

MEMORANDUM



To: Councillors
Strategy, Policy and Planning Committee

From:

Date: 14 February 2013

File Ref: 4.000867, 8.00139

Subject: **Trophic Level Indices for Rotorua Lakes**

1 Purpose

The purpose of this memo is to present findings on how the Trophic Level Indices (TLIs) for the Rotorua lakes were developed for inclusion in the Regional Water and Land Plan and how these relate to historical water quality.

2 Background

In the Strategy, Policy and Planning Committee meeting on the 27th November 2012, during the discussion around the update for the Lake Rerewhakaaitu nutrients and action plan status, a Councillor asked staff to report back on where the Trophic Level Indices for the Rotorua Lakes came from.

3 Discussion

TLI targets for Rotorua/Te Arawa lakes were included in the proposed Regional Water and Land Plan. The statutory consultation process for the Proposed Regional Water and Land Plan occurred between 2002 and 2004.

These target lake water quality levels reflect a desired water quality agreed through the public consultation process. The Council has twice consulted with the public on the desired levels for the six lakes¹ in the Tarawera River catchment – the first public consultation related to the Regional Tarawera Regional Catchment Plan in 1994, and the second consultation related to the Draft Regional Water and Land Plan in 2000/2001. The full history of setting TLIs is provided in Section 4.

Since the early 2000s, the use of TLIs has been considered 'best practice' for measuring lake water quality. Even then, there were criticisms about using TLI as the triggering point for water quality management (as commented in submissions on the Proposed Water and Land Plan, further submissions and appeals). The TLI and Lake Submerged Plant Indicators (LakeSPI), however, were and still are the most practical indicators available (and recognised by the Ministry for the Environment).

¹ That includes Lake Tarawera, Lake Rotokakahi (green Lake), Lake Okareka, Lake Tikitapu (Blue Lake), Lake Ōkātina and Lake Rotomahana but excludes Lake Okaro.

The Proposed Regional Water and Land Plan based the Objective 11 TLIs for most lakes on the 1994 water quality level (particularly the six lakes in the Tarawera catchment); additional improvement was asked for the supertrophic Lake Ōkaro, and eutrophic Lake Rotorua and Lake Rotoehu. Council scientists also considered conditions and characteristics for each lake (such as different lake behaviours between a large lake like Lake Rotorua and a small lake like Rerewhakaaitu, see Table One for a simple lake characteristics comparison) and suggested the target water quality levels. Council's Science Manager at the time undertook the assessment and made the TLI recommendations. Table Two shows how the lake TLIs in Objective 11 compared to and their TLI levels in 1994.

Table One Comparing some basic physical characteristics² between Lake Rotorua and Lake Rerewhakaaitu as examples of different lake conditions:

Physical characteristics	Lake Rotorua	Lake Rerewhakaaitu
Lake size:	8,060 ha	530 ha
Catchment area:	50,060 ha	5,290 ha
Average depth:	11 m	7 m
Deepest point:	45 m	15 m
Formed:	140,000 years ago	700 years ago

Table Two Comparing the TLIs in Objective 11 in the Regional Water and Land Plan to the historical TLI levels in 1994³ (Bold underline font indicate the initial lakes TLI calculated in 2001⁴):

Lake TLI in Objective 11 and its explanation in the Regional Water and Land Plan	July 1993/ June 1994 TLI average	July 1994 / June 1995 TLI average	Three- yearly annual average TLI in 1994	Comparing TLI in Objective 11 to the 1994 level
Lake Ōkāreka 3.0 Level in 1994. Part of the Tarawera catchment	<u>2.97</u> 2.89	<u>3.20</u> 3.17	--	Same level
Lake Ōkātina 2.6 Level in 1994, which has been unchanged	<u>2.60</u> 2.61	<u>2.56</u> 2.52	--	Same level
Lake Rotoiti 3.5 Level in 1994. Relates to the year of notification of the Regional Plan for the Tarawera River Catchment	<u>3.81</u> 3.73	<u>3.75</u> 3.68	--	More stringent (see Table Three)
Lake Rerewhakaaitu 3.6 Level in 1994. Note: Environment Bay of Plenty has been working within Rerewhakaaitu catchment due to concern about lake water quality degradation. However, this seems to be in relation to natural lake water level changes.	<u>3.16</u> 3.15	<u>3.33</u> 3.26	3.2	More lenient (see Table Three)
Lake Rotokakahi 3.1 Level in 1994, which has been unchanged	<u>3.12</u> 3.09*	<u>3.35</u> 3.27*	--	Same level

² Data extracted from page 9 and 27 of the "State of the Rotorua/Te Arawa Lakes 2009-2010"

³ Data extracted from Table 3.1 and Appendix 1 of 2010/2011 Rotorua Trophic Level Index Update. Explanation extracted from the Explanation section of the Operative Regional Water and Land Plan.

