Technical Memorandum
Draft Baseline State for Taranaki Lakes (Trophic State)

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Purpose

The purpose of this memorandum is to provide an assessment of the baseline state of five attributes related to trophic state as a measure of the ecosystem health of lakes, as required by the National Policy Statement for Freshwater Management 2020 (NPS-FM). Attributes include: total nitrogen, ammonia (toxicity), total phosphorus, dissolved oxygen and phytoplankton (measured as chlorophyll-*a*).

Overview of lake trophic state

Lake trophic state is a common way of describing lake water quality. Trophic state is the product of a range correlated factors, including nutrients, algal growth and dissolved oxygen concentrations. When nutrient concentrations exceed natural levels, this can result in increased algal and macrophyte growth, which can potentially result in low dissolved oxygen conditions. These factors are described below.

Total nitrogen

Nitrogen is an essential nutrient for plant and algal growth, however elevated levels contribute to excessive growth and can cause negative ecological effects. Total nitrogen is the sum of all forms of nitrogen. Nitrogen can be present in water in a number of forms (nitrate, nitrite, ammoniacal nitrogen and organic nitrogen). The most common sources of nitrogen include leaching and run-off from agriculture and horticulture or from industrial or wastewater discharges.

Ammonia (toxicity)

Ammoniacal nitrogen (NH_4-N), also called 'ammonium', is the concentration of nitrogen present as either ammonia (NH_3) or ammonium (NH4) in water. The balance between ammonia and ammonium depends on the pH and temperature of the water. Ammoniacal forms of nitrogen enter waterways such as lakes primarily through point source discharges, such as raw sewage or dairy shed effluent. At high concentrations, ammonia and nitrate can be toxic for aquatic life.

Total phosphorus

Total phosphorus is a measure of all forms of phosphorus in the water, including dissolved and particulate, organic and inorganic. Phosphorus is naturally present in water in low concentrations. Like nitrogen, phosphorus is essential for plant growth, however an excess of phosphorus can encourage the nuisance growth of algae and macrophytes and be degrading to ecosystems. Phosphorus is naturally elevated in our region's soils due to the volcanic geology, however fertiliser application along with the discharge of domestic and animal waste also contribute to elevated levels of phosphorus in freshwater. Much of the phosphorus in lakes is a legacy of erosion caused by land development activities such as native vegetation clearance and fertiliser application.

Dissolved oxygen

Dissolved oxygen is critical to all aquatic life within a lake ecosystem. The unit of measure for dissolved oxygen in the context of this attribute is mg/L (milligrams per litre). Oxygen is able to enter water by diffusion from the atmosphere, aeration of the water through surface turbulence and as a product of photosynthesis. The oxygen content of water will decrease as nutrients and organic materials increase. Sources of nutrients and organic material include industrial wastewater, sewage discharges, and runoff from land. Excessive plant and algae growth and decomposition in response to increasing nutrients in waterways can significantly affect the amount of dissolved oxygen available (Goodwin & Young, 2022).

Phytoplankton

Phytoplankton are microscopic algae and cyanobacteria that drift or float in the water column and are able to produce oxygen through photosynthesis. All phytoplankton contain chlorophyll-*a* (chl-*a*) and a measure of this pigment can be used to assess the amount of algae in a lake, measured as phytoplankton biomass.

The amount of phytoplankton in a lake is often closely linked with the amount of nutrient enrichment and biological productivity of a lake ecosystem (referred to as the trophic state). Together with measurements of total nitrogen, total phosphorus and water clarity, phytoplankton can be used to calculate the trophic lake index score, which provides an indication of overall lake water quality.

Lake trophic state and the National Objectives Framework

The NPS-FM sets out requirements for Councils and communities to maintain or improve freshwater (where it is degraded). The NPS-FM provides a National Objectives Framework (NOF) that specifies nationally applicable standards for freshwater parameters (referred to as 'attributes') for both rivers and lakes. Improvement must be made where the current state of any attribute fails to achieve the national bottom line, or where it fails to achieve a target state identified by councils in consultation with tangata whenua and the community.

Total nitrogen

Total nitrogen is measured as mg/m^3 (milligrams per cubic metre) as shown in Table 1. It includes annual median numeric attribute states established for both seasonally stratified/brackish lakes and polymictic lakes. The total nitrogen (trophic state) attribute table includes a national bottom line: a maximum acceptable standard of 750 mg/m^3 for seasonally stratified/brackish lakes and 800 mg/m^3 for polymictic lakes. The NPS-FM requires councils to set appropriate concentrations, loads and exceedance criteria to achieve a target attribute state for any nutrient attribute (Ministry for the Environment, 2020).

Table 1: NOF Attribute – Total nitrogen (trophic state). Source: MfE, 2020.

Value (and component)	Ecosystem health (Water quality)	
Freshwater body type	Lakes	
Attribute unit	mg/m3 (milligrams per cubic metre)	
Attribute band and description	**Numeric attribute states**	
	Annual median	**Annual maximum**
	Seasonally stratified and brackish	Polymictic
A Lake ecological communities are healthy and resilient, similar to natural reference conditions.	≤160	≤300
B Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.	>160 and ≤350	>300 and ≤500
C Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions.	>350 and ≤750	>500 and ≤800
National bottom line	**750**	**800**
D 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.	>750	>800
For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.		

Ammonia (toxicity)

Ammonia (toxicity) is measured as mg NH_4–N/L (milligrams ammoniacal-nitrogen per litre) as per Table 2. It includes annual median and annual 95th percentile numeric attribute states, which apply to both lakes and rivers. The ammonia (toxicity) attribute table includes a national bottom line: a maximum acceptable standard of 0.24 NH_4–N/L (annual median) and 0.40 NH_4–N/L (annual 95th percentile).

Table 2: NOF Attribute – Ammonia (toxicity). Source: MfE, 2020.

Value (and component)	Ecosystem health (Water quality)	
Freshwater body type	Rivers and Lakes	
Attribute unit	mg NH4-N/L (milligrams ammoniacal-nitrogen per litre)	
Attribute band and description	**Numeric attribute states**	
	Annual median	**Annual 95th percentile**
A 99% species protection level: No observed effect on any species tested.	≤0.03	≤0.05

Value (and component)	Ecosystem health (Water quality)	
Freshwater body type	Rivers and Lakes	
Attribute unit	mg NH4-N/L (milligrams ammoniacal-nitrogen per litre)	
Attribute band and description	**Numeric attribute states**	
B 95% species protection level: Starts impacting occasionally on the 5% most sensitive species.	>0.03 and ≤0.24	>0.05 and ≤0.40
National bottom line	**0.24**	**0.40**
C 80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).	>0.24 and ≤1.30	>0.40 and ≤2.20
D Starts approaching acute impact level (that is, risk of death) for sensitive species.	>1.30	>2.20
Numeric attribute state is based on pH 8 and temperature of 20°C. Compliance with the numeric attribute states should be undertaken after pH adjustment.		

Total phosphorus (tropic state)

The attribute table for total phosphorus (trophic state) is presented in Table 3. Total phosphorus is measured as mg/m^3 (milligrams per cubic meter). The attribute table includes annual median numeric attribute states, and includes a national bottom line: a maximum acceptable standard of 12 mg/m^3.

Table 3: NOF Attribute – Total phosphorus (trophic state). Source: MfE, 2020.

Value (and component)	Ecosystem health (Water quality)
Freshwater body type	Lakes
Attribute unit	mg/m^3 (milligrams per cubic metre)
Attribute band and description	**Numeric attribute state**
	Annual median
A Lake ecological communities are healthy and resilient, similar to natural reference conditions.	≤10
B Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions.	>10 and ≤20
C Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions.	>20 and ≤50
National bottom line	**12**
D 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.	>12

Value (and component)	Ecosystem health (Water quality)
Freshwater body type	Lakes
Attribute unit	mg/m^3 (milligrams per cubic metre)
Attribute band and description	**Numeric attribute state**
For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.	

Dissolved oxygen

The attribute tables for lake-bottom dissolved oxygen, and mid-hypolimnetic dissolved oxygen are presented in Table 4 and Table 5. Dissolved oxygen is measured as mg/L (milligrams per litre). Both attribute tables include measured or estimated annual minimum numeric attribute states, however the mid-hypolimnetic dissolved oxygen attribute table is relevant to seasonally stratified lakes only. The lake-bottom dissolved oxygen attribute table includes a national bottom line: a measured or estimated annual minimum of 0.5 mg/L. For the mid-hypolimnetic attribute the national bottom line is 4.0 mg/L.

Table 4: NOF Attribute – Lake-bottom dissolved oxygen. Source: MfE, 2020.

Value (and component)	Ecosystem health (Water quality)
Freshwater body type	Lakes
Attribute unit	mg/L (milligrams per litre)
Attribute band and description	**Numeric attribute state**
	Measured or estimated annual minimum
A No risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.	≥7.5
B Minimal risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.	≥2.0 and <7.5
C Risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.	≥0.5 and <2.0
National bottom line	**0.5**
D Likelihood from lake-bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments.	<0.5
To be measured less than 1 metre above sediment surface at the deepest part of the lake using either continuous monitoring sensors or discrete dissolved oxygen profiles.	

Table 5: NOF Attribute – Mid-hypolimnetic dissolved oxygen. Source: MfE, 2020.

Value (and component)	Ecosystem health (Water quality)
Freshwater body type	Seasonally stratifying lakes
Attribute unit	mg/L (milligrams per litre)
Attribute band and description	**Numeric attribute state**
	Measured or estimated annual minimum
A	≥7.5

Value (and component)	Ecosystem health (Water quality)
Freshwater body type	Seasonally stratifying lakes
Attribute unit	mg/L (milligrams per litre)
Attribute band and description	**Numeric attribute state**
No stress caused to any fish species by low dissolved oxygen	
B Minor stress on sensitive fish seeking thermal refuge in the hypolimnion. Minor risk of reduced abundance of sensitive fish and macro-invertebrate species.	≥5.0 and <7.5
C Moderate stress on sensitive fish seeking thermal refuge in the hypolimnion. Risk of sensitive fish species being lost.	≥4.0 and <5.0
National bottom line	**4.0**
Significant stress on a range of fish species seeking thermal refuge in the hypolimnion. Likelihood of local extinctions of fish species and loss of ecological integrity.	<4.0
To be measured using either continuous monitoring sensors or discrete dissolved oxygen profiles.	

Phytoplankton

Phytoplankton (trophic state) is measured as chl-*a*/ m^3. It includes numeric attribute states established for both annual median (as a measure of general lake health) and annual maximum (as a measure for the occurrence of large blooms). The phytoplankton (trophic state) attribute table (Table 6) includes a national bottom line for both measures: a minimum acceptable standard of 12 mg chl-*a*/ m^3 for the annual median; and an annual maximum value of 60 mg chl-*a*/ m^3.

Table 6: NOF Attribute – Phytoplankton (trophic state). Source: MfE, 2020.

Value (and component)	Ecosystem health (Aquatic life)	
Freshwater body type	Lakes	
Attribute unit	mg chl-*a*/ m^3 (milligrams chlorophyll-a per cubic metre)	
Attribute band and description	**Numeric attribute states**	
	Annual median	Annual maximum
A Lake ecological communities are healthy and resilient, similar to natural reference conditions.	≤2	≤10
B Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.	>2 and ≤5	>10 and ≤25
C 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.	>5 and ≤12	>25 and ≤60
National bottom line	**12**	**60**

Value (and component)	Ecosystem health (Aquatic life)	
Freshwater body type	Lakes	
Attribute unit	mg chl-*a*/ m^3 (milligrams chlorophyll-a per cubic metre)	
Attribute band and description	**Numeric attribute states**	
D 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.	>12	>60
For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.		

Lake monitoring in the Taranaki region

Prior to 2022, lake monitoring undertaken by the Taranaki Regional Council largely focused on a single lake, Lake Rotorangi. Lake Rotorangi is an artificial lake used for hydroelectric generation and monitoring has been undertaken primarily for the purpose of compliance with resource consents associated with the hydroscheme. Monitoring began in 1988 and included both water quality and biological monitoring. Presently, water quality surveys are conducted four times a year at two established sites. Physicochemical parameters are measured at the surface of the lake, as well as at depths corresponding to the epilimnion and hypolimnion. Biological sampling is also carried out at varying frequencies, including phytoplankton, macrophyte and macroinvertebrate sampling.

