Technical assessments undertaken to inform the target attribute state framework of proposed Plan Change 1 to the Natural Resources Plan for the Wellington Region

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Glossary

Term	Meaning
BSP	Biophysical Science Programme (for Whaitua Te Whanganui-a-Tara)
CFU	Colony Forming Unit
CMP	Collaborative Modelling Programme
Cu	Copper
DFS	Deposited fine sediment
DGV	Default Guideline Value from the Australian and New Zealand guidelines for fresh and marine water quality
DIN	Dissolved inorganic nitrogen
DRP	Dissolved reactive Phosphorus
E. coli	*Escherichia coli*
EQR	Ecological Quality Rating (for macroalgae)
GW	Greater Wellington
LakeSPI	Lake Submerged Plant Indicators
NH_4-N	Ammoniacal – nitrogen
NRP	Natural Resources Plan (for the Wellington Region)
NPS-FM	National Policy Statement for Freshwater Management
NO_3-N	Nitrate – nitrogen
NOF	The National Objectives Framework
NOs	Nutrient outcomes (as defined in Clause 3.13 of the NPS-FM 2020)
Part-FMU	Part Freshwater Management Unit
PC1	Plan Change 1 (to the Natural Resources Plan)
REC	River Environment Classification
SFS	Suspended Fine Sediment (as measured by visual clarity)
TAG	Technical Advisory Group
TAoP	Te Awarua-o-Porirua
TAS	Target attribute state
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
Whaitua	Whaitua is the Māori word for catchment or space. The Wellington Region is divided into five whaitua, which will eventually each have a Whaitua Committee responsible for them.
WMU	Water Management Unit (used in TAoP WIP)
WTWT	Whaitua Te Whanganui-a-Tara
WIP	Whaitua Implementation Programme
Zn	Zinc

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1 Introduction

1.1 Background and report objectives

Plan Change 1 (PC1) to the Natural Resources Plan (NRP) for the Wellington Region will implement the National Policy Statement for Freshwater Management (NPS-FM) 2020 for Te Awarua-o-Porirua (TAoP) Whaitua and Whaitua Te Whanganui-a-Tara (WTWT). This involves setting objectives, policies, rules and other methods to manage activities such as urban development, earthworks, stormwater, wastewater and rural land use. Accordingly, PC1 will:

- Define Target Attribute States ('TASs') for the compulsory attributes in Appendix 2 of the NPS-FM 2020;
- Set equivalent coastal water quality and ecology objectives ('coastal objectives'); and
- Establish provisions that will contribute to the achievement of those TASs and coastal objectives.

The TASs and coastal objectives in PC1 will be based on those published by WTWT and TAoP Whaitua Committees ('the Committees) in their Whaitua Implementation Programmes ('WIPs'). However, a Technical Advisory Group[1] ('TAG') and other experts commissioned by Greater Wellington (GW) to provide specific pieces of advice have recommended that the WIP approach be refined prior to being adopted in PC1 to ensure robustness and consistency with current national policy. The purpose of this report is to document the technical assessments that informed those recommended refinements to ensure transparency in the PC1 TAS and coastal objective setting process (as required by Clause 3.6 of the NPS-FM 2020).

1.2 Structure of report

This report collates the technical memoranda provided to GW by internal and external technical experts during the PC1 TAS development process. In Part 1 the purpose and conclusions of each of these memoranda are:

- Summarised; and
- Incorporated into a set of recommended TASs and coastal objective tables for WTWT and TAoP Whaitua.

The bodies of each of these memoranda are then reproduced in Part 2 (Section 3 to Section 13) and their supplementary material provided in Appendix A to J.

Note – In general, only those minor formatting and editorial changes necessary to ensure consistency in appearance and terminology have been made to the memoranda in Part 2. However, the lead author of this report (Dr Michael Greer) has made new additions to some memoranda to account for relevant technical advice or policy changes that has arisen after their publication. These additions have been made at the end of the relevant memorandum in new, clearly labelled, sub-sections.

1 Membership = Mr Ned Norton (Land Water People Ltd), Mr James Blyth (Taylor Collaborations Ltd), Mr Brent King (GW) and Dr Michael Greer (Torlesse Environmental Ltd).

1.3 Scope and limitations

- The specific matters covered in this report are:
    - The part Freshwater Management Units (part-FMUs) and sites for which TASs and coastal objectives should be set;
    - How baseline states, TASs and nutrient outcomes should be set to ensure consistency with both the *intent* of the WIPs and the requirements of the NPS-FM 2020;
    - The sediment load reductions needed to meet the suspended fine sediment (SFS; as measured by visual clarity) TASs and the coastal objectives for sedimentation rate (TAoP only);
    - The need for a conservative approach to managing heavy metal losses in the TAoP whaitua; and
    - The alignment between existing water quality standards/objectives in the NRP and the TASs.
- This report does not cover the full range of topics that GW will need to produce expert evidence on during the PC1 hearing process. Rather it is intended to inform the PC1 S32 report, and, in tandem with Greer (2023a, 2023b), transparently document the technical work that has been completed since the WTWT and TAoP WIPs were published. Consequently, detailed introductions to the freshwater and coastal environments in TAoP and WTWT, the NPS-FM 2020 and the NRP are not provided.
- The recommendations made in this report were made by technical experts based on the best available information. However, whether they are adopted in PC1 is ultimately a policy decision to be made by GW.

Part 1 – Synthesis of technical work conducted during the development of PC1

At the beginning of the PC1 development process Aquanet Consulting Ltd (now Traverse Environmental Ltd) conducted a detailed review of the TAoP and WTWT WIPs and associated technical reports. This review identified a number of issues with the approach to setting the WIP targets and objectives that need to be addressed in order to ensure that PC1's TASs and coastal objectives are robust, defensible and measurable. Each of these identified issues, and how they have been addressed, are summarised in Section 2.1 to Section 2.9.

2 Summary of technical issues identified with WIP approach and the recommended approach for resolving them

2.1 Issue 1: The TAoP and WTWT WIPs do not set TASs at the site scale as required by the NPS-FM 2020 (full detail in Section 3)

The WTWT and TAoP WIPs split those whaitua into different 'management zones'[2] and set TASs that apply across the entirety of those management zones (i.e., all rivers must meet the TAS). In contrast, the NPS-FM 2020 requires regional councils to "*identify the site or sites to which the TASs target attribute state applies*". To address this difference in approach, GW commissioned Collaborations (Taylor Collaborations Ltd) to define a TASs site list based on the existing monitoring network that captures the variability between the WIP TASs without imposing arduous and redundant monitoring restrictions on GW (i.e., by requiring monitoring at multiple sites with similar current states, catchment characteristics and future mitigations).

The TASs site list developed by Collaborations was then used to further refine the management zones in the WIPs into part-FMUs for inclusion in PC1. The philosophy behind this refinement process was:

- Each part-FMU ideally has a single TAS site;
- The management units recommended in the WIPs are an appropriate starting point for selecting part-FMUs; and
- The list of TAS sites recommended by Collaborations provides an appropriate indication of where TASs need to be set to detect the impact of practice change on water quality and ecology across the TAoP Whaitua and WTWT. As such, overlaying that list of sites with the management units in the WIPs is an appropriate method of identifying where those management units need to be refined.

The recommended PC1 part-FMU and TAS site framework developed through this process is set out in Table 1.

[2] Referred to as Water Management Units (WMUs) in the TAoP WIP and Sub-catchment areas in the WTWT WIP.

Table 1: Recommended part-FMUs and TASs sites for TAoP Whaitua and WTWT.

Whaitua	Catchment	Recommended part-FMUs	Recommended TAS site
TWT	Te Awa Kairangi, Ōrongorongo and Wainuiomata	Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Ōrongorongo	Whakatikei R. @ Riverstone
		Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott
		Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua
		Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.
		Waiwhetū Stream	Waiwhetū S. @ Whites Line E.
		Wainuiomata urban streams	Black Ck @ Rowe Parade end
		Wainuiomata rural streams	Wainuiomata R. DS of White Br.
	South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels
	Korokoro catchment	Korokoro Stream	Korokoro S.@ Cornish St. Br.
	Wellington urban catchment	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge
		Wellington urban	Karori S. @ Mākara Peak
TOaP		Taupō	Taupō S. @ Plimmerton Domain
		Pouewe	Horokiri S. @ Snodgrass
		Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.
		Takapū	Pāuatahanui S. @ Elmwood Br.
		Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot

2.2 Issue 2: The TAoP WIP does not include TASs for the compulsory attributes introduced in the NPS-FM 2020 and the WTWT targets for many of those attributes were set based on limited data (full detail in Section 4)

The 2020 version of the NPS-FM introduced several attributes that were either not monitored by GW until recently and/or were not included in the TAoP or WTWT WIPs. The NPS-FM 2020 does not allow local authorities to "*delay making decisions solely because of uncertainty about the quality or quantity of the information available*". Thus, it is not an option to simply ignore these attributes in PC1. Instead, the following approach is recommended for setting baseline states and TASs (reviewed and agreed to by the TAG):

- General approach for river attributes considered in the WIPs (WTWT and TAoP):
    - Do not set baseline states where monitoring and modelling data are demonstrably inadequate to do so, instead simply acknowledge that there are "*insufficient data*";
    - Adopt all WIP TASs where except where they:
        - Do not meet the relevant NPS-FM National Bottom Line (NBL); or
        - Are below the baseline state,

      in which case set the TAS at the better of the NBL or baseline state.

      Note – The decision to include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data was made late in the PC1 development process. Thus, it is not captured in Torlesse's recommendations to the TAG in Section 4.

    - Include a new Fish Community Health attribute without baseline states and TASs set at the same band as those for Macroinvertebrate Community Index and Quantitative Macroinvertebrate Community Index (Q/MCI); and
    - Do not define baseline state for ecosystem metabolism and set a narrative TAS that ensures the attribute is at least maintained.
- Approach for river attributes not considered in the TAoP WIP:
    - Suspended fine sediment (SFS):
        - Set baseline states from:
            - Monitoring data; or
            - The results of the sediment concentration modelling conducted as part of the TAoP Collaborative Modelling Project (CMP) (Easton *et al.*, 2019b) and the regional sediment-clarity relationships developed by Collaborations (see Sections 2.6 and 9 below); and
        - Set TASs at the better of baseline state or the NBL.

          Note – The decision to use modelling data from the TAoP CMP as 'the best available' source of baseline data when monitoring data are not available was made late in the PC1 development process. Thus, it is not captured in Torlesse's recommendations to the TAG in Section 4.

    - Deposited fine sediment (DFS):
        - Set baseline states based on monitoring data where available; and
        - Set TASs at the better of baseline state or NBL.
    - Macroinvertebrate average score per metric (ASPM):
        - Set baseline states based on monitoring data where available; and
        - Set TASs at same level as Q/MCI.
    - Fish Index of Biotic Integrity (F-IBI) and dissolved oxygen (DO):
        - Do not set baseline states given lack of monitoring data; and
          Set a narrative TAS that ensures the attribute is at least maintained.

          Note – This differs from the recommended approached accepted by the TAG as the monitoring data required to set baseline states has not been collected.

    - Dissolved reactive phosphorus (DRP):
        - Set baseline state based on monitoring data or the results of the water quality modelling conducted as part of the TAoP CMP (Easton *et al.*, 2019b); and
        - Set TASs for the 95th percentile concentration at the baseline state and set a separate TAS for the median concentrations that reflects recommended nutrient outcomes (NOs) developed in accordance with Clause 3.13 of the NPS-FM 2020 and the associated national guidance (see Section 2.4).
- General approach for lake attributes in WTWT:
    - For attributes with existing monitoring data:

- Set baseline states based on all available data regardless of whether they meet the requirements of the NPS-FM 2020 and/or were collected outside of the NPS-FM 2020 prescribed baseline period.
- Adopt all WIP TAS where available except where they are below the baseline state, in which case set the TAS at the better of the NBL or baseline state.

  Notes:
  - *The decision to include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data was made late in the PC1 development process. Thus, it is not captured in Section 4 or Section 7; similarly.*
  - *The decision to set baseline states for lakes off limited data collected outside of the NPS-FM 2020 prescribed baseline period was made after the memorandum reproduced in Section 7 was published. This approach was considered justified as the alternative was to have a lakes TAS table in PC1 without any baseline states other than for submerged plants (natives and invasive species).*

- Lake bottom dissolved oxygen:
  - Do not set baseline states given lack of monitoring data; and
  - Set TASs in accordance with the WTWT WIP.
- Submerged plants (natives and invasive species):
  - Set baseline state based on results of Lake Submerged Plant Indicators (LakeSPI) 2016 surveys; and
  - Set TASs in accordance with the WTWT WIP except where that would allow a degradation from baseline state.

2.3 Issue 3: The WIPs do not explicitly set TASs for the habitat component of the NPS-FM 2020 compulsory value of ecosystem health (full detail in Section 5)

The NPS-FM 2020 identifies habitat as one of the five biophysical components of ecosystem health and notes that it is necessary for regional councils to manage and treat it as a value. Neither the WTWT nor TAoP WIPs includes specific habitat attribute TASs. To determine whether this is an issue that GW needs to address in PC1, Torlesse reviewed the relevant literature to identify whether:

- The existing compulsory attributes in the NPS-FM 2020 manage habitat;
- There are multi-metric habitat attributes that targets could be set for habitat; and
- There are individual habitat attributes that targets could be set for habitat.

Upon receiving that review the TAG agreed that it was not necessary to set specific TASs for habitat in PC1 as:

- Meeting the targets for existing compulsory attributes will:
  - Manage some key components of habitat; and
  - Require habitat be managed to achieve ecological outcomes.

- The existing multimeric habitat metrics are generally not fit for this purpose; and
- A lack of relevant guideline values means that attribute state thresholds cannot be defined for most of the individual habitat metrics that are not currently included in Appendix 2 of the NPS-FM 2020.

2.4 Issue 4: The WIPs do not set nutrient outcomes in accordance with clause 3.13 of the NPS-FM 2020 (full detail in Section 6)

The NPS-FM 2020 requires regional councils to:

- Set appropriate instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus (nutrient outcomes (NOs)).
- Identify limits on resource use that will achieve any NOs.

Unfortunately:

- The NOs in the TAoP WIP were developed prior to the release of the NPS-FM 2020 and are no longer relevant; and
- The WTWT WIP is silent on NOs.

Consequently, it was necessary for GW to define the NOs in PC1 in isolation from the WIPs. To that end, Torlesse used the available national guidance from MfE (2022a, 2022b) to identify median dissolved inorganic nitrogen (DIN) and DRP concentrations that can be used as NOs for the TAoP Whaitua and WTWT (see Table 2). Specifically, these median concentrations were identified by:

1. Selecting periphyton biomass thresholds (based on the WIP TASs) and under-protection risk thresholds (based on the guidance in MfE (2022b));
2. Obtaining NOs from updated versions of the tables in Snelder *et al.*'s (2022)[3];
3. Assessing confidence in the NOs through the approach specified in MfE (2022b); and
4. Applying the NOs or one of the following alternative criteria (where appropriate; see footnotes to Table 2 for further detail):
    a. The baseline concentration where lower than the NOs;
    b. The WIP target states for nitrate (NO_3-N) toxicity or DRP where lower than the NOs;
    c. The saturation concentrations for periphyton where lower than the NOs; and
    d. The relevant reference concentration from McDowall *et al.* (2013) where the identified NOs = 0.

[3] These updates were made in response to validation exercises conducted for several regions revealing the original NC are generally too permissive (see Section 6 and Appendix F).

Table 2: Recommended NOs for TAS sites in WTWT and TAoP Whaitua. Selected from the updates to the Snelder *et al.* (2022) (under-protection risk = 50%) except where alternative criteria are more appropriate (see footnotes).

Whaitua	Part-FMU	Site	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	Y	1.03[a]	0.018[a]
	Pouewe	Horokiri S. @ Snodgrass		0.64[b]	0.014[b]
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.		~0.48[b]	0.025
	Takapū	Pāuatahanui S. @ Elmwood Br.		0.33[b]	0.012[b]
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot		0.92[b]	0.018[b]
TWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone		0.15[c]	0.006[d]
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	N	0.20[b]	0.004[b]
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	Y	0.44[b]	0.006[e]
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.		0.24[b]	0.018[b]
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.		0.56[b]	0.018[e]
	Wainuiomata urban streams	Black C. @ Rowe Parade end		0.5[b]	0.018[e]
	Wainuiomata rural streams	Wainuiomata R. DS White Br.		0.17[b]	0.011[e]
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels		0.42[b]	0.018[e]
	Korokoro Stream	Korokoro Stream @ Cornish St. Br.		0.26	0.006[e]
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge		1.03[b]	0.018[e]
	Wellington urban	Karori S. @ Mākara Peak		1.29[b]	0.035[e]

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS). Sum of NO_3-N and NH_4-N TAS applied as alternative DIN criteria (improvement likely required for both attributes). NPS-FM 2020 attribute state C thresholds applied as alternative DRP thresholds (reflects modelled baseline state).
[b] Snelder *et al.* (2022) nutrient outcome > than current concentrations. Baseline concentrations applied as alternative criteria.
[c] Site in reference condition and nutrient outcome represents an improvement which is unlikely to be possible. Baseline concentrations applied as alternative criteria.
[d] Snelder *et al.* (2022) nutrient outcome = 0. The lesser of McDowall *et al.* (2013) 80th %ile trigger, baseline state or WIP TAS applied as alternative criteria.
[e] Snelder *et al.* (2022) nutrient outcome > than the DRP TAS. TAS applied as alternative criteria.

2.5 Issue 5: The WTWT WIP baseline states for the Parangārehu Lakes are not supported by monitoring data (full detail in Section 7)

The baseline states for lake attributes in the WTWT WIP were based on the best available data at the time and expert opinion (Heath, 2022; Schallenberg, 2019). However, the paucity of lake water quality data at that time means they can only be considered estimates, rather than accurate state assessments. To establish more precise estimates of baseline state, Mr Alton Perrie (Senior Environmental Scientist – GW) analysed all of the available lake monitoring data for the NPS-FM 2020 2A and 2B attributes currently monitored in Lake Kōhangatera and Lake Kōhangapiripiri (all but lake bottom dissolved oxygen). It is recommended that the resulting baselines are incorporated in the TAS tables in PC1 (see Table 7 below).

2.6 Issue 6: The scale of sediment load reductions required to meet the visual clarity TASs are unclear (full detail in Section 9)

The NPS-FM 2020 SFS attribute uses visual clarity rather than a direct measure of suspended sediment concentration. Consequently, the difference between the baseline state and TASs for this attribute does not provide a clear indication of the degree by which sediment losses must be reduced, since the relationship between visual clarity and sediment concentration/load is not linear. To address this issue Collaborations developed site and regional specific relationships between visual clarity and total suspended solid (TSS) concentrations. These relationships were then used to calculate the sediment load reductions required to meet the recommended PC1 SFS TASs through the methods described in Neverman *et al.* (2021) and Hicks *et al.* (2019) (see Table 3).

Table 3: Estimated sediment load reductions required to achieve the SFS TASs for TAoP Whaitua and WTWT. Baseline clarity medians below the target are in bold. *Note – baseline states and load reduction targets have been updated from those originally provided by Collaborations to account for the February 2023 amendments to the NPS-FM 2020 definition of baseline state (i.e., baseline state = median visual clarity on the 7th of September 2017).*

Part-FMU	Target Attribute Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual TSS load (t/year)	TSS load reduction required to meet clarity target
WTWT TAS					
Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	4	4	3,189	0%
Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	**1.5**	**2.22**	**10,965**	**-51%**
Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	1.2	1.2	181	0%
Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	**2.4**	**2.95**	**102,303**	**-24%**
Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	1.1	1.1	228	0%
Wainuiomata urban streams	Black C. @ Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**
Wainuiomata rural streams	Wainuiomata R. DS White Br.	**2.1**	**2.22**	**12,243**	**-7%**
Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	3.2	3.2	290	0%
Wellington urban	Karori S. @ Mākara Peak	3.2	3.2	2,159	0%
Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	**1.6**	**2.22**	**4,437**	**-34%**
TAoP TAS					
Pouewe	Horokiri Stream @ Snodgrass	2.3	2.3	764	0%
Takapū	Pāuatahanui S. @ Elmwood Bridge	**1.8**	**2.22**	**2311**	**-24%**
Te Riu o Porirua	Porirua S. @ Milk Depot	1.7	1.7	1705	0%
Taupō	Taupō S. @ Plimmerton Domain	1.2	1.2	15	0%
Wai-o-hata	Duck Ck at @ Tradewinds Dr. Br.	1.2	1.2	526	0%

2.7 Issue 7: The link between the TAoP WIP coastal objectives and load reduction targets for sediment and metal attributes are not supported by sufficiently robust technical analysis (full detail in Section 11 to Section 13)

The TAoP WIP assumes that:

- A 40% reduction in sediment loads to the Onepoto Arm and Pāuatahanui Inlet (the main arms of Te Awarua-o-Porirua harbour) is needed to achieve the WIP coastal objectives for sedimentation rate. **However**;
- That 40% sediment load reduction will result in a commensurate increase in sediment copper (Cu) and zinc (Zn) concentrations in the the Onepoto Arm and Pāuatahanui Inlet due to a loss of dilution. **Thus**;
- A 40% reduction in total Cu and Zn loads to the Onepoto Arm and Pāuatahanui Inlet is also needed to maintain sediment metal concentrations and achieve the relevant WIP coastal objectives.

Due to size of the sediment and metal load reductions proposed in the WIP, the review by Aquanet Consulting identified that further scrutiny of the assumptions above was needed prior to PC1 being notified. This has since been provided by:

- Mr Brent King (Team Leader, Evaluation and Insights – GW) – Relationship between sediment load reductions and harbour sedimentation rate (Section 11);
- Dr Jennifer Gadd (Aquatic Chemist – NIWA) – Relationships between sediment load reductions, metal load reductions and sediment metal concentrations (Section 13); and
- Dr Megan Oliver (Principal Advisor Knowledge – GW) – The need to take a precautionary approach to maintaining sediment metal concentrations in TAoP harbour (Section 12).

Based on the advice provided by the experts listed above, there is now adequate evidence to support the inclusion of the WIP coastal objectives for sedimentation rate and sediment Cu and Zn concentrations in PC1, as well as the associated loads reduction targets.

2.8 Additional minor recommendations and conclusions made through PC1 TAG process

- For those attributes with multiple assessment statistics (e.g., median and 95th percentile concentrations) and multiple potential baseline periods (dissolved Cu and Zn in rivers only) it is recommended that baseline state be calculated from the baseline period with the lowest average concentration of the attribute;
- Many of the TASs in the WTWT and TAoP WIPs have been set to maintain the baseline state. It is clear from the NPS-FM 2020 definition of **degrading** that when setting TASs maintain does not mean 'within an attribute state. Thus, 'maintain' TASs need to capture the baseline state in some way, rather than simply denoting an attribute state. This could be addressed by incorporating a "maintain or improve" narrative into the relevant TASs that then cross-reference a footnote to the effect of:

  "Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

  - *Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and*

- *Taking the impact of climate and human activity into account."*

- The enterococci attribute state framework used in both the TAoP and WTWT WIPs is not appropriate for use in PC1 as the different assessment statistics are in direct conflict with one another (e.g., the attribute state B thresholds require the 95th percentile concentration to be lower than the 90th percentile concentration). It is recommended that only the "*95th percentile*" statistic be used as that is the one which has been drawn from MfE/MoH (2003); and
- The WTWT and TAoP WIP TASs are not well aligned with the exiting numeric water quality and ecology objectives/ standards in the NRP. However, that in itself is not justification for not adopting them in PC1.

2.9 Recommended TASs and coastal objectives based on additional technical work conducted during PC1 development.

Table 4 to Table 8 set out TASs and coastal objectives tables for WTWT and TAoP Whaitua that account for all of the technical recommendations set out in this report. The differences between the baseline states and TASs in those tables provide an indication of the environmental change required by the TASs and, have been used to define default TASs that prescribe the direction of change required for each attribute across each part-FMU[4] (Table 5 and Table 8). The attribute state frameworks behind the river and lakes TASs are provided in Appendix A.

Table 4: Recommended coastal objectives for the TAoP Whaitua.

			Onepoto Arm		Pāuatahanui Inlet		Coast
Parameter	**Unit**	**Statistic**	**Intertidal**	**Subtidal**	**Intertidal**	**Subtidal**	
Enterococci	**cfu/100 mL**	95th %ile	≤500		≤200		≤200
Macroalgae	**EQR**	Latest score	Maintain or improve				Maintain or improve
Copper in sediment	**mg/kg**	Mean of latest round of replicate samples					
Zinc in sediment	**mg/kg**						
Muddiness	**% >50% mud**	Latest score					
	% of sample						
Sedimentation rate	**mm/year**	5-year mean	1		2		

[4] Where baseline state is unknown, this direction of change is based on the difference in the assumed baseline in the WIP and the TAS.

Table 5: Recommended river TASs for TAoP Whaitua.

				Taupō					Pouewe					Wai-o-hata					Takapū				
				Taupō S. @ Plimmerton Domain				Part FMU default TAS[1]	Horokiri S. @ Snodgrass				Part FMU default TAS[1]	Duck Ck @ Tradewinds Dr. Br.				Part FMU default TAS[1]	Pāuatahanui S. @ Elmwood Br.				Part FMU default TAS[1]
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]		
Parameter	**Unit**	**Statistic**	**Timeframe**	**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**		**Numeric**	**State**	**Numeric**	**State**	
Periphyton biomass	mg chl-a/m^2	92nd %ile	By 2040	N/A[2]				M	436[3]	D	≤120	B	I	Insufficient data		≤120	B	I	Insufficient data		≤120	B	I
Ammonia (toxicity)	mg/L	Median		0.011	B[4]	≤0.03	A	I	0.002	A	M	A	M	0.013	A[4]	M	A	M	0.005	A	M	A	M
		95th %ile		0.051		≤0.05			0.013					0.044					0.018				
Nitrate (toxicity)	mg/L	Median		0.4	B[4]	≤1	A		0.6	A		A		0.5	B[4]	≤1	A	I	0.3	A		A	
		95th %ile		2.1		≤1.5			1.1					1.6		≤1.5			0.8				
Suspended fine sediment	Black disc (m)	Median		1.2	A[4]	≥0.93	A	M	2.3	C		C		1.2	A[4]	≥0.93	A	M	1.8	D	≥2.22	C	I
E. coli	/100mL	Median		735	E[4]	≤130	B	I	370	E	≤130	B	I	703	E[4]	≤130	C	I	275	E	≤130	C	
		%>260/100mL		96		≤30			63		≤30			92		≤20			55		≤20		
		%>540/100mL		62		≤10			32		≤10			59		≤34			18		≤34		
		95th %ile		5,299		≤1,000			4,950		≤1,000			4,783		≤1,200			6,050		≤1,200		
Fish	Fish-IBI	Latest		Insufficient data		M		M	Insufficient data		M		M	Insufficient data		M		M	Insufficient data		M		M
Fish community health (abundance, structure and composition)		Expert assessment[5]				N/A[5]	B	I			N/A[5]	A	I			N/A[5]	B	I			N/A[5]	B	I
Macroinvertebrates (1 of 2)	MCI	Median				≥100	B		115.0	B	≥130	A				≥100	B		101.2	D	≥105	B	
	QMCI	Median				≥5			6.0		≥6.5					≥5			3.8		≥5.25		
Macroinvertebrates (2 of 2)	ASPM	Median				≥0.4	B		0.5	B	M	B	M			≥0.4	B		0.4	C	≥0.40	C	M
Deposited fine sediment[3]	%cover	Median		N/A[6]					10	A		A				M		M	60	D	≤27	C	I
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		M		M	Insufficient data		M								Insufficient data		M		M
		7-day mean minimum																					
Dissolved inorganic nitrogen[7]	mg/L	Median		0.41[4]		≤1.03		I	0.64					0.48[4]					0.33				
Dissolved reactive phosphorus[7]	mg/L	Median		0.017[4]		M		M	0.011					0.018[4]		M			0.014				
		95th%ile		0.047[4]					0.026					0.05[4]					0.022				
Dissolved copper	µg/L	Median		0.61	D[4]	≤1	B	I	0.03	A[4]	M	A		0.47	C[4]	≤1	A	I	0.06	A[4]	M	A	
		95th %ile		4.69		≤1.8			0.12					2.93		≤1.4			0.27				
Dissolved zinc	µg/L	Median		3.91	C[4]	≤2.4	A		0.07	A[4]		A		1.96	B[4]	≤2.4	A		0.11	A[4]		A	
		95th %ile		32.25		≤8			0.23					13.04		≤8			0.48				
Ecosystem metabolism	g O_2 m^{-2} d^{-1}	N/A[8]		M																			

Parameter	Unit	Statistic	Timeframe	Te Rio o Porirua and Rangituhi					Island rivers TAS[1]
				Porirua S. @ Milk Depot				Part FMU default TAS[1]	
				Baseline		TAS[1]			
				Numeric	State	Numeric	State		
Periphyton biomass	mg chl-a/m^2	92nd %ile	By 2040	Insufficient data		≤120	B	I	M
Ammonia (toxicity)	mg/L	Median		0.006	A	M	A	M	
		95th %ile		0.034					
Nitrate (toxicity)	mg/L	Median		0.9	B	≤0.9	A	I	
		95th %ile		1.6		≤1.5			
Suspended fine sediment	Black disc (m)	Median		1.7	A	M	A	M	
E. coli	/100mL	Median		1400	E	≤130	C	I	
		%>260/100mL		95		≤20			
		%>540/100mL		83		≤34			
		95th %ile		6950		≤1200			
Fish	Fish-IBI	Latest		Insufficient data		M		M	
Fish community health (abundance, structure and composition)		Expert assessment[5]				N/A[5]	C	I	
Macroinvertebrates (1 of 2)	MCI	Median		87.0	D	≥90	C		
	QMCI	Median		4.3		≥4.5			
Macroinvertebrates (2 of 2)	ASPM	Median		0.3	D	≥0.3	C		
Deposited fine sediment[3]	%cover	Median		20	C	M	C	M	
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		M			
		7-day mean minimum							
Dissolved inorganic nitrogen[7]	mg/L	Median		0.92					
Dissolved reactive phosphorus[7]	mg/L	Median		0.018					
		95th%ile		0.034					
Dissolved copper	μg/L	Median		1.1	C	M	C		
		95th %ile		2.6					
Dissolved zinc	μg/L	Median		7.5	D	≤7.5	C	I	
		95th %ile		58		≤42			
Ecosystem metabolism	g O_2 m^{-2} d^{-1}	N/A[8]		M[8]					

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS).
[3] Baseline state based on limited data.
[4] Baseline state based on eWater Source model results. Further monitoring needed to confirm whether the attribute meets the TAS.
[5] The A, B, C and D states to be assigned on the basis of fish community health reflecting an excellent, good, fair and poor state of aquatic ecosystem health respectively.
[6] All rivers in part FMU naturally soft bottomed (River Environment Classification group = WW/L/SS).
[7] Median concentration targets reflect the nutrient outcomes required by Clause 3.13 of the NPS-FM 2020
[8] Further monitoring needed to define baseline state and develop attribute state framework.

Table 6: Recommended coastal objectives for WTWT.

<table>
<tr><th>Parameter</th><th>Unit</th><th>Statistic</th><th>Te Whanganui-a-Tara (Harbour and estuaries)</th><th>Mākara Estuary</th><th>Wainuiomata Estuary</th><th>Wai Tai</th></tr>
<tr><td>Benthic marine invertebrate diversity</td><td colspan="2">Subjective - State of ecosystem health and level of disturbance</td><td rowspan="8">Maintain or improve</td><td rowspan="5">Maintain or improve</td><td colspan="2" rowspan="9">Maintain or improve</td></tr>
<tr><td>Macroalgae</td><td>EQR</td><td rowspan="2">Latest score</td></tr>
<tr><td>Phytoplankton</td><td>mg chl-a/ m^3</td></tr>
<tr><td>Copper in sediment</td><td>mg/kg</td><td rowspan="2">Mean of latest round of replicate samples</td></tr>
<tr><td>Zinc in sediment</td><td>mg/kg</td></tr>
<tr><td rowspan="2">Muddiness</td><td>% >50% mud</td><td rowspan="3">Latest score</td><td>≤5</td></tr>
<tr><td>% of sample</td><td><10</td></tr>
<tr><td>Sedimentation rate</td><td>Current:Natural</td><td>≤2:1</td></tr>
<tr><td>Enterococci</td><td>cfu/100 mL</td><td>95th %ile</td><td>≤200</td><td>Maintain or improve</td></tr>
</table>

Table 7: Recommended lake TASs for WTWT.

Parameter	Unit	Statistic	Timeframe	Lake Kōhangatera Baseline Numeric	Lake Kōhangatera Baseline State	Lake Kōhangatera TAS[1] Numeric	Lake Kōhangatera TAS[1] State	Lake Kōhangapiripiri Baseline Numeric	Lake Kōhangapiripiri Baseline State	Lake Kōhangapiripiri TAS[1] Numeric	Lake Kōhangapiripiri TAS[1] State	Other lakes default TAS[1]
Phytoplankton[2]	**mg chl-a/m^3**	Median	By 2040	5.0	C	≤2	A	1.5	A	M	A	M
		Maximum		35		≤10		6.0				
Total nitrogen[2]	**mg/m^3**	Median		480	B	M	B	660	C	≤500	B	
Total phosphorus[2]	**mg/m^3**	Median		40	C	≤20	B	43	C	≤20	B	
Ammonia (toxicity)[2]	**mg/L**	Median		0.005	A	M	A	0.003	A	M	A	
		95th %ile		0.024				0.005				
***E. coli*[2]**	**/100mL**	Median		125	A		A	23	A		A	
		%>260/100mL		174				0				
		%>540/100mL		0				0				
		95th %ile		350				186				
Cyanobacteria (planktonic)[2]	**Total biovolume mm^3/L**	80th %ile		0.248	A		A	0.008	A		A	
Submerged plants (natives)	**Native Condition Index (% of max)**	Latest		81.4	A		A	35.7	C	≥75	A	
Submerged plants (invasive species)	**Invasive Impact Index (% of max)**	Latest		15.6	B		B	61.5	C	≤25	B	
Lake-bottom dissolved oxygen[3]	**mg/L**	Annual minimum		Insufficient data		≥7.5	A	Insufficient data		≥7.5	A	

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] Baseline state based on limited data collected over a period that is inconsistent with the monitoring requirements and baseline period defined in the NPS-FM 2020.

[3] Baseline state unknown; further monitoring needed to determine whether the attribute needs to be improved to the TAS or be maintained at a better state.

Table 8: Recommended river TASs for WTWT.