⁴ Data extracted from Burns, N. (2001) Trophic Level Index Baselines and Trends for 12 Rotorua District Lakes, 1990 to 2000, Lakes Consulting, prepared for Bay of Plenty Regional Council

Lake TLI in Objective 11 and its explanation in the Regional Water and Land Plan	July 1993/ June 1994 TLI average	July 1994 / June 1995 TLI average	Three-yearly annual average TLI in 1994	Comparing TLI in Objective 11 to the 1994 level
Lake Rotomā 2.3 Level in 1994, which has been unchanged	<u>2.26</u> 2.20	<u>2.32</u> 2.26	--	Same level
Lake Rotomahana 3.9 Level in 1994, which has been slightly higher than current [to 2007] water quality	-- 3.88	<u>3.82</u> 3.83	3.9	Same level
Lake Tarawera 2.6 Level in 1994, which is slightly lower than current [to 2007] water quality – not sufficient to take regulatory action, and may be part of a natural cycle	<u>2.82</u> --	<u>2.62</u> 2.67	2.8	More stringent (see Table Three)
Lake Tikitapu 2.7 Level in 1994, which is slightly lower than current [to 2007] water quality – not sufficient to take regulatory action	<u>2.71</u> 2.67	<u>2.65</u> 2.62	--	Same level
The following lakes' TLI are not set at the 1994 level. They are here for comparison purpose				
Lake Ōkaro 5.0 (see Table Four)	<u>5.46</u> 5.39	<u>5.53</u> 5.47	5.5	See Table Four
Lake Rotorua 4.2 (see Table Four)	<u>4.89</u> 4.84	<u>4.57</u> 4.61	4.7	See Table Four
Lake Rotoehu 3.9 (see Table Four)	<u>4.73</u> 4.70	<u>4.85</u> 4.81	4.5	See Table Four

*Data from Te Wairoa Stream, the Lake Rotokakahi outlet. Published in *Rotorua Lakes Water Quality Report 2009*.

The Regional Water and Land Plan (section 3.5 Para 6) outlines an explanation of the TLIs. The Plan does not provide any detailed explanation for the variations in how the TLI target were set. An assessment of alternative TLIs and a detailed cost/benefit analysis were not provided at the time of the Plan development. Staff have researched the matter of how the TLIs were set including advice on the background to the recommended TLIs in 2001. Table Three outlines the likely explanations of variations where the Lake TLIs were not exactly the same as the 1994 level.

Table Three The likely reasons for variations to other lakes' 1994 level:

Lake TLI in Objective 11	Likely explanation
Lake Rotoiti 3.5	Lake Rotoiti's objective TLI has been set lower than 1994 average to discount the influence of Lake Rotorua
Lake Rerewhakaaitu 3.6	Lake Rerewhakaaitu's objective TLI was difficult to set as it fluctuated over time. The TLI has accounted for this high level of TLI fluctuations. Around 2001, declining water quality in Lake Rerewhakaaitu was seen to be largely (but not solely) related to lake water level fluctuations
Lake Tarawera 2.6	Lake Tarawera's objective TLI is set similar to the water quality levels observed in 1994/1995 and 1995/1996. The data collected in Lake Tarawera previous to July 1994 were considered insufficient and open to higher statistical error.

Table Four Lakes which its Objective 11 targets are not set at 1994 level in the Water and Land Plan:

Lake TLI in Objective 11	Explanation in the Regional Water and Land Plan	Comments
Lake Okaro 5.0	Set at a realistic level that is lower than current TLI (i.e. to improve lake water quality)	Since trophic level monitoring started in 1991, this TLI target (5.0) has achieved once in 2009/2010 when the TLI level was 4.7
Lake Rotorua 4.2	Level set in relation to the removal of sewage from the lake. When the Rotorua city sewage discharge was moved to land disposal, water quality expectations for the lake were stated in documents associated with the consent ⁵	The water quality in Lake Rotorua has observed a steady deterioration from 1976 caused by city sewage treatment discharge, which caused a widespread public concern. Studies and communities suggested restoring lake conditions to the level prior to sewage treatment discharge, which is similar to the level in the 1960s ⁵
Lake Rotoehu 3.9	Set at a level that equates to the last 'good' year for water quality in the lake – 1992/1993	TLI 3.9 was the TLI average for July 1990 to June 1991 period ⁶ The TLI set at the medium values at three 'good' years before blue-green algal blooms commenced ⁷ .

In 2002/2003, the formal public submissions on the Proposed Regional Water and Land Plan showed a majority support (seven out of 11) for keeping the proposed (publicly notified) lake trophic level indices. The Hearing Panel and Council's decisions also supported the TLI objectives as it is in the proposed plan.

The TLIs in Objective 11 in the Operative Regional Water and Land Plan represent the targets agreed through the Resource Management Act plan preparation process between 2001 and 2008. Our knowledge of the lakes and their catchments has improved, and a lot of actions have already been implemented to improve water quality by the Lakes Partners and communities.

We recognise that TLI targets need to remain relevant and reflect current community values, the ability to achieve targets and economic reality. The Regional Water and Land Plan, including the TLI targets, are required to be reviewed before 2018.

⁵ When the Rotorua city sewage discharge was moved to land disposal, water quality expectations for the lake were stated in documents associated with the consent. That target was for Lake Rotorua's water quality to be similar to its 1960s' water quality. The sustainable nitrogen load to achieve that water quality was described in a paper published in 1989 (see Appendix Five for its abstract). The target trophic level corresponded the sustainable nitrogen load was confirmed in a paper *Lake Rotorua Nutrient Load Targets* (Rutherford, K., 2003) and further confirmed in a subsequent paper *Nutrient load targets for Lake Rotorua - a revisit* (Rutherford, K., 2008)

⁶ Data extracted from Burns, N. (2001) *Trophic Level Index Baselines and Trends for 12 Rotorua District Lakes, 1990 to 2000*, Lakes Consulting, prepared for Bay of Plenty Regional Council

⁷ Explanation extracted from Schedule 7 of the Draft Regional Water and Land Plan – see Appendix Two.

