Surface Water Quality Monitoring Report for Lake Forsyth/Te Wairewa: January – December 2018

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11 April 2019

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1 Executive Summary

- This report briefly summarises the surface water quality results of Lake Forsyth/Te Wairewa for the 2018 calendar year and provides an analysis of long term trends.
- Conductivity, salinity, turbidity, nitrogen, phosphorus, and phytoplankton and cyanobacteria counts all recorded statistically significant decreases since monitoring began. Trophic Level Index (TLI) also decreased over time, which is not surprising as this index is calculated from total nitrogen and total phosphorus (as well as chlorophyll a).
- There was no change in temperature or total cyanobacteria biovolume over time, but a statistically significant decrease in the biovolume of cyanobacteria species *Merismopedia* sp. and an increase in the cyanobacteria species *Dolichospermum*[1] spp. were recorded.
- The guideline levels for temperature (19°C) were exceeded on four occasions during the 2017 monitoring year, but all were by ≥1°C.
- The cyanobacteria biovolume alert level was exceeded on eighteen occasions during 2018 and the action level was exceeded on twelve occasions in 2018. This number of exceedances is within the range recorded since monitoring began in 2008, however it is towards the higher end. As a result of these exceedances, health warnings were issued from 20 February – 6 April 2018, 13 June – 6 July 2018, and from 5 October 2018 – present day.
- Unlike during 2014 - 2015, *Myriophyllum* (the native aquatic macrophyte) was not observed flowering in 2018.
- This report supports the evidence presented at the consent hearing that water quality continues to improve within the lake, most likely due to the canal opening regime. Most notably, there has been significant decrease in the TLI since over time.

2 Introduction

In accordance with the requirements of Condition 11c (monitoring and reporting) of consent CRC134849 (to take and divert water from, and dam, Lake Forsyth/Wairewa), this report briefly summarises the surface water quality results of Lake Forsyth/Te Wairewa for the 2018 calendar year and provides an analysis of long term trends. The data used in this report was provided by Environment Canterbury.

3 Methods

Samples were taken at least monthly from the lake and analysed for conductivity, salinity, temperature, turbidity, total nitrogen, total phosphorus, Trophic Level Index (TLI), and phytoplankton and cyanobacteria counts and biovolume. The data analysed was from when the monitoring began in 1993 until December 2018. Samples were typically collected from one site within the lake, with the exception of the salinity data, which was from three sites within the lake (Figure 1). The ECan water level recorder site is hereafter referred to as Recorder.

The graphs in this report were produced using Microsoft Excel 2013 and long-term data trends were analysed using Time Trends software (NIWA, 2014[2]). The Seasonal Kendall trend test was used to test the significance, magnitude and direction of the trends, providing an average annual percentage change. Phytoplankton and cyanobacteria data were analysed as dependant data. The rest of the data was analysed as independent data.

[1] This species has now changed name from *Anabaena* to *Dolichospermum* (Tina Bayer (ECan), pers. Comm)
[2] NIWA, 2014. Trend and equivalence analysis. Software Version 6.2. NIWA. http://www.jowettconsulting.co.nz/home/time-1/Timetrends_setup.zip?attredirects=0.

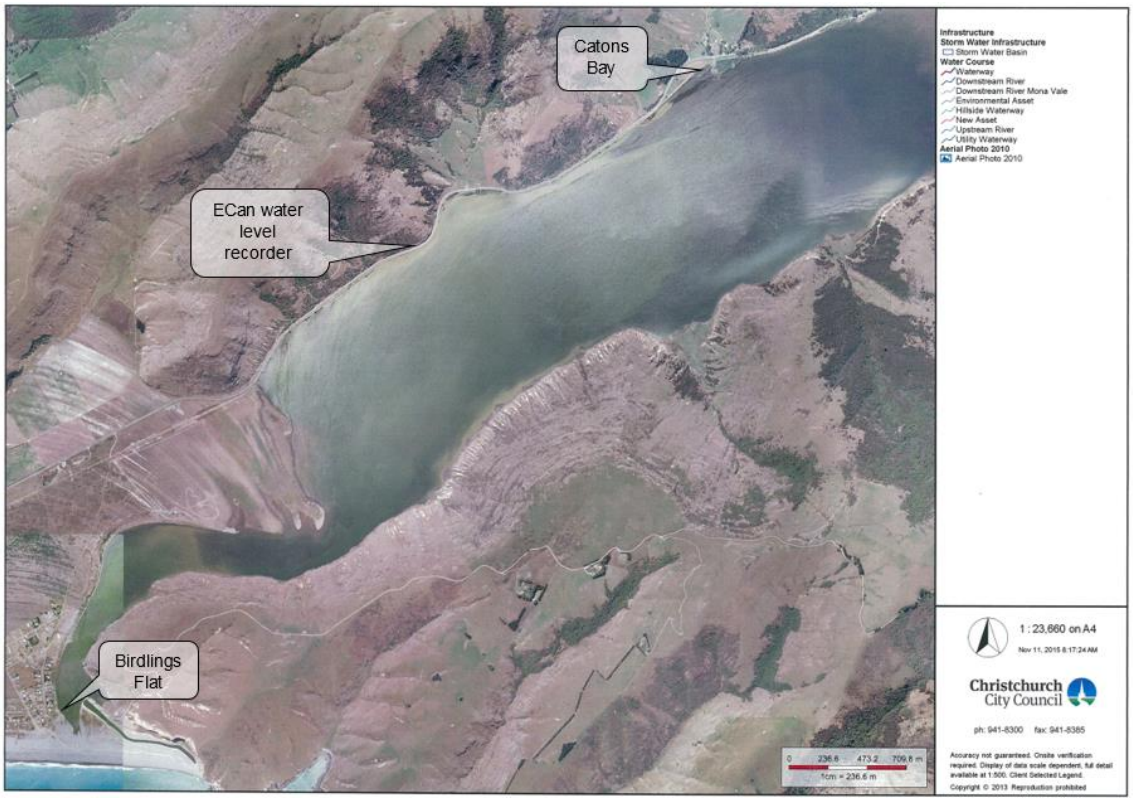

Figure 1. Water quality monitoring sites in Lake Forsyth/Te Wairewa.

4 Results

4.1 Water Quality measurements

Conductivity and salinity

- These two parameters are related to each other, so are presented together.
- A general decreasing trend was recorded over time for both parameters (Figures 2 – 3 in Appendix A).
- There was a significant decrease (5% per annum) in conductivity at the Recorder site since monitoring began.
- There was a significant decrease (7% per annum) in salinity at the Recorder site since monitoring began in November 1998. A significant decrease of 20% was also recorded at the Catons Bay site and a 15% decrease at Birdlings Flat since monitoring began in 2006.

Temperature

- No significant change over time was recorded for temperature since monitoring began in August 1993, with seasonal variations in levels as expected (Figure 4 in Appendix A).
- Frequent exceedances of the Land and Water Regional Plan guideline level (19°C; Environment Canterbury, 2015[3]) have occurred since monitoring began. Four of the 24 samples taken during the 2018 monitoring year exceeded this guideline, but all by 1°C or less.

[3] Environment Canterbury, 2015. Canterbury Land and Water Regional Plan - Volume 1. February 2017. Environment Canterbury, Christchurch.

Turbidity

- There was a significant per annum decrease in turbidity of 2% since monitoring began in July 1993 (Figure 5 in Appendix A).
- Compared to the rest of the 2018 data, there was a spike recorded in December (59 NTU). Approximately 152 mm of rain fell in the month preceding sampling, which represents 9.9% of the areas annual rainfall in 2018 (CCC rainfall recorder at Christchurch Akaroa Highway).

Total nitrogen

- There was a significant per annum decrease in nitrogen of 3% since monitoring began in September 1993 (Figure 6 in Appendix A).
- There were far fewer peak concentrations post ~ September 2010.
- Compared to the rest of the 2018 data, there was a spike recorded in December (2.4 mg/L). Approximately 152 mm of rain fell in the month preceding sampling, which represents 9.9% of the areas annual rainfall in 2018 (CCC rainfall recorder at Christchurch Akaroa Highway).

Total phosphorus

- There was a significant decrease in phosphorus of 3% per annum since monitoring began in July 1993 (Figure 7 in Appendix A).
- There were far fewer peak concentrations post ~ 2010.
- Compared to the rest of the 2018 data, there was a spike recorded in December (0.45 mg/L). Approximately 152 mm of rain fell in the month preceding sampling, which represents 9.9% of the areas annual rainfall in 2018 (CCC rainfall recorder at Christchurch Akaroa Highway).

TLI

- This index is calculated using chlorophyll a, total nitrogen and total phosphorus.
- A significant decrease in TLI of 1% per annum was recorded since monitoring began in September 1999 (Figures 8a - 8c in Appendix A).
- Prior to the canal opening there was an increasing trend (Figure 8b), however it has been decreasing since the initiation of the canal opening (Figure 8c).

