



Lake Waipori and Lake Waihola: Trophic Level Status



March 2005

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Executive Summary

Lake Waipori and Lake Waihola are situated on the lower Taieri Plain, 30 km south-west of Dunedin and 10 km from the coast. The lakes are situated in the Waipori-Waihola wetland complex that covers 2000 ha.

There has been concern that water quality in the lakes is deteriorating due to an increase in the intensity of land use, particularly dairying and forestry. In addition the flood control scheme and associated land drainage in the lower Taieri plain has changed the hydrological regime of the lakes.

To address this concern the Otago Regional Council began a two year trophic level monitoring programme to establish a baseline water quality level for the lakes. Monthly water sampling at three sites in Lake Waihola and two sites in Lake Waipori commenced in October 2002 and finished in October 2004. The sites selected for sampling were the same as those used by the University of Otago during a monitoring programme that ran between 1997 and 1998. In this way five years of data was available to calculate the trophic status of the lakes.

Four key variables were measured, chlorophyll *a* (Chla), secchi depth (SD), total phosphorus (TP) and total nitrogen (TN). For each of these trophic level indicators significant trends were calculated using Percent Annual Change (PAC) values and the Trophic Level Index (TLI) was also calculated which classifies the actual state of a lake at a specific time.

The monitoring results indicate that:

- Lake Waihola is classified as supertrophic and not changing status at present although between 1997 to 1998 there had been probable deterioration in its condition.
- Lake Waipori is classified as eutrophic and not changing status at present.

This baseline water quality level is an absolute measure of water quality for each lake, which will enable future monitoring to determine whether water quality in the lakes is improving or deteriorating.

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1. Introduction

As early as 1978 the Lower Taieri River (which includes Lake Waipori and Lake Waihola) was included in a list of eight water bodies in New Zealand where eutrophication was identified as an issue (OCB, 1983). More recent Otago Regional Council water quality monitoring had also noted elevated total phosphorus and total nitrogen concentrations.

In order to gain a better understanding of the nutrient status of the lakes a two year trophic level investigation was carried out between October 2002 and October 2004.

1.1 Objectives

The aim of the trophic level monitoring programme was to establish a baseline water quality level for Lake Waipori and Lake Waihola. By obtaining this absolute measure of water quality in each lake, future monitoring will be able to determine whether water quality in the lakes is improving or deteriorating.

Specific objectives include:

1. To obtain detailed physical-chemical water quality data for Lake Waipori and Lake Waihola.
2. To assign a numerical value for the trophic level of the lakes and to be able to quantify a change in this value.
3. To enable the establishment of an efficient and economic system of routine monitoring for the lakes.

2. Background Information

2.1 Catchment Description

Lake Waipori and Lake Waihola are situated on the lower Taieri Plain, 30 km south-west of Dunedin and 10 km from the coast (Figure 2.1). The lakes are situated in a wetland area that covers 2000 ha. The wetland is regarded as one of the largest and most significant remaining freshwater wetlands in New Zealand and supports a diverse and highly productive ecosystem.

Table 2.1 Land use in Lake Waipori and Lake Waihola Catchments

Waipori Catchment Summary (Meggat Burn)			Waipori Catchment Summary (West Taieri)		
Class	Hectares	% LC/CA	Class	Hectares	% LC/CA
			Indigenous Forest	429	4%
Inland Water	238	6%	Inland Water	8	0%
Inland Wetlands	138	3%	Inland Wetlands	3	0%
Planted Forest	3179	74%	Planted Forest	76	1%
Primary Pastoral	685	16%	Primary Pastoral	10077	88%
Scrub	50	1%	Scrub	313	3%
Tussock	33	1%	Tussock	462	4%
			Urban	57	0%
TOTAL	4324		TOTAL	11425	
Waipori Catchment Summary (Waipori)			Waihola Catchment Summary		
Indigenous Forest	2600	7%	Indigenous Forest	120	2%
Inland Water	1943	5%	Inland Water	675	9%
Inland Wetlands	194	0%	Inland Wetlands	96	1%
Planted Forest	7589	19%	Planted Forest	1194	16%
Primary Pastoral	8810	22%	Primary Pastoral	5167	68%
Scrub	799	2%	Riparian Willows	21	0%
Tussock	17763	45%	Scrub	270	4%
			Urban	44	0%
TOTAL	39698		TOTAL	7587	

Source: Landcover Database Version 1 (LCDBV1) 2000

Lake Waipori covers an area of 200 hectares and has a large upstream catchment which includes the Waipori River (39698ha) and the Meggat Burn (4324 ha). Water also flows into the lake from the West Taieri drainage system which comprises the Main West Taieri Drain and Contour Channel (11425 ha). The Meggat Burn catchment is predominantly forestry plantation, the Waipori catchment is mainly tussock with forestry and sheep and beef farming in the lower reaches. The Main Drain and Contour Channel catchments (West Taieri) have significant amounts of intensive agriculture (particularly dairying) within their catchments.

Lake Waihola covers an area of 62 hectares and receives water directly from the surrounding agricultural and indigenous forest catchment. Channels on the eastern side of the lake are connected to the lower Waipori River.

Table 2.1 shows the percentage of different land uses in the catchments.

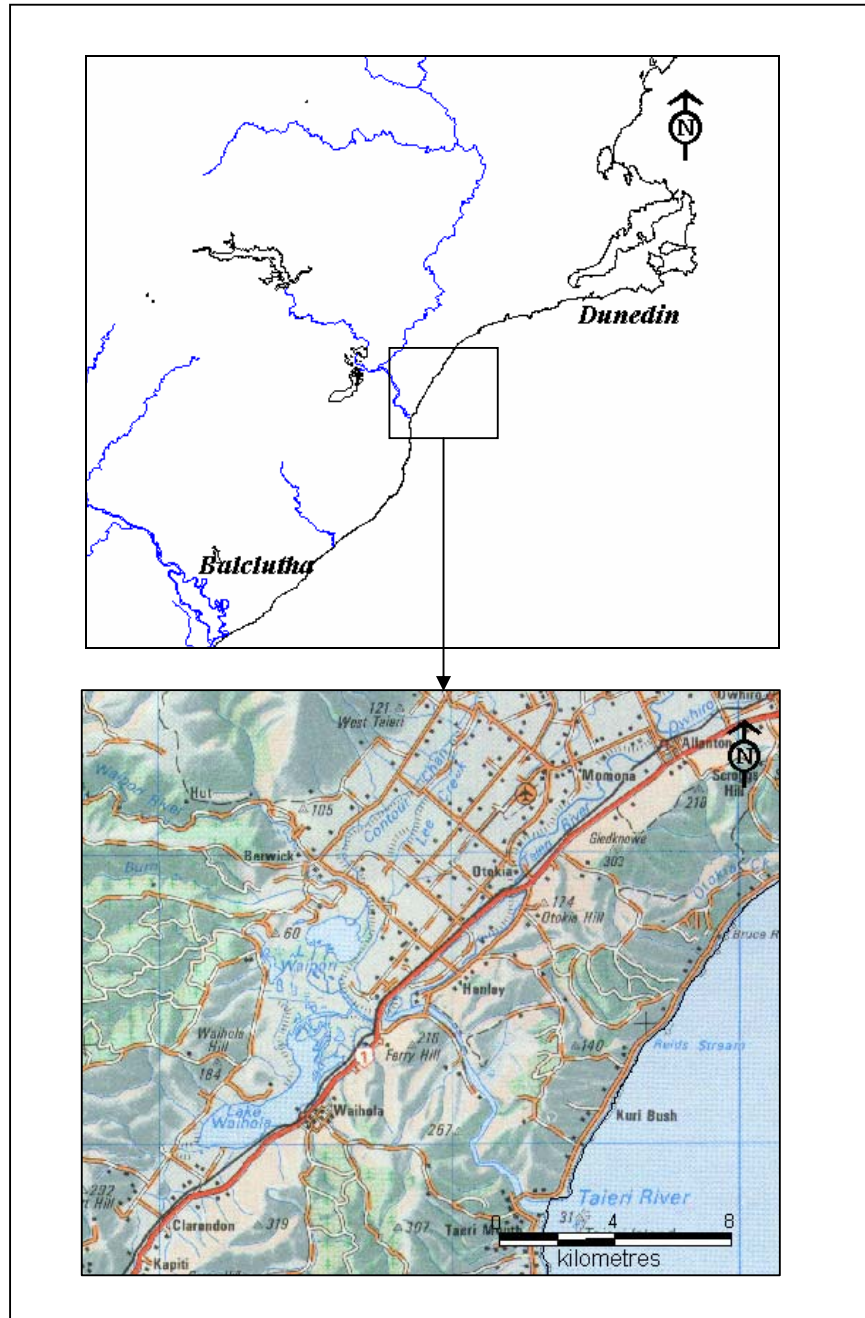


Figure 2.1 Location map - Lake Waipori and Lake Waihola

The lakes are shallow and lie only slightly above sea level. On a flood tide water from the Taieri River flows into the Lakes (Ryder 1995), the tidal fluctuations are in the order of 0.4m and 0.3m for Lake Waipori and Lake Waihola respectively.

2.2 Trophic Level Index

The trophic state of a lake refers to the '*life supporting capacity per unit volume of a lake*' (Burns *et. al*, 2000a). The trophic level of a lake is effected by physical, chemical, geological and biological factors.

The trophic level is a critical indicator of water quality as it provides a measure of the nutrient status of a body of water. Although trophic level monitoring is not a new concept, it is only recently that a trophic level index appropriate to New Zealand conditions has been developed. This report follows the protocol devised for monitoring trophic levels of New Zealand Lakes and Reservoirs by Burns *et. al* (2000a). 'Lakewatch' computer software also developed by Burns *et. al* (2000a) has also been used in this report.

For shallow unstratified lakes four commonly measured key variables are good indicators of the trophic level of a lake:

1. Chlorophyll *a* (Chl*a*)
2. Secchi depth (SD)
3. Total Phosphorus (TP)
4. Total Nitrogen (TN)

A key strength of this trophic level index is that it is capable of detecting quite small changes in trophic status. Detecting a small degree of deterioration in a lake enables remedial action to be taken before the lake undergoes extensive degradation.

3. Study Sites and Methods

3.1 Monitoring Sites

Water sampling at three sites in Lake Waihola and two sites in Lake Waipori commenced in October 2002 and finished in October 2004 (Figure 3.1).

Table 3.1 Grid References for Monitoring Sites

Monitoring Location	Grid Reference Easting	Grid Reference Northing
Waihola South (HS):	E2282027	N5460506
Waihola Mid (HM):	E2284442	N5461518
Waihola North (HN):	E2284967	N5462885
Waipori South (PS):	E2285867	N5466795
Waipori North (PN):	E2286194	N5467269

The Otago Regional Council chose the same monitoring stations that were used by the University of Otago in their 1997/98 study. This enabled a comparison of water quality and trophic state between the two monitoring periods (1997/1998 and 2002-2004). The University of Otago monitoring was undertaken at various stages of tide whilst the Otago Regional Council monitoring was standardised at high tide to eliminate the influence of tides on interpreting the TLI variables.

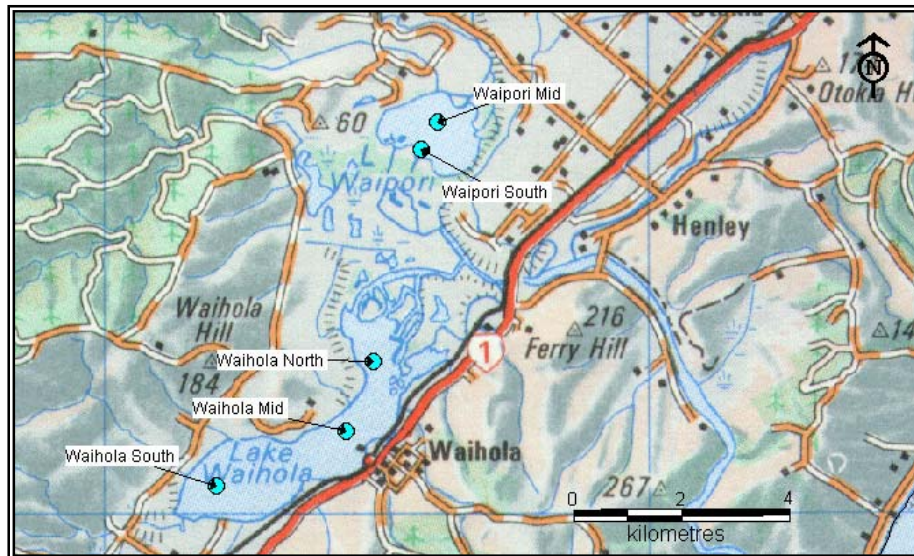


Figure 3.1 Location of water quality monitoring sites

3.2 Physico-chemical Monitoring

Table 3.2 lists the monthly water quality analyses undertaken for the lakes between October 2002 and September 2004. They include total nitrogen, total phosphorous, chlorophyll *a* and secchi depth, which are the four key variables required to calculate the trophic status of the lakes. Full results are detailed in Appendix 1.

Table 3.2 Laboratory analysis and field measurements

Field Measurements	Laboratory Analysis
Water Depth (WD)	Total Nitrogen (TN)
Secchi Depth (SD)	Total Phosphorus (TP)
Dissolved Oxygen (DO%) or (DO mg/l)	Nitrite-Nitrate Nitrogen (NNN)
Temperature (°C)	Ammoniacal Nitrogen (NH ₄)
Conductivity (Cond)	Dissolved Reactive Phosphorus (DRP)
Salinity (Sal)	Chlorophyll <i>a</i> at ¼ and ¾ depths (Chla)
Visual Assessment of Wind Speed (WS)	Inorganic suspended solids (ISS)
Visual Assessment of Wind Direction (WD)	<i>Escherichia coli</i> (<i>E. coli</i>)
Visual Assessment of Lake Condition (LC)	

Lakes Waipori and Lake Waihola are shallow and isothermal (unstratified). As some degree of sediment resuspension was expected, inorganic and total suspended solids were measured to provide background information on the degree of sediment resuspension at the time of sampling.



