

# 2021/22 Lake water quality and ecology monitoring



# Contents

- [2021/22 Lake water quality and ecology monitoring](#)
  - [Contents](#)
- [Disclaimer](#)
- [Overview](#)
  - [Monitoring network](#)
  - [Monitoring objectives](#)
  - [Monitoring results](#)
- [Methods](#)
  - [Analytical methods for physicochemical and microbiological water quality](#)
  - [State assessments](#)
  - [Trend assessments](#)
  - [LakeSPI assessments](#)
- [State assessment results](#)
  - [Trophic level index \(TLI\)](#)
  - [Proposed natural resources plan thresholds \(PNRP\)](#)
  - [National objectives framework \(NOF\)](#)
- [Trend assessment results](#)
  - [Ammoniacal nitrogen](#)
  - [Total nitrogen](#)
  - [Total phosphorus](#)
  - [Visual clarity](#)
  - [Chlorophyll \*a\*](#)
- [LakeSPI assessment results](#)
- [Supplementary data results](#)
  - [Nitrogen](#)
  - [Phosphorus](#)
  - [Phytoplankton](#)
  - [Water clarity](#)
  - [Sediment](#)
  - [Other water quality variables](#)
- [Resources](#)
  - [Useful Links](#)
  - [References](#)
- [Appendix](#)
  - [Monitoring details](#)

## Disclaimer

This report has been prepared by Environmental Science staff of Greater Wellington (GW) and as such does not constitute Council policy.

In preparing this report, the authors have used the best currently available data and have exercised all reasonable skill and care in presenting and interpreting these data. Nevertheless, GW does not accept any liability, whether direct, indirect, or consequential, arising out of the provision of the data and associated information within this report. Furthermore, as GW endeavours to continuously improve data quality, amendments to data included in, or used in the preparation of, this report may occur without notice at any time.

GW requests that if excerpts or inferences are drawn from this report for further use, due care should be taken to ensure the appropriate context is preserved and is accurately reflected and referenced in subsequent written or verbal communications. Any use of the data and information enclosed in this report, for example, by inclusion in a subsequent report or media release, should be accompanied by an acknowledgement of the source.

For the latest available results go to the [GW environmental data hub](#).

---

## Overview

Greater Wellington (GW) 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](#)). Water quality monitoring in Lake Onoke was established in 2009. Additional shorter-term targeted water quality monitoring and “one-off” sampling, including zooplankton communities, has also been undertaken in other lakes in the Wellington Region (see [Perrie & Milne 2012](#); [Perrie et al. 2015](#); [Duggan 2022](#); [Perrie & Royal 2022](#)).

In 2011 assessments of ecological condition, based on submerged macrophyte community structure and composition, were introduced for Lakes Kohangapiripiri, Kohangatera and Pounui. Assessments of macrophyte communities, termed LakeSPI (Submerged Plant Indicator) have since been expanded to other lakes and lagoons in the Wellington Region: Bartons Lagoon, Boggy Pond, Lake Nganoke, Lake Ngarara, Lake Waiorongomai, Matthews Lagoon and Turners Lagoon ([de Winton et al. 2022](#)). LakeSPI assessments are planned to occur every three-five years.

# Monitoring network

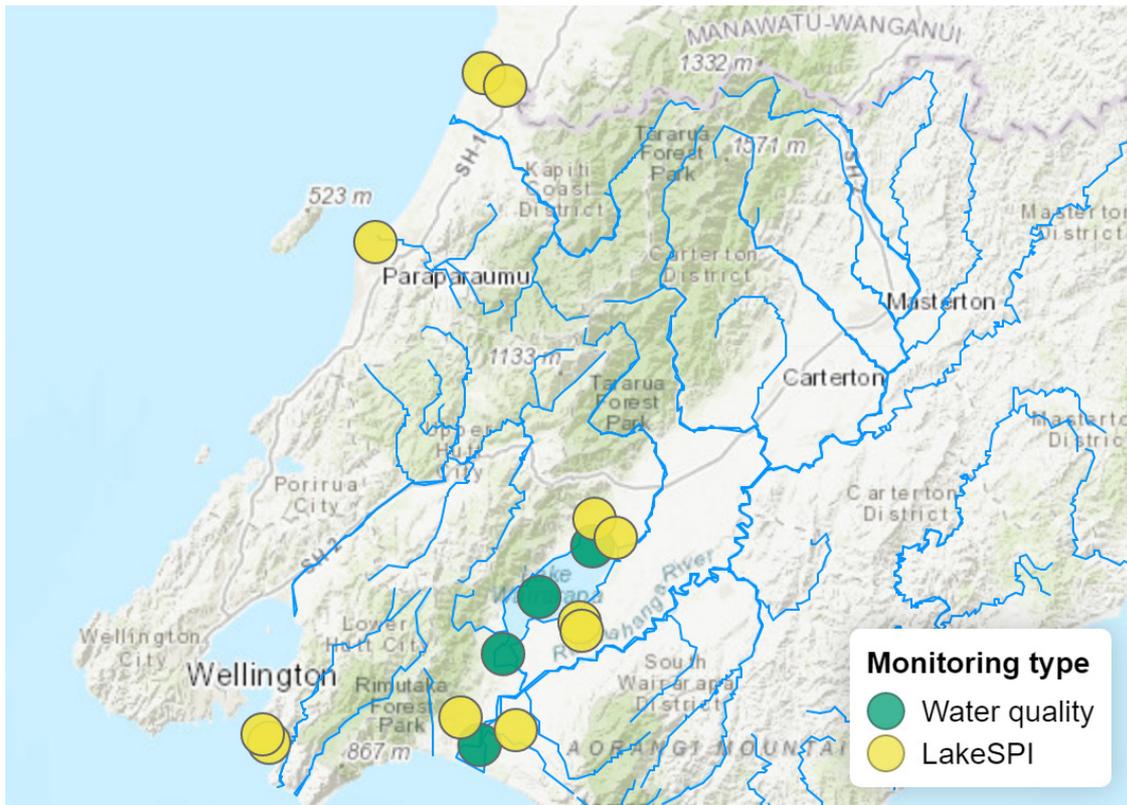


Figure 1: Locations of lake water quality and ecology monitoring sites.

Table 1: Lake attributes and catchment information.

Lake	Max depth (approx.)	Lake area	Catchment area	Catchment landcover
Wairarapa	2.5 m	7,850 ha	57,245 ha	<ul style="list-style-type: none"> <li>• Pasture 54.0%</li> <li>• Indigenous forest and scrub 43.9%</li> <li>• Urban 0.4%</li> <li>• Other 1.7%</li> </ul>
Onoke	5.5 m	622 ha	341,744 ha	<ul style="list-style-type: none"> <li>• Pasture 64.0%</li> <li>• Indigenous forest and scrub 27.5%</li> <li>• Exotic forest 3.7%</li> <li>• Horticulture 1.0%</li> <li>• Urban 0.7%</li> <li>• Other 3.1%</li> </ul>

## Monitoring objectives

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.

## Monitoring results

**State assessments** presents current lake status as assessed by the Trophic Lake Index (TLI), GW Proposed Natural Resources Plan (PNRP), and National Policy Statement for Freshwater Management National Objectives Framework (NOF). Links are provided with each for more information.

**Trend assessments** estimates the rate of change and direction of key lake water quality data at each site over periods of 5-, 10-, 15-, and all available- years.

**Supplementary data** provides annual summaries of dissolved oxygen, water temperature, pH, conductivity, visual clarity, turbidity, suspended solids, chlorophyll *a*, and dissolved and total nutrients.

## Methods

### Analytical methods for physicochemical and microbiological water quality

Lake Wairarapa monitoring sites are accessed by boat and the Lake Onoke monitoring sites (including the two upstream monitoring sites) 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 lake-bed 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 and temperature) are taken using a YSI DSS 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 [Appendix Table A1](#). All lake water samples collected for dissolved nutrient analysis are filtered in the laboratory.

## State assessments

See [Hickson-Rowden and Perrie \(2018\)](#) for the finer details on the application of the assessments outlined below

### Trophic Level Index (TLI)

Table 2: Classification of lake trophic status using the TLI [Burns et al. \(1999\)](#).

<b>Trophic status (nutrient enrichment)</b>	<b>TLI</b>	<b>Chlorophyll <i>a</i> (mg/m<sup>3</sup>)</b>	<b>Secchi depth (m)</b>	<b>Total phosphorus (g/m<sup>3</sup>)</b>	<b>Total nitrogen (g/m<sup>3</sup>)</b>
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	25-13	0.0018-0.0041	0.034-0.073
Oligotrophic (low)	2.0- 3.0	0.82-2.0	15-7.0	0.0041-0.0090	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

## Proposed Natural Resources Plan (PNRP)

Table 3: Selected attributes and narratives from GW’s [PNRP](#) as well as suggested measures and thresholds for attributes taken from [Greenfield et al. \(2015\)](#).

Attribute	Narrative	Measure	Threshold
Nutrients	Total nitrogen and phosphorus concentrations do not cause an imbalance in aquatic plant, invertebrate or fish communities	Total nitrogen (g/m <sup>3</sup> )	Median <0.0725
		Total phosphorus (g/m <sup>3</sup> )	Median <0.043
Phytoplankton	Phytoplankton communities are balanced and there is a low frequency of nuisance blooms	Chlorophyll <i>a</i> (mg/m <sup>3</sup> )	Median <5.0 and Maximum ≤60

## National Policy Statement for Freshwater Management (NPS-FM)

Attribute states and guideline values taken from the [National Policy Statement for Freshwater Management 2020 National Objectives Framework \(NOF\)](#).

Table 4: **Chlorophyll *a* (mg/m<sup>2</sup>)** NOF state bands.

Attribute state	Annual median	Annual maximum	Description
A	≤2	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
B	>2 and >5	>10 and >25	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>5 and >12	>25 and >60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes.
D	>12	>60	<b>National bottom line.</b> Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Table 5: **Total phosphorus (g/m<sup>3</sup>)** NOF state bands.

<b>Attribute state</b>	<b>Annual median</b>	<b>Description</b>
A	≤0.01	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
B	>0.01 and >0.02	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>0.02 and >0.05	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions.
D	>0.05	<b>National bottom line.</b> Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Table 6: **Total nitrogen (g/m<sup>3</sup>)** NOF state bands. Attribute states are calculated differently for polymictic lakes (polymictic) and seasonally stratified & brackish lakes (brackish). See this Land Air Water Aotearoa (LAWA) [factsheet](#) for more information.

<b>Attribute state</b>	<b>Annual median (polymictic)</b>	<b>Annual median (brackish)</b>	<b>Description</b>
A	≤0.3	≤0.16	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
B	>0.3 and >0.5	>0.16 and >0.35	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>0.5 and >0.8	>0.35 and >0.75	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions.
D	>0.8	>0.75	<b>National bottom line.</b> Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Table 7: **Ammonia (pH adjusted g/m<sup>3</sup>)** NOF state bands. Numeric attribute state is based on pH 8 and temperature of 20°C.

Attribute state	Annual median	Annual maximum	Description
A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested.
B	>0.03 and >0.24	>0.05 and >0.4	95% species protection level: Starts impacting occasionally on the 5% most sensitive species.
C	>0.24 and >1.3	>0.4 and >2.2	<b>National bottom line.</b> 80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).
D	>1.3	>2.2	Starts approaching acute impact level (that is, risk of death) for sensitive species.