To better understand the current state of lake health in Taranaki, monthly monitoring of six lakes recently commenced in May 2023. This monitoring forms part of a new State of the Environment (SoE) regional lakes monitoring programme, and seeks to align with requirements of the NPS-FM. The six lakes that have been chosen are all naturally formed lakes, greater than one hectare in area. The regional lakes monitoring programme involves the collection of water samples from a range of depths, at the deepest point in the lake, with the use of kayaks. Sampling methodology is based on the National Environmental Monitoring Standards (NEMS) Water Quality Guidelines (Part 3 of 4). Physicochemical parameters are assessed at each lake to provide data to assess against the requirements of the NPS-FM.

Further lake monitoring is carried out as part of the Can I Swim Here? Programme (CISH). Planktonic cyanobacteria have been monitored at four lakes (Lake Ratapiko, Lake Opunake, Lake Rotomanu and Lake Rotokare) since the 2006-2007 monitoring period, as part of CISH. Recently, the number of lakes surveyed in relation to this programme has increased to seven to include Lake Rotokare, Lake Herengawe and Lake Rotorangi. Fortnightly sampling is carried out annually between November and April, with sample collection based on *The New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters* (MfE and MoH, 2009). All samples are processed in-house using methods outlined in Procedure 051 "Processing and analysing planktonic cyanobacteria." The baseline assessment of this attribute is provided in a separate memorandum.

Table 7 sets out all lakes currently monitored by TRC, their locations and frequency of monitoring. Lakes selected for inclusion in the SoE regional lakes monitoring programme will be discussed in following sections of this memorandum and will be assessed for draft baseline state. In summary, the number of lakes surveyed in the SoE regional lakes monitoring programme in each Freshwater Management Unit (FMU) include one lake each in the Volcanic Ringplain and Northern Hill Country FMUs, and two lakes in each of the Southern Hill Country and Coastal Terraces FMUs. No lakes were identified as suitable for inclusion in the SoE regional lakes monitoring programme in either of the Waitara or Pātea FMUs.

Table 7: Monitored lakes in the Taranaki region

Proposed FMU	Lake	Easting	Northing	Programme	Frequency
Southern Hill Country	**Lake Rotokare**	1721453	5631971	SoE regional lakes monitoring programme and CISH	Monthly & November-April
	Lake Waikare	1754873	5607388	SoE regional lakes monitoring programme	Monthly
Coastal Terraces	**Lake Herengawe**	1740432	5593938	SoE regional lakes monitoring programme and CISH	Monthly & November-April
	Lake Kaikura	1720486	5604553	SoE regional lakes monitoring programme	Monthly
Pātea	**Lake Rotorangi**	1735037	5621609	Lake Rotorangi SoE monitoring programme and CISH	Quarterly & November-April
Volcanic Ringplain	**Barrett Lagoon**	1690018	5672617	SoE regional lakes monitoring programme	Monthly
	Lake Opunake	1674029	5632022	CISH	November-April
	Lake Rotomanu	1696309	5678128	CISH	November-April
Waitara	**Lake Ngangana**	1707622	5681333	CISH	November-April
	Lake Ratapiko	1714913	5659488	CISH	November-April
Northern Hill Country	**Lake Rotokawau**	1748508	5692929	SoE regional lakes monitoring programme	Monthly

Baseline states for lake (trophic state) attributes

The NPS-FM requires all regional councils to identify baseline states for all attributes described in Appendix 2A and 2B of the NPS-FM within each Freshwater Management Unit (FMU). When compared against national bottom lines and the relevant objectives for an FMU, baselines provide the reference point from which councils must either maintain or improve an attribute, which in turn will contribute toward achieving freshwater objectives for each compulsory and non-compulsory value. Waterbodies must not be allowed to degrade, or remain below an identified baseline state unless that state is determined to be naturally occurring.

Under Clause 1.4 of the NPS-FM, the baseline state, in relation to an attribute, is the best state out of the following:

a) the state of the attribute on the date it is first identified by a regional council under Clause 3.10(1)(b) or (c);

b) the state of the attribute on the date on which a regional council set a freshwater objective for the attribute under the National Policy Statement for Freshwater Management 2014 (as amended in 2017);

c) the state of the attribute on 7 September 2017.

The Council has not previously set freshwater objectives under the NPS-FM 2014 (amended 2017) for any lake attribute, so the state of such attributes under 1.4 (b) could not be calculated, and therefore was not considered here when determining baseline state. Given that no suitable monitoring data was collected prior to 7 September 2017, clause 1.4 (c) was also not considered. Clause 1.4 (a), or the state of the attribute when first identified by the regional council, was the only appropriate option for identifying baseline state for these attributes.

Under Clause 1.6 of the NPS-FM, local authorities must use the best information available at the time (and if practicable, using complete and robust data) to give effect to the NPS-FM. In the absence of complete and robust data, the best information available should be use which may include modelling, partial data, and local knowledge, and preferably use sources that provide the greatest level of certainty (or take all practicable steps necessary to reduce uncertainty).

Under the NPS-FM, total nitrogen, ammonia (toxicity), total phosphorus, lake-bottom dissolved oxygen, mid-hypolimnetic dissolved oxygen and phytoplankton are associated with the 'Ecosystem Health' value, which is a compulsory value within the NOF (NPS-FM, Appendix 1A). Furthermore, phytoplankton, total nitrogen, total phosphorus and ammonia (toxicity) are included as attributes that require limits to be set on resource use (NPS-FM, Appendix 2A). It is necessary for baseline states to be identified by TRC for the Taranaki region to ensure that target attribute states are set at a level that either achieve or exceed the best baseline state for that attribute and (at a minimum) achieve the national bottom line[1].

The remainder of this memo summarises the monitoring and work carried out by TRC to identify baseline states for total nitrogen, ammonia (toxicity), total phosphorus, lake-bottom dissolved oxygen, mid-hypolimnetic dissolved oxygen and phytoplankton.

Criteria for identifying site-based baseline states for attributes in lakes

Draft baseline state attribute grades for total nitrogen, ammonia (toxicity), total phosphorus, lake-bottom and mid-hypolimnetic dissolved oxygen and chlorophyll-*a* have been identified at six lakes in the Taranaki region. These grades correspond to the NOF attribute bands set out in Table 6 (phytoplankton), Table 1 (total nitrogen), Table 3 (total phosphorus), Table 2 (ammonia), Table 4 (lake bottom dissolved oxygen) and Table 5 (mid-hypolimnetic dissolved oxygen) of the NPS-FM, and have been identified using limited data from the regional State of the Environment (SoE) lakes monitoring programme together with modelled data.

Existing monitoring data from the SoE Lake Rotorangi monitoring programme has not been assessed here, as it does not meet the requirements stipulated in the NPS-FM.

The TRC SoE lakes monitoring programme was implemented in May 2023, which provides a limited data set to inform baseline states. However, TRC considers this to be the best available data to inform baseline state. It is also recommended that incomplete/partial data be included in the identification of site-specific baseline states (NPS-FM, Clause 1.6), as the monitoring for these sites will continue on a long-term basis. In the future these sites will have data which will be considered complete and scientifically robust in assessing progress toward target attribute states.

Modelling estimates have been utilised to support this baseline assessment by supplementing the limited available data. Data from two different modelling approaches have been utilised in this baseline assessment.

The Sediment Bacterial Index (SBI) was developed by Cawthron Institute and has been modified for the purposes of developing a regional model for predicting lake water quality attribute state in Taranaki (Schallenburg *et al*. 2023). SBIs were developed to model chlorophyll-*a*, total nitrogen and total phosphorus using data from a highly representative subset of 256 lakes, including eight Taranaki lakes, collected as part of the national Lakes380 research programme. A comparison of measured (using sediment indicator bacteria) and modelled (using lake, catchment, and land-use characteristics) SBI attributes for eight Taranaki lakes showed the two approaches produced similar values (Schallenberg *et al*. 2023).

A national dataset of modelled lake water quality commissioned by MfE and developed by Snelder *et al*. (2022) has also been considered. Snelder *et al*. combined monitored water quality variables with catchment and land-use data to estimate water quality for all lakes in New Zealand, which was subsequently used to

[1] See NPS-FM clauses 3.31, 3.32, and 3.33 for exceptions to this.

make predictions of water quality parameters such as total nitrogen, total phosphorus, ammonia and chlorophyll-*a*. The spatial water quality attribute models were variable in performance however, with the exception of the ammonia criteria, those utilised for this assessment were rated to have satisfactory to very good performance (Snelder *et al*. 2022). Table 8 summarises the performance of the MfE water quality attribute model utilised in this baseline assessment.

Table 8: Performance and ratings of the water quality models from Snelder et al. (2022). Performance ratings are based on Moriasi et al. (2015). N= number of lakes, R^2=coefficient of determination of observation verses predictions, NSE=Nash-Sutcliffe efficiency, PBIAS=percent bias, RMSD= root mean square deviation. Modified from Snelder et al (2022), Schallenberg et al (2023).

Attribute	N	R^2	NSE	PBIAS	RMSD	Rating
Total nitrogen (median)	124	0.78	0.77	3.66	0.23	Very good
Total phosphorus (median)	124	0.62	0.62	0.44	0.35	Good
NH_4-N (median)	80	0.31	0.31	0.74	0.35	Unsatisfactory
NH_4-N (maximum)	80	0.29	0.29	0.71	0.55	Unsatisfactory
Chlorophyll-a (median)	124	0.45	0.45	-0.82	0.41	Satisfactory

Caution is advised when interpreting absolute values estimated for specific locations with spatial water quality models, due to the associated uncertainty. Models such as these are generally more suitable for demonstrating broad scale patterns, and highlighting relative differences between areas of good water quality compared with areas of poor water quality. However, supplementing limited monitoring data with modelled data was determined to be the most robust option available for establishing site-based baseline state, in addition to providing regional estimates for lake attributes. Professional judgement was used when comparing the measured data and modelled estimates to determine an overall grade. Beyond the limited number of samples, another limitation associated with the monitored data was that the short data record meant the samples were not representative of a complete annual cycle, and all of the seasonal variation in water quality parameters that can occur during that time.

The NPS-FM requires annual median, maximum or 95th percentile calculations to determine attribute grades in lakes for total nitrogen, total phosphorus, phytoplankton (chlorophyll-*a*) and ammonia (toxicity). However, the NPS-FM does not specify the frequency and exact time period for monitoring. Henceforth, monthly sampling, at six lakes as part of the SoE lakes monitoring programme will inform annual calculation of attribute states. Furthermore, the NPS-FM does not specify which depth water samples must be collected from when assessing attribute state. Discrete samples are typically collected from the lake surface, epilimnion and hypolimnion where there is evidence of stratification. Due to the extremely limited data record, epilimnion and hypolimnion samples were pooled for each lake when calculating the baseline states for total nitrogen, total phosphorous and ammonia. The NPS-FM requires lake-bottom and mid-hypolimnetic dissolved oxygen be measured using either continuous monitoring sensors or discrete dissolved oxygen profiles. The NPS-FM does not specify the frequency of discrete monitoring profiles. Currently, continuous dissolved oxygen monitoring is not carried out, however monthly discrete dissolved oxygen profiles have been undertaken at six representative lakes since commencement of the SoE lakes monitoring programme in May 2023.

Site-based baseline states

Using both modelled data and TRC sampling data, draft baseline states have been determined and are summarised in Tables 9 and 10 and presented in Figures 1 to 5. Table 9 presents attribute bands for NOF attributes in regionally monitored lakes using modelled and monitored data. Table 10 provides a summary of lakes that fail national bottom line standards for freshwater attributes. Further details are provided in Appendix 1 (a-g).

Table 9: Overall site-based baseline assessment (BAS) for NOF attributes applied to regionally monitored lakes using TRC measured data in addition to SBI and MfE modelled data (Schallenburg et al. 2023 and Snelder et al. 2022), where applicable.

