Title: **Lake water quality in the Ruamāhanga Whaitua**

Purpose: To assist the Ruamāhanga Whaitua Committee to understand the current water quality and ecological health of lakes in the whaitua

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Key points

- There are a variety of lakes in the Ruamāhanga Whaitua, which a range of biodiversity, recreational, aesthetic and food resource values – the main three being Lake Wairarapa, Lake Onoke and Lake Pounui.

- Wairarapa Moana, (Lake Wairarapa, Lake Onoke and the wider wetland area) was highly modified by Lower Wairarapa Valley Development Scheme during the 1960s/70s. This has provided economic benefit, lessened floods, and increased agriculture land, but has had significant negative effects on the ecology of the lakes and loss of wetland area.

- Lake Wairarapa has degraded water quality, with elevated levels of nutrients (particularly phosphorus), algal biomass and poor water clarity. The low water clarity and high phosphorus in Lake Wairarapa is primarily due to the shallow nature of the lake which makes the lake bed sediments prone to resuspension by wind and wave action. The lake can be classed as being in a 'eutrophic' to 'supertrophic' state (ie, high to very high nutrient levels).

- Since the diversion of the Ruamahanga River out of Lake Wairarapa, the lake may also act as a 'sink' (reservoir for sediments) and there may be a historical build-up of sediments and nutrients stored on the lake bed (legacy nutrients). Algal blooms to do not appear to have been a significant issue in Lake Wairarapa but algal biomass is at times high and potentially toxic cyanobacteria species have been recorded at levels where they could pose a health risk to lake users.

- There has been little significant change in the state of the Lake Wairarapa since monitoring began in 1994.

- Lake Onoke is tidal barrier-bar type lake (also referred to as an intermittently closed and open lagoon (ICOL) and as long as the lake mouth remains open, it functions more like an estuary than a lake. There is a significant amount of flushing occurring due to the exchange of tidal salt water.

- Lake Onoke has degraded water quality, with elevated levels of nutrients (particularly phosphorus), poor water clarity and, at times, high algal biomass. It is also classed as being in a 'eutrophic' to 'supertrophic' state.

- The overall poor state of Lake Onoke and Lake Wairarapa is unsurprising given that they are both located in catchments dominated by pastoral landuse. Resuspension of lakebed sediments by wind appears to be a strong driver of water quality in both of these shallow lakes, particularly in Lake Wairarapa. Cleaner salt water inputs (tidal and/or back flow up into Lake Wairarapa) appear to improve water quality in both lakes (particularly Lake Onoke) through dilution of nutrients. Water quality in Lake Onoke is also strongly influenced by the prevailing flow and water quality in the Ruamahanga River.

- Recent information on Lake Pounui is limited to a LakeSPI assessment (which looks at the communities of aquatic plants – a key indicator of lake health) undertaken in 2011. Based on this assessment, Lake Pounui was classed as having high ecological health which reflects the lake being surrounded in unmodified indigenous vegetation. Two invasive weed species are present in the lake (*Potamogeton crispus* and *Elodea canadensis*) but were considered to have a relatively limited impact on the native vegetation present.

- Comparisons with available historical information indicate that aquatic plant communities in Lake Pounui have not changed significantly in the last 30–40 years.

1. Introduction

This summary looks at the state of water quality and ecosystem health of the major lakes in the Ruamāhanga Whaitua – Lake Wairarapa, Lake Onoke and Lake Pounui.

Significant factors include the historical loss of vegetation cover from farming which has led to loss of habitat. Flood protection measures have changed the river channel shape, diverted flows/natural intakes and this has resulted in less flushing, which has led to deterioration in water quality.

2. Background

There are a variety of lakes in the Ruamāhanga Whaitua, which provide a range of biodiversity, recreational, aesthetic and food resource values.

