Lake Ōkataina Nutrient Budget

Prepared for Bay of Plenty Regional Council

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1 Introduction

Once a lake's Trophic Level Index (TLI) has exceeded the Regional Water and Land Plan's (three year average) 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. Target TLI for Lake Ōkataina is 2.6.

A nutrient budget has been estimated for Lake Ōkataina based on nutrient export coefficients calculated from measured stream nutrient concentrations. These have been modified to match similar export coefficients from the scientific literature (Menneer *et al*. 2004). To verify the magnitude of the total nutrient budget 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 Rutherford and Cooper (2002) in proposing targets for the Lake Ōkataina Action Plan.

2 Nutrient budget

Nutrient export calculations in Table 1 were based on nutrient analyses of streams flowing into Lake Ōkataina. The final landuse nutrient coefficients chosen were based on the best fit to the scientific literature values derived from local studies.

The catchment boundary and land use portions have been supplied from the latest version created by the GIS section of the Bay of Plenty Regional Council.

Table 1 Nutrient budget 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	2.7	0.15	4	0.4	10.8
Exotic forest	436.0	0.40	4	174.4	1744.0
Indigenous forest	4224.8	0.28	3	1182.9	12674.4
Pastoral land	548.7	1.00	15	548.7	8230.5
Reserve, buildings, parking	2.8			0.9	71.0
wetlands	7.6			0.0	0.0
Sewage, septic waste (30 persons/d; 3.65 kgN/p/yr, 0.37 kgP/p/yr)				11.00	110.00
Rainfall on lake	1067.9	0.15	4	160.2	4271.6
TOTAL	**6291**			**2079**	**27112**

Stormwater (reserve and parking area) estimates are from Williamson (1985).
Rainfall nutrients to lake (Hoare, 1987)

The flow rate in the streams was very small compared to the discharge expected of the catchment and it was assumed that the median phosphorus concentration would represent geologically derived phosphorus rather than landuse derived phosphorus. The lowest discharge load of the stream phosphorus was chosen as best approximation for the catchment phosphorus runoff concentration for forest land use. A greater rate of phosphorus loss was expected to derive from the exotic forestry (Hamilton 2005). A higher level of phosphorus export is characteristic of pastoral land. The export coefficient calculated from the median total phosphorus level in the stream samplings was very close to the commonly used pastoral phosphorus export coefficient. This has been used for pastoral phosphorus export. It may be high for the intensity of pastoral use in the Ōkataina catchment but compensates for geologically derived phosphorus discharged in the small springs which may have 'old-age' groundwater.

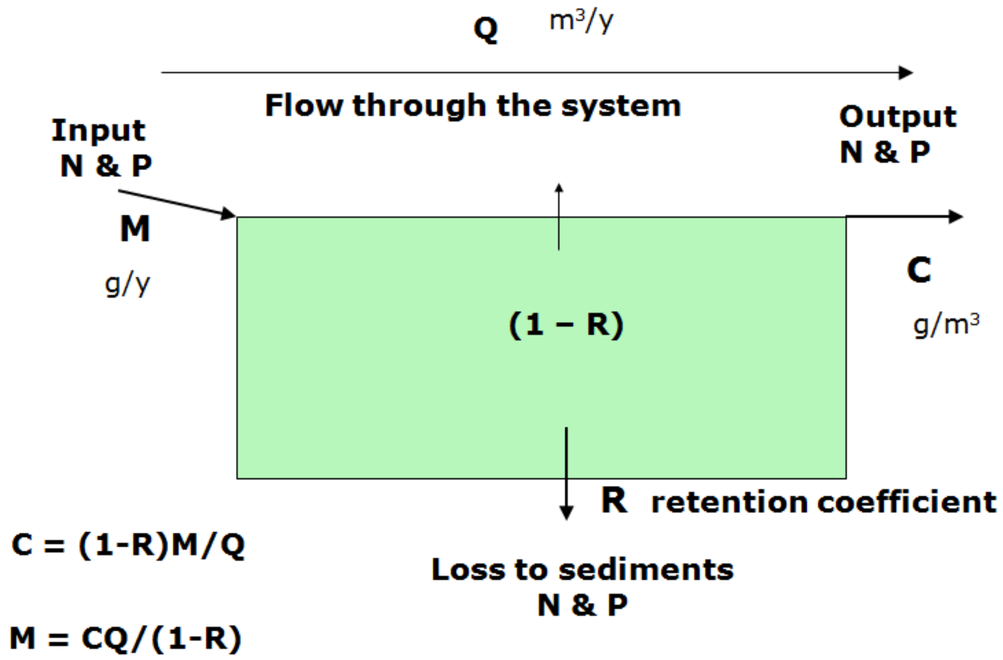
The low to median range of nitrogen concentration in the streams is equivalent to a nitrogen export range of 3 - 4 kg/ha/yr, which is within the commonly used export coefficient range for forest land. This has been used for native and exotic forest. The highest nitrate-nitrogen levels were about 0.5 g/m^3. It is assumed that these relatively high levels would arise from a landuse leaching more nitrogen than forestry and this concentration has been used to calculate the export coefficient for pastoral landuse around the Ōkataina catchment. The export coefficient of 15 kg N/ha/yr is commonly used to represent nutrient loss for moderate intensity sheep and beef farming.

3 In-lake nutrient levels

Catchment nutrient load can be modelled based on in-lake nutrient concentrations (C), flow through the system (Q), and nutrient retention within the lake (R). This 'back calculation' is based on a method used by Hoare (1980) for Lake Rotorua. The general concept is shown in the figure below.