				Te Awa Kairangi, Ōrongorongo and Wainuiomata																			
				Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems					Te Awa Kairangi lower mainstem					Te Awa Kairangi rural streams and rural mainstems					Te Awa Kairangi urban streams				
				Whakatikei R. @ Riverstone				Part FMU default TAS[1]	Hutt R. @ Boulcott				Part FMU default TAS[1]	Mangaroa R. @ Te Marua				Part FMU default TAS[1]	Hulls Ck adj. Reynolds Bach Dr.				Part FMU default TAS[1]
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			Baseline[2]		TAS[1]		
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State	
Periphyton biomass[2]	mg chl-a/m^2	92nd %ile	By 2040	Insufficient data		≤50	A	M	284	D	≤120	B	I	220	D	≤120	B	I	Insufficient data		≤200	C	M
Ammonia (toxicity)	mg/L	Median		0.002	A	M	A		0.002	A	M	A	M	0.002	A	M	A	M	0.008	A	M	A	
		95th %ile		0.004					0.003					0.01					0.012				
Nitrate (toxicity)	mg/L	Median		0.1	A		A		0.2	A		A		0.4	A		A		0.2	A		A	
		95th %ile		0.3					0.3					0.6					0.4				
Suspended fine sediment	Black disc (m)	Median		4	A		A		2.4	C	≥2.95	A	I	1.5	D	≥2.22	C	I	1.2	A		A	
E. coli	/100mL	Median		22	A		A		58	D	≤58	C		170	D	≤130	B		1,100	E	≤130	C	I
		%>260/100mL		5					18		≤18			35		≤30			100		≤34		
		%>540/100mL		3					8		≤8			18		≤10			79		≤20		
		95th %ile		290					1,250		≤1,200			2,450		≤1,000			13,000		≤1,200		
Fish	Fish-IBI	Latest		Insufficient data		≥34	A		Insufficient data		≥34	A	M	Insufficient data		≥34	A		Insufficient data		≥34	A	
Fish community health (abundance, structure and composition)		Expert assessment[3]				N/A[3]	A	I			N/A[3]	B	I			N/A[3]	B				N/A[3]	C	M
Macroinvertebrates (1 of 2)	MCI	Median		129.6	B	≥130	A		109.1	C	110	B		118.3	C	≥118.3	B				≥90	C	
	QMCI	Median		7.0		≥7			5.5		5.5			5.7		≥5.7					≥4.5		
Macroinvertebrates (2 of 2)	ASPM	Median		0.56	B	≥0.6	A		0.4	B	M	B	M	0.5	B	M	B	M			≥0.3	C	
Deposited fine sediment[2]	%cover	Median		25	C	≤13	A		5	A		A		0	A		A		11	B	M	B	
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A	
		7-day mean minimum				≥8.0					≥8.0					≥8.0					≥8.0		
Dissolved inorganic nitrogen[4]	mg/L	Median		0.15		M			0.2		M			0.44		M			0.24		M		
Dissolved reactive phosphorus[4]	mg/L	Median		0.008		≤0.006		I	0.004					0.010		≤0.006		I	0.018				
		95th%ile		0.011		≤0.011			0.008					0.015		≤0.015			0.027				
Dissolved copper	µg/L	Median		Insufficient data		≤1	A	M	0.3	A	M	A		Insufficient data		≤1	A	M	1.9	C	≤1.4	B	I
		95th %ile				≤1.4			0.6							≤1.4			3.6		≤1.8		
Dissolved zinc	µg/L	Median				≤2.4	A		0.5	A		A				≤2.4	A		8.0	C	≤8	B	
		95th %ile				≤8			1.9							≤8			19.2		≤15		
Ecosystem metabolism[5]	g O_2 m^{-2} d^{-1}	N/A[5]		M																			

				Te Awa Kairangi, Ōrongorongo and Wainuiomata															South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes				
				Waiwhetū Stream					Wainuiomata urban streams					Wainuiomata rural streams					Parangārehu catchment streams and South-west coast rural streams				
				Waiwhetū S. @ Whites Line East				Part FMU default TAS[1]	Black Ck @ Rowe Parade				Part FMU default TAS[1]	Wainuiomata River D/S of White Br.				Part FMU default TAS[1]	Mākara S. @ Kennels				Part FMU default TAS[1]
				Baseline		TAS[1]			Baseline[2]		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]		
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State	
Periphyton biomass[2]	mg chl-a/m^2	92nd %ile	By 2040	Insufficient data		≤200	C	M	Insufficient data		≤200	C	M	324	D	≤200	C	I	Insufficient data		≤200	C	M
Ammonia (toxicity)	mg/L	Median		0.027	B	≤0.02	A	I	0.025	B	≤0.03	A	I	0.004	A	M	A	M	0.005	A	M	A	
		95th %ile		0.076		≤0.05			0.066		≤0.05			0.025					0.023				
Nitrate (toxicity)	mg/L	Median		0.5	A	M	A	M	0.4	A	M	A	M	0.2	A		A		0.4	A		A	
		95th %ile		0.9					0.7					0.4					1.2				
Suspended fine sediment	Black disc(m)	Median		1.1	A		A		1.3	D	≥2.22	C	I	2.1	D	≥2.22	C	I	1.6	D	≥2.22	C	I
E. coli	/100mL	Median		495	E	≤130	C	I	1250	E	≤130	C		100	B	≤100	A		375	E	≤260	D	
		%>260/100mL		73		≤34			86		≤34			18		≤18			62		≤50		
		%>540/100mL		42		≤20			71		≤20			7		≤5			32		≤30		
		95th %ile		5,800		≤1200			4,360		≤1200			1,000		≤540			6,500		≤3,850		
Fish	Fish-IBI	Latest		Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M
Fish community health (abundance, structure and composition)		Expert assessment[3]				N/A[3]	C	I			N/A[3]	C	I			N/A[3]	B	I			N/A[3]	C	
Macroinvertebrates (1 of 2)	MCI	Median		55.4	D	≥90	C				≥90	C		109.5	C	≥110	B		107.3	C	M	C	
	QMCI	Median		2.2		≥4.5					≥4.5			4.9		≥5.5			5.1				
Macroinvertebrates (2 of 2)	ASPM	Median		0.1	D	≥0.3	C				≥0.3	C		0.4	B	≥0.6	A		0.4	B		B	
Deposited fine sediment[2]	%cover	Median		30	D	≤29	C		11	A	M	A	M	20	C	≤13	A		85	D	≤27	C	I
Dissolved oxygen	mg/L	1-day minimum		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A	M
		7-day mean minimum				≥8.0					≥8.0					≥8.0					≥8.0		
Dissolved inorganic nitrogen[4]	mg/L	Median		0.56		M		M	0.5		M			0.17		M			0.42		M		
Dissolved reactive phosphorus[4]	mg/L	Median		0.024		≤0.018		I	0.021		≤0.018		I	0.011		≤0.01		I	0.027		≤0.018		I
		95th%ile		0.049		≤0.049			0.035		≤0.035			0.023		≤0.023			0.064		≤0.054		
Dissolved copper	µg/L	Median		1.0	C	≤1	A		1.0	C	M	C	M	Insufficient data		≤1	A	M	Insufficient data		≤1	A	M
		95th %ile		4.0		≤1.4			2.0							≤1.4					≤1.4		
Dissolved zinc	µg/L	Median		18.3	D	≤8	B		11.2	D	≤11.2	C	I			≤2.4	A				≤2.4	A	
		95th %ile		51.5		≤15			71.2		≤42					≤8					≤8		
Ecosystem metabolism	g O_2 m^{-2} d^{-1}	N/A[5]		M																			

				Korokoro catchment					Wellington urban catchment										Island rivers TAS[1]
				Korokoro Stream					Kaiwharawhara Stream					Wellington urban					
				Korokoro S. @ Cornish St. Br.				Part FMU default TAS[1]	Kaiwharawhara S. @ Ngaio Gorge				Part FMU default TAS[1]	Karori S. @ Mākara Peak				Part FMU default TAS[1]	
				Baseline		TAS[1]			Baseline		TAS[1]			Baseline		TAS[1]			
Parameter	Unit	Statistic	Timeframe	Numeric	State	Numeric	State		Numeric	State	Numeric	State		Numeric	State	Numeric	State		
Periphyton biomass[2]	mg chl-a/m^2	92nd %ile	By 2040	Insufficient data		≤120	B	M	191	D	≤200	C	I	Insufficient data		≤200	C	M	M
Ammonia (toxicity)	mg/L	Median				≤0.03	A		0.004	A	M	A	M	0.009	A	M	A		
		95th %ile				≤0.05			0.031					0.026					
Nitrate (toxicity)	mg/L	Median				≥1	A		1.1	B		B		1.3	B		B		
		95th %ile				≥1.5			1.5					1.6					
Suspended fine sediment	Black disc (m)	Median				≥2.95	A		3.2	A		A		3.2	A		A		
E. coli	/100mL	Median				≤130	B	I	530	E	≤130	C	I	1400	E	≤130	C	I	
		%>260/100mL				≤30			73		≤34			97		≤34			
		%>540/100mL				≤10			50		≤20			83		≤20			
		95th %ile				≤1,000			5,150		≤1,200			4,550		≤1,200			
Fish	Fish-IBI	Latest				≥34	A	M	Insufficient data		≥34	A	M	Insufficient data		≥34	A	M	
Fish community health (abundance, structure and composition)		Expert assessment[3]				N/A[3]	C	I			N/A[3]	C	I			N/A[3]	C	I	
Macroinvertebrates (1 of 2)	MCI	Median				≥130	A		81.9	D	≥92.4	C		91.8	D	≥91.8	C		
	QMCI	Median				≥6.5			2.8		≥4.5			3.1		≥4.5			
Macroinvertebrates (2 of 2)	ASPM	Median				≥0.6	A		0.25	D	≥0.3	C	I	0.29	D	≥0.3	C		
Deposited fine sediment[2]	%cover	Median				≤13	A	M	20	C	≤13	A		25	C	≤19	B		
Dissolved oxygen	mg/L	1-day minimum				≥7.5	A		Insufficient data		≥7.5	A	M	Insufficient data		≥7.5	A	M	
		7-day mean minimum				≥8.0					≥8.0					≥8.0			
Dissolved inorganic nitrogen[4]	mg/L	Median				≤0.26			1.14		M			1.29		M			
Dissolved reactive phosphorus[4]	mg/L	Median				≤0.006		I	0.037		≤0.018		I	0.035					
		95th%ile				≤0.021			0.064		≤0.054			0.062					
Dissolved copper	µg/L	Median				≤1	A	M	1.3	C	≤1.3	B		1.3	D	≤1.3	C	I	
		95th %ile				≤1.4			2.8		≤1.8			5.9		≤4.3			
Dissolved zinc	µg/L	Median				≤2.4	A		6.1	B	≤2.4	A		16.2	D	≤16.2	C		
		95th %ile				≤8			12.8		≤8			43.0		≤42			
Ecosystem metabolism	$g\ O_2\ m^{-2}\ d^{-1}$	N/A[5]		M															

[1] M = Maintain; I = Improve. Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and
- Taking the impact of climate and human activity into account.

[2] Baseline state based on limited data.
[3] The A, B, C and D states to be assigned on the basis of fish community health reflecting an excellent, good, fair and poor state of aquatic ecosystem health respectively.
[4] Median concentration targets reflect the nutrient outcomes required by Clause 3.13 of the NPS-FM 2020
[5] Further monitoring needed to define baseline state and develop attribute state framework.

Part 2 – Reproduction of technical memoranda produced during the development of PC1

3 Recommended part-FMUs and TAS sites for Te Awarua-o-Porirua Whaitua and Whaitua te Whanganui-a-Tara

First published: 17/02/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington

The purpose of this memorandum is to document the part-FMU and TAS site selection, refinement and delineation that Torlesse and Collaborations have completed to date for TAoP Whaitua and WTWT.

Note: The part-FMUs and TASs sites presented in this memorandum are the authors technical recommendations, not GW Policy.

3.1 TAS site selection

A full methodology of how TAS sites were selected is provided in the Collaborations memorandum attached as Appendix B. Briefly, the processes involved:

1. Refining a set of 29 sub-catchments provided by GW to better account for their hydrological and land-use characteristics.
2. Identifying sub-catchments with similar:
   a. Current water quality (at the time);
   b. WIP TASs; and
   c. Catchment characteristics.
3. Over laying GW's monitoring network over the sub-catchments to:
   a. Identify the sub-catchments where additional sites are needed;
   b. Identify the sub-catchments where sites need to be moved to better detect land-use effects and the results of changing practice;
   c. Identify the most appropriate monitoring site for setting TASs in sub-catchments with multiple existing monitoring sites; and
   d. Identify the sub-catchments where a monitoring site is not necessary as progress towards TASs can be assessed based on monitoring data collected from a similar 'proxy' catchment (see Step 2 above).

The final recommended list of TAS sites (see Table 11) is largely consistent with the recommendations made by Collaborations (Appendix B). However, GW have separately determined that monitoring is not possible in the Takapūwahia or Gollans streams. Thus, those sites have been excluded.

<u>*Notes:*</u>

- *The Collaborations memorandum (Appendix B) refers to sub-FMUs rather than sub-catchments and makes recommendations on what these should be. That piece of work was* *produced some time ago and represents a first cut at turning the WIP management units (TAoP management units = WMUs; WTWT = Catchment × Sub-catchment area) into part-FMUs. As such, there are conflicts between the part-FMUs presented in the body of this memorandum and the sub-FMUs in Appendix B. The list set out in Table 11 represents the latest technical thinking, and Appendix B demonstrates how part-FMUs have evolved through time.*

- *Collaborations recommends a range of additional modelling sites. These are relevant for accounting and plan implementation monitoring, but not for the setting of TASs. As such they are not considered here.*

3.2 Part-FMU selection

3.2.1 Approach

The recommended part-FMUs in this memorandum have been developed based on the following technical assumptions:

- Each part-FMU ideally has a single TAS site;
- The management units recommended in the TAoP and WTWT WIPs (see Table 9) are an appropriate starting point for selecting part-FMUs (TAoP management units = WMUs; WTWT = Catchment × Sub-catchment area); and
- The list of TAS sites recommended by Collaborations provides an appropriate indication of where TASs need to be set to detect the impact of practice change on water quality and ecology across the TAoP Whaitua and WTWT[5]. As such, overlaying that list of sites with the management units in the WIPs is an appropriate method of identifying where those management units need to be refined.

The process of refining the WIP management units into part-FMUs was straight forward. Management units without TAS sites were merged with the management unit containing the relevant proxy catchment identified in the Collaborations memorandum. WIP management units with multiple TAS sites were then assessed to determine whether there was justification for splitting them based on land-use (i.e., would the same actions be needed to meet the target attribute state at each site). Table 9, Table 10, Table 11 respectively:

- Describe the original management units in the TAoP and WTWT WIPs;
- Outline the changes that have been made to them to develop the final recommended list of part-FMUs; and
- List the final recommended part-FMUs and the TAS site for each one.

[5] Note this site list does not reflect a representative monitoring network, and it will not be possible to define 'state' in all rivers across these whaitua based on the data collected at those sites. It is expected that plan effectiveness monitoring will extend beyond the TAS sites.

The original WIP management units and amended recommended part-FMUs are mapped in Appendix C (TAoP) and D (WTWT).

3.2.2 Split WIP management units

- Two WIP management units were identified as having more than one TAS site:
    - WTWT = Te Awa Kairangi forested mainstems (Hutt River at Te Marua Intake and Whakatikei River at Riverstone).
    - TAoP = Takapū (Pāuatahanui Stream at Elmwood Bridge and Duck Creek at Tradewinds Drive Bridge).
- For the Te Awa Kairangi forested mainstems it was decided that **the Hutt River at Te Marua Intake site should be removed** instead of splitting the management unit as:
    - The WIP TASs at the two sites and land-use practices required to achieve them (i.e., maintain their predominately forested upstream catchments) are sufficiently similar that there is limited benefit in splitting the WIP management unit into separate two part-FMUs;
    - The upstream catchment of the Hutt River at Te Marua Intake site is almost entirely within the native forests of the Kaitoke Regional Park, Pākuratahi Forest Regional Park and the Hutt Water Collection Area. (86%). Thus, water quality and ecology at this site is unlikely to be meaningfully impacted by upstream practice change and
    - GW science staff have indicated they would like the flexibility to cease monitoring at the Hutt River at Te Marua Intake site given its limited value for plan effectiveness monitoring and its close proximity to the NIWA monitoring site at Kaitoke .

      Note: This differs from the recommendation made in the original version of this memorandum provided to GW, which was to keep both sites in the same management unit.

- For the Takapū WMU in the TAoP WIP it was decided that the **Duck Creek catchment should have its own part-FMU** (Wai-o-hata in Table 10 and Table 11), as:
    - The Collaborations memorandum does not suggest that the two sites in the WIP WMU are suitable proxies for each other, meaning both need to be retained; and
    - Land-use in the Duck Creek catchment is significantly different than the rest of the WMU. Specifically, the Collaborations memorandum notes *"*[t]*he WIP included this catchment within Takapū* [management unit]*, though the catchment is unique with high proportions of pasture, exotic forest and residential land-uses that was not represented by any other* [management units]".

3.2.3 Merged WIP management units

- Based on the proxy catchment recommendations in the Collaborations memorandum (Appendix B) two catchments in the WTWT WIP were merged (Te Awa Kairangi catchment and Ōrongorongo and Wainuiomata catchment), and within those catchments, six sub-catchment groups were reduced to two part-FMUs (Table 10 and Table 11).
- In addition, two WMUs in the TAoP WIP were merged (Rangituhi and Te Rio o Porirua) to account for the fact that monitoring is not possible in one of them (Rangituhi) (Table 10 and Table 11). The South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes Catchments in the WTWT WIP were also merged for the same reason, resulting in all rivers in those Catchments being merged into a single part-FMU (Table 10 and Table 11).

  Note: The decision to merge these management units was made after the Collaborations memorandum was published and is based on monitoring feasibility. It was not a recommendation of the authors of that memorandum.

Table 9: Original management units set out in the TAoP and WTWT WIPs.

Whaitua	WIP Catchment (WTWT only)	WIP Sub-catchment area (WTWT) or WMU (TAoP)
WTWT	Te Awa Kairangi catchment	Te Awa Kairangi small forested
		Te Awa Kairangi forested mainstems
		Te Awa Kairangi lower mainstem
		Te Awa Kairangi rural mainstems
		Te Awa Kairangi rural streams
		Te Awa Kairangi urban streams
		Waiwhetū Stream
	Ōrongorongo and Wainuiomata catchment	Ōrongorongo
		Wainuiomata small forested
		Wainuiomata urban streams
		Wainuiomata rural streams
	South-west coast, Mākara and Ōhariu catchment	South-west coast rural streams
	Korokoro catchment	Korokoro Stream
	Wellington urban catchment	Kaiwharawhara Stream
		Wellington urban
	Parangārehu Lakes catchment	Parangārehu catchment streams
TOaP		Taupō
		Pouewe
		Rangituhi
		Takapū
		Te Rio o Porirua

Table 10: The WIP management units that were merged or split to create the final recommended part-FMUs.

<table>
<tr><th>Merge/split</th><th>Whaitua</th><th>WIP Catchment (WTWT only)</th><th>WIP Sub-catchment area (WTWT) or WMU (TAoP)</th></tr>
<tr><td rowspan="4">Merge</td><td rowspan="3">WTWT</td><td rowspan="2">• Te Awa Kairangi catchment
• Ōrongorongo and Wainuiomata catchment</td><td>• Te Awa Kairangi small forested
• Te Awa Kairangi forested mainstems
• Wainuiomata small forested
• Ōrongorongo</td></tr>
<tr><td>• Te Awa Kairangi rural mainstems
• Te Awa Kairangi rural streams</td></tr>
<tr><td>• South-west coast, Mākara and Ōhariu catchment
• Parangārehu Lakes catchment</td><td>• South-west coast rural streams
• Parangārehu catchment streams</td></tr>
<tr><td colspan="2" rowspan="2">TAoP</td><td>• Rangituhi
• Te Rio o Porirua</td></tr>
<tr><td>Split</td><td>• Takapū
• Wai-o-hata (new)</td></tr>
</table>

Table 11: Final recommended part-FMUs for TAoP Whaitua and WTWT and the recommended TAS site for each one.

<table>
<tr><th>Whaitua</th><th>WIP Catchment (WTWT only)</th><th>Recommended part-FMUs</th><th>Recommended TAS site</th></tr>
<tr><td rowspan="12">WTWT</td><td rowspan="7">Te Awa Kairangi, Ōrongorongo and Wainuiomata</td><td>Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Ōrongorongo</td><td>Whakatikei R. @ Riverstone</td></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td></tr>
<tr><td>Te Awa Kairangi rural streams and rural mainstems</td><td>Mangaroa R. @ Te Marua</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls Ck adj. Reynolds Bach Dr.</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetū S. @ Whites Line E.</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black Ck @ Rowe Parade end</td></tr>
<tr><td>Wainuiomata rural streams</td><td>Wainuiomata R. DS of White Br.</td></tr>
<tr><td>South-west coast, Mākara and Ōhariu catchment and Parangārehu Lakes</td><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td></tr>
<tr><td>Korokoro catchment</td><td>Korokoro Stream</td><td>Korokoro S.@ Cornish St. Br.</td></tr>
<tr><td rowspan="2">Wellington urban catchment</td><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td></tr>
<tr><td colspan="2" rowspan="5">TOaP</td><td>Taupō</td><td>Taupō S. @ Plimmerton Domain</td></tr>
<tr><td>Pouewe</td><td>Horokiri S. @ Snodgrass</td></tr>
<tr><td>Wai-o-hata</td><td>Duck Ck @ Tradewinds Dr. Br.</td></tr>
<tr><td>Takapū</td><td>Pāuatahanui S. @ Elmwood Br.</td></tr>
<tr><td>Te Rio o Porirua and Rangituhi</td><td>Porirua S. @ Milk Depot</td></tr>
</table>

One potential issue arising from merging multiple WIP management units into a single part-FMU is that the TAS set at the site may not fully capture the direction or magnitude of change signalled by the WIP TASs for the 'lost' management units. Table 12 sets out a summary of the WIP TAS improvements lost by the merging process set out in Section 3.2.3. In most cases the issues raised in Table 12 are inconsequential, as there is a high level of uncertainty in the baseline states for most of the lost WIP management units anyway (and, therefore, a high level of uncertainty in the level of improvement needed to meet the TASs). The exception being the aspirational TASs set for the Rangituhi management unit in the TAoP WIP not being captured by those set for the TAS site in the Te Rio o Porirua management unit.

Table 12: Identification of where the level of improvement indicated by the WIP TASs are different from those required when the WIP management units are merged into the part-FMUs in Table 11.

WIP	WIP management unit	Merged into	Attribute	Difference between TAS: When the part-FMUs inTable 11 are adopted	Difference between TAS: In the WIPs	Notes
TWT	Te Awa Kairangi rural streams	Te Awa Kairangi rural streams and rural mainstems	ASPM	Requires maintenance	Requires a one attribute state improvement	WIP baseline attribute state for lost management unit not supported by measured data
	Parangārehu catchment streams	Parangārehu catchment streams and South-west coast rural streams	Periphyton	Requires maintenance	Requires a one attribute state improvement	
			E. coli	Requires a one-attribute state improvement	Requires a two-attribute state improvement	
			Macroinvertebrates (MCI/QMCI)	Requires maintenance	Requires a one-attribute state improvement	
TAoP	Rangituhi	Te Rio o Porirua and Rangituhi	Periphyton	Requires a one-attribute state improvement	Requires maintenance	
			Ammonia (NH_4-N)			
			NO_3-N			
			E. coli	Requires a two-attribute state improvement	Requires a four-attribute state improvement	
			Macroinvertebrates (MCI/QMCI)	Requires a one attribute state improvement	Requires a two-attribute state improvement	
			Cu	Requires a one-attribute state improvement	Requires a three-attribute state improvement	
			Zn			

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4 Recommended approach to dealing with new attributes and values introduced in the NPS-FM 2020

First published: 13/07/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington

The NPS-FM 2020 introduced several new attributes that are not currently monitored and/or were not considered in the WIPs produced before August 2020. Table 13 provides:

- A review of the existing data available for each attribute;
- An analysis of what can be achieved by way of monitoring for the 2023 and 2024 plan changes;
- An assessment of whether the new attributes are managed by the existing TASs;
- Torlesse's recommended approach for setting targets for new attributes; and
- The PC1 TAG's recommended approach for setting targets for new attributes (discussed in meetings held on the 02/05/2022 and the 16/05/2022).

Note: Since this memorandum was first published GW have made the decision to include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data. Consequently, any recommendation in Table 13 to not set a numeric TASs where one has been included in the WIP should be disregarded.

Table 13: Recommended approach for dealing with new attributes introduced in the NPS-FM 2020.

Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach
Suspended fine sediment (rivers)	Long-term monthly record at existing RSoE monitoring sites.	Outcome:	• Full baseline and TASs for existing sites. • No baseline for new sites (could use general TSS to clarity relationships and dSedNet results but limited value if monitoring is planned – see sediment memo) .	Outcome:	Interim baseline for new sites (not robust enough to set a specific TASs above the baseline (i.e., 'improve' rather than A/B/C).	There is no technical justification to rely on other attributes to manage this attribute as: • This is a 2A attribute requiring limits on resource use. • Sediment loads, targets etc., have not been developed to reflect an unintended consequence of rural and urban mitigations. Sediment management is an important issue on its own. • Baseline states can easily be calculated for existing sites and reasonably robust interim baselines can be calculated for new sites from the normal routine monitoring GW conduct (if ESci can establish sites). • TASs have been set in the WTWT WIP and can be calculated from sediment load reductions in TAoP WIP.	• Existing sites – Establish baseline from monitoring data (already done) and ○ Set TASs in TAoP at current (i.e., de-couple from sediment load reductions). ○ Set TASs in WTWT in accordance with WIP. • New sites: ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline. ○ Establish sites by July 2022 and conduct two years of routine clarity monitoring. ○ Calculate interim baseline from resulting data. ○ Include baseline in 2024 plan change and set narrative TASs (i.e., 'maintain'/'improve').	Adopt recommended approach with changes • Existing sites. ○ Set baselines from monitoring data ○ Set TASs in TAoP at current (i.e., de-couple from sediment load reductions). ○ Set TASs in WTWT in accordance with WIP. • New sites ○ Do not set baselines in PC1 and only include narrative 'maintain or improve' TASs without a baseline. Additional tech work • Existing sites: ○ For TAoP calculate future visual clarity states that are consistent with load reductions using the approach set out in sediment memo. Use national approach bolstered with site specific TSS-visual clarity co-efficient – James or Hayden to do. Still need to have this prepared. ○ Calculate load reductions needed to achieve WTWT TASs using methods described in Section 9 and consider achievability based on available information (EP assessments and existing modelling). • New sites: ○ If ESci have capacity establish sites by July 2022 and conduct two years of routine clarity monitoring ○ Calculate interim baseline from resulting data. ○ Include baseline in 2024 plan change and set narrative TASs (i.e., 'maintain'/'improve').
		Effort:	Negligible – already monitored	Effort:	No additional effort beyond establishing new sites as visual clarity is part of GW's Environmental Science (ESci) department's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A	Start:	July 2022 at the latest to ensure two years of data at new sites			
Submerged plants (natives) and Submerged plants (invasive species) (lakes)	Surveys (LakeSPI may not be calculable for all) conducted in 2022 for: • Lake Wairongamai (Kapiti). • Lake Waitawa (Kapiti). • Lake Nganoke (Ruamāhanga). • Waikanae lagoons (Kapiti). • Wairarapa lagoons (Barton's, Boggy's,	Outcome:	• Up-to-date baseline and TASs for sites surveyed in 2022 (see left); • Slightly out of date baseline and TASs for Lake Kōhangatera and Lake Kōhangapiripiri – just outside the three-year monitoring frequency period; or • Updated baseline and TASs for Lake Kōhangatera and Lake Kōhangapiripiri – Marginal benefit as we are within the three-year monitoring period now and will only be just out at notification.	Outcome:	• Up to date baseline and TASs for sites surveyed in 2022 (see left); • Updated baseline and TASs for Lake Kōhangatera and Lake Kōhangapiripiri – This may well be needed if this attribute is not included in the plan until the 2024 PC as data for these lakes will be five years old at this point.	There is no technical justification to rely on other TAS to manage this attribute as: • This is the only attribute measured for most lakes (i.e., we know the most about this attribute). • There is an abundance of monitoring data, unlikely that any additional work needed if TASs for Lake Kōhangatera and Lake Kōhangapiripiri are set in PC1.	• Include baselines and TAS for WTWT and TAoP in PC1 based on 2019 survey results. • Set baselines and TASs for Kapiti, Ruamāhanga and Eastern Hills in 2024 PC based on 2022 surveys. • Do not monitor any new sites as a lot of lakes have now been surveyed.	Adopt recommended approach. However, check with ESci regarding future monitoring plans.
		Effort:	Minimal effort if Lake Kōhangatera and Lake Kōhangapiripiri re-surveyed (not recommended) – contracted to NIWA, costs likely to be >10K.	Effort:	Minimal effort if Lake Kōhangatera and Lake Kōhangapiripiri re-surveyed (recommended at this point) – contracted to NIWA, costs likely to be >10K.			

Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach
	Matthew's etc.) (Ruamāhanga). • Lake Rototawai (Ruamāhanga). • Pounui Lagoon (Ruamāhanga). • Lake Pounui (Ruamāhanga). Now outdated surveys conducted in 2019 for: • Lake Kōhangatera (TWT). • Lake Kōhangapiripiri (TWT). Assumed LakeSPI not applicable to Wairarapa and Onoke due to depth and trophic status – confirmed with Mary de Winton.	Start:	If Lake Kōhangatera and Lake Kōhangapiripiri are re-surveyed this will need to be contracted ASAP – conducted summer of 2022/2023.	Start:	If Lake Kōhangatera and Lake Kōhangapiripiri are re-surveyed this will need to be contracted by mid-2023 – conducted summer of 2023/2024.			
Fish (rivers)	Little to no data for any existing or new sites.	Outcome:	• Conduct fish surveys at all existing and new sites in WTWT and TAoP where IBI needs to be set. • Postpone fishing of areas to be covered by 2024 PC until summer 2023/2024 due to effort required to fish every site in the region in one year.	Outcome:	Conduct fish surveys at all existing and new sites in in areas covered by 2024 PC where IBI needs to be set.	• Very little justification for leaving out of PC and relying on management via environmental flows and the water quality, plant and macroinvertebrate attributes. • These factors all exert a significant influence over the health of fish populations. • However, as the IBI is a presence absence metric it is not particularly sensitive to changes in these attributes, even when they create a shift in abundance or composition. • Changes are likely to be the result of large-scale habitat change, the removal of fish passage barriers or broader population level processes that may be impacted by factors working across a range of spatial scales.	• Conduct fish surveys at all relevant existing and new sites in WTWT and TAoP in 2022/2023 and include baseline states and TASs in PC1. • Conduct fish surveys at all relevant existing and new sites in the rest of the region in 2023/2024 and include baseline states and TASs in PC1 . • See Section 4.1 for options for setting TASs for this attribute,	Confirm data availability with ESci and pursue recommended approach to fill any gaps. • Conduct fish surveys at all relevant existing and new sites in WTWT and TAoP in 2022/2023 and include baseline states and TASs in PC1. • Conduct fish surveys at all relevant existing and new sites in the rest of the region in 2023/2024 and include baseline states and TASs in PC1. General approach for TASs: • Await national IBI calculator, upon arrival calculate national IBI for sites. • Set IBI TASs at current attribute state with maintain or improve narrative. • Adopt fish narrative approach set out in memo below with following modifications: The abundance, structure and composition of fish communities are maintained or improved and are reflective of a/n excellent/good/fair/poor state of aquatic ecosystem health. • Set to be consistent with WIP MCI TASs in WTWT. • Set to be consistent the WIP narrative fish TASs in TAoP.
		Effort:	Very high – Potentially three monitoring officers for 0.5 to 1 day per site (60 person days).	Effort:	Very high – Potentially three monitoring officers for 0.5 to 1 day per site (~60 person days).			
		Start:	• Scoped and planned July 2022. • Commenced in December 2022.	Start:	• Scoped and planned July 2023. • Commenced in December 2023.			

Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach
Macroinvertebrates (1 of 2) and Macroinvertebrates (2 of 2) (rivers)	Long-term monthly record at existing RSoE monitoring sites.	Outcome:	• Full baseline and TASs for existing sites. • No baseline for new sites.	Outcome:	Interim baseline for new sites (not robust enough to set a specific TAS above the baseline (i.e., 'improve' rather than A/B/C).	There is very little technical justification for relying on other TAS to manage this attribute as: • Baseline states can easily be calculated for existing sites and interim baselines can be calculated for new sites from the normal routine monitoring GW conduct (if ESci can establish sites). • Ultimately the water quality and periphyton attributes should be managed to achieve these invertebrate outcomes. Thus, it is important to set a TAS for macroinvertebrates to match the level at which the other TASs have been set (now and into the future).	• Existing sites – Establish baseline from monitoring data (already done) and set TASs in PC1. • New sites: ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline. ○ Establish monitoring sites by July 2022 and conduct two years of macroinvertebrate monitoring. ○ Calculate interim baseline from resulting data. ○ Include baseline in 2024 PC and set narrative TASs ('maintain'/'improve').	• Adopt recommended approach. Waiting for ESci to confirm capacity for new sites.
		Effort:	Negligible – Already monitored	Effort:	No additional effort beyond establishing new sites as invertebrate monitoring is part of ESci's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A	Start:	July 2022 at the latest to get two years of data at new sites.			
Deposited fine sediment (rivers)	Long-term monthly record at existing RSoE monitoring sites.	Outcome:	• Full baseline and TASs for existing sites. • No baseline for new sites .	Outcome:	• Interim baseline for new sites (not robust enough to set a specific TAS above the baseline (i.e., 'improve' rather than A/B/C).	• There is some technical justification for relying on other TASs to manage this attribute as: ○ Overall sediment input will be controlled by the visual clarity attribute and associated limits. ○ Action planning for the macroinvertebrate attribute states will require some management of deposited fine sediment in many places. ○ There is significant uncertainty around how changes in sediment load will affect deposited fine sediment cover and over what timeframe. Thus, the achievability of any TAS set above the baseline will be uncertain. • Nevertheless, assuming that ESci can establish the required additional sites, there will be baseline data available and sufficient information on the direction of change in sediment load to set a narrative 'maintain' or 'improve' TAS.	• Existing sites – Establish baseline from monitoring data (already done) and ○ Set TASs in TAoP at current. ○ Set TASs in WTWT in accordance with WIP. • New sites: ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline. ○ Establish monitoring sites by July 2022 and conduct two years of sediment cover monitoring. ○ Calculate interim baseline from resulting data. ○ Include baseline in 2024 PC and set narrative TASs ('maintain'/'improve').	• Adopt recommended approach. Waiting for ESci to confirm capacity for new sites.
		Effort:	Negligible – already monitored just not reported.	Effort:	No additional effort beyond establishing new sites as deposited sediment monitoring is part of ESci's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A.	Start:	July 2022 at the latest to get two years of data at new sites.			
Dissolved oxygen (rivers)	Limited data for a small number of sites in the Kapiti, Eastern Hills and Ruamāhanga Whaitua.	Outcome:	• Full baseline for sites in WTWT and TAoP. • No baseline for sites in other Whaitua.	Outcome:	Full baseline for other sites	• There is a moderate technical justification for relying on other TAS/provisions to manage this attribute as: ○ Factors that drive DO should be controlled via the periphyton attribute, environmental flows and wastewater rules (2a attribute applies which requires limits). ○ In large parts of the region DO is unlikely to be a significant problem due to climate, hydrology and topography. ○ Where DO is a problem (mainly low gradient streams) it will need to be managed (via action plans) to meet the macroinvertebrate TASs (i.e., not including it in the PC will not mean it will be ignored).	• Conduct DO monitoring at relevant existing and new sites in WTWT and TAoP in 2022/2023 and include baseline states and TASs in PC1. • Conduct DO monitoring at relevant existing and new sites in the rest of the region in 2023/2024 and include baseline states and TASs in 2024 PC. • As this attribute can generally be managed through other TASs and plan provisions there is a strong justification for only monitoring and setting TASs for sites identified as high risk. Conducting widespread DO monitoring at all sites would be costly and time consuming and may be of less value than focusing monitoring efforts on new sites or other attributes such as F-IBI.	• Adopt recommended approach pending ESci confirming capacity for additional monitoring stream and sites.
		Effort:	Moderate. • Would require the purchase/rental of >10 D-Opto probes. • Additional time (during monitoring run) would need to be spent at each site to install probe. • Each site would likely need to be revisited outside of routine monthly sampling for retrieval. • Data would need to be cleaned and processed.	Effort:	Moderate. • Would require the purchase/rental of >10 D-Opto probes. • Additional time (during monitoring run) would need to be spent at each site to install probe. • Each site would likely need to be revisited outside of routine monthly sampling for retrieval. • Data would need to be cleaned and processed.			
		Start:	Summer 2022	Start:	Summer 2023			

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Attribute	Existing data	Achievable outcome by 2023 PC		Achievable outcome by 2024 PC		Justification for management through other TAS, limits etc. (is there a need for TAS)	Recommended approach	PC1 Technical Teams recommended approach
Lake bottom dissolved oxygen (lakes)	No data to my knowledge	Outcome:	Unlikely to be able to assign a baseline or TASs to any lakes.	Outcome:	Short baseline data series for all lakes likely to be identified in the NRP.	There is a strong justification for relying on other TAS/provisions to manage this attribute as it is designed to control nutrient release from bed sediments. Thus, there is a large amount of cross over with the nutrient attributes (one controls the process, the others controls the outcome).	• Do not attempt to define a baseline state at 2024 PC and only set TAS at 'maintain' and the bottom-line. • Monitoring this attribute requires significant work and targeted management may only be necessary in the future if external nutrient load control proves unsuccessful at achieving nutrient and/or phytoplankton TASs. • This needs to be discussed with a lake expert and will need to have a strong policy justification.	• Adopt recommended approach with some caveats: ○ Policy to determine whether inclusion needed in PC1 for Parangārehu Lakes (avoid re-visiting WTWT and TAoP chapters in 2024). ○ ESci would like to revisit possibility of monitoring. If his team have capacity, we can change. ○ Approach lake expert to review justification about attribute redundancy .
		Effort:	N/A.	Effort:	Very large – Would require a new monthly lake monitoring programme (new sites even in Wairarapa and Onoke) or installation of a number of fixed monitoring stations.			
		Start:	N/A.	Start:	July 2022 to get two years of data.			
Mid-hypolimnetic dissolved oxygen (seasonally stratifying lakes)	No data to my knowledge.	Outcome:	Unlikely to be able to assign a baseline or TASs to any lakes.	Outcome:	Short baseline data series for all seasonally stratified lakes likely to be identified in the NRP.	There may be some technical justification for relying on other TAS/provisions to manage this attribute as I assume hypolimnion oxygen will be driven by primary production (managed by LakeSPI and phytoplankton attributes). However, this should be checked with a lake expert.	• Check with a lake expert regarding whether this attribute is already managed by LakeSPI and phytoplankton attribute. If it is do not attempt to define a baseline state at 2024 PC and only set TAS at 'maintain' or the bottom-line. • If the lake expert things this attribute is not sufficiently managed by the LakeSPI, and phytoplankton attributes then progress with plan to establish new monitoring programme for seasonally stratified lakes likely to be identified in the NRP.	• Adopt recommended approach with some caveats: ○ Policy to determine whether inclusion needed in PC1 for Parangārehu Lakes (avoid re-visiting WTWT and TAoP chapters in 2024). ○ ESci would like to revisit possibility of monitoring. If this team have capacity, we can change. • Approach lake expert to review justification about attribute redundancy.
		Effort:	N/A.	Effort:	Very large – Would require a new monthly lake monitoring programme or installation of a number of fixed monitoring stations.			
		Start:	N/A.	Start:	July 2022 to get two years of data.			
Dissolved reactive phosphorus	Long-term monthly record at existing RSoE monitoring sites	Outcome:	• Full baseline and TASs for existing sites. • No measured baseline for new sites (could use modelled results for TAoP sites).	Outcome:	Interim baseline for new sites (not robust enough to set a specific TAS above the baseline (i.e., 'improve' rather than A/B/C).	There is limited technical justification to rely on other TAS to manage this attribute as: • Baseline states can easily be calculated for existing sites and interim baselines can be calculated for new sites from the normal routine monitoring GW conduct (if ESci can establish sites). • Nutrient exceedance criteria need to be set for this attribute regardless of where TASs are included in the NRP.	• Existing sites – Establish baseline from monitoring data (already done) and set TASs. • New sites: ○ Do not set baselines or TASs in PC1 or only include narrative 'maintain' TASs without a baseline. ○ Establish monitoring sites by July 2022 and conduct two years of routine monitoring. ○ Calculate interim baseline from resulting data. ○ Include baseline in 2024 PC and set narrative TASs ('maintain'/'improve').	• Adopt recommended approach pending ESci confirming capacity for additional sites.
		Effort:	Negligible – already monitored.	Effort:	No additional effort beyond establishing new sites as DRP is part of ESci's routine monitoring protocols (whether establishing new sites is achievable will require discussions with ESci).			
		Start:	N/A	Start:	July 2022 at the latest to get two years of data at new sites			
Ecosystem metabolism (both gross primary production and ecosystem respiration) (rivers)	None.	Outcome:	• Full baseline for sites in WTWT and TAoP • No baseline for sites in other Whaitua.	Outcome:	Full baseline for other sites.	• There is a strong technical justification for relying on other TAS/provisions to manage this attribute as: ○ Factors that drive ecosystem metabolism should be partially managed via nutrient exceedance criteria, the periphyton and DO attributes, and wastewater rules. ○ There are no attribute state thresholds in the NPS-FM.	• Calculate for DO sites in WTWT and TAoP in 2022/2023 and include baseline (as measured value) and TASs (narrative 'maintain') in PC1. • Calculate for DO sites in the rest of the region in 2023/2024 and include baseline (as measured value) and TASs (narrative 'maintain') in 2024 PC. • There seems to be a strong justification for only monitoring and setting TASs for sites identified as high risk for DO. Conducting widespread monitoring at all sites would be costly and reasonably time consuming and may be of less value than focusing monitoring efforts on new sites or other attributes such as F-IBI.	• Adopt recommended approach pending ESci confirming capacity for additional monitoring stream and sites
		Effort:	Same as DO.	Effort:	Same as DO.			
		Start:	Summer 2022.	Start:	Summer 2023.			