Lake Wairarapa is the largest and most well-known lake in the region. The lake is 7,850 ha which is almost equal in size to the Wellington Harbour. Other than some limited sampling in Lake Onoke, Lake Wairarapa is the only lake that GWRC routinely monitors for water quality. Lake Wairarapa is shallow, only 2.5 m at its deepest point. It is considered to be isothermal, which means the temperature does not change from the lake bottom to the lake surface. The lake is often turbid (cloudy) due to it being shallow and having windy conditions which stir up sediment from the lake bottom. Land use in the catchment is predominantly pastoral (~70%).

Lake Onoke is approximately 622 ha in size and is the second largest lake in the Ruamāhanga Whaitua. The main inflow to the lake is the Ruamahanga River which drains the entire Wairarapa Valley – a large agricultural catchment (~64% of the upstream landuse is pastoral). Lake Onoke is a type of coastal lake called a 'barrier-bar lake' (also referred to as an intermittently closed and open lagoon (ICOL). It is tidal when the lake mouth (through a spit at its southern end) is open to the sea. It is around 5–6 m deep at its deepest point but the majority of the lake is shallow (<1 m). The lake depth varies depending on the tidal cycle (i.e. if the lake mouth is open, semi-blocked or blocked) and on the flow conditions in the Ruamahanga River. When the lake level is low, low tides can expose extensive mud flats in the centre of the lake. Lake levels are managed by GWRC's Flood Protection Department and the lake mouth is typically opened within days to weeks of closure to minimise flood risk.

The water quality in Lake Onoke is also affected by wind-activated suspension of lakebed sediment. Other key drivers of water quality include prevailing conditions in the Ruamahanga River and the tidal movement of salt water in and of the lake. The movement of salt water is significant because as long as the lake mouth is open the lake functions more like an estuary than a lake in that there is a significant amount of flushing occurring. When the mouth is closed (rare due its management for flood risk) it has limited flushing capability and is at risk from eutrophication (ie, algal blooms).

The lower Ruamahanga River, Lake Onoke, Lake Wairarapa and associated wetlands have been significantly modified through flood protection and drainage activities carried out under the Lower Wairarapa Valley Development Scheme (LWVDS). The most significant changes took place in the 1960s and 1970s and included the diversion of the Ruamahanga River from its direct course into Lake Wairarapa to its current course across the Kumenga Peninsula directly into Lake Onoke, the separation of Pounui Lagoon from Lake Onoke, and the drainage of over 1,200 ha of wetlands. Barrage gates were installed at the outlet of Lake Wairarapa to regulate lake water levels. The LWVDS is considered to have had major socio-economic benefits in terms of flood protection and development of land for agricultural use. However, these works have highly modified the environment and have had significant negative impacts on the wetland, lake, river and stream ecosystems.

Lake Pounui is a small (~46 ha), moderately shallow (maximum depth ~10 m), lowland lake situated in the foothills of the Remutaka Range in South Wairarapa. Lake Pounui's upstream catchment is almost completely unmodified indigenous forest. This makes it relatively rare when compared to most other small lowland lakes in New Zealand as the vast majority are located in catchments that have been highly modified.

3. What is the water quality of Lake Wairarapa?

Lake Wairarapa has degraded water quality, with elevated levels of nutrients (particularly phosphorus) and algal biomass, and poor water clarity.

The low water clarity and high phosphorus levels in Lake Wairarapa are primarily due to the shallow nature of the lake which makes the lake bed sediments prone to resuspension by wind and wave action.

At times the high level of salinity (elevated conductivity) indicates Lake Wairarapa, located 12 km from the coast, is influenced by a backflow of saline water from Lake Onoke. Results indicate that water quality in Lake Wairarapa is better than it could be due to this greater salinity – water clarity improves and levels of phosphorus and chlorophyll decline. The saline inputs have a 'diluting' effect.

