BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

Lake Tarawera Nutrient Budget

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Part 1: Introduction

Policies relating to the environmental quality of the Rotorua lakes in the Bay of Plenty Regional Council's Water and Land Plan are based on measured parameters of the lake water. When the measured indicator fails to meet the standard set in the plan, a remediation process is initiated. Lakes fail to comply when there is an oversupply of nitrogen and phosphorus due to the prevailing land uses. To reduce the nitrogen and phosphorus load some changes in land use or land management are required or some other intervention may be employed to achieve the same end.

Once the Trophic Level Index (TLI) value for a lake has exceeded the Regional Water and Land Plan's TLI target specified in Objective 11 by 0.2 for two consecutive years, Stage 3 of Method 41 of the Plan is initiated. Stage 3 is development of an Action Plan for the lake catchment which includes quantifying the reduction of nitrogen and phosphorus to achieve the Objective 11 TLI. The target TLI for Lake Tarawera is 2.6 TLI units and the catchment nitrogen and phosphorus load reduction target is calculated from the difference between the TLI of 2.6 and the current TLI.

A nutrient budget has been estimated for Lake Tarawera based on nutrient export coefficients calculated from the scientific literature (Menneer *et al.* 2004). From this information, the size of the manageable portions of nitrogen and phosphorus inflows can be considered. To estimate the magnitude of nitrogen and phosphorus to be reduced a separate assessment has been carried out. In this case the total catchment input of nitrogen and phosphorus has been estimated from the in-lake nutrient levels. A budget from Hoare (1980) is used for this assessment as per the method of NIWA (Rutherford and Cooper 2002) in proposing targets to return Lake Tarawera to its objective TLI of 2.6 specified in the Water and Land Plan. For the Tarawera basin, a very accurate budget can be estimated because the flow through the lake is continuously monitored and recent groundwater investigations (White *et al.* 2010) have provided a measurement of groundwater flow from the lake.

An increasing trend of phosphorus and nitrogen concentrations has been recorded in Lake Tarawera from 1994 to 2008 (Scholes, 2010). Since then (2009 to 2011) the nitrogen concentration has fallen but the phosphorus concentration has remained elevated and increased.

There are seven lakes within the catchment of Lake Tarawera and each of these has residence times of at least several months to years. The residence time of Tarawera itself is seven years. According to models based on this figure and lake morphology it will be of the order of 25 years before the lake equilibrates to a step change in nutrient loads from its catchment (pers comm. Prof. D Hamilton). Accordingly, the current state of the lake is taken as the median of the last 11 years of annual average data (Scholes, 2011) from July 1999 to June 2011. Short-term fluctuations in nitrogen and phosphorus concentrations which have occurred over recent years may be part of the usual variation or could indicate a change in the state of the lake due to land use change some decades ago.

Part 2: Nutrient budget

The catchment boundary and land use type and area have been supplied by the GIS section of the Bay of Plenty Regional Council. (Land Use Data: LandcoverUse_RotLakes03-2003 land use data from Rotorua Lakes. Catchment data: Catchments_RDCLiDAR-boundaries derived from 2006 LiDAR data).

This analysis in Table 1 relates to the land within the catchment of Lake Tarawera only as specified by the job brief. This is compared to the budget (Hamilton *et al.* 2006) where the catchment of Lake Tarawera plus those of the other lake catchments are considered individually and added to obtain a total load for the whole Tarawera basin.

Table 1 Nutrient budget for the catchment of Lake Tarawera (omitting the catchments of other lakes of the complete drainage basin) based on land-use nutrient loss estimates.

	Area	Rate of P loss	Rate of N loss	P Load	N Load
	ha	kg/ha/yr	kg/ha/yr	kg/yr	kg/yr
Bare Ground	279.5	0.5	3	140	839
Exotic Forest	1524.4	0.4	4	610	6098
Indigenous Forest	6421.0	0.28	3	1798	19263
Mixed scrub/pasture	136.6	0.5	5	68	683
Mixed sheep/beef/deer	1725.9	1	10	1726	17259
Beef	81.1	1	15	81	1217
Horse/lifestyle grazing	21.1	0.8	8	17	169
Recreation/other grass	50.0	0.3	4	15	200
wetland	0.1	0	0	0	0
Urban built (stormwater)	93.5	0.8	8	75	748
Septic tanks (3.65 kgN/p/yr, 0.37 kgP/p/yr)	1512	people		552	5519
Rainfall on lake	4138.8	0.15	4	621	16555
Total	15704.5			**5562**	**67710**

Stormwater (Urban built) estimates are derived from Williamson (1985).
Rainfall nutrients to lake (Hoare, 1987).
Septic tank discharge from BOPRC data.