4.1 Potential methods for setting TASs for fish

The NPS-FM 2020 includes the F-IBI as a compulsory attribute in Appendix 2B. However, there are several technical issues that makes setting site specific TASs for fish difficult at the current time, especially ones that are consistent with the NPS-FM 2020 attribute states. These issues and potential options for addressing them are set out in Section 4.1.1 to 4.1.5 below.

4.1.1 Issues with NPS-FM 2020 F-IBI attribute and the F-IBI in general

4.1.1.1 Lack of clarity regarding how the NPS-FM 2020 attribute state thresholds have been selected

The *Science Technical Freshwater Science and Technical Advisory Group (STAG) Report to the Minister for the Environment* (STAG, 2019), which originally proposed the NPS-FM 2020 fish attribute, contains no information on how the attribute state thresholds for F-IBI were determined, as such their relevance to the Wellington Region is unclear. Compared to most other regions, the average F-IBI in Wellington is high (40 – 50 (MfE, 2019)). As such the applicability of the attribute state framework that sets the most stringent threshold at 35 is questionable. It also means that the fish attribute state framework in the TAoP WIP is unlikely to align well with the NPS-FM 2020 attribute states.

The STAG themselves noted these issues with their proposed attribute state framework:

- *"Some members note that we do not understand the scale of natural variation, how to take this into account and question whether some degree of region-specific modification may be required"* (STAG, 2019)*; and*
- *"Some members register concerns regarding the proposal to introduce Fish IBI into the NOF as an attribute, owing to [] the need for more detailed and independent evaluation of the methodology and rationale used to derive the proposed numeric attribute states for the fish IBI"* (STAG, 2020).

4.1.1.2 Lack of clarity regarding how the F-IBI used in the NPS-FM is supposed to be calculated

Several national F-IBI score calculations exist, including:

- Joy and Death (2004); and
- MfE (2019).

However, their relevance to the NPS-FM 2020 attribute states is unclear. While the attribute state table itself notes "*the F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004*", this is not overly helpful due to the ambiguity introduced by the word "general". Furthermore, while the STAG suggests the attribute states should be assessed using Joy and Death (2004) (with Salmonids excluded) they also note that the "*Fish IBI would need to be standardised in a national model" and that this "may change the results gained from current programmes*".

What makes this noteworthy is that it suggests that the NPS-FM 2020 attribute states may have been determined based on F-IBI scores that were calculated in a manner that is different from how regional councils will ultimately be expected to benchmark their data against the attribute state thresholds. It must be noted, however, that this may be the case regardless, as salmonids appear to have been excluded from the F-IBI when the STAG were considering the attribute state thresholds, but the NPS-FM makes no reference to this method.

The MfE website suggests that a National F-IBI calculator is being developed and will be available in mid-2022. Hopefully at that point it will become clear whether the NPS-FM 2020 IBI attribute states are appropriate for use in the Wellington Region, or whether some degree of modification will be needed.

Note: This memorandum was first published prior to the release of the national F-IBI calculator on the MfE website.

4.1.1.3 Lack of baseline data

To my knowledge the TAS sites identified in Nation and Blyth (2022) have not been fished using the Joy *et al.* (2013) methods (as stipulated in the NPS-FM 2020). As such, it is not possible to calculate a baseline F-IBI state for these sites (noting that how F-IBI should be calculated is still unclear). Furthermore, attempting to assign a baseline state from data collected from a nearby proxy site would be inappropriate.

The F-IBI at a site is influenced by factors such as general habitat characteristics of the fished reach, specifically, the occurrence of pools and riffles, and the presence of fish passage barriers. Thus, one would need to be confident that a proposed proxy site was similar to the TAS site in this regard before using it to assign a baseline state. Even then, there would be significant uncertainty around the resulting assessments. An example is provided below in Figure 1. From that aerial photograph the differences in habitat in a 150-metre fishing reach in the Wainuiomata River at the Manuka Track monitoring site and the closest fished site downstream are clearly visible. The lack of riffles and pools at the later site means that F-IBI could be significantly different from at the upstream monitoring site despite how close they are.

Another complication is the lack of directly transferable proxy data. While MfE (2019) provides a F-IBI score for all sites fished between 1998 and 2018, the F-IBI has been calculated differently to that prescribed by the NPS-FM 2020. We are also unable to conduct our own benchmarking against the NPS-FM 2020 attribute states using data from the New Zealand Freshwater Fish Database (NZFFD) due to the lack of certainty around the NPS-FM 2020 F-IBI calculation methodology

4.1.1.4 The F-IBI is unlikely to adequately capture the Committees' desires for improvement in fish community health

The F-IBI is a presence absence metric that responds strongly to only one component of fish community health, diversity; for the F-IBI to change at a site, a species must be introduced or extirpated.

Certain actions, such as removing fish passage barriers and naturalising modified waterways, can improve F-IBI at a site by allowing the recolonisation of previously inaccessible or uninhabited reaches. However, while managing discharges, controlling works on the bed and conducting restoration works can improve the structure and composition of the resident fish community, the impact on diversity is likely to be limited in many cases. The migratory nature of many native fish species facilitates the constant colonisation of most rivers and streams, even where they provide poor habitat and have degraded water quality. Thus, the F-IBI at a site may not respond to changes in water quality and habitat despite the abundance and health of certain resident species improving (i.e., all species that the river can support were already there prior to implementing the mitigations just in a poorer state).

It must also be noted that in some rivers and streams a low F-IBI score may not be a symptom of land-use, discharges or water takes. Rather they may be the result of a wider species conservation issues or the presence of an invasive species, both of which are hard to manage through a regional plan and may be covered by legislation other than the Resource Management Act ('the RMA').

Figure 1: Aerial photograph demonstrating the differences in pool and riffle habitat in 150 metre fishing reaches (blue lines) in the Wainuiomata River at the Manuka Track monitoring site (top) and the closest fished site downstream (bottom).

4.1.1.5 The F-IBI does not cover key components of fish community health.

The F-IBI responds to changes in diversity, it is not sensitive to other important aspects of fish community health such as abundance, structure and composition. While harder to quantify, these factors are more likely to respond to regulation and mitigation actions than diversity. For example, removing a fish passage barrier constructed in the last ten years might not change the diversity of a fish community dominated by long-lived migratory species. However, it might result in additional recruitment and, consequently, affect abundance and size class distribution. Such improvements would not be detectable from the F-IBI.

4.1.2 Options for using existing regional information for setting TASs for fish

4.1.2.1 General issues of using the Wellington F-IBI

A Wellington specific F-IBI has been developed by Joy and Henderson (2004) and is used in Objective O19 of the operative NRP. However, using the regional F-IBI to set or benchmark TASs has some technical and policy pitfalls:

- The Wellington F-IBI framework is the better part of 20 years old. Thus, it is not informed by the latest fishing data (minor issue);
- As mentioned in Section 4.1.1.1 , on average F-IBI scores are higher Wellington rivers than in many other regions. As such the Wellington specific thresholds do not align with those in the NPS-FM 2020 (see Table 14 below);
- There are also other potential reasons why the NPS-FM 2020 and Wellington attribute state thresholds do not align:
    - The NPS-FM 2020 adopts a four-band attribute state framework, while the Wellington system originally adopted a seven-band approach. These seven bands were then reduced to four through the NRP appeals process by merging the two top categories into the A band and the three bottom categories into the D band. It is unclear what the thresholds would have been, or how they would have differed from the NPS-FM 2020, if Joy and Henderson (2004) had originally created a four band framework comparable to that in the NPS-FM 2020; and
    - The national F-IBI calculator may simply generate lower values than the regional IBI calculator from the same fish data. As such it is possible that when Wellington fish data are analysed using an appropriate national F-IBI calculator the NPS-FM 2020 attribute state thresholds will prove to be accurate descriptors of the state of fish communities in the region. However, it must be noted that initial analysis conducted by GW suggests that this is unlikely to be the case, and that the national F-IBI calculator may generate higher values than the regional version (Figure 2).
- It is unclear whether the lack of alignment between the NPS-FM 2020 attribute state thresholds and the Wellington specific thresholds poses a significant problem should the latter be used to set target TASs as they are more stringent than the national version. However, it is apparent that benchmarking against any F-IBI thresholds should be done using the F-IBI calculator that informed the development of said thresholds. Thus, if the Wellington F-IBI thresholds are adopted in the NRP then benchmarking should be conducted using just the Wellington F-IBI calculator. As such, the primary risk of using the Wellington F-IBI thresholds comes from the potential for future central government directions stipulating a specific national F-IBI calculator that regional councils are to use when reporting.
- Should the regional F-IBI be used to set TASs, there would still be a lack of data for some TAS sites.

Table 14: Comparison of the NPS-FM 2020 and Wellington F-IBI thresholds.

Attribute band	NPS-FM 2020 threshold	Wellington thresholds used in NRP
A	≥34	≥48
B	<34 and ≥28	<48 and ≥38
C	<28 and ≥18	<38 and ≥30
D	<18	<30

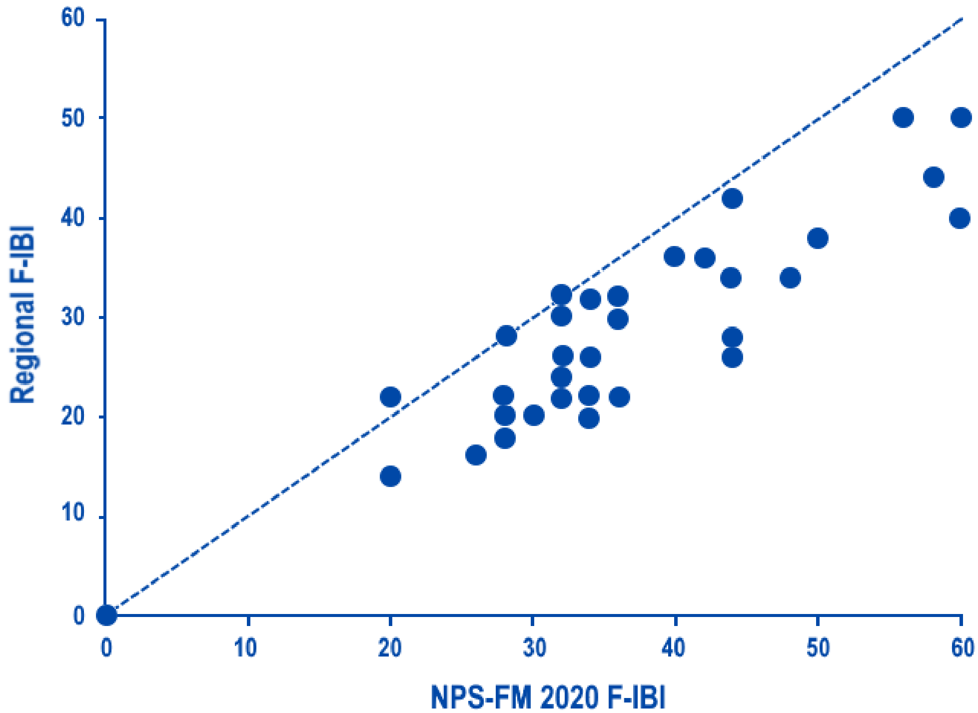

Figure 2: Comparisons of Wellington F-IBI vs draft National F-IBI scores calculated from the same data.

4.1.2.2 Option to use the F-IBI scores in Objective O19 of the NRP as TASs

One option for using the regional F-IBI in the absence of baseline state data for the TAS sites is to adopt the NRP O19 F-IBI thresholds. In additional to the general short comings of adopting the regional F-IBI (see above) the main issue with adopting such an approach is that it is designed to achieve a blanket 'good' level of ecosystem health (i.e., B state) in most rivers and an 'excellent' level of ecosystem health (A state) in Class 1 rivers and rivers with high macroinvertebrate community health. As such they do not factor in any variability in current state between sites (should it exist), or what is achievable based on the target states of related attributes.

4.1.2.3 Option to use the regional F-IBI thresholds and regional calculator to assign relevant TASs for sites

While there are technical issues with the regional F-IBI in terms of its age and how the attribute state thresholds have been calculated, there are benefits in adopting this approach as it could potentially bypass the issues with the National F-IBI framework described above in Sections 4.1.1.1 and 4.1.1.2 in that:

- We know how the F-IBI thresholds have been developed;
- We have a way to calculate the F-IBI and benchmark it against the thresholds; and
- We know that the F-IBI thresholds are relevant to the Wellington Region.

However, as mentioned in Section 4.1.2.1 , the primary risk of adopting such an approach is that central government may, in the future, require F-IBI to be assessed using a national metric which is unlikely to correspond well to the Wellington F-IBI thresholds. This could result in a reporting headache in which F-IBI changes due to shifts in calculation method rather than an actual change in fish community health.

4.1.2.4 Option to use the NPS-FM 2020 F-IBI thresholds and the regional F-IBI calculator to assign TASs

As previously mentioned, this approach is unlikely to work. It is clear from the attribute state thresholds and work conducted by GW that there is a risk that the regional and national F-IBIs do not align well. Accordingly, mixing and matching metrics and thresholds is not appropriate.

4.1.3 Recommended approach for setting F-IBI attribute states

4.1.3.1 Options for TAoP

1. Define current state using the selected F-IBI (Wellington or national) and set the TASs based on the desired improvements signalled in the WIP (see Table 15 for example). This is unlikely to be appropriate as the WIP uses a narrative approach for fish with attribute states that do not align with the Wellington or national F-IBI thresholds. The WIP narrative attributes encompass a range population characteristics which may be more sensitive to regulation and mitigation than the F-IBI. As such, the potential for improvements in this subjective attribute may be far greater than for F-IBI.
2. Define current state using the selected F-IBI (Wellington or national) and set the TASs at current. This is a defensible approach and reflects the uncertainty around GW's ability to have a material impact on fish presence-absence in many waterways. It can also be supported by the WTWT Biophysical Science Programme (BSP) Freshwater Quality and Ecology Expert Panel (hereafter referred to as 'the Freshwater Panel') outputs.
3. Define current state using the selected F-IBI (Wellington or national) and undertake an expert panel assessment of the regulatory actions recommended in the WIP to assess their likely effect on F-IBI. Based on the Freshwater Panel outputs (Greer *et al.*, 2022). this will likely show that current state is the most appropriate TAS. Limited benefit over Option 2 (Greer *et al.*, 2022).

4.1.3.2 Options for WTWT

1. Define current state using the selected F-IBI (Wellington or national) and set TASs based on the desired improvements signalled in the WIP. This is unlikely to be defensible as the WIP

TASs in many areas represent an improvement which is in direct conflict with the Freshwater Panel outputs.

2. Define current state using the selected F-IBI (Wellington or national) and set the TASs at current at all time steps. This is a defensible approach and reflects the uncertainty around GW's ability to have a material impact on fish presence-absence in many water ways. It can also be supported by the WTWT BSP Freshwater Panel outputs (Greer *et al.*, 2022).

4.1.4 Incorporating a narrative attribute to account for other aspects of fish health

As stated in Section 4.1.1.5 the F-IBI only responds to changes in diversity, it is not sensitive to other important aspects of fish community health such as abundance, structure and composition. As such, adopting a narrative attribute approach that captures these components of fish community health in addition to implementing an F-IBI attribute state would best capture the intent of the TAoP WIP. However, I do not consider that the narrative attribute states in that WIP are appropriate as, despite being relatable to the lay person:

- They do not define the specific components of fish community health to be measured;
- The terminology used is inconsistent between attribute states. I.e.:
    - A = Typical of undisturbed;
    - B = Low stress;
    - C = Moderate stress; and
    - D = Large changes.
- Some of the key assessment categories referenced are likely to remain difficult to benchmark against for the foreseeable future:
    - When assessing against the A state it is unclear how one would define what is typical of the reference condition for that stream type. While there are (poor performing) presence-absence models, we are a long way off being able to define reference state abundance, composition or structure for a given stream: and
    - When assessing against the B and C attribute states it is difficult to determine what a low or moderate level of stress would be in the absence of specific stress index (which is not forthcoming).

Instead, it is my opinion that adapting the O19 narrative fish objectives into a four-band framework would be more appropriate for the following reasons:

- The O19 narrative fish objective was conferenced on, mediated, and agreed to during the NRP appeals;
- The excellent-good-fair-poor scale set out in Table 15 is widely used when setting environmental guidelines and corresponds well to A-B-C-D attribute state framework in the NPS-FM 2020. Thus, while the various components of the recommended narrative cannot currently be benchmarked against the prescribed level of ecosystem health, the wording allows for the adoption of any future relevant community health indices provided they are graded in the four-category scale that has become ubiquitous in ecosystem health metrics; and

- While it is not possible to benchmark the various components of the narrative against the prescribed level of ecosystem health, they are all currently measurable. Thus, any direction of change can be assessed and reported on. This is a key difference between this framework and the narrative attribute states in the TAoP WIP.

In terms of selecting the level at which the narrative TASs is set, there is two defensible options:

- Set it to reflect the Q/MCI objective (preferred), which should in turn reflect the likely outcome of meeting the water quality, habitat and periphyton attribute states (in the absence of any fish passage issues); or If the F-IBI attribute states are set to maintain current state due to the uncertainty around GW's ability to effect change in this metric, then the narrative attribute state could be set at the same level. However, this could well be questioned because managing water quality, periphyton and habitat to achieve an improving Q/MCI TASs would be expected to translate into an improvement in fish community structure and composition regardless of whether new species move into the site or not.

Table 15: Potential fish community health narrative attribute.

Value	Ecosystem health (Aquatic life)
Freshwater body type	Rivers
Attribute unit	N/A
Attribute band	Attribute description
A	The abundance, structure and composition of fish communities are reflective of an excellent state of aquatic ecosystem health
B	The abundance, structure and composition of fish communities are reflective of a good state of aquatic ecosystem health
C	The abundance, structure and composition of fish communities are reflective of a fair state of aquatic ecosystem health
D	The abundance, structure and composition of fish communities are reflective of a poor state of aquatic ecosystem health

4.1.5 Final summary of possible approaches to setting TASs for fish

1. Select which F-IBI to use based on the risks:
    a. Wellington F-IBI – We already know how the F-IBI thresholds have been developed, we have a way to calculate the F-IBI and benchmark it against the thresholds and we know that the F-IBI thresholds are relevant to the Wellington Region. The major risk is that if we adopt it and central government direction requires benchmarking using a national F-IBI these would not align with the Wellington thresholds.
    b. National F-IBI (preferred) – In theory there is a low risk of a national F-IBI being required that does not align with the NPS-FM 2020 attribute (although there is some uncertainty around this now). However, there are some questions around the applicability of the F- IBI thresholds to the Wellington Region and this will remain the case until the national F-IBI calculator is released (in the next few months).
2. Define current state using the selected F-IBI (preferably national) and set the TASs at current. This is a defensible approach and reflects the uncertainty around GW's ability to

have a material impact on presence-absence in many water ways. It can be supported by the WTWT BSP Freshwater Panel outputs (Greer *et al.*, 2022).

3. Adapt the O19 narrative fish attribute into a four-band framework and set the TASs to reflect the Q/MCI TASs (preferred), which should in turn reflect the likely outcome of meeting the water quality, habitat and periphyton attribute states.

Notes:

- *The recommended approach above was discussed in the PC1 TAG meetings held on the 02/05/2022 and the 16/05/2022. The TAG agreed that the approach was reasonable (Table 13):*
- *For WTWT, GW have not accepted the TAGS recommendation to set F-IBI TASs at baseline state and have instead adopted the WIP TASs (added by Michael Greer September 2023).*

4.1.6 Additional note on sites

The TAG discussed what flexibility there is around F-IBI TAS sites, given that the water quality sites may not be fit for this purpose. They considered that for the F-IBI TASs a site be a reach between two points or even a stream. One way to implement this in the plan change process could be through a footnote to the relevant table (see Table 16 for a rough example).

Table 16: Example for incorporating date flexibility for fish into a TAS table.

Site[1]	NH_4-N toxicity		NO_3-N toxicity		F IBI[2]	
	Baseline state	TAS	Baseline state	TAS	Baseline state	TAS
River @ location	B	A	A	A	Unknown	Maintain or improve
River @ location	B	A	A	A	Unknown	Maintain or improve
River @ location	B	A	A	A	Unknown	Maintain or improve

[1] Applies to all attributes except F-IBI, which may be assessed at different sites on the rivers identified in this column.
[2] The Regional Council will:

(i) Identify the representative sites at which progress towards the F-IBI TASs will be monitored on the main stems of the rivers listed in Table XX; and
(ii) Keep a record of the locations of representative monitoring sites in an action plan developed in accordance with Method MXX.

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5 Habitat attribute review

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To: Plan Change 1 Policy and Technical Team
Greater Wellington

The NPS-FM 2020 identifies habitat as one of the five biophysical components of aquatic ecosystem health. Accordingly, the NPS-FM 2020 notes that it is necessary to manage habitat (Appendix 1A(1) and (3)) and treat it as a value (3.9(1)). That raises the following questions:

- Do the existing compulsory attributes already manage habitat?
- Are there multi-metric habitat attributes that targets could be set for?
- Are there individual habitat attributes that targets could be set for?

5.1 Relevance of existing attributes to habitat management

How the existing compulsory attributes relate to the management of habitat are set out below in Table 17.

Table 17: How the existing NPS-FM 2020 attributes relate to habitat.

Attribute	How it provides for habitat
Deposited sediment	Deposited sediment cover is a key component of aquatic habitat quality. Setting TASs for this attribute ensures that deposited cover does not degrade habitat quality and that the bed is composed of substrates that provide a diversity of habitats (including those in the hyporheic zone)
Fish	The health and functioning of fish communities is heavily impacted by the diversity, quality, and quantity of habitat available. Thus, meeting the fish TASs will require that habitat is managed.
Macroinvertebrates	EPT taxa have a significant influence over all macroinvertebrate indices for which TAS must be set. This is by historical design as they are the most sensitive taxa to organic pollution (which the MCI was developed for). However, these taxa also favour undisturbed, structurally complex habitat such as gravely-cobbly riffles clear of filamentous algae/macrophytes. As such, achieving the macroinvertebrate TASs will require some protection or enhancement of benthic habitat
Periphyton	Nuisance blooms of periphyton smother benthic habitat used by invertebrates and fish. As such, managing periphyton to the biomass TASs will influence benthic habitat quality and quantity.

5.2 Applicability of existing multimeric indicators

A description and an assessment of the strength and weaknesses of the existing multimeric indicators that could be used to set TASs for habitat are provided in Table 18.

5.3 Potential individual habitat attributes that targets could be set for

There are many habitat metrics that GW could measure, set a baseline state for, and assign a ‘maintain or improve’ type TAS for (specifically, all the individual components of the Rapid Habitat Score (RHS), Rabid Habitat Pressure Score (RHPS), Stream ecological valuation (SEV) and Habitat Quality Index (HQI). However, to my knowledge, of these attributes only macrophyte volume has a (somewhat) defensible effects-based guideline value that can be relied upon. The guideline, which is from Matheson *et al.* (2012) is 50% volume/CAV and is already included in O19 of the NRP.

5.4 Recommended approach to managing habitat

In my opinion setting specific TASs for habitat in PC1 is not necessary as:

- Meeting the targets for existing compulsory attributes will:
    - Manage some specific components of habitat; and
    - Require habitat generally to be managed to achieve ecological outcomes.
- The existing multimeric habitat metrics are generally not fit for this purpose and a lack of relevant guideline values means that attribute state thresholds cannot be defined for most of the individual habitat metrics that are not currently included in Appendix 2 of the NPS-FM 2020.

Note: The recommended approach above was discussed in the PC1 TAG meeting on the 13/06/2022. The TAG agreed that the approach was reasonable.

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Table 18: Potential multimeric habitat indices that could be used as TASs in PC1.

Attribute	Source	Description	Specific attributes considered	Existing grading system?	Pros	Cons
RHS	Clapcott (2015)	• Provides a 'habitat quality score' for a river reach which indicates general stream habitat condition for the physical aspect, such as the structure of the stream banks or the nature of the stream bed. • Developed to help with national standardisation of stream habitat assessment. • Involves scoring 10 attributes on a scale of 1 – 10 and taking the sum. Observed score can be compared to the average score from reference site(s) to provide a HQS % assessment	• Deposited sediment • Invertebrate habitat diversity • Invertebrate habitat abundance • Fish habitat diversity • Fish habitat abundance • Hydraulic heterogeneity • Bank erosion • Bank vegetation • Riparian width • Riparian shade	Yes, from Clapcott *et al.* (2020) A = >75 B = >50 - ≤ 75 C = >25 - ≤ 50 D = ≤ 25	• Established and widely used. • Monitored by GW (i.e., there is existing data and no extra monitoring burden). • Fast and cheap to do, new sites could be scored quickly. • Has existing national grading system that has previously been used in national reporting.	• Generally, only supposed to apply to hard-bottomed wadable streams and is poor at accounting for natural variability in deposited sediment cover. Clapcott *et al.* (2020) recommends scoring deposited sediment as a deviation from reference state but does not provide an updated scoring system to do this. • Applicability of national guidelines to Wellington untested. • Scoring system somewhat subjective.
RHPS	Holmes *et al.* (2020)	• Complements the RHS, but where the RHS measures the state of habitat, the RHPS assesses the degree of habitat modification and potential pressures such as instream or bank engineering. As such, it provides an indication of the whether a site is at risk of degradation rather than a measure of how degraded that site is. • Involves scoring 12 river pressure attributes on a scale of 1 – 10 and taking the sum.	• Nuisance benthic algae • Nuisance aquatic macrophytes • Instream structures (structures below the base flow waterline) • Instream disturbance • Discharges and drains • Introduced riparian plants occurring at nuisance levels • Bank modification • Livestock riparian disturbance • Human riparian disturbance • Occurrence of rubbish in the stream and riparian area • Surrounding land use and flood plain modification • Flood plain constraints	No	• Provides an indication of future risk from activities by the plan change (i.e., may be more directly impacted by provisions than RHS which is more impacted by factors outside of human control). • Is similar to the RHS in terms of monitoring effort.	• Is still in draft (untested). • Attribute state thresholds have not been developed. • Scoring system somewhat subjective. • Current state is unknown.
SEV Fish spawning habitat and Habitat for aquatic fauna function scores	Storey *et al.* (2011)	• Developed to assess physical habitat quality in Auckland's urban streams but now used extensively in Wellington for consenting purposes. • Combines measurements and visual assessment of 29 variables, to calculate a scores for 14 ecological functions including fish spawning habitat and habitat for aquatic fauna.	Too long to list	No	• There is a lot of data for the Wellington Region. • The SEV is a well-established and generally accepted measure of stream health.	• Not currently monitored by GW. • Using the individual habitat function scores of the SEV is not standard procedure. • No existing attribute state thresholds (exist for individual variables but are inconsistent and given different weightings). • Intensive to monitor compared to the RHS.
HQI	Death *et al* (n.d.).	The HQI provides an assessment of the relative change in selected geomorphic characteristics and habitat quality from reference condition (or some other pre-defined time-step. It is calculated by determining the ratio between a river's current geomorphological characteristics and the appropriate historical condition.	• Sinuosity • Active channel • Bank full channel • Permitted Floodplain • Braiding Index • Pools • Thalweg length	No	• Can be done as a desktop exercise • Provides an indication of large-scale habitat changes caused by activities such as river engineering • Was developed for Wellington	• Only considers geomorphology. Thus, does not capture key components of aquatic habitat such as cover. • Attribute state thresholds have not been developed. • May not be possible to measure for all sites, especially where those with a canopy or where there is dearth of historical aerial photographs. • Generally, captures the effects of one or two activities (urban channel modification and flood protection).

6 Recommended nutrient outcomes for sites in PC1 based on national guidance

First published: 28/03/2023

To: Plan Change 1 Policy and Technical Team
Greater Wellington Regional Council

6.1 Introduction

The NPS-FM 2020 (amended February 2023) requires regional councils to:

- Set appropriate instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus (nutrient outcomes (NOs)).
- Identify limits on resource use that will achieve any nutrient outcomes.

On that basis NOs effectively act as NPS-FM 2020 Appendix 2A attributes. However, unlike Appendix 2A attributes, the NPS-FM 2020 does not define a state framework from which NOs can be selected. Instead, Clause 3.13 requires regional councils to define their own NOs in accordance with the following:

- To achieve a target attribute state for any nutrient attribute, and any attribute affected by nutrients, every regional council must, at a minimum, set appropriate instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus (examples of attributes affected by nutrients include periphyton, dissolved oxygen, submerged plants, fish, macroinvertebrates, and ecosystem metabolism).
- Where there are nutrient-sensitive downstream receiving environments, the instream concentrations and exceedance criteria, or the instream loads, for nitrogen and phosphorus for the upstream contributing water bodies must be set so as to achieve the environmental outcomes sought for the nutrient-sensitive downstream receiving environments.
- In setting instream concentrations and exceedance criteria, or instream loads, for nitrogen and phosphorus under this clause, the regional council must determine the most appropriate form(s) of nitrogen and phosphorus to be managed for the receiving environment.

This memorandum provides recommendations on how to set NOs for TAoP Whaitua and WTWT in accordance with Clause 3.13 of the NPS-FM 2020 based on the best available national guidance (all guidance released post the 2023 amendments to the NPS-FM 2020).

6.2 Available guidance

6.2.1 Framework

The most comprehensive national guidance on how regional councils should develop NOs comes from MfE (2022a). This document is focused on how regional councils should set instream concentrations thresholds (ICTs) as NOs. To do that, it first describes the relationship between the nutrients and the various attributes in Appendix 2 of the NPS-FM 2020 (Figure 3). It then sets out a framework for navigating the difficult decisions regional councils will face when setting NOs based on the PrOACT framework for smart decision-making:

1. **P**roblem: Define the decision problem carefully so the right problem will be solved. Section 1 of this guidance presents the problem to be solved.
2. **O**bjectives: Clearly define and differentiate fundamental and means objectives (aims in this case) that must be met to solve the problem.
3. **A**lternatives: As far as practicable, present the full range of alternative strategies for meeting the fundamental aims. This is critical as it frames the entire approach to solving the problem, ensuring the choices available to decision-makers are preserved.
4. **C**onsequences: Describe how well the alternative strategies enable the fundamental aims to be met.
5. **T**rade-offs: Balance the pros and cons of the alternative strategies that can be chosen to meet the fundamental aims.

As part of that framework, the MfE (2022a) guidance defines the Fundamental Aims and Means Aims of ICTs, against which various NOs development strategies can be assessed. These are presented below and in Figure 3:

- **Fundamental Aim (FA) 1** is to establish a set of ICTs that protects the target states of all nutrient-affected attributes within regions.
- **Fundamental Aim (FA) 2** is to minimise the cost to councils of setting ICTs for nutrient-affected attributes.
- FA1 means aims
    - **Means Aims (MA) 1–8** are to define dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) ICTs that allow councils to meet the target states for each of the following attributes:
    - Chl a (MA1)
    - MCI (MA2)
    - QMCI (MA3)
    - ASPM (MA4)
    - F-IBI (MA5)
    - DO (MA6)
    - GPP (MA7)
    - ER (MA8).
- FA2 means aims
    - **Means Aim 9** is to minimise the number of attribute-specific ICTs required by councils.
    - **Means Aim 10** is to minimise unnecessary data analyses employed to derive ICTs.
    - **Means Aim 11** is to minimise the duplication of effort.
    - **Means Aim 12** is to minimise unnecessary collection of data.

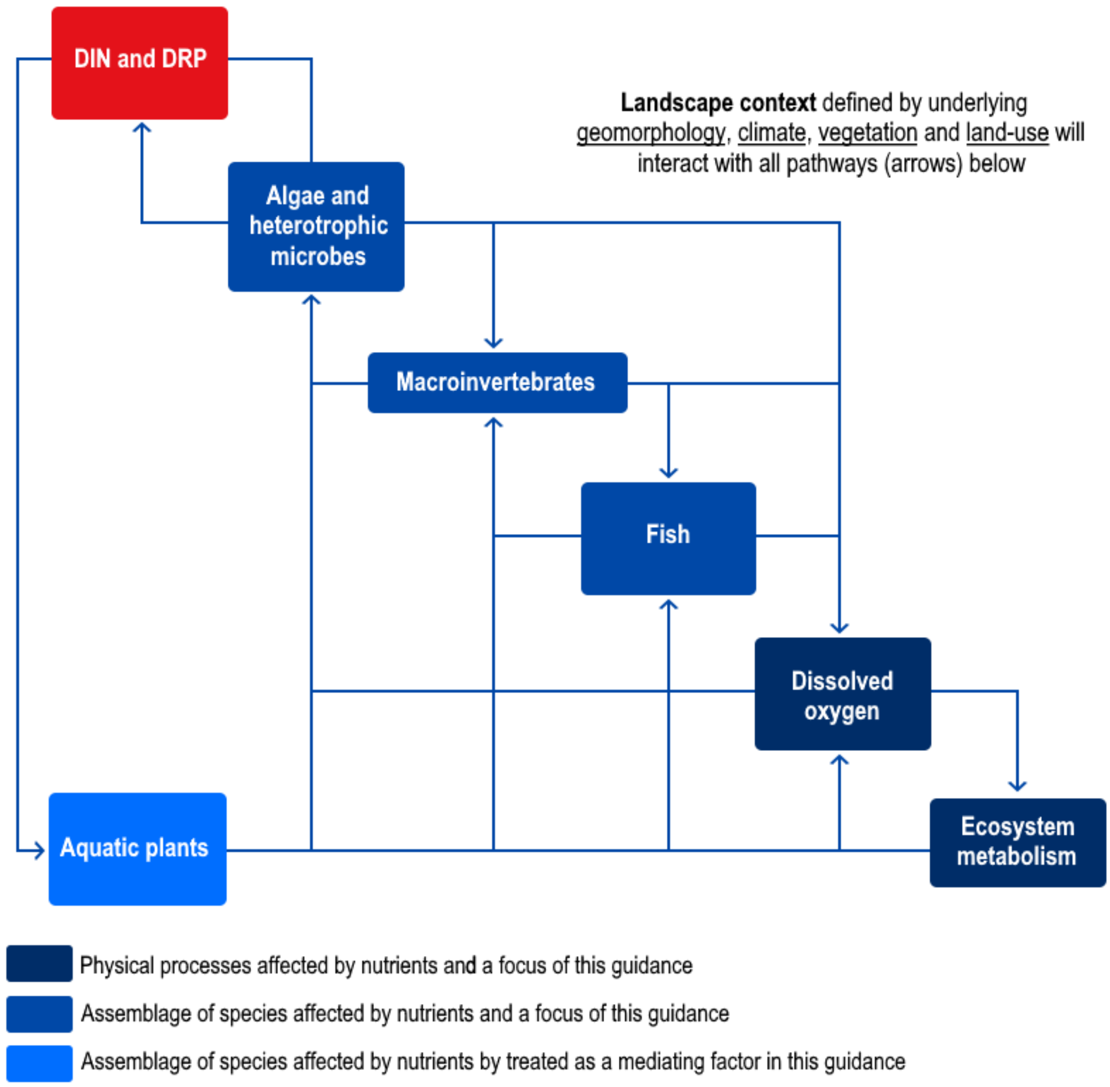

Figure 3: Simple conceptual model summarising the primary links between nutrients and the constituents of river ecosystems. Re-created from MfE (2022a) (Figure 2-1).

6.2.2 Possible strategies for developing nutrient outcomes

MfE (2022a) propose four possible strategies that regional councils could use to set NOs. These are set out in Table 19. How each of these strategies achieve the various Fundamental Aims and Means Aims identified in MfE (2022a) are set out in Figure 4.

Table 19: Description of the four strategies proposed in MfE (2022a) for setting NOs.