The Trophic Level Index (TLI) gives an indication of lake productivity and the level of nutrient enrichment, known as the 'trophic state' (see glossary for more information). It is calculated using four key variables of lake water quality: chlorophyll *a*, Secchi depth (or water clarity), total phosphorus and total nitrogen. TLI classes the lake as 'supertrophic', indicative of 'very high' nutrient enrichment. This TLI score is heavily influenced by very low water clarity and high total phosphorus concentrations.

Due to the lake's susceptibility to wind-driven sediment suspension, the trophic state of Lake Wairarapa may better be defined in terms of the levels of chlorophyll *a* and total nitrogen concentrations – which both indicate a eutrophic state ('high' nutrient enrichment). Thus, Lake Wairarapa can be classified as eutrophic/supertrophic.

Wind disturbance is a strong driver of water quality in Lake Wairarapa. Given that most water samples are taken in calm weather conditions when it is safe to sample, it is likely that results indicate better water quality than is actually the case.

4. Seasonal patterns in water quality

Total nitrogen concentrations are highest in the winter months. This is likely due to the increased 'flushing' of agricultural land that occurs during the wetter months, as wetter soils and a high groundwater table, promote the 'flushing' of nitrogen from the soil into the groundwater and ends up in the lake via tributary streams and drains. This seasonal pattern may also be influenced by less uptake of nitrogen by phytoplankton growth and lower rates of denitrification[1] during the winter months.

Concentrations of total phosphorus are highest in spring and early summer, matching the increased suspended sediment from more frequent high winds in spring that reduce water clarity.

5. How does the lake compare nationally?

Overall, Lake Wairarapa can be considered to be in a poorer than average condition when compared to other similar shallow coastal lakes in pastoral catchments in New Zealand. A comparison with national median values shows that while concentrations of total nitrogen and chlorophyll *a* are slightly lower than the national median values, concentrations of total phosphorus are significantly higher and measurements of water clarity are significantly poorer.

6. Phytoplankton blooms

In May 2008 the first obvious algal bloom was recorded since sampling first began in 1994. This bloom was dominated by Anabaena lemmermannii, a toxin-producing species of cyanobacteria. Phytoplankton blooms have not been considered a significant problem in Lake Wairarapa due to the highly turbid nature of the lake. However, measurements of chlorophyll a regularly indicate elevated algal levels and it is likely that blooms are more common than previously thought and they are simply not visible given the turbid appearance of the lake. In the case of bloom noted in 2008, the levels of cyanobacteria were high enough to potentially pose a health risk to lake users.

Macrophytes (aquatic plants)

While extensive macrophyte growths can hinder recreational activities, the presence (and composition) of macrophyte beds are considered a significant factor influencing lake health as they can benefit water quality through taking up nutrients and stabilising lakebed sediments which improves water clarity. They also provide habitat for a range of fauna. Currently there is a lack of macrophytes in Lake Wairarapa, but lake experts agree that, historically, the lake would have had some and that their absence is contributing to the overall poor condition of the lake.

7. What is influencing the water quality in Lake Wairarapa?

7.1 Nutrient sources

The poor water quality reported for Lake Wairarapa is unsurprising given that agricultural land uses occupy over half of the lake’s catchment, including farming operations that border most of the lake’s margin (or border the connecting wetlands adjacent to the lake).

There are multiple pathways by which nutrients from agricultural land use may enter the lake. Some contributions of these different pathways have a greater impact than others and this is currently being investigated. Some of the pathways for nutrients into the lake are:

[1] A bacterial process removing *nitrate* from soil, air, or water that requires low oxygen conditions and usually forms nitrogen gas. This can occur in wetland environments prior to the nitrogen entering the lake system and so helps to mitigate nitrogen inputs into the lake. The rate of denitrification is slower at colder temperatures during winter.

- **Tributary inflows**: Only two tributaries (Tauherenikau and Waiorongomai rivers) are routinely monitored and while results show these rivers typically have good or excellent water quality, there are numerous lowland streams and artificially-constructed drains that enter the lake along its northern and eastern shores. These waterways typically drain catchments dominated by intensive agriculture and recent sampling shows that many carry very high nutrient concentrations.