A large amount of the bare ground would be on Mount Tarawera and a nominal nutrient export has been allocated. A population of 1,512 people allows for the impact of the septic tank leachate from residents as well as visitors using public toilets. In comparison the nutrient budget (Hamilton *et al.* 2006) derived loads of 6,036 kg P/yr and 51,146 kg N/yr from the immediate catchment of Lake Tarawera. The phosphorus loads are reasonably comparable but a higher nitrogen export is estimated in the current report by the use of higher nitrogen export coefficients for forestry and grazing land uses.

The purpose of estimating the above catchment outputs of nitrogen and phosphorus is to assess the size of the manageable portions of the load. In this case the urban load and the output from pastoral land uses are the manageable loads.

Part 3: Catchment load from in-lake nutrient levels

This ‘back calculation’ is based on a method used by Hoare (1980) for Lake Rotorua. The general concept is shown in Figure 1.

A monitoring site has continuously recorded the outflow of Lake Tarawera since 1972. A mean flow of 6.7 m^3/s (1972 – 2005) is calculated for the Tarawera Lake outlet site in the Bay of Plenty Regional Council’s Environmental Data Summaries (2005). Recent groundwater investigations (White *et al.* 2010) have provided an estimate of groundwater flow from the catchment of the Tarawera group of lakes. An additional 4 m^3/s is added to the surface discharge so that the average annual discharge from the Tarawera group of lakes is 10.7 m^3/s. This flow rate is used in the calculation of nutrient loads as there is a large discharge of water to Lake Tarawera from the contributing catchments of several other lakes (Okataina, Okareka, Tikitapu, Rotokakahi, Rotomahana, Okaro, part of Rerewhakaaitu), which makes the calculation of a water balance from rainfall data difficult.

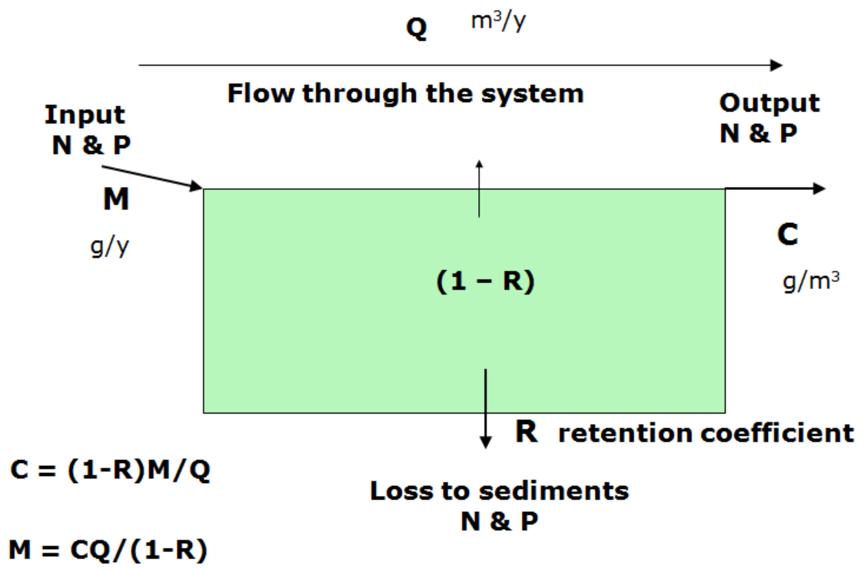

Figure 1 Schematic of lake model.

With these assumptions the catchment nutrient load (M) in the equation above can be calculated.

There are empirical formulae for calculating the phosphorus retention coefficient. In this case R is calculated to be 0.57, based on the method of Nurnberg as described in Rutherford and Cooper (2002) and shown in Table 2 below. Professor Hamilton has independently calculated a retention coefficient of 0.53 (pers comm).

Hoare (1980) found that the R value in Lake Rotorua was similar for nitrogen and phosphorus. This has been assumed for Lake Tarawera.

An assessment of the nitrogen and phosphorus load discharged to Lake Tarawera is carried out using the median lake concentration from 1999 to 2011 (Table 2) and the average annual outflow at the Tarawera lake outlet for 1972 to 2005 (Bay of Plenty Regional Council Environmental Data Summaries to Dec 2005) plus an estimate of groundwater discharge from White *et al.* (2010).

In contrast to the nutrient budget in Table 1, the estimate in Table 2 relates to the whole drainage basin of the Tarawera catchment to Lake Tarawera.

Table 2 Nutrient budget derived from in-lake nutrient concentrations based on the median annual average lake nutrient levels from 1999 to 2011 (Scholes 2011) and the average flow from the lake outlet.

lake concentration mg/m^3	10.59	112.32		**C**
	land	**lake**	**total**	
Lake volume (m^3)		2273700000		
Area (ha)	10833	4138.8		
flow (l/sec)	10.7			
flow/yr(m^3)			337435200	**Q**
Hydraulic loading (Q/lake area A) (m/yr)			8.2	**Q/A**
Retention R (15/(18+Q/A))			0.57	**R**
	TP	**TN**		
M=CQ/(1-R) kg/yr	8379	88875		**M**

In Table 2, the load M estimated for the whole drainage basin would be expected to be higher than the load estimated for the immediate catchment of Lake Tarawera. The phosphorus load is 51% higher and the nitrogen load 31% higher in Table 2 compared to Table 1. Hamilton *et al.* (2006) estimated that the whole basin load on Lake Tarawera was about 65 – 70% higher than the immediate load from their estimate of the load from the Lake Tarawera catchment. However, the whole catchment nitrogen load of Hamilton *et al.* (2006) is very similar to the load calculated above in Table 2 and the phosphorus load is reasonably close, being only 24% higher than that calculated in Table 2.