Strategy	Summary
Strategy 1: Use ICTs that have already been developed for a nutrient-affected attribute	Implementing Strategy 1 involves obtaining peer-reviewed, published ICTs from New Zealand technical reports and papers, ideally for all nutrient-affected attributes. However, ICTs references only exist for: • Periphyton (Ton Snelder *et al.*, 2022) • Macroinvertebrates (Canning *et al.*, 2021)
Strategy 2: Model ICTs for the most sensitive attribute	The objective of Strategy 2 is to generate, for each type of river, a single set of six ICTs for an attribute determined to be most sensitive to nutrient enrichment.
Strategy 3: Model ICTs of a subset of attributes for which sufficient data exist	• The objective of Strategy 3 is to generate, for each type of river, a set of ICTs for attributes for which there are sufficient available data. • The key differences between Strategies 2 and 3 are the determinants of attributes selected for ICTs modelling. In Strategy 2, the aim is to model ICTs for attributes that are likely the most nutrient-sensitive attributes within each type of river and for which we have sufficient data. In Strategy 3, the main determinant is data availability, resulting in a selection of attributes that are not necessarily the most nutrient sensitive within river types
Strategy 4: Implement monitoring to obtain data to refine ICTs for a subset of attributes	• The objective of Strategy 4 is to evaluate whether collecting more data to refine ICTs of an attribute justifies the data collection cost and, if it does, design and implement monitoring to obtain that data. • After exploring Strategies 2 and 3, it may be concluded that (a) ICTs are required for particular attributes; and (b) there is insufficient data — nationally, regionally or both — to model ICTs for those attributes. In that case, there is an option of designing an adaptive monitoring programme to collect the data required to develop and/or refine ICTs for a specific attribute over time • This is not necessarily a strategy for setting ICTs. But rather a method for determining whether there is justification for improving or broadening the scope of ICTs set under Strategy 2 or 3

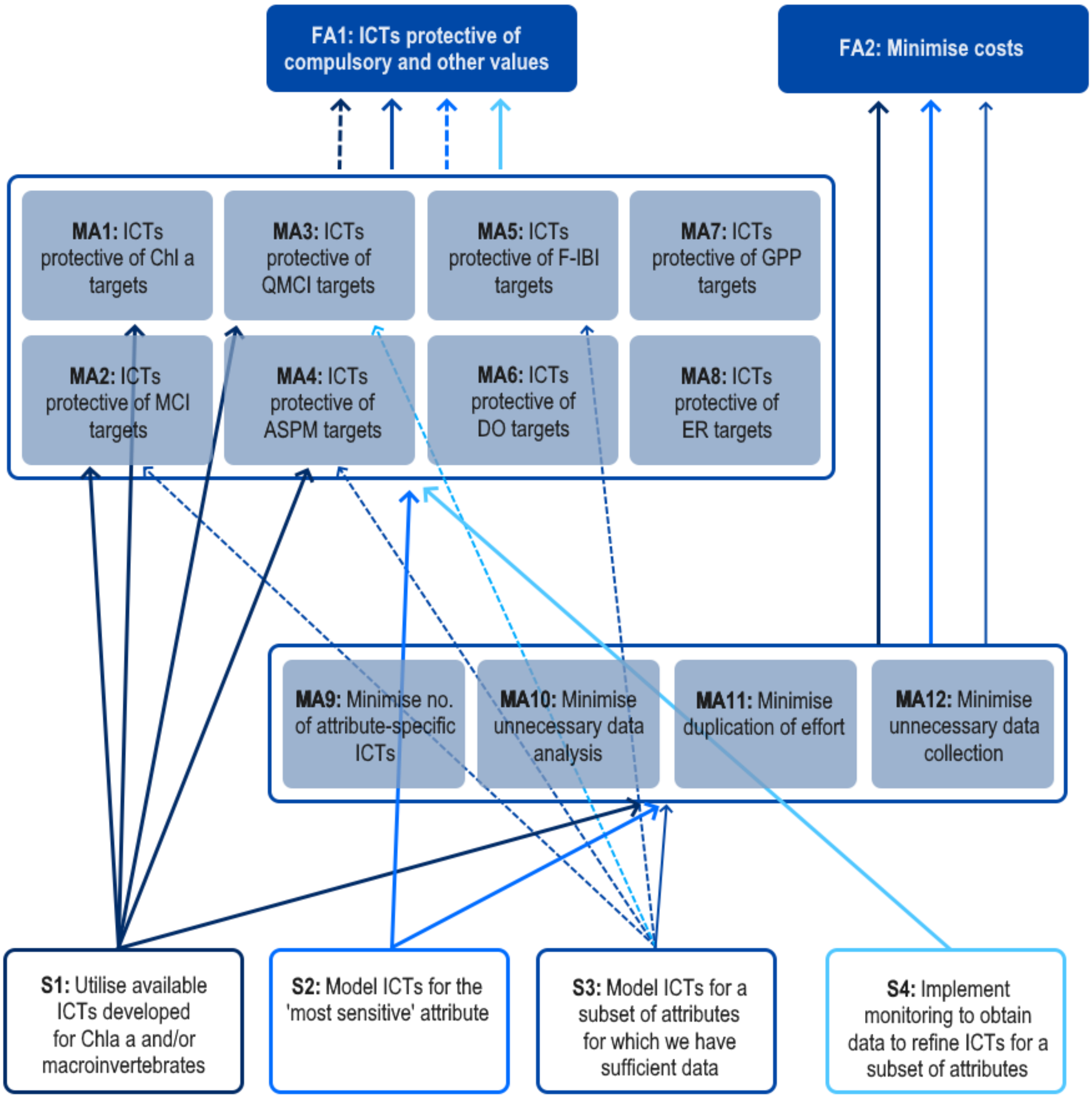

Figure 4: Aims network linking four strategies for obtaining ICTs (strategies 1 to 4 (Table 19) to means aims (MA) and fundamental aims (FA). Heavy solid lines = strongly facilitates aim; light solid line = weakly facilitates aim; dashed line = extent to which aim has been met unknown. Re-created from MfE (2022a) (Figure 3-6).

6.3 Identification of suitable strategy for adoption in PC1

An assessment of which of the four strategies for setting NOs in MfE (2022a) are feasible before PC1 is notified is set out in Table 20. Importantly, this is not an assessment of which strategy should be used in the long-term. Rather it simply denotes which can be used to set NOs in the limited timeframe available.

Of the four strategies set out in MfE (2022a), only Strategy 1 is likely to yield useable NOs before PC1 is notified (Table 20) as Strategies 2, 3 and 4[6] all require modelling which:

- Ideally should be based on as yet unavailable national scale modelling; and
- Cannot be conducted in the absence of this national scale modelling, as regional scale modelling does not exist and cannot be conducted in time for PC1 notification.

As such, it is recommended that GW pursue strategy 1 for PC1, but begin actively working towards defining how long-term NOs will be developed for future plan changes. This is consistent with guidance in MfE (2022a) which notes that "*[i]f councils have not yet developed their own ICTs using sound approaches (see Strategy 2), then we recommend implementing Strategy 1 in the short term, for inclusion in regional plans. Strategy 1 is not, however, a long-term solution, given the uncertainties about how its implementation will meet FA1*".

Table 20: Assessment of whether the four strategies for setting nutrient ICTs in MfE (2022a) are feasible before PC1 is notified.

Strategy	Feasible before PC1 notification	Notes
Strategy 1: Use ICTs that have already been developed for a nutrient-affected attribute	**Yes**	Published New Zealand ICTs are available for periphyton and Macroinvertebrates. Accordingly, this strategy can be used to set nutrient ICTs in PC1 at minimal cost.
Strategy 2: Model ICTs for the most sensitive attribute	**No**	• Implementing this strategy involves a significant amount of modelling to link the response of all nutrient sensitive attributes to nitrogen and phosphorus concentrations. • MfE (2022a) recommends that this modelling should be done at a national level. • While MfE (2022a) note that while there is nothing precluding regional councils from conducting their own modelling where sufficient data are available, it would be inefficient. • GW are unlikely to be able to conduct the required modelling to implement this strategy in time to include the resulting ICTs in PC1
Strategy 3: Model ICTs of a subset of attributes for which sufficient data exist	**No**	• While less arduous than Strategy 2, implementing this strategy still involves a significant amount of modelling. • MfE (2022a) recommends that this modelling should be done at a national level. • GW are unlikely to be able to conduct the required modelling to implement this strategy in time to include the resulting ICTs in PC1
Strategy 4: Implement monitoring to obtain data to refine ICTs for a subset of attributes	**Not applicable**	This strategy involves assessing whether there is value in collecting additional data to improve ICTs developed under Strategy 2 or 3. Neither of which are currently feasible.

[6] Ultimately requires ICTs to be set in accordance with Strategy 2 or 3

6.4 Implementation of Strategy 1

Implementing Strategy 1 in MfE (2022a) is straightforward process that involves selecting already published NOs from New Zealand technical reports and papers. Accordingly; key tasks include:

1. Selecting which published set of NOs are most relevant to the areas covered by PC1. Two sets of ICTs currently exist:
    a. Periphyton (Ton Snelder *et al.*, 2022); and
    b. Macroinvertebrates (Canning *et al.*, 2021).
2. Identifying the specific numeric NOs from the source selected under Step 1 that correspond to the PC1 target attribute states (TASs) for the relevant nutrient sensitive attribute.

6.4.1 Selecting the relevant set of nutrient outcomes from the literature

6.4.1.1 Options

6.4.1.1.1 Snelder et al. (2022)

The Snelder *et al.* (2022) NOs are set in relation to the NPS-FM 2020 periphyton biomass attribute state thresholds. They were developed by using ordinary least-squares regression to fit models that explained the relationship between periphyton and environmental factors, including nutrient concentrations, hydrology, and physical habitat at regional council monitoring sites. NOs were then obtained by inverting the fitted models to find the concentrations associated with periphyton attribute state thresholds.

Due to model uncertainty, a single nutrient criterion cannot ensure that a target level of periphyton biomass is not exceeded. Instead, there is a probability distribution that describes the risk of under-protection at a specific river location. Accordingly, the NOs derived in Snelder *et al.* (2022) are presented in lookup table format that provide for choice in the level of under-protection risk that might be acceptable. These lookup tables are provided for:

– DIN, DRP, total nitrogen (TN) and total phosphorus (TP), under;
 └──► Shaded and unshaded conditions, across;
  └──► Twenty-one River Environmental Classification[7] (REC) source-of-flow classes, and
  └──► Six levels of risk ranging from 5% to 50% for;
   └──► Each of the NPS-FM 2020 periphyton biomass A/B, B/C and C/D attribute state thresholds (756 NOs to select from for each nutrient attribute).

The objective of the NOs is to maintain periphyton biomass at or below the nominated thresholds at a proportion of sites that is the complement of the under-protection risk.

6.4.1.1.2 Canning et al. (2021)

Canning *et al.* (2021) uses the 'minimisation of mismatch' between nutrients and biology approach, described by the '*European Union's 'Best practice for establishing nutrient concentrations to support good ecological status*' guidelines' to define a single NOs for each of DIN and DRP that relate to the NPS-FM 2020 national bottom lines for macroinvertebrates (Q/MCI and ASPM). Those NOs are based on measured macroinvertebrate and measured and modelled nutrient data from regional council monitoring

[7] The REC is a database of catchment spatial attributes, summarised for every segment in New Zealand's network of rivers.

sites and reflect the DIN and DRP thresholds that maximise the probability of a site meeting those thresholds and passing the NPS-FM 2020 Q/MCI and ASPM bottom lines, while minimising the passing of the ecological targets and failing on the nutrient threshold (or vice-versa)

6.4.1.2 Recommended option - Snelder et al. (2022)

MfE (2022a) does not recommend which set of NOs regional councils should use when implementing Strategy 1. However, it does note a number of weaknesses in the NOs developed by Canning *et al.* (2021) that make them less appealing than those presented in Snelder *et al.* (2022); Specifically;

- Canning *et al.* (2021) only provides NOs that relate to the bottom line for the nutrient sensitive attributes they are designed to protect, whereas Snelder *et al.* (2022) includes NOs that relate to each periphyton biomass attribute state;
- Canning *et al.'s* (2021) modelling approach does not account for the mediating effects of landscape context or other anthropogenic stressors on nutrient-macroinvertebrate relationships. In contrast Snelder *et al.* (2022) accounted for the mediating effects of several factors including:
    - Climatological and topographical variables as defined in the REC;
    - Hydrological variables;
    - Shaded versus unshaded streams; and
    - Deposited fine sediment.
- MfE (2022a) notes that while a "*single set of* [NOs] *for all of New Zealand may be seen as advantageous and/or practical by some, in that it is easy to implement. Others may view this as being being unrealistic and a biased*"; and
- No guidance is available to help regional councils implement the NOs developed by Canning *et al.* (2021). In contrast, MfE (2022b) provides detailed guidance on how councils should set NOs using the lookup tables developed by Snelder *et al.* (2022).

Furthermore, setting NOs aimed at directly achieving specific macroinvertebrate endpoints, as in Canning *et al.* (2021), fails to recognise that while elevated nutrients and degraded macroinvertebrate community health often co-occur, this is because both are driven by an increase in intensive land-use (which affects a range of environmental factors), and that any causative link between the two is generally indirect and complex. As such, setting blanket NOs based on such correlative relationships will not necessarily achieve the desired objective in terms of macroinvertebrate community health.

The limitations of the recommended NOs in Canning *et al.* (2021), and the general issues with setting NOs for macroinvertebrate health, mean that Snelder *et al.* (2022) currently represents the best available option when implementing Strategy 1 from MfE (2022a). It is worth noting, however, that the minimisation of mismatch approach used by Canning *et al.* (2021) should be considered as an option for exploring NOs for some nutrient sensitive attributes if and when GW develop more refined thresholds in accordance with Strategies 2 through 4 in MfE (2022a).

6.5 Implementation of Snelder *et al.* (2022) as published (superseded, see Section 6.6)

6.5.1 Introduction to guidance

Guidance on the interpretation and use of Snelder *et al.*'s (2022) look-up tables of in-stream nutrient concentrations and exceedance criteria is provided in MfE (2022b). That document outlines the following steps to be taken when selecting NOs from the Snelder *et al.* (2022) lookup tables:

1. Select an appropriate periphyton biomass threshold.
2. Select under-protection risk for a site.
3. Obtain NOs from the tables.
4. Assess confidence in the NOs.
5. Apply the NOs or alternative criteria. The five situations where alternative criteria should apply are:
    a. Where baseline concentrations are lower than the NOs, in which case use those;
    b. Where the look up table value = 0, in which case explore possible alternatives such as reference values from McDowall *et al.* (2013); and
    c. Where there are sensitive downstream receiving environments that require nutrient concentrations or loads that imply the identified criterion is too high.
    d. Where the identified criteria are higher than levels to achieve other TASs at the site (e.g., for NO_3-N toxicity).
    e. Where the look up table value is > than saturation point, in which case reduce to at least saturation point when the periphyton TAS represents an improvement.

6.5.2 Step 1a – Select periphyton biomass thresholds

The TASs for periphyton biomass that are being considered for inclusion in PC1 have been extracted from the WTWT and TAoP WIPs (Table 21).

Table 21: REC source of flow categories and periphyton TAS for sites in WTWT and TAoP Whaitua.

<table>
<thead>
<tr><th>Whaitua</th><th>Part-FMU</th><th>Site</th><th>REC source of flow category</th><th>Periphyton Target Attribute State</th></tr>
</thead>
<tbody>
<tr><td rowspan="5">TAoP</td><td>Taupō</td><td>Taupō S. @ Plimmerton Domain</td><td>WD/L</td><td rowspan="5">B</td></tr>
<tr><td>Pouewe</td><td>Horokiri S. @ Snodgrass</td><td>CW/L</td></tr>
<tr><td>Wai-o-hata</td><td>Duck Ck @ Tradewinds Dr. Br.</td><td>WW/L</td></tr>
<tr><td>Takapū</td><td>Pāuatahanui S. @ Elmwood Br.</td><td>CW/L</td></tr>
<tr><td>Te Rio o Porirua and Rangituhi</td><td>Porirua S. @ Milk Depot</td><td>WW/L</td></tr>
<tr><td rowspan="13">TWT</td><td rowspan="2">Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems</td><td>Hutt R. @ Te Marua Intake</td><td>CX/H</td><td rowspan="2">A</td></tr>
<tr><td>Whakatikei R. @ Riverstone</td><td>CW/L</td></tr>
<tr><td>Te Awa Kairangi lower mainstem</td><td>Hutt R. @ Boulcott</td><td>CW/L</td><td rowspan="2">B</td></tr>
<tr><td>Te Awa Kairangi rural streams and rural mainstems</td><td>Mangaroa R. @ Te Marua</td><td>CW/L</td></tr>
<tr><td>Te Awa Kairangi urban streams</td><td>Hulls C. adj. Reynolds Bach Dr.</td><td>WW/L</td><td rowspan="5">C</td></tr>
<tr><td>Waiwhetū Stream</td><td>Waiwhetū S. @ Whites Line E.</td><td>WW/L</td></tr>
<tr><td>Wainuiomata urban streams</td><td>Black C. @ Rowe Parade end</td><td>CW/L</td></tr>
<tr><td>Wainuiomata rural streams</td><td>Wainuiomata R. DS White Br.</td><td>CW/L</td></tr>
<tr><td>Parangārehu catchment streams and South-west coast rural streams</td><td>Mākara S. @ Kennels</td><td>CW/L</td></tr>
<tr><td>Korokoro Stream</td><td>Korokoro S.@ Cornish St. Br.</td><td>CW/L</td><td>B</td></tr>
<tr><td>Kaiwharawhara Stream</td><td>Kaiwharawhara S. @ Ngaio Gorge</td><td>CW/L</td><td rowspan="2">C</td></tr>
<tr><td>Wellington urban</td><td>Karori S. @ Mākara Peak</td><td>CW/L</td></tr>
</tbody>
</table>

6.5.3 Step 1b – Select under-protection risk thresholds

MfE (2022b) notes that

> "*Precise guidance on selecting the under-protection risk cannot be given, however councils should provide the demonstrable process that sets out how and why they made their under-protection risk decision. In broad terms, the risk a council adopts should be linked to the environmental outcomes it requires, and the values of the resources it is managing, with lower under-protection risk being adopted in places with higher value and vice versa*".

Here the method for selecting the recommended under-protection risk for TAoP Whaitua and WTWT was simply to identify the level at which the corresponding unshaded[8] NOs:

- Require reductions in DIN and DRP concentrations in those rivers where the periphyton biomass TAS represents an improvement; but
- Do not require such large reductions in nutrient concentrations as to be unachievable.

The results of this analysis are presented in Table 22 and Table 23, which show the 15% under protection risk is the best available option for implementing the Snelder *et al.*'s (2022) look-up tables as:

- At the 20% under-protection risk the unshaded NOs only require reductions in DIN or DRP concentrations in one of these sites; Porirua Stream at Milk Depot (Table 22).;

[8] Unshaded values were used in this step as they provide an indication of the applicability of the under-protection risk in the absence of the co-variate effect of shade.

- At the 15% under-protection risk >10% reductions in DIN and DRP concentrations are required in four of those same five sites (Table 22); and
- However, at the 10% under-protection level the required reductions in DIN and DRP are so large that final concentrations would need to approximate reference condition (Table 23).

Table 22: Required reductions in DIN and DRP concentrations to meet the unshaded Snelder *et al.* (2022) NOs at under-protection levels between 10% and 20%. Data are only provided for those sites where an improvement in periphyton biomass is required, and long-term nutrient data are available.

	% reduction					
	10% under-protection		15% under-protection		20% under-protection	
Site	DIN	DRP	DIN	DRP	DIN	DRP
Horokiri S. @ Snodgrass	88%	70%	59%	20%	0%	0%
Pāuatahanui S. @ Elmwood Bridge	80%	75%	32%	33%	0%	0%
Porirua S. @ Milk Depot	96%	90%	87%	80%	66%	50%
Hutt R. @ Boulcott	71%	40%	2%	0%	0%	0%
Mangaroa R. @ Te Marua	86%	67%	53%	11%	0%	0%

Table 23: The unshaded Snelder *et al.* (2022) NOs at 10% and 15% under-protection risk for those sites where an improvement in periphyton biomass is required and long-term nutrient data are available. Baseline states for reference (undisturbed) sites are provided for comparative purposes.

	DIN concentration (mg/L)		DRP concentration (mg/L)	
Site name	At 10%	At 15%	At 10%	At 15%
Horokiri S. @ Snodgrass	0.058	0.196	0.003	0.008
Pāuatahanui S. @ Elmwood Bridge	0.054	0.196	0.003	0.008
Porirua S. @ Milk Depot	0.034	0.12	0.002	0.004
Hutt R. @ Boulcott	0.058	0.196	0.003	0.008
Mangaroa R. @ Te Marua	0.058	0.196	0.003	0.008
Reference sites				
Whakatikei R. @ Riverstone	0.120		0.008	
Hutt R. @ Te Marua Intake Site	0.065		0.004	
Wainuiomata R. @ Manuka Track	0.054		0.011	

6.5.4 Step 2 – Obtain nutrient outcomes from tables

It is my understanding GW will utilise riparian planting to help control periphyton growth as part of their action planning process. Accordingly, NOs with a 15% under-protection risk have been selected for sites in WTWT and TAoP on the assumption that they will be shaded in the future. The exception being the Hutt River at Boulcott, which is far too wide for riparian planting to be an effective method of controlling periphyton (predicted width at median flow for all other rivers ≤ 15 metres (Booker, 2010)). The resulting NOs are set out in Table 24.

Table 24: Snelder *et al.* (2022) NOs for TAS for sites in WTWT and TAoP Whaitua. Under-protection risk = 15%.

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	WD/L	Maintain	Y	N/A[a]	
	Pouewe	Horokiri S. @ Snodgrass	CW/L	B		1.085	0.025
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L			0.866	0.015
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L			1.085	0.025
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L			0.866	0.015
WTWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	CW/L	A		0.004	0
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B	N	0.196	0.008
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L		Y	1.085	0.025
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L	C		3.336	0.131
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L			3.336	0.131
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L			3.335	0.152
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L			3.335	0.152
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L			3.335	0.152
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B		1.085	0.025
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C		3.335	0.152
	Wellington urban	Karori S. @ Mākara Peak	CW/L			3.335	0.152

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS).

6.5.5 Step 3 – Assess confidence in the nutrient outcomes

MfE (2022b) sets out a methodology by which NOs selected from the look-up tables Snelder *et al.* (2022) can be validated. The objective of this validation exercise is to use monitoring data to assess whether the NOs are reasonably consistent with local observations of the relationships between periphyton abundance and nutrient concentrations.

Dr Ton Snelder has conducted the validation exercise described in MfE (2022b) using periphyton and nutrient data collected from across the Wellington Region. This analysis is provided in Appendix E to this report. Dr Snelder concluded that "[t]*he validation of the criteria of Snelder et al. (2022) for the Wellington region, based on 16 monitoring sites, indicates that the criteria are too permissive (i.e., biomass thresholds will be exceeded at more sites than expected given the selected under-protection risk even when nutrient criteria are complied with)*". On that basis, he noted that a "*reasonable conclusion is that* ***the criteria are the best available and are appropriate to use****, but that they are uncertain*.

6.5.6 Step 4 – Application of the nutrient outcomes or alternative criteria

The final step in implementing the MfE (2022b) guidance on setting NOs based on the Snelder *et al.*'s (2022) look-up tables is to determine where alternative criteria are the most appropriate option. The specific situations where this is the case are:

1. Where current concentrations are lower than the lookup table value, in which case use those;
2. Where the look up table value equals zero, in which case explore possible alternatives such as reference values from McDowall *et al.* (2013); and
3. Where there are sensitive downstream receiving environments that require nutrient concentrations or loads that imply the identified criterion is too high.
4. Where the identified NOs are higher than levels to achieve other attribute states at the site (e.g., the NO_3-N toxicity or DRP target attributes).
5. Where the lookup table value is greater than the saturation point (1 mg/L for DIN; 0.025 mg/L for DRP), in which case reduce to at least saturation point when the periphyton TAS represents an improvement.

Table 25 provides an update to Table 24, with alternative criteria applied to address the issues outlined above.

Table 25: NOs for TAS for sites in WTWT and TAoP Whaitua. Selected from the Snelder *et al.*'s (2022) lookup tables (under-protection risk = 15%) except where alternative criteria are more appropriate (see footnotes).

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	WD/L	Maintain	Y	~0.41[b]	~0.017[b]
	Pouewe	Horokiri S. @ Snodgrass	CW/L	B		0.64[b]	0.011[b]
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L			~0.48[b]	0.015
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L			0.33[b]	0.014[b]
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L			0.866	0.015
WTWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	CW/L	A		0.015[c]	0.006[d]
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B	N	0.196	0.004[b]
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L		Y	0.44[b]	0.006[e]
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L	C		0.24[b]	0.018[b]
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L			0.56[b]	0.018[e]
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L			0.5[b]	0.018[e]
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L			0.17[b]	0.011[e]
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L			0.42[b]	0.018[e]
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B		1.03[f]	0.006[e]
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C		1.03[b]	0.018[e]
	Wellington urban	Karori S. @ Mākara Peak	CW/L			1.29[b]	0.031[e]

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS). Modelled baseline state applied as alternative criteria.
[b] Snelder *et al.* (2022) nutrient outcome > than current concentrations. Current concentrations applied as alternative criteria.
[c] Site in reference conditions and NOs represents and improvement which is unlikely to be possible.
[d] Snelder *et al.* (2022) nutrient outcome = 0. The lesser of McDowall *et al.* (2013) 80^{th} %ile trigger, current state or WIP TAS applied as alternative criteria.
[e] Snelder *et al.* (2022) nutrient outcome > than the dissolved reactive phosphorus TAS. TAS applied as alternative criteria.
[f] Snelder *et al.* (2022) nutrient outcome > than TAS for NH_4-N and NO_3-N toxicity. Sum of NH_4-N and NH_4-N TAS applied as alternative criteria.

6.6 Implementation of updates to Snelder *et al.* (2022) nutrient outcomes (supersedes Section 6.5)

6.6.1 Background to updates

Since conducting the validation exercise described in Section 6.5.5, Dr Snelder has revised the NOs set out in Snelder *et al.* (2022). These revisions were made in response to validation exercises conducted for several regions revealing the original NOs are generally too permissive.

The process by which Dr Snelder developed the updated NOs are explained in detail in Appendix F. Briefly, the same general methodology was followed as in Snelder *et al.* (2022) except generalised linear models were used instead of ordinary least squares models. The resulting NOs are more stringent than those produced by Snelder *et al.* (2022), and generally consistent with GW monitoring data. As such, they represent the best available option for implementing Strategy 1 in MfE (2022a) (Dr Snelder agrees; *pers. comm.* 22/03/2023).

It is important to note that several parties, including GW, are pushing for a national level update to Snelder *et al.* (2022) to address the issues identified by Dr Snelder in Appendix F. If this update includes an expansion of the input data set to capture monitoring conducted since 2019 it may produce slightly different NOs from those set out in Appendix F.

6.6.2 Step 1a – Select periphyton biomass thresholds

The TASs for periphyton biomass that are being considered for inclusion in PC1 are set out in Table 21.

6.6.3 Step 1b – Select under-protection risk thresholds

Re-running the process described in 6.5.3 using the updated NOs in Appendix F suggests that adopting an under protection risk of 50% is the best available option for ensuring achievable reductions in nutrient concentrations at those sites where the TASs requires an improvement in periphyton biomass (Table 26 and Table 27).

Table 26: Required reductions in DIN and DRP concentrations to meet the unshaded updated Snelder *et al.* (2022) NOs at under-protection levels between 25% and 50%. Data are only provided for those sites where an improvement in periphyton biomass is required, and long-term measured nutrient data are available.

Site	% reduction					
	25% under-protection		30% under-protection		50% under-protection	
	DIN	DRP	DIN	DRP	DIN	DRP
Horokiri S. @ Snodgrass	95%	91%	92%	82%	59%	0%
Pāuatahanui S. @ Elmwood Bridge	90%	93%	84%	86%	19%	21%
Porirua S. @ Milk Depot	97%	94%	95%	89%	75%	56%
Hutt R. @ Boulcott	84%	75%	74%	50%	0%	0%
Mangaroa R. @ Te Marua	93%	90%	88%	80%	40%	0%

Table 27: Unshaded updated Snelder *et al.* (2022) NOs at 30% and 50% under-protection risk for those sites where an improvement in periphyton biomass is required and long-term nutrient data are available. Baseline states for reference (undisturbed) sites are provided for comparative purposes.

Site name	DIN concentration (mg/L)		DRP concentration (mg/L)	
	At 30%	At 50%	At 30%	At 50%
Horokiri S. @ Snodgrass	0.051	0.263	0.002	0.011
Pāuatahanui S. @ Elmwood Bridge	0.051	0.263	0.002	0.011
Porirua S. @ Milk Depot	0.046	0.231	0.002	0.008
Hutt R. @ Boulcott	0.051	0.263	0.002	0.011
Mangaroa R. @ Te Marua	0.051	0.263	0.002	0.011
Reference sites				
Whakatikei R. @ Riverstone	0.120		0.008	
Hutt R. @ Te Marua Intake Site	0.065		0.004	
Wainuiomata R. @ Manuka Track	0.054		0.011	

6.6.4 Step 2 – Obtain nutrient outcomes from tables

Table 28 provides an update to Table 24 based on the update to the Snelder *et al.* (2022) NOs set out in Appendix F.

Table 28: Updated NOs for TAS for sites in WTWT and TAoP Whaitua. Under-protection risk = 50%.

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	WD/L	Maintain	Y	N/A[a]	
	Pouewe	Horokiri S. @ Snodgrass	CW/L	B		1.33	0.034
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L			1.23	0.025
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L			1.33	0.034
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L			1.23	0.025
TWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	CW/L	A		0.008	0.000
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B	N	0.26	0.011
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L		Y	1.33	0.034
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L	C		3.03	0.147
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L			3.03	0.147
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L			3.30	0.163
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L			3.30	0.163
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L			3.30	0.163
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B		0.26	0.011
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C		3.30	0.163
	Wellington urban	Karori S. @ Mākara Peak	CW/L			3.30	0.163

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (River Environment Classification group = WW/L/SS).

6.6.5 Step 3 – Assess confidence in the nutrient outcomes

As stated in Section 6.6.1 Dr Snelder has conducted the validation exercise described in MfE (2022b) for the updated NOs set out in Appendix F (results of validation can also be found there). He concluded that:

> *"For most of the levels of under protection risk, the confidence bound includes the associated level of under-protection risk". This indicates that the new criteria are consistent with the monitoring data within the inherent uncertainty in both the observations of [periphyton biomass] and the uncertainty in the criteria themselves."*

6.6.6 Step 4 – Application of the nutrient outcomes or alternative criteria

Table 29 provides an update to Table 25, with alternative criteria applied where appropriate (see Section 6.5.6). This represents the recommended NOs for inclusion in PC1.

Table 29: NOs for TAS for sites in WTWT and TAoP Whaitua. Selected from the updates to the Snelder *et al.* (2022) (Appendix F) (under-protection risk = 50%) except where alternative criteria are more appropriate (see footnotes).

Whaitua	Part-FMU	Site	REC source of flow category	Periphyton Target Attribute State	Shaded	DIN (mg/L)	DRP (mg/L)
TAoP	Taupō	Taupō S. @ Plimmerton Domain	WD/L	B	Y	~0.41	~0.017[a]
	Pouewe	Horokiri S. @ Snodgrass	CW/L			0.64[b]	0.011[b]
	Wai-o-hata	Duck Ck @ Tradewinds Dr. Br.	WW/L			~0.48[b]	~0.018[b]
	Takapū	Pāuatahanui S. @ Elmwood Br.	CW/L			0.33[b]	0.014[b]
	Te Rio o Porirua and Rangituhi	Porirua S. @ Milk Depot	WW/L			0.92[b]	0.018[b]
TWT	Ōrongorongo, Te Awa Kairangi and Wainuiomata small forested and Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	CW/L	A		0.15[c]	0.006[d]
	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	CW/L	B	N	0.20[b]	0.004[b]
	Te Awa Kairangi rural streams and rural mainstems	Mangaroa R. @ Te Marua	CW/L		Y	0.44[b]	0.006[e]
	Te Awa Kairangi urban streams	Hulls C. adj. Reynolds Bach Dr.	WW/L	C		0.24[b]	0.018[b]
	Waiwhetū Stream	Waiwhetū S. @ Whites Line E.	WW/L			0.56[b]	0.018[e]
	Wainuiomata urban streams	Black C. @ Rowe Parade end	CW/L			0.5[b]	0.018[e]
	Wainuiomata rural streams	Wainuiomata R. DS White Br.	CW/L			0.17[b]	0.01[e]
	Parangārehu catchment streams and South-west coast rural streams	Mākara S. @ Kennels	CW/L			0.42[b]	0.018[e]
	Korokoro Stream	Korokoro S.@ Cornish St. Br.	CW/L	B		0.26	0.006[e]
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	CW/L	C		1.14[b]	0.018[e]
	Wellington urban	Karori S. @ Mākara Peak	CW/L			1.29[b]	0.035[e]

[a] All rivers in part FMU naturally soft bottomed and unlikely to support periphyton growth (REC = WW/L/SS). Modelled baseline state applied as alternative criteria.
[b] Snelder *et al.* (2022) nutrient outcome > than baseline concentrations. Baseline concentrations applied as alternative criteria.
[c] Site in reference conditions and nutrient outcome represents an improvement which is unlikely to be possible. Baseline concentrations applied as alternative criteria.
[d] Snelder *et al.* (2022) nutrient outcome = 0. The lesser of McDowall *et al.* (2013) 80th %ile trigger, baseline state or WIP TAS applied as alternative criteria.
[e] Snelder *et al.* (2022) nutrient outcome > than the dissolved reactive phosphorus WIP TAS. WIP TAS applied as alternative criteria.

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7 Assessment of the current state of the Parangārehu Lakes

To: Michael Greer and Rachel Pawson

From: Alton Perrie

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7.1 Introduction

The purpose of this memorandum is to:

1. Provide an overview of previous assessments of the current state of the Parangārehu Lakes (Lake Kōhangapiripiri and Lake Kōhangatera);
2. Update the assessment of the current state of the Parangārehu Lakes using data collected during 2022/23;
3. Make recommendations on current baseline states of selected NPS-FM 2020 attributes to be included in PC1 to the NRP for the Wellington Region; and,
4. Provide commentary on the improvements (indicated by TASs) desired in the WTWT WIP.

Previous assessments of the current state of the Parangārehu lakes undertaken by Schallenberg (2019) and during the WIP process (documented in Heath (2022)) used the best available data and expert opinion to assess the current state of these lakes. However, these assessments highlighted the paucity of water quality data available, and the current states presented can only be considered estimates rather than accurate state assessments established by a robust monitoring programme. Heath (2022) placed only low to moderate confidence in any current state assessments made for the NPS-FM 2020 water quality attributes presented in the WIP. However, assessments of the current state of aquatic plant NPS-FM 2020 attributes in the WIP are considered robust as both lakes have been assessed on several occasions following appropriate methods.

Given the limited water quality data available, assessments against NPS-FM 2020 water quality attribute thresholds presented in this memo used all of the data available (i.e., states are not calculated from monthly measurements spanning a one-year period). Given this lack of data, it is also important to acknowledge that the water quality reporting requirements of the NPS-FM 2020 could not be adhered to. The data used in this memorandum are provided in Table 30.

Table 30: Available water quality data for the Parangārehu Lakes that was used in this memorandum. Values below the detection limit have been halved. - indicates not sampled/no result on this date.

Date	Chlorophyll *a* (mg/m^3)	TN (mg/L)	TP (mg/L)	pH	NH_4-N (mg/L)	*E. coli* (cfu/100 mL)	Cyanobacteria biovolume (mm^3/L)
Lake Kōhangapiripiri							
Mar. 2011	1.5	0.72	0.026	7.1	0.005	-	-
Mar. 2013	1.5	0.53	0.034	7.3	0.005	-	-
Feb. 2016	1.5	0.73	0.086	7.8	0.086	-	-
April 2018	1.5	0.51	0.021	7.4	0.0025	-	-
April 2019	5	0.7	0.05	7.6	0.0025	-	-
July 2022	1.5	0.8	0.046	7.2	0.061	50	0
Sep. 2022	1.5	0.5	0.025	7.4	0.007	10	0.0001
Nov. 2022	1.5	0.46	0.04	7.5	0.0025	23	2
Feb. 2023	1.5	0.62	0.051	7.5	0.008	10	0.001
Mar. 2023	6	0.73	0.098	7.5	0.034	220	0.008
June 2023	-	-	-	-	-	-	0.0006
Lake Kōhangatera							
Mar. 2011	1.5	0.49	0.025	8	0.005	-	-
Mar. 2013	1.5	0.41	0.05	7.5	0.005	-	-
Feb. 2016	5	0.53	0.034	9.2	0.0025	-	-
April 2018	1.5	1.23	0.096	7	0.025	-	-
April 2019	35	0.48	0.04	8.3	0.01	-	-
July 2022	1.5	0.74	0.052	7.1	0.011	400	0
Sep. 2022	6	0.33	0.039	7.3	0.007	50	0.04
Nov. 2022	17	0.41	0.058	7.5	0.006	11	0.0003[1] 20[1]
Feb. 2023	4	0.55	0.071	7.2	0.007	200	0.01
Mar. 2023	8	0.4	0.039	7.2	0.067	200	0.3
June 2023	6	0.45	0.04	7.3	0.008	30	0.0007

[1] Two samples were collected for analysis of cyanobacteria biovolume on this sampling occasion given the visual evidence of a phytoplankton bloom in the southern part of the lake.

7.2 Current state

7.2.1 Water quality attributes

Water quality data are inherently variable month to month and can exhibit strong seasonal patterns, hence monthly data collected over 2-5 years is typically recommended to establish the state of lake water quality (Burns *et al.*, 2000; McBride, 2016). While the NPS-FM 2020 does require annual statistics for some lake attributes, McBride (2016) indicates that these statistics would be far more robust if calculated annually but based on a five-year rolling approach (i.e., a median statistic is generated annually using the last five years of data; see McBride (2016) for more details). Water quality data assessed in Schallenberg (2019) and Heath (2022) were also typically collected during summer or autumn months when other field work was being undertaken (i.e., aquatic plant assessments) and are therefore not representative of seasonal variability.

In August 2022, GW commenced a bi-monthly water quality sampling programme to help better understand the current state of water quality in the Parangārehu lakes. This more recently collected water quality data, along with historically available data are discussed further below in the context of setting current attribute states for key lake water quality attributes in the NPS-FM 2020.

Due to the paucity of data available prior to 2017, it is considered that, for water quality attributes, the current attribute states presented in the memorandum represent the best available estimates of 'baseline state' (i.e., the state as 7 September 2017) despite being calculated from data collected more recently than allowed for by the NPS-FM 2020.

7.2.1.1 Nutrient attributes for phytoplankton growth

Schallenberg (2019) and Heath (2022) estimated the TN[9] states of Lakes Kōhangapiripiri and Kōhangatera to be "C" and "B" respectively. Median concentrations calculated based on all available data (incl. more recently collected data) are 0.660 and 0.480 mg/L which confirms the placement of the lakes in these bands (Table 30, Table 31). However, it is worth noting that the median concentration for Lake Kōhangatera is very close to the NPS-FM 2020 threshold between "B" and "C" bands (0.500 mg/L). Furthermore, there is a high level of variability in the data collected to date (Figure 5).

Both lakes were estimated to be in a "C" state for TP (Heath, 2022; Schallenberg, 2019). Calculation of median TP concentrations using all available data again confirms the placement of the lakes in this NPS-FM band, but as with TN, there is considerable variation in this limited dataset (Figure 5) and median values place these lakes near the "C"/"D" threshold of 0.050 mg/L (Table 31).

Overall, the low number of data points available to make these current state assessments and the variability in the data collected to date, make the confidence in current state assessments very low.

Table 31: Summary of state estimates for Lakes Kōhangapiripiri and Kōhangatera from Schallenberg (2019) and the WIP (Heath, 2022) for key lake water quality attributes in the NPS-FM 2020. Median and maximum (where applicable) concentrations and their associated NPS-FM state and WIP TASs are also presented.