- **Stock grazing the lake margins** contribute directly to the lake's nutrient load, particularly the urine patches from dairy cows. In some areas, stock directly access the lake and excrete in the water. There is also stock access to tributary streams, drains and water races.

- **Flood waters from the Ruamahanga River** bringing sediments, nutrients and other contaminants can enter Lake Wairarapa via the Oporua Floodway and backflow through the barrage gates. While this only occurs a few times a year, it is potentially a significant pathway for contaminants. Water flows into the lake during floods and are held there with barrage gates closed while the river goes down. There is less flushing and the sediment and associated nutrients (nitrates and phosphorus) settle on the lake bottom meaning the lake acts as a reservoir for not only flood water but also sediments and nutrients. It is unclear whether the lake has become even more of a 'sink' or repository for nutrients and sediments since the diversion of the Ruamahanga River but the ability of the lake to 'flush' itself has been reduced2.

- **Groundwater**: The influence of groundwater inputs to the lake are poorly understood and work is currently underway to assess this, although groundwater modelling suggests the volume of groundwater input is probably not significant.

- **Legacy sediments:** The likely store of nutrients in the lakebed sediments has important implications for the lake's water quality. Even if nutrient inputs entering the lake are reduced, there is potentially a significant store within the lakebed. Concentrations of total phosphorus and total nitrogen demonstrate an increase with wind disturbance. This means the wind can re-suspend lakebed sediments and may have a lasting impact on lake water quality.

- **Point source impacts:** There are other sources of nutrients to the lake such as treated wastewater from Featherston, which discharges into Abbotts Creek (a tributary of Lake Wairarapa). The amount of nutrients form this source is unknown, but basic calculations suggest that it is a significant source of nutrients in low to moderate flows.

8. What is the water quality of Lake Onoke?

Lake Onoke water quality is degraded: water clarity is low, concentrations of nutrients (dissolved reactive phosphorus and nitrite-nitrate nitrogen) are typically elevated and, at times, phytoplankton biomass (as indicated by chlorophyll a) is high.

The TLI classes the lake as supertrophic, indicative of 'very high' nutrient enrichment. Similar to Lake Wairarapa, Lake Onoke's TLI score is influenced by low Secchi depth (water clarity) and high levels of total phosphorus. Wind can re-suspend lakebed sediments and is a key driver of

[2] An investigation into changes in the morphology of Lake Wairarapa by Trodahl (2010) indicated that in the two decades post the Lower Wairarapa Valley Development Scheme, the rate of 'infilling' increased by ten-fold along the eastern shore of Lake Wairarapa. However, this was accompanied by deepening of some other parts of the lake.

water quality in Lake Onoke. The high levels of total phosphorus and poor water clarity in Lake Onoke are driven by the shallow nature of the lake prone to suspended sediment, and are not a result of high phytoplankton biomass. Given that total nitrogen and chlorophyll a are indicative of a lower trophic state, Lake Onoke may be better described as being in a 'eutrophic to supertrophic' condition.

Water quality is likely to vary spatially across the lake, with poorer water quality on the western side of the lake where less flushing occurs. Caution must therefore be taken in applying the TLI classification to the whole of Lake Onoke. Lake Onoke, a coastal lake, has high salinity (conductivities) due to the tidal movement of salt water in and out of the lake. The salinity also varies as a result of river flow conditions and if the lake mouth is open or closed. The water quality improves with increasing salinity, suggesting there is a 'dilution' effect arising when clean and clearer saline water is present in a greater proportion.

9. What is influencing the water quality in Lake Onoke?

- The effect of Ruamahanga River flows

  Flow conditions in the Ruamahanga River strongly influence water quality in Lake Onoke. Water quality deteriorates with an increase in river flow, reflecting monitoring being undertaken near the mouth of the Ruamahanga River and the increased flushing of nutrients and sediments from the large agricultural catchment during periods of sustained rainfall.

