greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Lakes State of the Environment monitoring programme

Annual data report, 2014/15

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Contents

1. Introduction

This report summarises the key results of Lakes State of the Environment (LSoE) monitoring in the Wellington Region for the period 1 July 2014 to 30 June 2015 inclusive. The LSoE programme involves monthly monitoring of water quality and/or periodic assessments of submerged plant community structure and composition in selected lakes.

Information on lake water levels during 2014/15 is presented in Harkness (2015).

2. Overview of Lakes SoE monitoring programme

Greater Wellington Regional Council (GWRC) routinely monitors water quality in two lakes in the Wellington Region, Lake Wairarapa and Lake Onoke. Monitoring in Lake Wairarapa commenced in 1994 and the programme remained largely unchanged until 2012/13 when changes in monitoring frequency and some site locations and variables were implemented (see Cockeram & Perrie 2013 and Cockeram & Perrie 2014). In August 2009, water quality monitoring programmes were established for two additional lakes, Onoke and Waitawa (Figure 2.1). Monitoring of Lake Onoke is ongoing while monitoring of Lake Waitawa is restricted to 12-month periods every five years (initially in 2009/10 and then again in 2014/15).

In 2011 assessments of ecological condition, based on submerged macrophyte (plant) community structure and composition, were introduced for Lakes Kohangapiripiri, Kohangatera and Pounui (Figure 2.1). Lake Kohangatera vegetation was assessed again in 2013 (see de Winton 2013 and Cockeram & Perrie 2013) and vegetation in all three lakes is scheduled to be re-assessed in early 2016, along with an inaugural assessment of vegetation in Lake Waitawa.

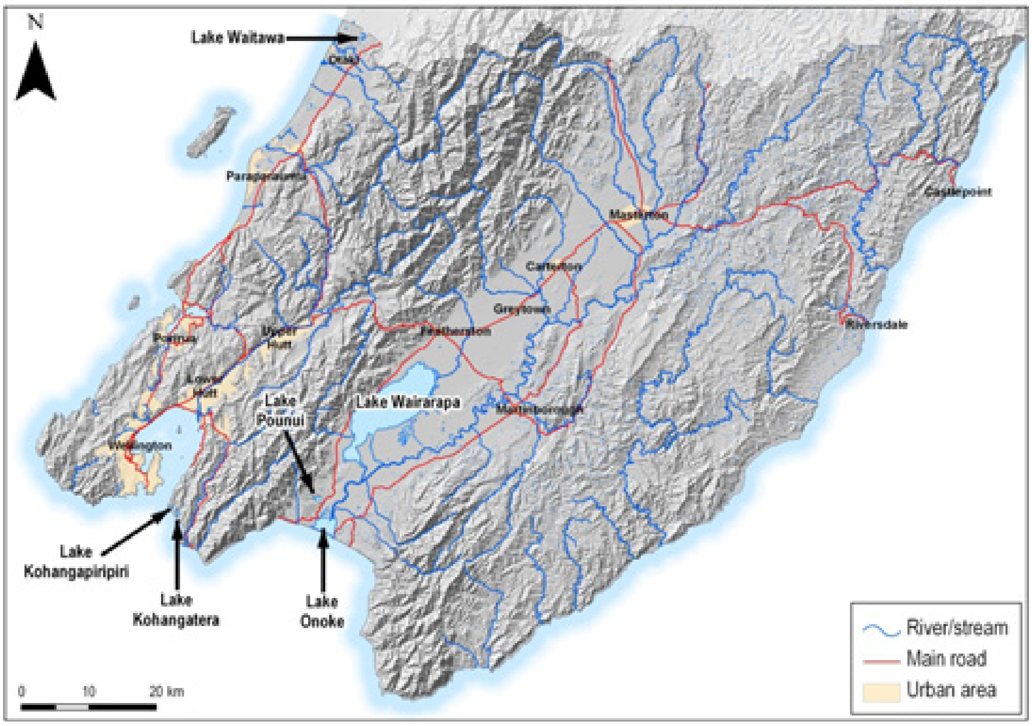

Figure 2.1: Locations of lakes routinely monitored in the Wellington Region

2.1 Monitoring objectives

The aims of GWRC's Lakes SoE monitoring programme are to:

1. Assist in the detection of spatial and temporal changes in the condition of selected lakes;
2. Contribute to our understanding of freshwater biodiversity in the Wellington Region;
3. Determine the suitability of lakes for designated uses;

4. Provide information to assist in targeted investigations where remediation or mitigation of poor water quality or ecosystem health is desired; and
5. Provide information required to determine the effectiveness of regional plans and policies.

2.2 Monitoring sites, variables and protocol

Two types of lake monitoring are undertaken in the Wellington Region:

- Monthly analysis of water samples for a variety of physico-chemical variables (eg, dissolved oxygen, water temperature, pH, conductivity, visual clarity (Secchi depth), turbidity, suspended solids, chlorophyll *a* and dissolved and total nutrients) and monthly assessment of the phytoplankton community (taxa presence, relative abundance and, where potentially toxic cyanobacteria are present, cell counts and potentially cyanotoxin analysis); and

- Periodic assessments of macrophyte community structure and composition (as an indicator of ecological condition) in selected lakes.

In general, routine water quality monitoring is limited to Lakes Wairarapa and Onoke and macrophyte assessments are limited to Lakes Kohangapiripiri, Kohangatera and Pounui.

2.2.1 Monitoring in 2014/15

As well as ongoing water quality monitoring in Lakes Wairarapa and Onoke, monthly water quality monitoring was undertaken in Lake Waitawa during 2014/15 (this lake was last monitored in 2009/10). Two sites were monitored; one in the middle of the lake and one for recreational purposes at the lake's edge.

Two monitoring sites were added to the Lake Onoke sampling programme in July 2014. These sites are located upstream of Lake Onoke (Figure 2.2) and were selected to provide further information on the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River on the water quality in Lake Onoke (see Milne et al. 2014 for details).

Monitoring site locations and coordinates are provided in Figures 2.2 and 2.3, and Appendix 1, respectively. Note that as the monitoring site in Lake Onoke is located where the Ruamahanga River enters the lake, it is unlikely to be representative of water quality across the whole lake (see Perrie & Milne 2012).

In addition to monthly water quality measurements, continuous monitoring of water temperature (Lake Wairarapa and Lake Waitawa) and dissolved oxygen (Lake Waitawa) was undertaken over selected periods.[1] The full list of variables monitored, together with details of field and analytical methods for each lake and site, is provided in Appendix 2.

No LakeSPI surveys were undertaken in 2014/15.

[1] Continuous monitoring of conductivity also occurs near the Barrage Gates located at the southern end of Lake Wairarapa but the data are not reported here.

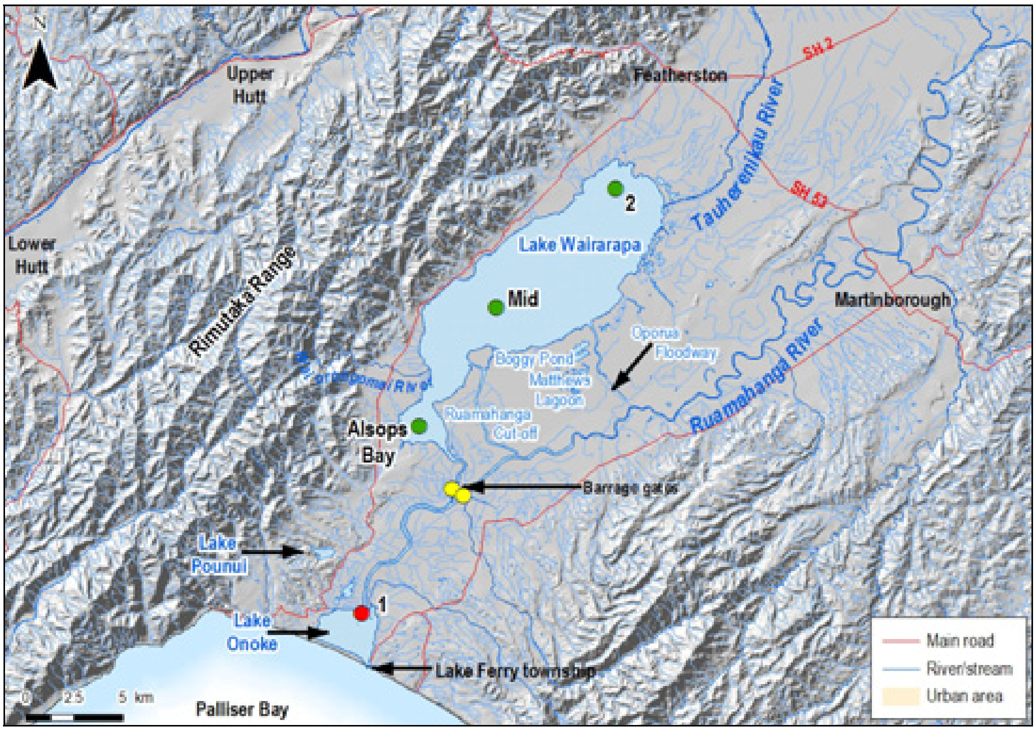

Figure 2.2: Lake Wairarapa and Lake Onoke sites monitored during 2014/15. Green circles = Lake Wairarapa sites, red circles = Lake Onoke main site and yellow circles = new sites sampled to help inform the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River on water quality in Lake Onoke