Figure 3.2 Lake Waihola

(Source: R. Ozanne)



Figure 3.3 Lake Waipori

Source (R. Ozanne)

Dissolved nutrients (ammoniacal nitrogen, nitrite-nitrate nitrogen and dissolved phosphorus) were also monitored since they enable calculation of total inorganic nitrogen and organic phosphorus which are more directly related to the organic particles in a lake than total nitrogen and total phosphorus (Burns *et. al.* 2000b).

E. coli was also monitored as both Lake Waipori and Lake Waihola are used for contact recreation and both lakes receive discharges carrying faecal matter.

For the first two monitoring occasions, two water samples were collected per site; one at one-quarter depth and one at three-quarter depth. However the nutrient variation at different depths was negligible and this enabled integrated depth samples to be taken.

4. Data Analysis

4.1 Site grouping

Regression analysis was undertaken on the 1997 to 2004 ORC data to check for spatial correlation between the different stations on each lake (i.e. three sites in Lake Waihola and two sites in Lake Waipori). Results showed statistically significant relationships at the 95% confidence level or above for the four key variables (Chla, TP, TN and SD) in Lake Waihola, but in Lake Waipori there two stations did not show a significant statistical relationship for Chla and SD. The Lake Waipori data was grouped for the main report, but separate station Trophic Level Index (TLI) and Percent Annual Change (PAC) analysis was also undertaken (Appendix 2).

4.2 Removing Weather Effects

4.2.1 Deseasonalising

The primary objective of TLI monitoring is to detect a significant change in a lake over time. Seasonal changes in Chla, SD, TP and TN may obscure the small scale changes that occur when the trophic level of a lake alters. As a result of this and in order to determine trends with more confidence, the data on the trophic state variables were deseasonalised before fitting them to a trend line.

Figure 4.1 and Figure 4.2 shows data plotted as a function of the time of year of collection (with no regard to year of collection) and a polynomial curve fitted to the observed data.

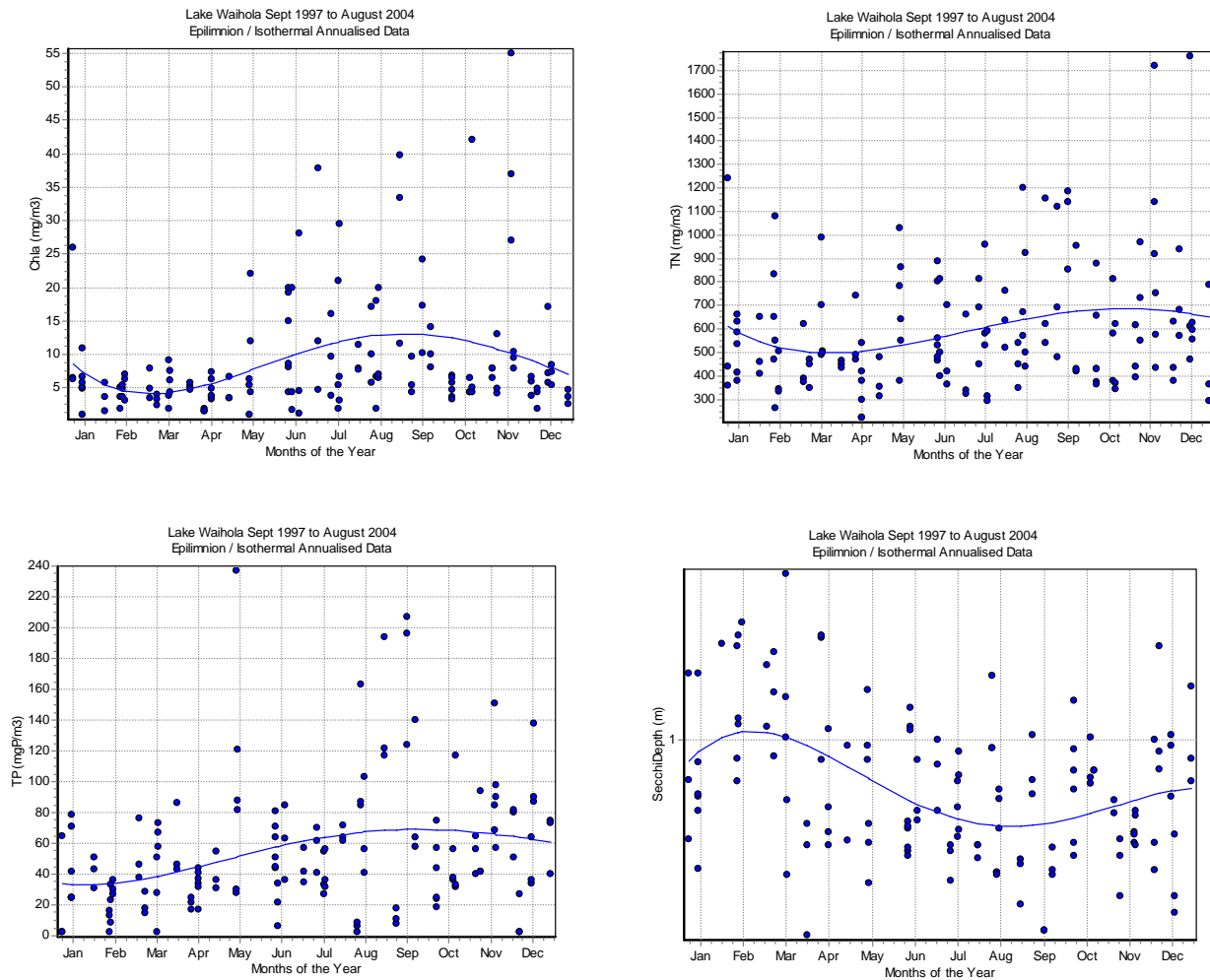


Figure 4.1 Chlorophyll *a*, Secchi Depth, Total Phosphorus and Total Nitrogen for Lake Waihola. Plotted as a function of time of year of collection with a polynomial curve fitted to the observed data

Lake Waihola shows considerable scatter in all variables, although there appears to be a spring increase in Chla, clearer water quality in January/February and higher TP and TN concentrations in the September to December period.

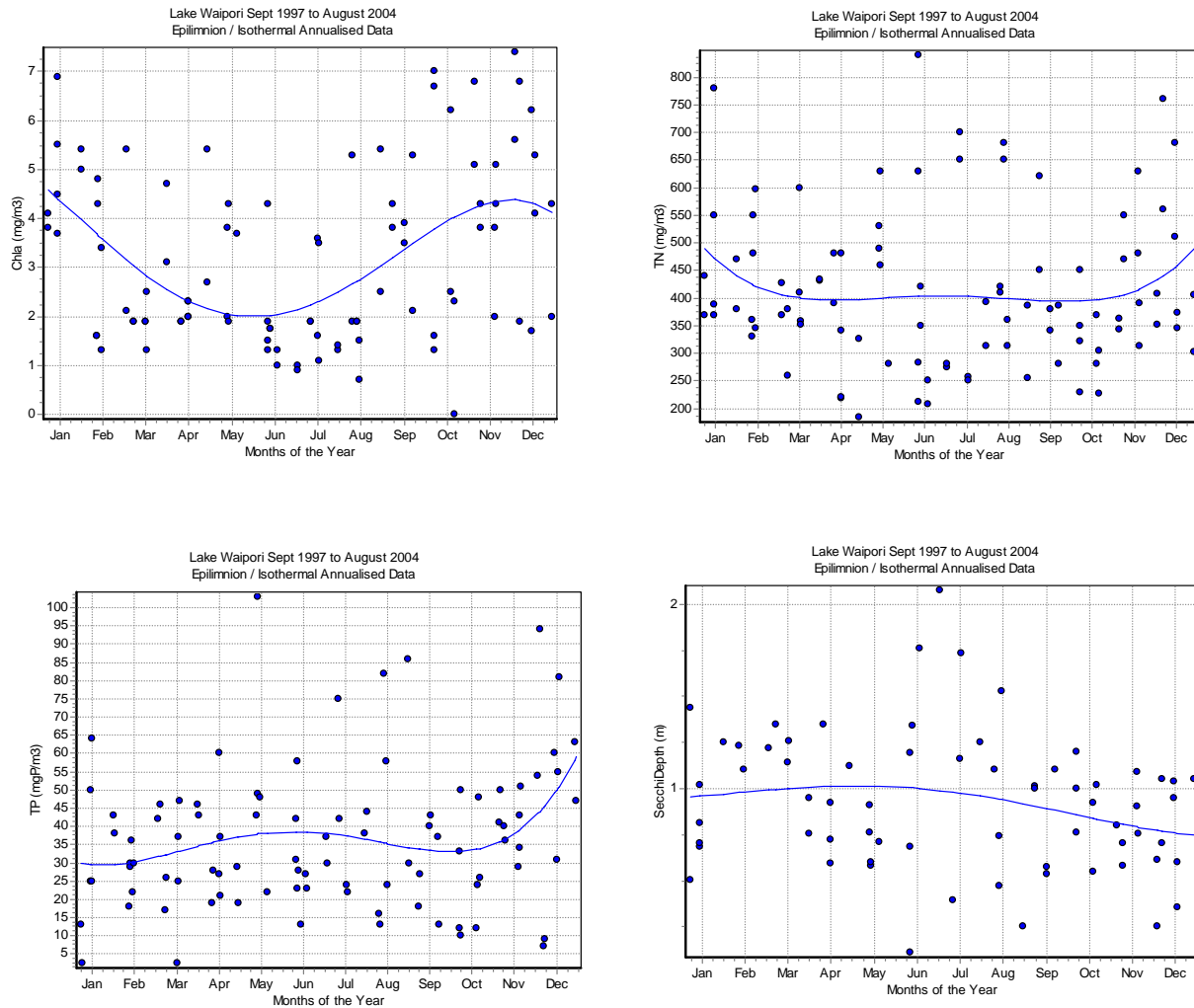


Figure 4.2 Chlorophyll *a*, Secchi Depth, Total Phosphorus and Total Nitrogen for Lake Waipori. Plotted as a function of time of year of collection with a polynomial curve fitted to the observed data

Lake Waipori shows a definite seasonal pattern in Chla with the expected decrease in the winter period. The graph for TN shows considerable scatter with a slight increase in summer, TP does not show much variation throughout the year until a sharp increase in December and Secchi depth shows a decrease in winter although the pattern is not pronounced.

4.2.2 Dewatering

Wind-induced turbulence of lake water can resuspend large amounts of sedimented materials (Burns *et. al.* 2000a). As Lake Waipori and Lake Waihola are shallow there was the possibility that sediment disturbance by wind-induced turbulence would be a stronger process than change caused by seasons.

To test for this occurrence, the key components (Chla, TN, TP and SD) were plotted against the corresponding inorganic suspended solid (ISS) values. A strong correlation between TP and ISS was found in both Lakes (Figure 4.3 to Figure 4.4).

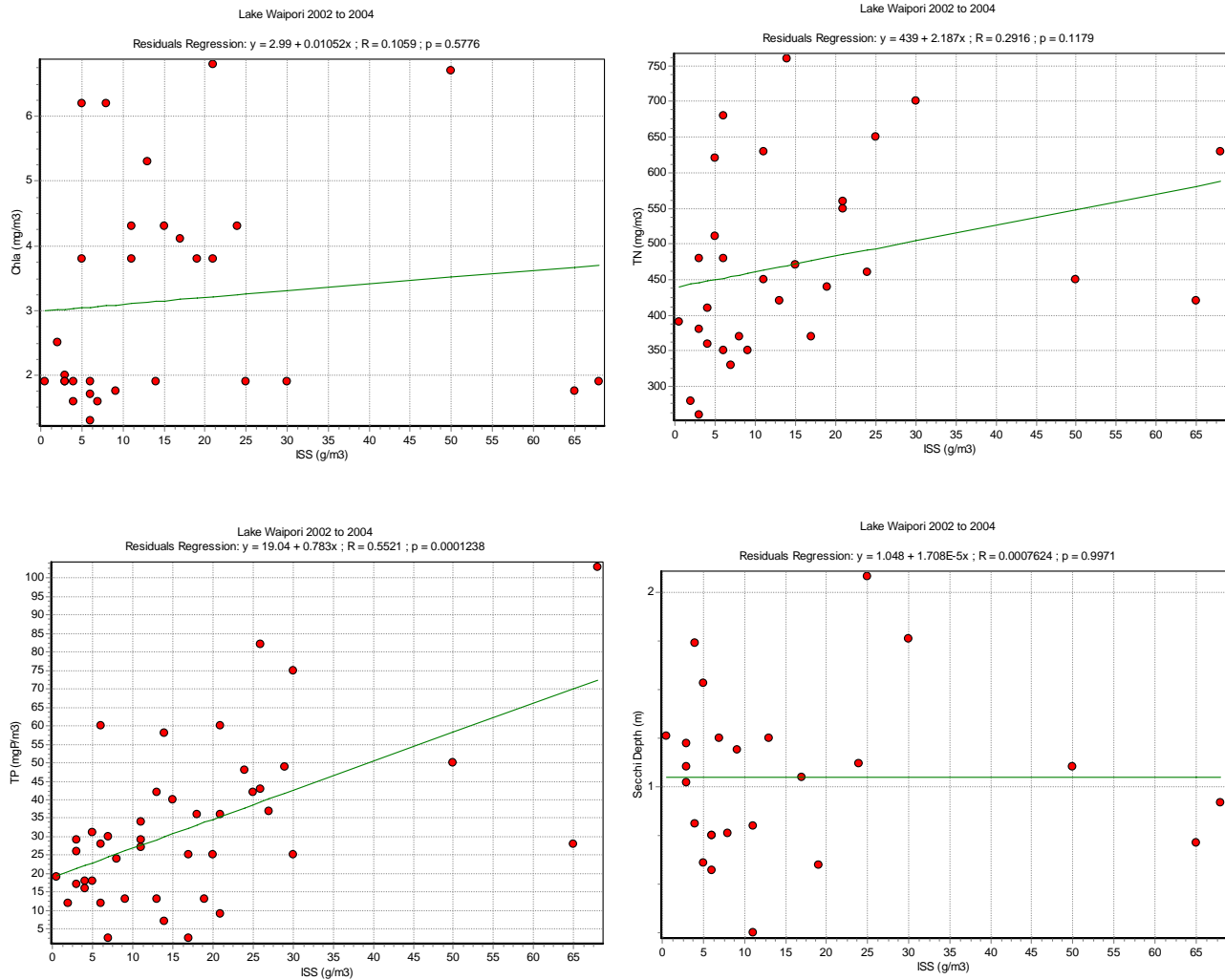


Figure 4.3 Lake Waipori 1997 to 2004. Chlorophyll *a*, Secchi Depth, Total Phosphorus and Total Nitrogen plotted against Inorganic Suspended Solid values