- The effect of Lake Onoke mouth closure

  Insufficient monitoring has been carried out in Lake Onoke to date to assess the effects of lake mouth blocking on the water quality. Levels of chlorophyll *a* are higher when the lake mouth is blocked or has been recently blocked. The lake's susceptibility to eutrophication issues, such as elevated algae biomass, is reduced by the lake mouth remaining open most of the time. The lake mouth blocks on average nine times per year for an average of just over six days. Issues associated with eutrophication are likely to increase when the mouth is blocked for extended periods of time.

10. Synthesis: water quality in Lakes Wairarapa and Onoke

Water quality of Lakes Onoke and Wairarapa are in a degraded state. Concentrations of nutrients and chlorophyll a are typically elevated and water clarity is generally poor. Water clarity is far poorer than the national median for lakes in pastoral catchments; total phosphorus concentrations also exceed the national median in Lake Wairarapa and dissolved reactive phosphorus concentrations exceed the national median in Lake Onoke. The lakes are classified as being eutrophic to supertrophic (ie, having high to very high nutrient enrichment). Re-suspension of lakebed sediments by wind appears to be a strong driver of water quality in both of these shallow lakes, particularly Lake Wairarapa. Higher levels of salinity improve the water quality of both lakes – water clarity is generally better, and concentrations of total nitrogen, total phosphorus and chlorophyll a lower. This suggests that salinity has a 'dilution' effect on water quality in Lake Onoke. Ruamahanga River flow also influences water quality in

Lake Onoke, with a deterioration of water quality typically occurring under high flow conditions.

Given that the lakebed sediments may contain high stores of nutrients – particularly phosphorus water quality issues could persist for some time following any improvements on land use management in the catchment and likely to be the case while the lakes remain devoid of rooted aquatic vegetation.

11. Lake Pounui: ecological condition

Based on an assessment of its aquatic plant community (LakeSPI) undertaken in 2011, Lake Pounui is considered to have 'high' ecological condition. Lake vegetation was found to extend to moderate depths of up to 5 m and was relatively diverse, with all six key native community types present. Two invasive weed species were recorded during the survey (Potamogeton crispus and Elodea canadensis) but were considered to have a relatively limited impact on the native vegetation present.

12. What are the trends?

The current poor state of water quality in Lake Wairarapa is reflected in it being classed as 'supertrophic'. There have been some small improvements in water clarity and dissolved reactive phosphorus, but there has been little change of overall water quality and lake condition, since monitoring began in 1994.

Given that monitoring of Lake Onoke's water quality only commenced in 2009 it is not yet possible to assess whether water quality is getting better or worse.

In terms of the ecological condition of Lake Pounui, comparisons of the current lake vegetation with descriptions from 1976 indicate that the aquatic vegetation has remained in a relatively stable over the last 30 or 40 years. Only very limited recent water quality monitoring information is available for Lake Pounui. This limited information, when compared against historical information, suggests that water quality in Lake Pounui may have declined over the last 30 years – however, more robust monitoring is required to confirm this.

13. Knowledge gaps

- There is limited information on the influence and amounts of different nutrient sources into each lake and the contribution from internal nutrient cycling. GWRC has recently carried out preliminary investigations into a water and nutrient balance for Lake Wairarapa. Such a balance is critical for identifying and addressing the major nutrient pathways.

- There is no regular monitoring of basic biological information (e.g. phytoplankton species and fish populations) in the lakes.

- There is a lack of information around water quality linkages between Lake Wairarapa and Lake Onoke.

The conclusions drawn about water quality in Lakes Wairarapa and Onoke in this report are based on relatively limited monitoring data. The monitoring is not frequent enough at Lake Wairarapa to describe seasonal trends and detect the effects land use, water takes and discharges. In the case of Lake Onoke, only one site has been sampled regularly and the site located near the Ruamahanga River inflow, are not representative of the lake as a whole.

