Technical memorandum – Nutrients (rivers)

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Purpose

The purpose of this memorandum is to provide an assessment of the baseline state of nutrients including ammonia (toxicity), nitrate (toxicity) and dissolved reactive phosphorus as measures of ecosystem health, as required by the National Policy Statement for Freshwater Management 2020 (NPS-FM). This memo also addresses nutrient criteria to support the achievement of other freshwater ecosystem health outcomes.

Overview of nutrients

Nutrients including nitrogen and phosphorus are essential for the growth of benthic river algae (periphyton) and vascular plants (macrophytes), which are an important food source for many small invertebrates and fish. The main nutrients in Taranaki waterways are inorganic forms of nitrogen (N) and phosphorus (P). Only small amounts of each are required in a natural ecosystem; too much can cause excessive algae and plant growth. This may lead to adverse effects on dissolved oxygen and pH levels, water clarity and biodiversity.

Nitrogen can be present in water in a number of forms (nitrate, nitrite, ammoniacal nitrogen and organic nitrogen). In rivers and lakes, too much nitrogen can lead to excessive growth of aquatic plants or algae. At high concentrations, ammonia and nitrate can be toxic for aquatic life.

Phosphorus can be present in water in different forms, and is an essential nutrient for instream plant life. Most phosphorus enters rivers attached to sediment. 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 Taranaki streams and rivers.

Ammonia (toxicity)

Ammoniacal nitrogen (NH_4-N), also called ‘ammonium’, is the concentration of nitrogen present as either ammonia (NH_3) or ammonium (NH_4) in water. The balance between ammonia and ammonium depends on the pH and temperature of the water. These ammoniacal forms can be transformed to other forms of nitrogen and are very important plant fertilisers but are generally less mobile in the soil than nitrate.

Ammoniacal forms of nitrogen enter waterways primarily through point source discharges, such as wastewater or dairy shed effluent. It is toxic to aquatic life at high concentrations.

Nitrate (toxicity)

Nitrate is the concentration of nitrogen present in the form of the nitrate ion. Nitrate is a water soluble molecule made up of nitrogen and oxygen with the chemical formula NO_3. It is a very important plant nutrient but because of its high water-solubility, it leaches readily through soils and into groundwater, particularly after heavy rainfall. Nitrate is one of the most common contaminants of rivers, streams, lakes and groundwater in rural and urban areas.

Sources of nitrate include excessive application of inorganic fertiliser, animal and human waste. Nitrogen fixation and soil cultivation can also cause nitrate leaching if poorly managed. On grazed pastures, animal urine patches can be a major source of nitrate leaching.

Dissolved Reactive Phosphorus (DRP)

Phosphorus occurs naturally in rocks and minerals, and is commonly found in soils and sediments. Weathering of rocks and minerals releases phosphorus. In its soluble form, DRP provides an indication of a waterbody's ability to support nuisance algal or plant growths (algal blooms), which is turn can impact aquatic ecosystems.

Phosphorus binds strongly to soil particles, but once the capacity of the soil to store phosphorus is exceeded, it will leach downward through the soil profile into groundwater. Typically, natural DRP concentrations in groundwater are low (<0.1 mg/L) however, in Taranaki soils are naturally high in phosphorus due to the volcanic geology. Where concentrations are elevated above natural background levels, influences of human and intensive land use activities such as fertiliser use, and wastewater and effluent discharges also contribute to excess DRP through erosion and leaching.

Nutrients and the National Objectives Framework

The NPS-FM sets out requirements for councils and communities to maintain or improve freshwater (where it is degraded). It contains a National Objectives Framework (NOF) that specifies nationally applicable standards for particular freshwater parameters (referred to as 'attributes') in rivers and lakes. Nitrogen (total nitrogen, nitrate and ammonia) and phosphorus (total phosphorus and dissolved reactive phosphorus) are some of those attributes. Total nitrogen and total phosphorus attributes apply to lakes. Nitrate (as a measure of toxicity to freshwater species) and dissolved reactive phosphorus both apply to rivers. Ammonia (toxicity) applies to both lakes and rivers.

The NOF defines categorical attribute states for ammonia, nitrate, and DRP in four attribute bands (A through D). The attribute bands indicate the extent to which a particular value is provided for, ranging from band A (good) to band D (poor).

The NOF attribute states for ammonia and nitrate are defined by two numeric attribute bands respectively, annual median and annual 95th percentile concentrations (Appendices 2A) as shown in Table 1 and Table 2. The NPS-FM sets national bottom lines for DRP to protect 95% of instream species from toxic effects. The NOF requires the councils to set limits on resource use to maintain or reduce instream ammonia and nitrate concentrations in rivers to protect ecosystem health, and to meet limits for other attributes that may be impacted by nutrients, such as the growth of algae (periphyton). These limits are likely to be much lower than those required to avoid toxicity effects.

The NOF attribute state for DRP is defined by two numeric attribute bands, five year median and five year 95th percentile concentrations (Appendices 2B) as shown in Table 3. The NPS-FM attribute state bands for DRP concentration are more broadly related to reference condition, eutrophication, primary production, macroinvertebrate community and fish, and functional aspects of stream health. The bands are to be applied across all streams, including those dominated by macrophytes. No national bottom line is specified for DRP however, the NOF requires councils to prepare action plans for instream DRP concentrations to protect or improve ecosystem health.

Table 1: NOF Attribute – Ammonia (Toxicity). Source: MfE (2023).

Value (and component)	Ecosystem health (Water quality)	
Freshwater body type	Rivers and lakes	
Attribute unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)	
Attribute band and description	**Numeric attribute state**	
	Annual median	Annual 95th percentile
A 99% species protection level: No observed effect on any species tested.	≤0.03	≤0.05
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.		

Table 2: NOF Attribute – Nitrate (Toxicity). Source: MfE (2023).

Value (and component)	Ecosystem health (Water quality)	
Freshwater body type	Rivers and lakes	
Attribute unit	mg NO_3 – N/L (milligrams nitrate-nitrogen per litre)	
Attribute band and description	**Numeric attribute state**	
	Annual median	Annual 95th percentile
A High conservation value system. Unlikely to be effects even on sensitive species.	≤1.0	≤1.5
B Some growth effect on up to 5% of species.	>1.0 and ≤2.4	>1.5 and ≤3.5
National Bottom Line	**2.4**	**3.5**
C Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.	>2.4 and ≤6.9	>3.5 and ≤9.8
D Impacts on growth of multiple species, and starts approaching acute impact level (that is, risk of death) for sensitive species at higher concentrations (>20 mg/L).	>6.9	>9.8
This attribute measures the toxic effects of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes may be more stringent.		

Table 3: NOF Attribute Table 20 – Dissolved reactive phosphorus. Source: MfE (2023).

Value (and component)	Ecosystem health (Water quality)	
Freshwater body type	Rivers	
Attribute unit	DRP mg/L (milligrams per litre)	
Attribute band and description	**Numeric attribute state**	
	Annual median	Annual 95th percentile
A Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to dissolved reactive phosphorus (DRP) enrichment are expected.	≤1.0	≤1.5
B Ecological communities are slightly impacted by minor DRP elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.	>1.0 and ≤2.4	>1.5 and ≤3.5
C Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.	>2.4 and ≤6.9	>3.5 and ≤9.8
D Impacts on growth of multiple species, and starts approaching acute impact level (that is, risk of death) for sensitive species at higher concentrations (>20 mg/L).	>6.9	>9.8
This attribute measures the toxic effects of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes may be more stringent.		

Monitoring of nutrients in Taranaki

In Taranaki, ammonia, nitrate, and DRP concentrations are monitored at 25 state of environment monitoring sites. Sampling is carried out monthly, regardless of weather and flow conditions, and has been undertaken at most sites since around 2004/2005. Additionally, NIWA undertakes monthly monitoring of ammonia, nitrate-nitrite nitrogen (NNN), and DRP concentrations at one additional site under the National River Water Quality Network (NRWQN). This site has a long-term record extending back to 1989. This brings the total number of long-term monitoring sites to 25 (Appendix A). These sites have been used to inform the setting of ammonia, nitrate, and DRP baseline states.

Baseline states for nutrients

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. If a waterbody is already at or below the national bottom line, then it must be improved to either achieve the national bottom line or better.