4 The history of setting lakes' TLI in the Regional Plan

4.1 Lakes water quality target setting history summary table

Table Five Summary of the Rotorua Lakes water quality targets considered in the planning process:

Lake	Early planning	Regional Water and Land Plan (Explanation of TLI in Objective 11)
Lake Ōkāreka	Level in 1994	Level in 1994
Lake Rotokakahi	Level in 1994	Level in 1994
Lake Rotomahana	Level in 1994	Level in 1994
Lake Tarawera	Level in 1994	Level in 1994*
Lake Tikitapu	Level in 1994	Level in 1994
Lake Ōkataina	Level in 1994	Level in 1994
Lake Rotomā	Level in 1994	Level in 1994
Lake Rotoehu	Level in 1990	Level in 1992/ 1993**
Lake Rerewhakaaitu	Level in 1998	Level in 1994***
Lake Rotorua	Level in 1998	Prior to sewage treatment discharge****
Lake Rotoiti	Level in 1998	Level in 1994*****
Lake Ōkaro	--	A realistic level*****

* The TLI in Objective 11 matches the actual level in 1994/1995

** The TLI in Objective 11 matches the actual level in 1990/1991

*** The TLI in Objective 11 matches the actual level in 1990/1991

**** The TLI in Objective 11 matches the expected level in 1960s

***** The TLI in Objective 11 matches the expected level in 1970s

***** The TLI in Objective 11 was achieved once in 2009/2010.

4.2 The history of Lakes TLI origins and the target setting process

From 1993 to 1999, the Regional Council planned to develop a range of Regional Plans; including the Regional Tarawera River Catchment Plan (RTRC Plan).

In 1994, when the Council was consulting on the RTRC Plan, the community said they wanted the water quality to stay as it was. This concept is also partly based on a 1993 report⁸ identifying key sources of nutrients input to 14 lakes in Rotorua. That report identified that the present (1993) water quality should be maintained.

⁸ Sigma Consultants, NIWA, Bioresearches Ltd and NZFRI, June 1993. *Report on Rural land Use Practices in the Rotorua District*. Report prepared for Rotorua District Council. In that report, the report noted that Rerewhakaaitu is a difficult lake to characterise in terms of its trophic status. See Appendix Three for its summary for Lake Rerewhakaaitu.

To reflect the communities' desires, the RTRC requires the water quality of lakes in the Tarawera River catchment⁹ remain at the 1994 standard. The Regional Water and Land Plan (initiated in 1998¹⁰) covered the rest of the lakes (Lake Rotorua, Rotoiti, Rotomā, Rotoehu, Rerewhakaaitu and Ōkaro).

The early draft of the Regional Water Plan (March 1999, version 1.3, background information missing), suggested establishing the natural state water quality classification at the following levels:

- Lake Rotorua – 1998
- Lake Rotoiti – 1998
- Lake Rerewhakaaitu – 1998
- Lake Rotomā – 1994
- Lake Rotoehu – 1990.

We had difficulties in finding the reasons why these levels were proposed in the archived documents.

Meanwhile (1999-2000), the Rotorua Te Arawa Lakes Strategy Group¹¹ (the Group) was developing *“A Strategy for lakes in the Rotorua district”* (a strategy published August 2000). At the time, the lack of clear lake water quality standards was an issue faced by the Group. The challenge was evident in its Strategy, which stated that *“we consider defining and refining water quality standards critical to assess future discharges and to determine performance criteria, benefits and costs for upgrading current activities”*. One of the key goals in the Strategy was to *“define water quality standards”*.

In late 2000¹², Trophic Level Indices for Rotorua lakes between 1990 and 2000 were developed in retrospect. The Council first commissioned Noel Burns of Lakes Consultancy (August 2000) to develop the historical trophic level index values for six Rotorua District lakes (Lake Rotoehu, Tarawera, Ōkāreka, Rotokakahi, Rotomahana and Tikitapu). Later in May 2001, the same consultant developed the trophic level index values for all twelve Rotorua District lakes.

In the same year, the Council released a more encompassing and integrated Regional Water and Land Plan (version 2.0), which included a Natural State (lake) water quality class (including water temperature and the Trophic Level Index - see Appendix Two) that applied to the Rotorua lakes. The community had already indicated lakes in the Tarawera River catchment were to stay at 1994 quality level. Few comments were received on the lake water quality class in the Draft Plan.

⁹ That includes Lake Tarawera, Lake Rotokakahi (green Lake), Lake Ōkāreka, Lake Tikitapu (Blue Lake), Lake Ōkātina and Lake Rotomahana but excludes Lake Ōkaro.

¹⁰ Note that the Regional Water and Land Plan was initially only the 'Regional Water Plan', until a Council decision to develop an integrated plan was made around 2000.

¹¹ Rotorua Te Arawa Lakes Strategy Group contains three main agencies: Te Arawa Lakes Trust (previously known as Te Arawa Māori Trust Board), Bay of Plenty Regional Council (previously known as Environment Bay of Plenty) and Rotorua District Council.

¹² In 2000, the Ministry for the Environment also developed a protocol for monitoring trophic levels of lakes and reservoirs. Since then, scientists in New Zealand started using trophic level index (TLI) to communicate lake water quality. The Trophic Level is one of two lake water quality indices adopted by New Zealand Government.