## Trend assessments

Trends assessments are estimated at each site using monthly data over periods of 5-, 10-, and 15-years, where sufficient data is available. These results are then categorised into differing levels of trend direction likelihood. Series with too many censored values ([Appendix Table A1](#)) can still have a trend direction estimated but are unable to have a reliable trend rate estimated and this is shown as ‘N/A’ in the map hover labels and tables. Site-periods with too few data for reliable estimates of both direction and rate are shown as “not assessed”.

The trend methodology follows the same approach as described in this [LAWA trends factsheet](#) except that due to monitoring network interruptions, we use a slightly lower data requirement threshold of 85% (i.e., at least 85% of all possible months or quarters worth of data in that period) rather than the 90% threshold for trends on LAWA.

## LakeSPI assessments

Submerged aquatic plant communities are assessed using 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.

The first LakeSPI surveys were carried out in autumn 2011 and are intended to be repeated at five-yearly intervals except where more frequent surveys are warranted.

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 listed in the table below ([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

Each sub-component condition index is also rated against [National Policy Statement for Freshwater Management 2020](#) NOF guidelines:

Attribute state	Native Condition index	Invasive Impact index
A	>75	0*
B	>50 and >75	>1 and >25
C	>20 and >50	>25 and >90
D	≤20	≥90

*\*Note Invasive Impact index scores for non-vegetated lakes are not included in the A band.*

## State assessment results

The following sections present maps of state assessments under each framework. Details on each assessment framework and calculations are available in [Hickson-Rowden and Perrie \(2018\)](#) and the [state assessments methods](#) section.

### Trophic level index (TLI)

The Trophic Level Index (TLI) measures water quality status of New Zealand lakes using four variables; chlorophyll *a*, Secchi depth (water clarity), total phosphorus and total nitrogen. The maps show the overall mean TLI score for each lake and the table includes each of the four TLI variables. These values are calculated for the periods July 2021 to June 2022 and the three-year rolling mean period July 2019 to June 2022 (note the variable number of samples between sites).

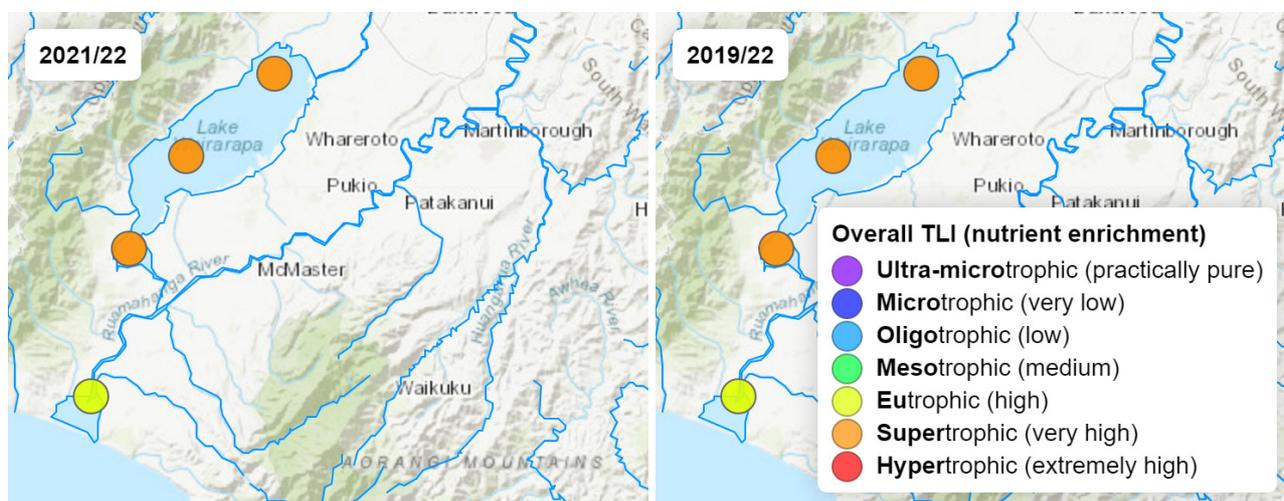


Figure 2: TLI states for the three year period 2019/20 to 2021/22 and latest one year period 2021/22

Table 8: TLI overall and variable scores, abbreviated trophic level classes are provided in brackets.

Lake	Site	Years	No. samples	Overall TLI	Chlorophyll <i>a</i>	Secchi depth	Total phosphorus	Total nitrogen
Wairarapa	Site 2 - stump	2019/22	30	5.3 (Super)	4.8 (Eu)	6.6 (Hyper)	5.7 (Super)	4.3 (Eu)
Wairarapa	Site 2 - stump	2021/22	11	5.3 (Super)	4.6 (Eu)	6.6 (Hyper)	5.6 (Super)	4.4 (Eu)
Wairarapa	Middle	2019/22	30	5.3 (Super)	4.7 (Eu)	6.5 (Hyper)	5.7 (Super)	4.2 (Eu)
Wairarapa	Middle	2021/22	11	5.2 (Super)	4.5 (Eu)	6.5 (Hyper)	5.7 (Super)	4.3 (Eu)
Wairarapa	Alsops Bay	2019/22	21	5.3 (Super)	4.7 (Eu)	6.5 (Hyper)	5.5 (Super)	4.3 (Eu)
Wairarapa	Alsops Bay	2021/22	10	5.2 (Super)	4.6 (Eu)	6.4 (Hyper)	5.4 (Super)	4.4 (Eu)
Onoke	Site 1	2019/22	30	4.7 (Eu)	3.5 (Meso)	6.1 (Hyper)	4.9 (Eu)	4.4 (Eu)
Onoke	Site 1	2021/22	10	5.0 (Eu)	3.8 (Meso)	6.4 (Hyper)	5.2 (Super)	4.5 (Eu)

## Proposed natural resources plan thresholds (PNRP)

Comparison of lake data against PNRP outcomes for the three-year period July 2019 to June 2022. Note that this only includes Lake Onoke data for the 15 times the lake mouth was closed out of 30 samples over the three-year period July 2019 to June 2022

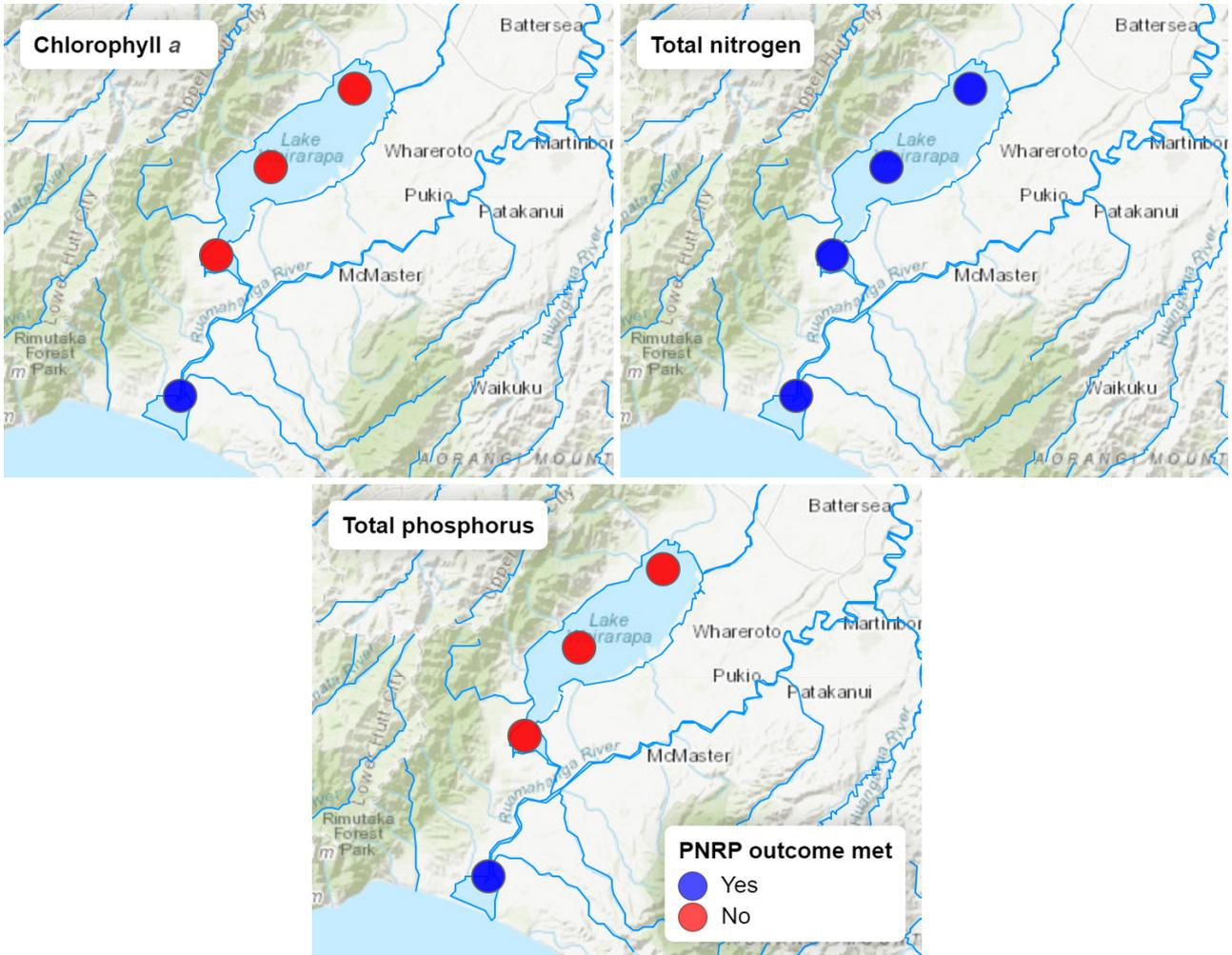


Figure 3: PNRP results for the three attributes assessed: Chlorophyll *a*, Total nitrogen, and Total phosphorus.

Table 9: PNRP attribute scores, values with asterisks indicated exceedances of PNRP thresholds.

Lake	Site	No. samples	Chlorophyll <i>a</i> median	Chlorophyll <i>a</i> max	Total nitrogen median	Total phosphorus median
Wairarapa	Site 2 - stump	30	11.5*	41.0	0.43	0.086*
Wairarapa	Middle	30	12.0*	56.0	0.40	0.069*
Wairarapa	Alsops Bay	21	12.0*	31.0	0.44	0.071*
Onoke	Site 1	15	<3.0	24.0	0.43	0.024

## National objectives framework (NOF)

Comparison of lake data annual summaries against NPS-FM NOF attribute states for the one-year period July 2021 to June 2022. Note that the Lake Onoke data below only includes the 3 samples taken when the lake mouth was closed out of 10 total samples over the 2021/22 monitoring year.