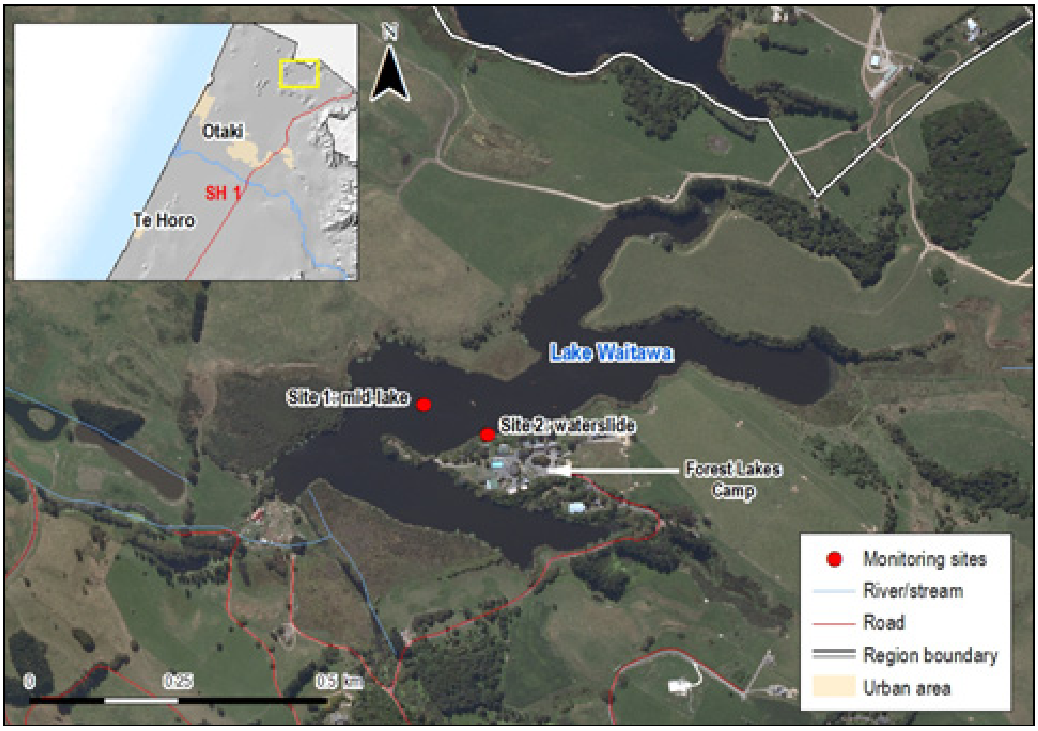

Figure 2.3: Lake Waitawa sites monitored during 2014/15

2.3 Data analysis and reporting

2.3.1 Water quality

Water quality data collected from Lakes Wairarapa, Onoke and Waitawa are summarised and assessed using the trophic level index (TLI). The TLI was developed by Burns et al. (2000) for assessing the water quality status of New Zealand lakes. The TLI is calculated using four key variables of lake water quality (chlorophyll *a*, Secchi depth, total phosphorus and total nitrogen) and is based on the following four regression equations:

1. $TLc = 2.22 + 2.54 \log(\text{Chlorophyll } a)$
2. $TLs = 5.10 + 2.27 \log\left(\frac{1}{\text{Secchi depth}} - \frac{1}{40}\right)$
3. $TLp = 0.218 + 2.92 \log(\text{Total phosphorus})$
4. $TLn = -3.61 + 3.01 \log(\text{Total nitrogen})$

TLI scores are calculated for each individual sampling occasion and then averaged (mean) over the reporting period.[2] Lake water quality is assigned an overall trophic level status according to this mean TLI score (Table 2.1). TLI scores (and hence trophic level status) are calculated and reported for an annual and, where data are available, a three-year (rolling mean) period. For lakes with multiple monitoring sites (Lake Wairarapa), TLI scores are calculated for each individual site and then averaged to provide an overall TLI score for the lake. For Lake Waitawa, TLI scores are calculated by pooling results from water samples collected from the entire lake water column and epilimnion (when the lake was considered 'mixed' or 'stratified', respectively).

Table 2.1: Classification of lake trophic status using the TLI (after Burns et al. 2000) and nutrient enrichment descriptions described in Burns et al. (1999)

Trophic status (nutrient enrichment)	TLI	Chlorophyll *a* (mg/m³)	Secchi depth (m)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
Ultra-microtrophic (practically pure)	0.0–1.0	0.13–0.33	33–25	0.00084–0.0018	0.016–0.034
Microtrophic (very low)	1.0–2.0	0.33–0.82	25–15	0.0018–0.0041	0.034–0.073
Oligotrophic (low)	2.0–3.0	0.82–2.0	15–7.0	0.0041–0.009	0.073–0.157
Mesotrophic (medium)	3.0–4.0	2.0–5.0	7.0–2.8	0.0090–0.0200	0.157–0.337
Eutrophic (high)	4.0–5.0	5.0–12	2.8–1.1	0.0200–0.0430	0.337–0.725
Supertrophic (very high)	5.0–6.0	12–31	1.1–0.4	0.0430–0.0960	0.725–1.558
Hypertrophic (extremely high)	>6.0	>31	<0.4	>0.0960	>1.558

[2] This TLI calculation approach differs to that outlined in Burns et al. (2000) and that used in previous reporting (eg, Cockeram & Perrie 2013). See Cockeram and Perrie (2014) for a summary of the changes to previous TLI reporting.

During data processing, any water quality variables reported as less than or greater than detection limits were replaced by values one half of the detection limit or the detection limit respectively (eg, a value of <2 became 1, a value of >400 became 400). The exceptions are minimum and maximum values presented in the tabulated summaries in Sections 3–5 and Appendix 3 (eg, if a value was reported as <2 the minimum value presented is <2).

Continuous water temperature and dissolved oxygen data are graphed and no formal analysis of this data is undertaken.

2.3.2 Phytoplankton

Phytoplankton relative abundance data collected from Lakes Onoke and Wairarapa are not reported here. In Lake Waitawa, biovolumes for potentially toxic cyanobacteria species present are calculated and the total biovolume from each monthly sample is compared against the alert level framework provided in the interim national cyanobacteria guidelines for recreational fresh waters (MfE/MoH 2009; Table 2.2). Phytoplankton samples that were analysed for cyanotoxins are also compared against guidelines provided in MfE/MoH (2009).

Table 2.2: Biovolume alert level framework used to assess the health risk to recreational users from potentially toxic phytoplankton species (from MfE/MoH 2009). Interpretation of the guidelines in terms of the risk to human health is also presented

Alert level	Biovolume (mm^3/L)	Risk to human health
Surveillance (green mode)	≤0.5 mm^3/L	Low risk
Alert (amber mode)	0.5 to <1.8 mm^3/L	Increased risk
Action (red mode)	≥1.8 mm^3/L	High risk

2.3.3 Submerged aquatic plant community assessments

Submerged aquatic plant communities are assessed using the nationally accepted LakeSPI (Submerged Plant Index) methodology developed by Clayton and Edwards (2006), (refer Appendix 2). Application of the LakeSPI method results in three indices expressed as a percentage of expected pristine state:

- A native condition index (ie, the diversity and quality of the indigenous flora);
- An invasive condition index (ie, the degree of impact by invasive weed species); and
- An overall LakeSPI index that synthesises components of both the native condition and invasive condition indices to provide an overall indication of lake ecological condition.

The LakeSPI index is used to place the lake vegetation into one of five categories of lake condition (Table 2.3; Verburg et al. 2010).

Table 2.3: Classification of lake ecological condition using the LakeSPI index (from Verburg et al. 2010)

Lake ecological condition	LakeSPI index (% of expected pristine state)
Non-vegetated	0
Poor	>0–20
Moderate	>20–50
High	>50–75
Excellent	>75

3. Lake Wairarapa

Water samples were collected from Lake Wairarapa on 12 occasions during 2014/15. However, due to intermittent access to the Alsops Bay site, this site was only sampled on eight occasions[3]. A summary of water quality for each site is presented in Table 3.1.