During 2001, the further target Trophic Level Indices (TLIs) were recommended as an Objective in the draft Proposed Regional Water and Land Plan (version 3.2 and version 3.3) for:

Lake Ōkātina – TLI 2.6	Lake Ōkaro – TLI 5.0	Lake Rerewhakaaitu – TLI 3.6
Lake Rotomā – TLI 2.3	Lake Rotoiti – TLI 3.5	Lake Rotorua – TLI 4.2.
Lake Rotoehu – TLI 3.9		

After an intensive consultation period in late 2001, the Council notified a Proposed Regional Water and Land Plan (Proposed Plan, version 4.0) in February 2002. The TLI levels for the 12 lakes were set out in the Proposed Plan as an Objective:

“The water quality in the Rotorua lakes is maintained or improved to meet the following Trophic Level Indices:

(a) Lake Ōkāreka – 3.0	(e) Lake Rotoehu – 3.9	(i) Lake Rotomahana – 3.9
(b) Lake Ōkaro – 5.0	(f) Lake Rotoiti – 3.5	(j) Lake Rotorua – 4.2
(c) Lake Ōkātina – 2.6	(g) Rotokakahi – 3.1	(k) Lake Tarawera – 2.6
(d) Lake Rerewhakaaitu – 3.6	(h) Lake Rotomā – 2.3	(l) Tikitapu – 2.7.”

The Council notified the Proposed Plan in 2002 and consulted with the public following the process set out in the Resource Management Act.

By early 2003, the Council had received three submissions and eight further submissions on this particular Objective. Four of these submissions asked the Trophic Level Indices to be removed; seven of them considered the Trophic Level Indices are appropriate and supported this Objective.

In 2004, a hearing committee considered the submissions and recommended that Council retain Trophic Level Indices as they appear in the plan, and to add explanation notes and an additional Objective *“Reduced occurrence of cyanobacterial algal blooms on the Rotorua Lakes”*. The relevant submission points, Council’s decisions and the subsequent amendments (redline/strikeout copy) is attached as Appendix One.

The Proposed Plan became operative in December 2008, after all submissions and appeals have been resolved and publicly notified (First Schedule, clause 20 of Resource Management Act 1991).

Michelle Lee
Planner

for Natural Resources Policy Manager

February 2013

Appendices

- Appendix One Relevant submissions and Council's decisions on the Proposed Regional Water and Land Plan 2002 and the resulted amendments
- Appendix Two Trophic Level Indices for Lakes in the *Draft Regional Water and Land Plan 2000*
- Appendix Three Lake Rerewhakaaitu water quality and land use summary by SIGMA et al (1993)
- Appendix Four Lake Rerewhakaaitu water quality TLI values between 1990 to 2001 outlined in a Council's environmental report 2001
- Appendix Five An abstract of "Management of Phosphorus and Nitrogen Inputs to Lake Rotorua, New Zeland", a paper by Rutherford, J. C., Pridmore, R. D. and White, E. published in 1989 in the *Journal of Water Resources Planning and Management*

Appendix One

Environment B.O.P

Version: 8.0

Proposed Regional Water and Land Plan

Printed: 26 February 2004

Chapter	Sections	Page.	Para. #	Subs#	FSub
3	Land and Water Integration	3.2.o10	22	8	8
21.0011	Request	<p>The issue of setting of Trophic Level Indices has yet to be discussed in open public forum. The issues surrounding the time-frames to reach these pre-determined levels for a community resource has bearing on the use of other community resources.</p> <p>The improvement of lake water quality is reliant on the improvement of the Trophic Level Indices quoted in Objective 10 (3.2 p22) through the implementation of policies 21-24, 26-29 and Methods 56-58. The Trophic Level Index (TLI) is the best available mechanism to assess long-term catchment health. TLI's can vary substantially around a mean but over 3 years distinct trends can be seen in the moving average. This is compounded by the fact that, as stated in "Management of Nutrient Inputs to Lake Rotorua" Noel Burns May 2002 ; There can be no certainty in the management of the water quality of lake Rotorua because the Lake is so susceptible to changes in climatic conditions.</p> <p>There is no evidence presented in the Plan or elsewhere that the control of nutrients at the site specific level coupled with mitigation measures will maintain or improve the TLI's. It is the linkage between the TLI and site specific land use which is not well understood.</p> <p>Whilst TLI are accepted as being the best current practice available the levels at which they have been set in Objective 10 is questioned as there are options as to the levels of these TLI's that have not been discussed in a public forum. The TLI are being used as the environmental performance standard for the lakes.</p> <p>If the current levels of nutrient input are sustained the set TLI of 4.2 for Lake Rotorua will be achievable in 20 years. Should efforts be made now to increase nutrient removal and so reduce the time frame for target achievement? If a level of 4.2 is achieved, which future management regime options would be preferable? Retaining the same level of nutrient input or continuing a downward trend in the TLI? If the 4.2 level is surpassed would additional permitted development be an appropriate response? Will trade offs between uses be more effective in the longer term with even more regulation by rules on a catchment basis or will some sort of N tradeable permits be more effective? Similarly the situation in the other lake catchments needs to be worked through.</p>			
Recommendations: Reject		<p>Reword Objective 10 to read "the water quality in the Rotorua Lakes is maintained or improved to meet the TLI's agreed after public consultation and introduced by way of a plan change"</p> <p>Remove (a) to (l).</p>			
53.0198	Oppose	<p>Fish & Game are opposed to the extent that the objectives, policies, methods and explanations referred to establish a target standard for improvement over time in the respective water bodies.</p>			
Recommendations: Accept		<p>Seek that submission 21.0011 be rejected.</p>			
66.0153	Oppose	<p>The Trophic Level Indices set in the Plan are appropriate and largely based on 1990 levels.</p>			
Recommendations: Accept		<p>Seek that submission 21.0011 be rejected.</p>			
136.015	Support	<p>Support for reasons given by original submitter.</p>			
Recommendations: Reject		<p>Seek that submission 21.0011 be accepted.</p>			