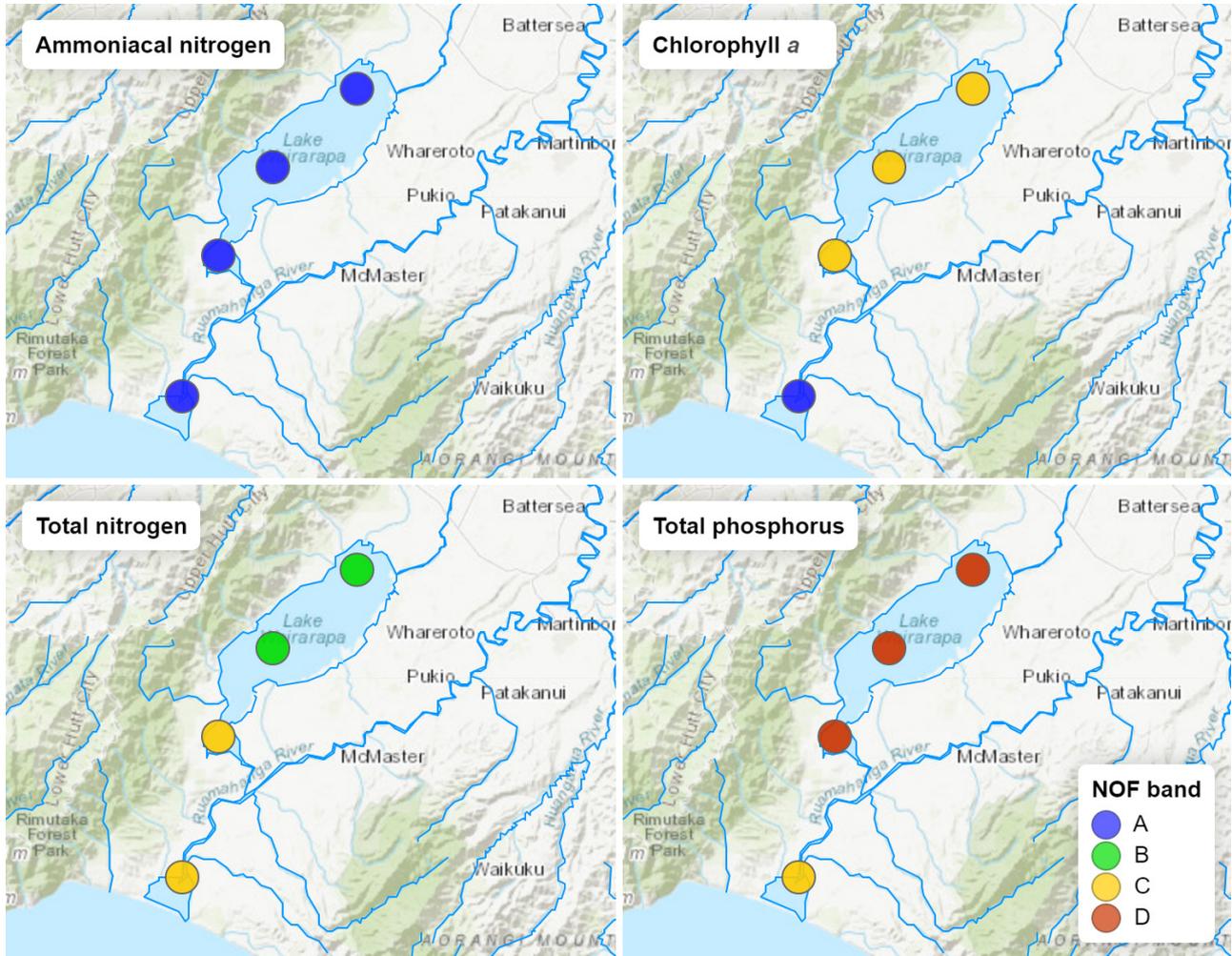


Figure 4: NOF states for the four attributes assessed: Ammoniacal nitrogen, Chlorophyll *a*, Total nitrogen, and Total phosphorus.

Table 10: Individual NOF attribute scores with states provided in brackets. Where there are multiple attributes for Chlorophyll *a* and Ammoniacal nitrogen, the worst state determines the overall band in the maps above.

Lake	Site	No. samples	Type	Ammoniacal nitrogen max	Ammoniacal nitrogen median	Chlorophyll <i>a</i> max	Chlorophyll <i>a</i> median	Total nitrogen median	Total phosphorus median
Wairarapa	Site 2-stump	11	Polymictic	0.024 (A)	<0.005 (A)	34 (C)	10 (C)	0.40 (B)	0.058 (D)
Wairarapa	Middle	11	Polymictic	0.022 (A)	<0.005 (A)	24 (B)	7 (C)	0.40 (B)	0.066 (D)
Wairarapa	Alsops Bay	10	Brackish	0.021 (A)	<0.005 (A)	22 (B)	12 (C)	0.46 (C)	0.058 (D)
Onoke	Site 1	3	Brackish	0.012 (A)	0.011 (A)	4 (A)	<3 (A)	0.67 (C)	0.031 (C)

## Trend assessment results

Trends assessments are estimated at each site using data over periods of 5-, 10-, and 15- years, where sufficient data is available, and presented in the following maps. See the [trend assessments methods](#) section for more information.

In the following tables, the confidence in trend direction is marked by:

- ↑↑: very likely improving
- ↑: likely improving
- →: indeterminate
- ↓: likely degrading
- ↓↓: very likely degrading

Note that series with too many censored values can still have a trend direction estimated but the rate is marked **N/A** in the tables.

# Ammoniacal nitrogen

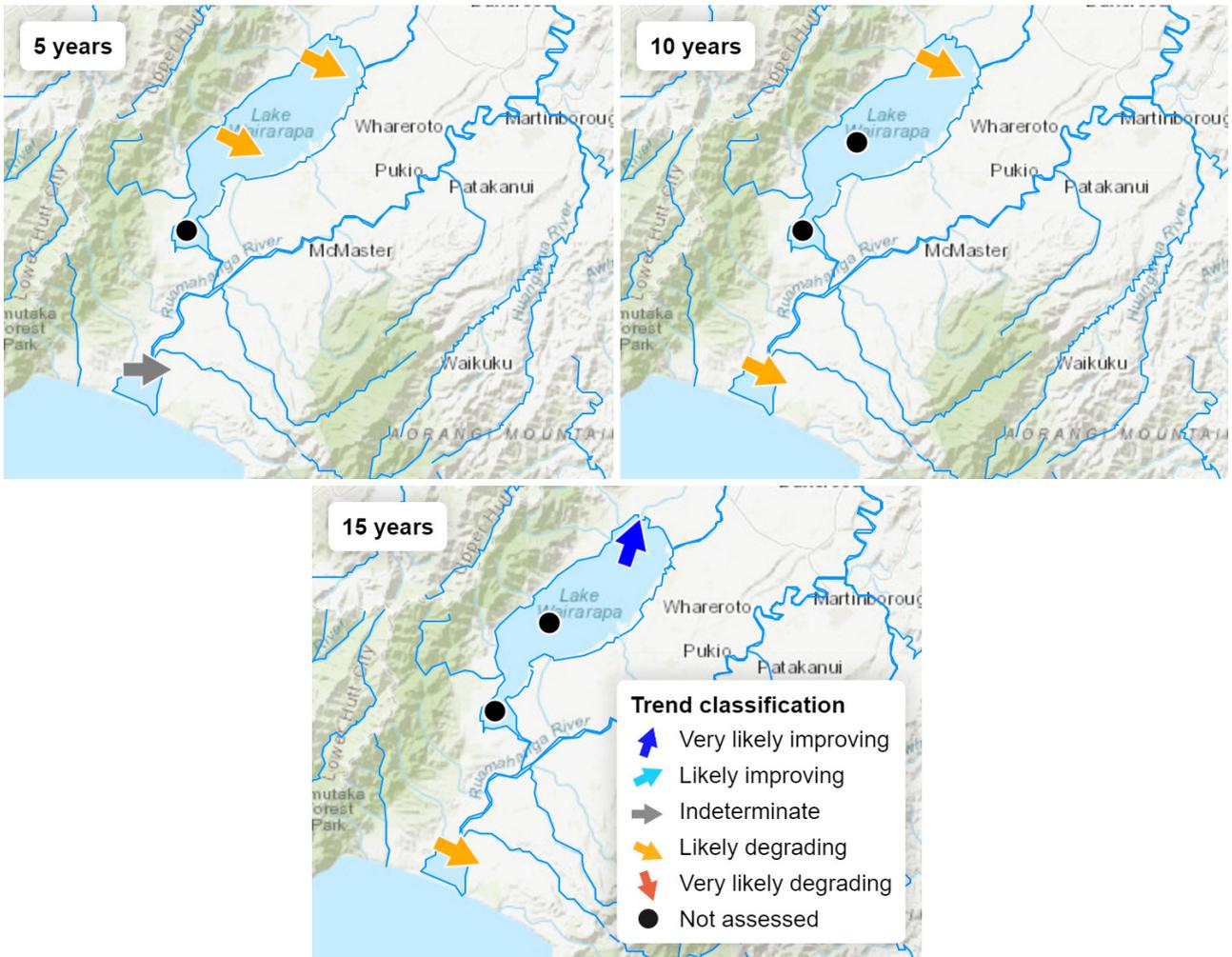


Figure 5: Ammoniacal nitrogen 5, 10, and 15 year trends

Table 11: Ammoniacal nitrogen trend results and applicable state assessments, see the [National Objectives Framework \(NOF\)](#) methods section for full details on assessment criteria.

Lake	Site	Median (3-yr)	NOF state	Trend classification		
				5 yr	10 yr	15 yr
Onoke	Site 1	0.014	A	→ N/A	↓ N/A	↓ N/A
Wairarapa	Alsops Bay	<0.005	A			
Wairarapa	Middle	<0.005	A	↓ N/A		
Wairarapa	Site 2 - stump	<0.005	A	↓ N/A	↓ N/A	↑↑ N/A