Lake	Total nitrogen (annual median)				Total phosphorus (annual median)				Chlorophyll-*a* (annual median and maximum)				Ammonia (toxicity) (annual median)			Ammonia (toxicity) (annual 95th percentile)			Dissolved Oxygen	
	SBI	MfE	TRC	BAS	SBI	MfE	TRC	BAS	SBI	MfE	TRC	BAS	MfE	TRC	BAS	MfE	TRC	BAS	Lake-bottom	Mid-hypolimnetic
Lake Rotokawau	D	D	B	C	D	C	B	C	D	D	D	D	A	B	B	B	B	B	D	D
Barrett Lagoon	D	D	D	D	D	D	B	C	D	D	B	C	A	B	B	C	B	B	D	N/A
Lake Rotokare	D	B	C	C	C	B	C	D	C	B	D	D	A	A	A	A	B	B	D	D
Lake Kaikura	C	D	D	D	D	D	C	C	D	C	B	C	A	A	A	B	B	B	C	N/A
Lake Herengawe	D	D	D	D	D	D	C	C	D	D	D	D	A	A	A	B	A	B	A	N/A
Lake Waikare	C	B	C	C	C	B	D	D	C	B	C	C	A	A	A	A	B	B	D	D

Table 10: Summary of lakes with NOF attribute baseline grades below the national bottom line

	Lake Rotokawau	Barrett Lagoon	Lake Rotokare	Lake Kaikura	Lake Herengawe	Lake Waikare	Total
Total nitrogen (annual median)		D		D	D		3
Total phosphorus (annual median)			D			D	2
Chlorophyll-*a* (annual median)	D		D		D		3
Ammonia (toxicity) (annual median)							0
Ammonia (toxicity) (annual 95th percentile)							0
Lake-bottom dissolved oxygen	D	D	D			D	4
Mid-hypolimnetic dissolved oxygen	D		D			D	3
Total	3	2	4	1	2	3	

Total Nitrogen

Draft baseline states identified for total nitrogen are presented in Figure 1. Of the six lakes, three are in band C (Lake Rotokawau, North Hill Country (NHC), Lake Rotokare, Southern Hill Country (SHC) and Lake Waikare (SHC)) and three are in band D, below the national bottom line (Barrett Lagoon, Volcanic Ringplain (VRP), Lake Herengawe, Coastal Terraces (CT), and Lake Kaikura (CT)).

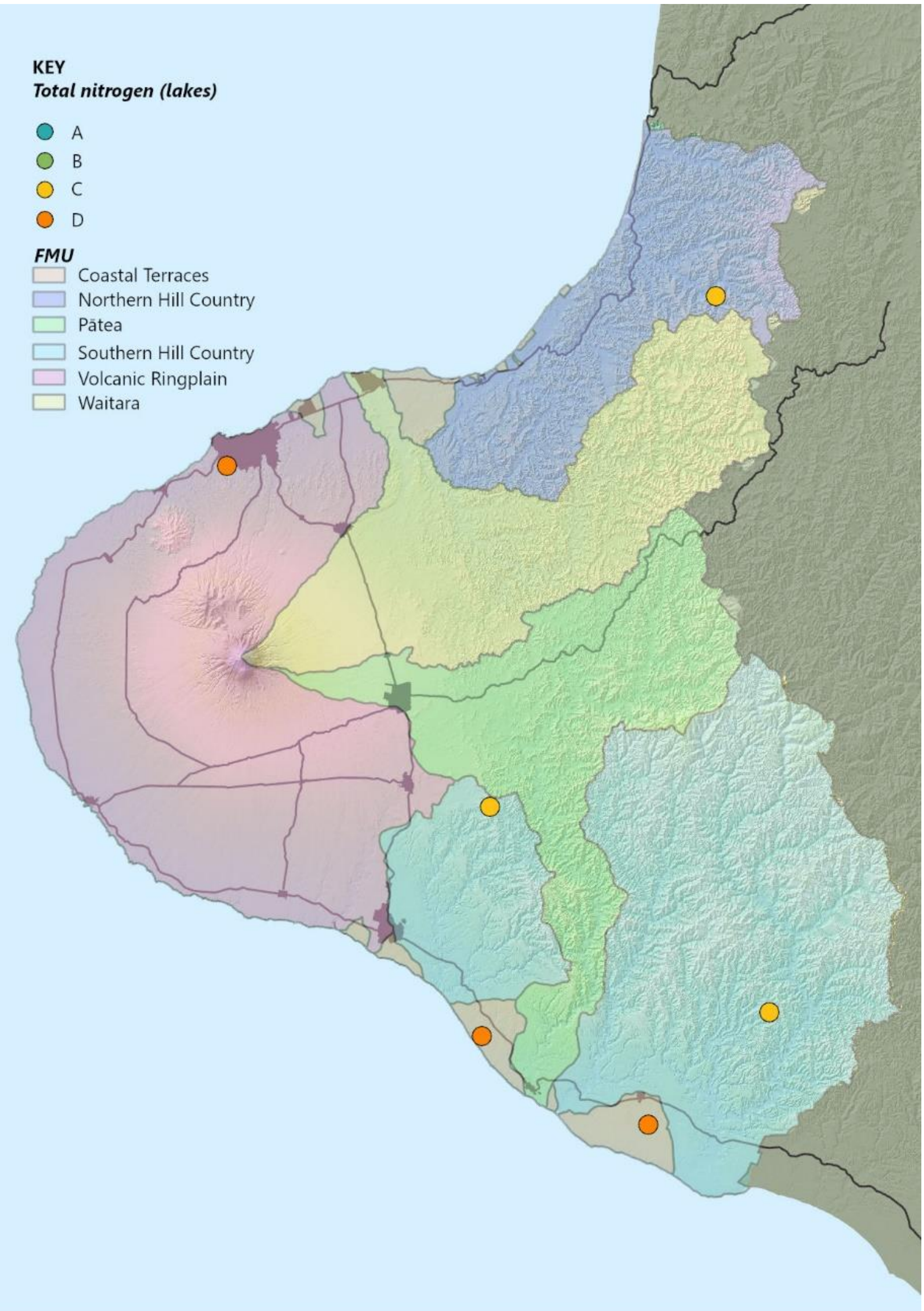

Figure 1: Draft baseline states identified for total nitrogen at six regionally representative Taranaki lakes

Ammonia (toxicity)

Draft baseline states identified for ammonia (toxicity) are presented for annual median and 95th percentile data in Figure 2. For all six lakes, band B applies for 95th percentile data. When the median values are applied, four lakes (Lake Rotokare (SHC), Lake Herengawe (CT), Lake Kaikura (CT) and Lake Waikare (SHC) are in band A, while Lakes Rotokawau (NHC) and Barrett Lagoon (VRP) are in band B.

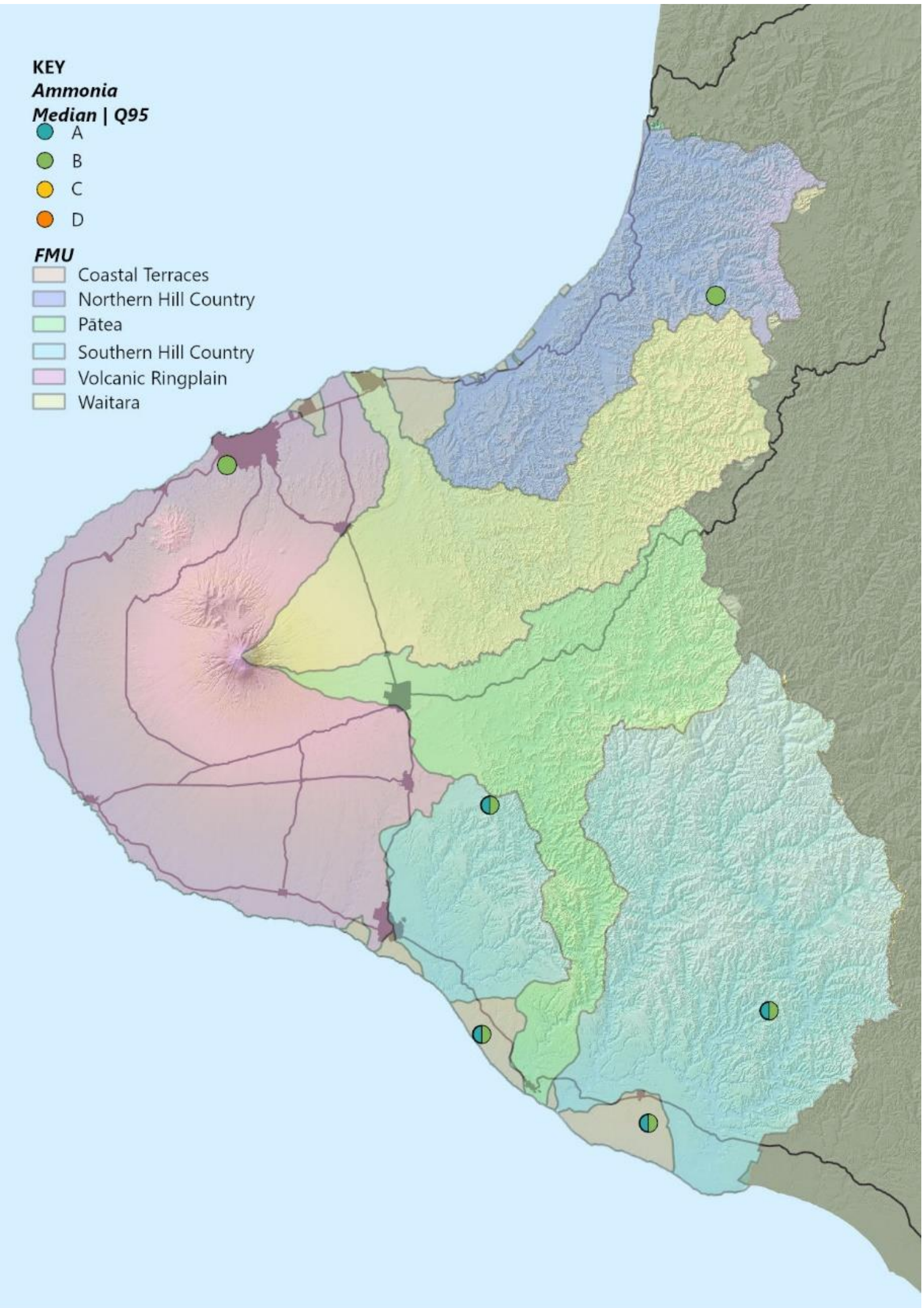

Figure 2: Draft baseline states identified for ammonia (toxicity) at six regionally representative Taranaki lakes

Total Phosphorus

Draft baseline states identified for total phosphorus are presented in Figure 3. For four lakes (Lake Rotokawau (NHC), Barret Lagoon (VRP), Lake Kaikura (CT) and Lake Herengawe (CT)), band C applies, while two lakes (Lake Rotokare (SHC) and Lake Waikare (SHC)) fall within band D.