Trophic level classes based on mean values and overall TLI scores at each site for the 2014/15 year and, where data records are sufficient[4], a three-year period (July 2012 to June 2015), are presented in Table 3.2. Annual mean TLI scores for each site ranged from 4.6 (eutrophic) to 5.0 (supertrophic). For the two sites where sufficient data were available to calculate TLI scores for the three-year period, scores were 5.0 (supertrophic) at Alsops Bay and 5.1 (supertrophic) at Site 2 (Table 3.2). Overall, based on the average (mean) of the two sites assessed over the three-year period, the lake can be classed as supertrophic with a TLI score of 5.1.

Continuous water temperature data collected between December 2014 and January 2015 from two depths at Site 2 (just below the lake surface and just above the lake bottom) and from the old pier located at the northern end of the lake (which is not a routine water quality sampling site) are presented in Figure 3.1. Water temperatures at both sites regularly exceed 22°C during this period. Data collected from two depths at Site 2 are generally very similar although there are occasions when water temperatures recorded from near the lake surface are warmer than those collected from near the lake bottom.

[3] The Alsops Bay site cannot be accessed when lake levels are low. This site was not sampled in September, October or November 2014 or in January 2015.

[4] Monthly sampling of the Lake Wairarapa Middle site only commenced in January 2014 and so there are insufficient data to calculate a three-year TLI as recommended in Milne et al. (2014). Although three-year TLI scores were calculated for Site 2 and the Alsops Bay site, the Alsops Bay site cannot be accessed during low lake levels so was only sampled on 20 occasions over the three-year period (ie, some care should be taken when interpreting the results for this site). Site 2 was sampled on 31 out of a possible 36 occasions over the three-year period; on five occasions it could not be sampled due to strong winds preventing safe access.

Table 3.1: Summary of water quality in Lake Wairarapa at each site, based on 12 sampling occasions (except at Alsops Bay, *n*=8) between July 2014 and June 2015 (D.L. = detection limit)

Variable	Site 2 (*n*=12)					Middle (*n*=12)					Alsops Bay (*n*=8)				
	Mean	Med	Min	Max	% *n* <D.L.	Mean	Med	Min	Max	% *n* <D.L.	Mean	Med	Min	Max	% *n* <D.L.
Water temperature (°C)	13.2	14.5	7.1	20.1	-	13.1	14.4	6.9	19.8	-	11.8	12.0	7.0	16.5	-
Dissolved oxygen (% saturation)	101	101	73	117	-	101	100	75	118	-	100	100	97	104	-
Dissolved oxygen (mg/L)	10.6	10.8	7.3	12.7	-	10.7	10.8	7.6	12.8	-	10.9	10.7	9.7	12.6	-
pH	7.7	7.7	7.4	8.2	-	7.7	7.7	7.4	8.3	-	7.5	7.4	6.9	8.1	-
Conductivity (µS/cm)	1,115	596	202	2,660	-	1,129	581	197	2,687	-	2,660	2,090	195	7,926	-
Secchi depth (m)	0.25	0.20	0.13	0.48	-	0.27	0.21	0.12	0.56	-	0.47	0.28	0.17	1.21	-
Turbidity (NTU)	64.5	62.5	12.4	167	0	68.8	71.0	11.5	150	0	39.6	44.5	4.2	76	0
Total suspended solids (mg/L)	65	53	14	181	0	66	64	9	173	0	34	33	6	56	0
Volatile suspended solids (mg/L)[1]	4.8	5.0	<2.0	11.0	25	4.9	5.5	<2.0	10.0	33	2.8	2.0	<2.0	7.0	63
Total nitrogen (mg/L)	0.556	0.465	0.240	0.990	0	0.537	0.445	0.170	1.030	0	0.411	0.335	0.150	0.810	0
Total Kjeldahl nitrogen (mg/L)	0.333	0.305	0.200	0.530	0	0.324	0.275	0.160	0.590	0	0.244	0.245	0.150	0.330	0
Nitrite-nitrate nitrogen (mg/L)	0.223	0.174	<0.002	0.520	17	0.211	0.168	<0.002	0.530	17	0.168	0.086	<0.002	0.480	38
Ammoniacal nitrogen (mg/L)	0.005	0.005	<0.010	0.005	100	0.005	0.005	<0.010	0.005	100	0.005	0.005	<0.010	0.005	100
Total phosphorus (mg/L)	0.060	0.058	0.023	0.105	0	0.065	0.065	0.022	0.131	0	0.042	0.040	0.014	0.083	0
Dissolved reactive phosphorus (mg/L)	0.008	0.008	<0.004	0.016	25	0.008	0.007	<0.004	0.018	17	0.007	0.008	<0.004	0.014	38
Chlorophyll *a* (mg/m³)[1]	3.9	3.5	<3.0	8.0	58	5.7	4.5	3.0	11.0	25	3.1	2.8	<3.0	6.0	63
Pheophytin *a* (mg/m³)[1]	2.5	1.5	<3.0	5.5	100	3.9	2.3	<3.0	15.0	100	1.8	1.5	<3.0	3.0	100
Absorbance at 340 nm (AU/cm)	0.046	0.048	0.014	0.094	0	0.050	0.056	0.015	0.090	0	0.036	0.035	0.010	0.086	0
Absorbance at 440 nm (AU/cm)	0.017	0.018	0.003	0.035	0	0.019	0.021	0.004	0.032	0	0.012	0.012	<0.002	0.030	25
Absorbance at 740 nm (AU/cm)	0.004	0.003	<0.002	0.008	42	0.004	0.005	<0.002	0.007	33	0.002	0.002	<0.002	0.005	50

[1] The detection limits for chlorophyll *a*, pheophytin *a* and volatile suspended solids (see Appendix 2) could not always be achieved by the laboratory.

Table 3.2: Trophic level values for each of the four TLI variables as well as an overall mean TLI score for Lake Wairarapa, based on both July 2014 to June 2015 and the three-year period July 2012 to June 2015 (note variable *n* between sites). Trophic level classes are provided in brackets

Site 2		
	Annual mean (*n*=12)	**Three-year mean (*n*=31)**
Total nitrogen	4.5 (eutrophic)	4.5 (eutrophic)
Total phosphorus	5.2 (supertrophic)	5.5 (supertrophic)
Secchi depth	6.5 (hypertrophic)	6.5 (hypertrophic)
Chlorophyll *a*	3.6 (mesotrophic)	4.0 (eutrophic)
Overall TLI score	**4.9 (eutrophic)**	**5.1 (supertrophic)**
Middle site		
	Annual mean (*n*=12)	Insufficient data to calculate three-year mean
Total nitrogen	4.4 (eutrophic)	
Total phosphorus	5.4 (supertrophic)	
Secchi depth	6.5 (hypertrophic)	
Chlorophyll *a*	4.0 (eutrophic)	
Overall TLI score	**5.0 (supertrophic)**	
Alsops Bay		
	Annual mean (*n*=8)	**Three-year mean (*n*=20)**
Total nitrogen	4.1 (eutrophic)	4.4 (eutrophic)
Total phosphorus	4.8 (eutrophic)	5.3 (supertrophic)
Secchi depth	6.1 (hypertrophic)	6.3 (hypertrophic)
Chlorophyll *a*	3.3 (mesotrophic)	4.0 (eutrophic)
Overall TLI score	**4.6 (eutrophic)**	**5.0 (supertrophic)**