Chapter	Sections	Page.	Para. #Subs#FSub
	<p>Decision: - Submission decision(s) as above. 21.0011, 53.0198(F), 66.0153(F), 136.0156(F), 154.0013(F), 136.0015, 65.0289(F), 66.0154(F) - Section 3.5 - Add: "Para 3A Environment Bay of Plenty uses the Trophic Level Index (TLI) system as a means of measuring lake water quality based on the amount of total nitrogen, total phosphorus and chlorophyll A (algae) present in the lake, and the clarity of the lake. Chlorophyll A and clarity (measured as secchi depth) are a consequence of the amount of total nitrogen and total phosphorus in a lake. The resulting numeric value is the TLI for an individual lake. The TLI methodology can be used to establish an average TLI value for a lake for the period over which water quality data has been collected, or determine the TLI trend during a specified period of time (i.e. the rate of change in the trophic level of a lake). An average TLI from one period can be used as a baseline, which can then be compared to a second average TLI from a later period of time. This comparison determines if lake water quality is remaining stable, improving or deteriorating. If water quality is found to be changing (either improving or deteriorating), the rate of change can then be investigated. This quantitative system provides definitive information about the state of the lake water quality in the region. The TLI methodology has been adopted by the Ministry for the Environment, and will be used in New Zealand to enable the comparison for water quality between different lakes. For a detailed explanation of the TLI methodology refer to 'Protocol for Monitoring New Zealand Lakes and Reservoirs' (Burns, 2000).</p> <p>Para 3B An explanation of each of the TLIs in Objective 10 is given in Table 1B. Many of the TLIs have been set at the 1994 level, as at this time the community expressed the expectation lake water quality should be no lower than at that time during consultation on the Regional Plan for the Tarawera River Catchment. In 1993, Sigma Consultants et al, prepared a report for Rotorua District Council on the effects of land use activities on water quality. The report identified that lake water quality targets should be no less than their present (1993) quality.</p> <p>Table 1B. Explanation of TLI in Objective 10 [note the following appears in table format]</p> <p>Lake ___ Current TLI(at 2001) ___ TLI in Objective 10 ___ Explanation of TLI in Objective 10</p> <p>Okareka ___ 3.3 ___ 3.0 ___ Level in 1994. In 1994 the Regional Plan for the Tarawera River Catchment was publicly notified, which stated that lake water quality would be maintained at current state. Lake Okareka lies within the Tarawera Catchment. Lake water quality classifications have been updated in the Regional Water and Land Plan to include TLI's, but retain community ideal of 'no degradation from 1994'.</p> <p>Okaro ___ 5.7 ___ 5.0 ___ Set at a realistic level that is lower than current TLI (i.e. to improve lake water quality).</p> <p>Okataina ___ 2.6 ___ 2.6 ___ Level in 1994 (which has been unchanged).</p> <p>Rerewhakaaitu ___ 3.6 ___ 3.6 ___ Level in 1994 (note: Environment Bay of Plenty has been working within the Rerewhakaaitu catchment due to concern about lake water quality degradation. However, this seems to be in relation to natural lake water level changes.)</p> <p>Rotoehu ___ 4.5 ___ 3.9 ___ Set at a level that equates to the last 'good' year for water quality in the lake - 1992/93.</p> <p>Rotoiti ___ 3.9 ___ 3.5 ___ Level in 1994. Relates to the year of notification of the Regional Plan for the Tarawera River Catchment, and consistency with the goal for other lakes (i.e. lake water quality to be maintained at 1994 levels).</p> <p>Rotokakahi ___ 3.3 ___ 3.3 ___ Level in 1994 (which has been unchanged).</p> <p>Rotoma ___ 2.3 ___ 2.3 ___ Level in 1994 (which has been unchanged).</p> <p>Rotomahana ___ 3.8 ___ 3.9 ___ Level in 1994 (which is slightly higher than current water quality).</p> <p>Rotorua ___ 4.6 ___ 4.2 ___ Level set in relation to the removal of sewage from the lake. When the Rotorua city sewage discharge was moved to land disposal, water quality expectations for the lake were stated in documents associated with the consent.</p> <p>Tarawera ___ 2.8 ___ 2.7 ___ Level in 1994 (which is slightly lower than current water quality - not sufficient to take regulatory action, and may be part of a natural cycle).</p> <p>Tikitapu ___ 2.8 ___ 2.7 ___ Level in 1994 (which is slightly lower than current water quality - not sufficient to take regulatory action)."</p> <p>30.0001, 65.0289(F), 66.0154(F) - no change to plan.</p> <p>Reasons for Decision: - 21.0011, 53.0198(F), 66.0153(F), 136.0156(F), 154.0013(F), 136.0015, 65.0289(F), 66.0154(F) - Trophic Level Indices (TLIs) as they appear in the plan are retained. Text to explain how the TLIs were set and their scientific basis is added to the plan.</p> <p>30.0001, 65.0289(F), 66.0154(F) - support is noted.</p>		

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5576 07
Version 8.0
4 May 2004

Resource Planning Publication 2002/01
ISSN 1170 9022

PROPOSED REGIONAL WATER AND LAND PLAN

[Amended by Decisions]

REDLINE/STRIKEOUT

This version is the proposed plan amended in accordance with Council's decisions on submissions. From 4 May 2004 this amended plan becomes the Proposed Regional Water and Land Plan and supersedes all previous versions of the proposed plan.