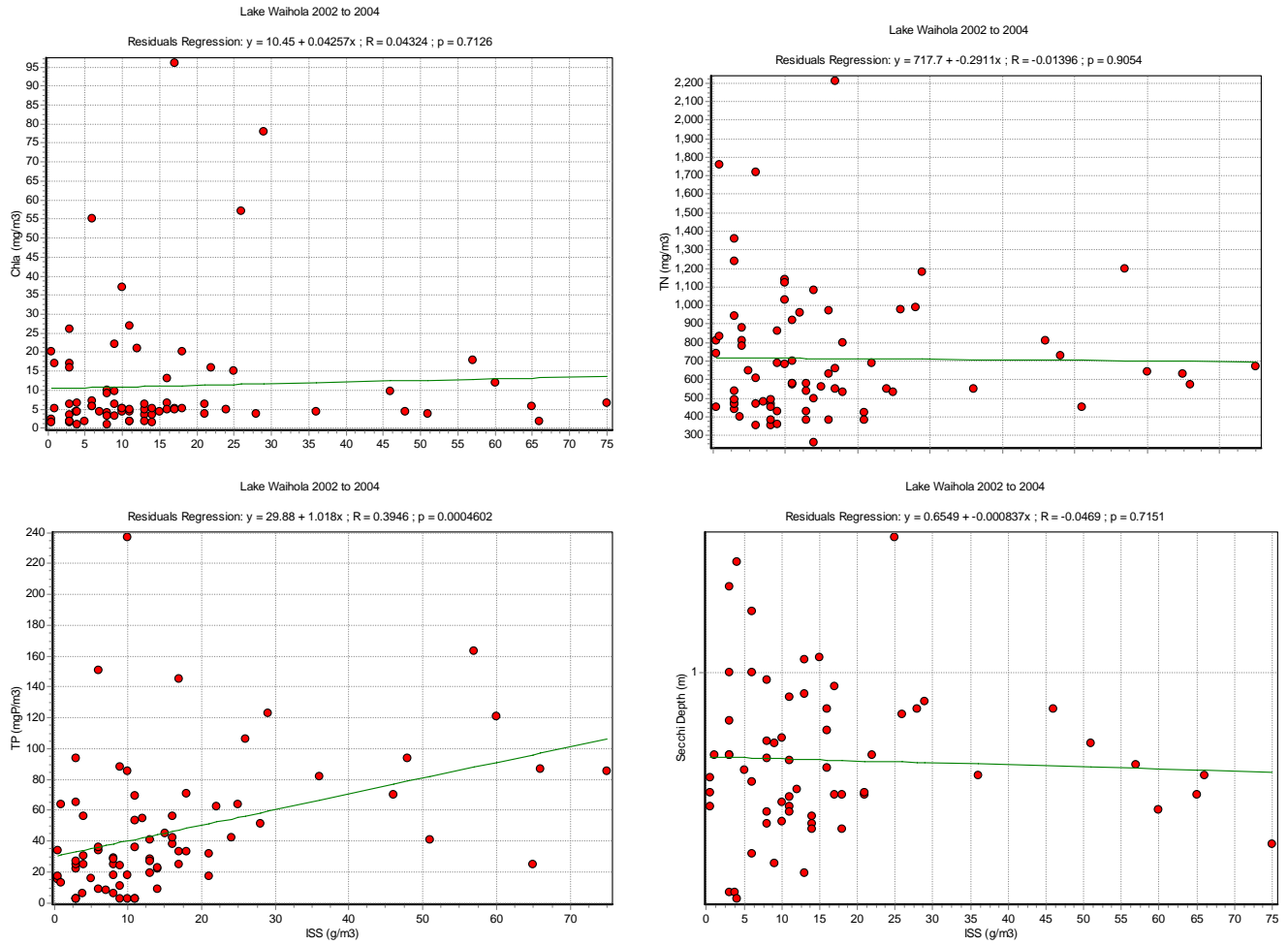


Figure 4.4 Lake Waihola 1997 to 2004. Chlorophyll *a*, Secchi Depth, Total Phosphorus and Total Nitrogen plotted against Inorganic Suspended Solid values

4.2.3 Observed and residual values

Deseasonalised residual values were obtained in order to increase the sensitivity of the trend detection, this was done by calculating the difference between measured data and the polynomial values. Even though TP concentrations in the lakes were influenced by wind, other key variables were not effected, therefore ISS values were not taken into account when calculating residuals.

Figure 4.5 to Figure 4.8 show the observed and residual values plotted against time (either 1997/1998 or 2002/2004) with straight line plots fitted to the data using ordinary least square regression. A p value calculated for the line indicates whether or not there is a trend.

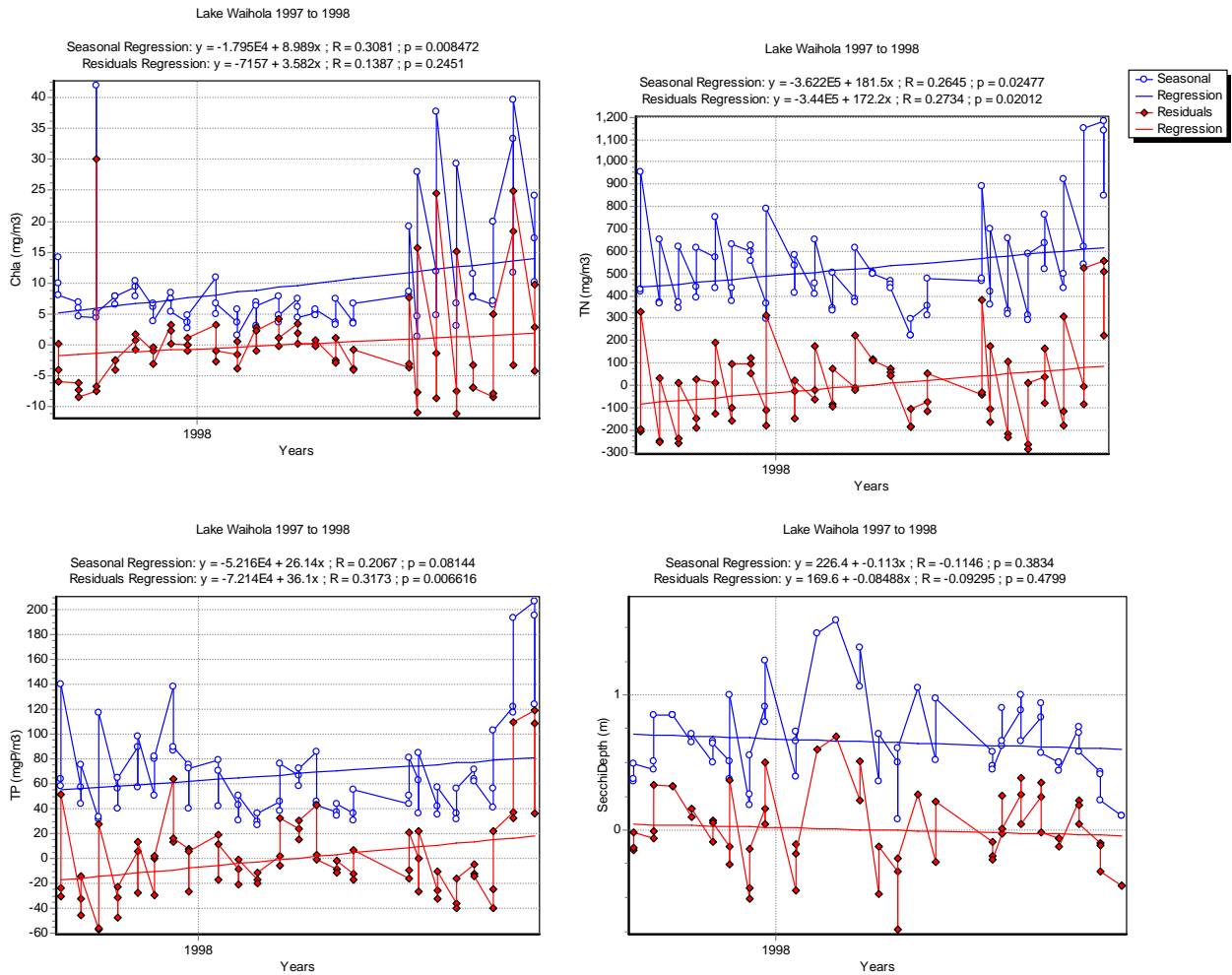


Figure 4.5 Lake Waiholo observed and residual plots (Chlorophyll a, Secchi Depth, Total Phosphorus and Total Nitrogen) against time for the period 1997 to 1998

During the 1997 to 1998 period the residual values for TP and TN showed significant trends (p values <0.05)

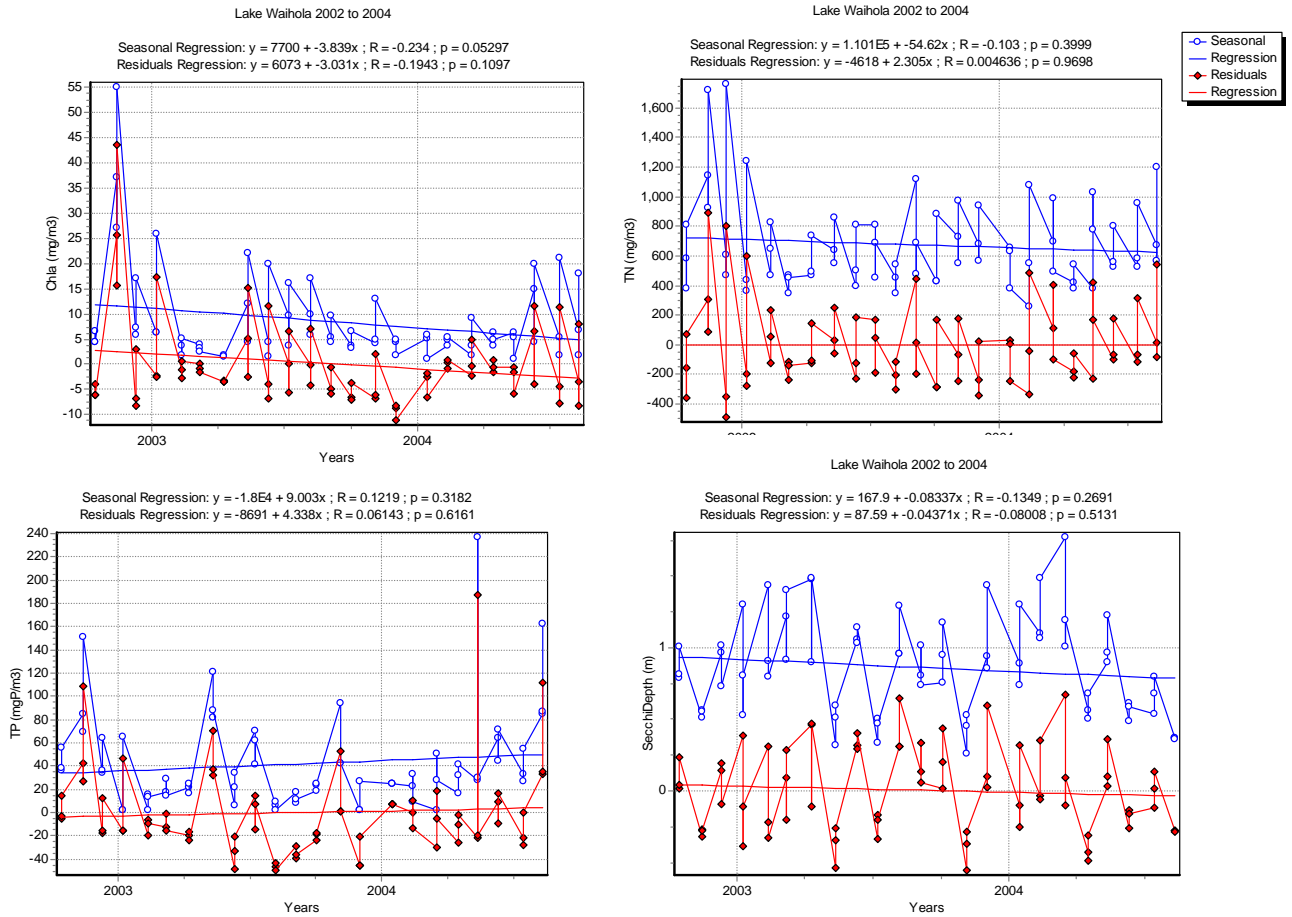


Figure 4.6 Lake Waihola observed and residual plots (Chlorophyll *a*, Secchi Depth, Total Phosphorus and Total Nitrogen) against time for the period 2002 to 2004

During the 2002 to 2004 period for Lake Waihola no significant trends were detected.