The baseline state is defined in Clause 1.4 (1) of the NPS-FM as the attribute's 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 (as amended in 2017) for nutrients, so the states of ammonia, nitrate, and DRP attributes under Clause 1.4 (b) could not be calculated and was excluded. Therefore the best state out of Clause 1.4 (a) and (c) were used to identify the baseline state for each of the nutrient 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, nutrient attributes are associated with the Ecosystem Health value, which is a compulsory value within the NOF (NPS-FM, Appendix 1A). Nitrate and ammonia are included in the NOF as Appendix 2A attributes, requiring the setting of limits, while DRP is an Appendix 2B attribute and requires the development of an action plan. It is necessary for baseline states to be identified by TRC for the Taranaki region to ensure that target attribute states for all nutrient criteria 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.

Under Clause 3.13, it is also a requirement that appropriate instream nutrient concentrations and exceedance criteria, or instream loads are set to support the achievement of target attribute states for any other attribute affected by nutrients. This includes providing for any downstream nutrient-sensitive receiving environments.

The remainder of this memo summarises the monitoring and work carried out by TRC to identify baseline states for nitrate, ammonia and DRP in the region's rivers.

Criteria for identifying site-based baseline states for nutrients

Site-specific baseline attribute states for ammonia, nitrate, and DRP concentrations are derived from monitored data. The numeric attribute states for each attribute are calculated from either:

- Complete data, defined as monthly monitored data for 90% of months in the 5-year period (Larned et al., 2018), or
- Partial data, defined as monthly monitored data that have no less than three years of measurements, as recommended by Milne et al., 2023. These data do not fit the previous time periods and filtering rules at the time but the monitoring for these data will continue on a long-term basis and with additional results in the future, these sites will assist in tracking progress toward target attribute states and freshwater outcomes.

The time periods and filtering rules used in the calculations of numeric attribute states are consistent with those used for sites in the NRWQN and in the neighbouring regions (Manawatū-Whanganui and Waikato). The numeric attribute bands for the median and 95th percentile concentrations of ammonia and nitrate are calculated over a five year state period (Whitehead et al., 2022). The numeric attribute bands for the median and 95th percentile concentrations of DRP are calculated over the five year state period as required by the NPS-FM. The NOF attribute states for ammonia, nitrate, and DRP concentrations are defined as the "worse" of the two associated numeric attribute states; for instance, if one numeric state shows an A band while the other shows a B band, the NOF attribute state will be graded a B.

All 95th percentile concentrations are calculated using the Hazen method. pH correction to ammonia is applied to adjust values to equivalent pH 8 values as required by the NPS-FM, following the methodology outlined in Hickey, 2014. Nitrate-nitrite-nitrogen (NNN) data is used in the absence of nitrate data. Censored values (values outside of the detection limit(s)) are handled following the methodology used by Larned et al (2018). Left censored values (values below the detection limit(s)) are replaced with imputed values generated using ROS (Regression on Order Statistics), following the procedure described in Larned et al. (2015).

Site-based baseline states

There are 25 monitoring sites in the Taranaki region with regular monitoring of nutrients, including one site operated by NIWA (Appendix A). Most sites have monthly monitoring records extending back to at least 2004/2005.

Ammonia achieved band A at 16 of the 25 sites (64%), while 8 sites (32%) achieved band B. Ammonia concentrations failed to achieve the national bottom line (band C) at one site (4%): the Waingongoro River upstream Mangawhero Stream confluence (WGG000620). This site is located approximately 4km downstream of Eltham and is likely impacted by industrial, municipal, and agricultural discharges as well as diffuse run-off in the vicinity of Eltham.

Nitrate achieved band A at 16 of 25 sites (64%), while 7 sites (28%) achieved band B. Nitrate concentrations failed to achieve the national bottom line (band C) at two (8%) Waiokura Stream sites (WKR000500 and WKR000700), within a catchment that lies exclusively in intensive dairy landscapes.

Dissolved reactive phosphorus achieved band A at 5 out of 25 sites (20%), while 3 sites (12%) achieved band B. Four sites (16%) achieved bands C and 13 sites (52%) band D. The majority of band C and D sites graded sites (15 out of 17; 88%) are located on the volcanic ring plain, reflecting naturally elevated phosphorus levels in the region's volcanic soils. The two sites located in the hill country are either impacted by industrial, municipal, and agricultural discharges (Tawhiti Stream at Duffy's, TWH000435) or potentially affected by a major erosion event in June 2015 (Whenuakura River at Nicholson Rd, WNR000450).

It should also be noted that the baseline median DRP concentrations at 8 monitoring sites exceeded the "saturating concentration" of 0.025 mg/l defined by Snelder et al (2021) as the nutrient concentration beyond which further increase in periphyton biomass is unlikely.

Since the site-specific baseline attribute states are derived from monitored data collected via the Council's state of environment water quality monitoring programme, some limitations of network monitoring design are therefore inherited by the site-specific attribute states and expressed as uncertainty. Two types of uncertainty have been identified by TRC. Firstly, under-representation of the natural variability is introduced by the inability of a discrete monthly sampling regime to adequately capture the "true" variability of water quality state. Secondly, lack of spatial representation arises from the limited spatial coverage of the existing monitoring network. Each type of uncertainty is identified and assessed in the following sections.

Maps of the site-specific baseline attribute states for ammonia, nitrate, and DRP concentrations at each state of environment monitoring site are presented in Figure 1, Figure 2 and Figure 3, respectively.

Table 4: Site-based baseline state for the ammonia attribute derived from monitored data at 25 monitoring sites in the Taranaki region. Sites with an asterisk (*) indicates where partial/incomplete data is used for baseline states setting.

FMU	Site Code	Clause 1.4(a) - from record starting date			Clause 1.4(c) - September 2017			Annual Median NOF Band	Annual 95th Percentile NOF Band	Ammonia NOF Overall
		n	median	95th	n	median	95th			
Southern Hill Country	*TWH000435	59	0.0150	0.0425	ND	ND	ND	A	A	A
	WNR000450	59	0.0151	0.0428	59	0.0151	0.0428	A	A	A
Pātea	MGH000950	61	0.0078	0.02415	60	0.00935	0.02075	A	A	A
	PAT000200	60	0.00155	0.00685	60	0.0017	0.0095	A	A	A
	PAT000360	60	0.04335	0.094	60	0.04485	0.08325	B	B	B
	*MKR000495	52	0.0152	0.04367	ND	ND	ND	A	A	A
Volcanic Ring Plain	WGG000500	65	0.0137	0.077225	60	0.01495	0.08085	A	B	B
	WGG000620	59	0.0899	0.75138	70	0.0397	0.4447	B	C	C
	MWH000498	58	0.1031	1.29952	60	0.0306	0.105	B	B	B
	WGG000640	63	0.1108	0.56384	60	0.0304	0.31095	B	B	B
	WGG000900	63	0.0229885	0.057269825	61	0.0288	0.08159	A	B	B
	PNH000200	60	0.00495	0.01585	60	0.007	0.02385	A	A	A
	PNH000900	60	0.0327	0.1413	60	0.0256	0.07575	A	B	B
	WKH000500	60	0.00565	0.0361	60	0.0069	0.025	A	A	A
	*WKR000500	52	0.0105	0.05957	ND	ND	ND	A	B	B
	WKR000700	60	0.01405	0.04555	59	0.0129	0.046095	A	A	A
	MRK000420	60	0.0123	0.07845	60	0.01165	0.05005	A	B	B
	KPA000950	58	0.0041	0.03344	58	0.0041	0.03344	A	A	A
	STY000300	60	0.0002	0.0089	60	0.0013	0.0101	A	A	A
Waitara	MTA000068	58	0.0032	0.01206	58	0.0032	0.01206	A	A	A
	MGN000195	64	0.0067	0.01595	63	0.0039	0.009605	A	A	A
	MKW000300	56	0.00505	0.02149	60	0.0061	0.02425	A	A	A
	WTR000540	59	0.0081	0.028215	59	0.0081	0.028215	A	A	A
	WTR000800	64	0.0102	0.02874	60	0.0108	0.02635	A	A	A
Northern Hill Country	WMR000100	59	0.0039	0.013555	59	0.0039	0.013555	A	A	A

Table 5: Site-based baseline state for the nitrate attribute derived from monitored data at 25 monitoring sites in the Taranaki region. Sites with an asterisk (*) indicates where partial/incomplete data is used for baseline states setting. Rows highlighted in blue represent when nitrate-nitrite-nitrogen (NNN) is used in place of nitrate data.