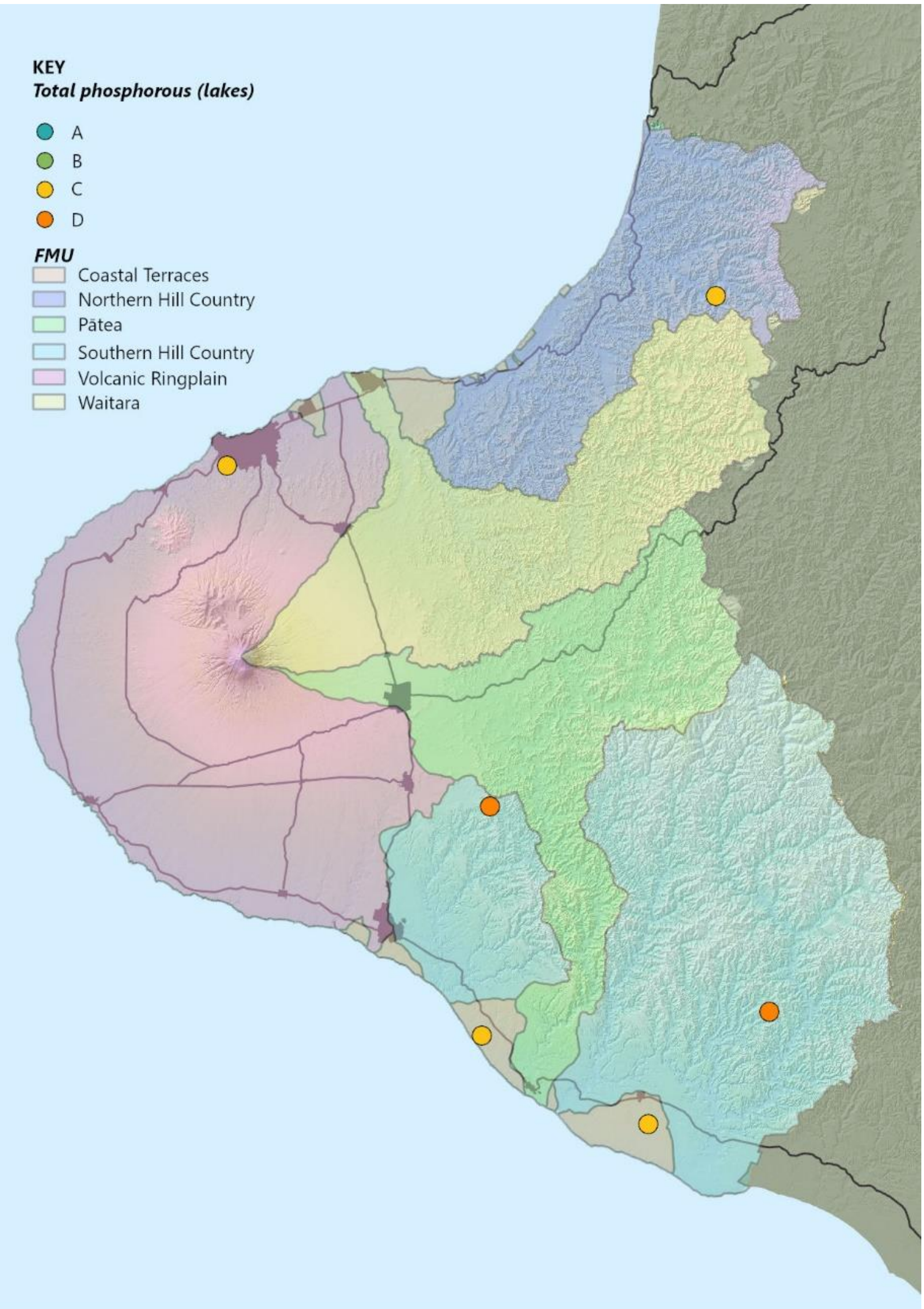

Figure 3: Draft baseline states identified for total phosphorus at six regionally representative Taranaki lakes

Dissolved oxygen

Draft baseline states identified for lake-bottom and mid-hypolimnetic dissolved oxygen are presented in Figure 4. For lake-bottom dissolved oxygen, four out of six lakes are in band D and fail to achieve the national bottom line (Lake Rotokawau (NHC), Barrett Lagoon (VRP), Lake Rotokare (SHC) and Lake Waikare (SHC)). For Lake Kaikura (CT), band C applies, and for Lake Herengawe (CT) band A applies. The mid-hypolimnetic dissolved oxygen attribute is only applicable to seasonally stratifying lakes. Based off preliminary monitoring data, Lake Rotokare, Lake Waikare and Lake Rotokawau appear to undergo seasonal stratification, while Lake Kaikura, Lake Henregawe and Barrett Lagoon do not. All three of the seasonally stratifying lakes failed to meet the national bottom line for mid-hypolimnetic dissolved oxygen (band D).

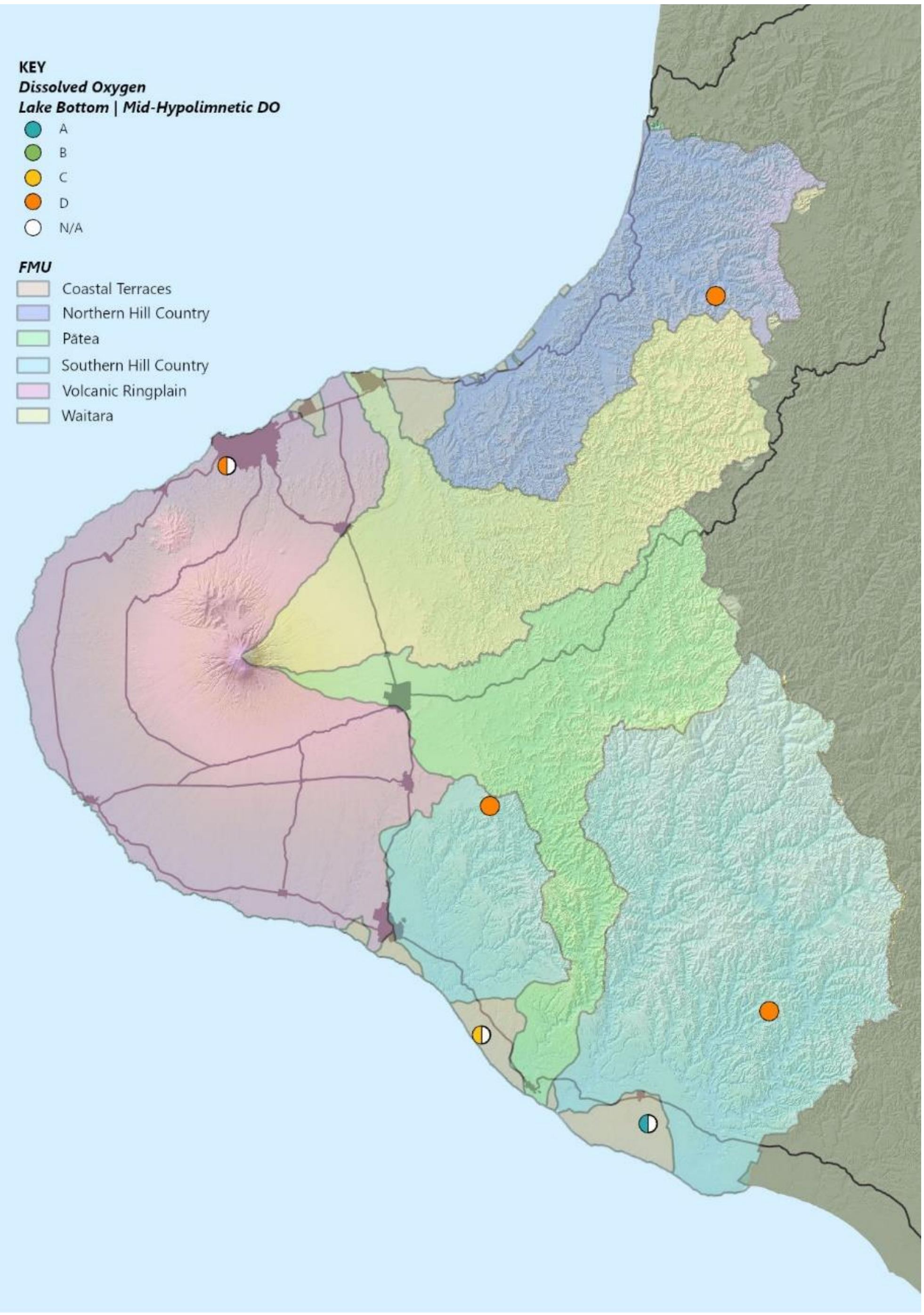

Figure 4: Draft baseline states identified for lake-bottom and mid-hypolimnetic dissolved oxygen at six regionally representative Taranaki lakes

Phytoplankton

Draft baseline states identified for phytoplankton (measured by chlorophyll-*a* concentration) are presented in Figure 5. Of the six lakes, three fail to achieve the national bottom line (Lake Rotokawau (NHC), Lake Rotokare (SHC) and Lake Herengawe (CT). Band C applies to the remaining three lakes (Barret Lagoon (VRP), Lake Waikare (SHC) and Lake Kaikura (CT).

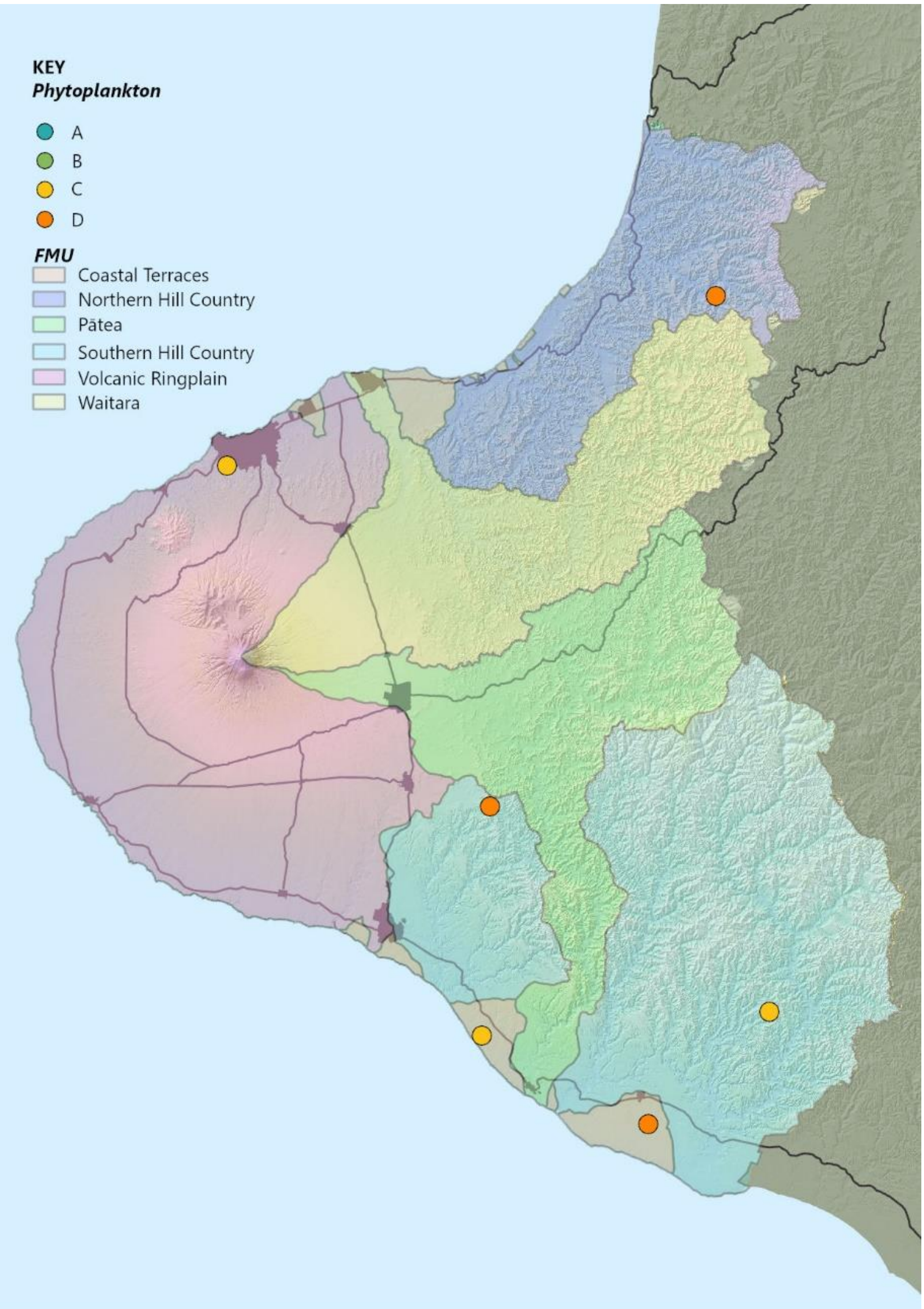

Figure 5: Draft baseline states identified for phytoplankton (trophic state) at six regionally representative Taranaki lakes

Baseline period and temporal state variability

For the six lake monitoring sites, data records are limited, with regular monitoring only commencing at the start of 2023. Therefore, baselines have been identified at all lakes using the earliest available data (sub-clause 1.4(a)), with there being no data to consider prior September 2017 for sub-clause 1.4(c).

While it is a requirement of the NPS-FM to select the 'best' state when assessing baselines, it is important to understand how representative that baseline is in terms of the variability of the data at a given site. As there is no long-term data record for these lake attributes to assess temporal variability against, professional judgement must be exercised. Given the limited available data, the baselines that have been identified for these lakes must be considered preliminary, and are associated with a higher level of uncertainty. This increased uncertainty was factored in to the baseline grades, with modelled data also considered to support the overall grading.