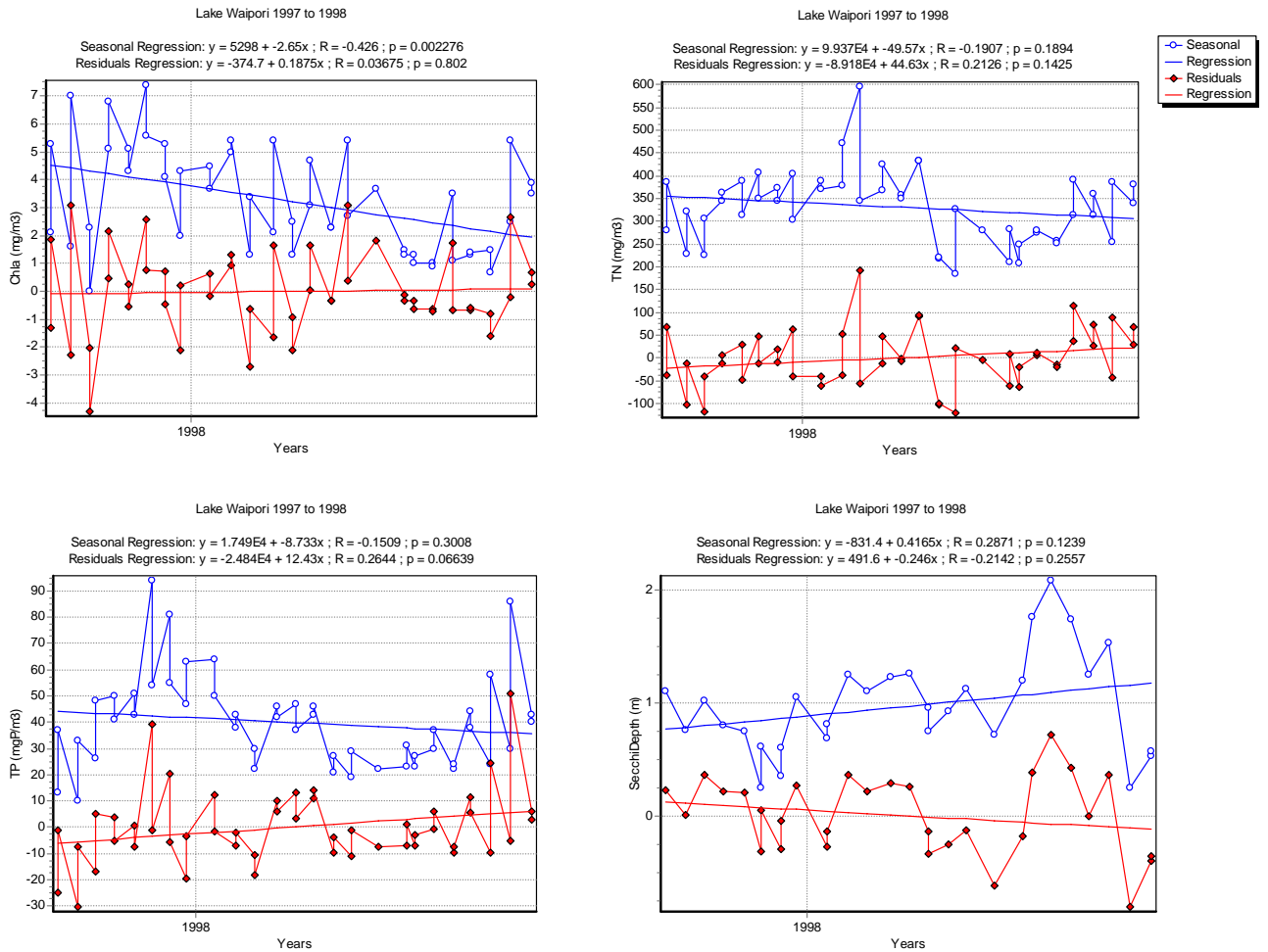


Figure 4.7 Lake Waipori observed and residual plots (Chlorophyll *a*, Secchi Depth, Total Phosphorus and Total Nitrogen) against time for the period 1997 to 1998

During the 1997 to 1998 period for Lake Waipori there was a significant trend for TP.

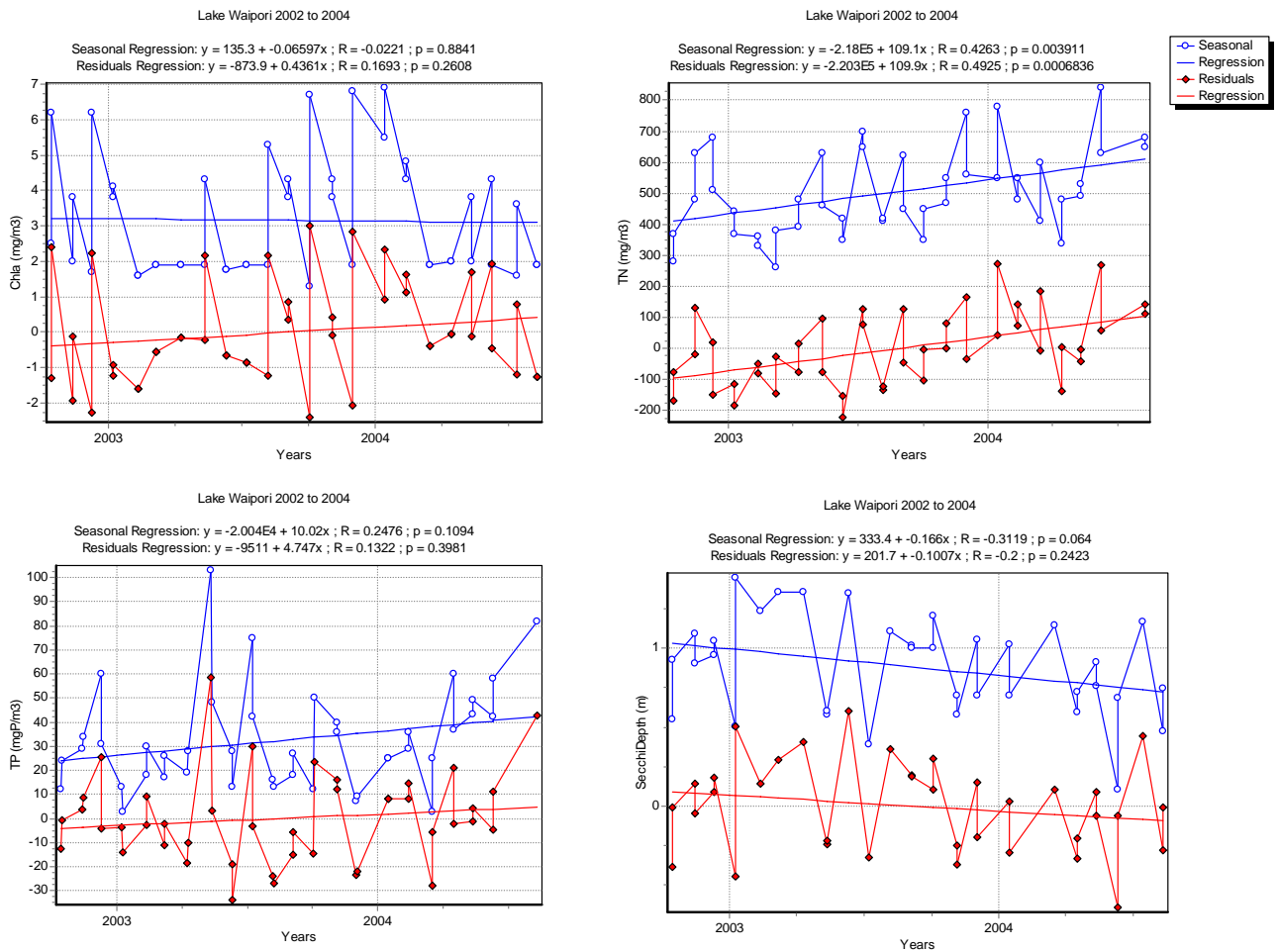


Figure 4.8 Lake Waipori observed and residual plots (Chlorophyll *a*, Secchi Depth, Total Phosphorus and Total Nitrogen) against time for the period 2002 to 2004

During the 2002 to 2004 period for Lake Waipori the only significant trend was for TN.

4.2.4 Trend Detection Using Percent Annual Change Analysis

For each of the trophic indicators (Chla, SD, TN, TP) significant trends were calculated using Percent Annual Change (PAC) values.

PAC values were calculated by determining the slope of the regression of the residual data plot with time (the slope of the regression line gives the annual change in a variable) and then dividing by the average value of the variable during the period of the observation. PAC values were only calculated from significant trend lines ($p < 0.05$).

The PAC values for the different variables were determined and then added together, averaged, and a p-value calculated (non-significant PAC values were replaced with zero).

Significant trends were determined by calculating the p-value of the PAC average and interpreting the result using the scale of probabilities (Table 4.1).

Table 4.1 Scale of probabilities devised by Burns *et al.*, (2000)

p-value of range of PAC averages	Interpretation
< 0.1	Definite change
0.1 – 0.2	Probable change
0.2 – 0.3	Possible change
> 0.3	No change

The average PAC value and its standard error indicate the magnitude of the change that has occurred in a lake. Changes indicating increased eutrophication are assigned positive values and changes indicating decreased eutrophication are given negative values. Table 4.3 and Table 4.4 give PAC values for Lake Waihola and Lake Waipori.

4.3 Trophic Level Index

The trophic level index classifies the actual state of a lake at a specific time. Burns *et al.* (2000a) determined that the following equations would give individual trophic values for Chlorophyll *a* (TLc), Secchi depth (TLs), total nitrogen (TLn) and total phosphorus (TLp):

- $TLc = 2.22 + 2.54 \log (Chla)$
- $TLs = 5.56 + 2.60 \log (1/SD - 1/40)$
- $TLp = 0.218 + 2.92 \log (TP)$
- $TLn = -3.61 + 3.01 \log (TN)$

The mean of these individual trophic values gives the trophic level index (TLI) for each lake:

$$TLI = \Sigma (TLc + TLs + TLp + TLn)/4$$

The higher the TLI, the lower the water quality. Trophic level bands are grouped into trophic states for quantitative description, microtrophic to hypertrophic as shown below and in Table 4.2.

- Microtrophic lakes are very clean, and often have snow or glacial sources.
- Oligotrophic lakes are clear and blue, with low levels of nutrients and algae.
- Mesotrophic lakes have moderate levels of nutrients and algae.
- Eutrophic lakes are green and murky, with higher amounts of nutrients and algae.
- Supertrophic lakes are fertile and saturated in phosphorus and nitrogen, and have very high algae growth and blooms during calm sunny periods.

- Hypertrophic lakes are highly fertile and supersaturated in phosphorus and nitrogen. They are rarely suitable for recreation and habitat for desirable aquatic species is limited.

Table 4.2 Values of variables defining the boundaries of different trophic levels (Burns *et al.*, 2000)

Lake Type	Trophic Level	Chla (mg/m ³)	Secchi Depth (m)	TP (mg/m ³)	TN (mg/m ³)
Ultra-microtrophic	0.0-1.0	0.13-0.33	33-25	0.8-1.8	16-34
Microtrophic	1.0-2.0	0.33-0.82	25-15	1.8-4.1	34-73
Oligotrophic	2.0-3.0	0.82-2.0	15-7	4.1-9.0	73-157
Mesotrophic	3.0-4.0	2.0-5.0	7-2.8	9.0-20	157-337
Eutrophic	4.0-5.0	5.0-12	2.8-1.1	20-43	337-725
Supertrophic	5.0-6.0	12-31	1.1-0.4	43-96	725-1558
Hypertrophic	6.0-7.0	>31	<0.4	>96	>1558

Results of the TLx and TLI calculations are shown in Table 4.3 and Table 4.4. TLI trends were calculated from four complete years of data (1997-1998 and 2002- 2004) to enable the calculation of four annual averages. The actual TLI value for the lakes was calculated from the most recent 2002 to 2004 data.

The p value of the average PAC value (Table 4.3 and Table 4.4) indicates the similarity of the four PAC values obtained for the lakes. Low p values indicate similar PAC values make up the average which indicates change in the lake.

TLI and PAC values are useful when used together to determine any probable change in a lake. The PAC value is most useful to decide whether a lake has changed trophic value or not as it uses all four variables without condensing data. The observed and residual plots enable scrutiny of the data which is not possible when using average values and the TLI value gives a clear idea of the state of the lake and uses TLI units to estimate the degree of change in a lake.

Table 4.3 shows good agreement between the two values.

Table 4.3 Comparison of Trophic Level values and time trends with Percentage Annual Change values

Lake	TLI Value		PAC average			TLI Trend			Conclusions about change
	TLI units year ⁻¹	SE	% year ⁻¹	SE	P value	TLI units year ⁻¹	SE	P value	
Waipori	4.58	0.30	5.49	5.49	0.39	0.05	0.19	0.891	No change
Waihola	5.03	0.17	0	0	1	-0.19	0.22	0.186	No change

TLI values were also calculated for the individual stations on Lake Waihola and Lake Waipori for 1997 to 2004. The average TLx for Lake Waipori and Lake Waihola are shown in Table 4.4.

Table 4.4 Average Trophic Level values for Lake Waipori and Lake Waihola

	TLc	TLs	TLp	TLn	TLI	Std Dev
Waipori						
South	3.63	5.69	4.98	4.3	4.65	0.21
Mid	3.41	6.02	4.8	4.25	4.62	0.25
Waihola						
South	5.18	6.32	6.96	3.97	5.61	0.44
Mid	4.66	6.38	6.65	3.64	5.33	0.46
North	4.32	5.91	8.27	3.37	5.44	0.55

The TLx values for Waipori South and Waipori Mid stations are similar, in particular the TLp and TLn values. TLs values are the highest in the lake and TLc values the lowest.

The TLx values for Waihola south and mid stations show similar values, however Waihola North station has an extremely high TLp value. TLp values in Lake Waihola are all high compared to the TLn values and may be due to the suspended sediment content of the water which is highlighted as being significant for Lake Waihola in Table 4.5.