FMU	Site Code	Clause 1.4(a) - from record starting date			Clause 1.4(c) - September 2017			Annual Median NOF Band	Annual 95th Percentile NOF Band	Nitrate NOF Overall
		n	median	95th	n	median	95th			
Southern Hill Country	*TWH000435	59	2.1	2.9	ND	ND	ND	B	B	B
	WNR000450	59	0.387	0.57635	59	0.387	0.57635	A	A	A
Pātea	MGH000950	61	0.1	0.24755	60	0.088	0.3035	A	A	A
	PAT000200	60	0.02	0.0695	60	0.019	0.0445	A	A	A
	PAT000360	60	0.823	1.125	60	0.8625	1.287	A	A	A
	*MKR000495	52	0.365	0.804	ND	ND	ND	A	A	A
Volcanic Ring Plain	WGG000500	62	0.922	1.9492	60	1.127	1.914	A	B	B
	WGG000620	58	1.521	2.304	70	1.3005	2.032	B	B	B
	MWH000498	58	2.174	2.7968	60	1.4665	2.4045	B	B	B
	WGG000640	59	1.608	2.2968	60	1.2005	2.056	B	B	B
	WGG000900	65	1.62	2.42875	61	1.673	2.66275	B	B	B
	PNH000200	60	0.0295	0.1335	60	0.0385	0.144	A	A	A
	PNH000900	60	0.714	2.119	60	1.209	3.212	A	B	B
	WKH000500	60	0.084	0.269	60	0.139	0.2615	A	A	A
	WKR000500	58	2.69	3.51	57	2.72	3.71	C	C	C
	WKR000700	60	3.077	3.962	59	2.944	3.99595	C	C	C
	MRK000420	60	0.848	1.4015	60	0.8395	1.295	A	A	A
	KPA000950	58	0.37	0.96	58	0.37	0.96	A	A	A
	STY000300	60	0.02	0.054	60	0.019	0.065	A	A	A
Waitara	MTA000068	58	0.1855	0.684	58	0.1855	0.684	A	A	A
	MKW000300	56	0.2475	0.7163	60	0.3325	0.6425	A	A	A
	MGN000195	65	0.086	0.2075	63	0.099	0.2702	A	A	A
	WTR000540	59	0.185	0.4355	59	0.185	0.4355	A	A	A
	WTR000800	65	0.245	0.51	59	0.337	0.63185	A	A	A
Northern Hill Country	WMR000100	59	0.49	1.1155	59	0.49	1.1155	A	A	A

Table 6: Site-specific baseline state for DRP concentrations derived from monitored data at 25 monitoring sites in the Taranaki region. Orange colour indicates where partial data is used for baseline states setting.

FMU	Site Code	Clause 1.4(a) - from record starting date			Clause 1.4(c) - September 2017			Annual Median NOF Band	Annual 95th Percentile NOF Band	DRP NOF Overall
		n	median	95th	n	median	95th			
Southern Hill Country	*TWH000435	59	0.026	0.04355	ND	ND	ND	D	C	D
	WNR000450	59	0.016	0.0251	59	0.016	0.0251	C	B	C
Pātea	MGH000950	61	0.004	0.01245	60	0.0055	0.011	A	A	A
	PAT000200	60	0.015	0.03	60	0.0225	0.037	C	B	C
	PAT000360	60	0.0375	0.0675	60	0.036	0.0805	D	D	D
	*MKR000495	52	0.00555	0.01904	ND	ND	ND	A	A	A
Volcanic Ring Plain	WGG000500	63	0.013	0.02735	60	0.029	0.0665	C	B	C
	WGG000620	59	0.068	0.63915	70	0.035	0.15	D	D	D
	MWH000498	58	0.112	1.242	60	0.027	0.0595	D	D	D
	WGG000640	63	0.119	0.36825	60	0.035	0.1045	D	D	D
	WGG000900	65	0.025	0.066	61	0.048	0.0797	D	D	D
	PNH000200	60	0.02	0.033	60	0.022	0.0395	D	C	D
	PNH000900	60	0.034	0.0825	60	0.0535	0.0845	D	D	D
	WKH000500	60	0.019	0.038	60	0.029	0.0515	D	C	D
	WKR000500	57	0.032	0.061	57	0.036	0.06395	D	D	D
	WKR000700	60	0.032	0.0575	59	0.032	0.0699	D	D	D
	MRK000420	60	0.0065	0.0245	60	0.0105	0.0285	B	B	B
	KPA000950	58	0.0195	0.0418	58	0.0195	0.0418	D	C	D
	STY000300	60	0.015	0.026	60	0.019	0.0295	C	B	C
Waitara	MTA000068	58	0.0028	0.01	58	0.0028	0.01	A	A	A
	MKW000300	56	0.022	0.035	60	0.0295	0.047	D	C	D
	MGN000195	65	0.01	0.01725	63	0.0092	0.015185	B	A	B
	WTR000540	59	0.006	0.01355	59	0.006	0.01355	A	A	A
	WTR000800	65	0.004	0.01175	60	0.00585	0.01545	A	A	A
Northern Hill Country	WMR000100	59	0.0092	0.015	59	0.0092	0.015	B	A	B

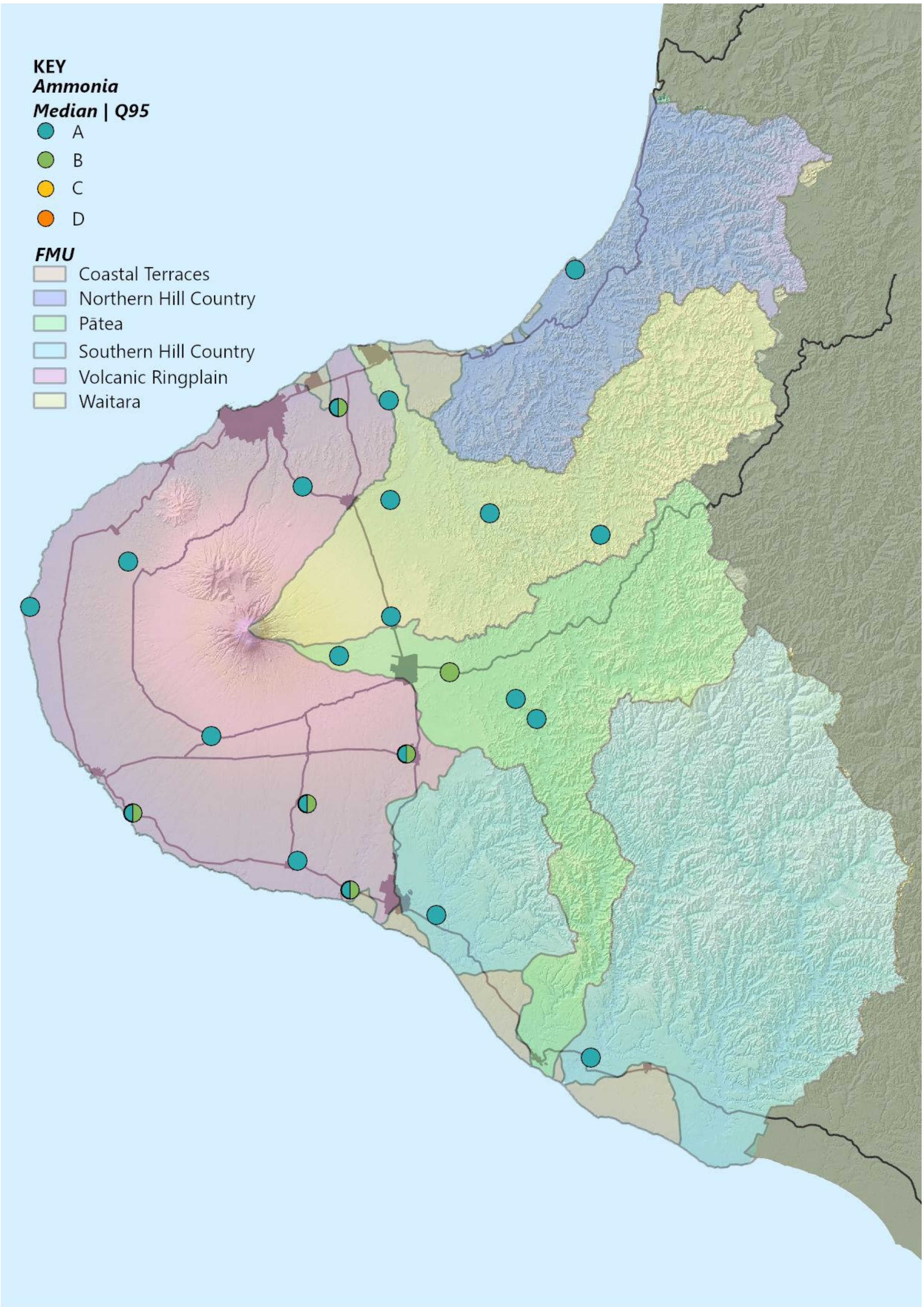

Figure 1: The baseline state of ammonia concentrations at each state of environment monitoring site, assessed against the NOF for both median and 95th concentrations.