Phytoplankton and cyanobacteria counts

- Total phytoplankton numbers significantly decreased by 12% per annum, since monitoring began in 2004 (Figure 9 in Appendix A).
- Cyanobacteria numbers significantly decreased by 31% per annum, since monitoring began in 2004 (Figure 9 in Appendix A).
- There was a reduction in peaks of concentration for both parameters since monitoring began, but particularly for cyanobacteria (Figure 9).
- *Merismopedia* sp. numbers were high when monitoring first began, but have now reduced to only occasional numbers from 2011, with a significant per annum decrease of 271% since monitoring began (Figure 10 in Appendix A).
- Counts of *Nodularia* spp. were recorded when monitoring first commenced, but only occasional re-occurrences have been recorded since 2010 (Figure 10 in Appendix A). Low numbers of *Nodularia* were occasionally recorded in 2018. No significant change was recorded since monitoring began, but this is likely due to the low counts recorded overall.
- *Dolichospermum* spp. have generally been present in low numbers; however, spikes in concentrations are typically recorded at least once a year, however there were none this year (Figure 10 in Appendix A). No significant change was recorded over time for this species.
- Small numbers of *Aphanizomenon* spp. have also been recorded, but there was no significant change in counts since monitoring began in 2004.

Phytoplankton and cyanobacteria biovolume

- A particularly large spike in *Nodularia spumigena* biovolume was recorded from March - May 2016 (Figure 11 in Appendix A). During the 2018 monitoring year this species was only record on five occasions, in small volumes.
- *Dolichospermum* spp. have generally been present in low volumes; however, spikes in concentrations are typically recorded a couple of times a year (Figure 11 in Appendix A).
- There was no significant change in biovolume since the monitoring began in 2008 for all cyanobacteria combined, or for the species *Nodularia spumigena* and *Aphanizomenon* spp.. The cyanobacteria *Merismopedia* sp. had a significant decrease of 13% per annum, while *Dolichospermum* spp. had a significant increase of 4% per annum.
- In the 2018 monitoring year, the alert guideline level of 0.5 mm^3/L was exceeded on eighteen occasions and the action guideline level of 1.8 mm^3/L was exceeded on twelve occasions (Ministry for the Environment and Ministry of Health, 2009[4]; Figure 12a in Appendix A). At least half of the alert and action exceedances were due to *Dolichospermum*[1] spp., however some were *Nodularia spumigena* and the last five alert and four action level exceedances (November- December) were due to *Aphanizomenon* spp.. This number of exceedances per annum is within the range previously recorded since monitoring began in 2008, however they represent the third (alert) and fourth (action) highest number of exceedances (Figure 12b in Appendix A).
- As a consequence, the Canterbury District Health Board advised the public to avoid contacting the water, to avoid eating fish or shellfish from the lake, and to keep livestock and pets away from the lake. These warnings were in place from 20 February – 6 April 2018, 13 June – 6 July 2018, and from 5 October 2018 – present day.

4.2 Lake Openings and Lake Water Quality

- Visually, it is difficult to identify relationships between lake water quality and the timing or duration of lake openings during the smaller time-scale of the 2018 monitoring period (Figure 13 in Appendix A). Given lake opening was limited to four occasions in 2018, relationships should be interpreted with caution, however there was a slight increase in temperature and decrease in salinity after each opening. Since the canal opening was instigated in 2009, there have been significant improvements in water quality within the lake, most notably a decrease in conductivity, salinity and TLI. This was highlighted in the Commissioner's decision on the lake opening consent, based on the evidence presented by a number of experts (Collins et al, 2016)[5].

4.3 Myriophyllum

- Flowerings of *Myriophyllum*, a native macrophyte, were noted in the consent hearing to be observed in the lake in 2014 and 2015 (Collins et al, 2016), anecdotally for the first time in many years. This species was noted to be indicative of a healthier lake environment, as they require good light penetration and a stable lake level.
- However in 2017 and 2018 no flowering or emergent growths were noted (Adrian Meredith and Tina Bayer, pers. comm, March 2019).

[4] Ministry for the Environment and Ministry of Health. 2009. New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters – Interim Guidelines. Prepared for the Ministry for the Environment and the Ministry of Health by SA Wood, DP Hamilton, WJ Paul, KA Safi and WM Williamson. Wellington: Ministry for the Environment.

[5] Collins, D., Cowie, B. & Langsbury, H. 2016. Decisions of hearings commissioners, in the matter of applications to the Christchurch City Council (RMA92021940 and RMA92030265), and the Canterbury Regional Council (CRC134837, CRC134839, CRC134864, CRC135060 and CRC 160434) made jointly by the Christchurch City Council and Wairewa Rūnanga Incorporated for consents to carry out activities associated with the artificial opening and closing of Te Roto o Wairewa/Lake Forsyth to the sea. Little River, Banks Peninsula, New Zealand.

5 Conclusion

- This report supports the evidence presented at the consent hearing that water quality continues to improve within the lake, most likely due to the canal opening regime. Most notably, there has been significant decrease in the TLI since canal openings were initiated.

6 Appendix A: Graphs

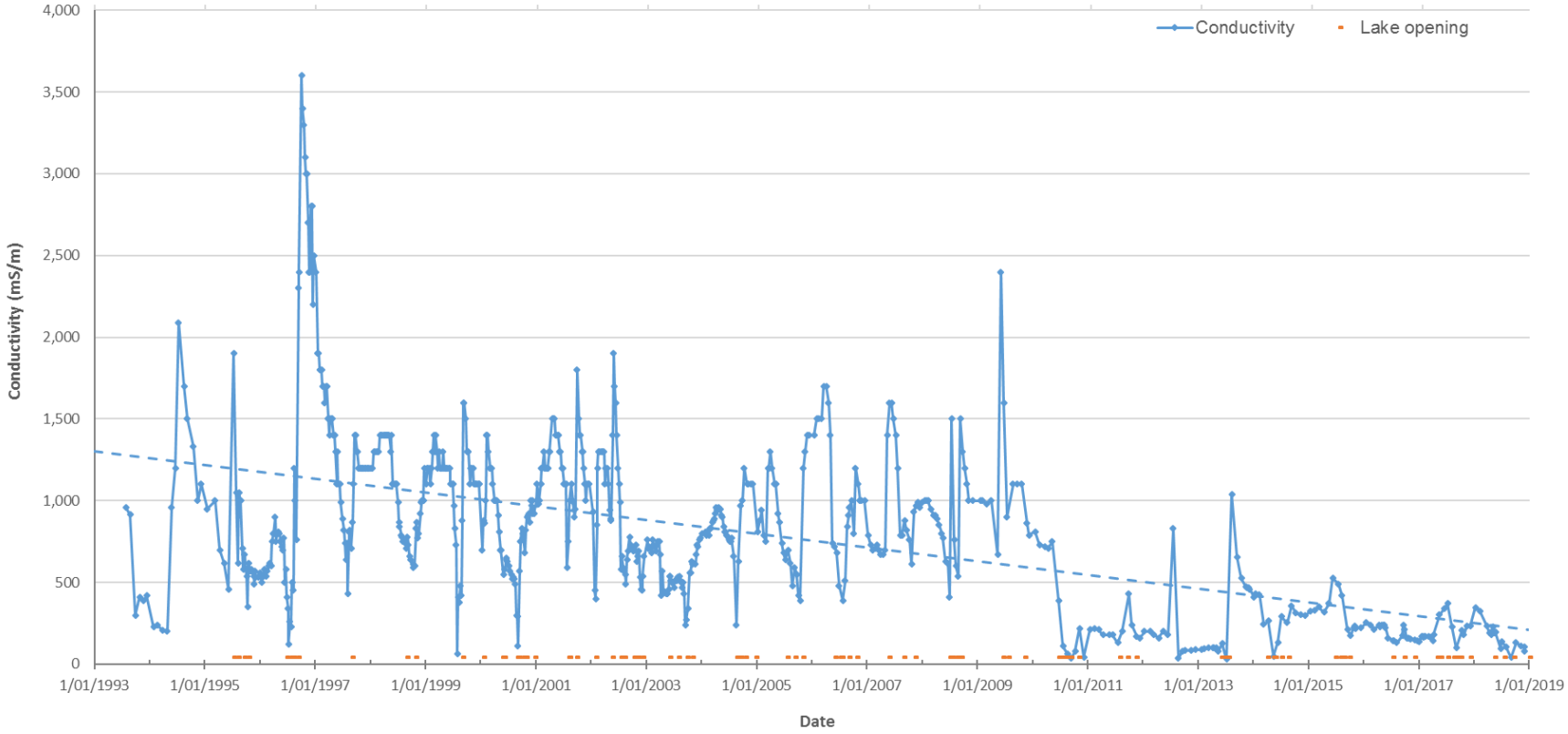

Figure 2. Conductivity of water at Wairewa/Lake Forsyth at the ECan Water Level Recorder site for the entire dataset (July 1993 - December 2018). The dashed line is a linear trendline.