14. Glossary

Anoxic – Without any oxygen.

chlorophyll *a* – A pigment used by plants, algae, and cyanobacteria to harvest energy from light as part of photosynthesis.

Denitrification – A bacterial process removing nitrate from soil, air, or water, requiring anaerobic conditions and usually forming nitrogen gas.

Macrophytes – aquatic plants and algae

Nitrogen – A chemical element, symbol N. Common forms of nitrogen in water include ammonia and nitrate. 'Nitrogen gas' N2 also makes up about 78 percent of the Earth's atmosphere. All life needs nitrogen for molecules such as proteins and DNA.

Phosphorus – A chemical element, symbol P. The most common form of phosphorus is only slightly soluble in water. Phosphates are constituents of bone and of molecules like DNA.

Phytoplankton – Microscopic algae and cyanobacteria drifting or floating in water.

Turbid – Murkiness or cloudiness of water due to *suspended sediment* and/or other material, including algae*.*

The trophic level- Increasing degree of *eutrophication*

(Source: Parliamentary Commissioner for the Environment (2013)

The trophic level of a lake or river describes the amount of biological activity (productivity), such as plant growth that is happening in the water. The trophic level can be measured using the TLI, which combines information on the clarity of the lake and the amounts of nitrogen, phosphorus, and chlorophyll (and thus plant growth) in the lake.

Table 1. The Trophic level (Source: Parliamentary Commissioner for the Environment (2013))

Trophic level	TLI	Lake condition
Microtrophic	1	Clear, very low in nutrients, very slow growing plants, few algae.
Oligotrophic	2	Low in nutrients, usually clear and blue, slow plant growth, may support periphyton.
Mesotrophic	3	Moderately clear and with moderate nutrient levels, usually blue-green, supporting plant growth, typically macrophytes.
Eutrophic	4	Increasingly green and turbid, with high nutrient levels supporting rapid macrophyte or phytoplankton growth that sometimes leads to oxygen depletion.
Supertrophic	5	Very high nutrient levels, usually with poor water clarity, often with severe oxygen depletion, probably no macrophytes, may be dominated by bacteria.

15. For more information

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Appendix 1. How does GWRC monitor lake water quality?

There are no national guidelines for assessing water quality of lakes. To assess the condition of the lake, GWRC compares the physico-chemical water quality data against a national dataset and trophic level index (TLI). It is difficult to compare the data Lake Onoke and Lake Wairarapa with other lakes in New Zealand as there are a wide range of lake types. The lakes of the Ruamāhanga Whaitua are shallow coastal lakes and Lake Onoke is particularly unique being a barrier-bar type lake and comparisons are best made against similar lake types.

Lake Wairarapa water quality monitoring programme

GWRC have monitored water quality in Lake Wairarapa since 1994. While sampling now occurs on a monthly basis at two main sites, the information in this report was based on data collected prior to 2012, when sampling was scheduled on a quarterly basis at four sites. However, sampling has occurred intermittently, as strong winds often prevent safe access to the sampling sites and is consequently, biased towards calmer weather conditions.

Water quality is assessed by measuring a range of physico-chemical and microbiological variables:

- dissolved oxygen
- 5-day biochemical oxygen demand
- water temperature
- pH, conductivity
- Secchi disc (water clarity)
- turbidity
- total and volatile suspended solids
- faecal indicator bacteria
- dissolved and total nutrients
- chlorophyll *a*.

Biological sampling is not currently undertaken in Lake Wairarapa, although one phytoplankton sample was collected in May 2008 when a phytoplankton bloom was evident. For the purposes of this summary, data from the four sampling sites within Lake Wairarapa were pooled.