# Total nitrogen

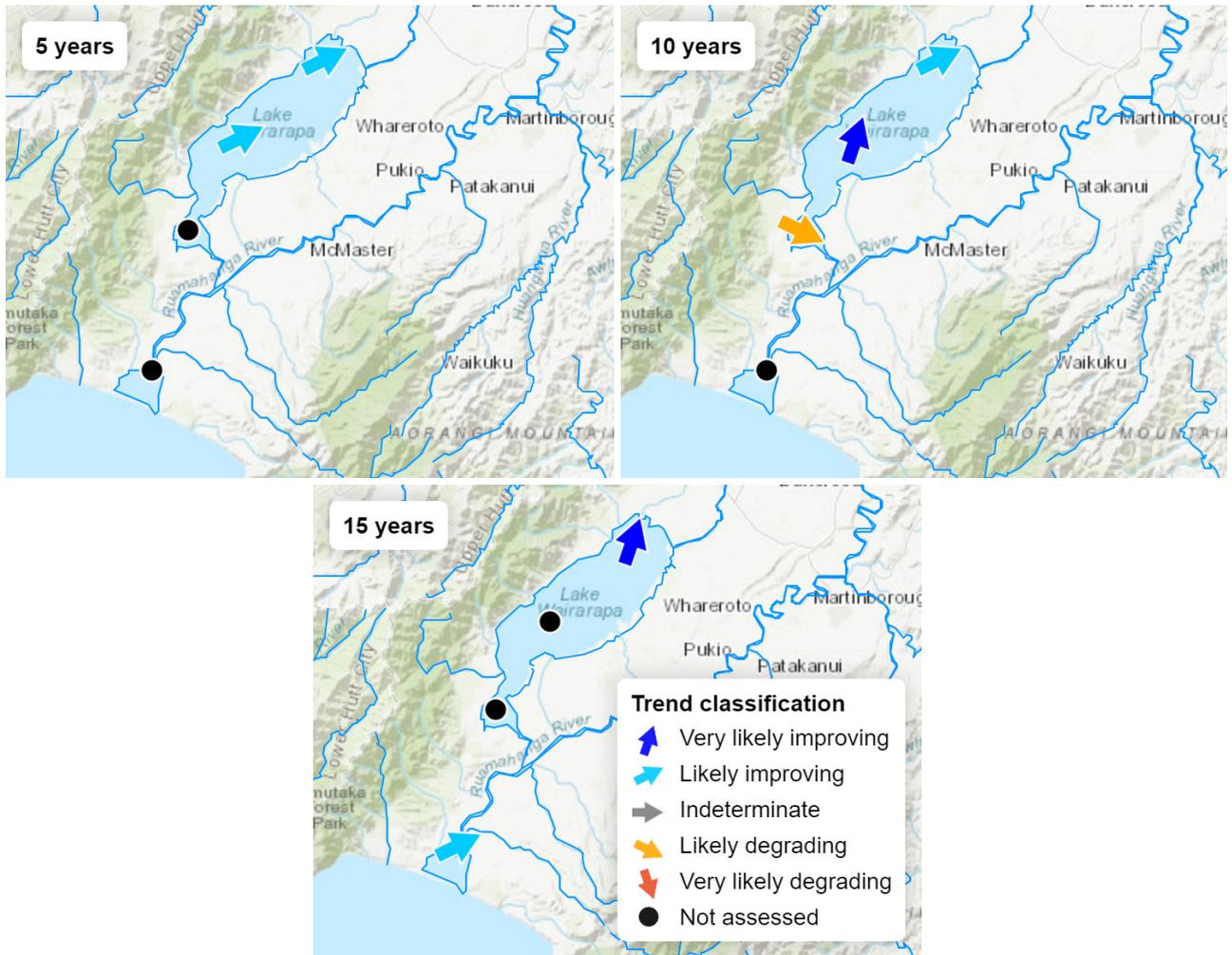


Figure 6: Total nitrogen 5, 10, and 15 year trends

Table 12: Total nitrogen trend results and applicable state assessments, see the [National Objectives Framework \(NOF\)](#), [Trophic Level Index \(TLI\)](#), and [Proposed Natural Resource Plan \(PRNP\)](#) methods sections for full details on assessment criteria.

Lake	Site	Median (3-yr)	NOF state	TLI (3-yr)	Meets PNRP	Trend classification		
						5 yr	10 yr	15 yr
Onoke	Site 1	0.46	C	Eutrophic (high)	Yes			↑ N/A
Wairarapa	Alsops Bay	0.44	C	Supertrophic (very high)	Yes		↓ N/A	
Wairarapa	Middle	0.40	B	Supertrophic (very high)	Yes	↑ -0.017	↑↑ -0.040	
Wairarapa	Site 2 - stump	0.43	B	Supertrophic (very high)	Yes	↑ -0.012	↑ -0.006	↑↑ -0.015

# Total phosphorus

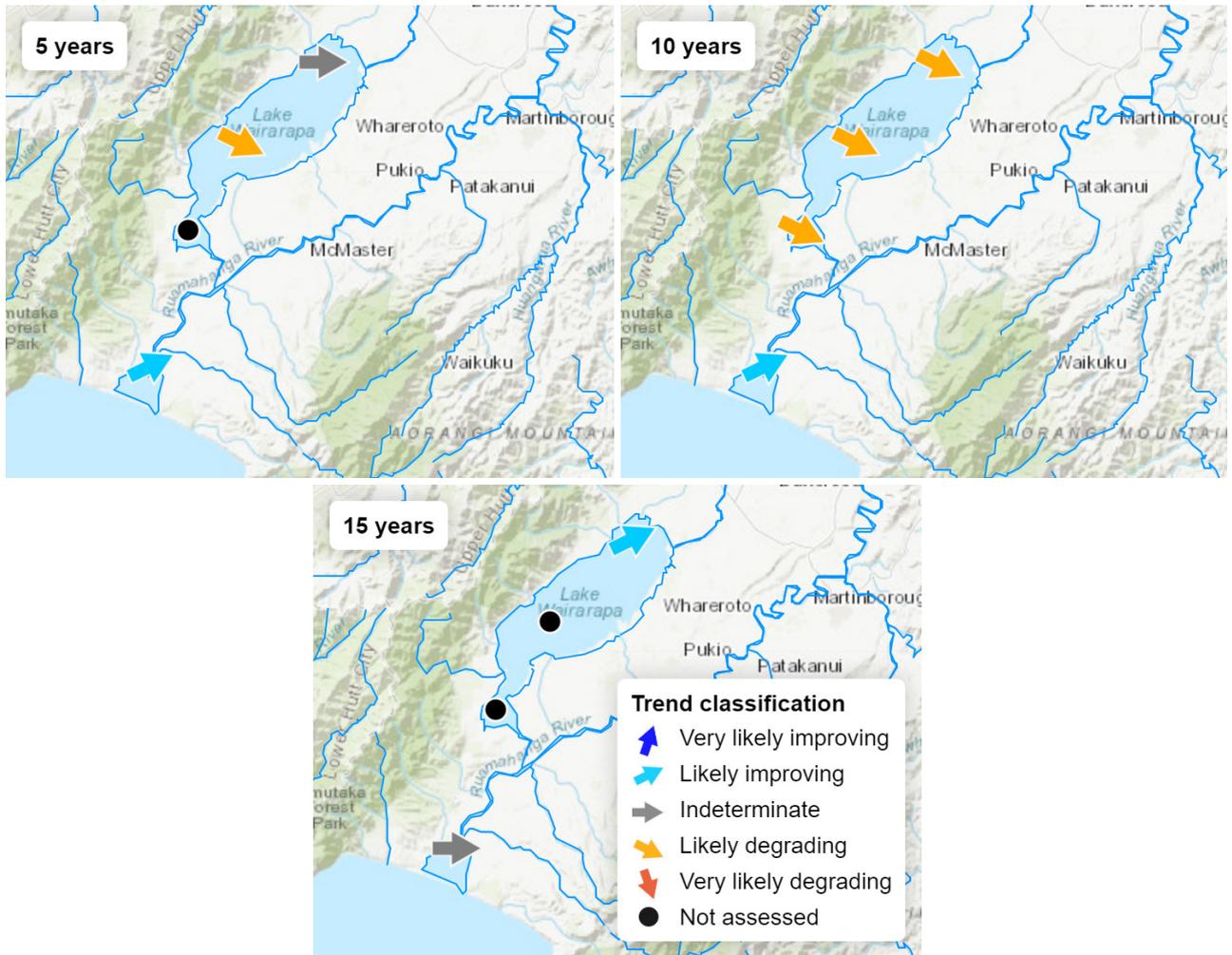


Figure 7: Total phosphorus 5, 10, and 15 year trends

Table 13: Total phosphorus trend results and applicable state assessments, see the [National Objectives Framework \(NOF\)](#), [Trophic Level Index \(TLI\)](#), and [Proposed Natural Resource Plan \(PRNP\)](#) methods sections for full details on assessment criteria.

Lake	Site	Median (3-yr)	NOF state	TLI (3-yr)	Meets PNRP	Trend classification		
						5 yr	10 yr	15 yr
Onoke	Site 1	0.035	C	Eutrophic (high)	Yes	↑ -0.0015	↑ N/A	→ -0.0001
Wairarapa	Alsops Bay	0.071	D	Supertrophic (very high)	No		↓ 0.0014	
Wairarapa	Middle	0.069	D	Supertrophic (very high)	No	↓ 0.0047	↓ 0.0018	
Wairarapa	Site 2 - stump	0.086	D	Supertrophic (very high)	No	→ N/A	↓ 0.0012	↑ -0.0015

# Visual clarity

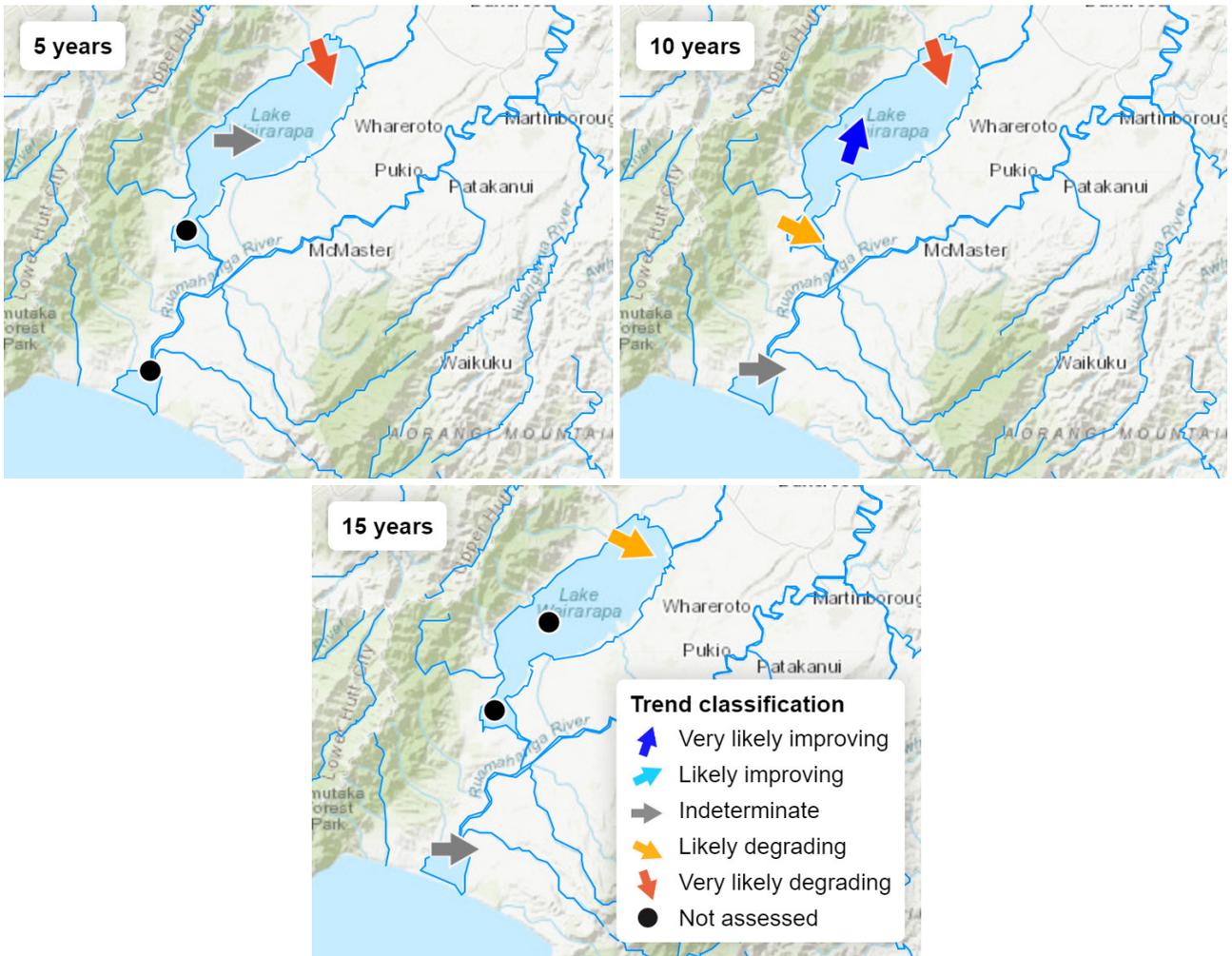


Figure 8: Visual clarity 5, 10, and 15 year trends

Table 14: Visual clarity trend results and applicable state assessments, see the [Trophic Level Index \(TLI\)](#) methods section for full details on assessment criteria.