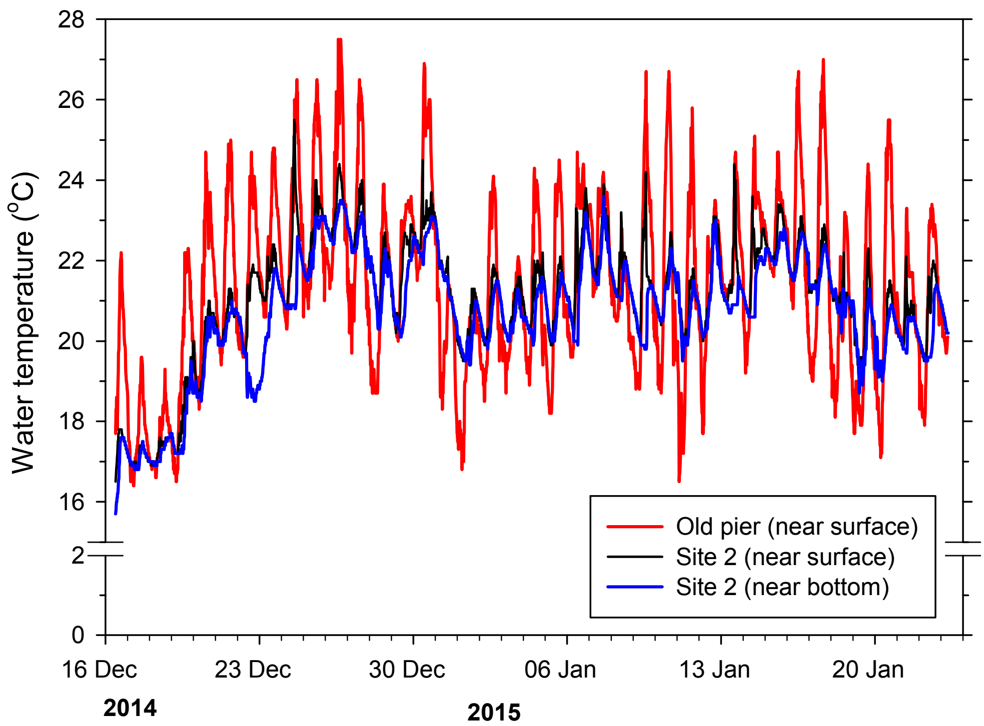

Figure 3.1: Continuous water temperature data collected from two sites (at two different depths at one site) in Lake Wairarapa during December 2014 and January 2015

4. Lake Onoke

Water samples were collected from one site on Lake Onoke on 12 occasions during 2014/15 and the results are summarised in Table 4.1. Trophic level classes based on mean values generated for the three-year period July 2012 to June 2015 ranged from mesotrophic (chlorophyll *a*) to supertrophic (Secchi depth). Overall, based on the three-year assessment, the lake can be classed as eutrophic with a TLI score of 4.6 (Table 4.2). Water quality summaries for the two sites sampled upstream of Lake Onoke are provided in Appendix 3.

Table 4.1: Summary of water quality in Lake Onoke, based on 12 sampling occasions between July 2014 and June 2015[1] (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	13.0	12.9	6.7	20.7	0
Dissolved oxygen (% saturation)	103	103	88	117	0
Dissolved oxygen (mg/L)	10.6	10.4	10.0	11.9	0
pH	7.7	7.7	7.1	8.1	0
Conductivity (µS/cm)	6,436	2,292	136	25,504	0
Secchi depth (m)	0.73	0.77	0.34	>1.04[2]	0
Turbidity (NTU)	14.0	11.5	1.7	38.0	0
Total suspended solids (mg/L)	16	13	<3	45	17
Volatile suspended solids(mg/L) [3]	1.3	1.0	<2.0	3.0	92
Total nitrogen (mg/L) [3]	0.553	0.395	0.200	1.260	17
Total Kjeldahl nitrogen (mg/L) [3]	0.180	0.150	0.140	0.340	25
Nitrite-nitrate nitrogen (mg/L)	0.357	0.235	<0.002	0.980	17
Ammoniacal nitrogen (mg/L)	0.014	0.005	<0.005	0.058	58
Total phosphorus (mg/L)	0.030	0.031	0.013	0.051	0
Dissolved reactive phosphorus (mg/L)	0.011	0.012	<0.004	0.022	17
Chlorophyll *a* (mg/m³)[3]	2.1	1.5	<3.0	5.0	83
Absorbance at 340 nm (AU/cm)	0.020	0.020	0.008	0.045	0
Absorbance at 440 nm (AU/cm)	0.005	0.005	<0.002	0.012	33
Absorbance at 740 nm (AU/cm)	0.001	0.001	<0.002	0.001	100

[1] The June 2015 sampling event was delayed until 13 July 2015.

[2] On two sampling occasions the Secchi disc was visible on the lake bottom (>1.02 and >1.04 m).

[3] The typical detection limit for chlorophyll *a*, total Kjeldahl nitrogen, total nitrogen and volatile suspended solids could not be achieved by the laboratory on all sampling occasions.

Table 4.2: Trophic level values for each of the four TLI variables as well as an overall TLI score for Lake Onoke based on both July 2014 to June 2015 (*n*=12) and the three-year period July 2012 to June 2015 (*n*=36). Trophic level classes are provided in brackets

Variable	TLI score	
	Annual mean (July 2014 to June 2015, *n*=12)	**Three-year mean (July 2012 to June 2015, *n*=36)**
Total nitrogen	4.3 (eutrophic)	4.5 (eutrophic)
Total phosphorus	4.4 (eutrophic)	4.9 (eutrophic)
Secchi depth	5.5 (supertrophic)	5.8 (supertrophic)
Chlorophyll *a*	2.9 (oligotrophic)	3.3 (mesotrophic)
Overall TLI score	**4.3 (eutrophic)**	**4.6 (eutrophic)**

5. Lake Waitawa

Water samples were collected from two sites (Site 1: mid-lake and Site 2: waterslide) on Lake Waitawa on 12 occasions during 2014/15. During this period, the lake was considered ‘mixed’ on five occasions and ‘stratified’ on seven occasions. Stratification occurred through September 2014 to March 2015 inclusive. See Appendix 2 for criteria for determining whether the lake was mixed or stratified and the sampling approach adopted in these different conditions.

Table 5.1 provides a summary of water quality at Site 1 based on depth-integrated samples collected from either the entire water column or the eplimnion (depending on when the lake was classified as mixed or stratified, respectively). A summary of the water quality from samples collected from the hypolimnion at Site 1, based on seven samples when the lake was stratified, is presented in Table 5.2.

Table 5.1: Summary of water quality at Site 1 (mid-lake) in Lake Waitawa, based on 12 depth-integrated samples collected from either the entire water column or the epilimnion (when mixed or stratified, respectively) between July 2014 and June 2015 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	16.4	17.2	9.2	25.3	-
Dissolved oxygen (% saturation)	95.3	88.8	50.7	158.4	-
Dissolved oxygen (mg/L)	9.3	10.1	5.1	15.0	-
pH[1]	7.9	7.6	7.2	9.0	-
Conductivity (µS/cm)	245	243	214	265	-
Secchi depth (m)	1.96	1.80	1.12	3.13	-
Turbidity (NTU)	5.01	3.85	0.99	12.30	-
Total suspended solids (mg/L)	5.6	4.5	2.0	11.0	0
Volatile suspended solids (mg/L)	4.1	3.0	<2.0	11.0	25
Total nitrogen (mg/L)	1.497	1.460	1.090	2.100	0
Total Kjeldahl nitrogen (mg/L)	1.242	1.255	0.810	1.630	0
Nitrite-nitrate nitrogen (mg/L)	0.255	0.104	<0.002	0.710	17
Ammoniacal nitrogen (mg/L)	0.127	0.044	<0.010	0.440	42
Total phosphorus (mg/L)	0.156	0.161	0.066	0.270	0
Dissolved reactive phosphorus (mg/L)	0.090	0.079	0.010	0.186	0
Chlorophyll *a* (mg/m³)	16.3	9.5	<3.0	47.0	8
Absorbance at 340 nm (AU/cm)	0.102	0.100	0.076	0.151	0
Absorbance at 440 nm (AU/cm)	0.019	0.019	0.013	0.032	0
Absorbance at 740 nm (AU/cm)	0.002	0.001	<0.002	0.007	83
E. coli (cfu/100mL)	8	4	<1	50	83
Faecal coliforms (cfu/100mL)	8	4	<1	53	83

[1]The summary of pH is based on 11 measurements.

Table 5.2: Summary of water quality at Site 1 (mid-lake) in Lake Waitawa, based on seven samples collected from the hypolimnion (when the lake was classed as stratified) between September 2014 and March 2015 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Total nitrogen (mg/L)	4.193	2.700	1.460	7.900	0
Total Kjeldahl nitrogen (mg/L)	4.163	2.700	1.260	7.900	0
Nitrite-nitrate nitrogen (mg/L)	0.031	0.003	0.001	0.199	43
Ammoniacal nitrogen (mg/L)	3.083	1.600	0.400	7.000	0
Total phosphorus (mg/L)	1.456	1.020	0.270	2.700	0
Dissolved reactive phosphorus (mg/L)	0.506	0.530	0.230	0.870	0

Water temperature and dissolved oxygen depth profiles (collected monthly) are provided in Appendix 4. Plots of continuous water temperature and dissolved oxygen are provided in Figures 5.1 and 5.2, respectively. The continuous water temperature data shows that thermal stratification, as indicated by different temperatures recorded at different depths, occurred numerous times between August and the end of April. The longest period of thermal stratification without any mixing of the entire lake water column occurred between mid-December and March (Figure 5.1).