Table 2: Summary of physico-chemical and microbiological water quality in Lake Wairarapa, based on 14 sampling occasions during 2006 to 2010 (data pooled from all four sites)

Variable	National median values*	Lake Wai. Median	Lake Wai. Minimum	Lake Wai. Maximum
Dissolved oxygen (% saturation)	—	98.6	92.5	117
pH	7.7	7.5	6.7	7.9
Conductivity (µS/cm)	192	774	136	3,200
Secchi depth (m)	2.0	0.24	0.09	1.23
Turbidity (NTU)	3.2	51.5	3.2	220
Total suspended solids (mg/L)	—	48.5	10	230
Dissolved reactive phosphorus (mg/L)	0.003	0.005	<0.004	0.029

Total phosphorus (mg/L)	0.037	0.080	0.030	0.290
Nitrite nitrogen (mg/L)	—	0.001	<0.002	0.004
Nitrite-nitrate nitrogen (mg/L)	—	0.053	<0.002	0.943
Ammoniacal nitrogen (mg/L)	0.013	0.016	<0.01	0.320
Total nitrogen (mg/L)	0.773	0.52	0.07	1.48
5-day biochemical oxygen demand (mg/L)	—	0.40	0.24	4.2
Chlorophyll *a* (mg/m^3)	8.8	5.95	<1.90	31
E. coli (cfu/100 mL)	—	10	<1	150
Faecal coliforms (cfu/100 mL)	—	11	<1	190
TLI score	3.9	5.4 (supertrophic)		

*National median values for physico-chemical and microbiological variables are from Verburg et al. (2010). National median TLI score is for shallow coastal lakes only, calculated from data in Drake et al. (2011)

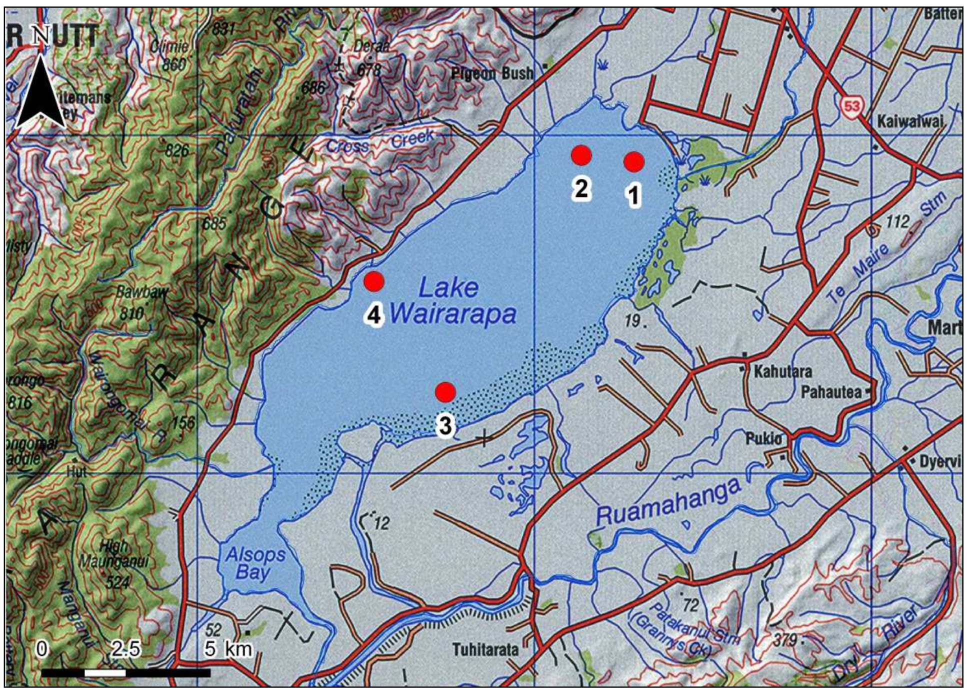

Figure 1: Location of GWRC water quality monitoring locations in Lake Wairarapa, as at 2012. Note that since 2012, sampling has occurred at two sites

Figure 2: Location of GWRC water quality monitoring locations in Lake Onoke

Biological sampling is not currently routinely undertaken in Lake Onoke, although phytoplankton samples were collected from both monitoring sites on two occasions to identify phytoplankton species and estimate relative species abundance.