Table 4.5 Trophic Level Index and Percentage Annual Change values for Lake Waiholā

LAKE WAIHOLA	Chla mg m ³	SD m	TP mg m ³	TN mg m ³	Avs of PAC values and of TLx=TLI values	Standard Error	p- value
1997 to 1998							
Change (units year ⁻¹)	3.58	-0.08	36.1	172.16			
Av Values 1997-98	9.51	0.65	68.03	525.75			
PAC (% year ⁻¹)	0	0	53.06	32.75	21.45	13.06	0.2
TLx 1997	4.66	5.99	5.48	4.42	5.16	0.35	
TLx 1998	5.35	8.16	6.77	5.49	6.44	0.65	
Averages	5.01	7.08	6.13	5.01	5.8	0.42	0.135
TLI 2-year average (1997–98) = 5.80 +/- 0.42 TLI units							
TLI time trend = 1.28 +/- 0.74 TLI units per year							
Assessment – Supertrophic Probable Degradation							
2002 to 2004							
Change (units year ⁻¹)	-3.03	-0.04	4.34	2.30			
Av Values 2002 - 04	8.43	0.86	41.91	674.49			
PAC (% year ⁻¹)	0	0	0	0	0	0	1
TLx 2002 – 03	4.84	5.67	4.92	4.91	5.08	0.2	
TLx 2003 – 04	4.25	5.74	4.99	4.9	4.97	0.3	
Averages	4.55	5.7	4.95	4.91	5.03	0.17	0.763
TLI 2-year average (2002-04) = 5.03 +/- 0.17 TLI units							
TLI time trend = 0.12 +/- 0.36 TLI units per year							
Assessment – Supertrophic No Change							
1997 to 2004							
Change (units year ⁻¹)	-0.18	0.03	-3.93	29.17			
Av Values 1997-04	8.98	0.76	55.24	598.54			
PAC (% year ⁻¹)	0	-3.95	-7.11	4.87	-1.55	2.59	0.59
TLx Averages	4.78	6.39	5.54	4.96	5.42	0.24	0.186
TLI 4-year average (1997-04) = 5.41 +/- 0.24 TLI units							
TLI time trend = 0.19 +/- 0.22 TLI units per year							
Assessment – Supertrophic No Change							

Table 4.6 Trophic Level Index and Percentage Annual Change values for Lake Waipori

LAKE WAIPORI	Chla mg m ³	SD m	TP mg m ³	TN mg m ³	Avs of PAC values and of TLx=TLI values	Standard Error	p- value
1997 to 1998							
Change (units year ⁻¹)	0.19	-0.25	12.43	44.63			
Av Values 1997-98	3.24	0.97	39.84	331.61			
PAC (%year ⁻¹)	0	0	0	0	0	0	1
TLx 1997	3.51	5.54	4.89	3.97			
TLx 1998	3.66	6.22	4.94	4.09			
Averages	3.59	5.88	4.92	4.03	4.6	0.34	0.741
TLI 2-year average (1997 -98) = 4.60 +/- 0.34 TLI units							
TLI time trend = 0.25 +/- 0.73 TLI units per year							
Assessment – Eutrophic No Change							
2002 to 2004							
	Chla mg m ³	SD m	TP mg m ³	TN mg m ³	Avs of PAC values and of TLx=TLI values	Standard Error	p- value
Change (units year ⁻¹)	0.55	-0.26	4.75	110.11			
Av Values 2002-04	3.18	0.98	32.42	501.63			
PAC (%year ⁻¹)	0	0	0	21.95	5.49	5.49	0.39
TLx 2002 – 03	3.36	5.44	4.07	4.39	4.44	0.43	
TLx 2003 – 04	3.61	5.93	4.69	4.64	4.72	0.47	
Averages	3.49	5.68	4.63	4.52	4.58	0.3	0.679
TLI 2-year average (2002-04) = 4.64 +/- 0.3 TLI units							
TLI time trend = 0.10 +/- 0.65 TLI units per year							
Assessment – Eutrophic No Change							
1997 to 2004							
	Chla mg m ³	SD m	TP mg m ³	TN mg m ³	Avs of PAC values and of TLx=TLI values	Standard Error	p- value
Change (units year ⁻¹)	0	0.03	-1.04	32.09			
Av Values 1997-04	3.21	0.93	36.37	411.08			
PAC (%year ⁻¹)	0	0	0	7.81	1.95	1.95	0.39
Averages	3.54	5.68	4.77	4.27	4.57	0.21	0.891
TLI 4-year average (1997-04) = 4.57 +/- 0.21 TLI units							
TLI time trend (4 years) = 0.05 +/- 0.19 TLI units per year							
Assessment – Eutrophic No Change							

4.4 Other Water Quality Analytes

Figure 4.9 and Figure 4.10 show observed and residual plots for other water quality variables measured in the lakes. A significant rise in NH₄ is found in both lakes during 2002 to 2004.

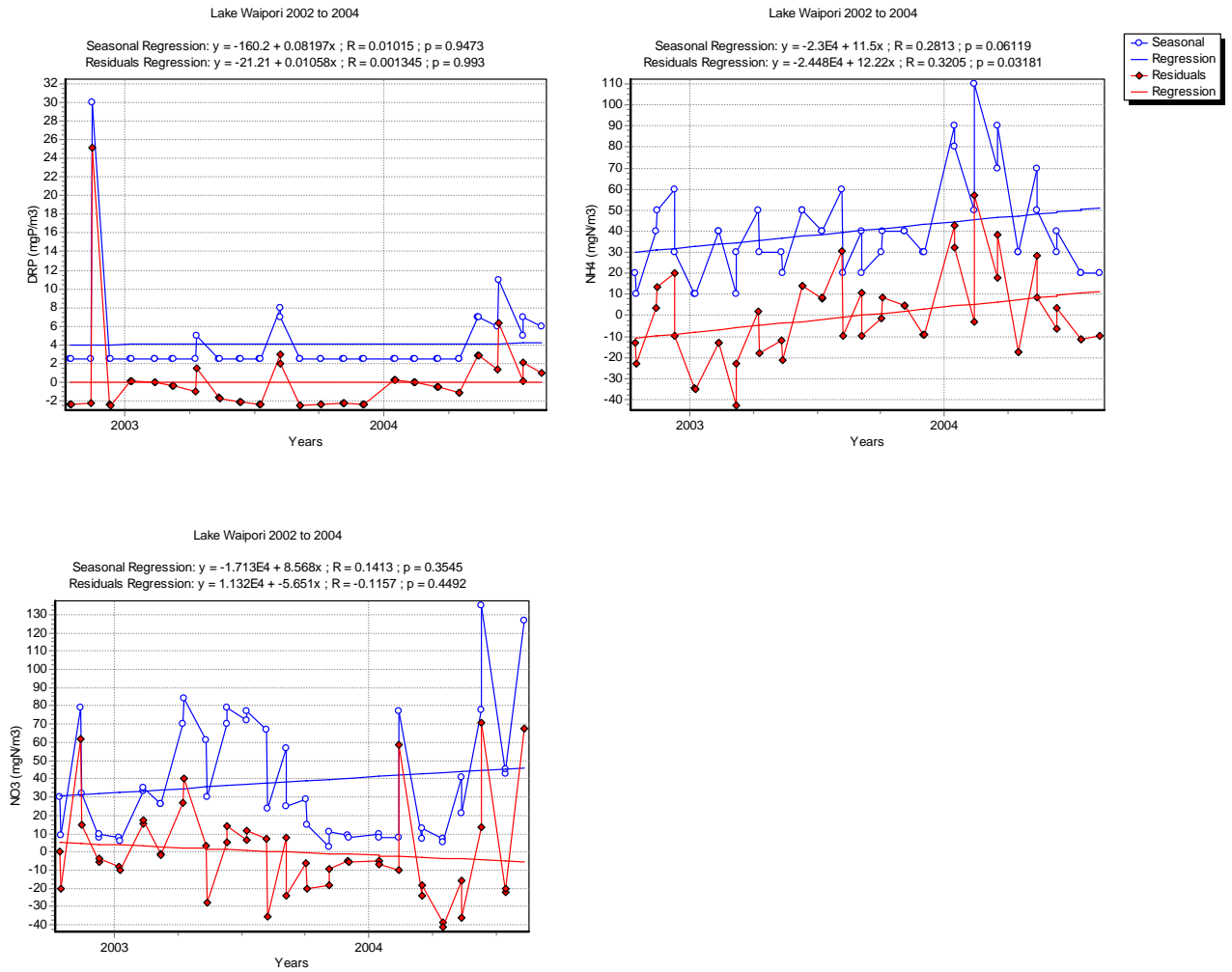


Figure 4.9 Residual plots for Lake Waipori variables (Dissolved Reactive Phosphorus, Ammoniacal Nitrogen and Nitrate Nitrogen) 2002 to 2004

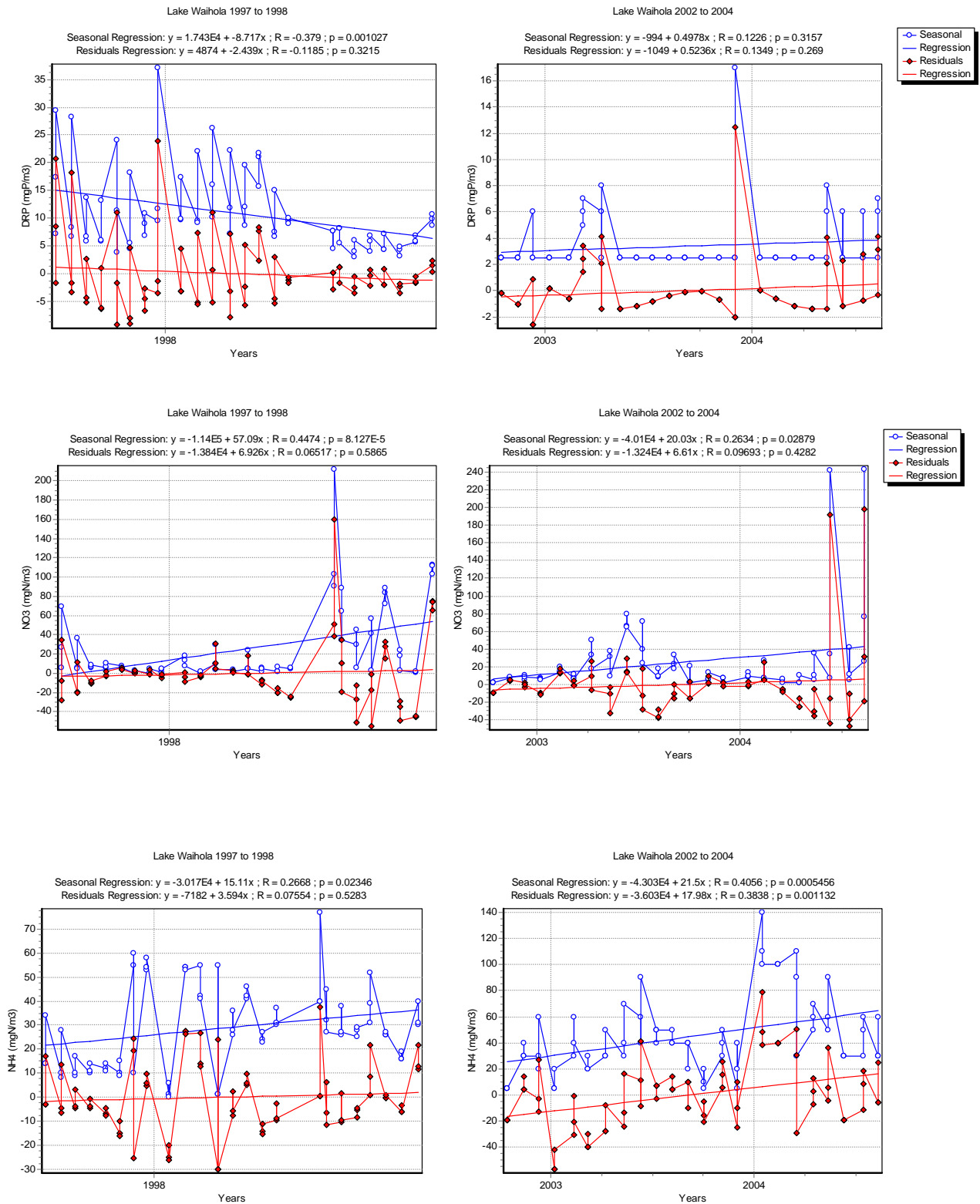


Figure 4.10 Residual Plots for Lake Waihola (Dissolved Reactive Phosphorus, Ammoniacal Nitrogen and Nitrate Nitrogen) for 1997/1998 and 2002/2004

5. Discussion

The TLI value for Lake Waihola (2002 to 2004) is 5.03 +/- 0.17 and is falling at the rate of 0.19 +/- 0.22 TLI units a year. The PAC results for Lake Waihola are shown in Table 4.5 and show an average decrease of -1.55% year⁻¹ with a *p* value of 0.59. This indicates that the lake has not changed during the period 1997 to 2004.

Lake Waihola is classified as supertrophic, although between 1997 to 1998 there was probable deterioration in its condition and it was only 0.2 TLI units from being graded hypertrophic. This can be seen clearly in Figure 4.6 which highlights the significant upward trend in observed values of TN and TP. The PAC results for these years show an average increase of 21.45% with a *p* value of 0.2 indicating the probable change.

Lake Waipori is classified as eutrophic. The TLI value for Lake Waipori (2002 to 2004) is 4.58 +/- 0.30 and is rising at the rate of 0.28 +/- 0.64 TLI units per year. The PAC results shown in Table 4.4 show that for Lake Waipori there is an average increase of 1.95% year⁻¹ with a *p* value of 0.39 indicating that the lake is not changing.

Figure 4.9 and Figure 4.10 show that between 2000 and 2002 ammoniacal nitrogen increased in both Lake Waipori and Lake Waihola.

The reason behind this increase is unclear. The most likely reason for the increase in ammoniacal nitrogen levels is the intensification of dairy farming. Table 2.1 depicts the high percentage of primary pastoral land in the catchments. As part of the Lower Taieri catchment programme, the Land Resources section is currently working with farmers to encourage best management practices to reduce nitrogen runoff into waterways and drains. Practices encouraged include careful disposal of effluent to land, riparian fencing and planting, nutrient budgeting and appropriate drainage management. Otago Regional Council is also supporting a four year programme run by AgResearch which is looking at nutrient budgets in the West Taieri area with the aim of limiting nitrogen run-off.

Another possibility is that when there is significant rainfall in the catchment, nitrogen enters watercourses as ammonia (saturated soils reduce the conversion of ammonia to nitrate nitrogen) and that significant amounts of rainfall may allow nitrogen to enter watercourses as ammonia. However isolated rainfall events are unlikely to be the cause of the upward trend in ammonia levels over the two year period.