Lake	Site	Median (3-yr)	TLI (3-yr)	Trend classification		
				5 yr	10 yr	15 yr
Onoke	Site 1	0.40	Eutrophic (high)		→ -0.01	→ 0.00
Wairarapa	Alsops Bay	0.27	Supertrophic (very high)		↓ -0.01	
Wairarapa	Middle	0.25	Supertrophic (very high)	→ 0.00	↑↑ 0.01	
Wairarapa	Site 2 - stump	0.20	Supertrophic (very high)	↓↓ -0.02	↓↓ -0.01	↓ 0.00

# Chlorophyll *a*

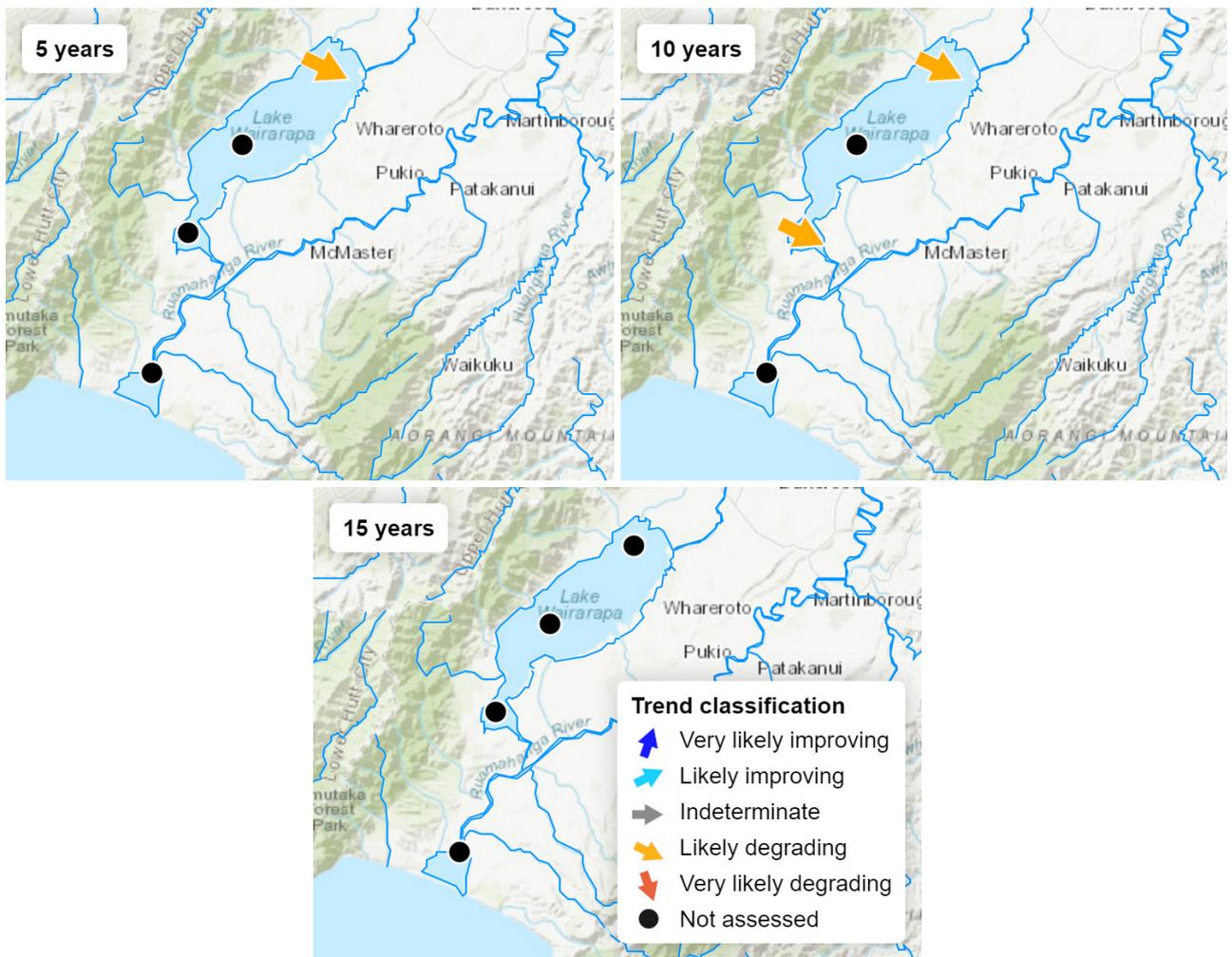


Figure 9: Chlorophyll *a* 5, 10, and 15 year trends

Table 15: Chlorophyll *a* trend results and applicable state assessments, see the [National Objectives Framework \(NOF\)](#), [Trophic Level Index \(TLI\)](#), and [Proposed Natural Resource Plan \(PRNP\)](#) methods sections for full details on assessment criteria.

Lake	Site	Median (3-yr)	NOF state	TLI (3-yr)	Meets PNRP	Trend classification		
						5 yr	10 yr	15 yr
Onoke	Site 1	<3.0	A	Eutrophic (high)	Yes			
Wairarapa	Alsops Bay	12.0	C	Supertrophic (very high)	No		↓ N/A	
Wairarapa	Middle	12.0	C	Supertrophic (very high)	No			
Wairarapa	Site 2 - stump	11.5	C	Supertrophic (very high)	No	↓ N/A	↓ N/A	

# LakeSPI assessment results

Submerged aquatic plant communities are assessed using the LakeSPI methodology. Metrics include measures of diversity from the presence of key plant communities, the depth of vegetation growth, and the extent that invasive weeds are represented. See the [LakeSPI assessments methods section](#) for more information, and the [technical report](#) for additional results.

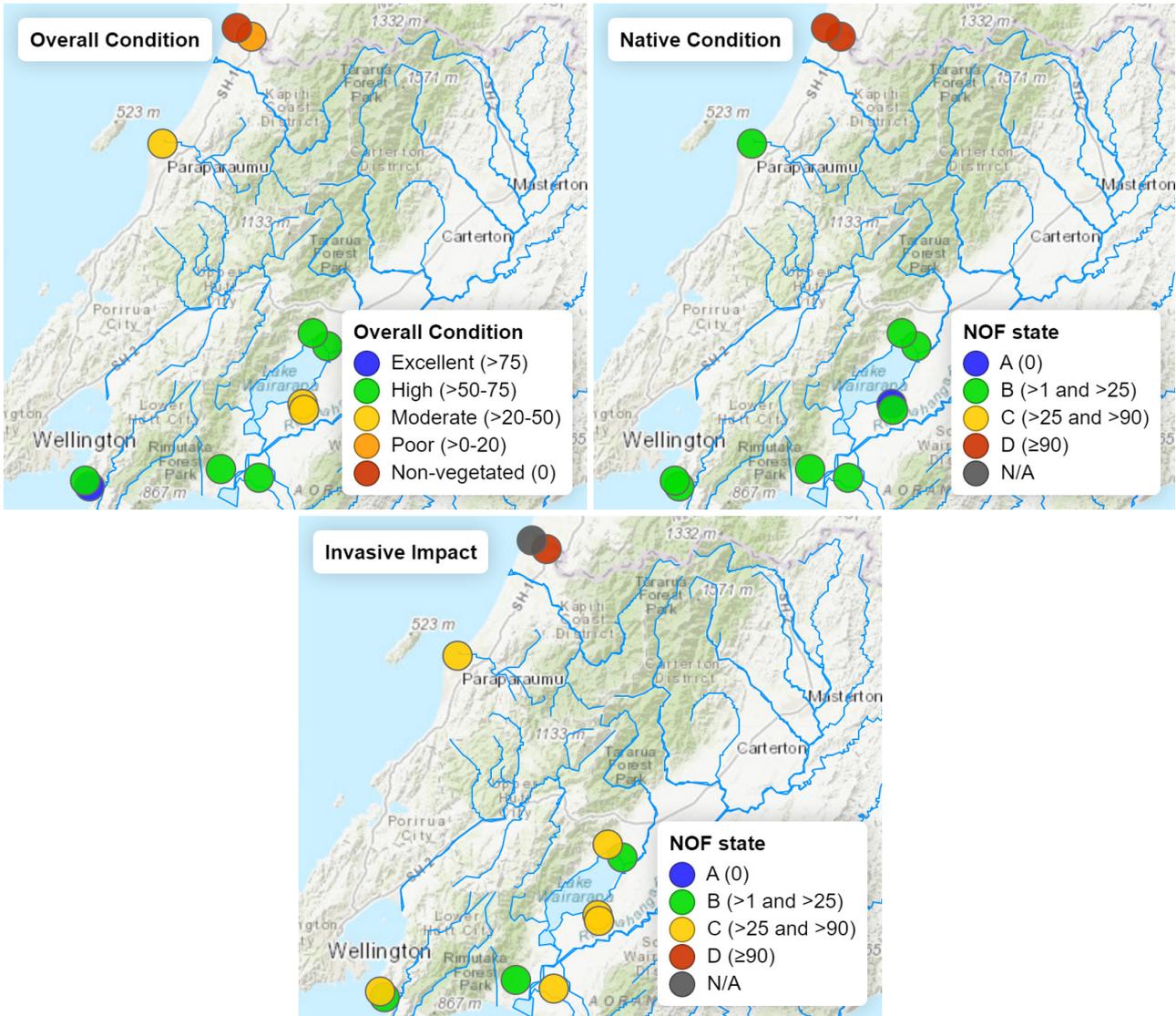


Figure 10: LakeSPI assessments from the latest surveys. Legend values in brackets correspond to: % of best possible for Overall Condition & Native Condition, and % of highest possible Invasive Impact.

Table 16: LakeSPI assessments from the latest surveys. Values refer to index scores (% of best possible for LakeSPI and Native Condition, and % of worst possible for Invasive Impact). NOF state letters, A (best) to D (worst), are included in brackets where applicable.