4 May 2004

Environment Bay of Plenty
Bay of Plenty Regional Council

Objective 9A Stewardship of natural resources which:

- (a) Sustains the life-supporting capacity of soil, water and ecosystems;
- (b) Maintains, and where appropriate, protects cultural, ecological, amenity, natural character and landscape values through management practices that avoid, remedy or mitigate adverse effects.

Objective 10 The water quality in the Rotorua lakes is maintained or improved to meet the following Trophic Level Indices:

- (a) Lake Okareka – 3.0
- (b) Lake Okaro – 5.0
- (c) Lake Okataina – 2.6
- (d) Lake Rerewhakaaitu – 3.6
- (e) Lake Rotoehu – 3.9
- (f) Lake Rotoiti – 3.5
- (g) Rotokakahi – 3.1
- (h) Lake Rotoma – 2.3
- (i) Lake Rotomahana – 3.9
- (j) Lake Rotorua – 4.2
- (k) Lake Tarawera – 2.6
- (l) Tikitapu – 2.7

Explanation:

Table 1 – Trophic Level Indices (TLI) – Current and Management Goals

Lake	TLI in Objective 10	Current TLI (at 2001)
Okareka	3.0	3.3
Okaro	5.0	5.7
Okataina	2.6	2.6
Rerewhakaaitu	3.6	3.6
Rotoehu	3.9	4.5
Rotoiti	3.5	3.9
Rotokakahi	3.3	3.3
Rotoma	2.3	2.3
Rotomahana	3.9	3.8
Rotorua	4.2	4.6
Tarawera	2.7	2.8
Tikitapu	2.7	2.8

Para 3A Environment Bay of Plenty uses the Trophic Level Index (TLI) system as a means of measuring lake water quality based on the amount of total nitrogen, total phosphorus and chlorophyll A (algae) present in the lake, and the clarity of the lake. Chlorophyll A and clarity (measured as secchi depth) are a consequence of the amount of total nitrogen and total phosphorus in a lake. The resulting numeric

⁹ Burns, N., 2001. Trophic Level Index Baselines and Trends for 12 Rotorua District Lakes, 1990 to 2000. Report by Lakes Consultancy prepared for Environment Bay of Plenty.

¹⁰ Wilson, A., and Ngapo, N., 1993. Bay of Plenty Regional Soil Conservation Assessment. Bay of Plenty Regional Council unpublished report.

value is the TLI for an individual lake. The TLI methodology can be used to establish an average TLI value for a lake for the period over which water quality data has been collected, or determine the TLI trend during a specified period of time (i.e. the rate of change in the trophic level of a lake). An average TLI from one period can be used as a baseline, which can then be compared to a second average TLI from a later period of time. This comparison determines if lake water quality is remaining stable, improving or deteriorating. If water quality is found to be changing (either improving or deteriorating), the rate of change can then be investigated. This quantitative system provides definitive information about the state of the lake water quality in the region. The TLI methodology has been adopted by the Ministry for the Environment, and will be used in New Zealand to enable the comparison for water quality between different lakes. For a detailed explanation of the TLI methodology refer to 'Protocol for Monitoring New Zealand Lakes and Reservoirs' (Burns, 2000¹¹).

Para 3B An explanation of each of the TLIs in Objective 10 is given in Table 1B. Many of the TLIs have been set at the 1994 level, as at this time the community expressed the expectation lake water quality should be no lower than at that time during consultation on the Regional Plan for the Tarawera River Catchment. In 1993, Sigma Consultants et al¹², prepared a report for Rotorua District Council on the effects of land use activities on water quality. The report identified that lake water quality targets should be no less than their present (1993) quality.

Table 1B Explanation of TLI in Objective 10

Lake	Current TLI (at 2001)	TLI in Objective 10	Explanation of TLI in Objective 10
Okareka	3.3	3.0	Level in 1994. In 1994 the Regional Plan for the Tarawera River Catchment was publicly notified, which stated that lake water quality would be maintained at current state. Lake Okareka lies within the Tarawera Catchment. Lake water quality classifications have been updated in the Regional Water and Land Plan to include TLI's, but retain community ideal of 'no degradation from 1994'.
Okaro	5.7	5.0	Set at a realistic level that is lower than current TLI (i.e. to improve lake water quality).
Okataina	2.6	2.6	Level in 1994 (which has been unchanged).
Rerewhakaaitu	3.6	3.6	Level in 1994 (note: Environment Bay of Plenty has been working within the Rerewhakaaitu catchment due to concern about lake water quality degradation. However, this seems to be in relation to natural lake water level changes.)
Rotoehu	4.5	3.9	Set at a level that equates to the last 'good' year for water quality in the lake – 1992/93.
Rotoiti	3.9	3.5	Level in 1994. Relates to the year of notification of the Regional Plan for the Tarawera River Catchment, and consistency with the goal for other lakes (i.e. lake water quality to be maintained at 1994 levels).
Rotokakahi	3.3	3.3	Level in 1994 (which has been unchanged).
Rotoma	2.3	2.3	Level in 1994 (which has been unchanged).
Rotomahana	3.8	3.9	Level in 1994 (which is slightly higher than current water quality).
Rotorua	4.6	4.2	Level set in relation to the removal of sewage from the lake. When the Rotorua city sewage discharge was moved to land disposal, water quality expectations for the lake were stated in documents associated with the consent.