Lake	Schallenberg (2019)	WIP	Median to date	Max. to date	TAS
Phytoplankton					
Kōhangapiripiri	"A/B"	"A"	1.5 mg/m^3 "A"	6 mg/m^3 "A"	"A"
Kōhangatera	"A/B"	"A"	5.0 mg/m^3 "B"	35 mg/m^3 "C"	"A"
TN					
Kōhangapiripiri	"C"	"C"	0.660 mg/L "C"	NA	"B"
Kōhangatera	"B"	"B"	0.480 mg/L "B"		"B"
TP					
Kōhangapiripiri	"C"	"C"	0.043 mg/L "C"	NA	"B"
Kōhangatera	"C"	"C"	0.040 mg/L "C"		"B"

Previously, Perrie and Milne (2012) speculated that given the low level of modification within the catchments of both lakes, the elevated concentrations of nutrients recorded may represent natural conditions associated with the natural dissolved organic matter in the lakes (i.e., while concentrations of TN are indicative of a super trophic state in Lake Kōhangatera this nitrogen is largely present in an organic form and not bioavailable). However, there is little information in the scientific lake literature to support this speculation and further monitoring and investigation would be required to establish whether this is the case or not.

[9] Following Schallenberg (2019), the polymictic total nitrogen NPS-FM 2020 thresholds were used in the assessment here.

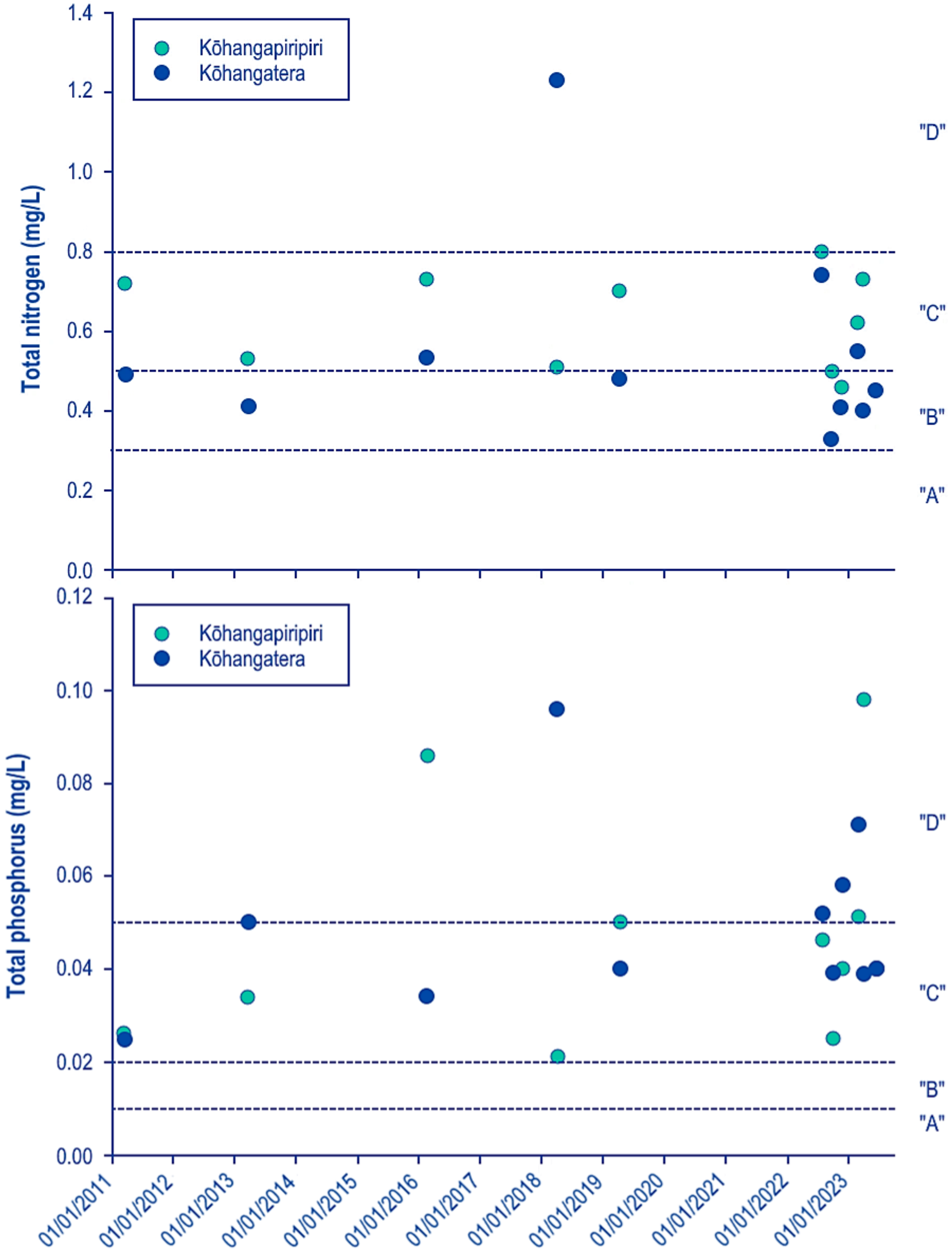

Figure 5: Available TN (top) and TP (bottom) concentration data for the Parangārehu Lakes (as of June 2023). Horozontal dashed lines indicate the various NPS-FM 2020 bands with band grades indicated on the right y-axis.

7.2.1.2 Phytoplankton and cyanobacteria attributes

Schallenberg (2019) placed both lakes in "A"/"B" states and Heath (2022) placed both lakes in the "A" state for the phytoplankton (trophic state) attribute. Additional data has recorded higher maximum chlorophyll *a* concentrations in Lake Kōhangatera (Figure 6) which would place this lake in a "C" state. The additional data collected from Lake Kōhangapiripiri still currently places this lake in the "A" state. Algal blooms have also previously been reported for these lakes (Gibbs, 2002) and a palaeoecological reconstruction for Lake Kōhangapiripiri indicates a significant increase in algal biomass post European settlement (https://lakes380.com/lakes/Kōhangapiripiri/).

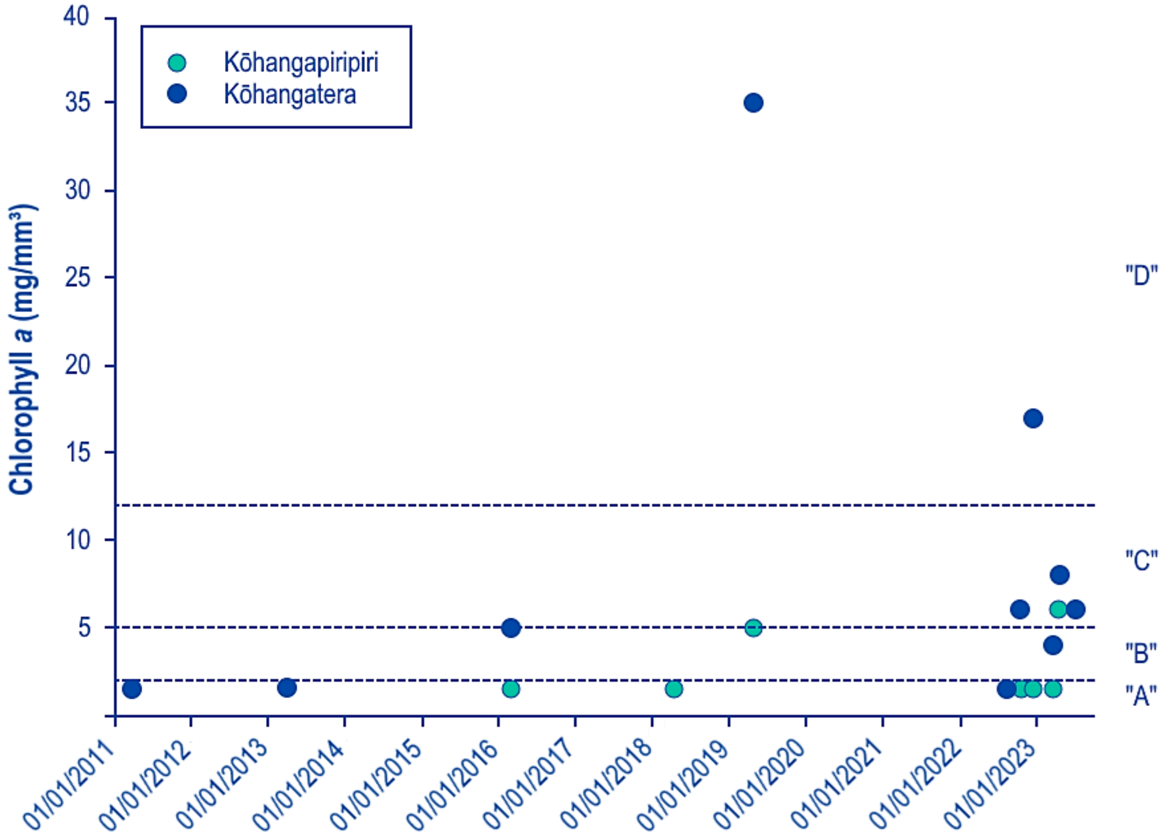

Figure 6: Available chlorophyll a concentration data for the Parangārehu Lakes (as of June 2023). Horizontal dashed lines indicate the various NPS-FM 2020 bands (median) with band grades indicated on the right y-axis.

Since July 2022, cyanobacteria biovolume data has been collected from these lakes for first time. While biovolume data are typically low, in November 2022 both lakes recorded high to extremely high cyanobacteria biovolumes (20 and 2 mm^3/L in Kōhangatera and Kōhangapiripiri, respectively; Figure 7). Based on data collected to date (see Table 30), the 80th percentile required by the NPS 2020 to assess the cyanobacteria attribute are 0.248 mm^3/L in Lake Kōhangatera and 0.008 mm^3/L in Lake

Kōhangapiripiri. This would place both lakes in the "A" band[10] for the cyanobacteria (planktonic) which aligns with the "A" band stated in the WIP (Heath, 2022).

Figure 7: Cyanobacterial scum (*Dolichospermum lemmermannii*) observed around the southern edge of Lake Kōhangatera (November 2022).

7.2.1.3 Ammonia toxicity

Schallenberg (2019) did not attempt to characterise a baseline state for NH_4-N toxicity in either lake. Heath (2022) estimated the baseline state for NH_4-N toxicity to be in the "A" band in the WIP for both lakes. Comparison of median pH-adjusted NH_4-N nitrogen concentrations calculated from all available data with thresholds in the NPS-FM 2020 would place both lakes in the "A" band (Median = 0.003 and 0.005 mg/L in Lakes Kōhangapiripiri and Kōhangatera, respectively). Similarly, 95th percentile pH-adjusted NH_4-N l concentrations would also place both lakes in the "A" band (95th percentile = 0.005 and 0.024 mg/L in Lakes Kōhangapiripiri and Kōhangatera, respectively).

[10] While currently placed in the "A" band, it's again important to highlight the data paucity for this attribute as the NPS-FM 2020 requires that the 80th percentile needs to be calculated from a minimum of 12 results collected over three years. Therefore, there is high uncertainty with this current state assessment. Regardless of the NPS-FM 2020 cyanobacteria band thresholds and statistical assessment, it is worth being aware that the currently recorded maximum concentrations in both lakes are above or well above the 1.8 mm^3/L action (red mode) of the New Zealand guidelines for cyanobacteria in recreational fresh waters (MfE/MoH, 2009).

7.2.1.4 E. coli

Heath (2022) considered there to be insufficient data to attempt to estimate a current *E. coli* state and Schallenberg (2019) did not attempt to assess a baseline *E. coli* attribute state. Five *E. coli* results are available for Lakes Kōhangapiripiri and six for Lake Kōhangatera that were collected during the 2022/23 year (Table 30). While restricted to just a few data points, *E. coli* results are typically low with maximum concentrations of 200 and 400 CFU/100mL recorded in Lake Kōhangapiripiri and Kōhangatera, respectively (median = 23 and 125 CFU/100mL, respectively). Comparisons of these data with thresholds in the NPS-FM 2020 would place both lakes in the "A" band for the various *E. coli* attribute thresholds (Table 32).

Table 32: Summary of *E. coli* statistics compared against NPS-FM 2020 thresholds.

Lake	Statistic	Numeric (% or CFU/100mL)
Lake Kōhangapiripiri	Median (CFU/100mL)	23
	95th %ile (CFU/100mL)	186
	% over 260	0
	% over 540	0
Lake Kōhangatera	Median (CFU/100mL)	125
	95th %ile (CFU/100mL)	350
	% over 260	17
	% over 540	0

7.2.2 Aquatic plant attributes

Assessments of the current state and baseline states (at 7 September 2017) of the two submerged plant attributes (native and invasive species) in the NPS-FM 2020 that are presented in the WIP are considered robust because assessments have been undertaken following appropriate methodology (Heath, 2022). However, it is still important to acknowledge that a level of band/state jumping is still evident between different assessments undertaken several years apart (Table 33). For example, when including the most recent surveys (February 2023), scores for native condition in Lake Kōhangapiripiri have ranged from a "C" state (2016) through to a "A" state (2023) (Table 33).

Table 33: Summary of native condition and invasive impact scores for submerged vegetation in Lakes Kōhangapiripiri and Kōhangatera. NPS-FM states, based on these scores, are presented in parentheses. Current states, baseline states and TASs for these attributes are also presented. Native condition and invasive impact scores are sourced from de Winton (2020) and de Winton (in prep).

Year	Lake Kōhangapiripiri		Lake Kōhangatera	
	Native condition	Invasive impact	Native condition	Invasive impact
2004	70.0 ("B")	38.5 ("C")	70.0 ("B")	23.0 ("B")
2011	72.9 ("B")	37.8 ("C")	82.9 ("A")	5.2 ("B")
2013	Not assessed	Not assessed	83.0 ("A")	8.1 ("B")
2016 (Baseline state)	35.7 ("C")	61.5 ("C")	81.4 ("A")	15.6 ("B")
2019	64.3 ("B")	48.1 ("C")	74.3 ("B")	9.6 ("B")
2023 (Current state)	81.4 ("A")	7.4 ("B")	78.6 ("A")	5.9 ("B")
WIP current states	"B"	"C"	"B"	"B"
WIP TAS	"A"	"B"	"A"	"B"

7.3 Recommendations on current/baseline states for NPS-FM 2020 lake attributes to be included in PC1

Based on a meeting held on 28/06/2023 attended by Dr Michael Greer (Principal Scientist/Director, Torlesse Environmental Ltd), Ms Rachel Pawson (Senior Policy Advisor, GW) and myself, it was agreed that all available data (including data collected during 2022/23) should be used to inform the baseline state of the water quality attributes to be included in PC1. This decision was made given the lack of data available prior to this point that was used to determine the current state estimates during the WIP process. Table 34 summarises the recommended current/baseline states to be included in the upcoming Plan Change. It should still be noted though that even with the inclusion of more recently collected data to determine these current states, these data still fall well short of the data requirements in the NPS-FM 2020 and those recommended by Burns *et al.* (2000) for understanding lake water quality. Hence, there is still low confidence in the accuracy of these current state assessments. The collection of additional water quality data from these two lakes needs to be a priority for GW moving forward. No changes are recommended to the baseline states presented in the WIP for NPS-FM aquatic plant attribute states.

Table 34: Recommended current (water quality attributes) and baseline (submerged plant attribute) states for selected NPS-FM water quality attributes to be included in PC1. An * indicate where these differ from the baseline states presented in the WIP.

Attribute	Lake Kōhangapiripiri	Lake Kōhangatera
TN	"C"	"B"
TP	"C"	"C"
Chlorophyll *a*	"A"	"C"*
Cyanobacteria	"A"	"A"
NH_4-N (toxicity)	"A"	"A"
E. coli	"A"	"A"
Submerged plants (natives)	"C"*	"A"*
Submerged plants (invasive species)	"C"	"B"

7.4 Improvements required by the WIP

7.4.1 Water quality attributes

Compared to their current state estimates (in Schallenberg (2019) and Heath (2022); see Table 31), the WIP requires reductions in nutrients in both lakes. Concentrations of TP are required to reduce to shift both lakes from their estimated "C" states up into "B" states and concentrations of TN are required to reduce in Lake Kōhangapiripiri to shift it from an estimated "C" state to a "B" state. Lake Kōhangatera is currently estimated as being in "B" state for TN and the WIP does not require an improvement from this state. However, without robust water quality data to understand the current nutrient concentrations in each lake, it is difficult to establish the actual size of nutrient reductions required to make these improvements.

Despite the current inability to establish accurate estimates of the nutrient state for these lakes, data available since the WIP assessments indicate that phytoplankton and cyanobacteria attributes may be in a poorer to much poorer state than originally estimated. Thus, understanding the current nutrient state and the influence of nutrients on the state of phytoplankton and cyanobacteria in these lakes should be a high priority to better enable protection of their outstanding values. Anthropogenic sources of nutrients that drive proliferation of phytoplankton, cyanobacteria and benthic algal blooms all have the potential to impact on the high aquatic plant values that both lakes are known for (i.e., they are scheduled as Outstanding Waterbodies in the Proposed Natural Resources Plan).

Notwithstanding the limitations in the current lake data, there is enough general understanding in lake management that reducing external anthropogenic nutrient inputs into these lakes will be beneficial to protecting their existing high values (MfE and Stats NZ, 2023). Unfortunately, though, based on the current data it is not possible to determine the extent to which anthropogenic nutrient loads must reduce to meet the WIP nutrient and phytoplankton TASs because:

- It is not possible to ***accurately*** determine the baseline state of these attributes from the available data (i.e., the level of in-lake improvement needed to meet the TAS is uncertain); and
- Relationships between external nutrient loads, in-lake nutrient concentrations and phytoplankton and cyanobacteria biomass have not been established.

As such, it is my opinion that based on the lack of robust data, the most defensible method of setting TAS for nutrients and phytoplankton may be to acknowledge in the Plan that an accurate baseline cannot be established but that there is a clear desire for these attributes to improve by 2040. This may best be captured in PC1 by a narrative 'improve' target. This approach would need to:

1. Be coupled with the implementation of a robust monitoring programme to fill current knowledge gaps (including current state and a lake nutrient budget); and
2. Ensure that processes are in place to minimise external nutrient load inputs in the catchments of both lakes.

7.4.2 Aquatic plant attributes

Based on the assessments in Schallenberg (2019) and Heath (2022), the WIP requires improvements in the submerged plants (natives) attribute in both lakes from the “B” band up into the “A” band. For the submerged plants (invasive), the WIP requires Lake Kōhangapiripiri to shift it from the “C” band to a “B” band. The WIP baseline for submerged plants (invasive) in Lake Kōhangatera is the “B” band and the WIP does not require an improvement from this band.

Based on the February 2023 surveys of aquatic plants that occurred post the setting of the WIPs TAS for aquatic plant attributes, both lakes are currently meeting their TAS (see Table 33). This indicates that these TAS are achievable for both lakes, although note the variability in these states in previous years.

In my opinion, maintaining these TAS post 2023 will require:

1. regular monitoring of the current presence of invasive weeds and their impact;
2. undertaking control of these invasive weeds as required (note this currently occurs in Lake Kōhangatera);
3. ensuring no new invasive weeds are introduced into these lakes;
4. ensuring no new non-native fishes are introduced into these lakes that may directly or indirectly (via water quality degradation pathways) impact native aquatic plants;
5. regular monitoring of the native aquatic plant communities to better understand their variability and their drivers (both natural and anthropogenic); and,
6. ensuring water quality is maintained to support healthy native aquatic plant communities.

7.4.3 Additional note based on decisions made after publication (Author: Michael Greer)

Since this memorandum was published GW have made the decision to:

- Include all TASs set out in the WIPs regardless of whether they are informed by monitoring or modelling data that meets the requirements of the NPS-FM 2020; and
- Set baseline states for lakes off limited data collected outside of the NPS-FM 2020 prescribed baseline period (Presented in Sections 7.2 and 7.3). This approach was considered justified as the alternative was to have a lakes TAS table in PC1 without any baseline states other than for submerged plants (natives and invasive species).

Consequently, the recommendations made in Section 7.4.1 have not been adopted in Table 7.

8 Recommended approach for setting 'maintain' TASs in PC1

First published: 13/07/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington Regional Council

Many of the TASs in the WTWT and TAoP WIPs represent a maintain state. It is clear from the NPS-FM 2020 definition of **degrading**, that when setting TAS maintain does not mean 'within an attribute state. Thus, 'maintain' TASs need to capture the baseline state in some way, rather than simply denoting an attribute state. One option for doing this is to set hard numeric objectives that reflect the baseline state. However, this would likely result in sites fluctuating between meeting and not meeting that TAS due to natural temporal variability in water quality and freshwater ecosystems. An alternative recommended approach that relies on using trend analysis or statistical comparisons between monitoring periods is set out below in Table 35.

Table 35: Possible method for presenting 'maintain' TASs without specifying numbers.

		Baseline state			Short term target		Long term target	
Site	**Assessment statistic**	**Baseline period**	**By statistic**	**Numeric State**	**Numeric State**	**Concentration**	**State**	**Conc.**
Site 1	Median	2012-2017	1.5 mg/L (B)	B	B	Maintain at baseline state or improve*	A	1 mg/L
	95th percentile		2.2 mg/L (B)					1.5 mg/L
Site 2	Median	2012-2017	B	C	C	Maintain at baseline state or improve*	A	1 mg/L
	95th percentile		3.6 mg/L (B)					1.5 mg/L
Site 3	Median	2012-2017	C	D	C	Maintain at baseline state or improve*	A	1 mg/L
	95th percentile		D			6.9 mg/L		1.5 mg/L

*At sites where monitoring is continuous (conducted at a regular interval over the period for assessment) maintenance and/or improvement at the baseline state shall be determined through benchmarking against the TAS thresholds and trend analysis. An attribute will not be considered to be maintained within an attribute state:

- If trend analysis indicates a deteriorating trend is more likely than not since the baseline period[11]:
- The trend is inconsistent with what would be expected based on climate cycles over the period for assessment;
- There is evidence of a human activity contributing to the trend.

At sites where monitoring is intermittent (conducted in blocks over the period for assessment) maintenance and/or improvement shall be determined using an appropriate statistical analysis such as the Kruskal-Wallis test. Water quality will not be considered to be maintain or improved if:

- Such an analysis detects statistically significant (if measured via a p-value) or meaningful (if measured via an effect size) degradation between monitoring blocks (including the baseline period).
- Changes in water quality is inconsistent with what would be expected based on climate cycles over the period for assessment;
- There is evidence of a human activity contributing to changes in water quality.

Note: The recommended approach above was discussed in the PC1 TAG meetings held on the 02/05/2022 and the 16/05/2022. The TAG agreed that the approach was reasonable.

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[11] The NPS-FM stipulates that degrading means that "*a deteriorating trend is more likely than not*". Thus, in Table 35 the trend categories that constitutes 'maintain or improve' has been determined from that definition. However, there may be some benefit in selecting site-specific trend categories for maintenance based on the value and condition of the stream.

8.1 Amendments made when drafting PC1 provisions (Author: Michael Greer)

During the development of PC1 it became clear that the footnote to Table 35 would take up too much space in the NRP. Accordingly, the wording was simplified to

"Maintenance, improvement or deterioration in the state of an attribute will be assessed through:

- *Benchmarking against the TAS thresholds and trend analysis or appropriate statistical analysis; and*
- *Taking the impact of climate and human activity into account."*

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9 Sediment load reductions to meet suspended fine sediment TASs

Subject:	**Plan Change 1 Sediment – Clarity relationship assessment**
Attention:	Rachel Pawson, Michael Greer, Alastair Smaill
From:	Stuart Easton, James Blyth
First published:	22 August 2023
Copies to:	Brent King

9.1 Introduction

This memo assesses suspended sediment and visual clarity (clarity) relationships for existing State of Environment (SOE) monitored TAS across WTWT and TAoP Whaitua. Analysis varied for both Whaitua:

9.1.1 Te Whanganui-a-Tara Whaitua

- Suspended sediment load reductions were estimated based on requirements to meet visual clarity targets set in the WIP.
    - Calculation of suspended sediment load reductions was necessary as only a baseline sediment model was built for this Whaitua, and clarity targets set by the Whaitua Committee were not linked directly to modelled scenarios with specified load reductions (but clarity targets were however guided by Expert Panel predictions of clarity attribute state improvements during mitigation scenarios that relied heavily on Porirua Whaitua water quality modelling).

9.1.2 Te Awarua-o-Porirua Whaitua

- Suspended sediment load reductions were estimated based on requirements to meet visual clarity targets set in WIP (as for WTWT).
    - As the NPS-FM 2020 identified clarity as an attribute in the National Objectives Framework (NOF) after the TAoP Whaitua was completed, clarity targets were set by GW more recently for three sites only.
- Clarity improvements were predicted, based on three previously modelled sediment load reduction scenarios.

Provided data are summarised in Section 9.2, analysis methodology is included in Section 9.3 and results are provided in Section 9.4. A brief limitations discussion is given in Section 9.5.

9.1.3 Scope of Works

Currently GW are exploring the use of sediment loads as part of the management framework for meeting the visual clarity target attribute states for TAoP and WTWT. Thus, it is important that the link between these two factors is understood when drafting the S32 technical report. Furthermore, visual clarity was not a compulsory attribute when the TAoP WIP was being developed and was not considered in the modelling for that Whaitua process. Linking sediment loads and visual clarity will help fill this gap and enable changes in visual clarity to be estimated under the scenarios already tested for the TAoP Whaitua. This will further GW's understanding of the benefits of certain non-regulatory management actions when drafting action plans.

9.2 Data

Data provided by GW comprised:

1. Suspended Sediment Concentration (SSC), Total Suspended Solids (TSS), and Clarity measurements from 2011 – 2021 for 23 SOE sites.
2. Paired Autosampler-derived SSC and Turbidity measurements for 3 sites: Horokiri Stream at Snodgrass, Pāuatahanui Stream at Gorge, and Porirua Stream at Town Centre.
3. Sediment load estimates from dSedNet modelling in TAoP Whaitua and WTWT. Scenario load reductions were available for TAoP Whaitua only.
4. Baseline and target TAS clarity medians and attribute states set by GW (*pers. comm.* Michael Greer October 2022).

9.2.1 Monitoring data

Analysed monitoring data were limited to the most recent 5 years (2016–2021 inclusive) to ensure consistency with current land use and climate patterns. To improve the relationship between clarity and suspended sediment, reported SSC and TSS values less than the detection limit were removed. Table 36 summarises the selected data. Due to the greater number of samples available, TSS was preferred to SSC to achieve a robust relationship with clarity measurements.

SSC is the preferable measurement to use for clarity relationships given it involves complete analysis of a sample container, while TSS involves analysing only a sub-sample. However, GW's monitoring record has a greater number of paired TSS and clarity measurements (see Table 36). Both TSS and SSC samples from SOE sites have collected limited numbers of event-based flows, where higher concentrations of suspended sediment occur. Subsequently, the greater number of TSS samples is predominantly at sediment concentrations below 200 mg/L, with a handful of samples between 200 and 500 mg/L (see Figure 8). It is expected the TSS and SSC relationship in Figure 8 would decrease if more event-based flows were captured. For this analysis, it was considered acceptable to use TSS to establish relationships with clarity, as both measurements were often collected concurrently during SOE monitoring rounds. Figure 8 plots all paired SSC:TSS samples and shows a strong correlation.

Table 36: Monitoring site data summary (2016-2021).

Monitoring Site	TAS?	Whaitua	Clarity Count	SSC Count (above detection)	TSS count (above detection)
Taupo Stream at Plimmerton Domain	Yes	TAoP	16	1	11
Horokiri Stream at Snodgrass	Yes	TAoP	58	145	28
Pāuatahanui Stream at Elmwood Bridge	Yes	TAoP	58	8	32
Porirua Stream at Milk Depot	Yes	TAoP	58	8	30
Whakatikei River at Riverstone	Yes	TWT	57	1	10
Hutt River at Te Marua Intake Site	Yes	TWT	58	2	8
Mangaroa River at Te Marua	Yes	TWT	57	5	20
Hulls Creek adjacent Reynolds Bach Drive	Yes	TWT	16	5	14
Hutt River at Boulcott	Yes	TWT	58	12	29
Waiwhetū Stream at Whites Line East	Yes	TWT	54	3	11
Black Creek at Rowe Parade end	Yes	TWT	17	4	16
Wainuiomata River Dnstr of White Bridge	Yes	TWT	58	2	9
Kaiwharawhara Stream at Ngaio Gorge	Yes	TWT	58	3	5
Karori Stream at Mākara Peak Mountain Bike Park	Yes	TWT	58	1	4
Mākara Stream at Kennels	Yes	TWT	58	13	55
Porirua Stream at Glenside Overhead Cables	No	TAoP	40	8	15
Akatarawa River at Hutt Confluence	No	TWT	58	1	9
Hutt River Opposite Manor Park Golf Club	No	TWT	58	10	27
Owhiro Stream at Mouth	No	TWT	17	6	15
Pākuratahi River 50m Below Farm Creek	No	TWT	57	4	12
Stokes Valley Stream at Eastern Hutt Road	No	TWT	17	4	12
Wainuiomata River at Manuka Track	No	TWT	58	0	1
Ōrongorongo River at Ōrongorongo Station	No	TWT	0	0	0

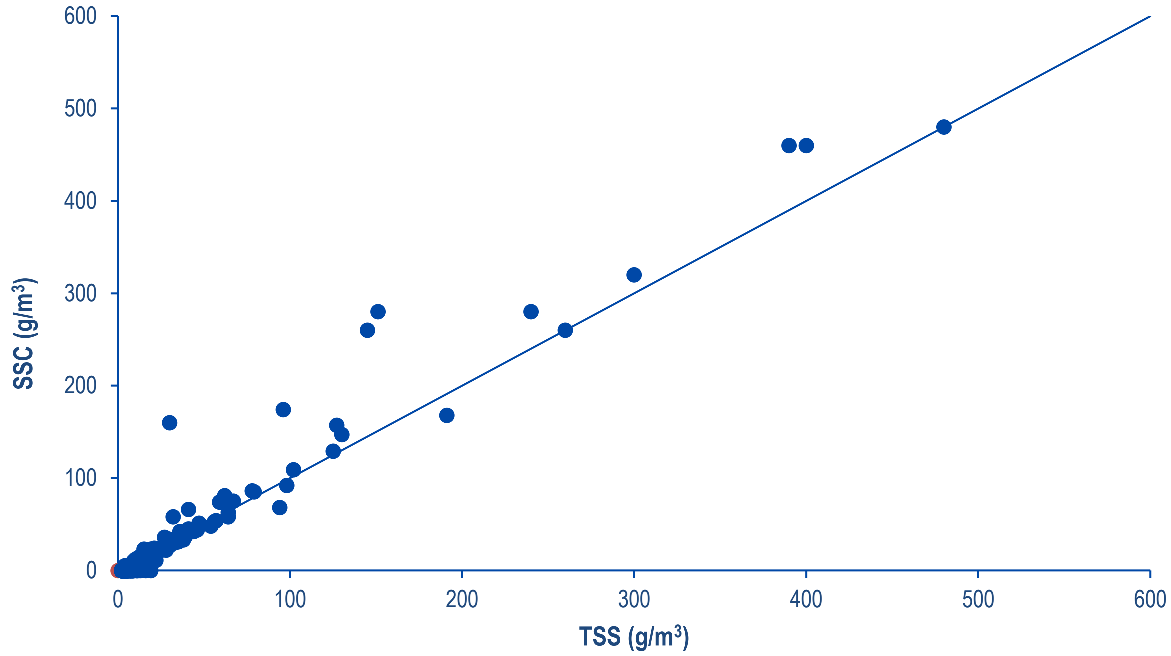

Figure 8: Paired SSC and TSS samples for all sites (n=106). 1:1 line plotted in blue.

9.2.2 Baseline Clarity and Targets

Baseline and target visual clarity medians and associated attribute states from the NPS-FM 2020 as provided by GW are shown in Table 37

Table 37: Baseline visual clarity and targets. Baseline medians below the target are in bold.

Site	Whaitua	Baseline median	Baseline attribute state	Target median	Target attribute state
Akatarawa River at Hutt Confluence	TWT	4.8	A	≥4.8	A
Hutt River at Te Marua Intake Site		4.6	A	≥4.6	A
Whakatikei River at Riverstone		4	A	≥4	A
Hutt River at Boulcott		**2.8**	B	≥2.95	A
Hutt River Opposite Manor Park Golf Club		3	A	≥3	A
Mangaroa River at Te Marua		**1.6**	D	≥2.22	C
Pākuratahi River 50m Below Farm Creek		4.5	A	≥4.5	A
Hulls Creek adjacent Reynolds Bach Drive		1.2	A	≥1.2	A
Waiwhetū Stream at Whites Line East		1.4	A	≥1.4	A
Ōrongorongo River at Ōrongorongo Station		≥2.95	A	≥[a]	A
Wainuiomata River at Manuka Track		3.9	A	≥3.9	A
Black Creek at Rowe Parade end		1.3	D	≥2.22	C
Wainuiomata River Dnstr of White Bridge		2.2	D	≥2.2	C
Mākara Stream at Kennels		**1.6**	D	≥2.22	C
Korokoro Stream		≥2.95	A	≥[a]	A
Kaiwharawhara Stream at Ngaio Gorge		3.6	A	≥3.6	A
Karori Stream at Mākara Peak Mountain Bike Park		3.2	A	≥3.2	A
Owhiro Stream at Mouth		**1.8**	D	≥2.22	C
Horokiri Stream at Snodgrass	TAoP	2.8	B	≥2.8	B
Pāuatahanui Stream at Elmwood Bridge		**2**	D	≥2.22	C
Porirua Stream at Milk Depot		2.4	A	≥2.4	A

[a] Maintain or improve

9.2.3 Autosampler data

Three autosamplers have collected SSC and turbidity measurements in the Porirua Whaitua since 2012; Horokiri Stream at Snodgrass, Pāuatahanui Stream at Gorge, and Porirua Stream at Town Centre. Of the sites, only Horokiri has clarity measurements that align with the turbidity and SSC samples:

- Horokiri Stream at Snodgrass clarity - turbidity relationship is poor ($r^2 = 0.45$, n = 63).
- Horokiri Stream at Snodgrass clarity - SSC relationship is strong ($r^2=0.97$), although there are only 6 paired samples above the SSC detection limit.

Due to the lack of matching clarity data, the autosampler information has been precluded from the remainder of the analysis.

9.2.4 Sediment load estimates

Baseline sediment loads were taken from previously modelled dSedNet results (Easton *et al.*, 2019b; Easton and Cetin, 2020). While monitoring locations generally align with the dSedNet reporting points, discrepancies are present; e.g., the Karori stream monitoring site is mid-way along a dSedNet sub-catchment, resulting in a likely overestimate of sediment load due to the increased contributing catchment area in the model. Furthermore, the reporting periods from which annual average loads are derived do not align between TAoP sites (2005-2014), WTWT sites (1992-2018), and the selected clarity monitoring period used in this analysis (2016-2021). Further limitations are outlined in the referenced reports. Reported sediment loads should therefore be viewed as estimates only.

9.3 Methodology

For WTWT sites and three TAoP sites with available data (Horokiri Stream at Snodgrass, Pāuatahanui Stream at Elmwood Bridge, and Porirua Stream at Milk Depot), the proportional change in sediment load required to meet visual clarity targets was estimated using the approach in Hicks *et al.* (2019) (also reported in Neverman *et al.* (2021)):

$$PR_v = 1 - (V_o/V_b)^{1/\alpha}$$

Equation 1

PR_v = minimum proportional reduction in load required to achieve the objective
V_o = target median visual clarity
V_b = baseline median visual clarity
α = co-efficient used in power law relationship between SSC and clarity, note TSS has been preferred in this analysis (see Section 9.2).

For each TAS with monitoring data, site specific TSS – visual clarity coefficients were calculated (see Section 9.4.1). Where r^2 values were less than 0.5, the regional coefficient of -0.782 was adopted (Figure 9), which is comparable to the national average of -0.76 reported in Hicks *et al.* (2019).

Baseline and target median visual clarity values were provided by GW (Table 37).

For TAoP sites, an inverse approach has also been applied to estimate the visual clarity reductions achieved under each of the three sediment load reduction scenarios modelled for the Porirua Whaitua: Business as Usual (BAU), Improved, and Water Sensitive (WS):

$$V_o = (1 - PR_v)^{\alpha} \times V_b$$

Equation 2

V_o = median visual clarity achieved under the scenario
PR_v = proportional reduction in load under the scenario
α = Co-efficient used in power law relationship between TSS and visual clarity.
V_b = median visual clarity calculated from the monitoring data (Section 9.2)

9.4 Results

9.4.1 Clarity : TSS relationship

Paired clarity and TSS samples were plotted for all data points (Figure 9), for each TAS site (Appendix G), and for all sites within each of the two Whaitua (Appendix H). The regional[12] clarity:TSS relationship is described by the equation (r^2 = 0.62):

$$Clarity = 4.11\, TSS^{-0.782}$$

Equation 3

In general, there was a robust relationship between the two variables which were expectedly negatively correlated. TAS site r^2 values were above 0.5 for all sites except Taupo Stream at Plimmerton Domain (n=11) and Waiwhetū Stream at Whites Line East (n=11). For these two sites, the analysis in Sections 9.4.2 and 9.4.3 used the regional exponent from Equation 3 (-0.782). For all other sites, the site-specific exponent was used. Inter-site exponent standard deviation = 0.1.

Data limitations are evident in paired samples at TSS concentrations below 10 mg/L. This is where there can be a high variability in field clarity measurements, yet the corresponding TSS concentrations exhibit low variability. The relationship strengthens when TSS exceeds 10 mg/L, indicating suspended sediment has a greater 'control' on clarity measurements, likely as flow increases following rainfall. It could be expected that the relationship would be improved with greater data availability or increased TSS reporting precision.

[12] Regional refers to this plan change's monitoring sites (i.e. TAoP and TWT Whaituas only, not all of Wellington regional).