Area	Waterbody	Latest survey	Overall condition	LakeSPI	Native Condition	Invasive Impact
Wainuiomata	Lake Kohangatera	2019	Excellent	83	74 (B)	10 (B)
Wairarapa	Barton's Lagoon	2022	High	74	71 (B)	22 (B)
Wairarapa	Lake Pounui	2022	High	72	52 (B)	7 (B)
Wairarapa	Turner's Lagoon	2022	High	68	74 (B)	31 (C)
Wairarapa	Lake Nganoke	2022	High	68	69 (B)	30 (C)
Wainuiomata	Lake Kohangapiripiri	2019	High	55	64 (B)	48 (C)
Waikanae	Lake Ngarara	2022	Moderate	45	64 (B)	58 (C)
Wairarapa	Boggy Pond	2022	Moderate	44	79 (A)	67 (C)
Wairarapa	Matthew's Lagoon	2022	Moderate	34	62 (B)	73 (C)
Ōtaki	Lake Waitawa	2022	Poor	6	0 (D)	96 (D)
Ōtaki	Lake Waiorongomai	2022	Non-vegetated	0	0 (D)	N/A

# Supplementary data results

## Nitrogen

### Total nitrogen

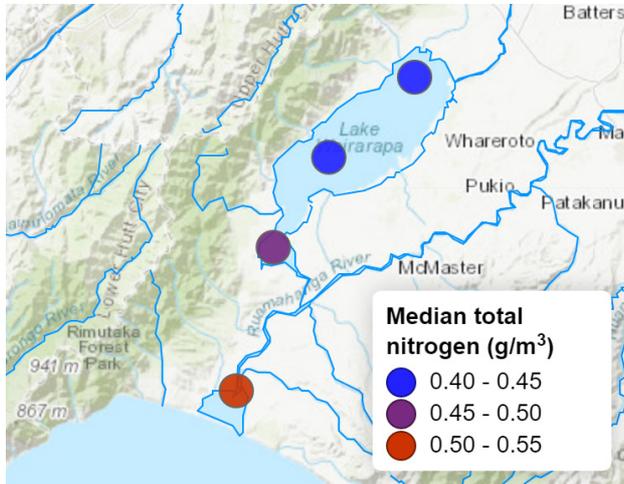


Figure 11: Median total nitrogen results.

Table 17: Total nitrogen results, all units are g/m<sup>3</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	<0.30	0.40	1.13
Wairarapa	Middle	11	<0.30	0.40	1.14
Wairarapa	Alsops Bay	10	<0.30	0.46	0.96
Onoke	Site 1	10	<0.30	0.54	0.98

### Ammoniacal nitrogen

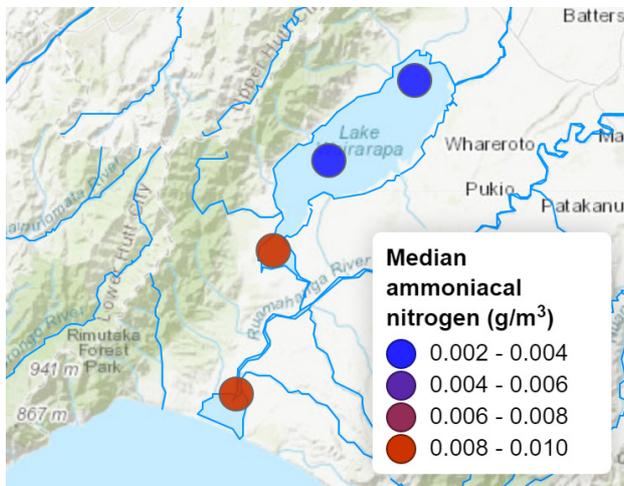


Figure 12: Median ammoniacal nitrogen results.

Table 18: Ammoniacal nitrogen results, all units are g/m<sup>3</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	<0.005	<0.005	0.045
Wairarapa	Middle	11	<0.005	<0.005	0.041
Wairarapa	Alsops Bay	10	<0.005	0.010	0.039
Onoke	Site 1	10	<0.005	0.008	0.036

## Total Kjeldahl nitrogen

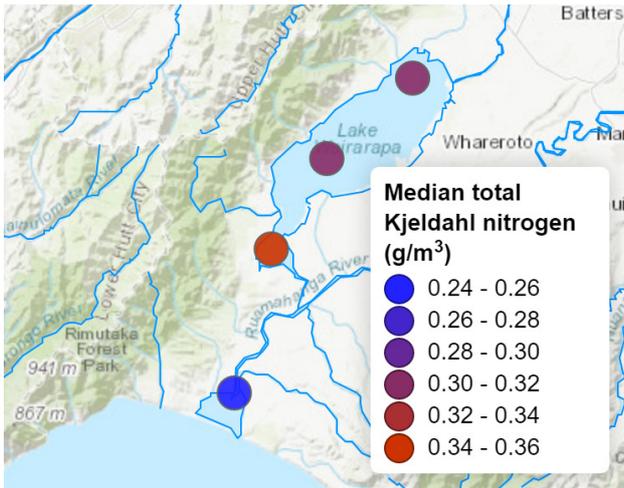


Figure 13: Median total Kjeldahl nitrogen results.

Table 19: Total kjeldahl nitrogen results, all units are g/m<sup>3</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	<0.20	0.32	0.45
Wairarapa	Middle	11	<0.20	0.32	0.51
Wairarapa	Alsops Bay	10	<0.20	0.35	0.47
Onoke	Site 1	10	<0.20	0.25	0.52

## Nitrite-nitrate nitrogen

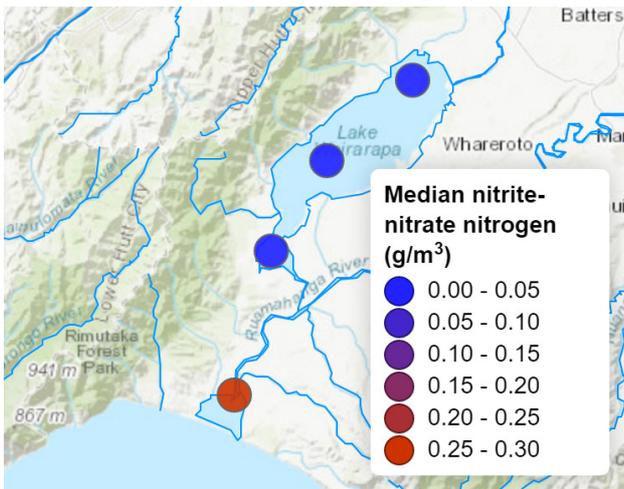


Figure 14: Median nitrite-nitrate nitrogen results.

Table 20: Nitrite-nitrate nitrogen results, all units are g/m<sup>3</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	<0.001	0.019	0.810
Wairarapa	Middle	11	<0.001	0.002	0.640
Wairarapa	Alsops Bay	10	<0.001	0.030	0.530
Onoke	Site 1	10	0.015	0.265	0.630

# Phosphorus

## Total phosphorus

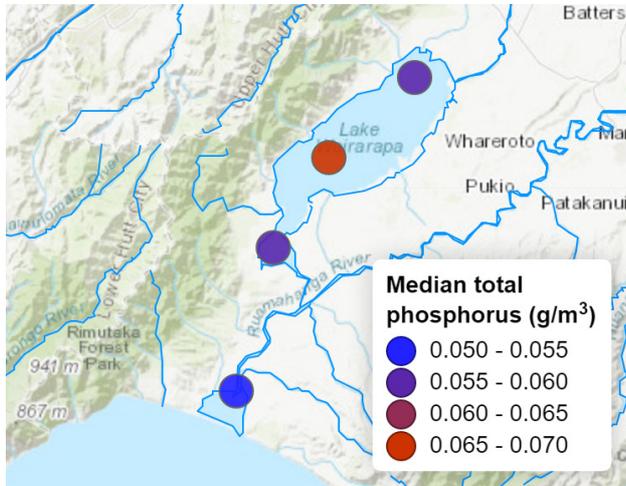


Figure 15: Median total phosphorus results.

Table 21: Total phosphorus results, all units are g/m<sup>3</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	0.034	0.058	0.151
Wairarapa	Middle	11	0.037	0.066	0.173
Wairarapa	Alsops Bay	10	0.032	0.058	0.122
Onoke	Site 1	10	0.012	0.054	0.129

## Dissolved reactive phosphorus

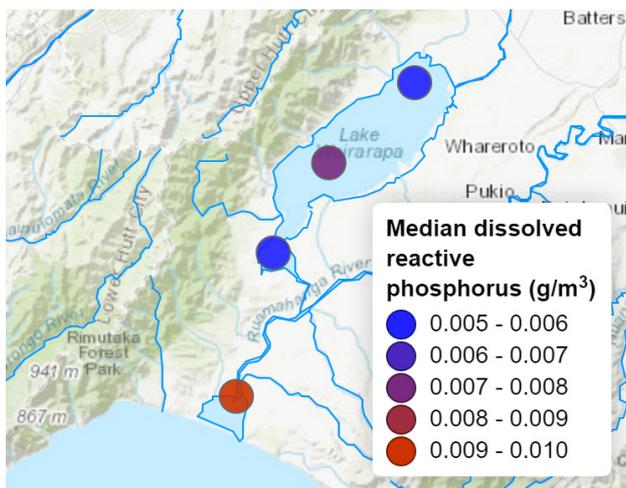


Figure 16: Median dissolved reactive phosphorus results.

Table 22: Dissolved reactive phosphorus results, all units are g/m<sup>3</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	0.002	0.006	0.046
Wairarapa	Middle	11	<0.001	0.008	0.018
Wairarapa	Alsops Bay	10	<0.001	0.005	0.036
Onoke	Site 1	10	<0.001	0.009	0.042

# Phytoplankton

## Chlorophyll *a*

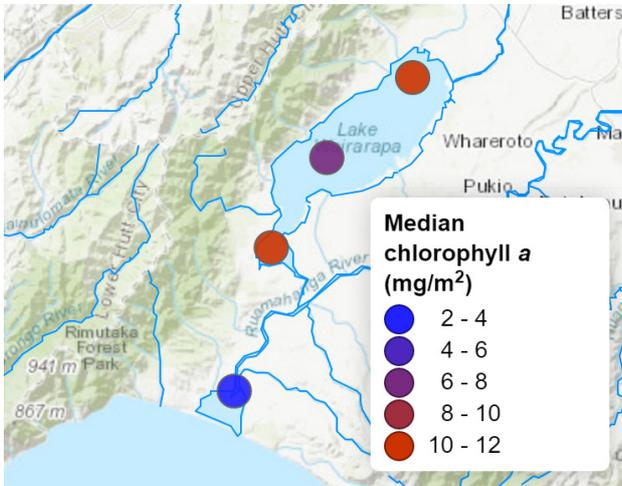


Figure 17: Median chlorophyll *a* results.

Table 23: Chlorophyll *a* results, all units are mg/m<sup>2</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	4.0	10.0	34.0
Wairarapa	Middle	11	3.0	6.5	24.0
Wairarapa	Alsops Bay	10	<3.0	11.5	22.0
Onoke	Site 1	10	<3.0	3.5	21.0

# Water clarity

## Secchi depth

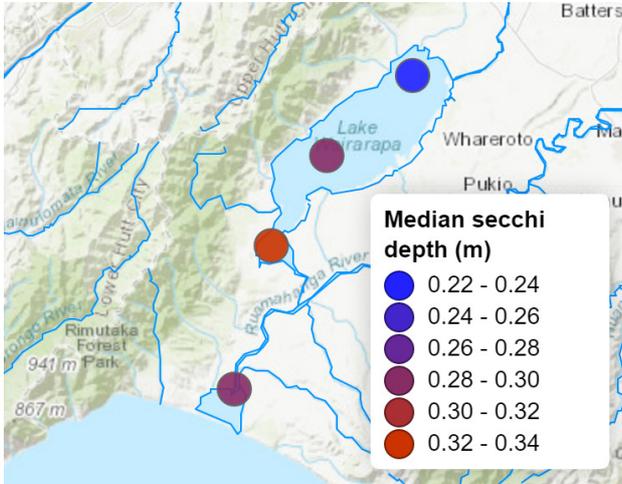


Figure 18: Median secchi depth results.