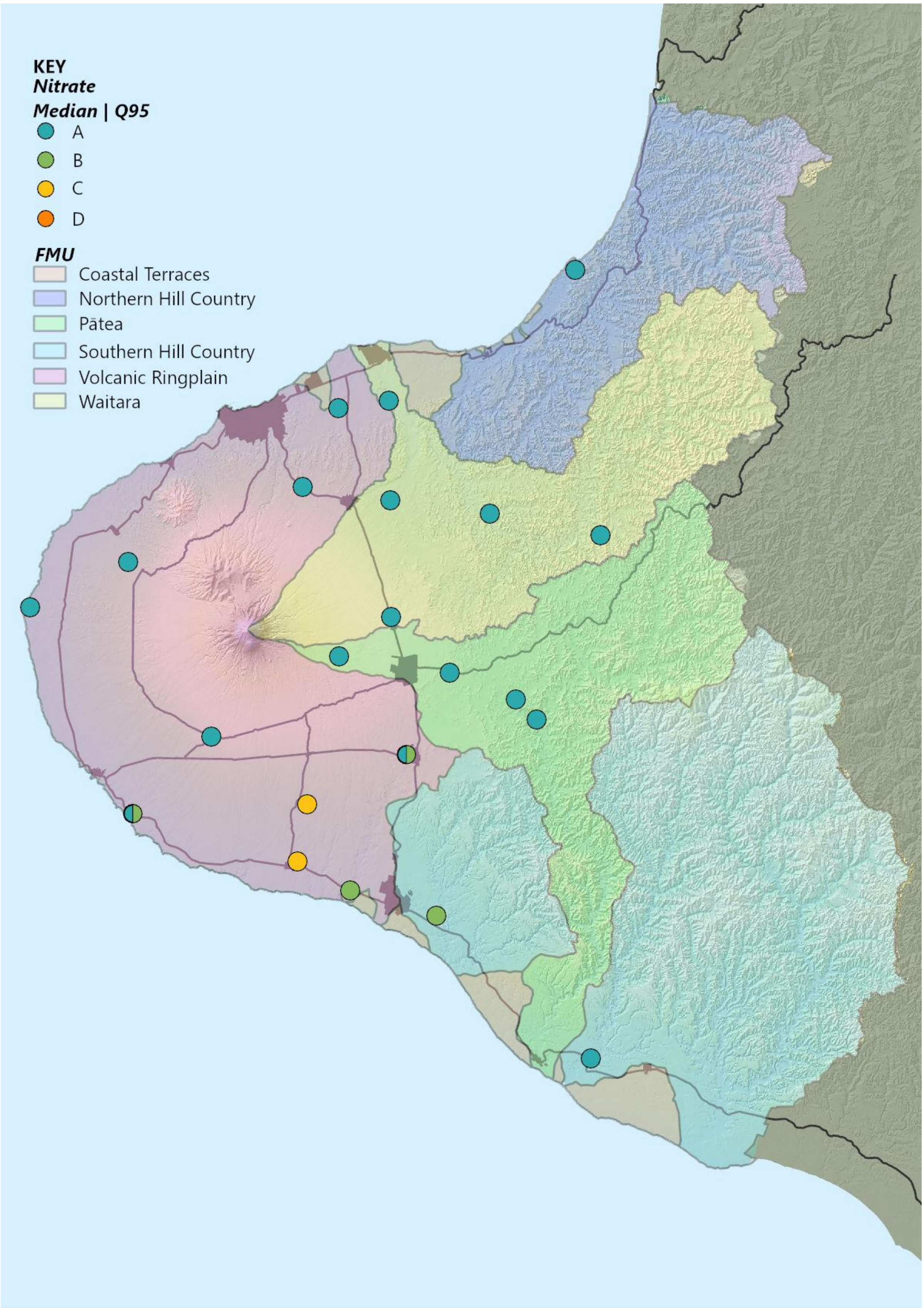

Figure 2: The baseline state of nitrate concentrations at each state of environment monitoring site, assessed against the NOF for both median and 95th concentrations.

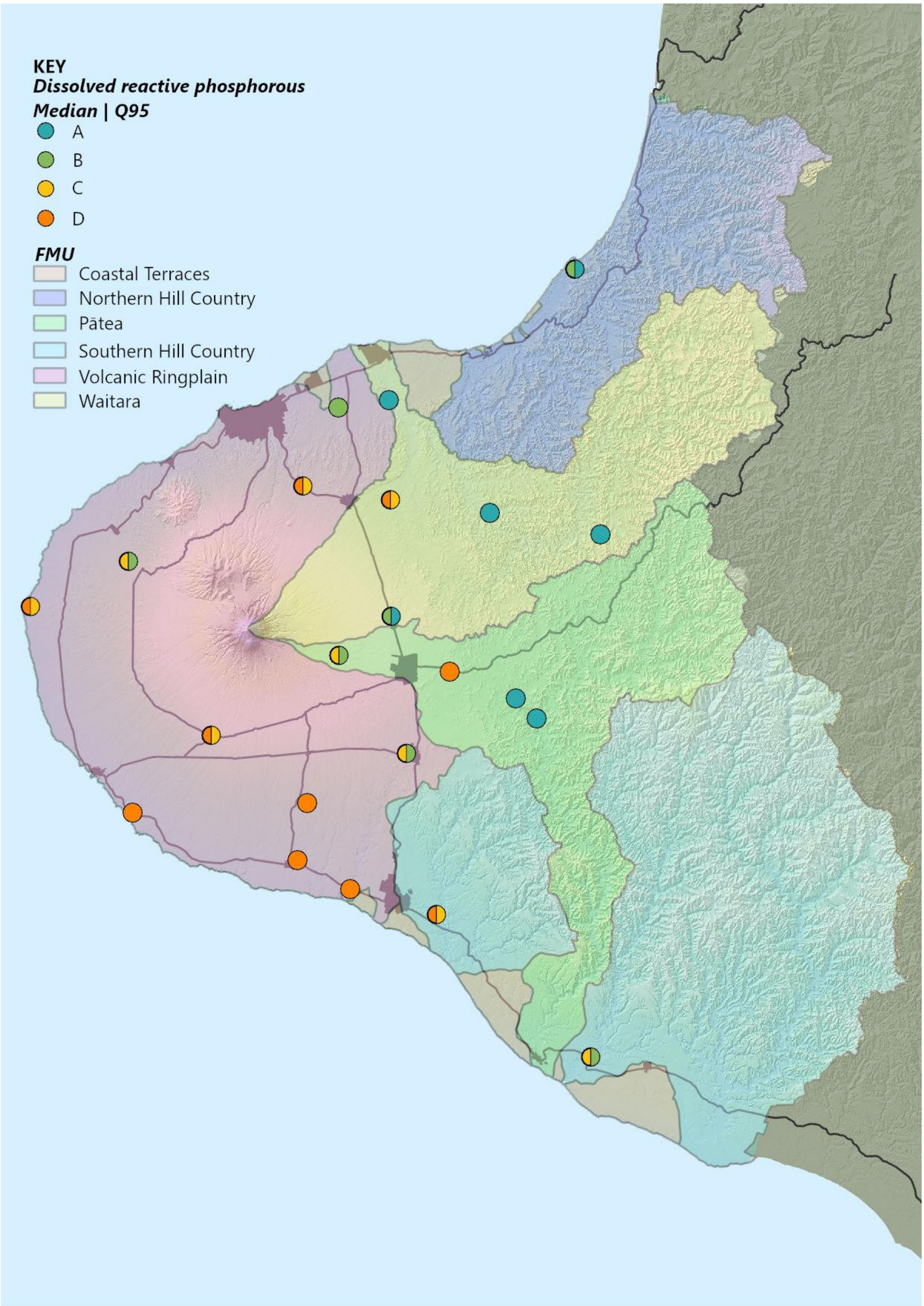

Figure 3: The baseline state of DRP concentrations at each state of environment monitoring site, assessed against the NOF for both median and 95th concentrations.