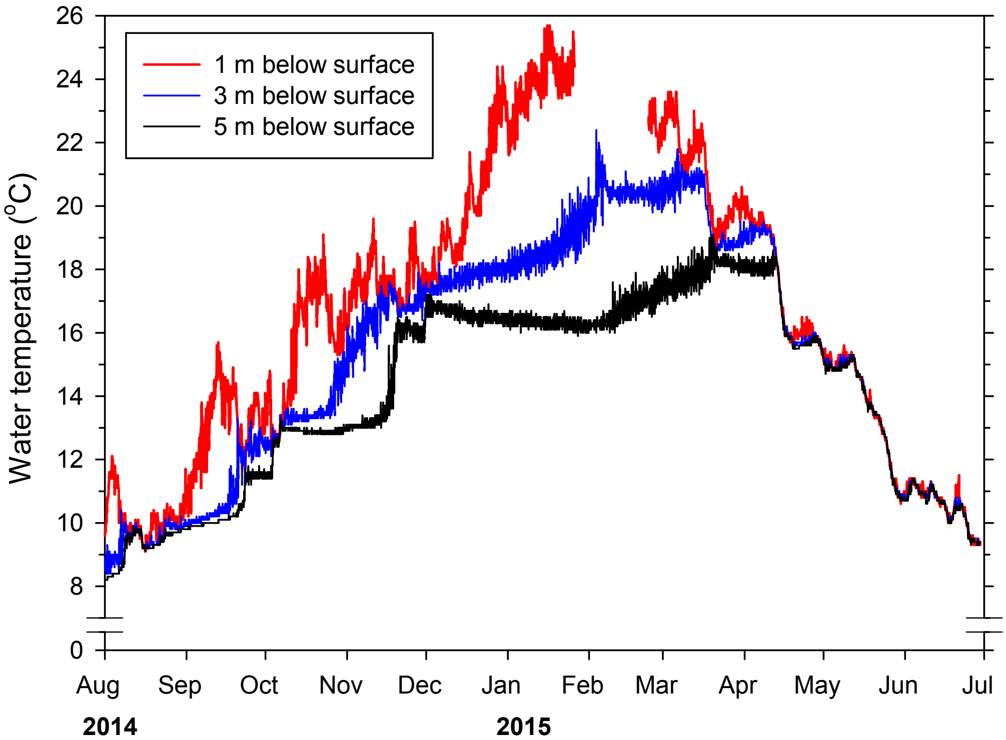

Figure 5.1: Continuous water temperature data collected from three different depths at Site 1 (mid-lake) in Lake Waitawa between August 2014 and July 2015. Note a period of missing data in February due to logger malfunction for the site located 1 m below the surface

Continuous monitoring of dissolved oxygen concentrations at a depth 3 m below the lake surface (or around the 3.5 m above the lake bottom) indicated that hypoxic conditions (eg, concentrations <2 mg/L) occurred regularly throughout the monitoring period. A sustained period of very low oxygen concentrations was recorded from around mid-December 2014 through to the beginning of February 2015 (Figure 5.2).

Trophic level classes, based on mean values generated over the 12-month monitoring period, ranged from eutrophic (chlorophyll *a* and Secchi depth) to hypertrophic (total phosphorus). Overall, the lake can be classed as supertrophic with a TLI score of 5.4 (Table 5.3).

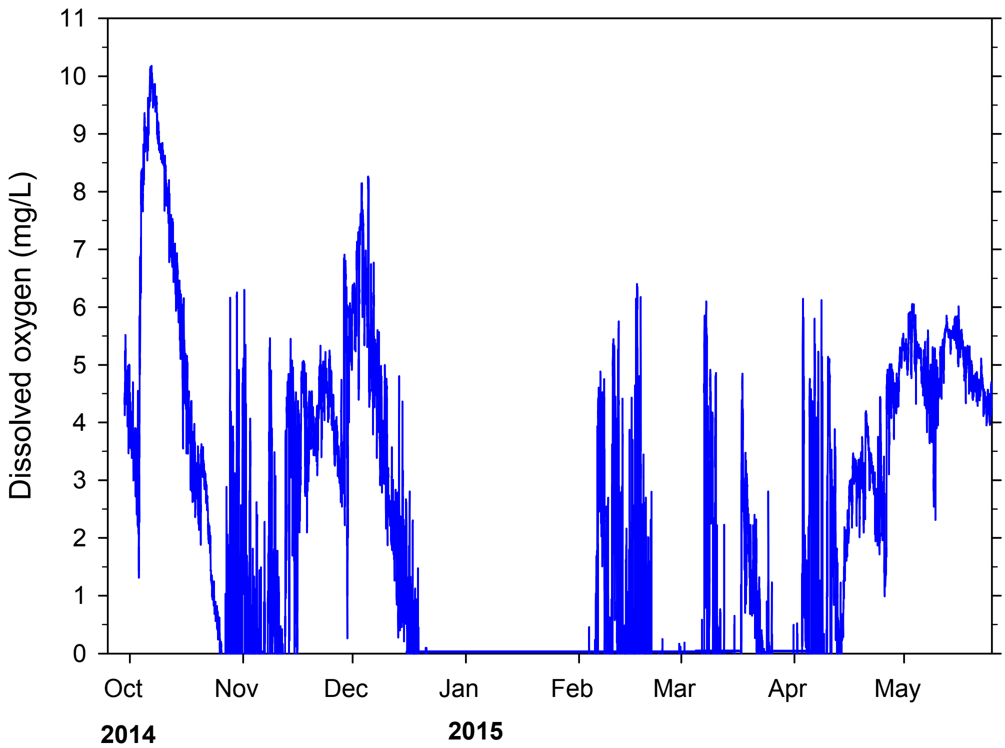

Figure 5.2: Continuous dissolved oxygen data collected from 3 m below the lake surface at Site 1 (mid-lake) in Lake Waitawa between October 2014 and June 2015

Table 5.3: Trophic level values for each of the four TLI variables as well as an overall TLI score for Site 1 (mid-lake) in Lake Waitawa, based on 12 depth-integrated samples collected from either the entire water column or the epilimnion (when mixed or stratified, respectively) between July 2014 and June 2015

Variable	**TLI score** **Annual mean** **(July 2014 to June 2015, *n*=12)**
Total nitrogen	5.9 (supertrophic)
Total phosphorus	6.5 (hypertrophic)
Secchi depth	4.4 (eutrophic)
Chlorophyll *a*	4.8 (eutrophic)
Overall TLI score	**5.4 (supertrophic)**

Median *E. coli* concentrations of 4 and 11 cfu/100mL were recorded at Sites 1 and 2, respectively, over the monitoring period (Table 5.1 and 5.4, respectively). Results from all sampling occasions were below the MfE/MoH (2003) 'surveillance' (safe level) guideline of 260 cfu/100mL at Site 1 and on 11 of the 12 sampling occasions at Site 2; on one occasion (December 2015) Site 2 exceeded the MfE/MoH (2003) 'action' (unacceptable health risk) guideline of 550 cfu/100mL.

Table 5.4: Summary of *E. coli* and faecal coliform results from Site 2 (waterslide) in Lake Waitawa, based on 12 samples collected between July 2014 and June 2015

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
E. coli (cfu/100mL)	79	11	1	700	0
Faecal coliforms (cfu/100mL)	81	14	1	700	0

Potentially toxic cyanobacteria species were recorded on every sampling occasion at both Lake Waitawa sampling sites; *Anabaena* and *Mycroscystis* were the most common genera recorded. Information on cell counts of potentially toxic cyanobacteria for each site and sampling occasion are provided in Appendix 5. Comparing the total sample biovolumes (potentially toxic species only) with the alert level framework in the interim national cyanobacteria guidelines for fresh water (MfE/MoH 2009) showed that Site 1 fell within the 'action (red mode)' level on four occasions and Site 2 on ten occasions (Table 5.5).

Phytoplankton samples collected from Site 2 (waterslide) in September 2014 and March 2015 contained moderate and very high cyanobacteria biovolumes, respectively, and were analysed for a suite of cyanotoxins. Low concentrations of anatoxin-a (0.22 µg/L) were detected in the September 2014 sample (coinciding with an *Anabaena*-dominated bloom) and high concentrations of microcystins (63 µg/L) were detected in the March 2015 sample (coinciding with a *Microcystis*-dominated bloom).[5] The concentration of microcystins recorded was over four times greater than the maximum allowable value[6] (13.2 µg/L) for exposure by a 15 kg child during recreation and is also greater than the maximum allowable value for a 70 kg adult (61.6 µg/L; MfE/MoH 2009). The presence of very high concentrations of microcystins in Lake Waitawa was further confirmed from a one-off sample collected in March from the jetty in the lake. This sample recorded a total microcystin concentration of 2,245 µg/L.