Table 24: Secchi depth results, all units are m unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	0.04	0.23	0.63
Wairarapa	Middle	11	0.06	0.30	0.73
Wairarapa	Alsops Bay	10	0.09	0.33	0.73
Onoke	Site 1	7	0.08	0.30	0.52

## Absorbance at 340 nm

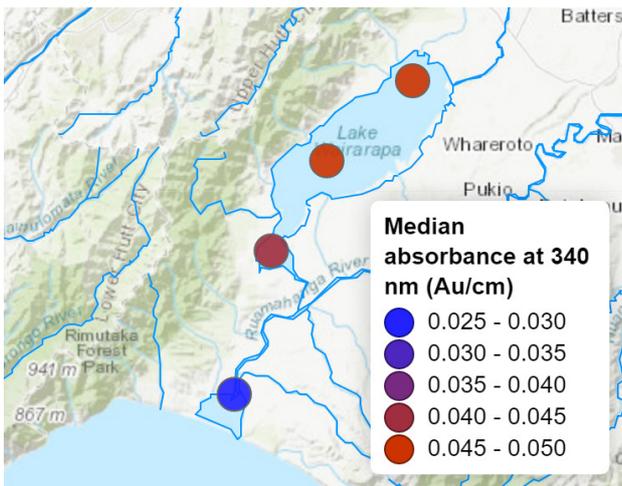


Figure 19: Median absorbance at 340 nm results.

Table 25: Absorbance at 340 nm results, all units are Au/cm unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	6	0.033	0.046	0.156
Wairarapa	Middle	6	0.029	0.046	0.109
Wairarapa	Alsops Bay	6	0.024	0.041	0.107
Onoke	Site 1	1	0.028	0.028	0.028

## Absorbance at 440 nm

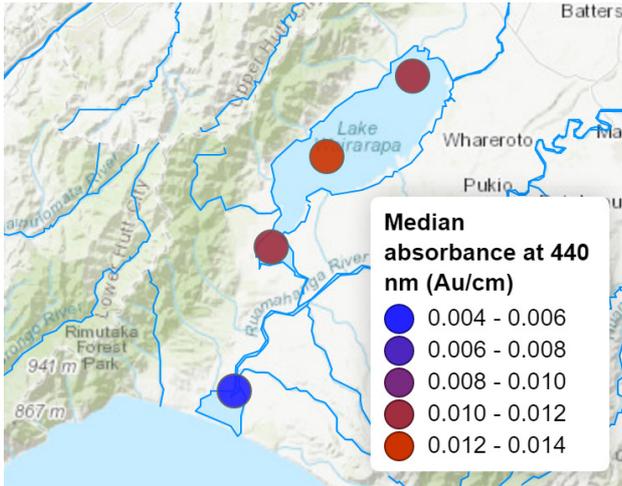


Figure 20: Median absorbance at 440 nm results.

Table 26: Absorbance at 440 nm results, all units are Au/cm unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	6	0.010	0.012	0.074
Wairarapa	Middle	6	0.008	0.014	0.045
Wairarapa	Alsops Bay	6	0.006	0.011	0.043
Onoke	Site 1	1	0.005	0.005	0.005

## Absorbance at 780 nm

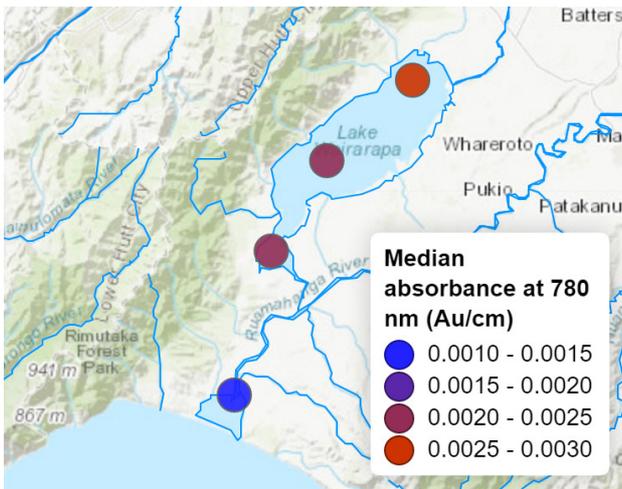


Figure 21: Median absorbance at 780 nm results.

Table 27: Absorbance at 780 nm results, all units are Au/cm unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	6	<0.002	0.003	0.018
Wairarapa	Middle	6	<0.002	0.003	0.010
Wairarapa	Alsops Bay	6	<0.002	0.003	0.010
Onoke	Site 1	1	<0.002	<0.002	<0.002

# Sediment

## Turbidity

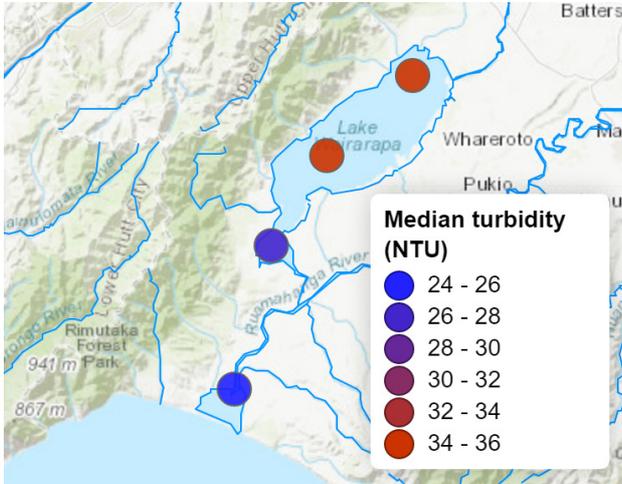


Figure 22: Median turbidity results.

Table 28: Turbidity results, all units are NTU unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	15.4	35.0	179.0
Wairarapa	Middle	11	11.0	34.0	210.0
Wairarapa	Alsops Bay	10	10.2	27.0	149.0
Onoke	Site 1	10	1.9	25.5	183.0

## Total suspended solids

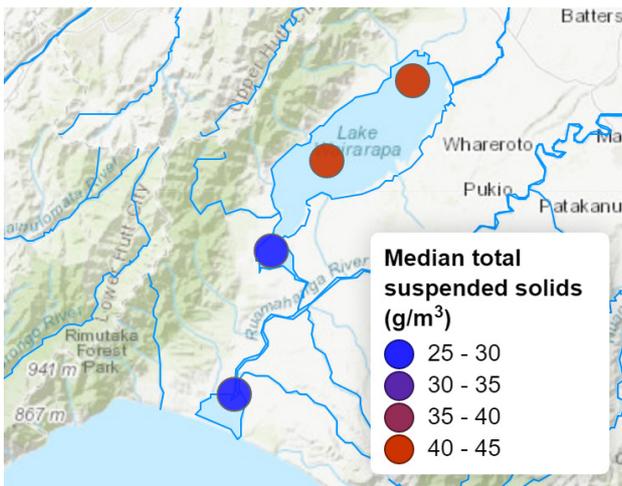


Figure 23: Median total suspended solids results.

Table 29: Total suspended solids results, all units are g/m³ unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	14.0	40.0	159.0
Wairarapa	Middle	11	16.0	43.0	178.0
Wairarapa	Alsops Bay	10	11.0	28.5	123.0
Onoke	Site 1	10	4.0	25.5	192.0

## Volatile suspended solids

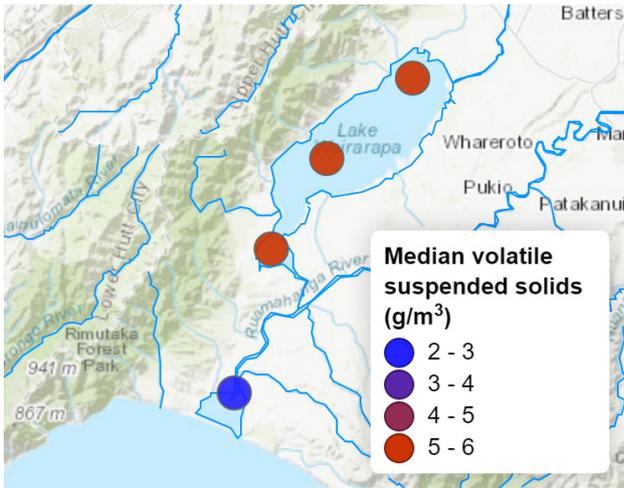


Figure 24: Median volatile suspended solids results.

Table 30: Volatile suspended solids results, all units are g/m<sup>3</sup> unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	<2.0	6.0	20.0
Wairarapa	Middle	11	2.0	6.0	19.0
Wairarapa	Alsops Bay	10	3.0	6.0	14.0
Onoke	Site 1	10	<2.0	2.5	9.0

# Other water quality variables

## Water temperature

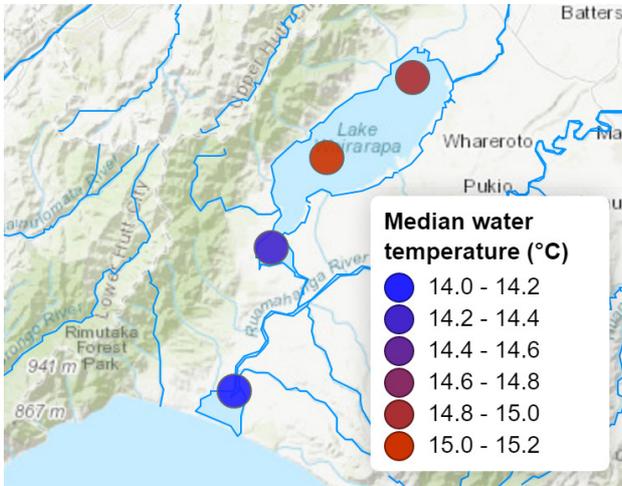


Figure 25: Median water temperature results.

Table 31: Water temperature results, all units are °C unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	9.1	14.8	19.4
Wairarapa	Middle	11	9.1	15.1	20.0
Wairarapa	Alsops Bay	10	8.9	14.2	18.8
Onoke	Site 1	10	9.9	14.2	21.0

## pH

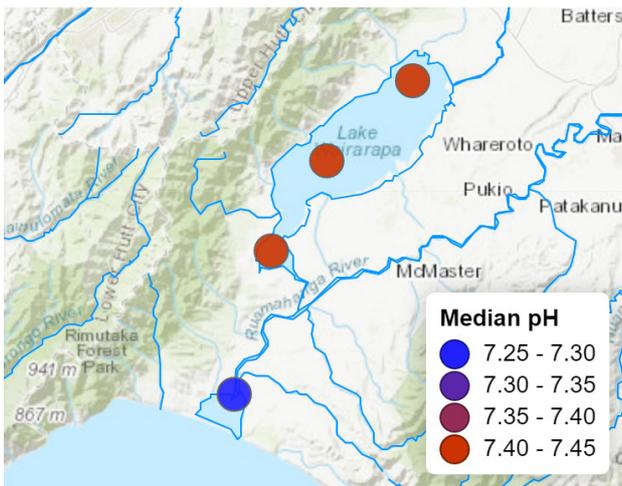


Figure 26: Median pH results.