Lake Pounui assessment of submerged aquatic plant communities

Submerged aquatic plant communities were assessed in Lakes Pounui using the LakeSPI (Submerged Plant Index) methodology, on one occasion in March 2011. LakeSPI is used to understand the ecological condition based on key features of macrophyte community structure and composition.

Lake Onoke water quality monitoring

GWRC began a water quality monitoring in Lake Onoke in August 2009. Water samples were collected on 20 occasions (approximately monthly) during the August 2009 to July 2011 period from Site 1, located where the Ruamahanga River enters the lake (Figure 2). On three occasions water samples were collected from an additional site (Site 2) located on the western margins of the lake. All sampling was undertaken at or within two hours following low tide to minimise any influence from the incoming tide. The sampling was carried on occasions when the lake mouth was open (13 occasions) and when it had been blocked for at least four days (7 occasions)3. Water quality was assessed by measuring a range of physico-chemical and microbiological variables: dissolved oxygen, water temperature, pH, conductivity, water clarity, turbidity, faecal indicator bacteria, dissolved and total nutrients, and chlorophyll a. Sediment and benthic invertebrate communities were also assessed at two sites on one occasion in early 2010.

[3] The effect of the lake blocking is discussed in the 'Water quality in Lake Onoke: Current State" section of this report.

Monitoring of Lake Onoke- the current state of water quality

The monitoring data from 2009-2011 shown in Table 2 indicates that water quality in Lake Onoke is degraded and Also shows how Lake Onoke compares with other lakes in New Zealand dominated by pastoral land cover.

Table 3: Summary of water quality in Lake Onoke, based on monthly sampling at Site 1 on 20 occasions over August 2009 to July 2011.

Variable	National median	Lake Onoke Median	Lake Onoke Min	Lake Onoke Max
Dissolved oxygen (% saturation)	—	96.7	79.5	132
pH	—	7.4	5.9	8.8
Conductivity (μS/cm)	192	1,438	70	7,856
Secchi depth (m)	2.0	0.40	0.11	>1.00
Turbidity (NTU)	3.2	17.9	3	350
Total suspended solids (mg/L)	—	16.0	<2.0	440
Dissolved reactive phosphorus (mg/L)	0.003	0.014	<0.004	0.024
Total phosphorus (mg/L)	0.037	0.035	0.016	0.340
Nitrite nitrogen (mg/L)	—	0.003	<0.002	0.005
Nitrite-nitrate nitrogen (mg/L)	—	0.167	<0.002	0.920
Ammoniacal nitrogen (mg/L)	0.013	0.013	<0.010	0.039
Total nitrogen (mg/L)	0.773	0.475	<0.300	1.430
Chlorophyll *a* (mg/m^3)	8.8	2.5	<3.0	19
E. coli (cfu/100mL)	—	150	<10	1,700
Enterococci (cfu/100mL)	—	49	<10	1,300
Faecal coliforms (cfu/100mL)	—	150	<10	1,700

The Lake SPI index used at Lake Pounui

LakeSPI is used to understand the ecological condition based on key features of macrophyte community structure and composition. The LakeSPI method 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.

These metrics are condensed into three indices expressed as a percentage of expected pristine state:

- A native condition index (i.e., the diversity and quality of the indigenous flora)

- An invasive condition index (i.e., the degree of impact by invasive weed species). An overall LakeSPI index that combines 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).

Table 4: 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

One-off water quality samples were also taken in Lake Pounui at the time of the submerged aquatic plant community assessment in March 2011.

Lake Pounui results: Lake Onoke has a LakeSPI index score of 56% which places it in the 'high' category for ecological condition. This reflects the predominantly unmodified nature of the lake's catchment. Out of the 206 lakes across New Zealand that have been surveyed to date, Lake Pounui is ranked 66th (de Winton et al. 2011).