Freshwater Management Unit (FMU) coverage and representativeness

Lakes currently surveyed in the Taranaki region are presented spatially in Figures 1 to 5 in relation to FMU's. Lakes are not evenly distributed throughout the region, therefore the number of lakes in each FMU is not proportionate to overall area. The TRC lakes monitoring programme was informed by a review of all lakes throughout the region, which identified 17 potential candidate lakes for inclusion. The following criteria were used to exclude lakes as suitable candidates for monitoring:

- Natural and unmodified. Artificial lakes were excluded on the basis that these lakes are less likely to be considered representative of the natural environment.
- Open water area ≥ 1 ha. Although there are many smaller lakes in the region, in most cases these are not particularly deep and in a number of cases may more reasonably be classed as wetlands.
- Suitable boat access to allow monitoring. Boat access is necessary as boats are required to enable sample collection from the deepest point of the lake.

Of these 17 lakes, eight were located in the Coastal Terrace FMU, five were located in the Southern Hill Country, three in the Volcanic Ring Plain and one in the Northern Hill Country. No suitable lakes were identified in the Waitara or Pātea FMUs. The final six lakes included in the monitoring programme were Lake Rotokawau, Barrett Lagoon, Lake Rotokare and Lake Waikare, and Lake Herengawe and Lake Kaikura. This set of lakes, which has been used to inform this site-based baseline setting process, are considered to be suitably representative of each applicable FMU within the Taranaki region.

FMU-based baseline states

Monitoring data provides a direct measurement of water quality parameters, and therefore it is the preferred method for assessing environmental state due to its accuracy and certainty. However, attempting to evaluate state at the FMU or region-wide scale using site based monitoring data can introduce site selection bias. This can result in under- or over-representation of lakes with certain characteristics.

Spatial modelling is a useful tool that can be used to help 'fill the gaps' between monitoring sites, and make predictions of water quality based on the catchment characteristics and land use. Models have been used to estimate baseline state for total nitrogen, ammonia, total phosphorous, and chlorophyll-a for all lakes in the Taranaki region as listed in the Freshwater Ecosystems (FENZ) geo-database[2]. It should be noted that FENZ is not a comprehensive database, and as such it was necessary to verify these lakes by cross checking recent

[2] https://www.doc.govt.nz/our-work/freshwater-ecosystems-of-new-zealand/

aerial photography prior to presenting this data here (Schallenburg *et al*. 2023). This process has identified 19 misclassified lakes that were subsequently removed from the analysis. The cross checking process also identified a number of lakes that were not registered on the FENZ database. Including these additional lakes in the analysis was not possible at the time this memorandum was prepared, but it is something that should be pursued in the future. A summary of the models, including their performance, is provided in the 'Criteria for identifying site-based baseline states' section of this memorandum. References to the source reports are also provided.

Caution is advised when interpreting absolute values or percentages based on spatial water quality models such as these, due to the uncertainty associated with the estimates. However, models remain useful for demonstrating broad-scale patterns in water quality that we might expect to see based on physical lake features, and characteristics of the surrounding catchments.

Total nitrogen

Table 11 presents estimates of total nitrogen concentrations translated to attribute bands for 67 Taranaki lakes, from two models (Schallenburg *et al*. 2023 and Snelder *et al*. 2022). Because mixing regimes for all Taranaki lakes have not yet been accurately classified, the estimates are assessed against the attribute criteria for both seasonally stratified lakes, and polymictic lakes (the criteria for polymictic lakes being comparatively less stringent, as shown in Table 1).

The two models estimate nearly the same proportion of lakes to be below the national bottom line for total nitrogen in seasonally stratified lakes (41 and 40 out of 67 lakes in band D; approximately 60%). The majority of the remaining lakes were graded within band C, based on both models. When applying the less stringent criteria for polymictic lakes, the number of lakes estimated to be failing the national bottom line remained very similar (35 and 38 out of 67 lakes in band D; or 52 – 56%). A higher proportion of lakes are classified in band B, when applying the polymictic attribute criteria compared to the seasonally stratified criteria.

Table 11: Modelled total nitrogen concentrations in 67 Taranaki lakes, expressed as NOF attribute grades

Lake classification	FMU	Schallenburg et al. (2023)					Snelder et al. (2022)			
		A	B	C	D		A	B	C	D
Seasonally stratified lakes	Southern Hill Country	0	0	14	20		0	5	15	14
	Coastal Terraces	0	0	4	10		0	0	0	14
	Pātea	0	0	1	0		0	0	1	0
	Volcanic Ringplain	0	2	5	7		0	1	5	8
	Waitara	0	0	0	3		0	0	0	3
	Northern Hill Country	0	0	0	1		0	0	0	1
	Total	0	2	24	41		0	6	21	40
Polymictic lakes	Southern Hill Country	0	5	11	18		1	15	5	13
	Coastal Terraces	0	0	5	9		0	0	0	14
	Pātea	0	1	0	0		0	1	0	0
	Volcanic Ringplain	1	1	7	5		0	2	4	8
	Waitara	0	0	1	2		0	0	0	3
	Northern Hill Country	0	0	0	1		0	0	1	0
	Total	1	7	24	35		1	18	10	38

Ammonia

Table 12 presents estimates of ammonia translated to attribute bands for 67 Taranaki lakes, from Snelder *et al*. (2022). The model estimates that annual median ammonia concentrations in all lakes across all six FMUs, sit within band A. Rather than the 95th percentile (as shown in Table 2), the model estimates maximum ammonia concentrations, as the attribute criteria was revised following the model development. Given that maximum values are higher than 95th percentiles, the assessment below likely overestimates the number of lakes that are graded within the B and C bands. As mentioned earlier, the performance of this ammonia model was considered unsatisfactory, and therefore caution is advised when interpreting these results.

Table 12: Modelled ammonia concentrations in 67 Taranaki lakes, expressed as NOF attribute grades

Lake classification	FMU	Snelder *et al.* (2022)			
		A	B	C	D
Annual median	Southern Hill Country	34	0	0	0
	Coastal Terraces	14	0	0	0
	Pātea	1	0	0	0
	Volcanic Ringplain	14	0	0	0
	Waitara	3	0	0	0
	Northern Hill Country	1	0	0	0
	Total	67	0	0	0
Annual maximum	Southern Hill Country	4	27	3	0
	Coastal Terraces	0	11	3	0
	Pātea	0	1	0	0
	Volcanic Ringplain	0	12	2	0
	Waitara	0	2	1	0
	Northern Hill Country	0	1	0	0
	Total	4	54	9	0

Total phosphorous

Table 13 presents estimates of total phosphorous concentrations translated to attribute bands for 67 Taranaki lakes, from two models (Schallenburg *et al.* 2023 and Snelder *et al.* 2022). Both models estimate very similar numbers of lakes which fall below the national bottom line (34 and 32 out of 67 lakes in band D, or 51% and 48%). Schallenburg *et al.* estimates that all of the remaining lakes, except one, are graded within band C. Snelder *et al.* estimates that 25 (37%) fall within band C, and 10 (15%) fall within band B.

Table 13: Modelled total phospohorus concentrations in 67 Taranaki lakes, expressed as NOF attribute grades

FMU	Schallenburg *et al.* (2023)					Snelder *et al.* (2022)			
	A	B	C	D		A	B	C	D
Southern Hill Country	0	0	19	15		0	8	17	9
Coastal Terraces	0	0	6	8		0	0	2	12
Pātea	0	0	1	0		0	0	1	0
Volcanic Ringplain	1	0	5	8		0	2	4	8
Waitara	0	0	1	2		0	0	0	3
Northern Hill Country	0	0	0	1		0	0	1	0
Total	1	0	32	34		0	10	25	32

Phytoplankton (chlorophyll-a)

Table 14 presents estimates of median chlorophyll-a concentrations translated to attribute bands for 67 Taranaki lakes, from two models (Schallenburg *et al.* 2023 and Snelder *et al.* 2022). Schallenburg *et al.* estimates that 48 lakes (72%) fall below the national bottom line (band D) for median chlorophyll-a concentrations. This is higher than the 37 lakes (55%) estimated by Snelder *et al.* to fall within band D.

Schallenburg *et al*. estimates the majority of the remaining lakes to be graded within band C, as does Snelder *et al*.

Table 14: Modelled chlorophyll-a concentrations in 67 Taranaki lakes, expressed as NOF attribute grades

FMU	Schallenburg *et al.* (2023)					Snelder *et al.* (2022)			
	A	B	C	D		A	B	C	D
Southern Hill Country	0	3	12	19		0	5	15	14
Coastal Terraces	0	0	0	14		0	0	3	11
Pātea	0	0	1	0		0	1	0	0
Volcanic Ringplain	1	0	2	11		0	1	3	10
Waitara	0	0	0	3		0	0	2	1
Northern Hill Country	0	0	0	1		0	0	0	1
Total	1	3	15	48		0	7	23	37

Dissolved oxygen

Lake bottom and mid-hypolimnetic dissolved oxygen state have not been modelled for Taranaki lakes. However, Schallenburg *et al*. (2023) made an estimate of Taranaki lakes that were at risk of experiencing oxygen depletion, as a function of maximum lake depth, and modelled chlorophyll-a concentrations. These predictors were selected given that deeper lakes that are highly productive are more likely to stratify and experience anoxia in the bottom waters. Based on this approach, 36 out of 67 lakes assessed in the Taranaki region (54%) were identified as being at risk of experiencing low dissolved oxygen conditions. Barrett Lagoon was presented as an outlier where oxygen depletion has been recorded, despite being a shallow lake with a maximum depth of approximately six metres. This highlights the potential for shallow lakes to also experience anoxia under the right conditions. Although mid-hypolimnetic dissolved oxygen conditions are harder to predict, the authors suggested that lakes which experience lake-bottom oxygen depletion are also susceptible to experiencing mid-hypolimnetic oxygen depletion.

Recommendations

Draft baseline states have been calculated for six representative lakes monitored across the Taranaki region, to provide the best known state for several lakes attributes as indicators of ecosystem health. Modelled estimates suggest that the site-based baselines provide a good representation of baseline state more broadly throughout each FMU.

When setting target states associated with the ecosystem health value, targets will need to be set at a level that (at a minimum) achieves the baseline state, or exceeds the baseline state where this is necessary to achieve improvement. Phytoplankton, total nitrogen, total phosphorus and ammonia (toxicity) are included in the NOF as attributes that require limits to be set on resource use in order to achieve the national bottom line (NPS-FM, Appendix 2A), whereas the dissolved oxygen attributes require action plan development (NPS-FM, Appendix 2B). All six regionally monitored lakes fail to meet the national bottom line standard for one or more attribute and therefore will require limit setting and/or Action Plans to deliver improvements in ecosystem health.

At this point in time it is not recommended to set targets at the FMU scale for these lake attributes based on the modelled estimates. Further monitoring, in the form of one-off synoptic surveys, as well as improvements to the regional lakes geo-spatial dataset, will help to improve the accuracy and confidence in these modelling estimates for future use.

The next step is to identify and assess the impact of possible actions and mitigations that are available to support the maintenance and improvement of freshwater quality in lakes in relation to ecosystem health.

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Snelder T, Fraser C, Whitehead A. 2022. *Spatial modelling of Lake water quality state incorporating monitoring data for the period 2016 to 2020*. Christchurch: Land Water People. Report No. 2021-15. Prepared for Ministry for the Environment.