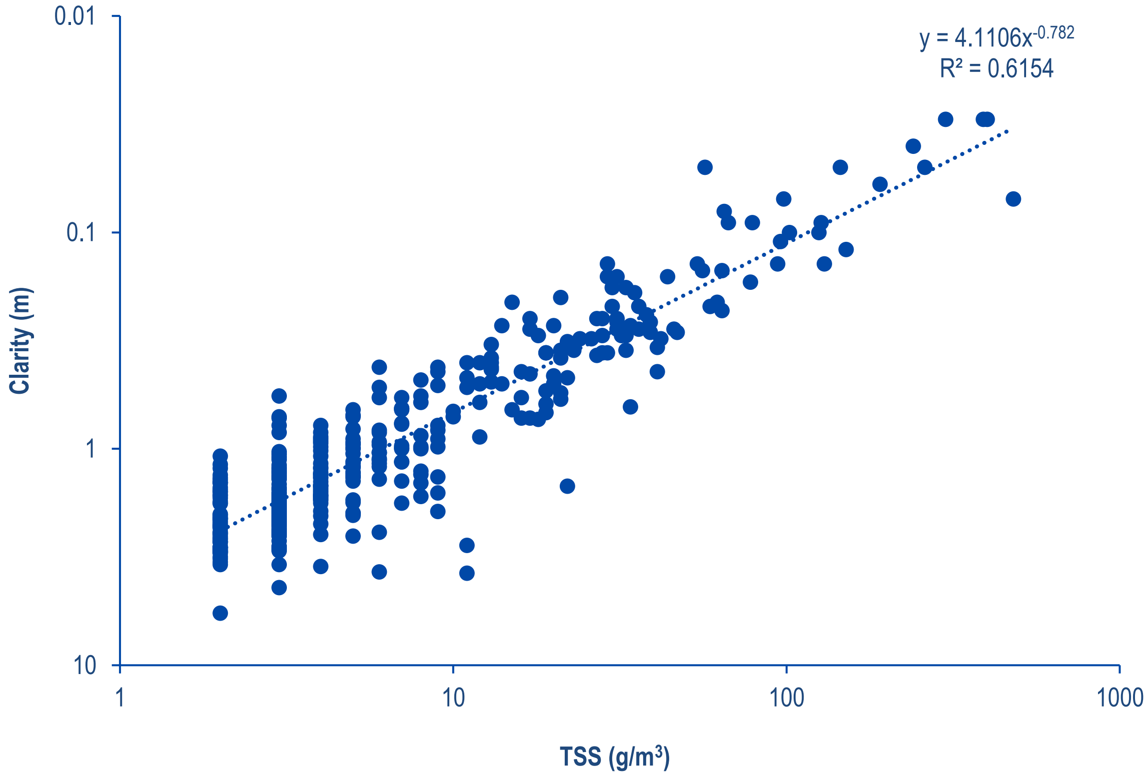

Figure 9: Paired Clarity measurements and TSS samples for all sites (n=373). Log10 scale.

9.4.2 Annual sediment load reductions

The estimated load reduction required to achieve clarity targets for monitored TAS as calculated by Equation 1 are presented in Table 38.

Significant (>10%) reductions in sediment load are required for four of the five sites that do not currently meet the clarity targets, in particular the Black Creek at Rowe Parade site. The remaining site, Hutt River at Boulcott, requires a 7% reduction in sediment load to achieve the 2.95 m clarity target.

Table 38 is extended in Appendix I to show the range of load reductions calculated with the regional exponent and inter-site standard deviation. For four of five sites that do not currently meet the clarity targets, the range in load reduction is relatively small (≤ 5%). For Mangaroa River at Te Marua, the reduction calculated with the regional exponent (-31% to -38%, ± 1. std. dev.) is significantly less than that calculated with the site-specific exponent (-45%) due to the relatively small clarity improvements observed in response to increased sediment load (TSS) for this site (see Appendix H).

Table 38: Estimated load reduction required to achieve clarity targets for monitored TAS. Current clarity medians below the target are in bold (Superseded – see Table 40).

Target Attribute Site	Part-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target
Te Whanganui-a-Tara TAS						
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	4	4	3,189	0%
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	**1.6**	**2.22**	**10,965**	**-45%**
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	1.2	1.2	181	0%
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	**2.8**	**2.95**	**102,303**	**-7%**
Waiwhetū Stream	Waiwhetū	Waiwhetū Stream at Whites Line East	1.4	1.4	228	0%
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	2.2	2.2	12,243	0%
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	3.6	3.6	290	0%
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	3.2	3.2	2,159	0%
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	**1.6**	**2.22**	**4,437**	**-34%**
Te Awarua-o-Porirua TAS						
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.8	2.8	764	0%
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**2**	**2.22**	**2311**	**-13%**
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	2.4	2.4	1705	0%

9.4.3 Porirua scenario clarity change

Estimated clarity achieved under modelled load reduction scenarios for monitored Porirua Whaitua TAS (as estimated by Equation 2) are presented in Table 39. The results indicate that under the Improved and WS scenarios, significant improvements in clarity are predicted for all monitored sites. The Taupo and Porirua Stream sites are predicted remain in the 'A' NOF band in all scenarios. Horokiri stream is predicted to improve from the 'B' band to the 'A' band in the Improved and WS scenarios. Pāuatahanui Stream at Elmwood bridge is predicted to be in the 'B' band the WS and Improved scenarios and above the target clarity, however, would remain below the national bottom line under the BAU scenario.

Table 39: Estimated clarity (m) and NOF band achieved under modelled sediment load reduction scenarios for monitored TAoP TAS.

Target Attribute Site	Part-FMU	Monitoring Site	Baseline clarity		BAU scenario clarity		Improved scenario clarity		WS scenario clarity	
			Median (m)	NOF band	Median (m)	NOF band	Median (m)	NOF band	Median (m)	NOF band
Taupo Stream	Plimmerton and Pukerua Bay	Taupo Stream at Plimmerton Domain	1.64 [a]	A	1.66	A	2.45	A	2.80	A
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.8	B	2.84	B	5.32	A	5.39	A
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**2**	**D**	**1.94**	**D**	2.59	B	2.83	B
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	2.40	A	2.31	A	2.57	A	2.58	A

[a] Median calculated from the monitoring data (2016-21) as Taupo Stream median and target clarity values were not set for the WIP (Section 9.2).

9.5 Limitations

The approach undertaken in this memo uses best available information and follows methods established in the literature, however limitations that are difficult to quantify are inherent in the data and methods. In particular, the use of median clarity and modelled average annual loads as key inputs fail to account for temporal aspects of erosion and sedimentation; for example, sediment mitigation measures that reduce high-flow loads (e.g., gullying or land sliding processes) may not be apparent in clarity measurements during mid- or low flows. Hence, it is unlikely that clarity values of upwards of 5 metres as predicted for the Horokiri Stream under the Improved and WS scenarios (Table 39) will be achieved in reality, even if the modelled ~50% reduction in sediment load occurs.

9.6 Update in response to February 2023 amendments to the NPS-FM 2020 (Author: Michael Greer)

The February 2023 amendments to the NPS-FM 2020 changed the definition of baseline state meaning some of the sediment load reductions listed in Table 38 are no longer relevant. Accordingly, an update is provided in Table 40 that accounts for these amendments (i.e., baseline state = median visual clarity on 07/09/2017). The Taupō and Wai-o-hata part-FMUs have also been added to Table 40 with baseline states calculated from:

- The results of sediment modelling (median TSS concentration) conducted as part of the TAoP CMP (Easton *et al.*, 2019b); and
- The regional TSS-visual clarity relationship set out in Equation 3.

Table 40: Updated estimated load reductions required to achieve clarity targets for monitored TAS. Baseline clarity medians below the target are in bold. Changes made from Table 38 are denoted in red.

Target Attribute Site	Part-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target
Te Whanganui-a-Tara TAS						
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	4	4	3,189	0%
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	**1.5**	**2.22**	**10,965**	**-51%**
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	1.2	1.2	181	0%
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	**2.4**	**2.95**	**102,303**	**-24%**
Waiwhetū Stream	Waiwhetū	Waiwhetū Stream at Whites Line East	1.1	1.1	228	0%
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	**2.1**	**2.22**	**12,243**	**-7%**
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	3.2	3.2	290	0%
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	3.2	3.2	2,159	0%
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	**1.6**	**2.22**	**4,437**	**-34%**
Te Awarua-o-Porirua TAS						
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.3	2.3	764	0%
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**1.8**	**2.22**	**2311**	**-24%**
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	1.7	1.7	1705	0%
Taupō Stream	Taupō	Taupō Stream at Plimmerton Domain	1.2	1.2	15	0%
Duck Creek	Wai-o-hata	Duck Creek at at Tradewinds Drive Bridge	1.2	1.2	526	0%

First published: 13/07/2022

To: Plan Change 1 Policy and Technical Team
Greater Wellington Regional Council

10 Alignment between existing numeric standards in the operative NRP and the WIP TASs

The purpose of this memorandum is to assess whether the TASs in the TAoP and WTWT WIP are consistent with existing numeric standards in the objectives, policies and rules of the operative NRP. This assessment has been conducted to inform the Plan Change 1 Policy and Team about where the WIP TASs sit in relation to existing NRP provisions. There is no requirement for the PC1 TASs to be consistent with the operative NRP. Thus, the findings presented here should not be treated as an assessment of the appropriateness of the WIP TASs.

10.1 Alignment between the NRP O18 and O19 objectives and WIP TASs

Objective O18 (relates to contact recreation and Māori customary use) and O19 (relates to biodiversity, aquatic ecosystem health and mahinga kai) of the NRP sets out general water quality and ecology objectives for all rivers in the Wellington Region. In doing so, they include numeric outcomes for the NPS-FM 2020 compulsory attributes identified in Table 41. Furthermore, the Cu and Zn TASs set in the TOaP and WTWT WIPs are covered by the O19 toxicant objective for rivers.

Table 41: Description of NPS-FM 2020 compulsory attributes with numeric objectives set in Objectives O18 and O19 of the NRP.

Attribute	NRP objective	Freshwater body type	Notes on NRP objectives
Cyanobacteria (planktonic)	O18	Lakes	Only applies to significant contact recreation freshwater bodies and sites with significant mana whenua values
E. coli		Rivers and lakes	Assessment statistics different from those in the NPS-FM 2020
Suspended fine sediment		Rivers	• Listed as water clarity • Only applies to significant contact recreation freshwater bodies and sites with significant mana whenua values
Deposited fine sediment			Only applies to significant contact recreation freshwater bodies and sites with significant mana whenua values
Periphyton (trophic state)	O19		Corresponds to periphyton biomass objective rather than the periphyton cover objective.
Macroinvertebrates (1 of 2)			MCI/QMCI
Fish			Corresponds to the Index of Biotic Integrity column
NO_3-N toxicity			Included in toxicants
NH_4-N toxicity			
Phytoplankton (trophic state)		Lakes	N/A
Total nitrogen (trophic state)			
TP (trophic state)			
Submerged plants (natives)			
Submerged plants (invasive species)			
Lake-bottom dissolved oxygen			
Mid-hypolimnetic dissolved oxygen			

Inconsistencies (i.e., where the TAS is less protective than the NRP objectives) between the O18 and O19 numeric objectives and the TOaP and WTWT WIP TASs are set out in Table 42. All other TASs are consistent with (i.e., equally, or more protective than) the NRP objectives. This analysis is based on the following assumptions:

- The O18 *E. coli* attributes are equivalent to the NPS-FM 2020 E states as:
  - The statistical, flow and seasonal restrictions on the *E. coli* objective in Table 3.1 of Objective O18 of the NRP means that concentrations can exceed 540 CFU/100mL ~40 % of the time (NPS-FM 2020 E state threshold = 30%); and
  - The objective for median *E. coli* concentrations Table 3.2 of Objective O18 of the NRP is roughly four times higher than the NPS-FM 2020 E state threshold for that statistic.
- The NPS-FM 2020 attribute states take priority over regionalised thresholds for MCI and Fish IBI; and
- The NRP river-classes and the NPS-FM 2020 sediment classes for sites in the different TAoP Whaitua and WTWT part-FMUs are consistent with those set out in Table 44.

Table 42: Inconsistencies (TAS less protective than the NRP objective) between the numeric objectives in O18 and O19 of the NRP and the TAoP Whaitua and WTWT WIP TASs. Parenthesised numbers denote the number of attribute state differences between the NRP objective and the WIP TAS. The NPS-FM 2020 attribute states have been used for macroinvertebrates and fish.

Whaitua	Part-FMU	Site	Attributes (and no# of attribute states between TAS and NRP objective)
TAoP Whaitua	Te Rio o Porirua	Porirua S. @ Glenside	NH_4-N (1), Cu (1), Zn (1)
	Te Rio o Porirua	Porirua S. @ Milk Depot	
WTWT	Wellington urban	Karori S. @ Mākara Peak	Cu (1), Periphyton (1)
		Owhiro S. @ Mouth	
	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	Periphyton (1)
	South-west coast rural streams	Mākara S. @ Kennels	
	Waiwhetū Stream	Waiwhetū S. @ Whites Line East	
	Te Awa Kairangi rural mainstems	Mangaroa R. @ Te Marua	
	Te Awa Kairangi urban streams	Hulls Ck adj. Reynolds Bach Dr.	Periphyton (1)
		Stokes Valley S. @ Eastern Hutt Rd	
	Te Awa Kairangi rural streams	Pākuratahi Catchment	Periphyton (1), macroinvertebrates (1)
	Wainuiomata urban streams	Black Creek @ Rowe Parade	
	Wainuiomata rural streams	Wainuiomata R. D/S of White Br.	Periphyton (1)
	Parangārehu Lakes	Lake Kōhangatera	Invasive submerged plants (1), total nitrogen (1), TP (1)
		Lake Kōhangapiripiri	

10.2 Alignment between the operative NRP permitted activity rule standards and the WIP TAS and NPS-FM 2020 attributes

The permitted activity rules in the NRP includes receiving environment water quality standards for some of the attributes for which targets have been set in the TAoP and WTWT WIPs. These standards are described in the context of the NPS-FM 2020/WIP attribute states in Table 43.

Table 43: Description of NRP permitted activity receiving environment water quality standards for attributes with TASs in the TAoP and WTWT WIPs.

NRP Rule	Attribute	Receiving environment standard
Rule R91	NH_4-N toxicity	B state in all rivers
	NO_3-N toxicity	A state in all rivers
	Cu toxicity	A state in significant rivers and river class 1
		B state in all other rivers
	Zn toxicity	A state in significant rivers and river class 1
		B state in all other rivers
Rule R55	NH_4-N toxicity	B state in all rivers
	NO_3-N toxicity	A state in all rivers
	Cu toxicity	B state in all rivers
	Zn toxicity	
Rule R59	*E. coli*	E state in all rivers
	Dissolved oxygen	C state in all rivers

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Table 44: Locations, NRP river classes, NPS-FM 2020 sediment classes and significance (in relation to Objectives O18 and O19 of the NRP) of sites in different TAoP Whaitua and WTWT part-FMUs.

Whaitua	Part-FMU	Site	Easting	Northing	NRP river class	SFS class	DFS class	Sig. O18	Sig. O19
TAoP	Pouewe	Horokiri S. @ Snodgrass	1761804	5450652	2	3	4	N	N
TAoP	Rangituhi	N/A			2	2	1	N	N
TAoP	Takapū	Pāuatahanui S. @ Elmwood Bridge	1761097	5446783	2	3	4	Y	N
TAoP	Taupō	Taupō S. @ Plimmerton Domain	1756919	5450368	6	2	0	Y	N
TAoP	Te Rio o Porirua	Porirua S. @ Glenside	1753290	5438364	2	3	4	Y	N
TAoP	Te Rio o Porirua	Porirua S. @ Milk Depot	1754366	5443031	2	2	2	Y	N
TWT	Kaiwharawhara Stream	Kaiwharawhara S. @ Ngaio Gorge	1749069	5431077	2	3	4	Y	N
TWT	Korokoro Stream	N/A			2	3	4	Y	N
TWT	Ōrongorongo	Ōrongorongo R. @ Ōrongorongo Station	1758930	5413094	1	3	4	Y	Y
TWT	South-west coast rural streams	Mākara S. @ Kennels	1743530	5433635	2	3	4	N	N
TWT	Te Awa Kairangi forested mainstems	Akatarawa R. @ Hutt Confluence	1776183	5449184	1	3	4	Y	Y
TWT	Te Awa Kairangi forested mainstems	Hutt R. @ Te Marua Intake Site	1780071	5450158	1	3	4	Y	Y
TWT	Te Awa Kairangi forested mainstems	Pākuratahi R. 50m Below Farm Ck	1784607	5451677	1	3	4	Y	Y
TWT	Te Awa Kairangi forested mainstems	Whakatikei R. @ Riverstone	1772256	5446748	4	3	4	N	N
TWT	Te Awa Kairangi lower mainstem	Hutt R. @ Boulcott	1761038	5437628	4	3	4	Y	N
TWT	Te Awa Kairangi lower mainstem	Hutt R. Opposite Manor Park	1766679	5442285	4	3	4	Y	N
TWT	Te Awa Kairangi rural mainstems	Mangaroa R. @ Te Marua	1778726	5448590	1	3	4	N	N
TWT	Te Awa Kairangi rural streams - Mangaroa Lower	N/A			6	3	4	N	N
TWT	Te Awa Kairangi rural streams - Mangaroa Upper				3	3	4	N	N
TWT	Te Awa Kairangi rural streams - Pākuratahi				1	3	4	N	Y
TWT	Te Awa Kairangi small forested				1	3	4	N	Y
TWT	Te Awa Kairangi urban streams	Hulls Ck adjacent Reynolds Bach Dr.	1767288	5442588	2	2	2	N	N
TWT	Te Awa Kairangi urban streams	Stokes Valley S. @ Eastern Hutt Rd	1766285	5441567	2	3	4	N	N
TWT	Wainuiomata rural streams	Wainuiomata R. D/S of White Br.	1757315	5415739	4	3	4	Y	N
TWT	Wainuiomata small forested	Wainuiomata R. @ Manuka Track	1768301	5430792	1	3	4	Y	Y
TWT	Wainuiomata urban streams	Black Ck @ Rowe Parade end	1763349	5429187	3	3	4	N	N
TWT	Waiwhetū Stream	Waiwhetū S. @ Whites Line East	1760977	5434510	6	2	2	N	N
TWT	Wellington urban	Karori S. @ Mākara Peak	1744222	5427016	2	3	4	N	N
TWT	Wellington urban	Owhiro S. @ Mouth	1747228	5421631	2	3	4	N	N

Table 45 sets out where the NRP permitted activity receiving environment water quality standards are inconsistent (i.e., less protective) with the TOaP and WTWT WIP TASs. All other permitted activity standards are consistent with (i.e., equally, or more protective than) the WIP TAS. This analysis is based on the following assumptions:

- The *E. coli* receiving environment standard in Rule R57 of the NRP references Table 3.1 of the NRP. Thus, it is equivalent to the NPS-FM 2020 E state for the reasons set out in Section 10.1;
- The NRP Schedule V 95% species protection threshold for NO_3-N equates to the NPS-FM 2020 A attribute state;
- The NRP Schedule V 95% species protection threshold for NH_4-N equates to the NPS-FM 2020 B attribute state; and
- The NRP river-classes for sites in the different TAoP and WTWT part-FMUS are consistent with those set out in Table 44.

Table 45: NRP permitted activity standards that are inconsistent with the TAoP and WTWT WIP TASs. Parenthesised numbers denote the number of attribute state differences between the NRP permitted activity standards and the WIP TAS.

Permitted activity rule	Attribute	Part-FMU
Rule R91	NH_4-N	Everywhere (1) except: • Kaiwharawhara Stream • Te Rio o Porirua • Wellington urban
	Cu	Everywhere (1) except: • Taupō • Te Awa Kairangi rural mainstems • Te Awa Kairangi small forested • Kaiwharawhara Stream • Wainuiomata small forested • Wainuiomata urban streams • Ōrongorongo
	Zn	Everywhere (1) except: • Te Rio o Porirua • Te Awa Kairangi rural mainstems • Waiwhetū Stream • Ōrongorongo
Rule R82	NH_4-N	Everywhere (1) except: • Te Rio o Porirua • Wellington urban • Kaiwharawhara Stream
	Cu	Everywhere (1) except: • Taupō • Te Rio o Porirua • Kaiwharawhara Stream • Wellington urban • Wainuiomata urban streams
	Zn	Everywhere (1) except: • Te Rio o Porirua • Waiwhetū Stream
Rule R57	*E. coli*	Everywhere (1+)
	Dissolved oxygen	Everywhere in WTWT (2)

11 Review of the sediment load reduction required to achieve sedimentation rate targets in Te Awarua-o-Porirua

To: Rachel Pawson, Environmental Policy

From: Brent King, Team Leader, Science Integration

First published: 2nd December 2022

Reviewed by: John Oldman (see Appendix J)

11.1 Purpose

This memo provides further information on the derivation of the sediment loads and load reduction 'targets' given in TAoP WIP. It provides recommended changes to the way the current load is expressed and further justification for the reduction targets.

11.2 Derivation of the limits and load reductions

Sediment load reduction targets were expressed in TAoP WIP (Table 46). These were designed to reflect the reductions necessary to achieve the sedimentation rate objectives in TAoP (Table 46).

Table 46: Total sediment load limits and targets to be achieved by 2040 in TAoP Whaitua (adapted from TAoP WIP).

Metric	Pāuatahanui	Onepoto
Sedimentation rate objective (2040)	Net average sedimentation rate is less than 2mm/year in Pāuatahanui Inlet (rolling average over the most recent 5 years of data)	Net average sedimentation rate is less than 1mm/year in Onepoto Arm (rolling average over the most recent 5 years of data)
Current total sediment load Annual average (tonnes/yr)	5,200	2,800
Sediment limit Annual average (tonnes/yr)	5,200	2,800
Sediment target % reduction from limit	40	40

The harbour modelling illustrated that reductions in sediment load would be required to reach the sedimentation rate objectives from estimated current sedimentation rates of 4.7mm/year for Pāuatahanui Inlet and 4.1mm/year for Onepoto Arm (Oldman, 2019). The modelling, however, did not directly estimate the amount of load reduction required to achieve the specific objectives set for each WMU.

The load reductions required were instead found in two ways (GWRC, 2019).

For Pāuatahanui, this was:

- Harbour modelling indicating that a sediment reduction of around 45% is estimated to result in a sedimentation rate of around 2mm/yr

- The bulk of sediment reductions in catchments draining to the Pāuatahanui Inlet are estimated to come through the mitigations associated with the modelled 'improved' scenario. This produced a load reduction of around 40%.
- While additional sediment reductions were made in the modelled 'Water Sensitive' scenario, the additional cost for these was significant.

For Onepoto, this was

- Harbour modelling indicating that a sediment reduction in Onepoto source loads of between 15 and 58% estimated to result in a sedimentation rate of between 2.5 and 0.3mm/yr
- Simple linear interpolation between these points suggests a load reduction of 40-45% may approximate to a sedimentation rate of around 1mm/yr
- The bulk of sediment reductions in catchments draining to the Onepoto Arm are estimated to come through the mitigations associated with the modelled 'improved' scenario with small additional reductions in the modelled 'Water Sensitive' scenario. The 'improved' scenario produced a load reduction of around 45%.

In both cases, the 'limit' from which the reduction target is expressed was the annual average sediment load from the 2005-14 period.

11.3 Reviews of the limits and load reductions

Brydon Hughes of Land Water People (LWP) provided review comments on the logic and basis used to establish water quality objectives, limits and targets in the TAoP WIP (Hughes, 2019) (Comments on the derivation of harbour sedimentation rate objectives, limits and load reductions noted:

- Harbour sedimentation modelling limited to a single 'representative' year (2010) while catchment model included multi-year variability
- While heavily reliant on interpolation of model results, the overall approach utilised to develop sediment loads and targets follows a logical process which appropriately recognises limitations of the available data
- Due to model uncertainties, greater emphasis in terms of policy development should be placed on the sediment load percentage reduction target rather than the absolute sediment load estimate. Future modelling may update or change calculated sediment load estimates creating potential issues meeting absolute numerical load limits. However, the numeric percentage reduction target will ensure progress toward achieving nominated water quality objectives

Further review (Greer, 2022) noted that further justification is needed for using a linear relationship based on just two points to set a sediment load target that could have significant impacts on land-use. It also noted it is not appropriate to link just the 2010 annual sediment load with the sedimentation rate from the harbour model, as those average sedimentation rates consider annual sedimentation in 2010 **and** sedimentation in events in 2004, 2005, 2006 and 2013.

11.4 Sedimentation rates and sediment input variability

Sediment plate data collected annually from 2008, with more extensive coverage from 2013 (Stevens and Forrest, 2020) illustrated a generally positive (i.e., depositing) sedimentation rate across this period, with very high spatial and temporal variability in annual deposition or erosion rates (Figure 10). Bathymetric surveys carried out in 2009, 2014 and 2019 similarly illustrate a generally positive deposition rate across the longer period, though rates were around 0mm/yr between 2009 and 2014, and around 10mm/yr between 2014 and 2019 (Waller, 2019) (Figure 11).

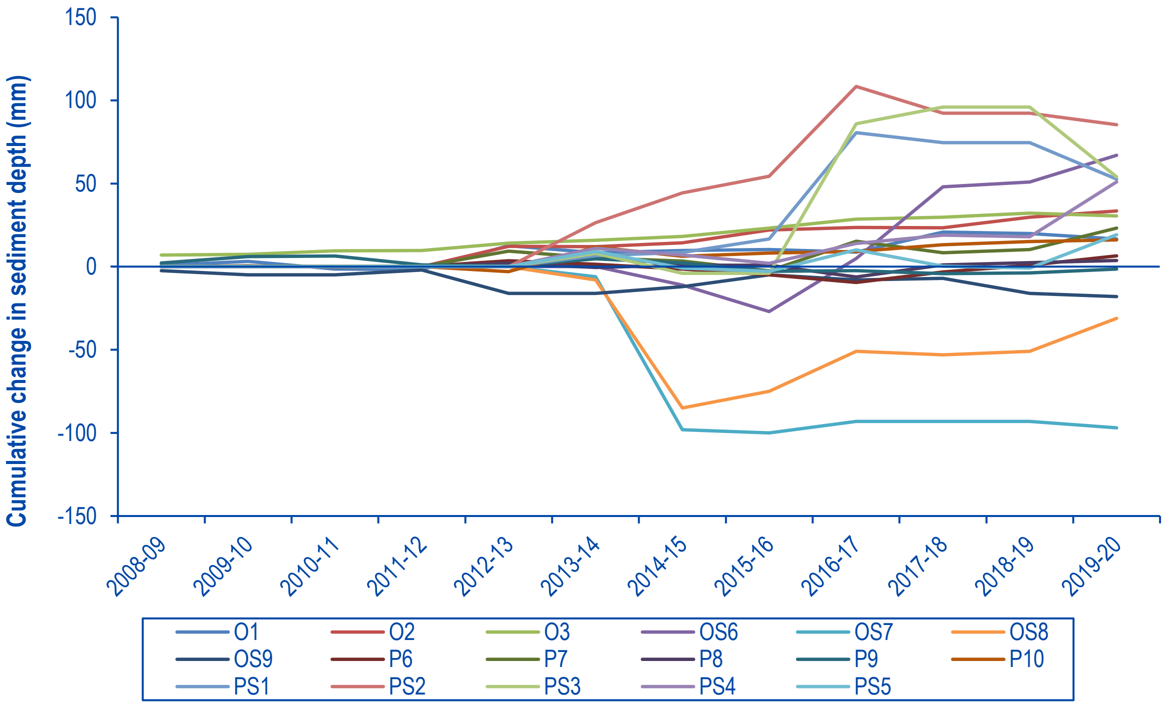

Figure 10: Cumulative change in sediment level over sediment plates in TAoP (adapted from Stevens and Forrest (2020)).

This variability demonstrates the importance of developing the harbour model over a range of events. TAoP catchment water quality modelling used the period 2005-14 as a representative range of climatic conditions (Easton *et al.*, 2019a). The ten-year running average of freshwater inflows for the period 2005-2014 is close to the long-term average value from 1975-2016, and there is sequence of higher than average inflows followed by lower than average inflows throughout the period 2005-2014 (Oldman, 2019).

Sediment input loads are also highly variable, and the sediment load delivered to Te Awarua-o-Porirua through the 2005-14 period appears to be relatively low, at ~8,000 tonnes/year, compared with a long-term average of ~12,800 tonnes/year (Figure 12).

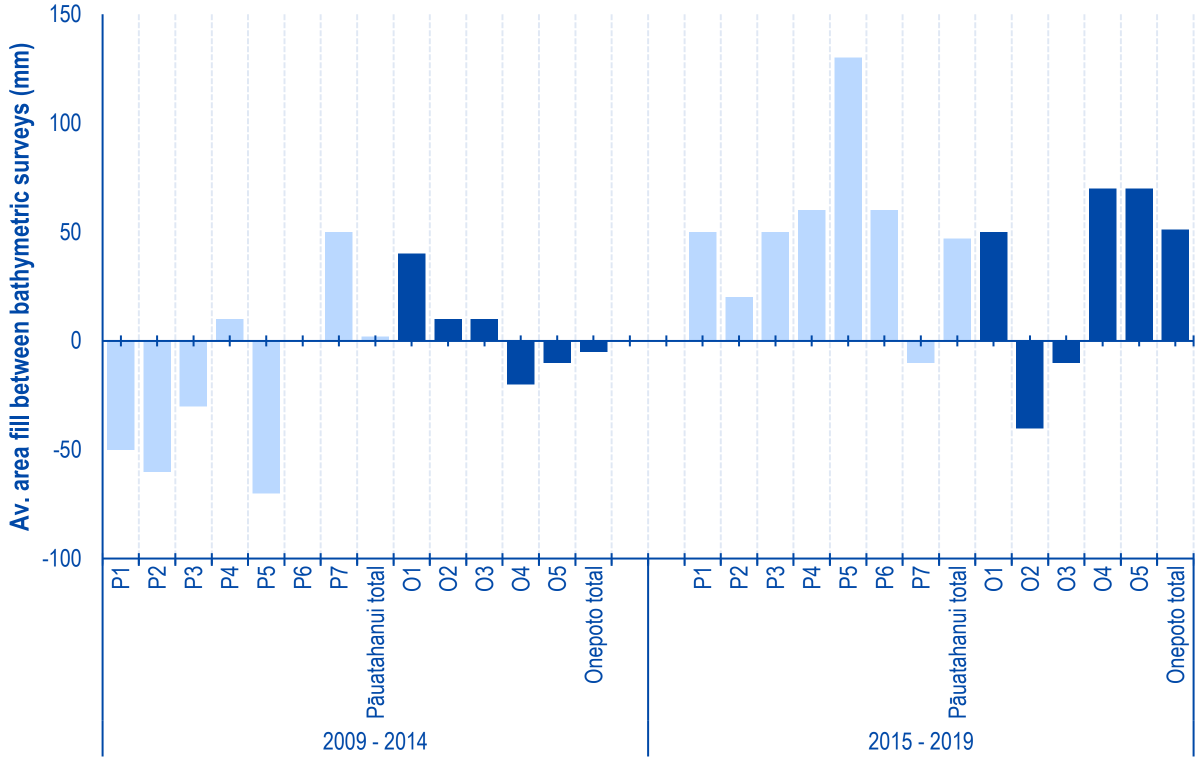

Figure 11 - Average area fill between bathymetric surveys (adapted from Waller (2019)).

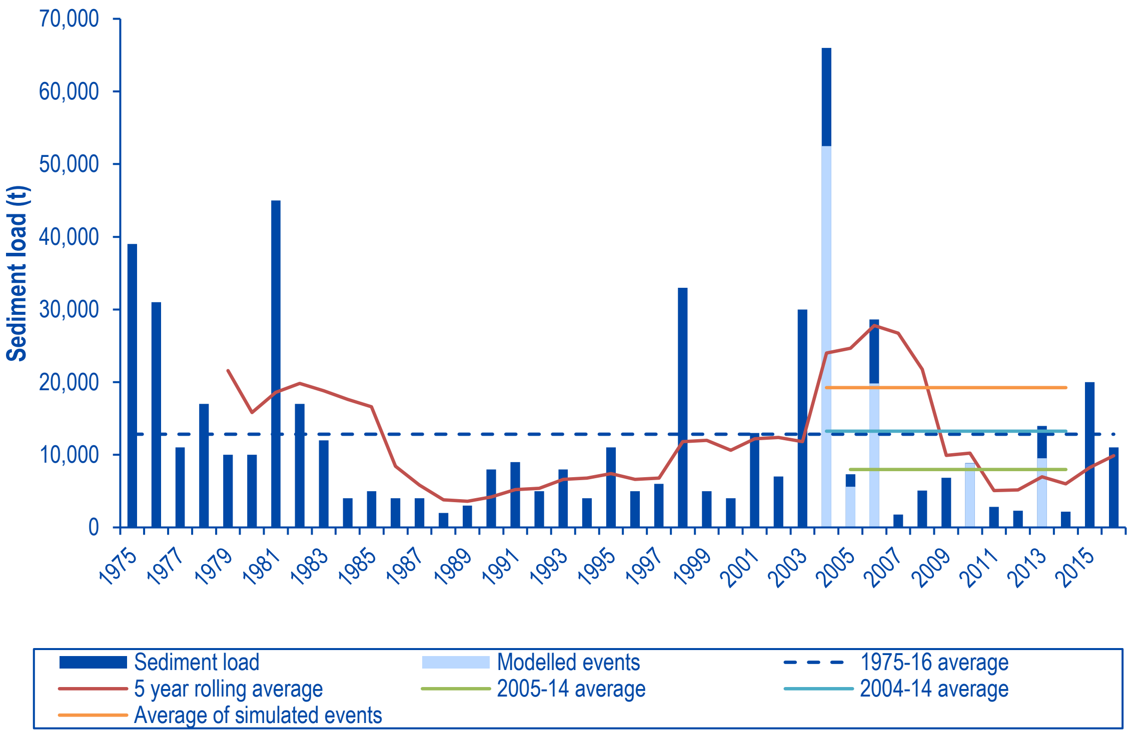

Figure 12: Estimated annual sediment loads to TAoP (adapted from Oldman, (2019)).

To make the harbour model more representative of the longer-term sediment load, harbour modelling was carried out using sediment load inputs of one whole year (2010) and several storm events in 2004, 05, 06 and 13. The sediment load data demonstrated that the majority (70-80%) of the year's sediment was delivered during individual events. Incorporating the 2004 event brought the average of the simulated events to ~19,200. The average annual sediment for the 2004-14 period was ~13,200.

Simulating the events illustrated the effect that they can have on sediment deposition, which wasn't well reflected in the simulation of one year. The 2010 year simulation represented the 2005-14 'average' conditions well, but it could be considered a relatively low input year in the historical context. This suggests that using the annual average sediment load from the 2005-14 period might be underestimating the sediment inputs that are associated with the current sedimentation rates of TAoP. This, therefore, may be unsuitable as a 'limit' from which to express sediment reductions.

Revision of sediment load reduction requirements

The catchment and harbour modelling illustrated how the sedimentation rate could be expected to change following changes in sediment inputs with alternative catchment management, such as earthworks controls, livestock exclusion and stabilising erosion prone land. As for the baseline, the scenario modelling was also run over one whole year and a series of events, and reporting described how the average sedimentation depth changed across all these model runs (Table 47). These results indicate how the sedimentation rate could respond if the sediment input were at that given level (Figure 13).

Table 47: TAoP sedimentation scenario results[1].

Simulation	Duration	Baseline			BAU			Water Sensitive		
		Annual load (t)	Event load (t)	Sed depth (mm)	Annual load (t)	Event load (t))	Sed depth (mm)	Annual load (t)	Event load (t)	Sed depth (mm)
Onepoto										
2004	31	29,000	23,200	14.30	18,100	14,500	8.64	4,400	3,500	1.57
2005	32	1,700	900	0.09	1,800	1,000	0.07	1,200	600	-0.16
2006	47	9,800	7,400	3.93	7,300	5,000	2.41	3,700	2,200	0.57
2010	364	3,300	3,300	0.97	2,800	2,800	0.58	1,400	1,400	-0.31
2013	61	4,800	2,900	1.19	4,200	2,200	0.69	2,300	900	-0.11
Average		9,700	7,540	4.06	4,025	5,100	2.48	2,150	1,720	0.31
Pāuatahanui										
2004	31	36,600	29,300	11.55		26,900	10.75		10,600	4.43
2005	32	5,600	4,700	1.99	5,700	4,800	1.97	3,400	2,800	1.10
2006	47	18,800	12,400	4.82	18,200	11,800	4.58	7,900	4,900	1.93
2010	364	5,500	5,500	2.40	5,400	5,400	2.34	3,000	3,000	1.38
2013	61	9,200	6,600	2.51	9,000	6,300	2.36	5,000	2,900	0.98
Average		15,100	11,700	4.66	14,400	11,000	4.40	6,500	4,800	1.96

[1] Further information from modelling in Oldman (2019) provided by John Oldman via email (13/11/2021)

Most events are modelled for a period of between 30-60 days and incorporate around 70-80% of the annual sediment load (Table 47). As such, these may not account for sediment input, redistribution and export occurring over the remainder of the year. Redistribution of sediments may result in small changes in deposition patterns and rates at sub-estuary level, however, the effects on basin wide deposition rates are expected to be relatively small. Accounting for these processes across the remainder of the year may result in relatively small changes for some plotted points moving left and up on Figure 13.

Figure 13 illustrates that the sediment input that corresponds to the target sedimentation rate in Pāuatahanui appears to be around 5,000 tonnes/yr for 2mm/yr, and around 3,000 tonnes/yr for 1mm /yr for Onepoto. However, the uncertainty noted could mean that the sediment inputs could be larger for a corresponding sedimentation rate.