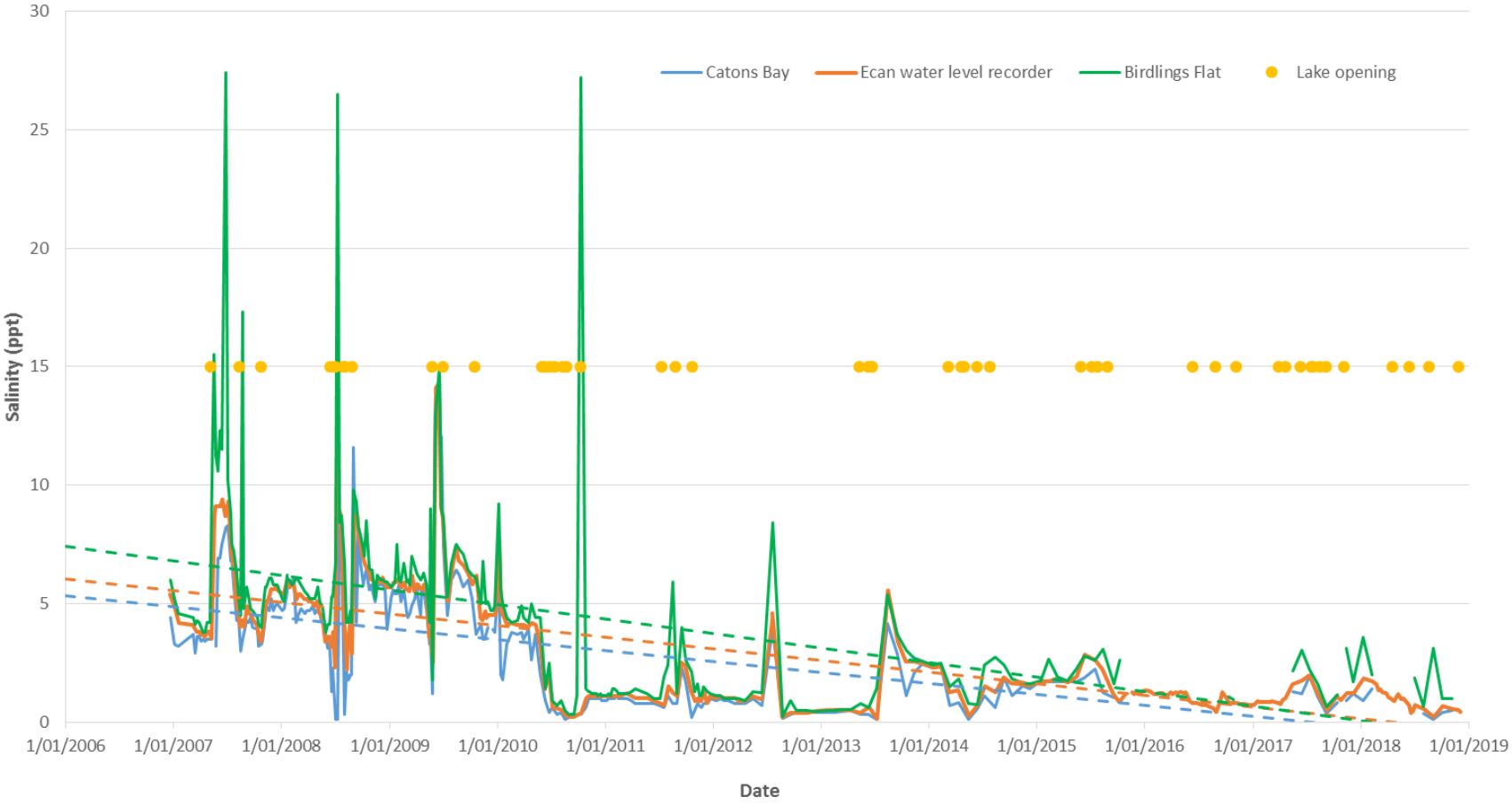

Figure 3. Salinity of water at Wairewa/Lake Forsyth at three sites (ECan Water Level Recorder, Catons Bay and Birdlings Flat) from the entire dataset (December 2006 - December 2018). The dashed lines are linear trendlines.

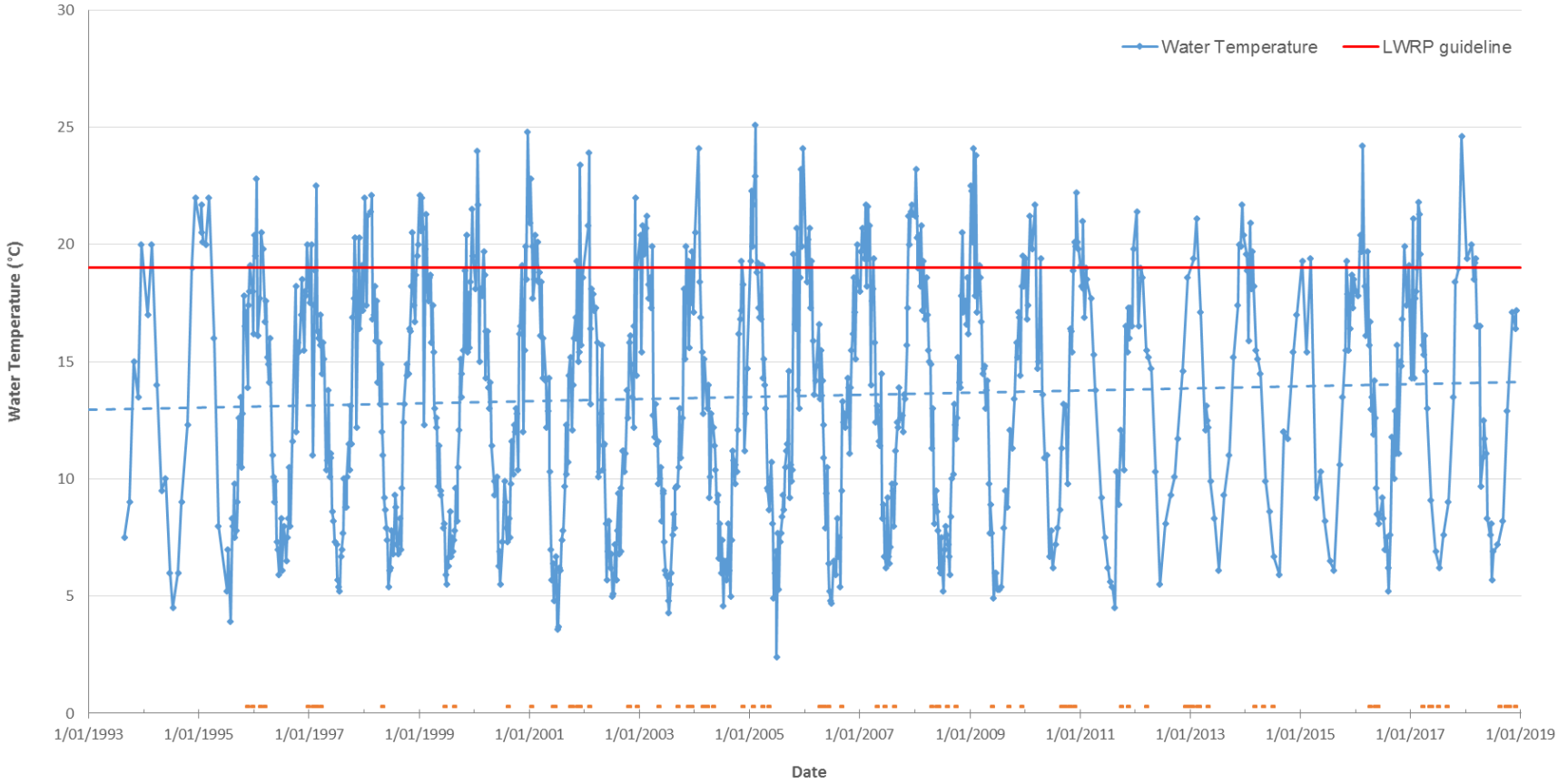

Figure 4. Water Temperature at Wairewa/Lake Forsyth at the ECan Water Level Recorder site for the entire dataset (August 1993 - December 2018). The dashed line is a linear trendline. Red line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (19°C).