Baseline period and temporal state variability

This baseline assessment has been carried out using data that demonstrates the best state, out of the baseline periods defined in the NPS-FM. The council has not previously set freshwater objectives for nutrient attributes, and therefore sub-clause 1.4(b) is not applicable.

Clause 3.10(4) of the NPS-FM states that “attribute states and baseline states may be expressed in a way that accounts for natural variability and sampling error”. Acknowledging the natural variability of attribute states informs target attribute states (TAS) setting and long-term vision/objectives development at a site-specific level. This section discusses the uncertainty associated with setting site-specific baseline states that originates from the natural variability of water quality states and outlines the steps TRC is taking to address the uncertainty.

Site-specific water quality attribute states derived from monthly monitored data are potentially uncertain (Snelder and Kerr, 2020). This is largely due to the changing nature of short-term flow regimes, linked to how chemicals are transported, concentrated, and diluted by hydrological flow paths and instream processes (Cassidy et al. 2018). A discrete (a single water sample collected in an individual container) monthly sampling regime is only able to provide a snapshot of the “true” water quality state over the assessment period and consequently does not capture temporally representative data. Because the assessments of attribute state are based on a collection of discrete values, they should therefore be considered as model outputs that contain unavoidable uncertainty (Snelder and Kerr, 2020).

In addition, variability in the five year flow regime produces another source of uncertainty in attribute state assessments. This uncertainty is associated with the fact that the flow regime at a monitoring site for any five year assessment period is unlikely to be a perfect representation of the long-term flow regime. The flow regime can be expected to vary significantly across state assessment periods. Therefore, the attribute state assessments can also be expected to vary over time in response to changes in flow (Snelder and Kerr, 2020).

Despite the aforementioned uncertainties associated with deriving baseline attribute states from monitored data, the site-specific numeric and NOF attribute states derived from complete data records are still considered the best estimates of the water quality state (Snelder and Kerr, 2020). However, it has been recommended that the attribute states derived from monitored data should be interpreted as the “best information at the time” and the uncertainty of the assessment is not an adequate reason to delay giving effect to the NPS-FM (Snelder and Kerr, 2020).

To evaluate the temporal variations of ammonia, nitrate, and DRP attribute states, an analysis has been performed by Land Water People Ltd. (LWP) (Fraser, 2022) comparing five year rolling numeric and NOF attribute states at monitoring sites where long-term data records are available. The outcome of the analysis is presented in the following section.

The numeric bands and NOF attribute bands for ammonia, nitrate, and DRP at a sub-set of monitoring sites (sites with long-term data records) are calculated for all 5-year periods from 1st July 2000 to 31st December 2017. The results are presented in Figure 4, Figure 5 and Figure 6.

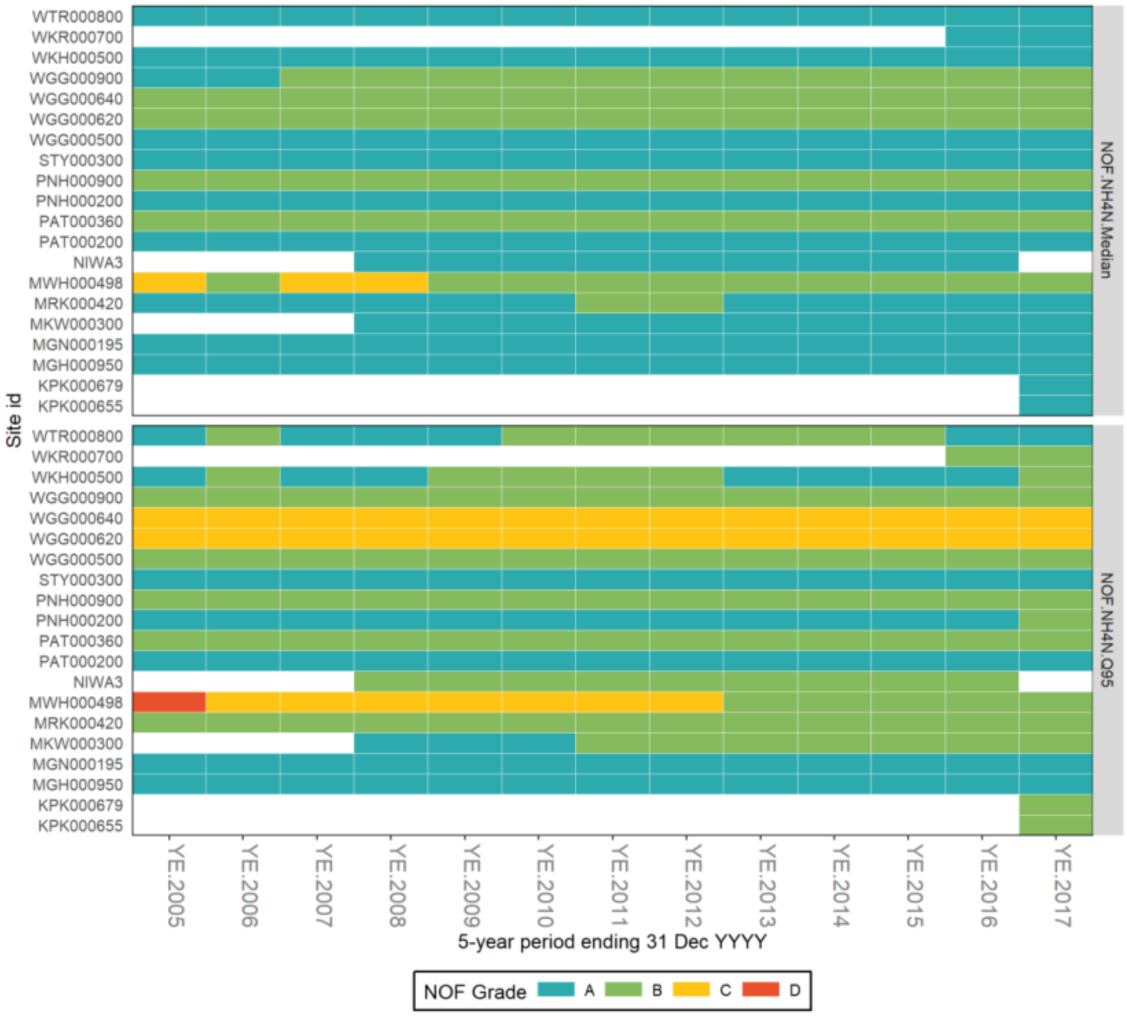

Figure 4: Temporal variation in NOF attribute bands for ammonia at a sub-set of monitoring sites from 2005 to 2017.