The difference in nutrient load estimates for the Lake Tarawera catchment between the estimates of Hamilton *et al.* (2006) and the estimates in Table 1 relate specifically to the export coefficients for forestry and pastoral land uses, particularly for nitrogen rather than for phosphorus.

Part 4: Nutrient reduction target

The TLI for 2010 met the objective TLI (2.6) of the Regional Water and Land Plan although the average lake phosphorus concentration was higher than it was in the early 1990s when the lake conformed to the target TLI value. Why the TLI decreased in 2010 is not known. In 2011, the TLI increased to 2.8 but exhibited an unusual condition with a very low nitrogen:phosphorus ratio.

The approach taken to adopting a nutrient reduction target is to regard the median nutrient concentrations from 1999 to 2011 as the typical lake condition. This is done having regard to the long residence time, of about 7-10 years, of water in Lake Tarawera and the uncertainty of the influence of changes in nutrient levels of water flowing from other lake catchments.

A nitrogen reduction consistent with removing septic tanks as part of the reticulated sewage scheme and implementation of considerable pastoral runoff remediation is needed to meet the target. The balance of the nutrient reduction would be achieved by reducing phosphorus inputs from all sources.

A reduction in the annual average concentration of total phosphorus of 1-2 mg/m^3 and total nitrogen of 16 mg/m^3 and chlorophyll and secchi disc data consistent with the levels in 2010 is calculated to attain the TLI of the W&L Plan.

Table 3 Nutrient load reduction derived from the reduction of in-lake nutrient concentrations calculated to attain the TLI objective of the Water and Land Plan.

lake concentration mg/m^3	1.59	16.32		C
	land	**lake**	**total**	
Lake volume (m^3)		2273700000		
Area (ha)	10833	4138.8		
flow (l/sec)	10.7			
flow/yr(m^3)			337435200	**Q**
Hydraulic loading (Q/lake area A)			8.2	**Q/A**
Retention R (15/(18+Q/A))			0.57	**R**
	TP	**TN**		
M=CQ/(1-R) kg/yr	1258	12913		**M**

Table 3 shows the loads of nitrogen and phosphorus that need to be reduced from Lake Tarawera inputs.

- Target load reduction for phosphorus 1,200 kg/yr
- Target load reduction for nitrogen 12,000 kg/yr

The average nitrogen concentration in Lake Tarawera in 2009/2010 and 2010/2011 has been consistent with the nitrogen target being met already but there is no basis yet to believe this is sustainable. For the reasons given above relating to residence time any action which could have resulted in an in-lake nitrogen reduction would have occurred up to decades ago. If it is a real reduction it might relate to the establishment of forestry in the catchment. The large surplus of phosphorus that has occurred in Lake Tarawera in 2010/2011 is consistent with a step change in nitrogen in a lake with a tendency towards nitrogen limitation. Similar circumstances have occurred in Lakes Rotorua and Rotoehu.

Part 5: Conclusion

Nutrient concentrations in Lake Tarawera have increased over the past decade but nitrogen has shown signs of decreasing in the last two years. This reduction cannot be relied on to be sustainable without taking some action within the catchment. Some specific actions can be taken to reduce the nutrient load on the lake.

Reticulating sewage out of the catchment will remove at least five tonnes of nitrogen from the annual load. The balance of the nitrogen load could be reduced by management actions on pastoral lands to intercept and reduce the effect of runoff waters and other actions such as wetland creation.

Almost half the target for phosphorus would be reduced from the lake inputs in reticulating sewage. Conservation methods applied to urban stormwater and rural run-off would be required to remove a greater load. Previously alum dosing of a stream was considered and also dosing a phosphorus adsorbing material in the littoral zone around the area of settlement. The latter method was to absorb phosphorus discharged from septic tanks in this environment and reduce the frequency of occurrence of blue-green algal blooms around the settlement.

Planning instruments to control nutrient loss to water bodies are important especially maintaining forest land use. A step change reduction in nitrogen in Lake Tarawera since 2009 could be related to a major catchment activity such as conversion of pastoral land to forestry several decades ago. Crater Block at Rerewhakaaitu/Rotomahana was one such conversion in the 1970s.

Land development in the lake catchments is a high priority issue for developers and residents, with district and regional plans both containing regulatory mechanisms to protect lake quality. A common approach and consistency between district and regional plans can be achieved within an action plan.

Part 6: References

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