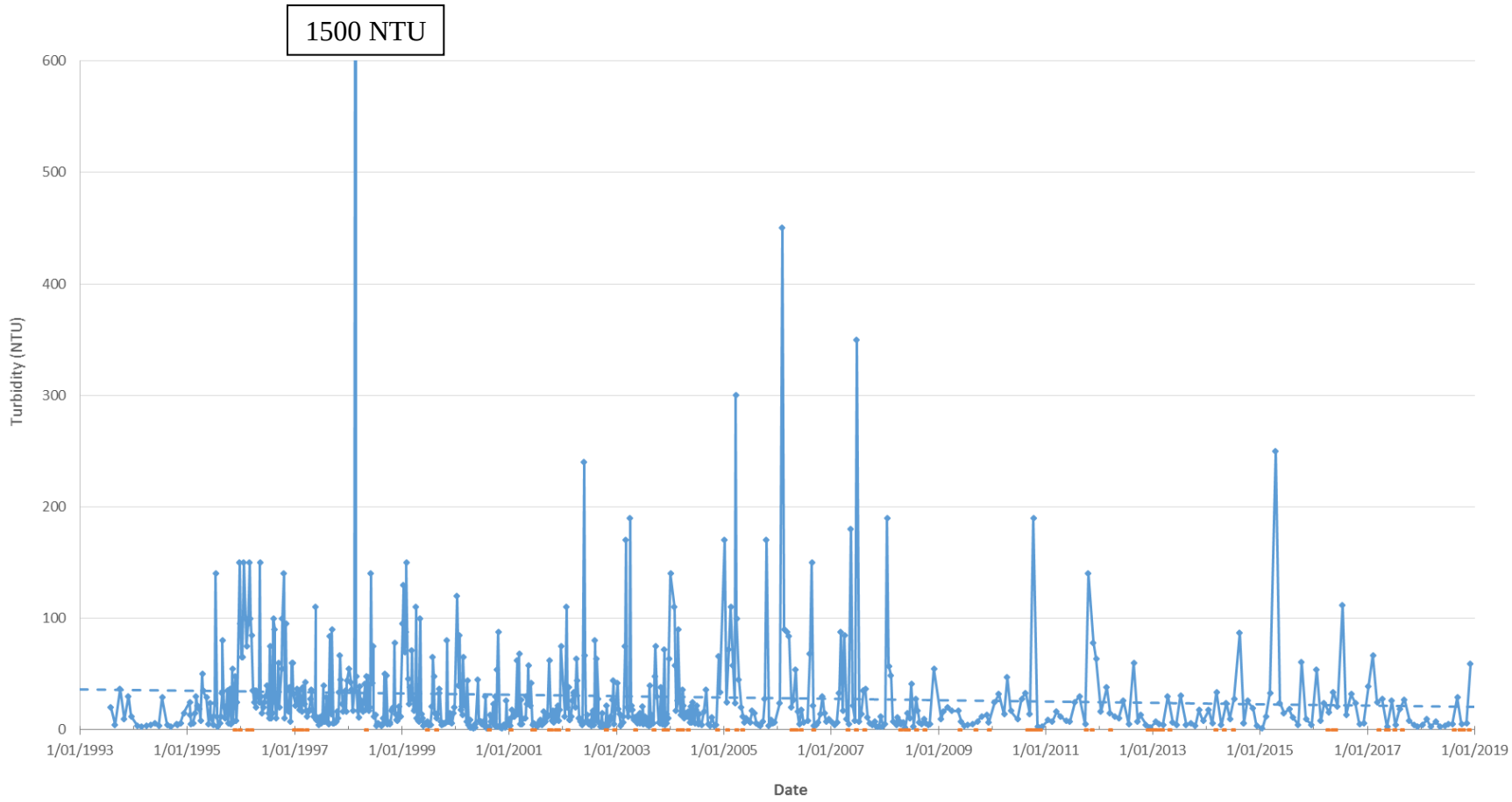

Figure 5. Turbidity of water at Wairewa/Lake Forsyth at the water level recording site for the entire dataset (July 1993 - December 2018). The dashed line is a linear trendline. One data point is significantly higher than the other data points and is therefore off the scale of the graph – the text box details the concentration of this sample.

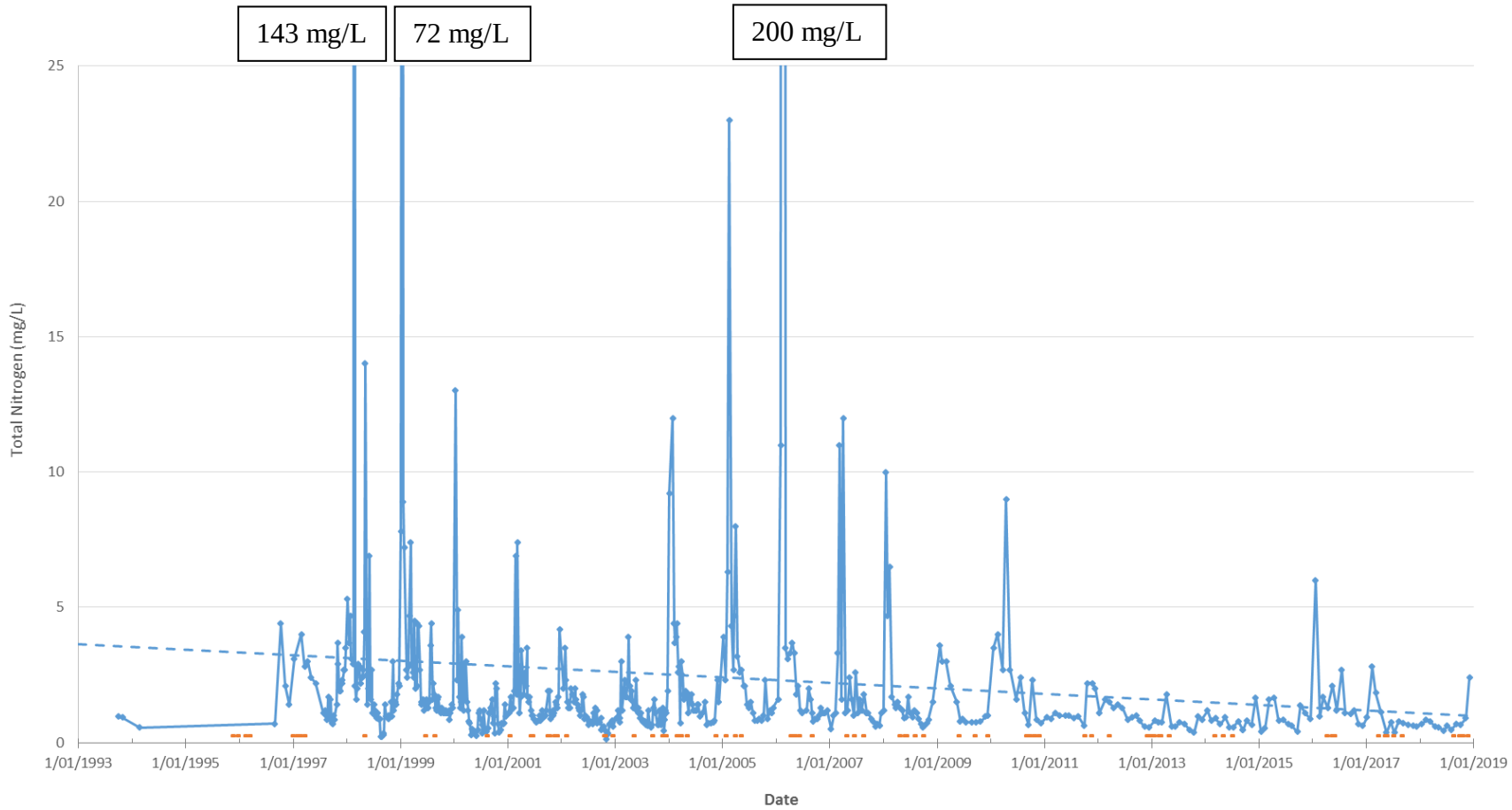

Figure 6. Total Nitrogen at Wairewa/Lake Forsyth at the ECan Water Level Recorder site for the entire dataset (July 1993 – December 2018). The dashed line is a linear trendline. Three data points are significantly higher than the other data points and are therefore off the scale of the graph – the text boxes detail their concentrations.