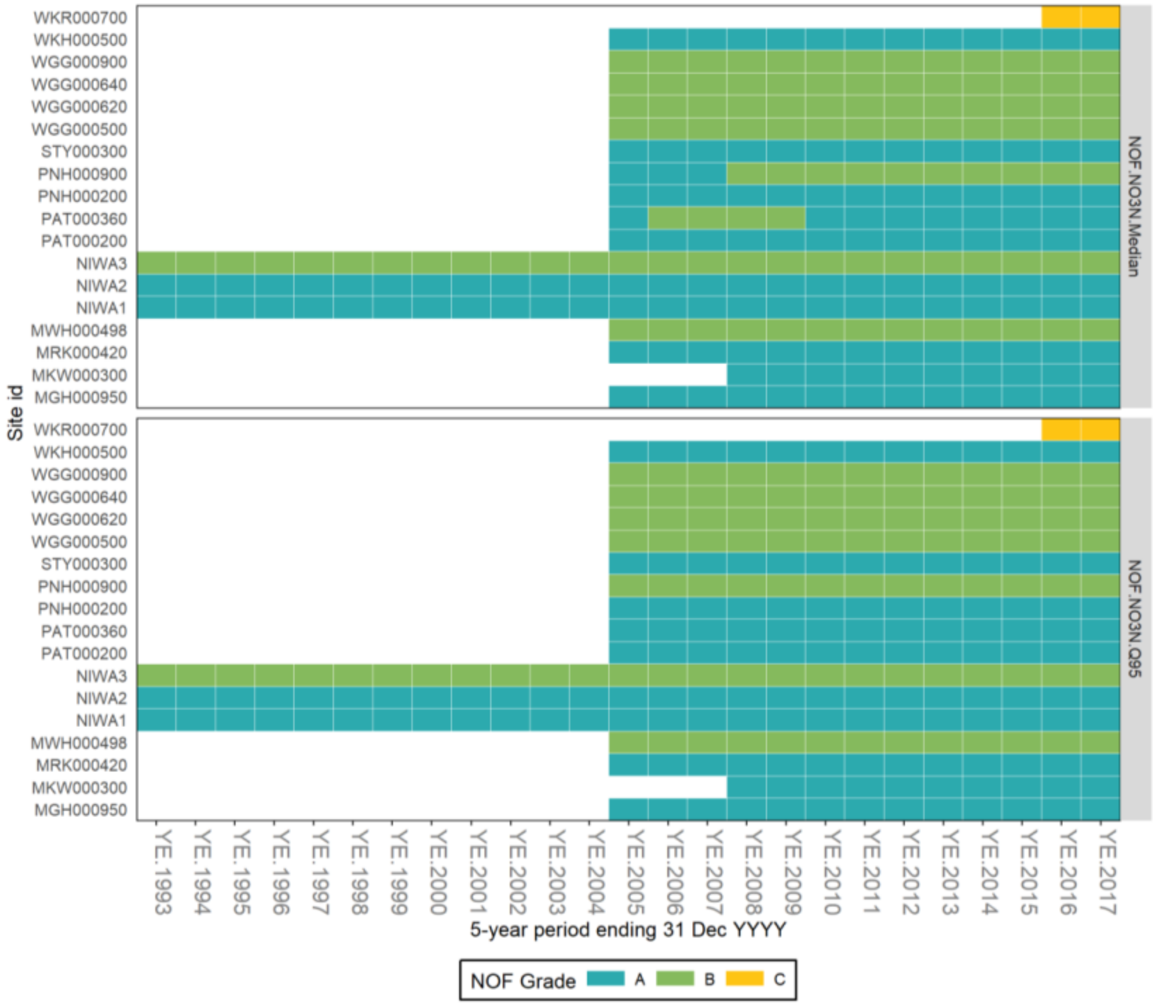

Figure 5: Temporal variation in NOF attribute bands for nitrate at a sub-set of monitoring sites from 1993 to 2017.

Figure 6: Temporal variation in NOF attribute bands for DRP at a sub-set of monitoring sites from 1993 to 2017.

In summary, the temporal variations of ammonia, nitrate, and DRP numeric attribute states are mostly stable from 1st July 2000 and 31st December 2017. The NOF attribute states only fluctuate between neighbouring bands (e.g. from A to B). However, the numeric attribute states for ammonia and DRP exhibit higher degrees of temporal variation than those of nitrate. Rolling attribute state analysis reveals that the NOF attribute states for ammonia and DRP vary temporally at a number of sites across the Waingongoro, Punehu, Pātea , Mangaehu, Waitara and Mangaoraka catchments (at sites WGG000620, WGG00640, PNH000200, PAT000200, MGH000950 and WGG000500, STY000300, PAT000200, WTR000800 / NIWA1, MGN000195 / NIWA2, and MRK000420). The numeric attribute states for nitrate remains consistent temporally at all assessed sites, except PAT000360.

A number of sites are located in upper catchments on the volcanic ring plain, sourced from within the Te Papakura o Taranaki where anthropogenic influence is likely to be negligible. Therefore, it is reasonable to assume that the temporal variations in ammonia attribute states at the Punehu Stream and Wiremu Road and Pātea River at Barclay Road Bridge sites (PNH000200 and PAT000200, respectively), and DRP attribute states at the Stony River at Mangatete Road, River at Barclay Road Bridge and Manganui River Upstream of Railbridge sites (STY000300, PAT000200, MGN000195, respectively) are the result of natural variability.

Four sites in the Waingongoro, Mangawhero and Pātea catchment (sites WGG000620, WGG00640, MWH000498, and PAT000360) are located downstream of major municipal and industrial point discharges.

Anthropogenic variability is a likely contributor to the temporal variations in ammonia (WGG000620, WGG00640) and nitrate (PAT000360) concentrations at these sites.

Five sites located in the Mangawhero, Mangaehu, Waingongoro, Waitara and Mangaoraka catchment (sites MWH000498, MGH000950, WGG000500, WTR000800, and MRK000420) are located in the mid- or lower-catchments, downstream of multiple point source discharges and diffuse sources. It is difficult to separate anthropogenic variability from natural variability at these sites.

Freshwater Management Unit (FMU) coverage and representativeness

The site-specific baseline setting approach introduces monitoring site selection biases and limited spatial representation to the baseline setting process, resulting in spatial under- or over-representation of regions, catchments, and rivers with certain characteristics. An assessment of the representativeness (Fraser, 2022) of the existing monitoring network (and subsequently baseline attribute states) at regional, catchment, and local levels is as follows:

At a regional level, the monitoring sites do not adequately cover all FMUs. Most notably, the Coastal Terrace FMU is not previously or currently monitored by TRC on a regular long-term basis. In addition, the Northern Hill Country FMU is under-represented in the monitoring network with only one monitoring site.

At a catchment level, the monitoring sites generally over-represent catchments with:

- mean annual temperature <12°C;
- mean annual effective precipitation >1500mm;
- 50% of the cumulative rainfall volume fell between 400m and 1000m;
- volcanic acidic dominant geology, and pastoral land cover.

and under-represent catchments with:

- mean annual temperature ⩾12°C;
- mean annual effective precipitation <500mm and ⩾1500mm;
- 50% of the cumulative rainfall volume fell above 1000m;
- alluvium and soft-sedimentary dominant geology, urban, scrub, exotic and indigenous forest land cover.

At a local level, the monitoring sites over-represent low-gradient, mid- and high-order river sections and under-represent high-gradient, low-order river sections.

To mitigate the limited spatial coverage of the available data records, modelling has been used to make predictions of the baseline state for each nutrient metric, at the river reach scale, across the entire Taranaki region. The modelling, carried out by Land Water People Ltd. (LWP) (Fraser, 2022) incorporates long-term water quality data from monitoring sites in the Taranaki, Manawatū-Whanganui, and Waikato regions, and provides a more representative, broad-scale assessment of spatial patterns of ammonia, nitrate, and DRP concentrations than is achievable based on monitoring data from individual sites alone. The modelled data are based on a digital drainage network of the Taranaki region that includes a range of catchment descriptors: geography and topography, climate, hydrology, geology, land cover and stocking density data.

The use of modelled data allows for an assessment of baseline states across both monitored and unmonitored waterways in the Taranaki region. Using modelled data, baseline states can be identified for each FMU, expressed as percentage waterway length in each FMU within each NOF attribute band.

Assessments of model uncertainty suggest good and very good model performance for median and 95^{th} nitrate concentrations respectively and unsatisfactory model performance for median and 95^{th} ammonia and DRP concentrations at individual river segments (Fraser, 2022).

While modelled water quality data made for individual river segments are uncertain, modelled data adequately reflect broad-scale spatial patterns in water quality and can be used to make comparisons between locations (Fraser, 2022). The FMU-scale spatial assessment also provides an opportunity for TRC to develop long-term vision/objectives for freshwater at FMU (potentially sub-FMU or catchment) level and inform resource use limit setting and action plan development. This assessment recognises that environmental outcomes are intended to be achieved for all waterbodies rather than only at a select few monitoring sites.

FMU-based baseline states

Modelled NOF attribute bands reflect broad-scale spatial patterns in ammonia, nitrate, and DRP concentrations in Taranaki. The least nutrient-enriched areas are generally located in the upper and middle catchments in the eastern hill country, in the northern part of the region, and within Te Papakura o Taranaki. The most nutrient-enriched areas are generally located along the coastal areas (particularly on the western and southern coasts) and lowland areas around the volcanic ring plain.

A tabulated summary of FMU-scale spatial assessments for ammonia, nitrate, and DRP concentrations in the five year period ending December 2017 is represented in Table 7. Modelled NOF bands for ammonia, nitrate, and DRP concentrations in Taranaki are represented in Figure 7, Figure 8 and Figure 9, respectively.