At Ōkataina it is not possible to measure an outflow so it is assumed that the out-flowing water is the same concentration as average lake water. The flow rate through the lake cannot be measured so rainfall – evapo-transpiration is calculated and added to the quantity of water falling directly on the lake. There are empirical formulae for calculating the retention coefficient. In this case R is calculated to be 0.62 based on the method of Nurnberg (1984) as described in Rutherford and Cooper (2002).

Figure 1 Schematic of lake model.



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

Average annual rainfall at Okere (BOPRC data summaries 2005) = 1927 mm.

Average annual evapo-transpiration (Et) for catchment 980 mm (Rutherford et al 2009, 2011) (Whitehead and Kelliher 1991).

Evaporation from lake surface = 500 mm (Rutherford and Cooper, 2002)

In the calculations below, the average lake concentration is assumed to be the average concentration from mid 2007 to mid 2010, from Scholes (2010).

The estimate of the catchment load, from in-lake nutrient concentrations (Table 2) is of a similar order to the estimate from land use export coefficients, septic tank and stormwater input, with phosphorus being 27 % lower and nitrogen 24 % lower.

Table 2 Nutrient budget derived from in-lake nutrient concentrations based on the average lake nutrient levels from mid 2007 – mid 2010 (Scholes 2010).

	TP	**TN**		
lake concentration mg/m^3	8.75	119.77		**C**
	land	**lake**	**total**	
Lake volume (m^3)		466010000		
Area (ha)	5222.6	1067.9	6290.5	
(rain -evt)m	0.947	1.427		
flow (l/sec)	1568.3		2051.5	
flow/yr(m^3)	49458022	15238933	64696955	**Q**
Hydraulic loading (Q/lake area A) m/y			6.1	**Q/A**
Retention R (15/(18+Q/A))			0.62	**R**
	TP	**TN**		
M=CQ/(1-R) kg/yr	1504	20580		**M**

Rainfall 1927 mm/yr, evaporation (catchment) 980mm/yr (Rutherford et al, 2009, 2011) Whitehead and Kelliher 1991), evaporation (lake) 500 mm/yr (Rutherford and Cooper, 2002).

Hoare (1980) found that the R value in Lake Rotorua was similar for nitrogen and phosphorus. This has been assumed for Lake Ōkataina and the same R value used for both nitrogen and phosphorus. Results from this and several other lake nutrient budgets suggest that the R value is likely to be similar but not equal.

4 Sensitivity analysis

The spreadsheet model in Figure 2 is tested for its sensitivity by adjusting the R value by ± 0.10 and rainfall by ± 0.1 m.

Table 3 shows that the calculation is sensitive to changes in the retention coefficient. A retention coefficient of 0.72 better matches the spreadsheet nutrient load output in Table 1. It is possible that the equation used to calculate the retention R underestimates the actual retention in Lake Ōkataina.

Table 3 Comparison of predicted annual nutrient input to Lake Ōkataina by varying the retention coefficient.

	Total Phosphorus kg/yr	*Total Nitrogen kg/yr*
R = 0.52	1180	16140
R = 0.62	1500	20500
R = 0.72	2020	27700

Table 4 Comparison of predicted annual nutrient input to Lake Ōkataina by varying the rainfall in the rainfall – evapotranspiration (ET).

Rain – ET m	*Total Phosphorus tonne/yr*	*Total Nitrogen tonne/yr*	*R*
0.747	1350	18560	0.65
0.847	1430	19590	0.64
0.947	1500	20580	0.62
1.047	1570	21530	0.61

There is poor rainfall data for the Ōkataina catchment although there are four rain gauges in adjoining catchments. A lower rainfall (or higher ET) than used for the calculation in Table 2 produces a lower output than Table 2 calculates, and higher rainfall a higher output and the R value decreases.

The rainfall estimate has no confirmation from a gauge in the Ōkataina catchment. Nevertheless, the agreement between Tables 1 and 2 is reasonable considering that the pasture export coefficients in Table 1 are estimates for relatively productive systems and at least some of the pasture in the Okataina catchment appears to be of low productivity.

5 Nutrient reduction target

The objective TLI for Lake Ōkataina is 2.6 and the median TLI for the three years period 2007 – 2010 was 2.8. A reduction in lake nitrogen and phosphorus of 5 and 2.2 mg/m^3 is required to lower the TLI to 2.6. This can be converted to a catchment load.

• Target load reduction for phosphorus	380	kg/yr
• Target load reduction for nitrogen	860	kg/yr

That is about one/tenth of the estimated nitrogen load from pasture but over half the phosphorus load. Nitrogen tends to be the nutrient that has a greater effect on algal growth in Lake Ōkataina so a reduction in nitrogen may lower the other components of the TLI (secchi disc clarity and chlorophyll *a*) sufficiently to attain the target TLI without fully meeting the phosphorus target.

6 Conclusion

A nutrient budget has been derived from the latest determination of landuse for the Okataina catchment. About one third of the catchment nutrient load, calculated in Table 1, comes from pastoral landuse. It is possible that reductions could be made in nutrient loss from these areas but a survey of the properties would be needed to provide recommendations for remedial action.

At the north end of the lake there is a Lodge and public toilet facilities. The impact of wastewater from these facilities has been estimated from visitor figures. There is a nutrient contribution from septic tanks and wastewater treatment systems at these sites, which is in the order of 10% of the nitrogen reduction target and 3% of the phosphorus reduction target.

An engineer's report on the sewage treatment plant at the lodge, referenced to the resource consent, could be requested from Rotorua District Council as well as the public toilet disposal systems. Catchment monitoring of springs and streams could be continued while the planning process was initiated.

Pastoral land use and septic tank effluent disposal would be the two primary land uses where investigations into methods of nutrient control could lead to a reduction in the nutrient load on the lake.

There is a lack of raingauge data between Rotorua airport and Lake Rotoma and at least one site in the Ōkataina catchment would assist future hydrological studies.

7 References

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