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Appendix 1 (a) Summary of TRC sampling data at regionally monitored lakes

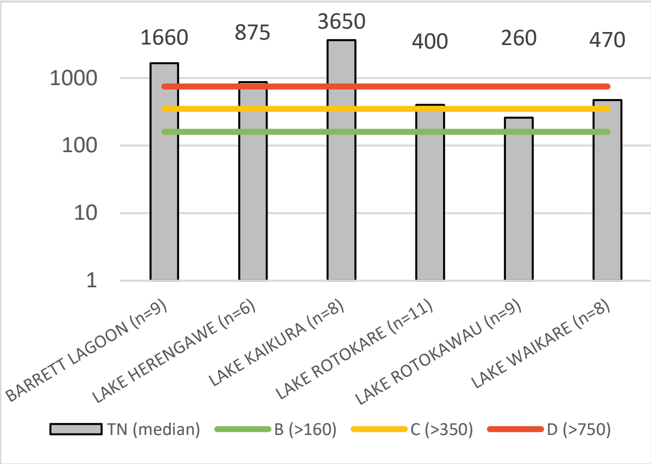

Figure 6: Median values for total nitrogen (mg/m³) at six Taranaki lakes up to July 2023

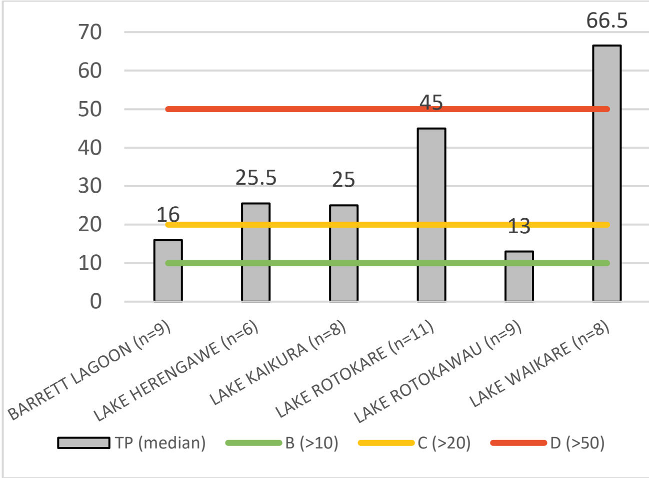

Figure 7: Median values for total phosphorus (mg/m³) at six Taranaki lakes up to July 2023

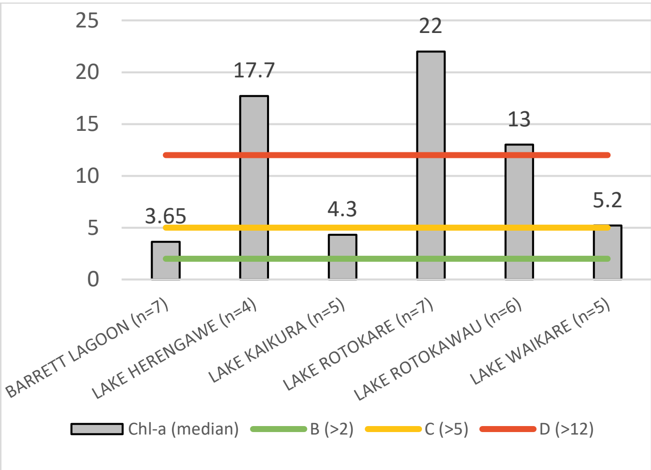

Figure 8: Median values for chlorophyll-a (mg chl-a/m³) at six Taranaki lakes up to July 2023

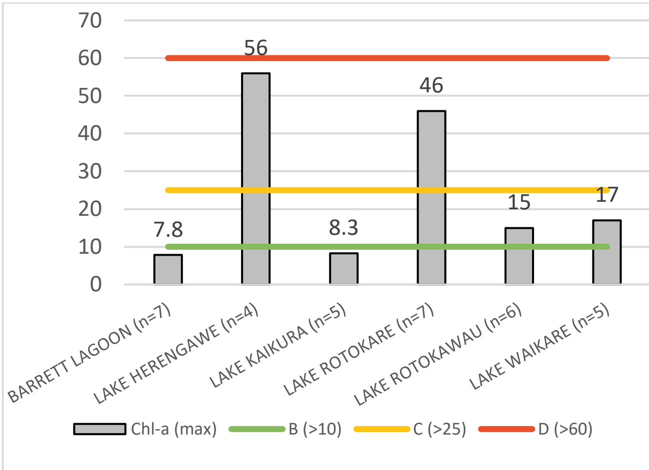

Figure 9: Maximum values for chlorophyll-a (mg chl-a/m³) at six Taranaki lakes up to July 2023

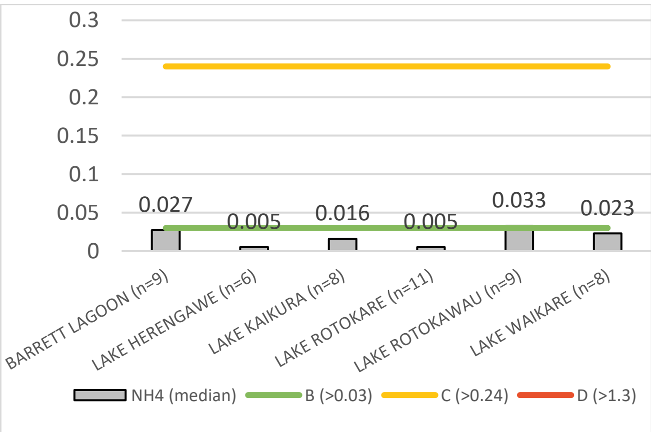

Figure 10: Median values for ammonia (mg NH_4N/L) at six Taranaki lakes up to July 2023

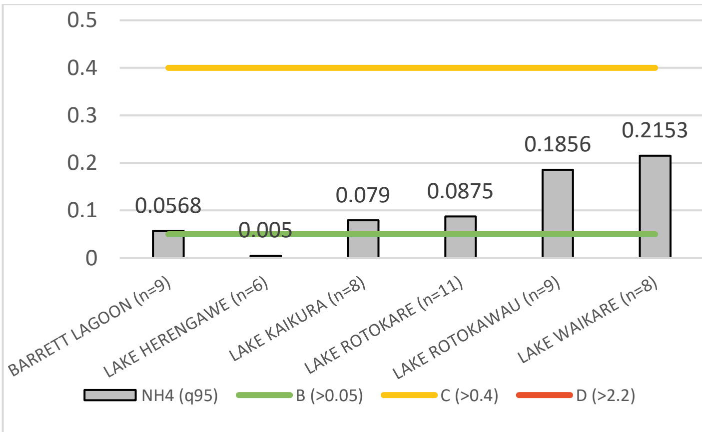

Figure 11: 95th percentile values for ammonia (mg NH_4N/L) at six Taranaki lakes up to July 2023

NB: Total nitrogen attribute bands are shown for seasonally stratified lakes. Preliminary measurements indicate that Lake Rotokare, Lake Rotokawau and Lake Waikare are seasonally stratifying, while the remaining lakes appear to be polymictic. The attribute band thresholds for polymictic lakes are B (>300), C (>500) and D (>800).

Appendix 1 (b) Measured and modelled data for TN in Taranaki lakes

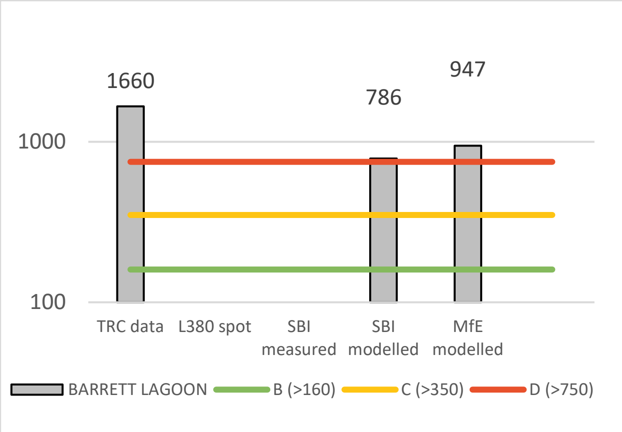

Figure 12: Measured and modelled data for total nitrogen (mg/m³) at Barrett Lagoon

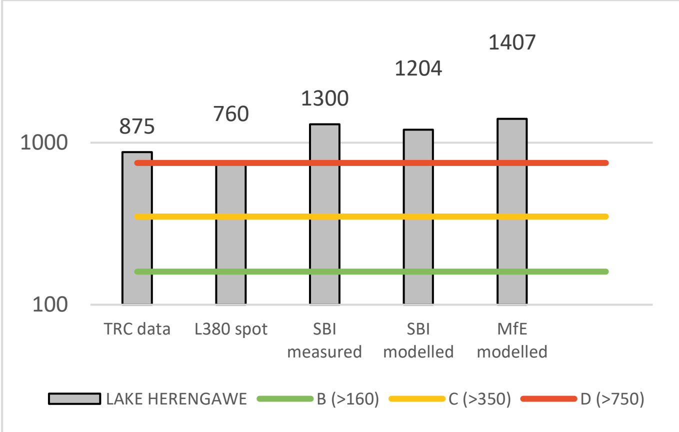

Figure 13: Measured and modelled data for total nitrogen (mg/m³) at Lake Herengawe

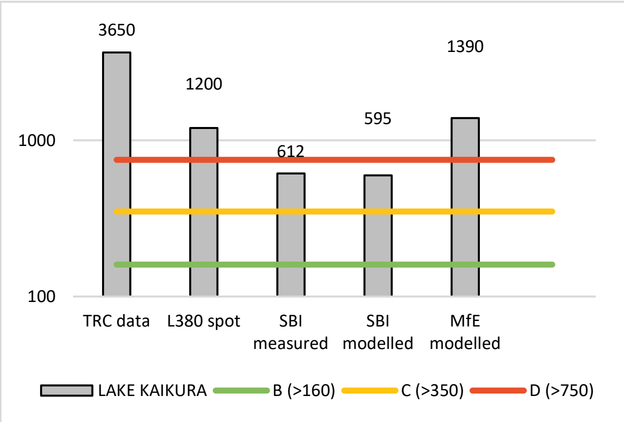

Figure 14: Measured and modelled data for total nitrogen (mg/m³) at Lake Kaikura

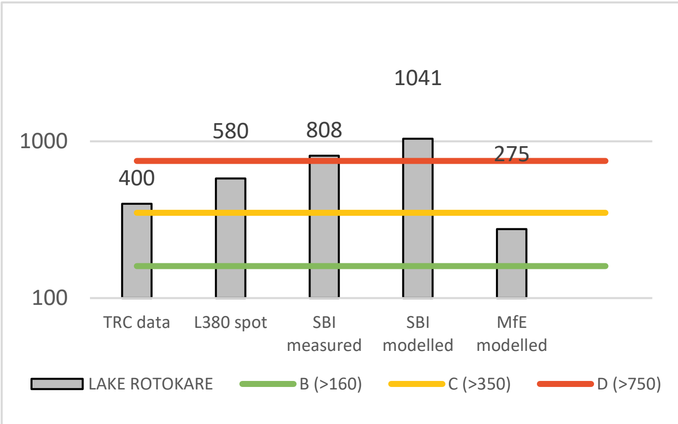

Figure 15: Measured and modelled data for total nitrogen (mg/m³) at Lake Rotokare

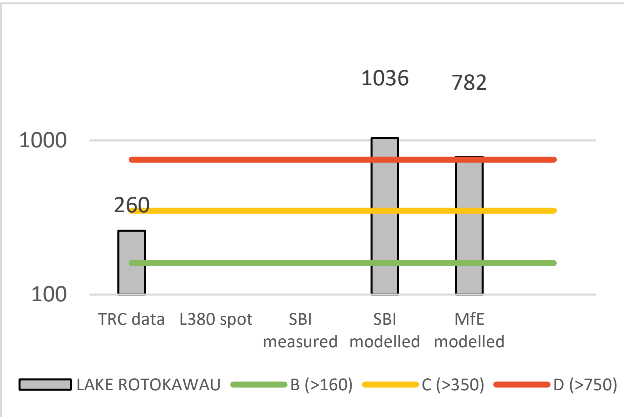

Figure 16: Measured and modelled data for total nitrogen (mg/m³) at Lake Rotokawau

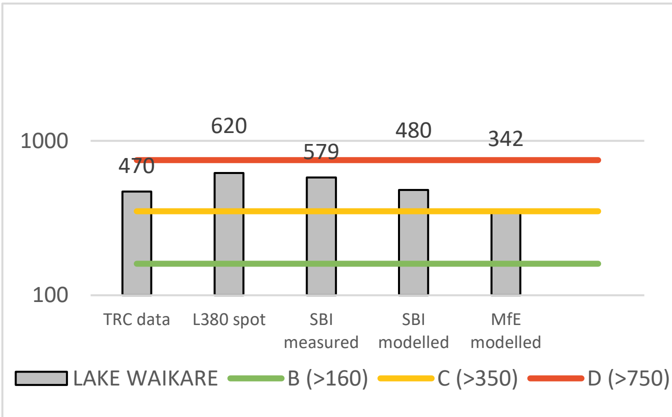

Figure 17: Measured and modelled data for total nitrogen (mg/m³) at Lake Waikare

NB: Attribute bands are shown for seasonally stratified lakes. Preliminary measurements indicate that Lake Rotokare, Lake Rotokawau and Lake Waikare are seasonally stratifying, while the remaining lakes appear to be polymictic. The attribute band thresholds for polymictic lakes are B (>300), C (>500) and D (>800).