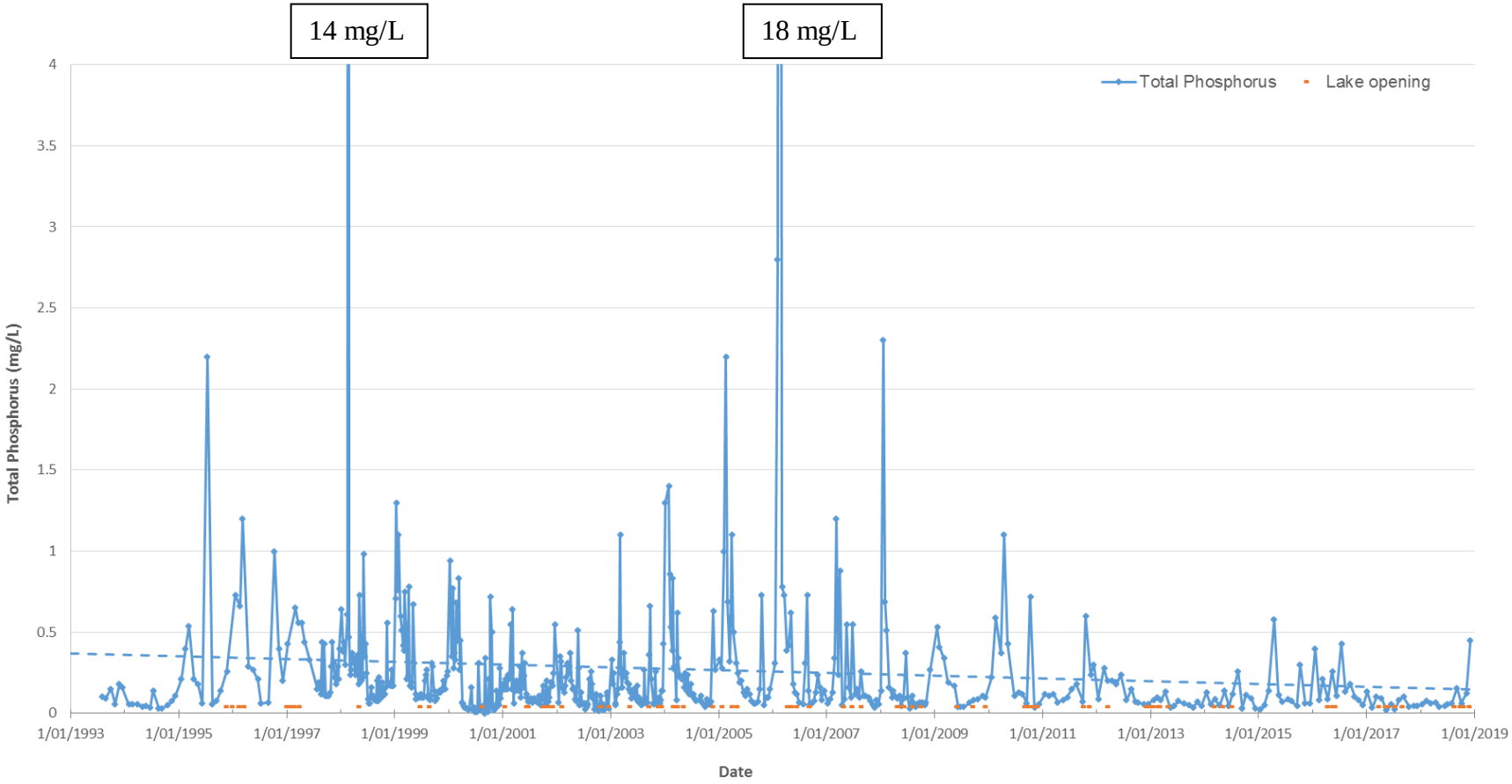

Figure 7. Total phosphorus at Wairewa/Lake Forsyth at the ECan Water Level Recorder site for the entire dataset (July 1993 – December 2018). The dashed line is a linear trendline. Two data points are significantly higher than the other data points and are therefore off the scale of the graph – the text boxes detail their concentrations.

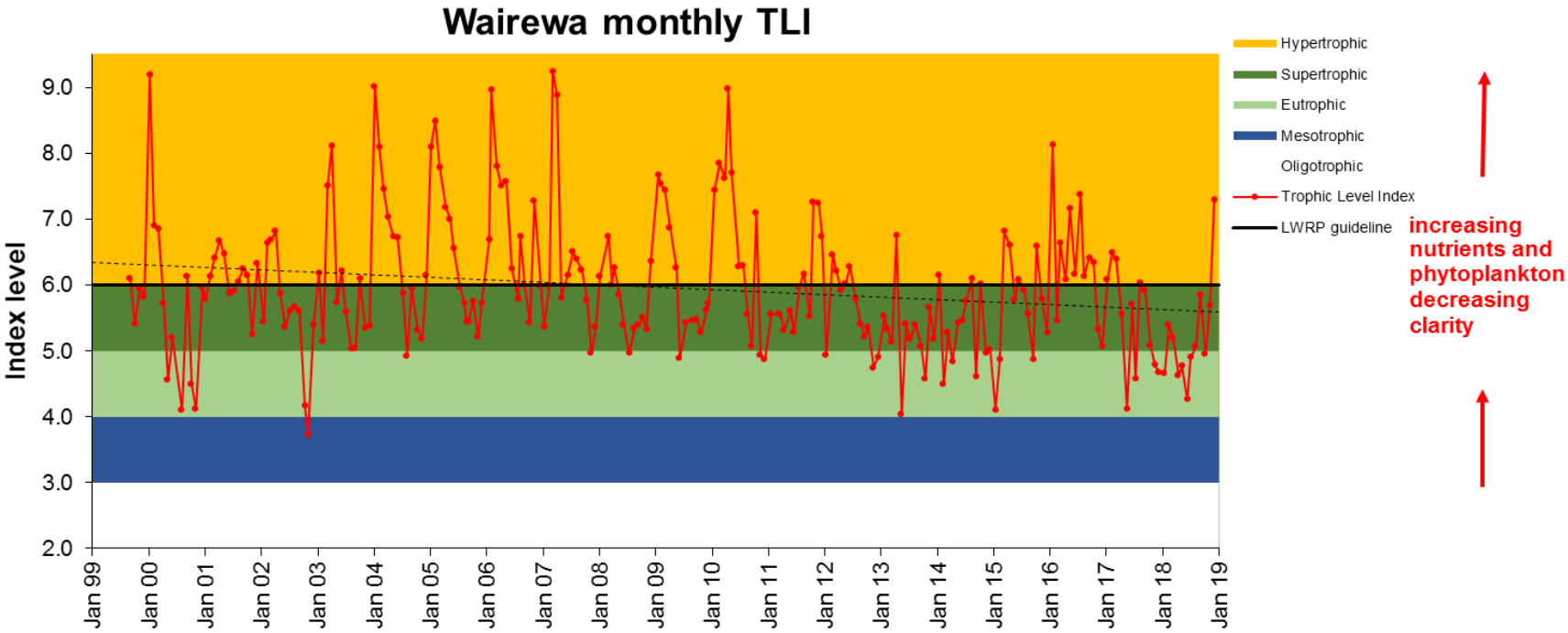

Figure 8a. Trophic Level Index (TLI) at Wairewa/Lake Forsyth at the ECan Water Level Recorder site for the entire dataset (September 1999 – December 2018). The dashed line is a linear trendline. Solid black line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (6). Graph modified from Environment Canterbury versions.

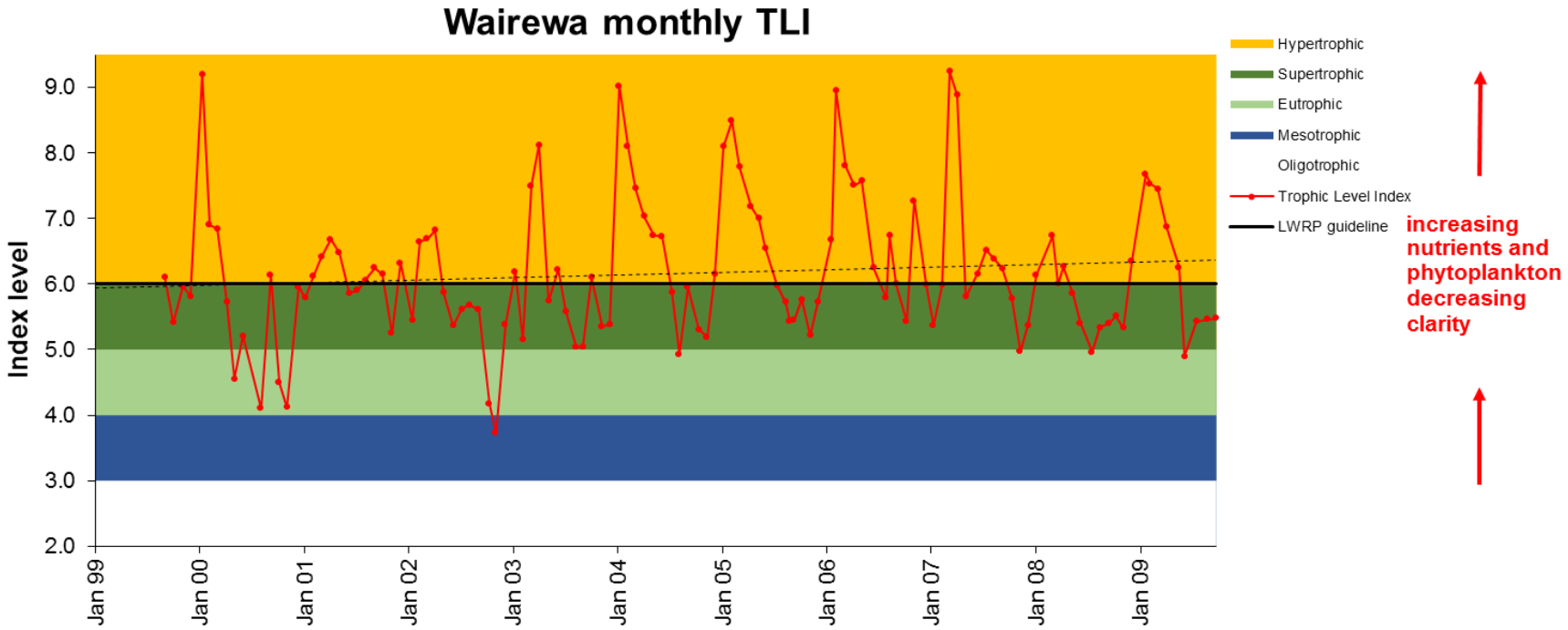

Figure 8b. Trophic Level Index (TLI) at Wairewa/Lake Forsyth at the ECan Water Level Recorder site prior to the construction of the canal opening (September 1999 –September 2009). The dashed line is a linear trendline. Solid black line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (6). Graph modified from Environment Canterbury versions.