[5] Additional (frozen) samples were subsequently analysed for the presence of microcystins from both Site 1 (*n*=8) and Site 2 (*n*= 7) over the monitoring period. Microcystins were detected on two occasions from Site 1 (0.6 and 1.4 µg/L) and three occasions from Site 2 (3.3, 12 and 48.2 µg/L).

[6] Note that there are no 'maximum allowable values' for anatoxin-a in MfE/MoH (2009).

Table 5.5: Total biovolumes of potentially toxic cyanobacteria for Site 1 (mid-lake) and Site 2 (waterslide) in Lake Waitawa on each sampling occasion during 2014/15. The total biovolumes are coloured based on the alert level framework in MfE/MoH (2009): green=surveillance, amber=alert and red=action

Month	Total biovolume of potentially toxic cyanobacteria in sample (mm^3/L)	
	Site 1 (mid-lake)	Site 2 (waterslide)
July 2014	0.154	133.3
August 2014	0.750	4.57
September 2014	4.58	10.40
October 2014	0.998	3.12
November 2014	0.103	0.250
December 2014	3.14	273.7
January 2015	15.28	4.15
February 2015	38.14	48.89
March 2015	0.821	4,337.8
April 2015	0.229	19.2
May 2015	0.825	6.07
June 2015	0.021	0.075

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Appendix 1: Lake SoE water quality monitoring sites

Lake	Site no./name	Monitoring variables[1]	NZTM site coordinates		Lake characteristics
			Easting	Easting	
Wairarapa	2 (stump)	Monthly sampling: typical water quality suite plus phytoplankton (relative abundance). Continuous water temperature at two depths (near water surface and near lake bottom)	1791644	5439152	Max depth: ~2.5 m; Lake area: 7,850 ha; Catchment area: 57,245 ha; Landcover: indigenous forest and scrub 43.9%, pasture 54%, urban 0.4% and other 17%.
	Middle	Monthly sampling: typical water quality suite	1785607	5433715	
	Alsops Bay	Monthly sampling: typical water quality suite plus occasional phytoplankton	1781568	5427654	
	Old pier	Continuous water temperature only	1792753	5440224	
Onoke	1	Monthly sampling: typical water quality suite plus phytoplankton (relative abundance)	1778829	5417842	Max depth: ~5.5 m; Lake area: 622 ha; Catchment area: 341,744 ha; Landcover: indigenous forest and scrub 27.5%, pasture 64%, exotic forest 3.7%, urban 0.7% and other 3.1%
	Ruamahanga River at Boat Ramp[2]	Monthly sampling: typical water quality suite	1783984	5423866	
	Lake Wairarapa downstream of Barrage Gates[2]	Monthly sampling: typical water quality suite	1783638	5423977	
Waitawa	1 (mid-lake)	Monthly sampling: typical water quality suite plus phytoplankton (unit counts and cell counts of potentially toxic cyanobacteria). Continuous water temperature at three depths and continuous dissolved oxygen at one depth	1783301	5489532	Max depth: ~7 m; Lake area: 16 ha; Catchment area: 278 ha; Landcover: indigenous forest and scrub 2%, pasture 94.1%, urban 1.1% and other 2.8%
	2 (waterslide)	Monthly sampling: *E. coli* and faecal coliforms plus phytoplankton (unit counts and cell counts of potentially toxic cyanobacteria)	1783423	5489474	
	Jetty	One-off sample for microcystins (cyanotoxin) only	1783335	5489445	

[1] The 'typical' water quality suite varies slightly between sites/lakes but for all sites that are sampled regularly (monthly), water samples are, at minimum, analysed for core lake water quality variables (eg, dissolved and total nutrients, chlorophyll *a* and water clarity (Secchi depth). The exception is Site 2 (waterslide) at Lake Waitawa where samples are only analysed for *E. coli* and faecal coliforms.

[2] These sites are located upstream of Lake Onoke and were selected to provide information on the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River on water quality in Lake Onoke.

Appendix 2: Monitoring variables and methods

Physico-chemical water quality (monthly spot measurements)

Lake Wairarapa and Lake Onoke

Lake Wairarapa monitoring sites are accessed by boat and the Lake Onoke monitoring site (as well as the two upstream monitoring sites sampled as part of this programme) are accessed by wading from the lake or river edge. Water samples are collected in accordance with the sub-surface grab method for sampling isothermal lakes described in Smith et al. (1989) and in the case of Lake Onoke, a 'grab pole' is used to collect water samples in an effort to minimise the potential effects of re-suspension of lakebed sediments (caused by wading) on the samples. Note that the sub-surface grab method differs from protocols outlined in Burns et al. (2000) for the sampling of isothermal lakes.

Field measurements (conductivity, dissolved oxygen, pH and temperature) are generally taken using a YSI 556 field meter which is calibrated on the day of sampling. Secchi disc measurement methodology is consistent with the procedure outlined in Burns et al. (2000) except that an underwater viewer is not used. Note that all field measurements collected from Lake Onoke (and upstream sites) are made from a 'wading position', although care is taken to minimise any disturbance of lakebed sediments.

Water samples requiring laboratory analysis are stored on ice upon collection and couriered overnight to RJ Hill Laboratories in Hamilton. The variables monitored and current analytical methods are summarised in Table A2.1. All lake water samples collected for dissolved nutrient analysis are filtered in the laboratory.

Lake Waitawa

Site 1 (mid-lake) is accessed by boat whereas water samples collected from Site 2 (waterslide) are collected from the lake edge with a 'grab pole' (no wading). Water samples collected from Site 2 are consistent with the sub-surface grab method for sampling isothermal lakes described in Smith et al. (1989). Sampling methodology for Site 1 is different from that previously used during 2009/10 (Perrie & Milne 2012):

- Water temperature and dissolved oxygen depth profiles are carried out every 0.5 m from just below the lake surface until the lake bottom (~ 6.5–7 m deep). If the profile shows that dissolved oxygen concentrations are fairly similar throughout the water column and no hypoxic conditions are present (defined as concentrations of dissolved oxygen ≤ 2 mg/L), the lake is considered 'mixed' and one water sample is collected. This is a depth-integrated sample collected using a sampling tube lowered from the lake surface to 1 m above the lake bottom. The sampling tube is then retrieved and drained into a bucket and water samples (physico-chemical and phytoplankton) are collected from the bucket.

- If hypoxic conditions are present, the lake is considered 'stratified' and two separate water samples are collected: one from the top water layer (epilimnion) defined as from the surface to 0.5 m above the hypoxic layer, and one from the bottom layer of water (hypolimnion) within the hypoxic layer. The sample collected from the epilimnion is a depth-integrated sample collected using a sampling tube. The depth that this sample is collected to is variable given the vertical progression (up and down) of the hypoxic layer over the sampling period. The hypolimnion sample is a discrete sample collected using a Van-Dorn sampler and this sample is always collected 0.5 m above the lake bottom. Water samples collected from the hypolimnion are only analysed for total and dissolved nutrients.

Note that the above approach differs from the protocols outlined in Burns et al. (2000) for the sampling of stratified lakes. Determination of whether a lake is mixed or stratified is also typically determined using water temperature depth profiles (cf. dissolved oxygen) and is based on the location of the thermocline (a layer of water where water temperature changes rapidly and separates the epilimnion and hypolimnion). However, differences in dissolved oxygen concentration between the surface and bottom layers of the lake are also considered to indicate stratification (Burns et al. 2000). Given the relatively shallow nature of Lake Waitawa, and that hypoxic conditions are present at times when there is negligible difference in water temperature between the surface and lake bottom waters, differences in dissolved oxygen are considered more appropriate to define whether the lake is mixed or stratified and inform the sampling approach.

Field measurements (conductivity, dissolved oxygen, pH and temperature) are taken using a Hach HQ40d field meter which is calibrated on the day of sampling. Secchi depth methodology is consistent with that undertaken in Lakes Onoke and Wairarapa and samples requiring laboratory analysis (Table A2.1) are stored on ice upon collection and couriered overnight to RJ Hill Laboratories in Hamilton.