¹¹ Burns, N., 2000. Protocol for Monitoring New Zealand Lakes and Reservoirs. Ministry for the Environment.

¹² Sigma Consultants, NIWA, Bioresarches Ltd, and NZFRI, June 1993. Report on Rural Land Use Practices in the Rotorua District. Report prepared for Rotorua District Council.

Schedule 7 - Trophic Level Indices For Lakes

Lake	Classification Trophic Level Index (TLI)	Current Trophic Level Index	Comment
Okareka	3.0	3.4	TRI set at 1994 baseline in relation to the Proposed Regional Plan for the Tarawera River Catchment.
Okaro	to be developed		
Okataina	to be developed		
Rerewhakaaitu	to be developed		
Rotoehu	3.9	4.7	TLI set at the median values of the three 'good' years before blue-green algal blooms commenced.
Rotoiti	to be developed		
Rotokakahi	3.1	3.2	TRI set at 1994 baseline in relation to the Proposed Regional Plan for the Tarawera River Catchment.
Rotoma	to be developed		
Rotomahana	3.9	3.8	TRI set at 1994 baseline in relation to the Proposed Regional Plan for the Tarawera River Catchment.
Rotorua	to be developed		
Tarawera	2.6	2.6	TRI set at 1994 baseline in relation to the Proposed Regional Plan for the Tarawera River Catchment.
Tikitapu	2.7	2.7	TRI set at 1994 baseline in relation to the Proposed Regional Plan for the Tarawera River Catchment.

Scale of Trophic Level Index

<3.0	oligotrophic
3.0 - 4.0	mesotrophic
>4.0	eutrophic

4.12 LAKE REREWHAKAAITU

This lake essentially consists of two different basins : the main basin which is relatively shallow (15 m) and is easily mixed by wind action, and a deeper (31 m) explosion crater, Awaatua, which strongly stratifies. Awaatua is now physically separated from Lake Rerewhakaaitu and thus is not considered in this report. There is one principal inflow, the Mangakino Stream, and normally no surface outflow from the lake. (Table 4.12.1).

Pasture contributes in excess of 90 % of the nutrient input. (Tables 4.12.2 & 4.12.3; Figure 4.12.1). The potential contribution of nutrients by the sediment in Awaatua, as a result of stratification and deoxygenation of bottom waters is unknown. One particular characteristic of this lake is the rapid removal of reactive phosphorus that enters the lake, the mechanism being either chemical (Fish 1978) or biological (White & Payne 1980).

The lake is described as mesotrophic i.e. with a moderate level of productivity, (BOPRC 1991) although recent monitoring by the Regional Council indicated clear water (Secchi disc : 5 m) and generally low levels of nutrients (Table 4.12.4). Fish noted (1978) that Rerewhakaaitu was a difficult lake to characterise in terms of its trophic status.

The lake is used for fishing and boating and because of its shallow nature there are extensive areas of swamp and marsh vegetation on the lake margins that provide nesting sites and habitat for a number of species of water birds. Some 40 % of the lake bed has been colonised by a recently introduced submerged macrophyte, Lagarosiphon major. (BOPRC 1991).

The recent water quality data obtained by the Regional Council in 1990-91 (Table 4.12.4) indicates that the water quality of the lake has improved over the past 9 years. Should this trend continue then it would indicate that there are mechanisms already operating either within the lake (biological utilisation or chemical removal) or the catchment (changes in farming practices) that are acting to reduce the availability of nutrients to the lake ecosystem. The fact that the lake is located in a pastoral catchment that has been identified as the principal source of nutrients provides scope for ensuring that the present nutrient input levels do not increase by encouraging conversion of pasture into forest and/or fencing off the lake margins to provide riparian protection. (BOPRC 1991). No additional actions are recommended until the monitoring data provides a clear indication of the water quality trends in the lake (Table 4.1.1).

Appendix Four

Lake Rerewhakaaitu 1990 to 2001 (1 Jul 1990 - 30 Jun 2001)

Percent Annual Change (PAC)

Lake	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TN (mg/m3)	HVOD (mg/m3/day)	Avg PAC	Std Err	P-Value
Change - Units Per Year	(0.15)	(0.00)	(-0.11)	3.58				
Average Over Period	(4.71)	(5.34)	(7.09)	365.89				
Percent Annual Change (%/Year)	0.00	0.00	0.00	0.98	0.00	0.24	0.24	0.39