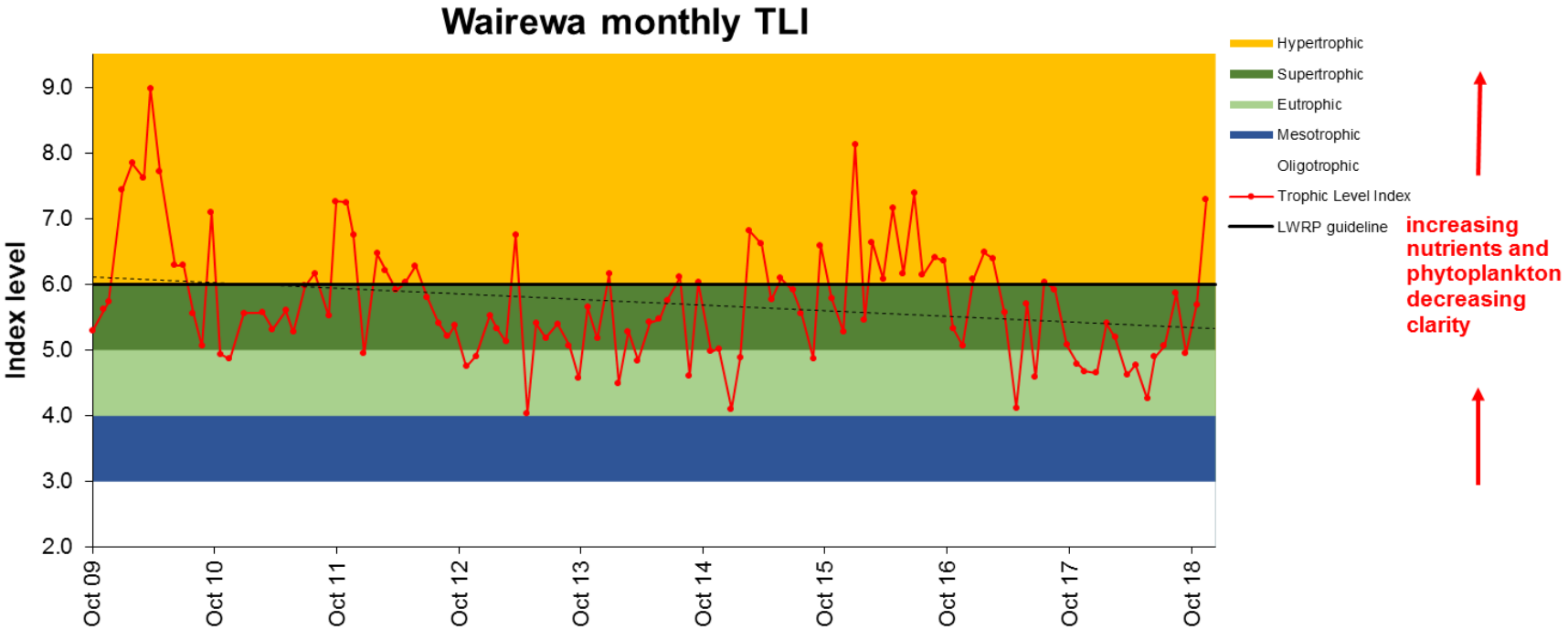

Figure 8c. Trophic Level Index (TLI) at Wairewa/Lake Forsyth at the ECan Water Level Recorder site after the construction of the canal opening (October 2009– December 2018). The dashed line is a linear trendline. Solid black line = Land and Water Regional Plan (LWRP) guideline for coastal lakes (6). Graph modified from Environment Canterbury versions.

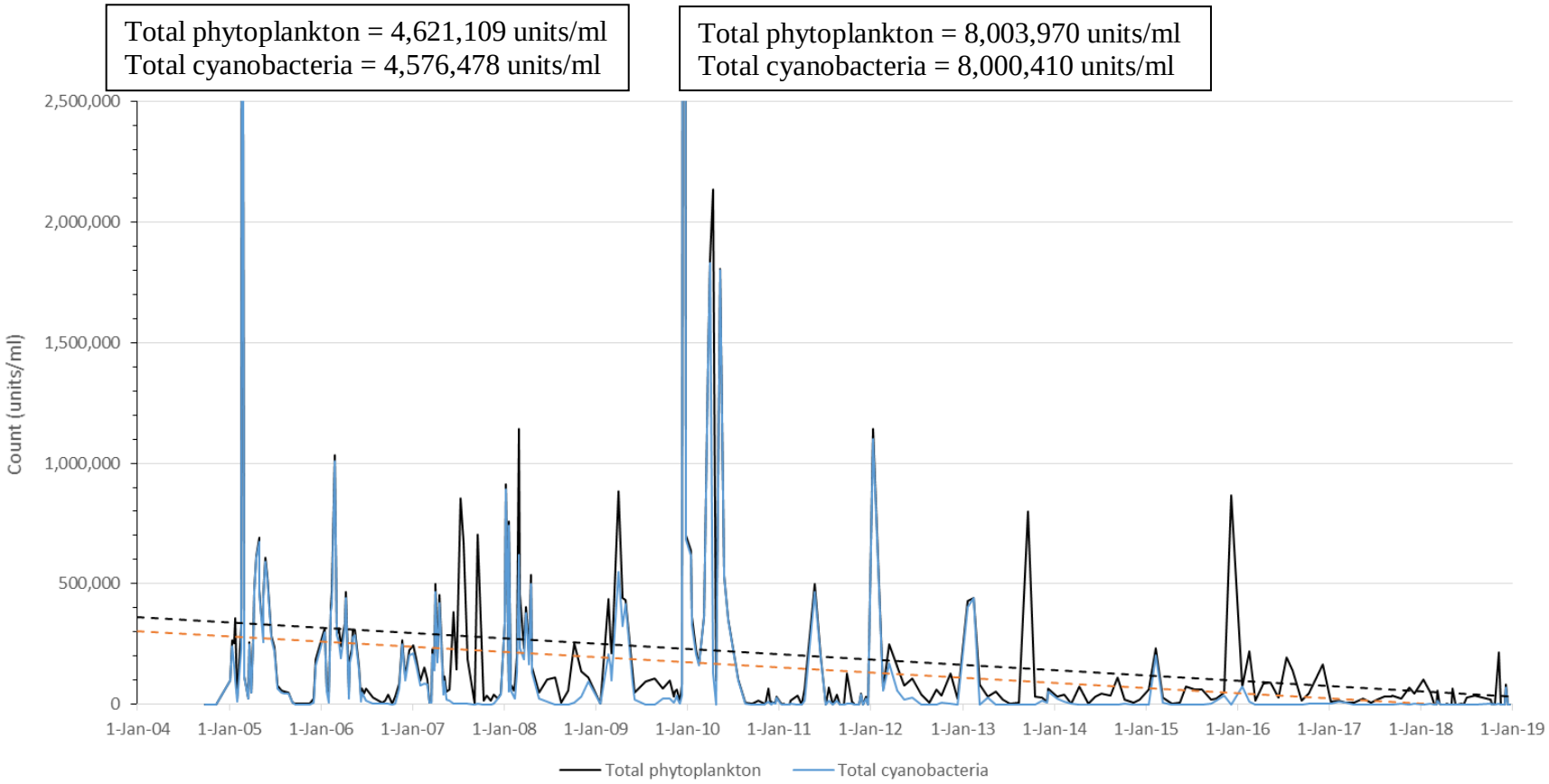

Figure 9. Total phytoplankton and cyanobacteria (a subset of phytoplankton) counts at Wairewa/Lake Forsyth at the ECan Water Level Recorder site from September 2004 to December 2018. The dashed lines are linear trendlines. Two data points are significantly higher than the other data points and are therefore off the scale of the graph – the text boxes detail their concentrations.