Appendix 1 (c) Measured and modelled data for TP in Taranaki lakes

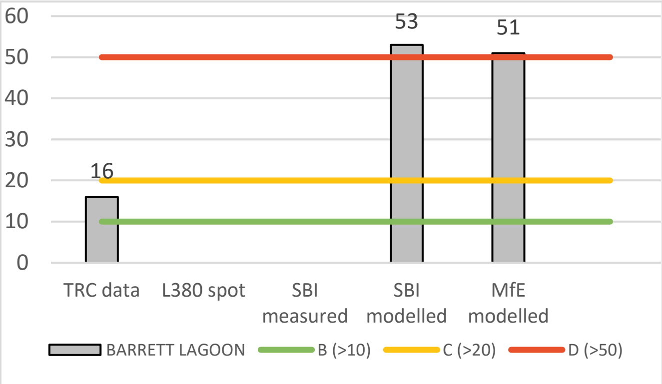

Figure 18: Measured and modelled data for total phosphorus (mg/m³) at Barrett Lagoon

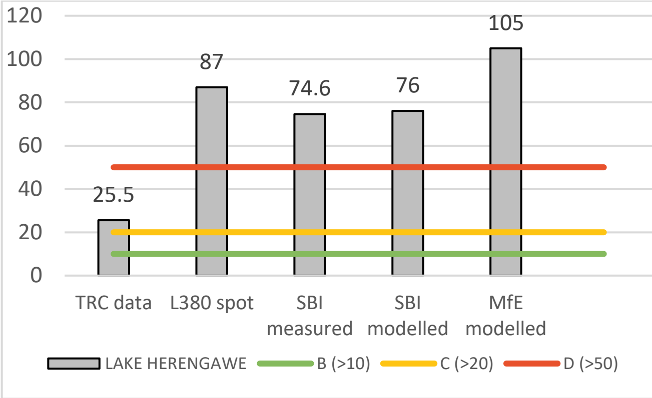

Figure 19: Measured and modelled data for total phosphorus (mg/m³) at Lake Herengawe

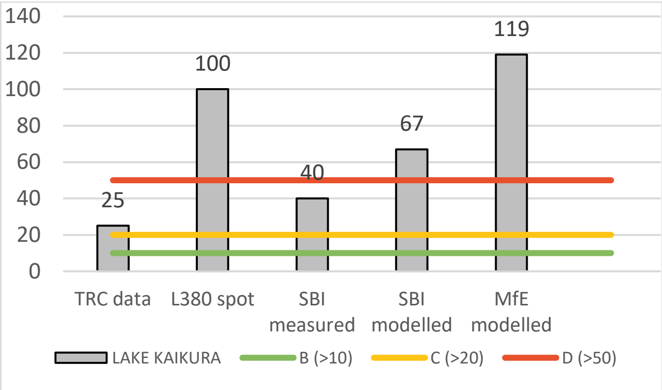

Figure 20: Measured and modelled data for total phosphorus (mg/m³) at Lake Kaikura

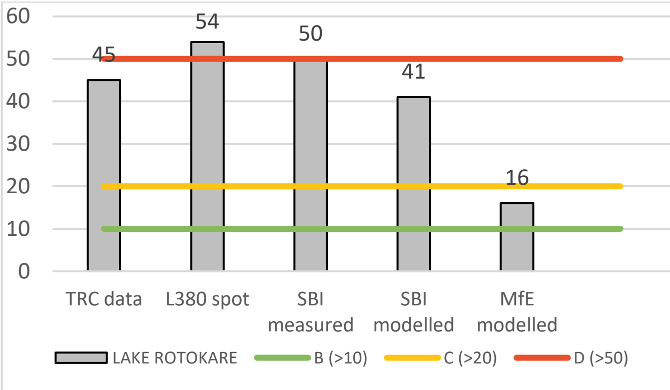

Figure 21: Measured and modelled data for total phosphorus (mg/m³) at Lake Rotokare

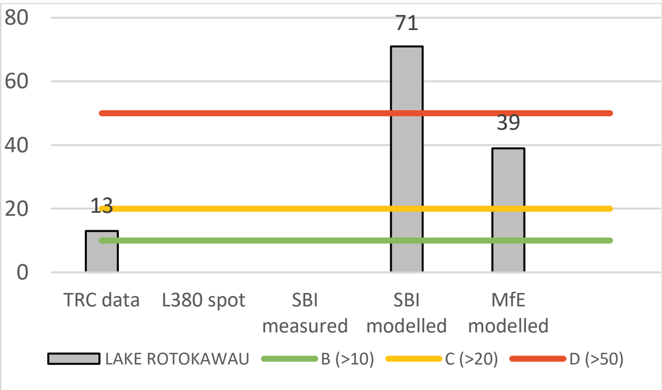

Figure 22: Measured and modelled data for total phosphorus (mg/m³) at Lake Rotokawau

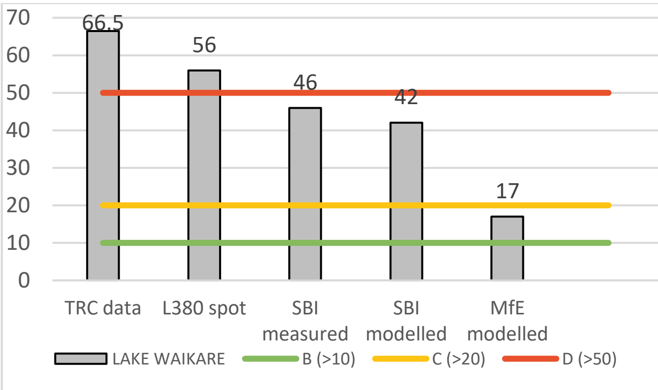

Figure 23: Measured and modelled data for total phosphorus (mg/m³) at Lake Waikare

Appendix 1 (d) Measured and modelled data for chlorophyll-*a* in Taranaki lakes

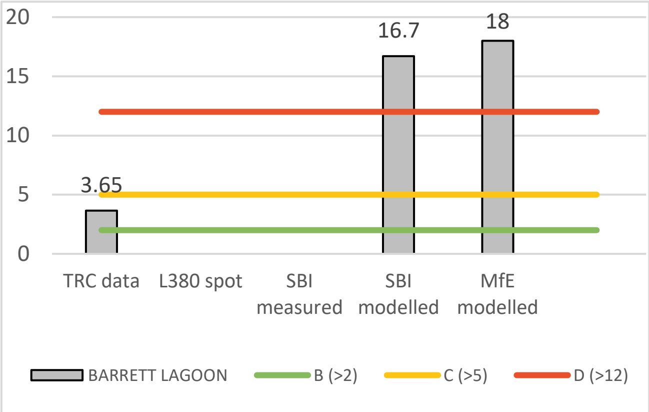

Figure 24: Measured and modelled data for chlorophyll-a (mg chl-a/m³) at Barrett Lagoon

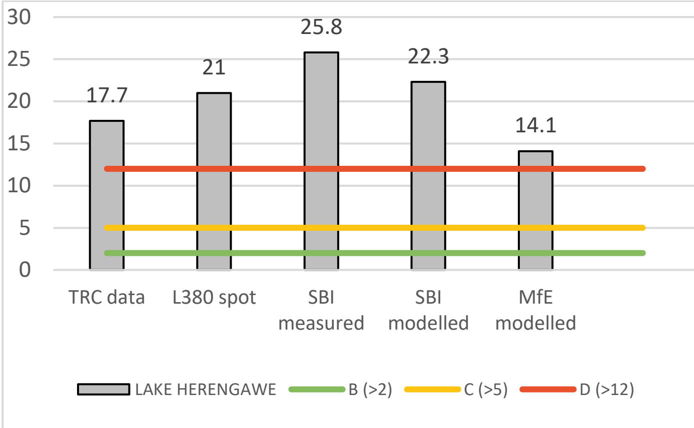

Figure 25: Measured and modelled data for chlorophyll-a (mg chl-a/m³) at Lake Herengawe

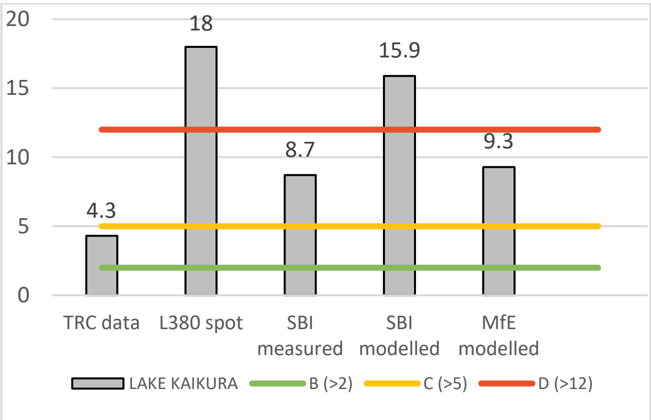

Figure 26: Measured and modelled data for chlorophyll-a (mg chl-a/m³) at Lake Kaikura

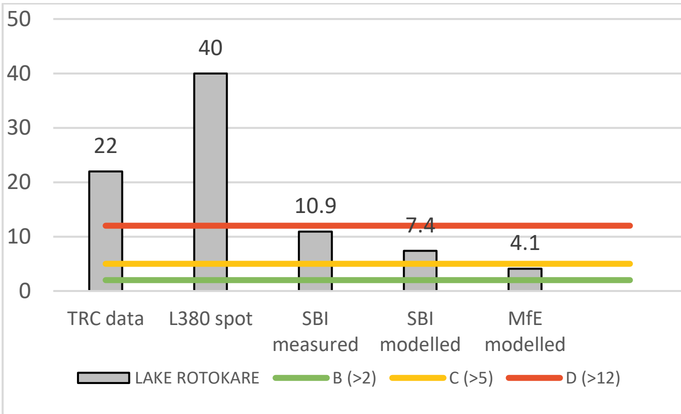

Figure 27: Measured and modelled data for chlorophyll-a (mg chl-a/m³) at Lake Rotokare

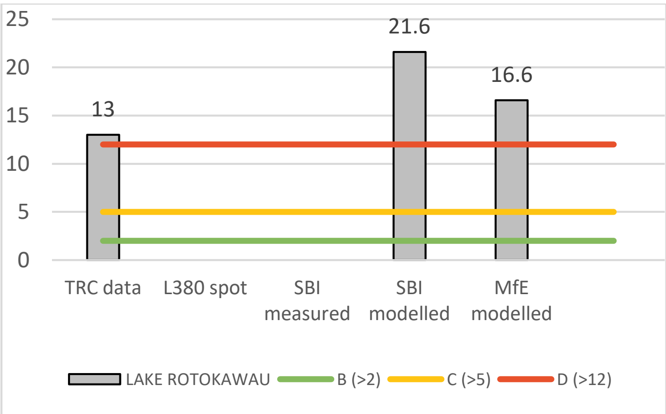

Figure 28: Measured and modelled data for chlorophyll-a (mg chl-a/m³) at Lake Rotokawau

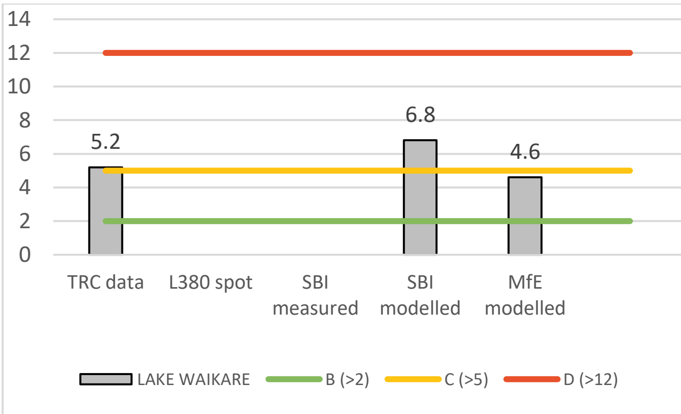

Figure 29: Measured and modelled data for chlorophyll-a (mg chl-a/m³) at Lake Waikare