Table A2.1: Laboratory analytical methods for lake water samples

Variable	Method	Detection limit
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 22nd Ed. 2012	0.05 NTU
Total suspended solids	Filtration using Whatman 934 AH, Advantec GC-50 or 1-2 equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 22nd Ed. 2012	2 mg/L
Volatile suspended solids[1]	Filtration (GF/C, 1.2 µm). Ashing 550°C, 30 min. Gravimetric. APHA 2540 E 22nd Ed. 2012	2 mg/L
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N	0.002 mg/L
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3 - I (modified) 22nd Ed. 2012	0.002 mg/L
Nitrate-N + Nitrite-N (NNN)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3 - I (modified) 22nd Ed. 2012	0.002 mg/L
Ammoniacal nitrogen	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4+-N + NH_3-N) APHA 4500-NH_3 F (modified from manual analysis) 22nd Ed. 2012	0.01 mg/L
Total Kjeldahl nitrogen	Kjeldahl digestion, phenol/hyperclorite colorimetry (Discrete Analysis). APHA 4500-N Org C. (modified) 4500- F (modified) 22nd Ed. 2012	0.1 mg/L
Total nitrogen	Calculation: TKN + Nitrate-N +Nitrite-N	0.1 mg/L
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22nd Ed. 2012	0.004 mg/L
Total phosphorus	Total Phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22nd Ed. 2012	0.004 mg/L
Chlorophyll *a* (mg/m^3) [1]	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd Ed. 2012	0.003 mg/L
Pheophytin *a* (mg/m^3) [1]	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd Ed. 2012	0.003 mg/L
Absorbance at 340 nm	Filtered sample. Spectrophotometry, 1cm cell. APHA 5910 B 22nd Ed. 2012	0.002 AU/cm
Absorbance at 440 nm	Filtered sample. Spectrophotometry, 1cm cell. APHA 5910 B 22nd Ed. 2012	0.002 AU/cm
Absorbance at 740 nm	Filtered sample. Spectrophotometry, 1cm cell. APHA 5910 B 22nd Ed. 2012	0.002 AU/cm
Faecal coliforms	APHA 9222D 22nd Ed. 2012	1 cfu/100mL
E. coli	APHA 9222G 22nd Ed. 2012	1 cfu/100mL

[1] Note the detection limit for these variables is not always achieved (ie, is often higher than indicated here).

Physico-chemical water quality (continuous measurements)

Onset Hobo stowaway tidbit loggers were deployed to record continuous water temperature measurements at 15 minute intervals at sites in Lake Waitawa and Lake Wairarapa. Loggers were deployed at variable depths depending on the lake/site.

A D-Opto logger was deployed to record continuous dissolved oxygen concentrations in Lake Waitawa at a depth of approximately 3 m below the surface (or 3.5 m above the lake bottom). The logger was calibrated monthly during its deployment.

Phytoplankton samples

Sampling methods for phytoplankton are consistent with the water quality sub-surface grab method described for Lake Wairarapa, Lake Onoke and Site 2 (water slide) at Lake Waitawa. The Lake Waitawa Site 2 samples targeted any visible phytoplankton scums and hence likely represent the worst case scenario. At Site 1 (mid-lake) in Lake Waitawa, phytoplankton samples were taken from the depth-integrated water sample collected from either the entire water column or the epilimnion (when the lake was classed as mixed or stratified, respectively). Phytoplankton samples were collected from both Lake Waitawa sites and frozen to allow for subsequent cyanotoxin analysis where required. All phytoplankton samples were sent to the Cawthron Institute in Nelson for analysis.

Submerged aquatic plants

Surveys of submerged aquatic plants follow the nationally accepted LakeSPI (Submerged Plant Index) methodology developed by Clayton and Edwards (2006). This involves scuba divers assessing 11 metrics over a 2 m wide transect from the shore to the deepest vegetation limit at several sites which are representative of the lake. Metrics include measures of diversity from the presence of key of plant communities, the depth of vegetation growth, and the extent that invasive weeds are represented.

Appendix 3: Water quality data located upstream of Lake Onoke

Tables A3.1 and A3.2 summarise monthly water quality data collected from two sites located upstream of Lake Onoke during 2014/15. These sites, Lake Wairarapa downstream of Barrage Gates and Ruamahanga River at Boat Ramp, were selected to provide information on the relative effects of the discharges from Lake Wairarapa and the Ruamahanga River (respectively) on water quality in Lake Onoke.

Table A3.1: Summary of water quality for Lake Wairarapa downstream of Barrage Gates, based on 12 sampling occasions between July 2014 and June 2015 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	13.5	13.8	7.0	21.3	-
Dissolved oxygen (% saturation)	98	95	88	116	-
Dissolved oxygen (mg/L)	9.9	9.9	7.0	12.0	-
pH	7.4	7.4	6.4	7.6	-
Conductivity (µS/cm)	1,655	373	134	6,998	-
Secchi depth (m)	0.55	0.45	0.26	>1.10[1]	-
Turbidity (NTU)	22.5	15.5	1.2	56.0	0
Total suspended solids (mg/L)	24	20	<2.0	58	8
Volatile suspended solids (mg/L) [2]	2.3	1.5	<2.0	5.0	50
Total nitrogen (mg/L)	0.587	0.475	0.140	1.590	0
Total Kjeldahl nitrogen (mg/L)	0.237	0.210	0.130	0.510	0
Nitrite nitrogen (mg/L)	0.003	0.003	<0.002	0.009	42
Nitrate nitrogen (mg/L)	0.352	0.285	<0.002	1.070	17
Nitrite-nitrate nitrogen (mg/L)	0.354	0.285	<0.002	1.080	17
Ammoniacal nitrogen (mg/L)	0.017	0.005	<0.010	0.066	58
Total phosphorus (mg/L)	0.039	0.040	0.012	0.074	0
Dissolved reactive phosphorus (mg/L)	0.011	0.011	<0.004	0.030	25
Chlorophyll *a* (mg/m^3) [2]	2.6	1.5	<3.0	8	75

[1] On two sampling occasions the Secchi disc was visible on the bottom.

[2] The typical detection limit for chlorophyll *a* and volatile suspended solids could not be achieved by the laboratory on all sampling occasions.

Table A3.2: Summary of water quality for Ruamahanga River at Boat Ramp, based on 12 sampling occasions between July 2014 and June 2015 (D.L. = detection limit)

Variable	Mean	Median	Minimum	Maximum	% *n* <D.L.
Water temperature (°C)	13.5	12.8	7.7	21.5	-
Dissolved oxygen (% saturation)	100	98	79	119	-
Dissolved oxygen (mg/L)	10.4	10.1	9.4	11.9	-
pH	7.5	7.5	6.9	8.0	-
Conductivity (µS/cm)	559	201	71	1,816	-
Secchi depth (m)	0.94	0.96	0.45	>1.22[1]	-
Turbidity (NTU)	7.4	5.8	1.5	19.2	0
Total suspended solids (mg/L)	8	5	2	21	0
Volatile suspended solids (mg/L)	1.4	1.0	<2.0	4.0	75
Total nitrogen (mg/L)	0.609	0.420	0.150	1.340	0
Total Kjeldahl nitrogen (mg/L)	0.178	0.150	<0.100	0.370	8
Nitrite nitrogen (mg/L)	0.003	0.002	<0.002	0.007	33
Nitrate nitrogen (mg/L)	0.426	0.305	<0.002	1.050	17
Nitrite-nitrate nitrogen (mg/L)	0.429	0.305	<0.002	1.060	17
Ammoniacal nitrogen (mg/L)	0.018	0.005	<0.010	0.052	58
Total phosphorus (mg/L)	0.024	0.025	0.011	0.042	0
Dissolved reactive phosphorus (mg/L)	0.013	0.015	<0.0004	0.021	17
Chlorophyll *a* (mg/m^3)	1.6	1.5	<3.0	3.0	92

[1] On four sampling occasions the Secchi disc was visible on the bottom.

Appendix 4: Lake Waitawa water temperature and dissolved oxygen depth profiles

The following table summarises spot water temperature and dissolved oxygen measurements collected monthly from Site 1 (mid-lake) at Lake Waitawa between July 2014 and June 2015.