Table 32: pH results, all units are pH units unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	7.0	7.4	8.3
Wairarapa	Middle	11	7.0	7.4	8.0
Wairarapa	Alsops Bay	10	7.0	7.5	8.3
Onoke	Site 1	10	6.7	7.3	7.7

## Dissolved oxygen mg/L

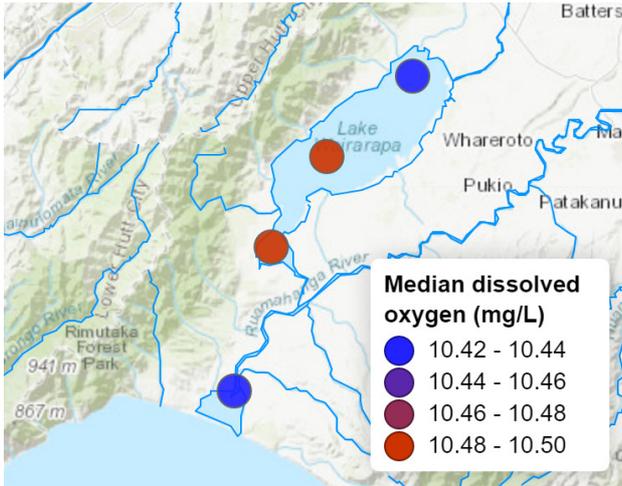


Figure 27: Median dissolved oxygen mg/l results.

Table 33: Dissolved oxygen results, all units are mg/L unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	9.02	10.42	11.02
Wairarapa	Middle	11	8.88	10.50	11.35
Wairarapa	Alsops Bay	10	9.50	10.50	11.80
Onoke	Site 1	10	8.32	10.44	11.00

## Dissolved oxygen % saturation

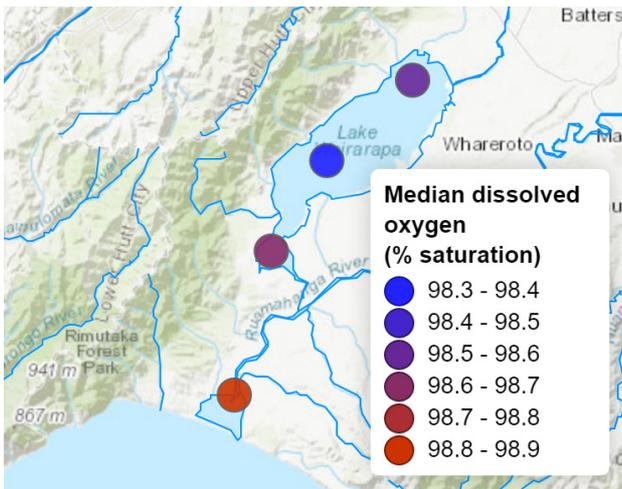


Figure 28: Median dissolved oxygen % saturation results.

Table 34: Dissolved oxygen % sat results, all units are % saturation unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	93.7	98.5	111.4
Wairarapa	Middle	11	96.0	98.3	114.9
Wairarapa	Alsops Bay	10	93.6	98.7	118.6
Onoke	Site 1	10	95.8	98.9	105.2

## Conductivity

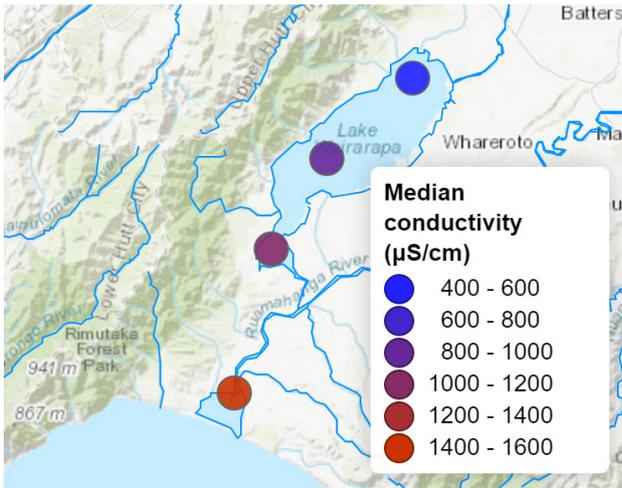


Figure 29: Median conductivity results.

Table 35: Conductivity results, all units are  $\mu\text{S/cm}$  unless otherwise noted.

Lake	Site	No. samples	Min	Median	Max
Wairarapa	Site 2 - stump	11	336.3	523.0	1285.0
Wairarapa	Middle	11	373.2	836.0	1523.0
Wairarapa	Alsops Bay	10	335.7	1095.0	1825.0
Onoke	Site 1	10	174.9	1558.0	10378.0

# Resources

## Useful Links

[Australian and New Zealand Guidelines for Fresh and Marine Water Quality](#)

[Greater Wellington Natural Resources Plan](#)

[National Policy Statement for Freshwater Management 2020](#)

[2017/18 Lake water quality and ecology report](#)

[Land Air Water Aotearoa \(LAWA\)](#)

## References

Burns N, Bryers G and Bowman E. 2000. *Protocols for monitoring trophic levels of New Zealand lakes and reservoirs*. Report prepared for the Ministry for the Environment by Lakes Consulting, Pauanui.

Burns NM, Rutherford JC and Clayton JS. 1999. *A monitoring and classification system for New Zealand lakes and reservoirs*. Journal of Lake and Reservoir Management, 15(4): 255-271.

Clayton T and Edwards T. 2006. *LakeSPI – A method for monitoring ecological condition in New Zealand lakes*. Technical report (version 2). Ministry for the Environment, Wellington.

Cockeram B and Perrie A. 2013. *Lakes State of the Environment monitoring programme: Annual data report, 2012/13*. Greater Wellington, Publication No. GW/ESCI-T-13/115, Wellington.

Cockeram B and Perrie A. 2014. *Lakes State of the Environment monitoring programme: Annual data report, 2013/14*. Greater Wellington, Publication No. GW/ESCI-T-14/119, Wellington.

de Winton M, Taumoepeau A, and David S. 2022. *LakeSPI surveys of waterbodies in Wellington Region: 2021/22*. Report No. 2022179HN prepared for Greater Wellington by NIWA, Hamilton.

Duggan, I.C. 2022. *Zooplankton Communities, and TLI and Lake Health Assessments, of Selected Lakes in the Wellington region*. ERI Report No. 136, a client report prepared for the Greater Wellington Regional Council. Environmental Research Institute – Te Tumu Whakaora Taiao, Division of Health, Engineering, Computing & Science, The University of Waikato, Hamilton. 12 pp. [doi:10.15663/ERI.Report.163](https://doi.org/10.15663/ERI.Report.163)

Greenfield S, Milne J, Perrie A, Oliver M, Tidswell S and Crisp P. 2015. *Technical guidance document: Aquatic ecosystem health and contact recreation outcomes in the Proposed Natural Resources Plan*. Greater Wellington, Publication No. GW/ESCI-T-15/45, Wellington.

- Greater Wellington. 2015. *Proposed Natural Resources Plan for the Wellington Region – Te Tikanga Taiao o Te Upoko o Te Ikaa a Maui*. Greater Wellington, Publication No. GW/EP-G-15/44, Wellington.
- Hickson-Rowden B. 2019. *Lake Water Quality and Ecology monitoring programme: Annual data report, 2017/18*. Greater Wellington, Publication No. GW/ESCI-T-18/143
- Ministry for the Environment. 2014. *National Policy Statement for Freshwater Management 2014*. Publication No. ME1155, Ministry for the Environment, Wellington.
- Perrie A, Heath MW and Cockeram B. 2015. *Lakes State of the Environment monitoring programme: Annual data report, 2014/15*. Greater Wellington Regional Council, Publication No. GW/ESCI-T-15/147, Wellington.
- Perrie A and Milne J. 2012. *Lake water quality and ecology in the Wellington region: State and trends*. Greater Wellington, Publication No. GW/EMI-T-12/139, Wellington.
- Perrie A and Royal C. 2022. *A preliminary assessment of water quality in selected shallow lakes and lagoons in the Wellington Region*. Greater Wellington Regional Council, Publication No. GW/ESCI-G-22/05, Wellington.
- Smith D, McBride G, Bryers G, Davis-Colley R, Quinn J and Vant W. 1989. *A national water quality network for New Zealand*. Department of Scientific and Industrial Research, Hamilton.
- Verburg P, Hamill K, Unwin M and Abell J. 2010. *Lake water quality in New Zealand 2010: Status and trends*. Report No. HAM2010-107 prepared for the Ministry for the Environment by NIWA, Hamilton.

# Appendix

## Monitoring details

Table A1: Water quality sampling methods and detection limits.

Variable	Method	Detection limit
pH	pH meter. APHA 4500-H+ B 22nd ed. 2012	0.1 pH units
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 g/m <sup>3</sup>
Volatile suspended solids	Filtration (GF/C, 1.2 µm). Ashing 550°C, 30 min. Gravimetric. APHA 2540 E 22nd Ed. 2012	2 g/m <sup>3</sup>
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N	0.001 g/m <sup>3</sup>
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO 3 - I (modified) 22nd Ed. 2012	0.001 g/m <sup>3</sup>
Nitrate-N + Nitrite-N (NNN)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO 3 - I (modified) 22nd Ed. 2012	0.001 g/m <sup>3</sup>
Ammoniacal nitrogen	Phenol/hypochlorite colorimetry. Flow injection analysers. (NH 4 -N = NH 4 +-N + NH 3 -N) APHA 4500-NH 3 F 22nd Ed. 2012	0.005 g/m <sup>3</sup>
Total Kjeldahl nitrogen	Kjeldahl digestion, phenol/hyperchlorite colorimetry (Discrete Analysis). APHA 4500-N Org C. (modified) 4500- F (modified) 22nd Ed. 2012	0.1 g/m <sup>3</sup>
Total nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N	0.05 g/m <sup>3</sup>
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 22nd Ed. 2012	0.001 g/m <sup>3</sup>
Total phosphorus	Total Phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd Ed. 2012	0.004 g/m <sup>3</sup>
Chlorophyll <i>a</i>	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd Ed. 2012	0.003 mg/m <sup>2</sup>
Pheophytin <i>a</i>	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd Ed. 2012	0.003 g/m <sup>3</sup>
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 780 nm	Filtered sample. Spectrophotometry, 1cm cell. APHA 5910 B 22nd Ed. 2012	0.002 AU/cm

Table A2: Water quality monitoring site information.

Lake	Site	Type	Lat	Lng
Wairarapa	Site 2 - stump	Polymictic	-41.176	175.285
Wairarapa	Middle	Polymictic	-41.227	175.214
Wairarapa	Alsops Bay	Brackish	-41.282	175.168
Onoke	Site 1	Brackish	-41.371	175.139

Table A3: LakeSPI monitoring site information.

Area	Waterbody	Depth (m)	Lat	Lng
Ōtaki	Lake Waiorongomai	1.5	-40.712	175.143
Ōtaki	Lake Waitawa	6.9	-40.725	175.173
Waikanae	Lake Ngarara	2.5	-40.877	175.005
Wairarapa	Turner's Lagoon	0.4	-41.151	175.287
Wairarapa	Barton's Lagoon	1.0	-41.168	175.314
Wairarapa	Boggy Pond	1.1	-41.251	175.267
Wairarapa	Matthew's Lagoon	1.3	-41.260	175.269
Wairarapa	Lake Nganoke	1.6	-41.356	175.186
Wairarapa	Lake Pounui	9.8	-41.344	175.114
Wainuiomata	Lake Kohangatera	2.1	-41.368	174.867
Wainuiomata	Lake Kohangapiripiri	1.8	-41.361	174.857