6. Conclusion

The objectives of the report have been fully met.

- TLI values have been established for the lakes. Lake Waipori is classified as eutrophic and Lake Waihola as supertrophic.
- PAC values have been established for the lakes, which conclude that the TLI status is stable at present.
- The baseline monitoring undertaken has concluded that future monitoring can be targeted to one site, preferably the mid sites in both lakes rather than the original three sites chosen for Lake Waihola and the two sites chosen for Lake Waipori

7. References

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Appendix 1 –

Lake:	Waiholo			Station:	Mid									
Date	Depth From (m)	TP (mgP/m3)	TN (mg/m3)	Chla (mg/m3)	NO3 (mgN/m3)	NH4 (mgN/m3)	DRP (mgP/m3)	Turb (ftu)	p H (pH unit)	EC (us/cm)	TSS (g/m3)	ISS (g/m3)		
17/09/97	0.2	64	421	14.1	6	14	7.2	20			128			
2/10/97	0.2	57	371	6.8	6	10	8.3	14			135			
16/10/97	0.2	32	345	4.3	6	9	5.9	4.9			161			
30/10/97	0.2	56	441	7.8	6	10	5.8	4			207			
14/11/97	0.2	90	573	9.4	8	12	24.1	17			1195			
27/11/97	0.2	51	377	6	0	10	4.5	13	7.41		806			
11/12/97	0.2	138	597	8.4	0	55	9.1	62	7.34		615			
23/12/97	0.2	75	365	3.6	1	53	9.6	9.4	8.2		798			
14/01/98	0.2	79	535	10.8	18	1	9.7	32	7.43		825			
30/01/98	0.2	43	411	3.6	0	54	9.6	2.1	7.87		3770			
13/02/98	0.2	30	345	6.9	10	55	10.2	3.2	7.79		2110			
2/03/98	0.2	46	386	7.9	4	1	11.9	4	7.95		6220			
16/03/98	0.2	67	500	7.5	5	26	8.7	21	7.55		5480			
30/03/98	0.2	86	465	5.2	2	41	15.7	11	7.56		5110			
14/04/98	0.2	37	222	3.6	2	24	7.5	4.3	7.73		5570			
27/04/98	0.2	36	354	3.5	5	30	9.6	8	7.71		5600			
8/06/98	0.2	44	466	8	103	40	7.7	14	7.21		1548			
15/06/98	0.2	63	420	1.2	89	32	8.2	11	7.26		4890			
29/06/98	0.2	42	336	11.9	30	26	3.1	6.2	7.37		779			
14/07/98	0.2	36	314	6.7	41	25	4.1	6.7	7.15		475			
27/07/98	0.2	72	636	11.4	84	31	4.4	16	7.31		738			
11/08/98	0.2	41	437	6.4	24	26	3.2	9.5	7.08		282			
26/08/98	0.2	122	622	33.3	1	16	5.7	26	7.02		489			
11/09/98	0.2	207	1183	17.2	113	40	9.9	74	7		323			
14/10/02	0.1	36	580	4.3	2.5	5	2.5	7.4			256	15		11
13/11/02	0.1	85	1140	37	7	30	2.5	14			217	19		10
9/12/02	0.1	34	610	5.8	11	30	6	5.1			183	10		6
7/01/03	0.1	2.5	440	6.4	7	5	2.5	3.6			3670	6		3
10/02/03	0.1	2.5	470	3.6	14	30	2.5	3.1			1240	6		3
7/03/03	0.1	18	350	4	7	20	5	4.1	7.64		600	11		8
9/04/03	0.1	22	470	1.5	34	30	6	3.4	7.07		411	6		3
12/05/03	0.1	121	640	12	31	30	2.5	28	7.45		297	68		60
3/09/03	0.1	18	1120	5.3	23	40	2.5	6.7	7.12		497	12		10
2/10/03	0.1	19	430	3.6	2.5	10	2.5	6.9	7.36		385	15		13
3/11/03	0.1	94	730	4.2	5	30	2.5	27	7.54		359	57		48
1/12/03	0.1	2.5	680	4.3	7	5	2.5	4.7	7.64		1810	13		10
14/01/04	0.1	25	660	5.1	8	140	2.5	5.1	7.82		13140	21		17
11/02/04	0.1	23	260	3.6	7	100	2.5	4.4	7.68		11170	17		14
15/03/04	0.1	2.5	700	1.9	5	110	2.5	2.6	8.17		8680	14		11
14/04/04	0.1	17	420	3.8	2.5	50	2.5	10	7.64		4503	25		21

11/05/04	0.1	28	380	6.2	5	50	2.5	6	7.65	4017	17	13
8/06/04	0.1	64	530	15	7	30	2.5	15	7.43	2741	29	25
13/07/04	0.1	33	530	5.3	5	30	2.5	12	7.5	1581	21	18
9/08/04	0.1	85	670	6.7	26	30	2.5	28	7.34	821	82	75

Lake:	Waiholo		Station:		Mid									
Date	Depth From (m)	TP (mgP/m3)	TN (mg/m3)	Chla (mg/m3)	NO3 (mgN/m3)	NH4 (mgN/m3)	DRP (mgP/m3)	Turb (ftu)	p H (pH unit)	EC (us/cm)	TSS (g/m3)	ISS (g/m3)		
2/10/97	0.2	75	654	4.6	37	28	28.2	28.2	7.5		165			
16/10/97	0.2	117	619	5.1	9	17	13.7	13.7	2.6		164			
30/10/97	0.2	65	616	7.8	11	14	13.2	13.2	2.2		164			
14/11/97	0.2	98	751	10.3	6	14	11.4	11.4	12.5		252			
27/11/97	0.2	82	629	3.8	3	15	18.3	18.3	3.5	8.1	590			
11/12/97	0.2	90	557	5.3	5	10	10.9	10.9	22	7.73	667			
23/12/97	0.2	73	789	4.7	5	58	37.1	37.1	1.6	9.1	475			
14/01/98	0.2	71	584	6.6	8	0	17.4	17.4	11.5	7.44	640			
30/01/98	0.2	51	653	1.4	2	53	22.1	22.1	1.1	9.54	530			
13/02/98	0.2	36	503	6.3	4	41	26.3	26.3	2	9.66	654			
2/03/98	0.2	76	618	4.8	2	1	22.3	22.3	2.7	9.33	2750			
16/03/98	0.2	73	499	4.3	5	28	19.6	19.6	3.3	8.55	3750			
30/03/98	0.2	43	433	5.7	5	46	21.7	21.7	8.6	7.46	4520			
14/04/98	0.2	44	299	7.4	7	27	15	15	1.7	8.66	4860			
27/04/98	0.2	55	478	6.7	6	31	10.1	10.1	3.5	7.86	5700			
8/06/98	0.2	81	890	19.2	212	77	7.7	7.7	18	7.23	2140			
15/06/98	0.2	85	701	28	35	27	5.5	5.5	7.8	7.51	1990			
29/06/98	0.2	57	660	37.8	6	27	6.1	6.1	6.5	7.69	1380			
14/07/98	0.2	56	590	29.4	3	29	6.9	6.9	9	7.24	1240			
27/07/98	0.2	62	764	7.7	89	52	7.2	7.2	16	7.36	871			
11/08/98	0.2	103	922	19.9	3	27	4.9	4.9	12	7.75	711			
26/08/98	0.2	194	1153	39.7	2	16	6.8	6.8	59	7.02	578			
11/09/98	0.2	196	1138	24.1	112	31	10.7	10.7	80	7.62	424			
14/10/02	0.1	56	810	4.3	2.5	5	2.5	2.5	4	7.67	262	9	4	
13/11/02	0.1	151	1720	55	8	30	2.5	2.5	15		235	18	6	
9/12/02	0.1	64	1760	17	8	60	2.5	2.5	6.1		231	9	1	
7/01/03	0.1	65	1240	26	5	20	2.5	2.5	13		397	12	3	
10/02/03	0.1	13	830	5.1	20	40	2.5	2.5	2.4		1710	4	1	
7/03/03	0.1	15	450	2.4	6	20	7	7	1.2	9.22	1254	2	0.5	
8/07/03	0.1	62	690	16	24	50	2.5	2.5	14	7.24	1250	28	22	
6/08/03	0.1	2.5	540	17	9	40	2.5	2.5	2.7	7.95	1165	7	3	
3/09/03	0.1	11	690	9.6	34	40	2.5	2.5	6.5	6.98	700	12	9	
2/10/03	0.1	25	880	6.5	2.5	5	2.5	2.5	3.5	7.16	525	7	4	
3/11/03	0.1	42	970	13	14	50	2.5	2.5	12	7.59	0	20	16	
1/12/03	0.1	27	940	1.9	2.5	20	17	17	2.1	9.24	559	5	3	
14/01/04	0.1	25	380	1	9	100	2.5	2.5	2.1	8.86	10330	9	8	
11/02/04	0.1	9	1080	5.3	7	100	2.5	2.5	2.6	8.79	12710	17	14	

15/03/04	0.1	28	490	9.1	2.5	30	2.5	2.1	7.98	10500	12	8
14/04/04	0.1	41	540	4.8	11	70	2.5	9.1	7.52	6840	18	13
11/05/04	0.1	30	780	0.95	36	90	8	2.3	7.62	4908	7	4
8/06/04	0.1	71	800	20	242	30	2.5	12	7.43	2913	22	18
13/07/04	0.1	55	960	21	12	60	2.5	7	7.7	2083	17	12
9/08/04	0.1	163	1200	18	243	60	7	28	7.38	1402	67	57

Lake:	Waiholo											
Date	Depth From (m)	TP (mgP/m3)	TN (mg/m3)	Station: Chla (mg/m3)	North NO3 (mgN/m3)	NH4 (mgN/m3)	DRP (mgP/m3)	Turb (ftu)	p H (pH unit)	EC (us/cm)	TSS (g/m3)	ISS (g/m3)
17/09/97	0.2	58	429	10	27	14	17.4	13			122	
2/10/97	0.2	44	364	5.8	5	8	6.7	10			140	
16/10/97	0.2	33	370	42	7	10	6.7	4.9			162	
30/10/97	0.2	40	394	6.4	7	11	6	5.8			210	
14/11/97	0.2	57	435	7.8	6	11	3.9	10			1180	
27/11/97	0.2	80	436	6.6	1	9	5.6	23	7.46		586	
11/12/97	0.2	87	626	7.4	0	60	6.9	31	7.48		617	
23/12/97	0.2	40	295	2.6	4	54	11.8	6.1	7.73		690	
14/01/98	0.2	42	414	4.9	13	6	9.8	6.7	7.44		906	
30/01/98	0.2	31	457	5.7	1	54	9.2	3.1	8.13		5650	
13/02/98	0.2	27	334	3	30	42	16	3.4	7.49		2030	
2/03/98	0.2	38	373	3.5	2	55	7.2	3.5	7.91		6480	
16/03/98	0.2	58	502	6.1	24	36	12	13	7.65		6800	
30/03/98	0.2	46	451	4.7	6	42	21	7.6	7.29		5910	
14/04/98	0.2	34	222	3.2	2	23	6.7	4.5	7.64		5440	
27/04/98	0.2	31	311	3.4	5	37	9.1	8	7.8		5590	
8/06/98	0.2	51	480	8.5	91	40	4.6	17	6.95		1865	
15/06/98	0.2	36	363	4.5	65	45	8.2	5.7	6.95		469	
29/06/98	0.2	35	321	4.7	45	38	4.1	4.8	7.08		575	
14/07/98	0.2	32	293	3	57	28	5.9	5.7	6.9		320	
27/07/98	0.2	64	519	7.8	72	39	4.4	16	7.23		609	
11/08/98	0.2	56	498	7	18	26	4.4	10.5	7.11		349	
26/08/98	0.2	117	540	11.6	1	19	5.9	24	7.3		448	
11/09/98	0.2	124	851	10.1	103	30	8.7	43	7.35		196	
14/10/02	0.1	38	380	6.5	2.5	5	2.5	9			167	21
10/02/03	0.1	16	650	1.75	15	60	2.5	4.4			891	8
7/03/03	0.1	29	470	3.2	12	30	6	5.4	7.27		490	10
9/04/03	0.1	25	490	1.9	50	30	2.5	4.7	7.13		288	6
12/05/03	0.1	82	550	4.3	38	40	2.5	17	7.35		503	41
10/06/03	0.1	22	500	1.6	80	40	2.5	5.5	7.23		243	15
8/07/03	0.1	41	450	3.8	71	40	2.5	18	7.24		820	58
6/08/03	0.1	9	350	5.8	18	40	2.5	4.7	7.31		283	8
1/12/03	0.1	2.5	570	4.8	7	40	2.5	5.1	7.42		1690	14

14/01/04	0.1	25	630	5.8	14	110	2.5	15	7.42	12510	72	65
11/02/04	0.1	33	550	4.8	27	100	2.5	5.4	7.57	8950	21	17
15/03/04	0.1	51	990	3.8	6	90	2.5	6.4	8.03	7930	32	28
14/04/04	0.1	32	380	6.2	2.5	60	2.5	10	7.95	6024	26	21
11/05/04	0.1	237	1030	5.3	11	60	6	5	7.43	2540	13	10
8/06/04	0.1	45	560	4.3	35	30	6	11	7.37	1296	18	15
13/07/04	0.1	27	580	1.9	42	50	6	8.3	7.2	773	15	13
9/08/04	0.1	87	570	1.9	76	30	6	23	7.13	372	71	66