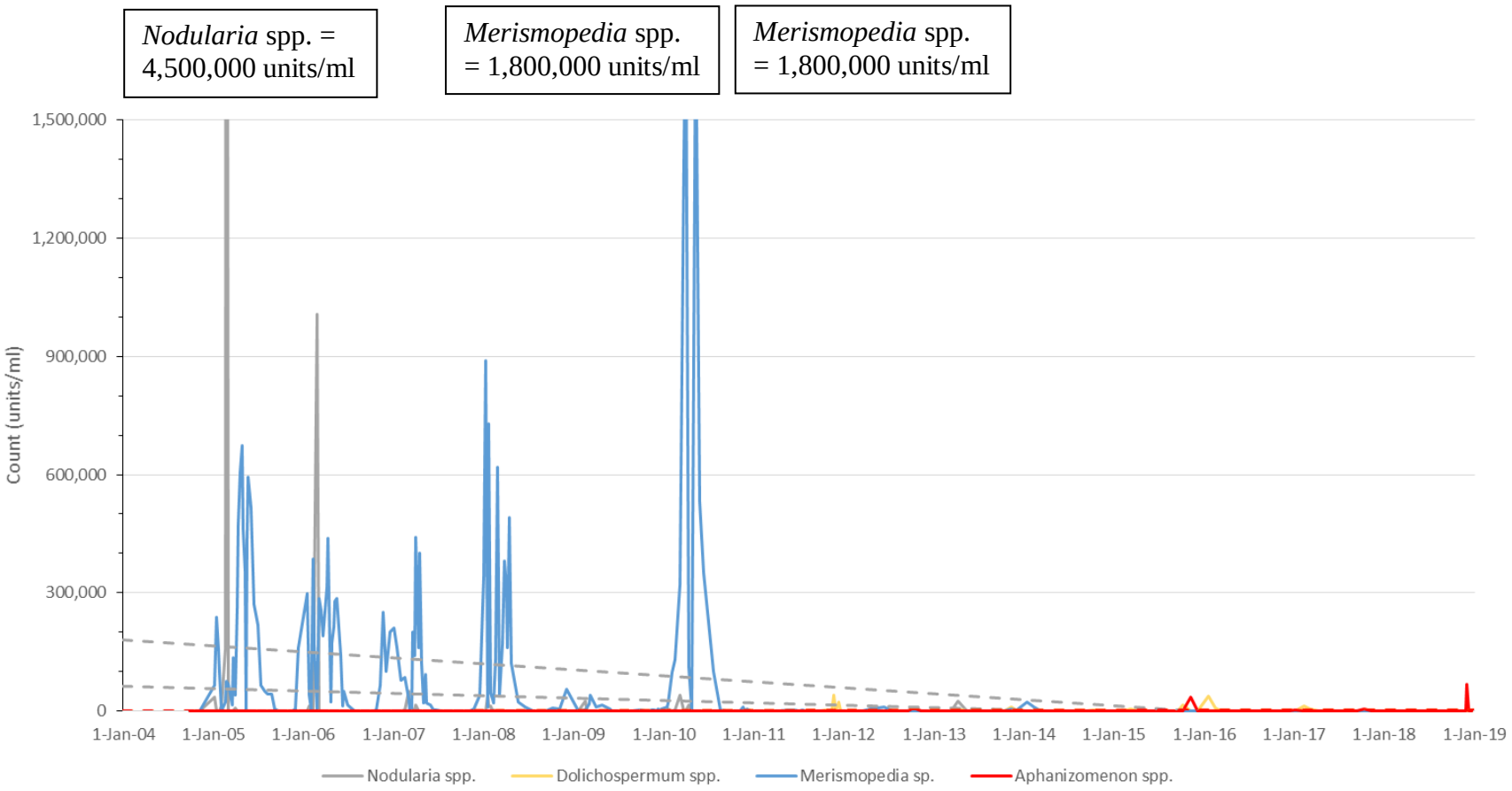

Figure 10. Counts at Wairewa/Lake Forsyth at the ECan Water Level Recorder site for the potentially toxic cyanobacteria *Nodularia* spp., *Dolichospermum* spp., *Merismopedia* spp. and *Aphanizomenon* spp. from September 2004 to December 2018. The dashed lines are linear trendlines. Three data points are significantly higher than the other data points and are therefore off the scale of the graph – the text boxes detail their concentrations.

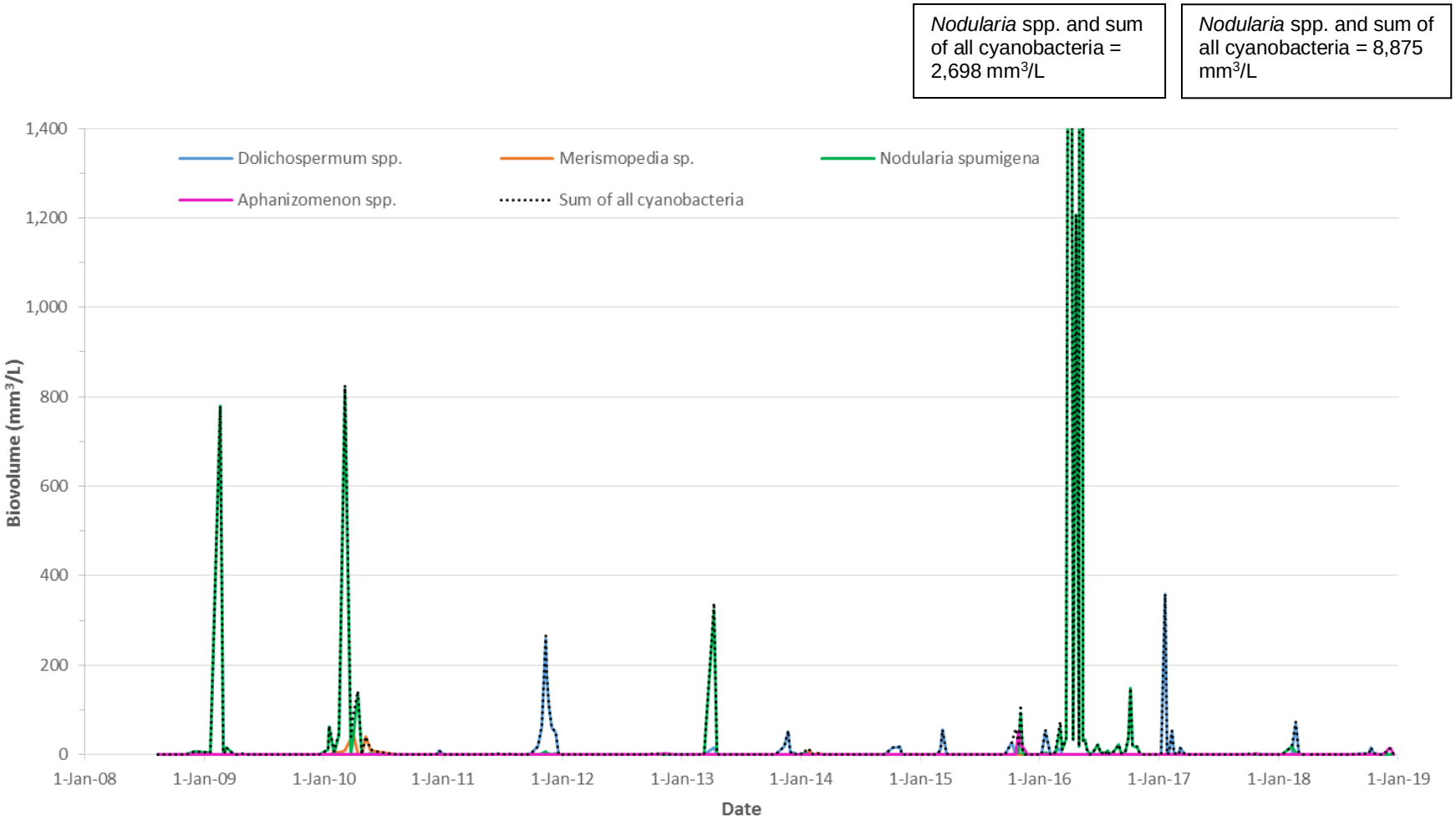

Figure 11. Biovolumes of potentially toxic cyanobacteria *Nodularia spumigena*, *Dolichospermum* spp., *Merismopedia* spp., *Aphanizomenon* spp. and the sum of all cyanobacteria at Wairewa/Lake Forsyth at the ECan Water Level Recorder site from August 2008 – December 2018. Two data points are significantly higher than the other data points and are therefore off the scale of the graph – the text boxes detail their concentrations.