Trophic Level Index Values and Trends

Period	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TN (mg/m3)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI Trend units/yr	Std. Err. TLI trend	P-Value
Jul 1990 - Jun 1991	3.90	4.95	9.83	321.86	3.72	3.60	3.12	3.94	3.60	0.17			
Jul 1991 - Jun 1992	3.14	6.34	8.00	356.96	3.48	3.28	2.86	4.07	3.42	0.25			
Jul 1992 - Jun 1993	2.74	6.40	5.47	314.17	3.33	3.27	2.37	3.91	3.22	0.32			
Jul 1993 - Jun 1994	2.20	5.97	5.40	295.53	3.09	3.36	2.36	3.83	3.16	0.31			
Jul 1994 - Jun 1995	2.42	5.50	6.90	333.11	3.19	3.47	2.67	3.98	3.33	0.27			
Jul 1995 - Jun 1996	7.80	3.26	8.86	398.14	4.49	4.13	2.98	4.22	3.95	0.33			
Jul 1996 - Jun 1997	8.43	3.75	10.53	446.27	4.57	3.96	3.20	4.37	4.02	0.30			
Jul 1997 - Jun 1998	17.18	3.84	9.67	547.67	5.36	3.93	3.10	4.63	4.25	0.48			
Jul 1998 - Jun 1999	7.38	2.40	6.00	499.50	4.42	4.50	2.49	4.51	3.98	0.50			
Jul 1999 - Jun 2000													
Jul 2000 - Jun 2001	2.64	6.49	5.74	358.18	3.29	3.25	2.43	4.08	3.26	0.34			
Averages	5.78	4.89	7.64	387.14	3.90	3.67	2.76	4.15	3.62	0.11	0.05	0.04	0.2123

SUMMARY:

PAC = 0.24 ± 0.24 % per year
P-Value = 0.39

TLI Value = 3.62 ± 0.11 TLI units
TLI Trend = 0.05 ± 0.04 TLI units per year
P-Value = 0.2123

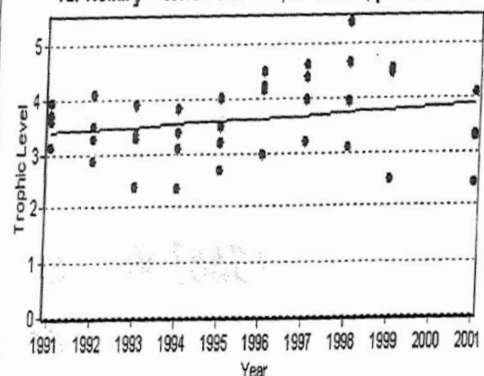
ASSESSMENT:

Mesotrophic
No Change

The guide used in the PAC average
P-Value evaluation is

P-Value Range	Interpretation
$P \leq 0.1$	Definite Change
$0.1 < P \leq 0.2$	Probable Change
$0.2 < P \leq 0.3$	Possible Change
$0.3 < P$	No Change

TLI Trend: $y = -89.16 + 0.04649x$; $R = 0.2016$; $p = 0.2123$



Appendix Five

MANAGEMENT OF PHOSPHORUS AND NITROGEN INPUTS TO LAKE ROTORUA, NEW ZEALAND

By J. C. Rutherford,¹ R. D. Pridmore,² and E. White³

ABSTRACT: The water quality of Lake Rotorua has deteriorated since the 1960s because of excessive phytoplankton growths caused by increased inputs of phosphorus and nitrogen from the Rotorua city sewage treatment plant. Removal of phosphorus alone may produce no measurable improvement in lake condition unless it can be made the limiting nutrient. Even then, this may take a number of years, because of recycling of phosphorus already in the lake system. Removal of nitrogen alone may reduce phytoplankton growth in the short term (say 5–10 yr) but is not recommended because the algal community may become dominated by heterocystous blue-green algae, which can meet their nitrogen requirements by fixing dissolved molecular nitrogen and form dense unsightly assemblages. Thus, removal of both nitrogen and phosphorus is recommended. A suggested aim is to restore the lake condition to that which prevailed prior to the 1960s, before widespread public concern about phytoplankton growths developed. The scientific view is that this lake condition is achievable and will reduce the frequency and magnitude of nuisance algal blooms, maintain reasonable water appearance and clarity for recreational purposes, minimize periods of deoxygenation, and reduce internal nutrient inputs. Removal of all sewage effluent from the catchment is expected to achieve the nutrient load reduction that is required. Any sewage discharge increases the risk that the lake condition will be unsatisfactory, but this risk is probably low if the sewage inputs are less than 3 tonnes (t) of phosphorus and 30 t of nitrogen per year.

INTRODUCTION

Lake Rotorua is a large (surface area = 81 km²), shallow (mean depth = 10.7 m), eutrophic lake which has important recreational and Maori cultural values. It is situated on the central volcanic plateau of the North Island of New Zealand. Of the catchment (424 km²), 30% is unmodified and 70% is pastoral farmland, exotic forest, or urban area. Treated sewage effluent from Rotorua City (pop. 60,000) is discharged into the lake. There has been a steady deterioration of lake water quality from 1976 to the present associated with an increased sewage nutrient load (Rutherford 1984). Lake Rotorua stratifies intermittently during November–March, typically for periods of 3–10 days but occasionally for >20 days. During stratification, hypolimnetic oxygen depletion and nutrient release from the sediments (internal nutrient inputs) have been observed (Fish 1975; White et al. 1978).

The objectives of this paper are to review recent trends in some of the water characteristics of Lake Rotorua, to comment on its external and internal inputs of nitrogen and phosphorus, to discuss the recommended external nutrient input targets set for the lake, and to estimate the likely recovery rate of the lake following nutrient diversion.

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Note. Discussion open until December 1, 1989. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on July 22, 1988. This paper is part of the *Journal of Water Resources Planning and Management*, Vol. 115, No. 4, July, 1989. ©ASCE, ISSN 0733-9496/89/0004-0431/\$1.00 + \$.15 per page. Paper No. 23640.