Lake:	Waipori	Station: Mid										
Date	Depth From (m)	TP (mgP/m3)	TN (mg/m3)	Chla (mg/m3)	NO3 (mgN/m3)	NH4 (mgN/m3)	DRP (mgP/m3)	Turb (ftu)	p H (pH unit)	EC (us/cm)	TSS (g/m3)	ISS (g/m3)
17/09/97	0.20	13.00	281.00	2.10	67.00	19.00	7.40	4.20		32.00		
2/10/97	0.20	10.00	229.00	1.60	61.00	14.00	6.60	2.70		42.00		
16/10/97	0.20	26.00	227.00	2.30	24.00	9.00	4.00	3.20		52.00		
30/10/97	0.20	50.00	344.00	5.10	9.00	12.00	8.80	6.40		84.00		
14/11/97	0.20	51.00	390.00	5.10	12.00	14.00	3.80	5.20		502.00		
27/11/97	0.20	94.00	408.00	7.40	2.00	7.00	5.90	44.00	7.75	257.00		
11/12/97	0.20	81.00	373.00	5.30	2.00	52.00	14.10	26.00	7.62	28.00		
23/12/97	0.20	47.00	405.00	2.00	4.00	3.00	13.70	5.10	7.60	150.00		
14/01/98	0.20	64.00	389.00	4.50	3.00	0.00	16.00	7.90	7.51	340.00		
30/01/98	0.20	38.00	379.00	5.00	0.00	54.00	7.50	3.10	7.73	2370.00		
13/02/98	0.20	30.00	596.00	1.30	191.00	45.00	22.30	5.10	7.27	880.00		
2/03/98	0.20	46.00	368.00	2.10	69.00	8.00	19.50	3.20	7.79	3730.00		
16/03/98	0.20	47.00	358.00	2.50	5.00	27.00	8.20	3.90	7.76	3640.00		
30/03/98	0.20	43.00	432.00	3.10	4.00	43.00	17.80	6.40	7.36	2930.00		
14/04/98	0.20	21.00	218.00	2.30	18.00	42.00	5.00	4.40	7.28	1710.00		
27/04/98	0.20	19.00	184.00	5.40	6.00	36.00	4.90	5.30	6.84	828.00		
8/06/98	0.20	23.00	211.00	1.50	17.00	34.00	3.90	3.30	6.65	39.00		
15/06/98	0.20	23.00	208.00	1.30	13.00	29.00	2.80	2.30	6.44	32.00		
29/06/98	0.20	30.00	275.00	1.00	16.00	32.00	2.20	2.40	6.95	29.00		
14/07/98	0.20	22.00	258.00	3.50	22.00	37.00	1.10	2.80	6.93	30.00		
27/07/98	0.20	44.00	313.00	1.30	33.00	31.00	9.00	3.50	6.91	32.00		
11/08/98	0.20	24.00	313.00	1.50	27.00	32.00	4.00	4.40	6.64	30.00		
26/08/98	0.20	30.00	254.00	2.50	26.00	21.00	3.20	6.20	6.71	39.00		
11/09/98	0.20	43.00	341.00	3.90	26.00	20.00	3.00	15.00	7.06	22.00		
14/10/02	0.10	12.00	280.00	2.50	30.00	20.00	2.50	2.90		35.00	4.00	2.00
13/11/02	0.10	29.00	480.00	2.00	79.00	40.00	2.50	4.20		42.00	6.00	3.00
9/12/02	0.10	60.00	680.00	1.70	8.00	60.00	2.50	5.10		50.00	13.00	6.00
7/01/03	0.10	13.00	440.00	3.80	8.00	10.00	2.50	6.30		2000.00	24.00	19.00
10/02/03	0.10	18.00	360.00	1.60	33.00	40.00	2.50	3.80		23.00	7.00	4.00
7/03/03	0.10	17.00	260.00	1.90	26.00	10.00	2.50	3.70	6.83	24.00	5.00	3.00
9/04/03	0.10	19.00	390.00	1.90	70.00	50.00	2.50	2.80	6.76	26.90	3.00	0.50

12/05/03	0.10	103.00	630.00	1.90	61.00	30.00	2.50	23.00	7.25	36.00	78.00	68.00
3/09/03	0.10	18.00	620.00	3.80	57.00	40.00	2.50	5.40	7.16	53.00	7.00	5.00
2/10/03	0.10	12.00	350.00	1.30	29.00	30.00	2.50	4.50	7.28	32.00	7.00	6.00
3/11/03	0.10	40.00	470.00	4.30	2.50	40.00	2.50	8.20	7.75	187.00	20.00	15.00
1/12/03	0.10	7.00	760.00	1.90	9.00	30.00	2.50	4.70	7.32		17.00	14.00
14/01/04	0.10	25.00	550.00	5.50	10.00	90.00	2.50	6.30	7.43	8130.00	24.00	20.00
11/02/04	0.10	29.00	480.00	4.30	8.00	50.00	2.50	4.00	7.34	5660.00	13.00	11.00
15/03/04	0.10	2.50	410.00	1.90	7.00	70.00	2.50	4.20	7.69	2370.00	9.00	7.00
14/04/04	0.10	60.00	340.00	2.00	7.00	30.00	2.50	12.00	7.83	269.00	24.00	21.00
11/05/04	0.10	43.00	490.00	3.80	41.00	70.00	7.00	8.50	7.07	51.00	30.00	26.00
8/06/04	0.10	42.00	840.00	4.30	78.00	30.00	6.00	0.65	7.19	41.00	15.00	13.00
13/07/04	0.10			1.60	43.00	20.00	5.00	4.20	6.92	32.00	13.00	12.00
9/08/04	0.10	82.00	680.00	1.90	127.00	20.00	6.00	14.00	6.85	44.00	30.00	26.00

Lake:	Waipori		Station: South									
Date	Depth From (m)	TP (mgP/m3)	TN (mg/m3)	Chla (mg/m3)	NO3 (mgN/m3)	NH4 (mgN/m3)	DRP (mgP/m3)	Turb (ftu)	p H (pH unit)	EC (us/cm)	TSS (g/m3)	ISS (g/m3)
17/09/97	0.2	37	387	5.3	78	31	5.1	7.6		106		
2/10/97	0.2	33	321	7	10	11	5.1	5.9		134		
16/10/97	0.2	48	305	0	11	10	4.7	5.2		190		
30/10/97	0.2	41	362	6.8	6	17	5.8	5.5		201		
14/11/97	0.2	43	314	4.3	11	10	9	8.7		137		
27/11/97	0.2	54	351	5.6	1	7	3.4	11	7.25	470		
11/12/97	0.2	55	346	4.1	7	53	14.2	13	7.51	320		
23/12/97	0.2	63	303	4.3	42	56	15.3	4.6	7.37	528		
14/01/98	0.2	50	370	3.7	4	3	13.4	6.7	7.37	504		
30/01/98	0.2	43	471	5.4	80	11	5.2	3.8	7.65	5990		
13/02/98	0.2	22	346	3.4	118	50	19.2	5.2	7.26	3240		
2/03/98	0.2	42	426	5.4	34	8	14.8	4.2	7.8	7080		
16/03/98	0.2	37	351	1.3	7	33	8	4.6	7.87	3220		
30/03/98	0.2	46	433	4.7	11	44	1.7	7	7.4	4160		
14/04/98	0.2	27	220	2.3	4	30	5.6	5.4	7.34	2850		
27/04/98	0.2	29	327	2.7	10	35	5.4	4.5	7.17	1646		
18/05/98	0.2	22	280	3.7	32	31	4.2	7.4	7.1	758		
8/06/98	0.2	31	282	1.3	40	45	7.2	5.9	6.67	68		
15/06/98	0.2	27	250	1	31	43	6.6	3.6	6.62	54		
29/06/98	0.2	37	281	0.9	30	36	4.1	3.3	6.77	42		
14/07/98	0.2	24	251	1.1	44	33	3.5	3.3	6.73	56		
27/07/98	0.2	38	392	1.4	72	53	2.5	5.6	6.91	102		
11/08/98	0.2	58	360	0.7	41	32	2.7	4.6	6.81	269		
26/08/98	0.2	86	386	5.4	31	21	5	29	6.81	41		
11/09/98	0.2	40	380	3.5	38	20	4.1	13	7.15	55		
14/10/02	0.1	24	370	6.2	9	10	2.5	6.5		109	11	8
13/11/02	0.1	334	630	3.8	32	50	30	6.8		98	15	11
9/12/02	0.1	31	510	6.2	10	30	2.5	4.8		134	8	5

7/01/03	0.1	2.5	370	4.1	6	10	2.5	6.8		3490	21	17
10/02/03	0.1	30	330	1.6	35	40	2.5	5.1		31	11	7
7/03/03	0.1	26	380	1.9	26	30	2.5	4.5	7.15	35	5	3
9/04/03	0.1	28	480	1.9	84	30	5	4.8	6.59	33.8	10	6
6/08/03	0.1	13	420	5.3	24	20	7	6.2	7.22	6260	15	13
3/09/03	0.1	27	450	4.3	25	20	2.5	6.8	7.25	223	14	11
2/10/03	0.1	50	450	6.7	15	40	2.5	15	7.35	140	59	50
3/11/03	0.1	36	550	3.8	11	40	2.5	12	7.41	234	26	21
1/12/03	0.1	9	560	6.8	8	30	2.5	7.4	7.38	1730	25	21
14/01/04	0.1	25	780	6.9	8	80	2.5	6.8	7.37	13430	35	30
11/02/04	0.1	36	550	4.8	77	110	2.5	5.3	7.52	8740	21	18
15/03/04	0.1	25	600	1.9	13	90	2.5	6.1	7.53	6260	21	17
14/04/04	0.1	37	480	2	5	30	2.5	13	7.42	3456	33	27
11/05/04	0.1	49	530	2	21	50	7	12	7.28	1812	33	29
8/06/04	0.1	58	630	1.9	135	40	11	11	7.21	101	16	14
13/07/04	0.1			3.6	45	20	7	8.6	7.03	422	19	16
9/08/04	0.1	66	650	1.9	130	30	7	13	6.98	168	20	16

Appendix 2 -

Lake Waipori (South Site) 1997 to 2004

Waipori

WPS 1997 to 2004 (17 Sep 1997 - 9 Aug 2004)

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	(0.06)	(-0.01)	(1.01)	31.71				
Average Over Period	(3.56)	(1.02)	(43.46)	418.62				
Percent Annual Change (%/Year)	0.00	0.00	0.00	7.57	0.00	1.89	1.89	0.39

Burns 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
Sep 1997 - Aug 1998	3.41	1.07	41.38	338.13	3.57	5.46	4.94	4.00	4.49	0.43			
Sep 1998 - Aug 1999	3.50	0.57	40.00	380.00	3.60	6.18	4.90	4.16	4.71	0.56			
Sep 2002 - Aug 2003	3.54	1.13	53.77	450.00	3.61	5.39	5.27	4.38	4.66	0.42			
Sep 2003 - Aug 2004	3.68	0.85	38.00	566.36	3.72	5.72	4.83	4.68	4.73	0.41			
Averages	3.58	0.90	43.29	433.62	3.63	5.69	4.98	4.30	4.65	0.21	0.07	0.19	0.7726

SUMMARY:

PAC = 1.89 ± 1.89 % per year
P-Value = 0.39

TLI Value = 4.65 ± 0.21 TLI units
TLI Trend = 0.07 ± 0.19 TLI units per year
P-Value = 0.7726

ASSESSMENT:

Eutrophic
No Change

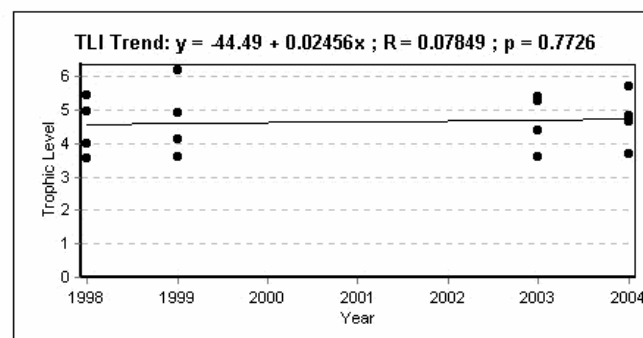
The guide used in the PAC average
P-Value evaluation is

P-Value Range

$P \leq 0.1$
 $0.1 < P \leq 0.2$
 $0.2 < P \leq 0.3$
 $0.3 < P$

Interpretation

Definite Change
Probable Change
Possible Change
No Change



Lake Waipori (Mid Site) 1997 to 2004

Waipori WPM 1997 to 2004 (17 Sep 1997 - 9 Aug 2004)

Percent Annual Change (PAC)

Lake	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TH (mg/m3)	HVOD (mg/m3/day)	Avg PAC	Std Err	P-Value
Change - Units Per Year	(-0.07)	(0.02)	(-0.50)	33.90				
Average Over Period	(2.83)	(0.70)	(36.29)	408.57				
Percent Annual Change (%/Year)	0.00	0.00	0.00	8.30	0.00	2.07	2.07	0.39

Burns Trophic Level Index Values and Trends

Period	Chla (mg/m3)	SD (m)	TP (mgP/m3)	TH (mg/m3)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI Trend units/yr	Std. Err. TLI trend	P-Value
Sep 1997 - Aug 1998	3.03	0.67	38.09	322.30	3.44	6.00	4.83	3.94	4.55	0.56			
Sep 1998 - Aug 1999	3.90	0.53	43.00	341.00	3.72	6.26	4.99	4.01	4.75	0.57			
Sep 2002 - Aug 2003	2.08	0.68	35.45	459.09	3.03	5.98	4.74	4.40	4.54	0.61			
Sep 2003 - Aug 2004	3.05	0.76	32.77	544.55	3.45	5.85	4.64	4.63	4.64	0.49			
Averages	3.01	0.66	37.33	416.74	3.41	6.02	4.80	4.25	4.62	0.25	0.01	0.23	0.9545

SUMMARY:

PAC = 2.07 ± 2.07 % per year
P-Value = 0.39

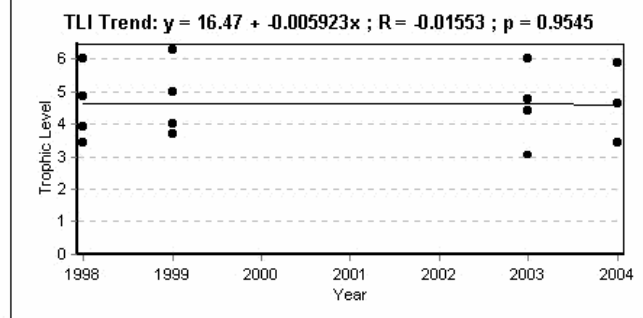
TLI Value = 4.62 ± 0.25 TLI units
TLI Trend = 0.01 ± 0.23 TLI units per year
P-Value = 0.9545