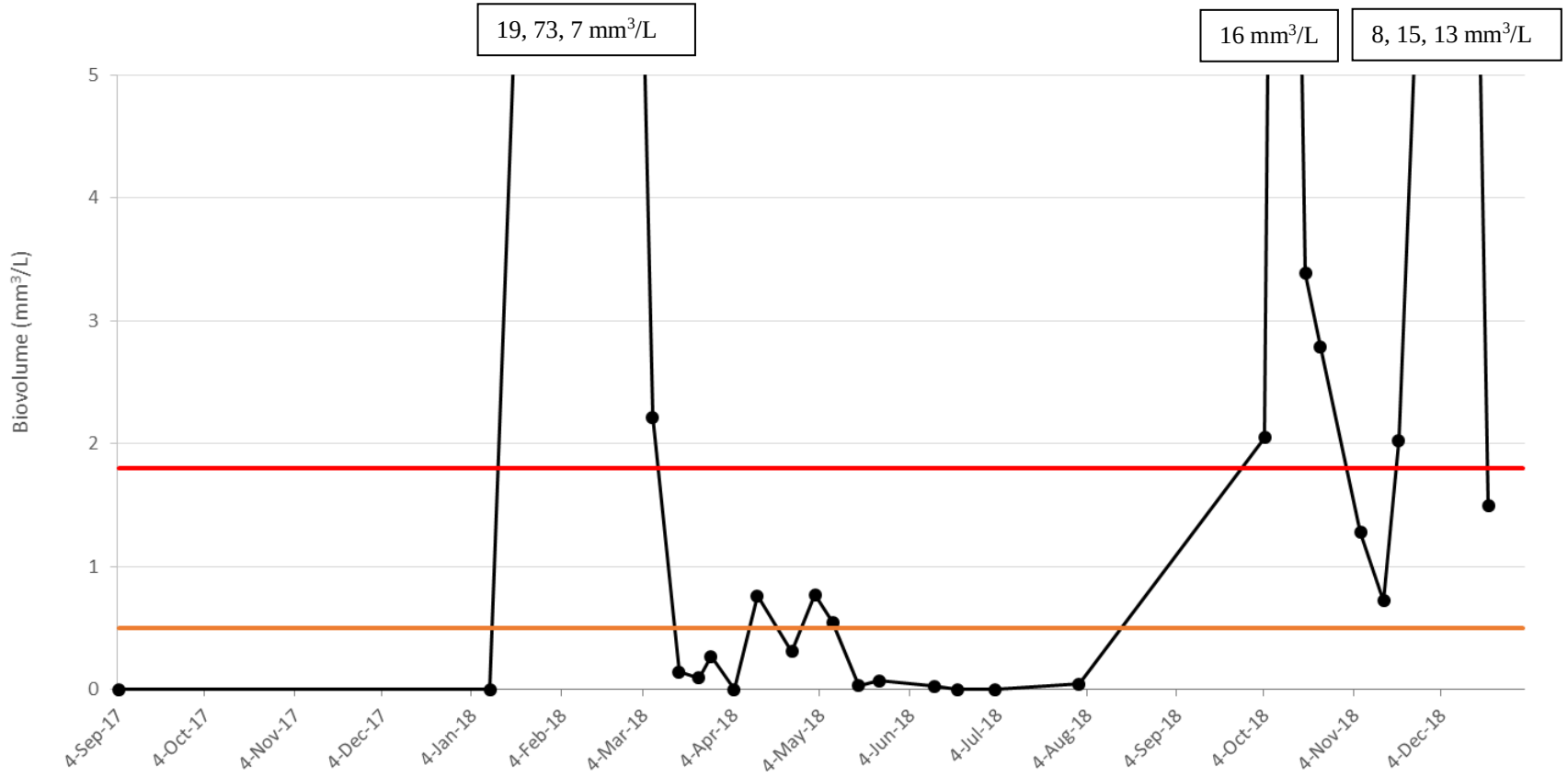

Figure 12a. Biovolume of the sum of all potentially toxic cyanobacteria (*Nodularia spumigena, Dolichospermum* spp., *Merismopedia* spp., and *Aphanizomenon* spp.) at the ECan Water Level Recorder monitoring site in 2018. Orange line = alert guideline level of 0.5 mm^3/L; red line = action guideline level of 1.8 mm^3/L (Ministry for the Environment and Ministry of Health, 2009).

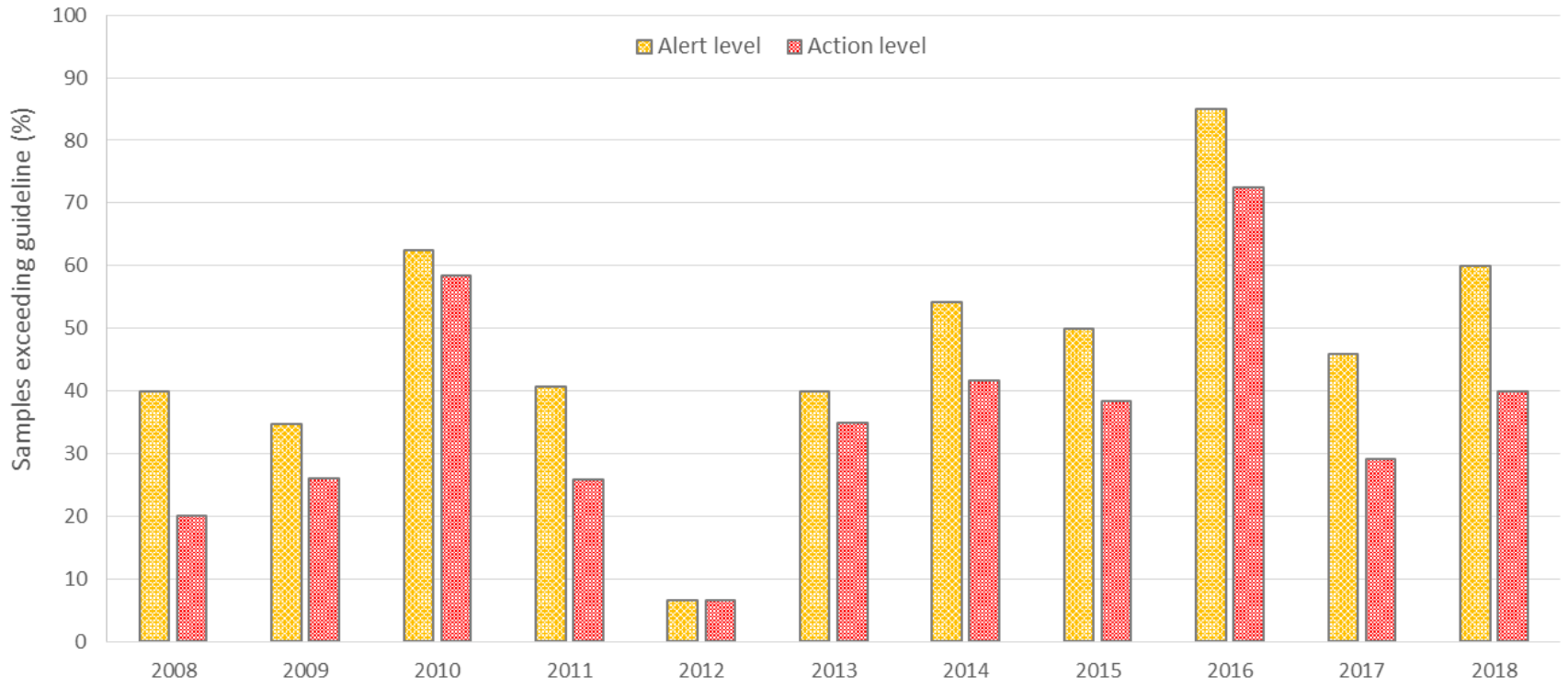

Figure 12b. Number of samples of potentially toxic cyanobacteria (*Nodularia spumigena, Dolichospermum* spp., *Merismopedia* spp., and *Aphanizomenon* spp.) that exceeded either the alert (0.5 mm^3/L) or action (1.8 mm^3/L) level at the ECan Water Level Recorder site from 2008- 2018 (Ministry for the Environment and Ministry of Health, 2009).

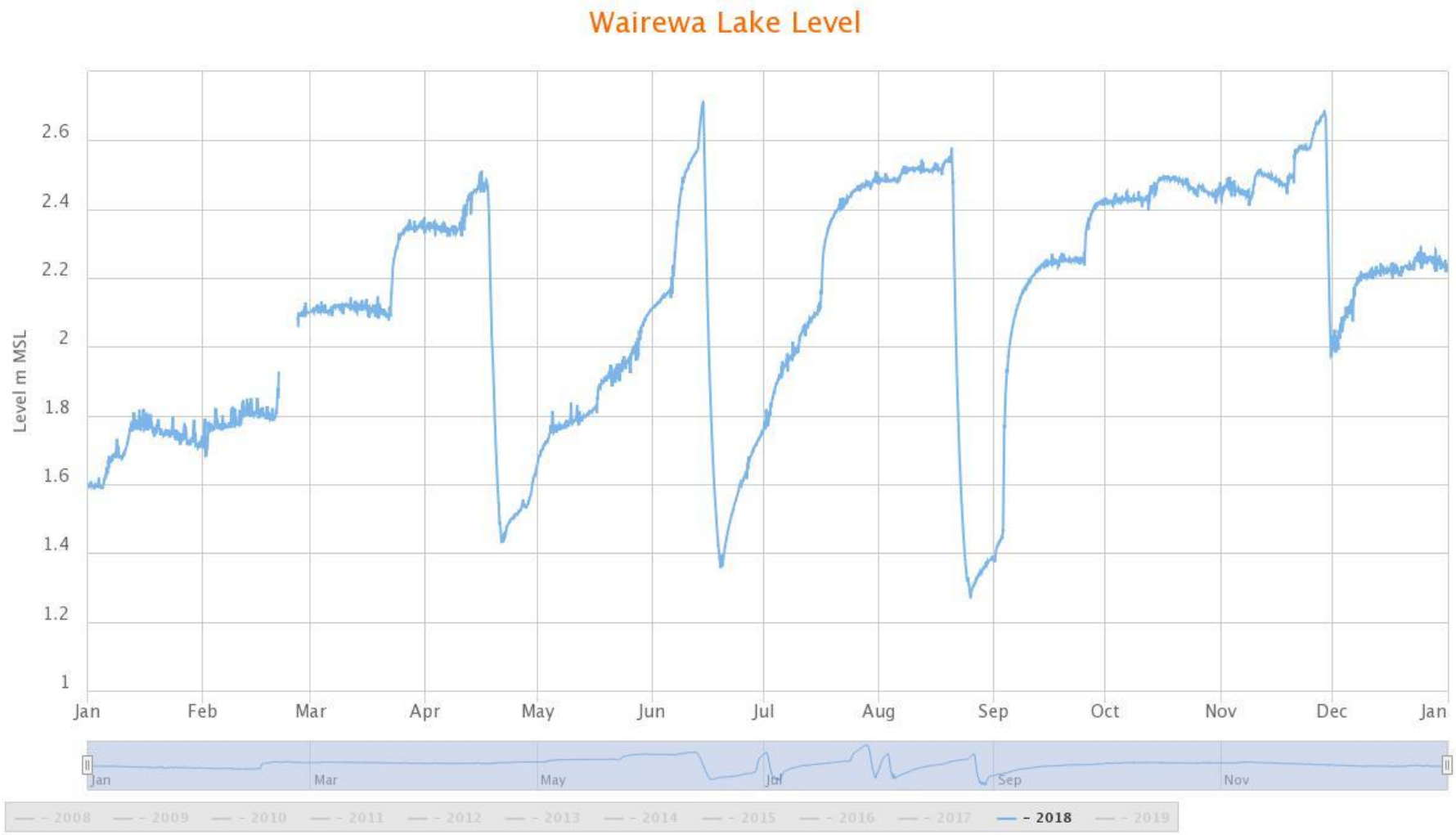

Figure 13. Water level in Lake Forsyth/Te Wairewa. Sharp drops in water level indicate when the lake was opened.