Table 7: Spatial assessment at FMU-scale for ammonia, nitrate, and DRP concentrations in the five year period ending December 2017, expressed as percentage waterway length in each FMU within each NOF attribute band.

NOF Band	No. sites	Ammonia				Nitrate				DRP			
		A	B	C	D	A	B	C	D	A	B	C	D
Southern Hill Country	2	81.8%	18.2%	0.0%	0.0%	85.0%	15.0%	0.0%	0.0%	0.0%	21.3%	55.4%	23.3%
Coastal Terraces	0	7.7%	92.1%	0.0%	0.0%	12.1%	87.8%	0.1%	0.0%	0.2%	2.7%	2.6%	94.5%
Pātea	4	68.2%	31.8%	0.0%	0.0%	76.1%	23.9%	0.0%	0.0%	0.0%	31.7%	33.3%	35.0%
Volcanic Ring Plain	13	26.5%	73.4%	0.03%	0.0%	31.0%	68.9%	0.1%	0.0%	0.0%	1.6%	14.5%	83.9%
Waitara	5	65.6%	34.4%	0.0%	0.0%	76.7%	23.3%	0.0%	0.0%	0.0%	34.7%	24.0%	41.3%
Northern Hill Country	1	95.2%	4.8%	0.0%	0.0%	12.1%	87.8%	0.1%	0.0%	0.2%	2.7%	2.6%	94.5%

These percentages provide an indication of the broad-scale spatial patterns for ammonia, nitrate, and DRP concentrations in the region. The modelled water quality data used in spatial assessment contain uncertainties. These uncertainties arise from the varying degrees of the model performance among these numeric attributes may reflect the varying degrees of influence some biophysical processes have on instream nitrogen and phosphorus concentrations respectively. Some of these biophysical processes may be poorly represented by the TRC spatial model. Examples of such processes include adsorption-desorption processes, deposition and suspension, biological assimilation, transformation, and removal (Fraser, 2022).

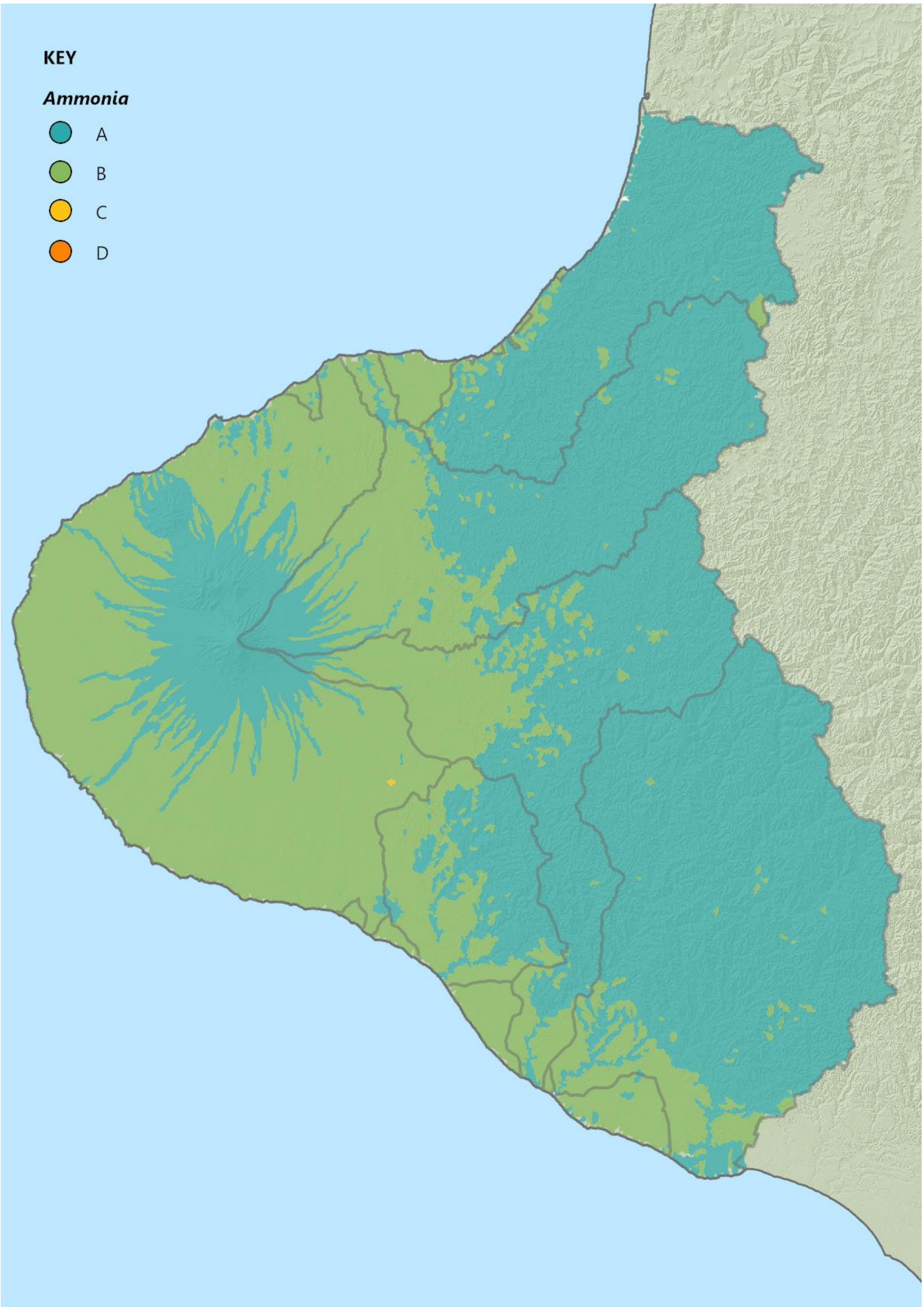

Figure 7: Modelled NOF attribute bands for ammonia concentrations the 5-year period ending December 2017 in the Taranaki region.