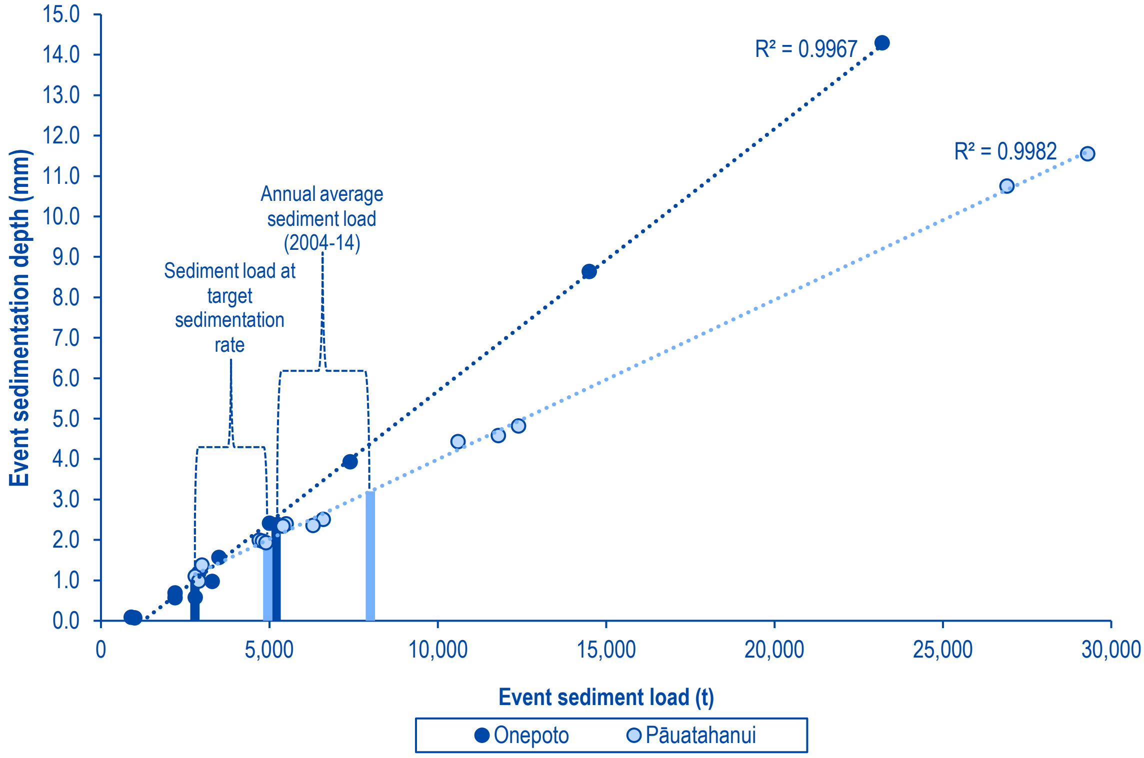

Figure 13: Simulated sedimentation events in TAoP.

These loads appear to nearly match the average inputs estimated for the 2005-14 period (Table 48). This period also coincided with lower sedimentation rates observed through the sediment plate monitoring (Figure 10) and the 2009-14 period of bathymetric surveys (Figure 11). This suggests that maintaining average sediment input rates at around the 2005-14 levels may be required to reach the sedimentation rate targets. This arguably suggests that the sedimentation rate targets could be achieved with very little further intervention beyond what is already planned for.

However, the 2015-14 sediment inputs are much lower than the long-term average (Figure 12 and Table 48) and the rolling average of sediment input is returning toward the longer-term levels. The more recent sediment plate (Figure 10) and bathymetric survey data (Figure 11) also suggest sedimentation rates have been higher in the more recent years (i.e., from 2014 onwards). Therefore, it may not be reasonable to assume that we could maintain sediment input at such levels by doing little more than already planned actions.

Table 48: Estimated sediment loads.

Metric	Onepoto			Pāuatahanui		
	Baseline	BAU	Water Sensitive	Baseline	BAU	Water Sensitive
Average sediment load for simulated events (t)	7,500	5,100	1,700	11,700	11,000	4,800
Average sediment load for simulated years (t/yr)	9,700	6,800	2,600	15,100	14,400	6,500
Average sediment load for 2004–14 (t/yr)	5,200	3,900	1,700	8,000	7,700	3,800
Average sediment load for 2005-14 (t)	2,800	2,500	1,400	5,200	5,100	2,800

As such, it may be more appropriate to express the reference point for reductions using the longer-term annual loads, which is well represented by the annual load for 2004-14. This period includes years with both larger events and lower input, which is reflective of the longer-term average and is likely more representative of the sediment inputs the harbour typically experiences.

Conclusion and Recommendations

Using the 2005-14 period sediment load averages to express the current sediment load and load limit in the WIP may not have been appropriate. These levels reflect a lower level of sediment input than the historical levels. Instead, the current sediment load should be expressed using the longer-term average annual load.

The modelled relationship between sediment load and sedimentation rate suggests that the sediment loads required to achieve the sedimentation rate targets in TAoP may be similar to those estimated through the 2005-14 period (around 5,000 and 3,000 tonnes per year in each arm). This is approximately a 40% reduction from the long-term average, which is well represented by the 2004-14 annual average load (Figure 13 and Table 48). This illustrates a need to reduce sediment inputs to TAoP to meet the sedimentation rate targets, which are unlikely to be achieved with the interventions that are already planned for.

There is uncertainty around the sediment load that is expected to achieve the target, and greater emphasis should be placed on the sediment load percentage reduction.

This sediment input baseline and load reduction targets in the WIP should be revised using the figures given in Table 49.

Table 49: Revised sediment load estimates and reduction targets for TAoP.

Metric	Pāuatahanui	Onepoto
Sedimentation rate objective (2040)	Net average sedimentation rate is less than 2mm/year in Pāuatahanui Inlet (rolling average over the most recent 5 years of data)	Net average sedimentation rate is less than 1mm/year in Onepoto Arm (rolling average over the most recent 5 years of data)
Long-term average annual load (2004-14) (t/yr)	8,000	5,200
Sediment limit Annual average (t/yr)	8,000	5,200
Sediment target % reduction from limit	40%	40%

Brent King

12 Technical memo to support coastal attribute implementation for TAoP and WTWT

To: Rachel Pawson, Environmental Policy

Copied to: Megan Melidonis, Evan Harrison

From: Megan Oliver, Senior Environmental Scientist

First published: 10th March 2023

12.1 Enterococci

The enterococci attribute state framework used in both the TAoP and WTWT WIPs is not appropriate for use in PC1.

The 95th percentile statistics and the narrative attribute states are in line with the Guideline values for microbiological quality of marine recreational waters in the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE/MoH 2003). However, the percent exceedance over 500 per 100mL assessment statistic is not supported by a quantitative microbial risk assessment (QMRA).

The specific percentage exceedance frequency adopted in the WIP is also in direct conflict with the 95th percentile thresholds for attribute state B, C and D. For example, at the C/D threshold the 95th percentile threshold allows for 500 per 100 mL to be exceeded five percent of the time, while the precent exceedance threshold allows the same threshold to be exceeded 20% of the time. It appears that this metric was adopted to provide some level of consistency with the NPS-FM E. coli attribute. However, it must be noted that:

- The *E. coli* NPS-FM thresholds are supported by a QMRA; and
- The percentage of exceedance statistics in the NPS-FM E. coli attribute do not contradict the 95th percentile thresholds.

It is recommended that the "*Percentage of exceedances over 500 enterococci per 100 ml*" statistic is deleted from the WIP enterococci attribute and ignored in any estimates of baseline state.

12.2 Sediment metals

12.2.1 Effects of metals

Metals, such as Cu and Zn, are normal constituents of marine and estuarine environments. In healthy environments, these trace metals occur in small but measurable amounts within animals and plant tissue, where they are a necessary part of nutrition and physiology. Metal concentrations in urban areas, however, typically exceed healthy concentrations, entering marine and coastal areas via industrial waste, and the wastewater and stormwater networks.

12.2.2 State and source of metals in Porirua Harbour

There have been several studies investigating the sources, concentrations and impacts of metals in Porirua Harbour (see Hooper (2002) for summary) but frequent, routine monitoring of metals in harbour sediments didn't begin until 2004. Results from almost two decades of monitoring indicate that concentrations of metals such as Zn and Cu do not currently exceed Australian and New Zealand guidelines for fresh and marine water quality (ANZG) (2018) Default Guideline Values (DGV) in sediments at representative sites and are generally very low. However, the concentrations of Zn almost doubled in the intertidal sediments of the inner Onepoto Arm (Figure 14) between the 2015 and 2020 sampling periods, and this represents a change of attribute bands and a declining state.

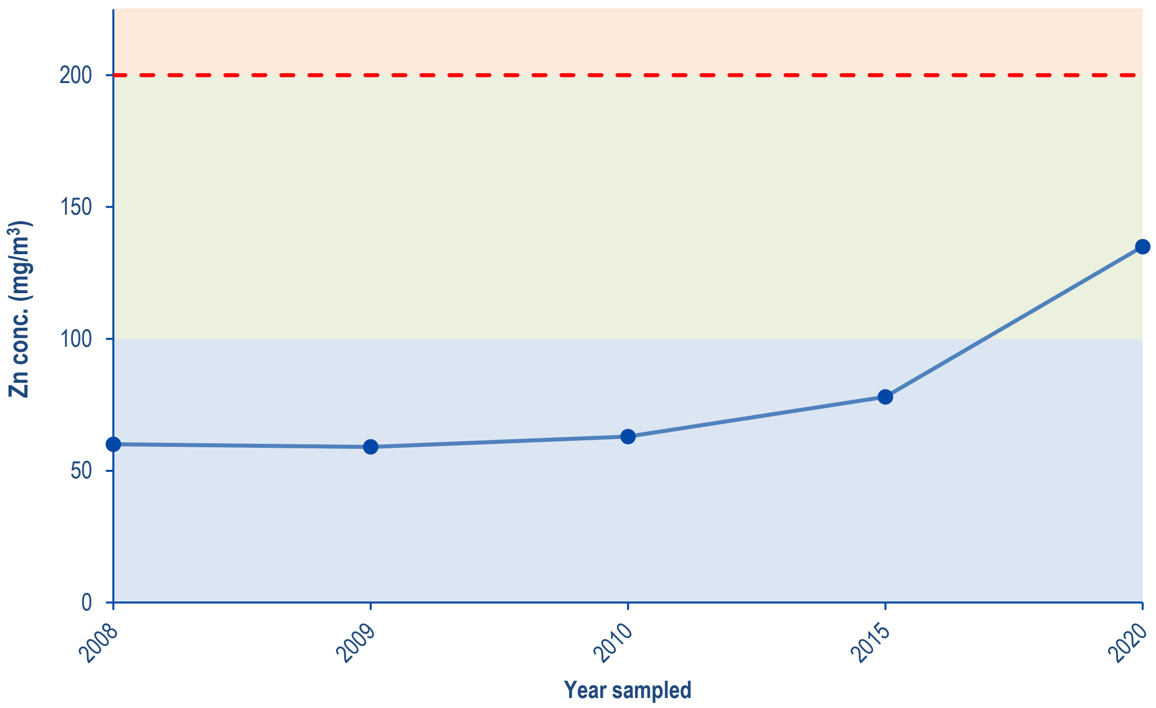

Figure 14: Concentrations of Zn in the intertidal sediments of the inner Onepoto Arm, Porirua Harbour. Blue shaded area represents the A band, green shading the B band, and orange shading the C band. The red dashed line on the boundary between B and C bands depicts the national Default Guideline Value for Zn concentrations in sediment.

The intertidal areas of Porirua Harbour are still relatively healthy, with sandy sediments, low concentrations of stormwater contaminants, and reasonable biodiversity values. Any increase in sediment metal concentrations should, therefore, be avoided to reduce likelihood of these areas being degraded by unforeseen toxicity effects. The objective state of 'maintain' should be interpreted as no significant decline within the band.

The subtidal areas of both arms are muddy, poorly oxygenated, have lower biodiversity values, and higher concentrations of contaminants, compared with the intertidal areas. While these areas are unlikely to show improvements over the timeframes of the NRP due to legacy contamination issues, it is important that the target attribute state not allow for any further degradation or increase in contaminant concentrations such as has been occurring in these low energy, depositional environments for multiple decades.

Studies targeting sediment in highly impact areas, such as near stormwater outfalls in the inner Onepoto Arm, indicate there are locally elevated hotspots where Cu and Zn (Figure 15) concentrations approach or exceed DGVs and are expected to be having negative ecological impacts (C band for Zn) (Sorensen and Milne, 2009). Furthermore, core samples from deeper sediments at these inner harbour sites indicate that contamination is present to some depth (Figure 15). Repeat monitoring of these impacted sites in the inner Onepoto Arm is planned for early 2024.

It is appropriate, therefore that Zn and Cu have been adopted throughout the TAoP and WTWT WIPs as attributes and proxies for a suite of other urban contaminants (e.g., mercury, cadmium, lead, hydrocarbons) and should be monitored as part of an ongoing programme of whaitua plan implementation.

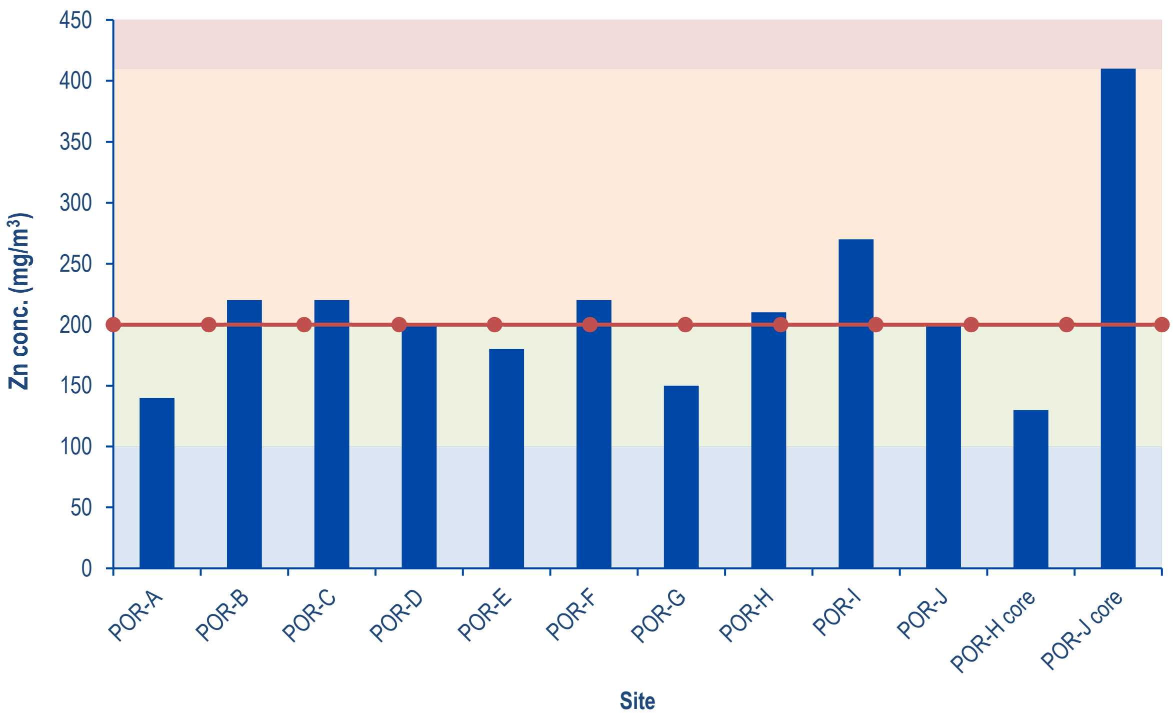

Figure 15: Concentrations of Zn in the intertidal sediments of sites targeted for investigation and known to be impacted by stormwater in the inner Onepoto Arm, Porirua Harbour. Grey shaded area represents the A band for this attribute, green shading the B band, orange shading the C band, and red shading for the D band. The red dashed line on the boundary between B and C bands depicts the national Default Guideline Value for sediment quality. Adapted from Sorenson and Milne (2009).

12.2.3 Justification for precautionary ‘maintain’ approach

There is a high level of uncertainty about the effects of metals on marine organisms across the full range of concentrations, and the antagonistic and synergistic effects of various sediment quality parameters. This makes it very difficult to predict how a degradation in sediment Cu or Zn attribute state would impact the ecology of the Porirua Harbour. However, research emerging from the Sustainable Seas National Science Challenge indicates that the cumulative impacts of high catchment sediment, nutrient and metal inputs to low energy environments such as estuaries have the potential to cause catastrophic changes in ecosystem health and functioning at concentrations lower than DGV. Furthermore, the DGVs were developed using sediment and invertebrate data from a North American data set and as such, have not been validated for New Zealand infauna, and should be applied with caution.

Cu and Zn toxicity to estuarine animals varies widely and can be more toxic to fish and invertebrates than the DGVs suggest. These toxic effects manifest themselves through impaired larval development, reproduction and slowed growth rates. It is appropriate, therefore, that a precautionary ‘maintain’ approach is taken to setting target attribute states; not doing so risks further, and potentially significant, environmental degradation. Due to the risk of adverse effects occurring below and between DGVs (see above), what constitutes ‘maintenance’ in the context of sediment metal target attribute states should reflect what is required by the NPS-FM 2020 for freshwater attributes (i.e., no degrading trends, even within an attribute state).

12.3 Monitoring attributes at sites within Porirua Harbour

Assessing impact, be that improvement or decline, in the marine environment, is difficult because of the scales over which pollutants disperse. For example, sediment entering a harbour or estuary from a number of rivers can distribute widely due to rain, wind and tides throughout a coastal zone, making it difficult to trace or attribute the sediment to a source. Monitoring changes, or tracking progress towards meeting environmental outcomes must, therefore, be set in areas of the coast that accumulate the attribute of interest, and are relatively stable over time, so you can return to it and reliably measure decline or improvement in state. When thinking about where sediment and pollutants accumulate in Porirua Harbour, we generally divide the harbour into the intertidal and subtidal zones of each of the two arms.

For monitoring data to be of sufficient resolution to benchmark against a ‘maintain objective, annual or biennial monitoring of intertidal sites at three to four sites in each arm is required. We already monitor two intertidal sites in each arm at regular intervals as part of our State of the Environment Monitoring programme, and have done so since 2007, so we have a good record against which to compare future results. Two to three additional sites could be added to the intertidal areas of each arm to represent other sub-estuary areas, as well as periodic sampling of the contaminant hotspots discussed in Section 12.2.212.3.3.

As for intertidal sites, tracking progress towards target states as set by the WIP, will require semi-regular (three to four-yearly) monitoring of at least two representative subtidal sites in each arm. These need to be sites that are not scoured out by rainfall events or prone to erosion that would alter the sediment grain size profile and limit repeated analyses of sediment health. Fortunately, we already have five sites (two in Onepoto and three in Pāuatahanui) that we monitor regularly as part of our State of the Environment programme, and these would be suitable for evaluating progress towards attribute targets.

12.3.1 Adoption of four band approach from WTWT for other attributes

At the time the TAoP WIP was prepared we adopted an assessment framework, benchmarked to the ANZG (2018) sediment quality guidelines[13], for Cu and Zn in sediment and simplified the five-scale framework to four bands for the WIP, which effectively grouped concentrations of Cu or Zn greater than the guideline values (GV-Low) into the D, or Poor band; they were previously separated into D and E. This was the assessment framework developed by Salt Ecology Ltd and widely used at that time for reporting on estuarine health.

More recent reporting has taken a different approach to creating a four-class scale and groups the previous A and B bands (values less than 0.5 of the GV-Low) into a single Very Good or A band and separated out values that are between GV Low -GV High (C Band, or Fair) and greater than GV-High (D band or Poor). These risk classifications were reviewed based on Hewitt *et al.* (2009) and updated to be more consistent with the National Objectives Framework structure for freshwater; an approach many other Regional Councils were using in their limit setting programmes, including the Whaitua programme.

The revised bands are a better reflection the overall ecological state. That is, if metals are <50% of the GV then conditions are very good, and the likelihood of adverse impacts are very low. If metals are approaching the GV-Low value, then likelihood of adverse impacts are low, and condition is deemed Good. Conditions are 'fair' when adverse effects are 'possible' (greater than GV-Low), and 'poor' when adverse effects are 'probable' (greater than GV-High).

The implications of this change are the A and B targets will be adjusted to A, and C targets will be adjusted to B. This is relevant for the Zn concentrations in the intertidal and subtidal sediments of the Onepoto Arm and the Cu concentrations of the subtidal Onepoto Arm. These are all 'maintain within a band' targets, but the widening of the A band does pose the risk of not maintaining baseline if targets are set based on the state thresholds for this attribute. Therefore, it is essential to define the baseline states in a numerical way and use that numeric to track progress towards the objective target. If, for example, monitoring shows a statistically significant increase in say, Zn concentrations, this should be considered an unacceptable decline in attribute state, irrespective of whether there is a change of band.

12.3.2 Revised baseline state assessment

As noted in the previous section, where possible, a numeric value should be calculated for each attribute to establish a baseline numeric state against which changes from that state, and progress towards the objective states, can be measured. State of the environment monitoring data can be used to calculate a baseline figure for Cu and Zn in the intertidal and subtidal areas of each estuary arm. We propose this figure be the mean concentration of the three replicates at each of the nine sites (four intertidal, five subtidal) measured during the 2015 sediment surveys (Table 50). We cannot nominate a site-specific numeric for the macroalgae attribute however, as the metric was developed to be an estuary-wide measure and cannot be scaled down to site level without losing rigour in the metric.

[13] The Guideline Value-High (GV-high) [formerly ANZECC (2000) Interim Sediment Quality Guideline high (ISQG-high)] can be interpreted as reflecting the potential for 'probable' ecological effects. The Default Guideline Value (DGV) [formerly ANZECC (2000) Interim Sediment Quality Guideline low (ISQG-low)] and can be interpreted as reflecting the potential for 'possible' ecological effects.

Subsequent assessments of state and progress towards targets should use the mean of replicate samples taken for each site in the most recent survey. Table 51 provides current state concentrations for Zn and Cu at all nine sites from the 2020 surveys and compares current values with the 2015 baseline values. The inner harbour sites in the Onepoto Arm show an increase in Zn and Cu concentrations in intertidal sediments; this is the area of both harbour arms for which the most stringent limits should be set. This represents a decline within a band.

Table 50: Baseline (2015) numeric values for Zn and Cu coastal water quality objectives.

			Onepoto Arm				Pāuatahanui Arm				
			Intertidal		Subtidal		Intertidal		Subtidal		
		Site	A	B	1	2	A	B	1	2	3
Total Zn in sediment		Baseline state (mg/m^3)	38	77.7	179	138.7	37.3	20.2	73	62.7	62
	Coastal Objective	Objective state	A	A	B	B	A	A	A	A	A
		Objective concentration (mg/m^3)	<100	<100	100-<200	100-<200	<100	<100	<100	<100	<100
		Objectives to be met by	M	M	M	M	M	M	M	M	M
Total Cu in sediment		Baseline state (mg/m^3)	4.2	3.9	20.5	18.2	4.8	2.0	11.0	9.5	8.0
	Coastal Objective	Objective state	A	A	A	A	A	A	A	A	A
		Objective concentration (mg/m^3)	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5	<32.5
		Objectives to be met by	M	M	M	M	M	M	M	M	M

Table 51: Current (2020) state numeric values (mg/m^3) for Zn and Cu coastal water quality objectives. Red text denotes a decline in state from baseline.

		Onepoto Arm				Pāuatahanui Arm				
		Intertidal		Subtidal		Intertidal		Subtidal		
	Site	A	B	1	2	A	B	1	2	3
Total Zn in sediment	Baseline state	38	77.7	179	138.7	37.3	20.2	73	62.7	62
	Current state	46.3	135.7	196	149	41.7	31	76.7	77.7	68.7
Total Cu in sediment	Baseline state	4.2	3.9	20.5	18.2	4.8	2.0	11.0	9.5	8.0
	Current state	4.5	7.5	20.7	18.2	4.8	3.8	10.4	11.5	7.9

12.3.3 Expert opinion of ecological importance of sedimentation rates vs sediment metals

The WIP proposes reducing sediment inputs by ~40% to achieve an average areal sedimentation rate of 2 mm per year. There is also a concurrent requirement to reduce catchment metal loads by 40%. Most of this sediment reduction is, however, targeted at rural areas (retirement of land, riparian planting), where metals, which are generated in urban settings, are not an issue. Therefore, a 40% reduction in sediment load won't result in a concurrent reduction in metal loading to the harbour. Indeed, the reduction in 'clean' sediment entering from rural areas may concentrate the sediment metal concentrations and accelerate a decline in this attribute.

Given the most recent monitoring results indicate an increasing concentration of Zn and Cu in the sediments of the Onepoto Arm, a reduction in metal loads entering from the urban areas is needed to maintain the objective state via a range of proposed mitigation options.

12.4 Conclusion

The known effects of metal toxicity in coastal invertebrates and sediments, combined with the limitations of the default sediment guidelines, the measured decline in attribute state for Zn (and Cu to a lesser degree) in the inner Onepoto arm, and recorded hotspots of contamination, require application of the precautionary approach and implementation of a range of mitigation options to stem the input of sediment metals to this sensitive receiving environment.

13 Metal reductions to achieve metal-sediment targets

From:	**Jennifer Gadd**
To:	Michael Greer. Torlesse Environmental Ltd Brent King, Rachel Pawson, Greater Wellington
First published:	14th April 2023

13.1 Introduction and scope

The TAoP WIP targets a reduction in sediment loads of 40% to reduce sediment accumulation and the muddiness of the Porirua Harbour. The WIP also recommends a 40% reduction in Cu and Zn loads (commensurate with the reduction in sediment) to ensure that metal concentrations in harbour bed sediments do not increase.

GW asked for technical advice around the validity of that assumption – that a 40% reduction in metals is also required.

13.2 Sources of metals and sediment in the Porirua catchment

The current sources of sediment and metals to each arm of the Porirua Harbour were modelled by Jacobs (see Easton *et al.,* (2019a, 2019b)).

For the Onepoto Arm, the majority of the sediment and metal loads (Table 52) are delivered via the Porirua River. This source makes up approximately 2/3 of the total sediment and metal loads (66-69%).

For Pāuatahanui Inlet (Table 52), most sediment (69%) is delivered via the Pāuatahanui River. However, a large proportion of the metals is sourced from the urban Duck Creek catchment, and in future scenarios via Pāuatahanui Stream, Horokiri and Motukaraka Creeks.

The key sources of the sediment and metals are not 100% clear in the modelling reports. Presumably the key sources of metals are urban sources, as suggested by those catchments with higher proportions of urban land use having higher metal loads. In future scenarios, Transmission Gully also contributes metals to the Pāuatahanui Arm.

Given that the sediment load reduction scenarios are based on reduction in rural sediment sources (reducing hillslope, landslide and stream bank erosion) I've assumed that these are the key sources of sediment. Though these sediments would contain some attached metals, these are expected to be low compared to the urban sources.

Table 52: Sediment and metal loads delivered annually to each harbour arm. Note this table was produced before the memorandum reproduced in Section 11 was drafted; hence the disparity with Table 49.

Harbour arm (WMU)	Sediment	Cu	Zn
Onepoto Arm	2,800 tonnes/yr	240 kg	2,650 kg
Pāuatahanui Inlet	5,200 tonnes/yr	70 kg	580 kg

13.3 Processes by which catchment delivered metals end up in bed sediment

Both Cu and Zn are found in a mixture of dissolved and particulate forms in stormwater and in streams. Within these freshwater systems, metals may adsorb to sediments (changing from dissolved to particulate) or desorb from the sediments (changing from particulate to dissolved), depending on their concentration, the amount of sediment and water chemistry such as pH. These suspended sediments may continue to be transported downstream or may settle in depositional locations within the streams – either temporarily or permanently.

Similarly, the metals delivered to the harbour will be found as a mixture of dissolved and particulate forms. The behaviour of metals in estuaries is complex and not all metals act the same – depending on their form and their chemical properties.

Metals that are attached to fine particles, or have high affinity for those particles, can be removed (from the water column) as small particles that are held apart by electrostatic repulsive forces flocculate into larger particles when the freshwater mixes with saline water. Some metals (those truly dissolved) behave conservatively and are simply diluted (Mosley and Liss, 2019). Metals delivered to the estuary as colloids (i.e., bound to dissolved organic matter) can disassociate at low salinities and therefore more metals are found in dissolved form.

Cu and Zn tend to show variable behaviour – as reviewed by Mosley and Liss (2019) some studies have suggested that they behave conservatively, and other studies have suggested removal or addition. It is likely that the particulate forms of Cu and Zn will accumulate in the bed sediment as the particles flocculate and these settle in depositional areas of the harbour. These newly deposited sediments will mix with the existing sediments through bioturbation as well as physical processes.

Dissolved Cu and Zn tend to be associated with colloids and this form is likely to dissociate at low salinities, but then be readsorbed (either to dissolved organic matter or inorganic particles) as pH increases towards mid to high salinities. This is predicted to be affected by sediment characteristics, such as cation exchange capacity and the amount of organic material present. Through these processes, dissolved metals are expected to be reduced to very low concentrations within fully saline waters.

In the Porirua Harbour example, as Cu and Zn will be transported in both dissolved and particulate form, all of these processes are relevant. It can be expected that the particulate forms flocculate, settle and mix with existing bed sediments. Dissolved forms can be expected to also become attached to particles within the harbour – whether those particles are also delivered via stormwater and streams or from different sources. More sediment delivered to the harbour provides more binding sites for the metals and more ability for them to adsorb to the sediment. The more sediment, the greater the binding capacity overall, but also the metal concentrations within a given volume of sediment can be expected to be lower.

Therefore, with lower sediment loads delivered, it makes sense that would be a higher concentration of metals bound to a given volume of sediment (assuming the adsorption capacity is not reached, which seems unlikely given the high concentrations of sediment relative to metals).

13.4 Modelling of metal-sediment concentrations

Oldman's (2019) modelling of sediment transport, deposition and metal accumulation is based on a mass-balance approach for the metals. The metals and sediments delivered from each catchment (in mg/L, as modelled by Easton *et al.* (2019a, 2019b)) are used to calculate metal-sediment concentrations (in mg/kg) used in the sediment modelling. These sediments delivered are uniformly mixed with the surface layer of the existing bed sediments.

Oldman (2019) lists three assumptions in their modelling approach:

- That there was no loss of seabed metals to the dissolved phase
- All the metal load was particulate; and
- Current observed metal concentrations in the harbour do not represent equilibrium conditions.

This is described by Oldman (2019) as worst-case, but assumption 1 also seems consistent with literature that suggests metal loss depends on stream alkalinity and dissolved carbon dioxide content; and that metals may be removed at low salinity (where a pH low can occur) but be readsorbed at higher salinity.

The inputs are the total Cu and Zn loads delivered from the catchments as calculated by Easton *et al.* (2019a, 2019b), which includes both dissolved and particulate forms. Treating all as particulate metals is consistent with the theory that dissolved metals will bind to sediment within the estuary, thus becoming particulate.

The third assumption presumably means there is additional capacity for metal adsorption in the sediments.

13.5 Proposed changes in sediment and metal loads

The load reduction targets are set out in the TAoP WIP and shown in Table 53. This sets out that the metal targets are based on ensuring the current Cu and Zn concentrations in the harbour sediments do not increase when the sediment loads are decreased by 40%.

Table 53: Targeted load reductions for sediment, Cu and Zn as set out in the WIP.

Harbour arm (WMU)	Sediment	Cu	Zn
Onepoto Arm	40% (1,120/2,800 kg)	40% (40% x 240 kg = 96 kg)	40% (40% x 2,650 kg = 1,060 kg)
Pāuatahanui Inlet	40% (2,080/5,200 kg)	40% (40% x 70 kg = 28 kg)	40% (40% x 580 kg = 232 kg)

The required reduction in sediment loads in the Pāuatahanui Inlet is expected to be achieved through reduction in stream bank erosion (largely in the Pāuatahanui River), land slide erosion in the catchment and some areas of reduced hill slope erosion. Only 3% of the sediment load to the Pāuatahanui Inlet is expected to come from non-rural areas – the Duck Creek catchment, with mixed urban/rural land use (M. Greer, pers. comm).

The reduction in sediment loads in the Onepoto Arm is expected to be achieved through a combination of rural (66%) and mixed urban/rural (34%) loads. The methods to achieve the planned load reduction are not specified.

Zn load reductions are expected to be achieved through additional treatment systems in existing urban areas, focussing on major roads and commercial/industrial areas; replacement of high Zn-yielding roofs and treatment of all impervious surfaces in new urban developments. Some of these methods will also reduce Cu loads.

13.5.1 Do metals loads need to be reduced by 40%?

The assumption stated in the WIP is that because sediment loads are targeted for a 40% reduction, metal loads must also be reduced by 40% to retain the same concentrations in the harbour sediments.

This assumption is consistent with our understanding of how metals are retained in harbour sediments.

However, the 40% metal reduction may be achieved to some extent through the targeted reduction in sediments, because sediments are themselves sourced of metals. This depends on the sources of metals and sediment within each of the harbour arms.

13.5.2 Pāuatahanui Inlet

The modelling indicates that the major sources of sediment to the Pāuatahanui Inlet are derived from rural sources. These would not be expected to be associated with high metal concentrations (at least to the extent of increasing concentrations within the harbour). Conversely the modelling suggests at least 50% of the metal loads are derived from urban sources (based on 40% of total loads coming from Duck Creek and Browns Bay alone). The Pāuatahanui Stream is also a major contributor of metals – at around 30-40% of the total loads to the Pāuatahanui Inlet. This catchment has only a low proportion (3-4%) of urban land use and roading but given that the modelled metals concentrations from urban land uses are at least 40x higher than that of rural land uses, it is likely that most metals delivered via this source are from urban land use.

Given the likely dominance of urban sources of metals, a reduction in the rural sediment loads (via stock exclusion, retirement, space planting etc) of 40% would not reduce the total metal loads to the Pāuatahanui Inlet by 40%. If the 50% of the metals are from urban, and 50% from rural sources (i.e., attached to the sediment), there would be a maximum of 20% reduction in metals through the sediment reductions. However, based on the information available, it is likely that the metals delivered from rural sources is much lower than 50% and therefore the reduction in metals from sediment mitigation would be much less than 20%.

13.5.3 Onepoto Arm

The modelling indicates that the major sources of sediment to the Onepoto Arm are derived from both rural (66%) and mixed rural-urban (34%) sources. Sediment reductions are from a combination of retirement/space planting and urban development. While the sources (in terms of land use) of metals are not clearly quantified, it is highly likely that urban land use dominates the loads to the Onepoto Arm.

Again, the rural sources of sediment would not be expected to be associated with high loads of metals and so reductions in sediment loads due to retirement and space planting are not expected to greatly reduce the metal loads. On the other hand, sediment load reductions due to treating greenfield developments and/or retrofitting existing urban areas would reduce metals. It is not possible to quantify the effect of this on total reduction in metal loads to the Onepoto Arm with the available data.

If it was assumed that around 25% of the planned sediment reductions (totalling 40% overall load) were from urban land use, then the maximum metal reduction would also be 25%, or 10% of the overall load. Therefore another 30% reduction must be achieved elsewhere to meet the 40% target. Note that it is also likely that a 25% reduction in sediment in urban areas would not equal a 25% reduction in metals. Typically, 40-60% of metals in stormwater are in the dissolved form and dissolved metals are not as readily removed as the particulate form. Therefore, it is likely that the required additional treatment must remove more than 30% of the total loads to the Onepoto Arm.

13.6 Summary

The assumption that a 40% reduction in sediment loads to the Porirua Harbour requires a 40% reduction in metal loads to the harbour to ensure metal concentrations do not increase is consistent with literature around metal deposition processes in estuaries. Although the required information is not available to quantify the reduction in metals with the planned mitigations, it is clear that the mitigations to sediment loads will not achieve a 40% reduction in metal loads to either harbour arm. Therefore, additional mitigations that target metals are required, and these may need to target around 30% or more of total metal loads to each arm.

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Appendices

Appendix A – Attribute state tables

Table A1: Attribute states for dissolved copper (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Copper (Toxicity)**		
Attribute Unit	µg DCu/L (micrograms of dissolved Copper per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95^{th} percentile**	
A	≤1	≤1.4	99% species protection level: No observed effect on any species tested
B	>1 and ≤1.4	>1.4 and ≤1.8	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>1.4 and ≤2.5	>1.8 and ≤4.3	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>2.5	>4.3	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Table A2: Attribute states for dissolved zinc (toxicity) developed by GW.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved Zinc (Toxicity)**		
Attribute Unit	µg DZn/L (micrograms of dissolved Zinc per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤2.4	≤8	99% species protection level: No observed effect on any species tested
B	>2.4 and ≤8	>8 and ≤15	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>8 and ≤31	>15 and ≤42	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
D	>31	>42	Starts approaching acute impact level (i.e., risk of death) for sensitive species

Values for this metal should be expressed as a function of hardness (mg/L) in the water column. The value given here corresponds to a standard hardness for ANZG 2018 guidelines of 30 mg CaCO3/L. Criteria values for other hardness may be calculated as per the equation presented in the ANZG 2018 guidelines.

Table A3: Attribute states for ammonia (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Ammonia (Toxicity)**		
Attribute Unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th percentile**	
A	≤0.03	≤0.05	99% species protection level. No observed effect on any species.
B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level. Starts impacting occasionally on the 5% most sensitive species.
National Bottom Line	**0.24**	**0.4**	
C	>0.24 and ≤1.30	>0.40 and ≤2.020	80% species protection level. Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).
D	>1.30	>2.20	Starts approaching acute impact level (i.e., risk of death) for sensitive species.

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 A4: Attribute states for nitrate (toxicity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Nitrate (Toxicity)**		
Attribute Unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th Percentile**	
A	≤1.0	≤1.5	High conservation value system. Unlikely to be effects even on sensitive species.
B	>1.0 and ≤2.4	>1.5 and ≤3.5	Some growth effect on up to 5% of species.
National Bottom Line	**2.4**	**3.5**	
C	>2.4 and ≤6.9	>3.5 and ≤9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
D	>6.9	>9.8	Impacts on growth of multiple species, and starts approaching acute impact level (i.e., risk of death) for sensitive species at higher concentrations (> 20 mg/l).

Note: This attribute measures the toxic effect of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes will be more stringent.

Table A5: Attribute states for suspended fine sediment (visual clarity) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health				
Freshwater Body Type	Rivers				
Attribute	**Suspended fine sediment**				
Attribute Unit	Visual clarity (metres)				
Attribute State	**Numeric Attribute state by suspended sediment class**				**Narrative Attribute State**
	Median				
	1	**2**	**3**	**4**	
A	≥1.78	≥0.93	≥2.95	≥1.38	Minimal impact of suspended sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.
B	<1.78 and ≥1.55	<0.93 and ≥0.76	<2.95 and ≥2.57	<1.38 and ≥1.17	Low to moderate impact of suspended sediment on instream biota. Abundance of sensitive fish species may be reduced.
C	<1.55 and >1.34	<0.76 and >0.61	<2.57 and >2.22	<1.17 and >0.98	Moderate to high impact of suspended sediment on instream biota. Sensitive fish species may be lost
National Bottom Line	**1.34**	**0.61**	**2.22**	**0.98**	
D	<1.34	<0.61	<2.22	<0.98	High impact of suspended sediment on instream biota. Ecological communities are significantly altered, and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Councils may monitor turbidity and convert the measures to visual clarity.

See Appendix 2C Tables 23 and 26 for the definition of suspended sediment classes and their composition.