Appendix 1 (e) Measured and modelled data for NH4 (median) in Taranaki lakes

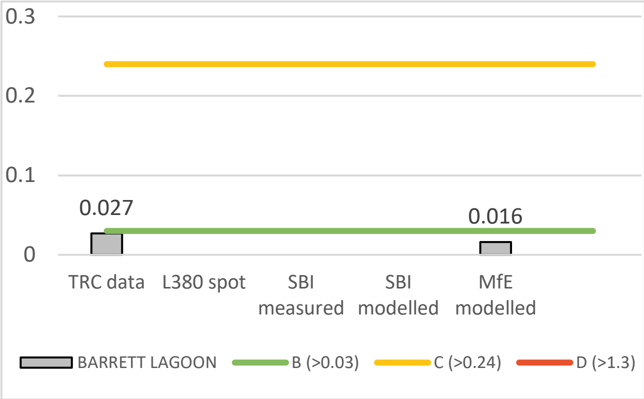

Figure 30: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Barrett Lagoon (median)

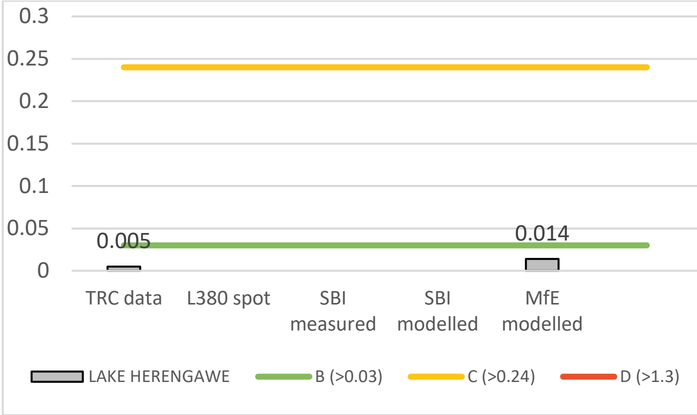

Figure 31: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Herengawe (median)

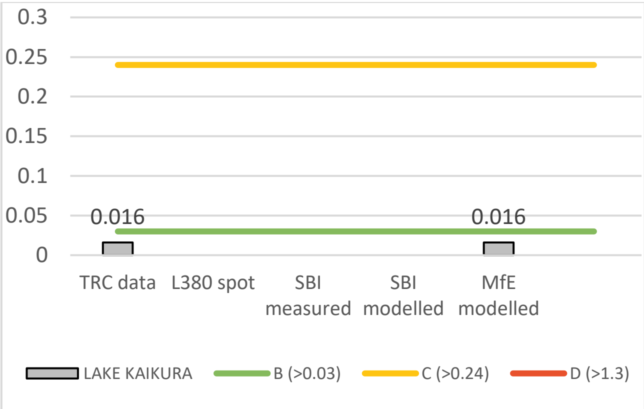

Figure 32: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Kaikura (median)

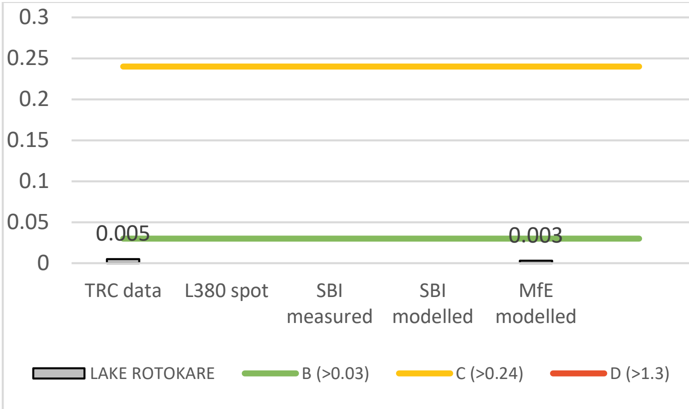

Figure 33: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Rotokare (median)

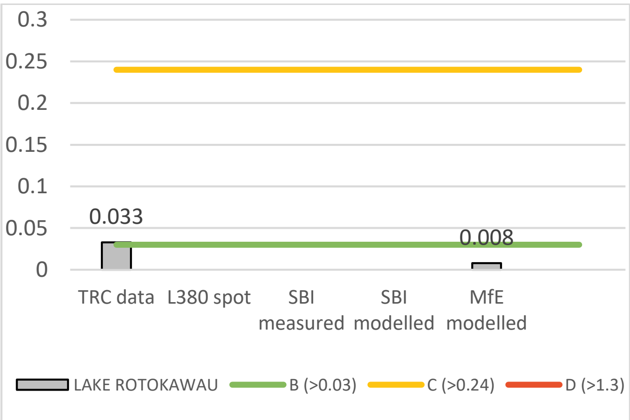

Figure 34: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Rotokawau (median)

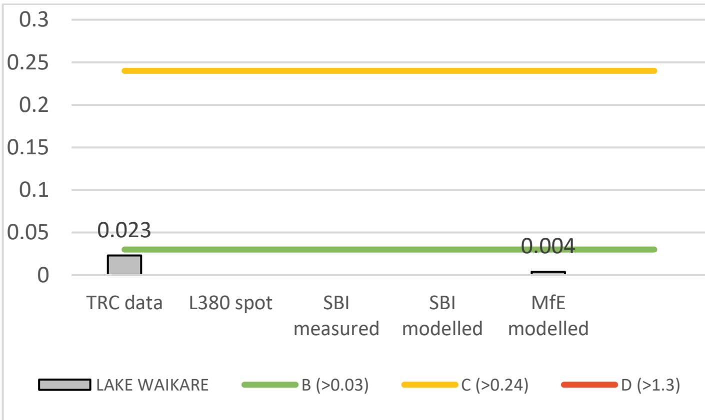

Figure 35: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Waikare (median)

Appendix 1 (f) Measured and modelled data for NH4 (Q95) in Taranaki lakes

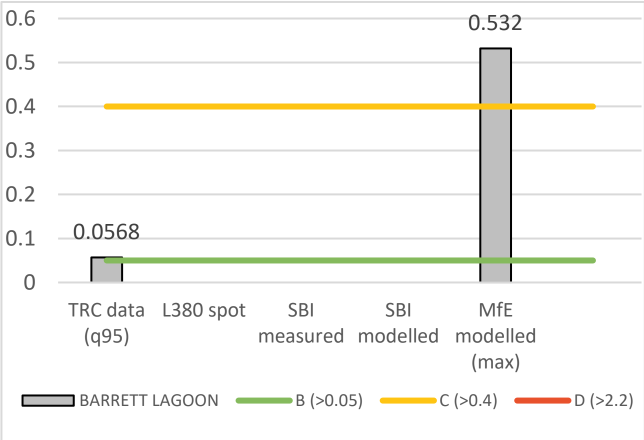

Figure 36: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Barrett Lagoon (95th percentile

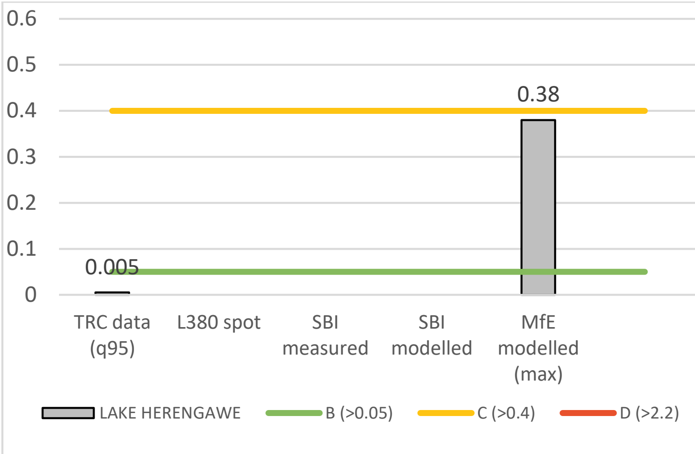

Figure 37: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Herengawe (95th percentile)

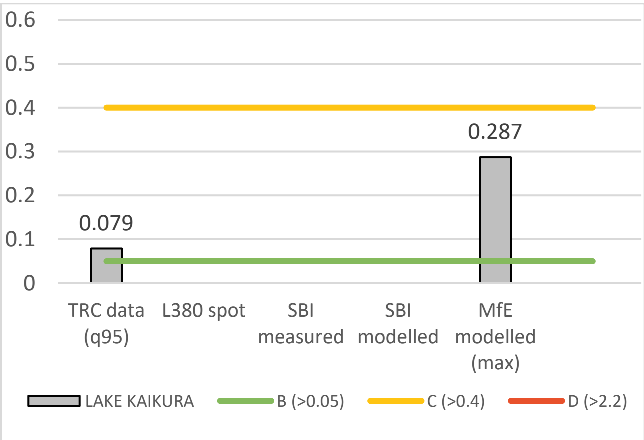

Figure 38: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Kailkura (95th percentile)

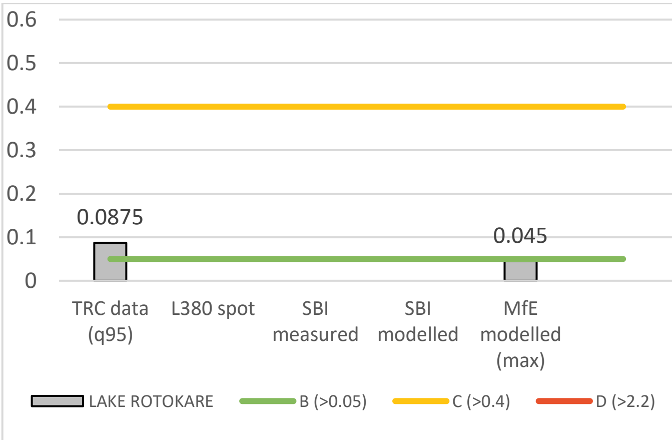

Figure 39: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Rotokare (95th percentile)

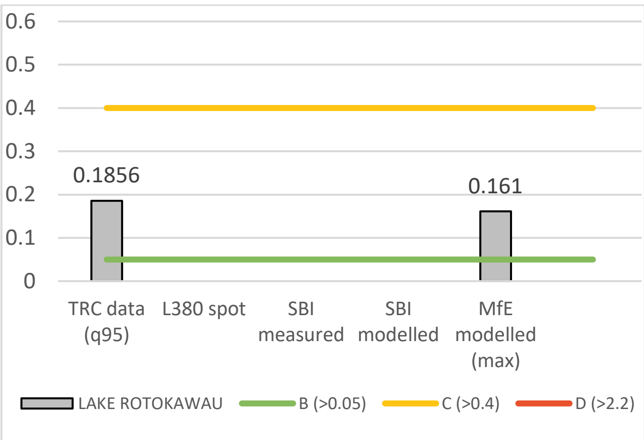

Figure 40: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Rotokawau (95th percentile)

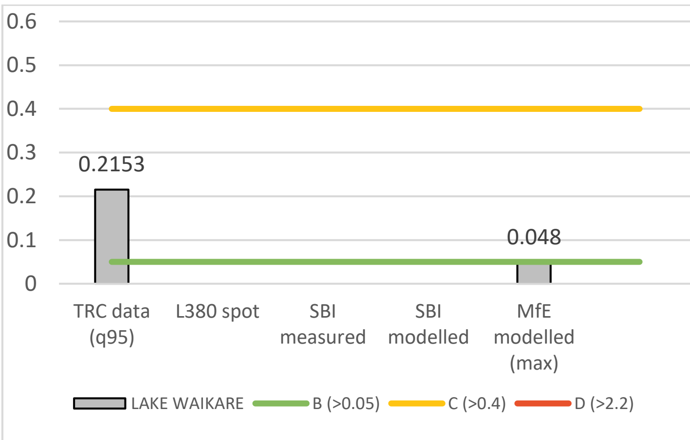

Figure 41: Measured and modelled data for ammonia (toxicity) (mg NH_4N/L) at Lake Waikare (95th percentile)

Appendix 1 (g) Minimum dissolved oxygen measurements in Taranaki lakes

Lake	Date profiled	Max depth (m)	Lake-bottom dissolved oxygen concentration (mg/L)	NOF grade
Lake Rotokare	23/03/2023	11	0	D
	02/05/2023	11	0	D
Lake Waikare	16/03/2023	18.9	0	D
	03/05/2023	18.9	0	D
Lake Herengawe	16/09/2022	3.9	8.7	A
	28/04/2023	3.9	7.9	A
Lake Kaikura	05/04/2023	4.5	10.7	A
	08/05/2023	4.5	4.4	B
Barrett Lagoon	20/04/2023	5.7	0	D
	01/02/2023	5.7	3.8	B
Lake Rotokawau	23/02/2023	11.9	0	D
	01/05/2023	11.9	0	D