Water temperature (°C)												
Depth (m)	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Surface (~0.20)	9.2	10.7	13.9	18.1	18.8	20.5	25.3	22.8	19.2	16.3	12.2	9.6
0.5	9.1	10.7	13.5	18.0	18.8	20.6	25.2	22.9	19.2	16.2	12.2	9.5
1	9.0	10.4	13.0	18.0	18.3	20.6	25.0	22.8	19.0	16.1	12.2	9.5
1.5	8.9	10.4	12.8	16.8	17.3	20.6	24.5	22.7	19.0	16.0	12.2	9.4
2	8.9	10.4	12.8	15.4	17.2	20.6	24.1	22.6	18.9	16.0	12.2	9.4
2.5	8.8	10.1	12.7	14.5	16.9	19.4	23.6	22.1	18.9	15.8	12.2	9.4
3	8.6	10.1	12.6	13.9	16.8	18.5	22.4	21.0	18.9	15.7	12.2	9.4
3.5	8.3	10.0	12.6	13.6	16.8	18.2	20.6	20.8	18.9	15.7	12.2	9.4
4	8.2	9.9	12.6	13.4	16.7	17.7	19.2	20.4	18.7	15.6	12.2	9.4
4.5	8.1	9.8	12.0	13.3	16.6	17.5	18.1	20.0	18.6	15.6	12.2	9.4
5	8.1	9.6	11.7	13.1	16.5	17.2	17.6	19.4	18.6	15.5	12.2	9.4
5.5	8.0	9.5	11.5	12.9	16.3	16.8	17.1	18.5	18.5	15.5	12.2	9.3
6	8.1	9.6	11.2	12.8	15.8	16.6	16.5	17.6	18.2	15.5	12.2	9.3
6.5	-	-	-	-	-	16.3	-	-	-	15.5	12.2	9.3
Dissolved oxygen (% saturation)												
Depth (m)	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Surface (~0.20)	83.9	93.7	112.4	158.4	75.0	117.4	138.8	136.1	54.9	58.7	50.7	63.5
0.5	83.6	92.2	112.5	157.0	72.0	118.9	139.6	136.3	54.7	57.4	50.4	63.8
1	83.4	92.2	111.5	162.0	70.8	120.9	139.4	134.1	47.8	56.9	50.8	64.4
1.5	83.3	91.2	107.6	59.8	58.8	120.9	111.1	133.9	46.1	54.7	50.3	64.5
2	82.9	89.5	105.3	37.0	58.1	124.0	91.6	119.4	45.7	51.1	49.9	65.2
2.5	82.5	88.3	102.0	38.9	54.3	38.2	38.0	63.1	45.2	43.8	49.4	64.4
3	78.9	87.0	98.6	39.0	53.2	7.9	2.4	22.2	44.7	43.0	49.2	64.8
3.5	74.6	84.4	98.7	38.1	51.5	4.0	2.0	1.9	43.4	42.7	49.2	64.4
4	73.4	82.3	97.5	37.5	49.0	3.1	1.1	1.3	5.8	41.8	48.7	61.1
4.5	71.2	73.7	64.1	37.9	45.1	3.0	0.9	1.1	2.0	40.8	48.7	61.0
5	70.6	71.8	53.2	29.0	35.6	2.5	0.9	1.0	1.6	39.2	48.4	60.7
5.5	70.3	69.1	40.3	17.9	15.2	2.2	0.8	0.9	1.3	36.0	48.1	58.6
6	70.0	64.9	19.1	1.9	1.5	1.9	0.7	0.9	1.3	33.3	47.7	58.1
6.5	-	-	-	-	-	1.8	-	-	-	31.1	47.6	57.1
Dissolved oxygen (mg/L)												
Depth (m)	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Surface (~0.20)	9.7	10.6	11.7	15.0	7.0	10.6	11.4	11.8	5.1	5.9	5.4	7.3
0.5	9.7	10.4	11.8	14.8	7.0	10.7	11.5	11.8	5.1	5.7	5.4	7.3
1	9.7	10.5	11.8	15.3	6.7	10.9	11.5	11.7	4.5	5.7	5.4	7.4
1.5	9.7	10.4	11.5	5.8	5.7	11.0	9.3	11.7	4.3	5.8	5.4	7.4
2	9.7	10.3	11.2	3.7	5.6	11.2	7.9	10.4	4.3	5.1	5.3	7.5
2.5	9.6	10.1	10.7	4.0	5.3	3.6	3.3	5.4	4.2	4.4	5.3	7.4
3	9.2	10.0	10.5	4.0	5.2	0.8	0.2	2.1	4.2	4.4	5.3	7.4
3.5	8.8	9.7	10.5	4.0	5.0	0.4	0.2	0.2	4.0	4.3	5.2	7.4
4	8.7	9.5	10.4	3.9	4.8	0.3	0.1	0.1	0.5	4.2	5.2	7.0
4.5	8.4	8.5	6.9	4.0	4.4	0.3	0.1	0.1	0.2	4.1	5.2	7.0
5	8.4	8.4	5.8	3.1	3.5	0.2	0.1	0.1	0.2	4.0	5.2	7.0
5.5	8.3	8.1	4.5	1.7	1.4	0.2	0.1	0.1	0.1	3.6	5.1	6.7
6	8.3	7.6	2.1	0.2	0.2	0.2	0.1	0.1	0.1	3.4	5.1	6.6
6.5	-	-	-	-	-	0.2	-	-	-	3.2	5.1	6.5

Appendix 5: Lake Waitawa cyanobacteria cell counts and biovolumes

Cyanobacteria cell counts from monthly water sampling of Lake Waitawa at Site 1 (mid-lake) and Site 2 (waterslide) during 2014/15 are presented in Table A5.1 and Table A5.2, respectively.

Table A5.1: Cell counts for potentially toxic species identified in phytoplankton samples collected from Lake Waitawa Site 1 (mid-lake) between July 2014 and June 2015. Average cell volume (from MfE/MoH (2009)) and calculated biovolumes are also presented. The total biovolumes in each sample are coloured based on the alert level framework in MfE/MoH (2009): green=surveillance, amber=alert and red=action

Month	Potentially toxic species identified in sample	Cell count (cells/mL)	Average cell volume (μm³)	Biovolume (mm³/L)	Total biovolume in sample (mm³/L)
July	*Anabaena cf.circinalis*	730	208	0.152	0.154
	Microcystis sp.	22	93	0.002	
August	*Anabaena cf.circinalis*	3,600	208	0.750	0.750
September	*Anabaena cf.circinalis*	22,000	208	4.576	4.58
October	*Anabaena cf.circinalis*	4,800	208	0.998	0.998
November	*Anabaena cf.circinalis*	490	208	0.102	0.103
	Microcystis sp.	11	93	0.001	
	Pseudanabaena sp.	4	16	0.000	
December	*Anabaena cf.circinalis*	15,000	208	3.120	3.14
	Microcystis sp.	250	93	0.023	
January	*Anabaena cf.circinalis*	72,000	208	14.976	15.28
	Microcystis sp.	3,300	93	0.307	
February	*Anabaena cf.circinalis*	9,000	208	1.872	38.14
	Microcystis sp.	390,000	93	36.270	
March	*Anabaena cf.circinalis*	1,400	208	0.291	0.821
	Microcystis sp.	5,700	93	0.530	
April	*Anabaena cf.circinalis*	1,100	208	0.229	0.229
May	*Anabaena cf.circinalis*	1,100	750	0.825	0.825
June	*Anabaena cf.circinalis*	97	208	0.020	0.021
	Microcystis sp.	10	93	0.001	

Table A5:2: Cell counts for potentially toxic species identified in phytoplankton samples collected from Lake Waitawa Site 2 (waterslide) between July 2014 and June 2015. Average cell volume (from MfE/MoH (2009)) and calculated biovolumes are also presented. The total biovolumes in each sample are coloured based on the alert level framework in MfE/MoH (2009): green=surveillance, amber=alert and red=action

Month	Potentially toxic species identified in sample	Cell count (cells/mL)	Average cell volume (µm³)	Biovolume (mm³/L)	Total biovolume in sample (mm³/L)
July	*Anabaena cf.circinalis*	640,000	208	133.1	133.3
	Microcystis sp.	1,400	93	0.130	
August	*Anabaena cf.circinalis*	22,000	208	4.58	4.58
September	*Anabaena cf.circinalis*	50,000	208	10.40	10.40
	Aphanocapsa sp.	1,800	2	0.003	
October	*Anabaena cf.circinalis*	15,000	208	3.12	3.12
	Aphanocapsa sp.	1,800	2	0.003	
November	*Anabaena cf.circinalis*	1,200	208	0.250	0.250
December	*Anabaena cf.circinalis*	1,300,000	208	270.4	273.7
	Microcystis sp.	35,000	93	3.26	
January	*Anabaena cf.circinalis*	19,000	208	3.95	4.15
	Microcystis sp.	2,000	93	0.186	
	Phormidium sp.	64	169	0.011	
February	*Anabaena cf.circinalis*	190,000	208	39.52	48.89
	Microcystis sp.	100,000	93	9.30	
	Phormidium sp.	430	169	0.073	
March	*Anabaena cf.circinalis*	6,100,000	208	1,268.8	4,337.8
	Microcystis sp.	33,000,000	93	3,069.0	
	Planktothrix sp.	870	169	0.024	
April	*Anabaena cf.circinalis*	25,000	208	5.200	19.15
	Microcystis sp.	150,000	93	13.95	
	Amhanocapsa sp.	340	2	0.001	
May	*Anabaena cf.circinalis*	21,000	208	4.37	6.07
	Microcystis sp.	5,900	93	0.549	
	Phormidium sp.	6,800	169	1.12	
June	*Anabaena cf.circinalis*	340	208	0.071	0.075
	Microcystis sp.	47	93	0.004	