuary which could show a different situation, caused by DS inputs).

Please let me know if you have any comments at this stage. I will programme a workshop for early next year to progress this,

Kind regards,

Andy Bruere
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