ASSESSMENT:

Eutrophic
No Change

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

P-Value Range	Interpretation
P ≤ 0.1	Definite Change
0.1 < P ≤ 0.2	Probable Change
0.2 < P ≤ 0.3	Possible Change
0.3 < P	No Change



Lake Waipori (South and Mid Sites) 1997 to 2004

Waipori

WPA 1997 to 2004 (17 Sep 1997 - 9 Aug 2004)

Percent Annual Change (PAC)

Lake	Chla (mg/m ³)	SD (m)	TP (mgP/m ³)	TN (mg/m ³)	HVOD (mg/m ³ /day)	Avg PAC	Std Err	P-Value
Change - Units Per Year	(0.00)	(0.03)	(-1.04)	32.09				
Average Over Period	(3.21)	(0.93)	(36.37)	411.08				
Percent Annual Change (%/Year)	0.00	0.00	0.00	7.81	0.00	1.95	1.95	0.39

Burns Trophic Level Index Values and Trends

Period	Chla (mg/m ³)	SD (m)	TP (mgP/m ³)	TN (mg/m ³)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI Trend units/yr	Std. Err. TLI trend	P-Value
Sep 1997 - Aug 1998	3.22	0.89	39.77	330.38	3.51	5.67	4.89	3.97	4.51	0.48			
Sep 1998 - Aug 1999	3.70	0.87	41.50	360.50	3.66	5.69	4.94	4.09	4.60	0.45			
Sep 2002 - Aug 2003	2.81	1.08	30.98	454.55	3.36	5.44	4.57	4.39	4.44	0.43			
Sep 2003 - Aug 2004	3.53	0.71	33.93	550.95	3.61	5.93	4.69	4.64	4.72	0.47			
Averages	3.32	0.89	36.54	424.10	3.54	5.68	4.77	4.27	4.57	0.21	0.05	0.19	0.8907

SUMMARY:

PAC = 1.95 ± 1.95 % per year
P-Value = 0.39

TLI Value = 4.57 ± 0.21 TLI units
TLI Trend = 0.05 ± 0.19 TLI units per year
P-Value = 0.8907

ASSESSMENT:

Eutrophic
No Change

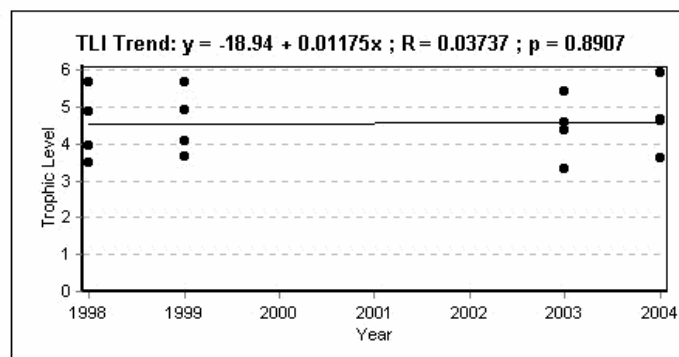
**The guide used in the PAC average
P-Value evaluation is**

P-Value Range

P ≤ 0.1
0.1 < P ≤ 0.2
0.2 < P ≤ 0.3
0.3 < P

Interpretation

Definite Change
Probable Change
Possible Change
No Change



Lake Waipori (South and Mid Sites) 1997 to 1998)

Waipori WP 1997 to 1998 (17 Sep 1997 - 11 Sep 1998)

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	(0.19)	(-0.25)	(12.43)	(44.63)				
Average Over Period	(3.24)	(0.97)	(39.84)	(331.61)				
Percent Annual Change (%/Year)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Burns 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
Sep 1997 - Aug 1998	3.22	0.99	39.77	330.38	3.51	5.54	4.89	3.97	4.48	0.45			
Sep 1998 - Sep 1998	3.70	0.55	41.50	360.50	3.66	6.22	4.94	4.09	4.73	0.56			
Averages	3.46	0.77	40.63	345.44	3.59	5.88	4.92	4.03	4.60	0.34	0.25	0.73	0.7412

<p>SUMMARY: PAC = 0.00 ± 0.00 % per year P-Value = 1.00</p> <p>TLI Value = 4.60 ± 0.34 TLI units TLI Trend = 0.25 ± 0.73 TLI units per year P-Value = 0.7412</p> <p>ASSESSMENT: Eutrophic No Change</p>	<p style="text-align: center;">The guide used in the PAC average P-Value evaluation is</p> <table style="width: 100%; border: none;"> <tr> <td style="border: none;">P-Value Range</td> <td style="border: none;">Interpretation</td> </tr> <tr> <td style="border: none;">P ≤ 0.1</td> <td style="border: none;">Definite Change</td> </tr> <tr> <td style="border: none;">0.1 < P ≤ 0.2</td> <td style="border: none;">Probable Change</td> </tr> <tr> <td style="border: none;">0.2 < P ≤ 0.3</td> <td style="border: none;">Possible Change</td> </tr> <tr> <td style="border: none;">0.3 < P</td> <td style="border: none;">No Change</td> </tr> </table>	P-Value Range	Interpretation	P ≤ 0.1	Definite Change	0.1 < P ≤ 0.2	Probable Change	0.2 < P ≤ 0.3	Possible Change	0.3 < P	No Change	<p style="text-align: center;">TLI Trend: $y = -496.3 + 0.2506x$; R = 0.1399 ; p = 0.7412</p>
P-Value Range	Interpretation											
P ≤ 0.1	Definite Change											
0.1 < P ≤ 0.2	Probable Change											
0.2 < P ≤ 0.3	Possible Change											
0.3 < P	No Change											

Lake Waipori (South and Mid Sites) 2002 to 2004

Waipori

WPA 2002 to 2004 (14 Oct 2002 - 9 Aug 2004)

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	(0.55)	(-0.26)	(4.75)	110.11				
Average Over Period	(3.18)	(0.98)	(32.42)	501.63				
Percent Annual Change (%/Year)	0.00	0.00	0.00	21.95	0.00	5.49	5.49	0.39

Burns 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
Oct 2002 - Aug 2003	2.81	1.08	30.98	454.55	3.36	5.44	4.57	4.39	4.44	0.43			
Sep 2003 - Aug 2004	3.53	0.71	33.93	550.95	3.61	5.93	4.69	4.64	4.72	0.47			
Averages	3.17	0.90	32.45	502.75	3.49	5.68	4.63	4.52	4.58	0.30	0.28	0.64	0.6790

SUMMARY:

PAC = 5.49 ± 5.49 % per year
P-Value = 0.39

TLI Value = 4.58 ± 0.30 TLI units
TLI Trend = 0.28 ± 0.64 TLI units per year
P-Value = 0.6790

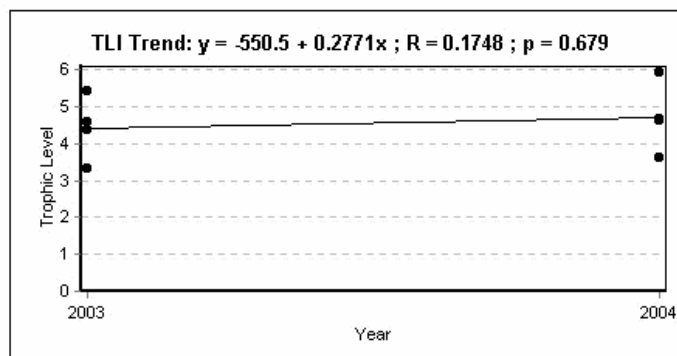
ASSESSMENT:

Eutrophic
No Change

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

P-Value Range

$P \leq 0.1$ Definite Change
 $0.1 < P \leq 0.2$ Probable Change
 $0.2 < P \leq 0.3$ Possible Change
 $0.3 < P$ No Change

Interpretation

Lake Waihola (South, Mid and North Sites) 1997 to 2004

Waihola WH 1997 to 2004 (17 Sep 1997 - 9 Aug 2004)

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	(-0.19)	0.03	-3.93	29.17				
Average Over Period	(8.85)	0.76	55.24	598.54				
Percent Annual Change (%/Year)	0.00	-3.95	-7.11	4.87	0.00	-1.55	2.59	0.59

Burns 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
Sep 1997 - Aug 1998	9.17	0.67	63.35	502.64	4.66	5.99	5.48	4.52	5.16	0.35			
Sep 1998 - Aug 1999	17.13	0.10	175.67	1,057.33	5.35	8.16	6.77	5.49	6.44	0.65			
Sep 2002 - Aug 2003	10.73	0.89	40.61	678.79	4.84	5.67	4.92	4.91	5.08	0.20			
Sep 2003 - Aug 2004	6.31	0.84	43.10	670.56	4.25	5.74	4.99	4.90	4.97	0.30			
Averages	10.84	0.62	80.68	727.33	4.78	6.39	5.54	4.96	5.42	0.24	-0.19	0.22	0.1859

SUMMARY:

PAC = -1.55 ± 2.59 % per year
P-Value = 0.59

TLI Value = 5.41 ± 0.24 TLI units
TLI Trend = -0.19 ± 0.22 TLI units per year
P-Value = 0.1859

ASSESSMENT:

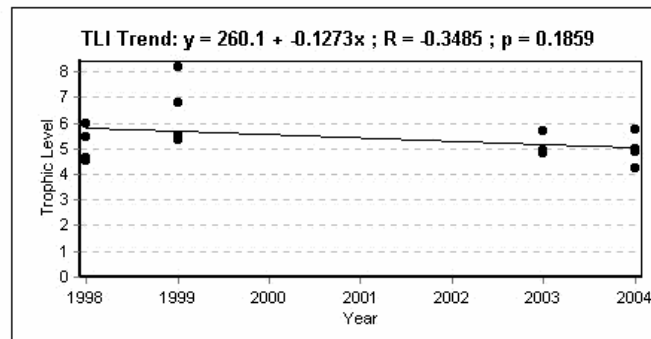
Supertrophic
No Change

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

P-Value Range

$P \leq 0.1$ Definite Change
 $0.1 < P \leq 0.2$ Probable Change
 $0.2 < P \leq 0.3$ Possible Change
 $0.3 < P$ No Change

Interpretation



Lake Waihola (South, Mid and North Sites) 1997 to 1998

Waihola

WH 1997 to 1998 (17 Sep 1997 - 11 Sep 1998)

Percent Annual Change (PAC)

Lake	Chla (mg/m ³)	SD (m)	TP (mgP/m ³)	TN (mg/m ³)	HVOD (mg/m ³ /day)	Avg PAC	Std Err	P-Value
Change - Units Per Year	(3.58)	(-0.08)	36.10	172.16				
Average Over Period	(9.51)	(0.65)	68.03	525.75				
Percent Annual Change (%/Year)	0.00	0.00	53.06	32.75	0.00	21.45	13.06	0.20

Burns Trophic Level Index Values and Trends

Period	Chla (mg/m ³)	SD (m)	TP (mgP/m ³)	TN (mg/m ³)	TLc	TLs	TLp	TLn	TLI Average	Std. Err. TL av	TLI Trend units/yr	Std. Err. TLI trend	P-Value
Sep 1997 - Aug 1998	9.17	0.67	63.35	502.64	4.66	5.99	5.48	4.52	5.16	0.35			
Sep 1998 - Sep 1998	17.13	0.10	175.67	1,057.33	5.35	8.16	6.77	5.49	6.44	0.65			
Averages	13.15	0.38	119.51	779.99	5.01	7.08	6.13	5.01	5.80	0.42	1.28	0.74	0.1349

SUMMARY:

PAC = 21.45 ± 13.06 % per year
P-Value = 0.20

TLI Value = 5.80 ± 0.42 TLI units
TLI Trend = 1.28 ± 0.74 TLI units per year
P-Value = 0.1349

ASSESSMENT:

Supertrophic
Probable Degredation

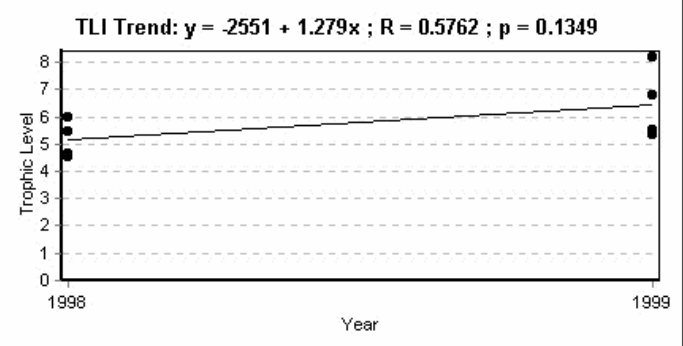
The guide used in the PAC average
P-Value evaluation is

P-Value Range

$P \leq 0.1$
 $0.1 < P \leq 0.2$
 $0.2 < P \leq 0.3$
 $0.3 < P$

Interpretation

Definite Change
Probable Change
Possible Change
No Change



Lake Waihola (South, Mid and North Sites) 2002 to 2004

Waihola WH 2002 to 2004 (14 Oct 2002 - 9 Aug 2004)

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	(-3.03)	(-0.04)	(4.34)	(2.30)				
Average Over Period	(8.43)	(0.86)	(41.91)	(674.49)				
Percent Annual Change (%/Year)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Burns 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
Oct 2002 - Aug 2003	10.73	0.89	40.61	678.79	4.84	5.67	4.92	4.91	5.08	0.20			
Sep 2003 - Aug 2004	6.31	0.84	43.10	670.56	4.25	5.74	4.99	4.90	4.97	0.30			
Averages	8.52	0.86	41.85	674.67	4.55	5.70	4.95	4.91	5.03	0.17	-0.12	0.36	0.7626

SUMMARY:

PAC = 0.00 ± 0.00 % per year
P-Value = 1.00

TLI Value = 5.03 ± 0.17 TLI units
TLI Trend = -0.12 ± 0.36 TLI units per year
P-Value = 0.7626

ASSESSMENT:

**Supertrophic
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