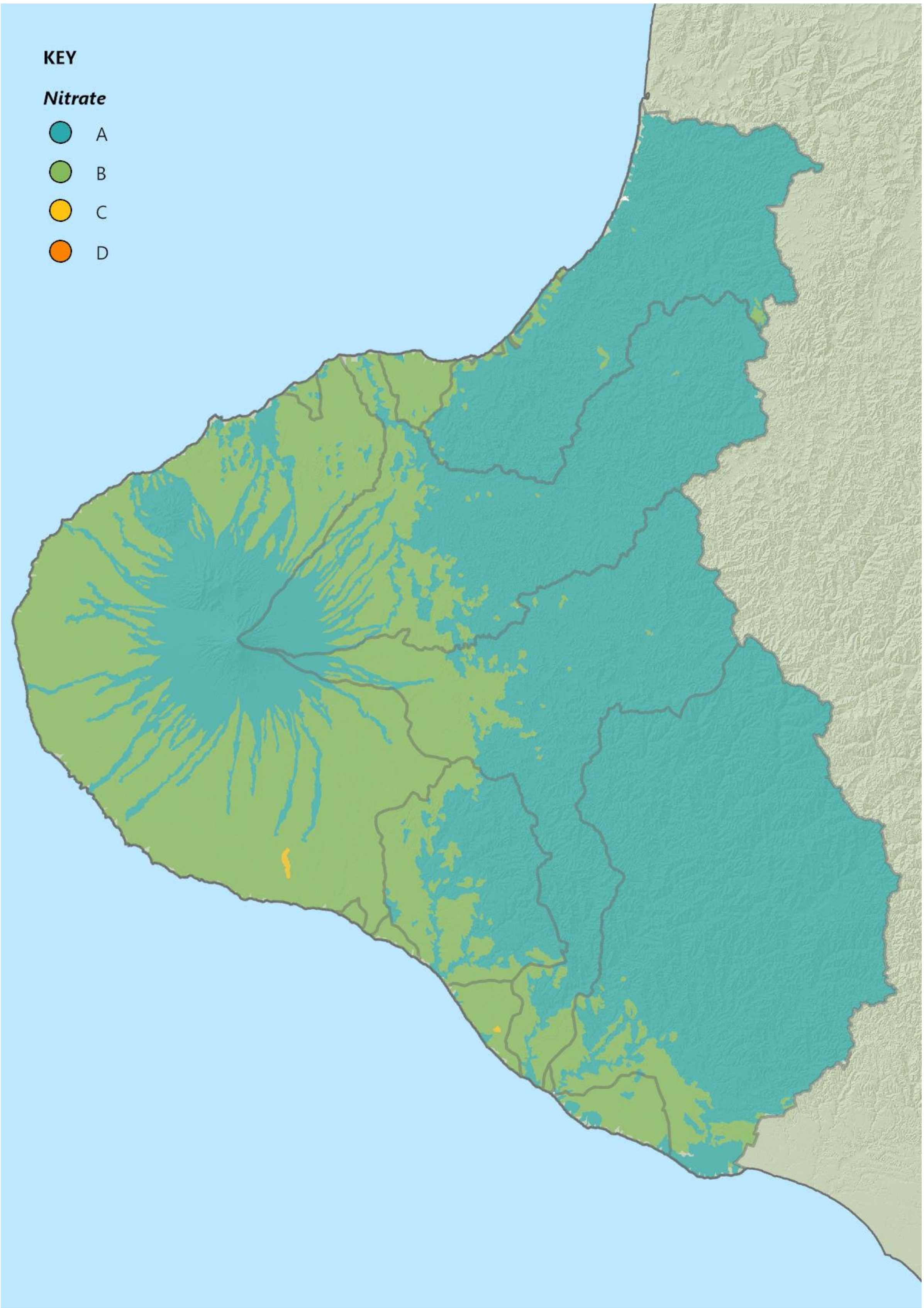

Figure 8: Modelled NOF attribute bands for nitrate concentrations the 5-year period ending December 2017 in the Taranaki region.

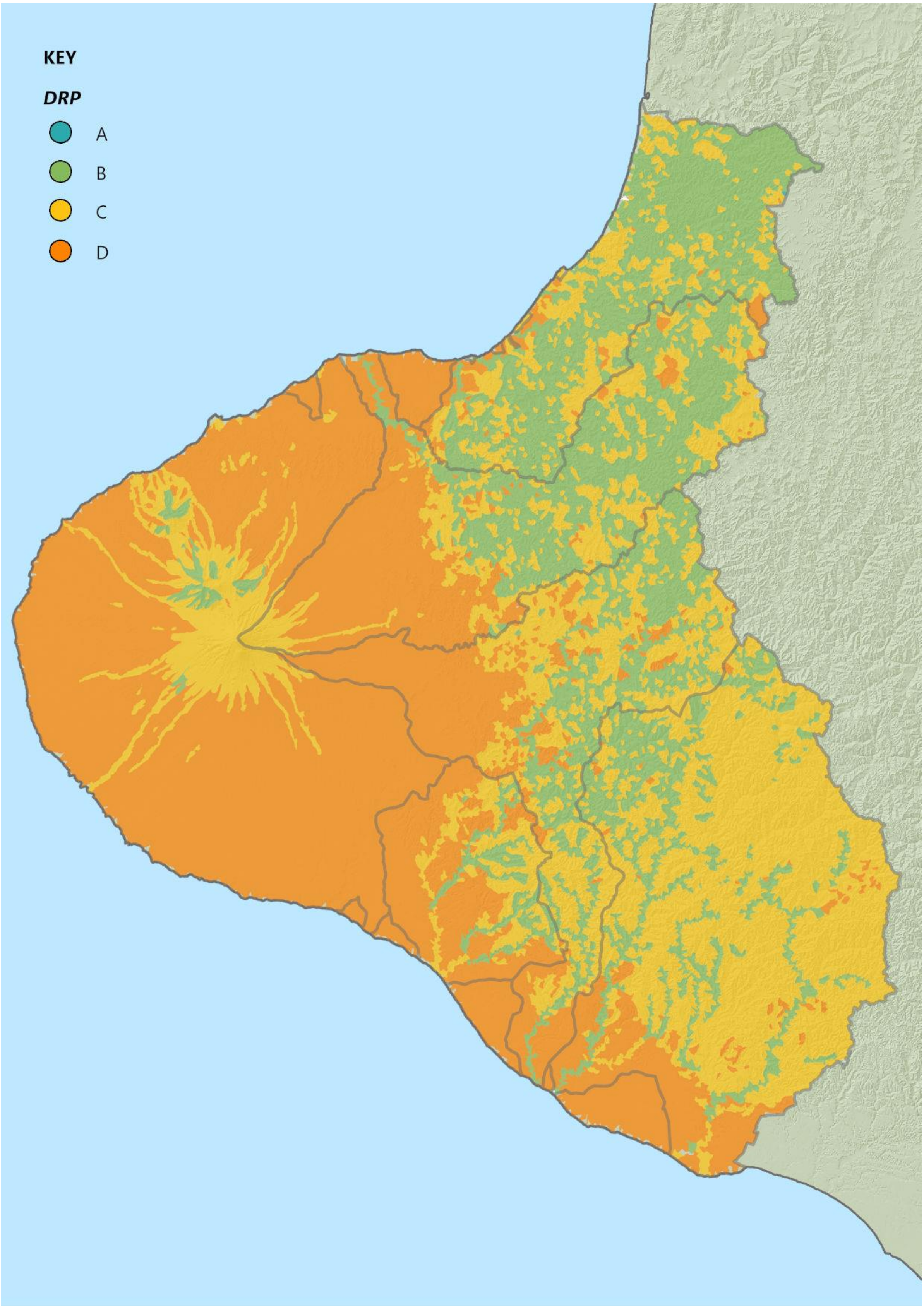

Figure 9: Modelled NOF attribute bands for DRP concentrations the 5-year period ending December 2017 in the Taranaki region.

Recommendations

Baseline states have been calculated for both monitoring sites and the stream network, to provide the best known state for nutrient attributes as an indicator of ecosystem health across each FMU.

Target attribute states will need to be set at a level that (at a minimum) achieves the best baseline state identified for each monitoring site, or exceeds the baseline state where this is necessary to achieve improvement. Consideration should be given as to whether target states should be set at broader spatial scales (e.g. at catchment or FMU scale) as well as at specific sites.

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 in relation to nutrients and more broadly, ecosystem health.

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Appendix A: Nutrient state of environment monitoring sites used for baseline states identification within each FMU

Freshwater Management Unit (FMU)	River/stream	Site name	Site code	Location	
				Easting	Northing
Southern Hill Country	Tawhiti Stream	Duffys water level recorder	TWH000435	1732757	5615551
	Whenuakura River	Nicholson Rd	WNR000450	1732757	5598479
Pātea	Mangaehu River	Raupuha Rd	MGH000950	1726300	5639062
	Makuri Stream	30m D/S Raupuha Rd	MKR000495	1723795	5641478
	Pātea River	Barclay Rd	PAT000200	1702620	5646598
		Skinner Rd	PAT000360	1715919	5644681
Volcanic Ringplain	Kapoaiaia Stream	Cape Egmont	KPA000950	1665690	5652452
	Mangaoraka Stream	Corbett Road	MRK000420	1702538	5676320
	Mangawhero Stream	D/s Mangawharawhara	MWH000490	1710795	5632738
	Punehu Stream	Wiremu Rd	PNH000200	1687323	5637020
		SH45	PNH000900	1677946	5627786
	Hangatahua (Stony) River	Mangatete Road	STY000300	1677460	5657823
	Waingongoro River	Eltham Rd	WGG000500	1710576	5634824
		U/S Mangawhero River confluence	WGG000620	1710708	5632961
		D/S Mangawhero River confluence	WGG000640	1710554	5632790
		SH45	WGG000900	1703943	5618570
	Waiwhakaiho River	SH3 (Egmont Village)	WKH000500	1698297	5666893
	Waiokura Stream	Skeet Rd	WKR000500	1698807	5628892
		Manaia Golf Course	WKR000700	1697636	5622019
Waitara	Manganui River	SH3	MGN000195	1708871	5651282
	Maketawa Stream	Tarata Road	MKW000300	1708784	5665231
	Matau Stream	U/s confluence with unnamed trib.	MTA000068	1733965	5661062
	Waitara River	Autawa Road	WTR000540	1720719	5663669
		Bertrand Road (NRWQN)	WTR000800	1708576	5677176
Northern Hill Country	Waikaramarama Stream	Waikaramarama Road - D/S of first bridge	WMR000100	1730866	5692865