The following are examples of naturally occurring processes relevant for suspended sediment:

- naturally highly coloured brown-water streams
- glacial flour affected streams and rivers
- selected lake-fed REC classes (particularly warm climate classes) where low visual clarity may reflect autochthonous phytoplankton production

Table A6: Attribute states for *E. coli* taken from Appendix 2A of the NPS-FM 2020.

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	***E. coli***				
Attribute Unit	*E. coli* / 100ml (number of *E. coli* per hundred millilitres)				
Attribute State	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100ml	**% exceedances over 260 cfu/100ml**	**Median concentration (cfu/100ml)**	**95th percentile of *E. coli* /100ml**	**Description of risk of *Campylobacter* infection (based on *E. coli* indicator)**
A (blue)	<5%	<20%	<130	<540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 1% .
B (green)	5-10%	20-30%	<130	<1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 2%.
C (yellow)	10-20%	20-34%	<130	<1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 3% *.
D (orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >3%.
E (red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >7%.

Based on a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.

Table A7: Attribute states for periphyton (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Periphyton (Trophic state)**		
Attribute Unit	mg chl-a/m^2 (milligrams chlorophyll-a per square metre)		
Attribute State	**Numeric Attribute State (Default Class)**	**Numeric Attribute State (Productive Class[1])**	**Narrative Attribute State**
	Exceeded no more than 8% of samples[2]	**Exceeded no more than 17% of samples[2]**	
A	≤50	≤50	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat
B	>50 and ≤120	>50 and ≤120	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat
C	>120 and ≤200	>120 and ≤200	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat
National Bottom Line	**200**	**200**	
D	>200	>200	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat

At low risk sites monitoring may be conducted using visual estimates of periphyton cover. Should monitoring based on visual cover estimates indicate that a site is approaching the relevant periphyton abundance threshold, monitoring should then be upgraded to include measurement of chlorophyll-a.

Classes are streams and rivers defined according to types in the River Environment Classification (REC). The Productive periphyton class is defined by the combination of REC "Dry" Climate categories (that is, Warm-Dry (WD) and Cool-Dry (CD)) and REC Geology categories that have naturally high levels of nutrient enrichment due to their catchment geology (that is, Soft-Sedimentary (SS), Volcanic Acidic (VA) and Volcanic Basic (VB)). Therefore, the productive category is defined by the following REC defined types: WD/SS, WD/VB, WD/VA, CD/SS, CD/VB, CD/VA. The Default class includes all REC types not in the Productive class.

Based on a monthly monitoring regime. The minimum record length for grading a site based on periphyton (chlorophyll-a) is 3 years.

Table A8: Attribute states for the Fish index of Biotic Integrity taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Fish (rivers)**	
Attribute Unit	Fish Index of Biotic Integrity (F-IBI)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥34	High integrity of fish community. Habitat and migratory access have minimal degradation.
B	<34 and ≥28	Moderate integrity of fish community. Habitat and/or migratory access are reduced and show some signs of stress.
C	<28 and ≥18	Low integrity of fish community. Habitat and/or migratory access is considerably impairing and stressing the community
D	<18	Severe loss of fish community integrity. There is substantial loss of habitat and/or migratory access, causing a high level of stress on the community.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (See clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428 (see clause 1.8).

Table A9: Attribute states for the Macroinvertebrate Community Index score and Quantitative Macroinvertebrate Community Index score taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Macroinvertebrates (1 of 2)**		
Attribute Unit	Macroinvertebrate Community Index (MCI) score and Quantitative Macroinvertebrate Community Index (QMCI) score		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	QMCI	**MCI**	
A	≥6.5	≥130	Macroinvertebrate community, indicative of pristine conditions with almost no organic pollution or nutrient enrichment
B	≥5.5 and <6.5	≥110 and <130	Macroinvertebrate community indicative of mild organic pollution or nutrient enrichment. Largely composed of taxa sensitive to organic pollution/nutrient enrichment.
C	≥4.5 and <5.5	≥90 and <110	Macroinvertebrate community indicative of moderate organic pollution or nutrient enrichment. There is a mix of taxa sensitive and insensitive to organic pollution/nutrient enrichment.
National Bottom Line	**4.5**	**90**	
D	<4.5	<90	Macroinvertebrate community indicative of severe organic pollution or nutrient enrichment. Communities are largely composed of taxa insensitive to inorganic pollution/nutrient enrichment.

MCI and QMCI scores to be determined using annual samples taken between 1 November and 30 April with either fixed counts with at least 200 individuals, or full counts, and with current state calculated as the five-year median score. All sites for which the deposited sediment attribute does not apply, whether because they are in river environment classes shown in Table 25 in Appendix 2C or because they require alternate habitat monitoring under clause 3.25 are to use soft sediment sensitivity scores and taxonomic resolution as defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

MCI and QMCI to be assessed using the method defined in Stark JD, and Maxted, JR. 2007 A user guide for the Macroinvertebrate Community Index. Cawthron Institute: Nelson, New Zealand (See Clause 1.8), except for sites for which the deposited sediment attribute does not apply, which require use of the soft-sediment sensitivity scores and taxonomic resolution defined in table A1.1 in Clapcott *et al.* 2017 Macroinvertebrate metrics for the National Policy Statement for Freshwater Management. Cawthron Institute: Nelson, New Zealand (see clause 1.8).

Table A10: Attribute states for the Macroinvertebrate Average Score Per Metric taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Macroinvertebrates (2 of 2)**	
Attribute Unit	Macroinvertebrate Average Score Per Metric (ASPM)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
A	≥0.6	Macroinvertebrate communities have high ecological integrity, similar to that expected in reference conditions.
B	<0.6 and ≥0.4	Macroinvertebrate communities have mild-to-moderate loss of ecological integrity.
C	<0.4 and ≥0.3	Macroinvertebrate communities have moderate-to severe loss of ecological integrity.
National Bottom Line	**0.3**	
D	<0.3	Macroinvertebrate communities have severe loss of ecological integrity.

Sampling is to occur at least annually between December and April (inclusive) following the protocols for at least one of the backpack electrofishing method, spotlighting method, or trapping method in Joy M, David B, and Lake M. 2013. New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams. Massey University: Palmerston North, New Zealand. (see clause 1.8)

The F-IBI score is to be calculated using the general method defined by Joy, MK, and Death RG. 2004. Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. Environmental Management, 34(3), 415-428. (see clause 1.8)

Table A11: Attribute states for dissolved reactive phosphorus taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved reactive phosphorus**		
Attribute Unit	mg DRP/L (milligrams dissolved inorganic nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Median*	**95th percentile**	
A	≤0.006	≤0.021	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DRP enrichment are expected.
B	>0.006 and ≤0.010	>0.021 and ≤0.030	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.
C	>0.010 and ≤0.018	>0.030 and ≤0.054	Ecological communities are impacted by moderate DRP elevation above natural reference conditions, but sensitive species are not experiencing nitrate toxicity. If other conditions also favour eutrophication, DRP enrichment may cause increased algal and plant growth, loss of sensitive macroinvertebrate & fish taxa, and high rates of respiration and decay.
D	>0.018	>0.054	Ecological communities impacted by substantial DRP elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DIN enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia are lost

Numeric attribute state must be derived from the rolling median of monthly monitoring over five years.

Table A12: Attribute states for dissolved oxygen taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	**Dissolved oxygen**		
Attribute Unit	mg/L (milligrams per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	7-day mean minimum	**1-day minimum**	
A	≥8.0	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near pristine) sites.
B	≥7.0 and <8.0	≥5.0 and <7.5	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
C	≥5.0 and <7.0	≥4.0 and <5.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
National Bottom Line	**5.0**	**4.0**	
D	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

The 7-day mean minimum is the mean value of 7 consecutive daily minimum values.

The 1-day minimum is the lowest daily minimum across the summer period (1 November to 30 April).

Table A13: Attribute states for phytoplankton (trophic state) taken from Appendix 2A of the NPS-FM 2020.

<table>
<tr><td>Value</td><td colspan="3">Ecosystem health</td></tr>
<tr><td>Freshwater Body Type</td><td colspan="3">Lakes</td></tr>
<tr><td>Attribute</td><td colspan="3">Phytoplankton (Trophic state)</td></tr>
<tr><td>Attribute Unit</td><td colspan="3">mg chl-a/m³ (milligrams chlorophyll-a per cubic metre)</td></tr>
<tr><td>Attribute State</td><td colspan="2">Numeric Attribute State</td><td>Narrative Attribute State</td></tr>
<tr><td></td><td>Annual median</td><td>Annual maximum</td><td></td></tr>
<tr><td>A</td><td>≤2</td><td>≤10</td><td>Lake ecological communities are healthy and resilient, similar to natural reference conditions</td></tr>
<tr><td>B</td><td>>2 and ≤5</td><td>>10 and ≤25</td><td>Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.</td></tr>
<tr><td>C</td><td>>5 and ≤12</td><td>>25 and ≤60</td><td rowspan="2">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.</td></tr>
<tr><td>National Bottom Line</td><td>12</td><td>60</td></tr>
<tr><td>D</td><td>>12</td><td>>60</td><td>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.</td></tr>
</table>

For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.

Table A14: Attribute states for total nitrogen (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health		
Freshwater Body Type	Lakes		
Attribute	**Total nitrogen (Trophic state)**		
Attribute Unit	mg/m^3 (milligrams per cubic metre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual median	**Annual median**	
	Seasonally stratified and brackish	Polymictic	
A	≤160	≤300	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>160 and ≤350	>300 and ≤500	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>350 and ≤750	>500 and ≤800	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions
National Bottom Line	**750**	**800**	
D	>750	>800	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.

For lakes and lagoons that are intermittently open to the sea, monitoring data should be analysed separately for closed periods and open periods.

Table A15: Attribute states for total phosphorus (trophic state) taken from Appendix 2A of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Total phosphorus (Trophic state)**	
Attribute Unit	mg/m^3 (milligrams per cubic metre)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Annual median	
A	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions
B	>10 and ≤20	Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions.
C	>20 and ≤50	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions
National Bottom Line	**50**	
D	>50	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state (without native macrophyte/seagrass cover), due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Table A16: Attribute states for cyanobacteria (planktonic) taken from Appendix 2A of the NPS-FM 2020.

Value	Human contact		
Freshwater Body Type	Lakes and lake fed rivers		
Attribute	**Cyanobacteria (planktonic)**		
Attribute Unit	Biovolume mm³/L (cubic millimetres per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	80th percentile	**80th percentile**	
	biovolume equivalent for the combined total of all cyanobacteria	biovolume equivalent of potentially toxic cyanobacteria	
A	≤0.5	≤0.5	Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with freshwater).
B	>0.5 and ≤1.0	>0.5 and ≤1.0	Low risk of health effects from exposure to cyanobacteria (from any contact with freshwater).
C	>1.0 and ≤10	>1 and ≤1.8	Moderate risk of health effects from exposure to cyanobacteria (from any contact with freshwater).
National Bottom Line	**10**	**1.8**	
D	>10	>1.8	High health risks (for example, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with freshwater).

The 80th percentile must be determined using a minimum of 12 samples collected over 3 years. Thirty samples collected over 3 years is recommended.

Table A17: Attribute states for submerged plants (natives) taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Submerged plants (natives)**	
Attribute Unit	Lake Submerged Plant (Native Condition Index)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	(% of maximum potential score)	
A	>75%	Excellent ecological condition. Native submerged plant communities are almost completely intact.
B	>50 and ≤75%	High ecological condition. Native submerged plant communities are largely intact.
C	≥20 and ≤50%	Moderate ecological condition. Native submerged plant communities are moderately impacted.
National Bottom Line	**20%**	
D	<20%	Poor ecological condition. Native submerged plant communities are largely degraded or absent.

Monitoring to be conducted, and numeric attribute state to be determined, following the method described in Clayton J, and Edwards T. 2006. LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2. National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (see clause 1.8)

Lakes in a devegetated state receive scores of 0.

Table A18: Attribute states for submerged plants (invasive species) taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Submerged plants (invasive species)**	
Attribute Unit	Lake Submerged Plant (Invasive Impact Index))	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	(% of maximum potential score)	
A	0%	No invasive plants present in the lake. Native plant communities remain intact.
B	>1 and ≤25%	Invasive plants having only a minor impact on native vegetation. Invasive plants will be patchy in nature co-existing with native vegetation. Often major weed species not present or in early stages of invasion.
C	>25 and ≤90%	Invasive plants having a moderate to high impact on native vegetation. Native plant communities likely displaced by invasive weed beds particularly in the 2 – 8 m depth range.
National Bottom Line	**90%**	
D	>90%	Tall dense weed beds exclude native vegetation and dominate entire depth range of plant growth. The species concerned are likely hornwort and Egeria.

Monitoring to be conducted, and numeric attribute state to be determined, following the method described in Clayton J, and Edwards T. 2006. LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2. National Institute of Water & Atmospheric Research: Hamilton, New Zealand. (see clause 1.8).

Table A19: Attribute states for lake-bottom dissolved oxygen taken from Appendix 2B of the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	**Lake-bottom dissolved oxygen**	
Attribute Unit	mg/L (milligrams per litre)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Measured or estimated annual minimum	
A	≥7.5	No risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.
B	≥2.0 and <7.5	Minimal risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments
C	≥0.5 and <2.0	Risk from lake-bottom dissolved oxygen of biogeochemical conditions causing nutrient release from sediments.
National Bottom Line	**0.5**	
D	<0.5%	Likelihood from lake-bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments..

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.

Appendix B – Collaborations memorandum (Section 3)

Subject: **Spatial assessments of target attribute and monitoring sites, and consideration of Freshwater Management Units for 2022 plan change**

Attention: Greater Wellington Regional Council (GWRC)

From: Tom Nation, James Blyth

Date 27 March 2022

Copies to: Brent King, Rachel Pawson, Alastair Smaill, Michael Greer, Ned Norton, Amanda Valois, Evan Harrison

1 Introduction

The purpose of this memo is to document an approach for identifying and recommending sites to assign target attribute states (locations where water quality targets defined by Whaitua Committees will be applied) to support for the upcoming plan change, which specifically covers two Whaitua extents; te Awarua-o-Porirua and te Whanganui-a-Tara. The assessment presented in this memo covers:

- Consideration of the suitability of existing river long-term monitoring sites for the purpose of assigning target attribute states
- Consideration of redundant existing long-term monitoring sites for this purpose
- Consideration of potential redistribution of existing long-term monitoring sites to better suit this purpose
- While the primary objective of this work focussed on sites to express target attribute states, this ultimately fed into consideration of alternative sub-FMUs aligned to the recommended sites for targets[14].

Visions of the various Whaitua Implementation Plans (WIP's) were also incorporated throughout the tasks above.

The premise of this work is based on implementing the targets from the WIP's, freshwater accounting and requirements of the National Policy Statement for Freshwater Management (NPS-FM, Ministry for the Environment 2020). The use, non-use and suggestions about moving monitoring sites may not align with other GWRC interests or scientific requirements, and monitoring programme changes can be considered at a later date.

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[14] Sub-FMUs are essentially smaller management zones within the Whaitua that may be a single hydrological catchment or a collection of smaller catchments with similar landuses. The terminology can be re-defined at the plan change. Freshwater accounting is required at the FMU scale, not at a sub-FMU or sub-catchment.

2 Mātauranga-a-iwi monitoring and cultural sites

When defining target attribute sites and subsequent locations for water quality monitoring, ideally there would be an overlap between western science and mātauranga-a-iwi monitoring for aspects such as mahinga kai. Te Kāhui Taiao expressed over 26 sites with cultural significance within Te Whanganui-a-Tara Whaitua alone. Some of these sites already align with sub FMU boundaries and existing water quality monitoring locations, however a number have no or limited 'western' science data available.

The NPS-FM requires every local authority to actively involve tangata whenua in freshwater management, including developing and implementing mātauranga māori and other monitoring. This process is in development at GWRC, with new teams being built. In addition, there hasn't been an exercise by mana whenua to determine where the most suitable monitoring sites could be across both these Whaitua, aligning with GWRC's budget and resources. Following discussions with Vanessa Tipoki, it seems that the most logical approach is for mana whenua to lead this work in a separate project. While the outcomes of such work may not align with the target attribute and proposed monitoring sites (or FMU/sub FMU boundaries) from the current process, this could be corrected at a later date.

3 Spatial assessments

Spatial assessments were conducted at the sub-FMU scale and upstream of existing water quality monitoring sites. GWRC provided a spatial layer that consisted of ~29 sub-FMUs with corresponding 'accounting points'. Following a review of the sub-FMUs, it was identified that they did not always follow hydrological catchment boundaries or may have been agglomerated from a collection of similar landuses, despite being in different spatial areas. Revisions of these sub-FMUs was undertaken (see Section 6), which involved partitioning some so they aligned with hydrological catchment boundaries (mountains to sea approach). The purpose was to provide a range of comparable outputs at either a sub-FMU level, or where appropriate, a hydrological catchment (such as upstream of a monitoring point) which could help guide decisions on:

- Where target attribute sites could be set
- If there was sufficient monitoring within a sub-FMU at/near a target attribute site to help report on water quality state and trends

The spatial assessments included:

- Determining catchment area of a sub-FMU and draining to a monitoring site
- Assessing landuse areas of each sub-FMU and draining to a monitoring site for exotic forest, exotic vegetation (i.e., gorse), native forest, pastoral, urban residential, urban commercial, urban industrial, water and other (everything else).
    - For the monitoring sites, generally the three dominant landuses from each site were used for additional groupings in Table B1. In some cases, a similar proportion of landuses was indicated with a hyphen (i.e., native + exotic forest/exotic veg).

- Assessment of NZEEM[15] annual average sediment loads (t/year) of that sub-FMU and monitoring point.
    - NZEEM sediment loads is a suitable way to combine a number of parameters into one output to help for faster catchment comparisons. NZEEM includes assessments of slope, rainfall, land cover and geology.
- Defining which local territorial authority (TA) preside over each sub-FMU and monitoring point
    - While they are GWRC monitoring sites, many of the landuse or practice changes to improve water quality will be driven by TA's and Wellington Water (funded by TA's). Subsequently, some TA's may implement the regional policy statement in different ways and paces than others. Having targets and monitoring in similar catchments and different TA's could allow GWRC to apply different strategies and track differences in catchment changes for TAs.
- Comparing monitoring sites from other spatial sources in LAWA, such as NIWA's River Water Quality Network.
- Considering sites of cultural significance around both Whaitua as presented in the WIP's and Te Mahere Wai.

4 Target attribute sites

4.1 Method

We recommend discontinuing the use of the terminology 'accounting points' which is not used in the NPS-FM or guidelines to freshwater accounting (Ministry for the Environment 2015). Accounting is completed at the FMU scale, but not always to specific sites within an FMU (for example, nutrient loads may be calculated off all landuses within an FMU, but not always to a specific point, such as a target attribute site, unless it's a catchment/sub-FMU of interest).

The current approach for defining target attribute sites has focussed on:

- Using the revised sub-FMUs and GWRC's existing 'accounting points' and comparing their landuse and areas to monitoring sites.
- Identifying culturally significant sub-FMUs and waterbodies which will likely have Mātauranga Māori monitoring at some point in time and therefore could also have a suitable target attribute site and/or water quality monitoring site. Some of these sites have been identified in Table B2 and Section 5.3.
- Reviewing Te Mahere Wai, Te Awarua-o-Porirua and Te Whanganui-a-Tara WIP's to ensure alignment of sub-FMU/catchments with the "FMUs or WMU's" in these documents that were developed over many years by community representatives. Target attribute states were often set at the FMU scale in these reports, and this has been used to guide where a target attribute site could be located in a stream, lake or river in this document.

[15] New Zealand Empirical Erosion Model (NZeem®) was developed by Landcare Research. The primary contact is John Dymond. This is freely available as a raster layer in GIS.

The assessment steps were:

- Identify the monitoring sites in a sub-FMU
- Check how well the monitoring site matches the characteristics (e.g., area, land use, NZEEM, TA jurisdiction etc) of the sub-FMU it falls within
    - If not well matched, consider if a target attribute state could be set at the sub-FMU outlet (i.e., where it discharges into a harbour) rather than at an upstream existing monitoring site.
    - Further consideration is needed by GWRC as to how targets might be set in such catchments. See Waiwhetū Stream example below.
- Check for consistency in the water quality current state and the target attribute state set by Whaitua Committees (in various WIP's) across different sub-FMUs and monitoring sites within those. Alignment in both current and target water quality state can indicate target attribute sites may not be necessary at multiple locations, as this could be suitably represented by a single sub-FMU or target attribute site.
    - Where alignment was identified, selection of the appropriate existing site to use was based on a principle of using the site with the poorer water quality than the others. This approach is conservative in that it expresses the greater need for improvement, the strongest basis for justifying alternative management and we would expect this site to show the same or greater level of improvement as we track progress over time.
    - The sites not recommended for use are noted as 'target set by proxy from [site]'.
- Identify sub-FMUs without a suitable existing monitoring site to set targets at.
    - In some cases, these could be readily monitored, perhaps by repurposing some of the sites not used for setting targets.
    - Some of these might not be well suited to monitoring in the short-term, and modelling may be the best way to understand their conditions for target setting and tracking progress.

In addition, further spatial assessments were conducted where a target attribute state could be set at the sub-FMU *outlet* (i.e., where it discharges into a harbour) rather than at an upstream existing monitoring site.

An example of this would be Waiwhetū Stream, where water quality monitoring is conducted ~ halfway up the stream, but there is significant industrial land downstream that is underrepresented by the existing monitoring/target attribute site (see Figure B1). Subsequently, you could not assume that monitoring results at the existing upstream site (which is primarily residential) would reflect changes in water quality across the entire stream, given industrial and commercial land will respond to Water Sensitive Urban Design (WSUD) requirements differently. These situations may have resulted in *two* target attribute sites within a single sub-FMU, one at the existing monitoring site, and the other at the outlet. Most of the outlet sites are unsuitable for monitoring (based on discussions with GWRC Environmental Science staff) and have therefore been identified as 'modelling'[16] sites.

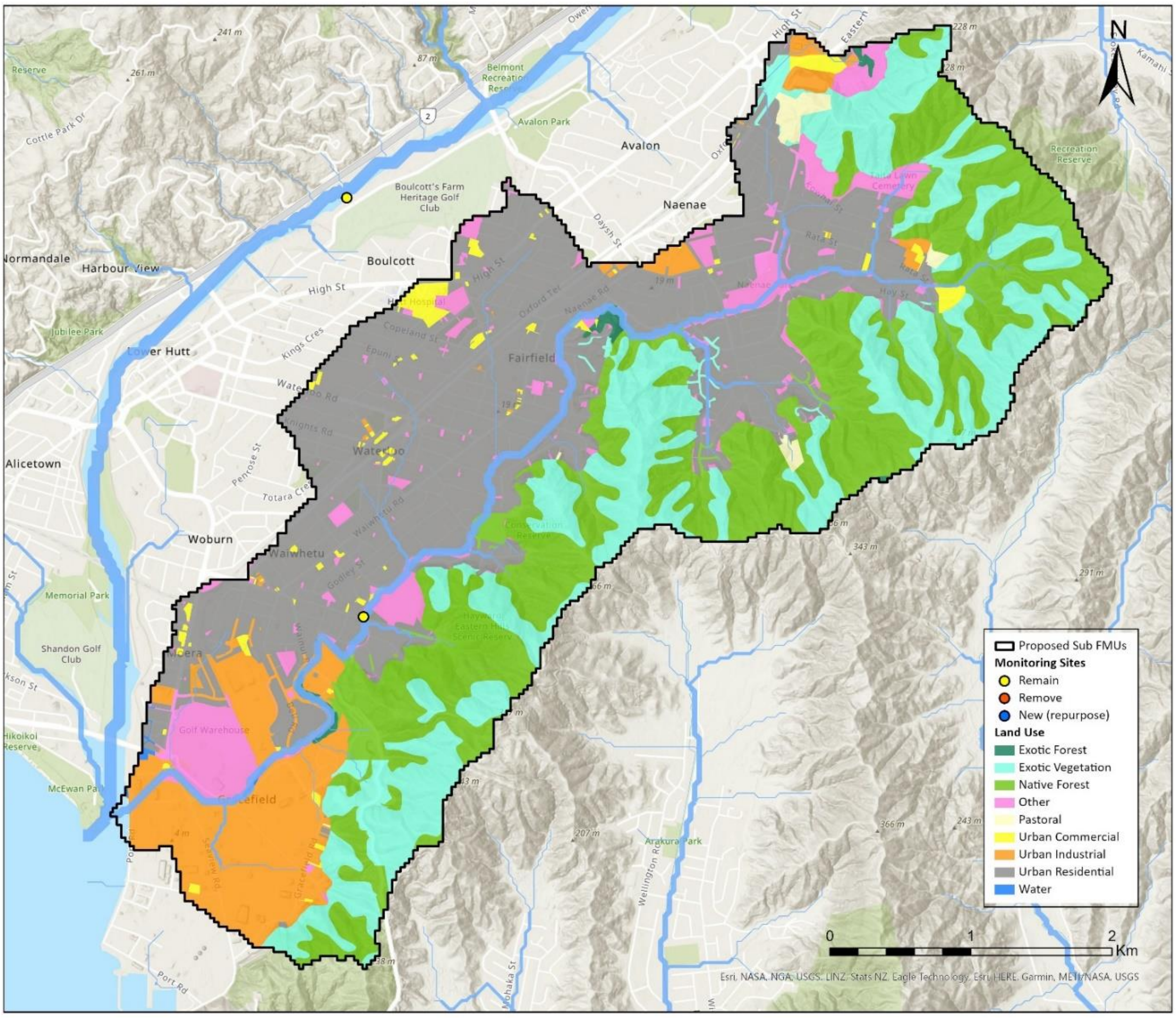

Figure B1 - Waiwhetū Stream - sub-FMU land use & monitoring site

A modelling target attribute site was applied for Eastbourne sub-FMU. This sub-FMUs has short and steep small urban streams with native headwaters that could not be proxied from other locations, and routine SOE water quality monitoring may not capture adequate samples for long term analysis, nor reflect the hydrology that drives contaminants in these areas. This may also be the case for Takapūwahia Stream in the Rangituhi sub-FMU (which has been proposed as a new monitoring site). It is likely that these sites could be better suited for event based monitoring of stormwater runoff, to see how changes in peak concentrations are reduced over time. However, Collaborations understand GWRC are not resourced for long term monitoring in such a manner, as it would require the use of autosamplers or staff on call to sample during wet weather.

16 Modelling in this situation refers to any method that isn't monitoring that would attempt to predict the concentrations or load for a sub-FMU/catchment at the outlet, which could include excel based calculations through to daily water quality modelling (if available).

See **Appendix B1** for a map of the proposed target attribute sites and **Appendix B2** for a summary of the sub-FMUs landuse, NZEEM loads and current/target water quality states. The current water quality state and targets for each sub-FMU was derived from the two WIP's. Appendix B was used in conjunction with Table B2. Landuse statistics for monitoring sites and sub-FMUs are presented in **Appendix B3** and **Appendix B4.**

4.2 Target attribute sites

Table B1 lists the proposed target attribute sites, aligning with the approach described in Section 3 and 4. Naming conventions can be modified during the plan change.

Table B1. Suggested target attribute sites including sub-FMU, monitoring (light green), modelling (blue) or proxy (dark green) representation.

Target Attribute Site	Sub-FMU	Monitoring Site	Targets set/assessed by proxy or modelling	TA
Taupo Stream	Plimmerton and Pukerua Bay	Taupo Stream at Plimmerton Domain	-	PCC
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	-	PCC
Horokiri Stream Outlet	Pouewe (Battle Hill)	-	Modelling	PCC
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	-	PCC
Pāuatahanui Stream Outlet	Takapū	-	Modelling	PCC
Duck Creek	Duck Creek	Duck Creek*	-	PCC
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	-	PCC
Porirua Stream Outlet	Te Riu o Porirua	-	Modelling	PCC
Takapūwahia Stream	Rangituhi	Takapūwahia Stream*	-	PCC
Titahi Bay	Titahi Bay	-	Proxy (Te Riu o Porirua)	PCC
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	-	UHCC
Akatarawa River	Akatarawa	-	Proxy (from Whakatikei)	UHCC
Te Awa Kairangi Upstream	Kaitoke	Hutt River at Te Marua Intake Site	-	UHCC
Pākuratahi River	Pākuratahi	-	Proxy (from Mangaroa)	UHCC
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	-	UHCC

Target Attribute Site	Sub-FMU	Monitoring Site	Targets set/assessed by proxy or modelling	TA
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	-	UHCC
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	-	HCC
Te Awa Kairangi Outlet	Te Awa Kairangi mainstem	-	Modelling	HCC
Korokoro Stream	Korokoro	Korokoro Stream*	-	HCC/WCC
Waiwhetū Stream	Waiwhetū	Waiwhetū at Whites Line East	-	HCC
Waiwhetū Stream Outlet	Waiwhetū	-	Modelling	HCC
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	-	HCC
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	-	HCC
Ōrongorongo River	Ōrongorongo	-	Proxy from Whakatikei	HCC
Gollans Stream	Parangārahu catchment streams	Gollans Stream above Lake Kōhangatera*	-	HCC
Eastbourne Streams	Eastbourne	-	Modelling	HCC
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	-	WCC
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	-	WCC
Karori Stream Outlet	Wellington Urban	-	Modelling	WCC
Owhiro Stream	Wellington Urban	-	Proxy from Kaiwharawhara or Karori Stream	WCC
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	-	WCC

* Indicates a re-purposed (new) monitoring site. See Section 5.3.

5 Using existing water quality monitoring sites for assigning target states

This section presents a list of water quality monitoring sites. GWRC provided a spatial layer showing 23 long term freshwater quality monitoring sites within the two Whaitua. A spatial assessment was conducted on monitoring sites following the approach outlined in Section 3.

Table B2 presents a summary of the assessments of each monitoring site. The dominant landuse and catchment landuse/NZEEM stats were used to define groupings. Their sediment loads were then averaged to produce a 'group average' sediment load. This information was used to assess what sites to keep or remove for each group. The water quality current state was derived from the most recent water quality assessments as output from Hayden (Salt Ecology), and may differ slightly to the current state presented for the sub-FMUs (from the WIP's) in **Appendix B2**.

In total, **eight** existing monitoring sites are not recommended to be used to assign and track target attribute states, and an additional **four** sites are suggested to be introduced for this purpose. **Fifteen** existing sites are suggested to be used, including using some recent sites (i.e., Black Creek) that have short data records and were installed for the purposes of providing data for Wellington Waters stage 1 global stormwater consent. This results in 19 sites being used to assign target attribute sites, compared with around 23 existing long-term monitoring sites.

This assessment does not consider the other purposes for which any sites might have been established, such as monitoring reference conditions or hazardous or contaminated sites. Consideration of moving monitoring sites to catchment outlets has been undertaken through discussions with GWRC environmental monitoring and science teams, resulting in all sites remaining at their current location.

Table B2. Water quality monitoring sites landuse, NZEEM loads and current/target state summary.

									WIP NOF current state (C) and targets (T) for five selected attributes											
									E.coli		N		Zn		Cu		Periphyton		MCI	
Catchment name	**Monitoring Point**	**Total Area (ha)**	**Dominant Landuse***	**NZEEM t/ha/yr**	**Grouped average (t/ha/yr)**	**TA**	**Monitoring comment**	**Use for target setting**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**
Mangaroa	Mangaroa River at Te Marua	10,356	Native + Pastoral + Exotic Forest	3.3	3.3	UHCC		Yes	D	B	A	A	-	A	-	A	C*	B	D	B
Pākuratahi	Pākuratahi River 50m Below Farm Creek	8,034	Native + Pastoral/Exotic Veg	2.8	2.8	UHCC		No	D	B	A	A	-	A	-	A	-	B	A	B
Kaiwharawhara Stream	Kaiwharawhara Stream at Ngaio Gorge	1,562	Native + Urban Res + Exotic Veg	1.4		WCC	Culturally important site	Yes	E	C	B	B	C	A	D	B	C	C	D	C
Wellington Urban	Owhiro Stream at Mouth*	957	Exotic Veg + Native + Urban Res	1.7	1.2	WCC	Also monitored by WWL since 2019. Part of Wellington Water stormwater consent monitoring. Kaiwharawhara can be used as proxy.	No	E*	C	B*	B	B*	A	C*	C	-	C	D*	C
Te Awa Kairangi urban streams	Stokes Valley Stream at Eastern Hutt Road*	1,128	Native + Urban Res + Exotic Veg	0.6		HCC	Waiwhetū Stream can be used to proxy plan progress. Part of Wellington Water stormwater consent monitoring.	No	E*	C	A*	A	D*	A	C*	A	-	C	-	C
Te Riu o Porirua (Porirua Stream)	Porirua Stream at Glenside overhead cables	1,504	Mixed (Pastoral + Urban Res)	1.7	1.7	PCC	Same catchment as Milk Depot, upstream (smaller)	No	E	C	B	A	C	C	B	C	-	B	D	C
Te Riu o Porirua (Porirua Stream)	Porirua Stream at Milk Depot	3,906	Mixed (Pastoral + Urban Res)	1.8		PCC	Same catchment of Glenside, downstream	Yes	E	C	B	A	D	C	D	C	-	B	D	C
Kaitoke	Hutt River at Te Marua Intake Site	18,971	Native + Pastoral/Exotic Veg	2.8		UHCC	NIWA NRWQN site Hutt River at Kaitoke monitored ~ 4.5 km upstream	Yes	A	A	A	A	-	A	-	A	-	A	A	A
Wainuiomata small forested	Wainuiomata River at Manuka Track	2,700	Native	2.0	2.5	HCC	Likely monitored by WWL and reference site.	Remove	A	A	A	A	-	A	-	A	-	A	A	A
Ōrongorongo	Ōrongorongo River at Station	9,597	Native + Exotic Veg	2.6		HCC	Similar landuse to Kaitoke, naturally high DRP.	Remove	B	A	A	A	-	A	-	A	-	A	C	A
Akatarawa	Akatarawa River at Hutt Confluence	11,644	Native + Exotic Forest	1.9	1.8	UHCC	~4.3 km downstream of Te Marua Intake Site. Proxy from Whakatikei due to similar landuse	Remove	B	A	A	A	-	A	-	A	-	A	A	A
Whakatikei	Whakatikei River at Riverstone	8,073	Native + Exotic Forest	1.8		UHCC	~26% exotic forest, similar to Akatarawa. Useful to monitor polices and WIP recs on forestry.	Yes	A	A	A	A	-	A	-	A	-	A	B	A
Te Awa Kairangi lower mainstem	Hutt River at Boulcott	60,547	Native + Exotic Forest/Pastoral	2.2	2.3	HCC	NIWA NRWQN site Hutt River at Boulcott was considered as a replacement but is no longer monitored. Tidal effects downstream mean the outlet cannot be monitored, this being the most suitable lower reach site.	Yes	D	C	A	A	A	A	A	A	C*	B	C	B

									WIP NOF current state (C) and targets (T) for five selected attributes											
									E.coli		N		Zn		Cu		Periphyton		MCI	
Catchment name	**Monitoring Point**	**Total Area (ha)**	**Dominant Landuse***	**NZEEM t/ha/yr**	**Grouped average (t/ha/yr)**	**TA**	**Monitoring comment**	**Use for target setting**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**	**C**	**T**
Te Awa Kairangi lower mainstem	Hutt River Opposite Manor Park Golf Club	55,865	Native + Exotic Forest/Pastoral	2.3		HCC	Mid-Point TAK monitoring site along boundary of two TA's (UHCC/HCC)	Remove	D	C	A	A	A	A	A	A	-	B	B	B
Wainuiomata rural streams	Wainuiomata River Downstream of White Bridge	13,160	Native + Exotic Veg + Pastoral	1.6	1.6	HCC		Yes	D	C	A	A	B*	A	A*	A	D*	C	C	B
Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2,885	Pastoral + Exotic Forest	4.6	4.6	PCC	Main harbour site - High levels exotic forest + sed yield. Pasture increases downstream	Yes	E	B	A	A	-	A	-	A	C	B	B	A
South-west coast rural streams	Mākara Stream at Kennels	7,204	Pastoral + Exotic Veg	3.1	3.1	WCC	Important rural site + exotic forest in different TA.	Yes	E	D	A	A	-	A	-	A	-	C	C	C
Takapū	Pāuatahanui Stream at Elmwood Bridge	3,930	Pastoral + Native/Exotic Forest	2.3	2.3	PCC	Main harbour site. 50 ha residential and Transmission Gulley downstream of monitoring point (but small relative to catchment size).	Yes	E	C	A	A	-	A	-	A	-	B	C	B
Plimmerton & Pukerua Bay	Taupo Stream at Plimmerton Domain*	1,142	Pastoral + Native	2.2	2.2	PCC	D/S of Plimmerton Farms Development, useful for regulation. Culturally significant site. Part of Wellington Water stormwater consent monitoring. Continue once stage 1 stormwater consent completed	Yes	E*	B	A*	A	A*	A	B*	B	-	B	-	B
Te Awa Kairangi urban streams	Hulls Creek adjacent Reynolds Bach Drive*	1,360	Urban (mixed) + Native/Exotic Forest	0.8	0.7	UHCC	Monitored for Silverstream Landfill? 16% commercial. Part of Wellington Water stormwater consent monitoring. Continue once stage 1 stormwater consent completed. Falls into different TA and useful to compare to Waiwhetū (HCC) and Kaiwharawhara (WCC).	Yes	E*	C	A*	A	C*	A	C*	A	-	C	-	C
Waiwhetū Stream	Waiwhetū at Whites Line East	1,346	Urban + Native/Exotic Veg	0.7		HCC	Culturally important site, large industrial area below existing monitoring site that isn't captured in WQ data	Yes	E	C	A	A	D	B	D	A	-	C	D	C
Wainuiomata urban streams	Black Creek at Rowe Parade end*	1,460	Urban + Native + Exotic Veg	0.8	0.8	HCC	Part of Wellington Water stormwater consent monitoring. Continue once stage 1 stormwater consent completed.	Yes	E*	C	A*	A	C*	A	C*	B	-	C	-	D
Karori Stream	Karori Stream at Mākara Peak Mountain Bike Park	689	Urban + Native	0.8		WCC	Similar stats to Wainui Urban Streams. Can compare TA responses to WIP/plan.	Yes	E	C	B	B	D	A	D	C	-	C	C	C

* Indicates "manual" monitoring site with short water quality record. Added by GWRC and paid for by Wellington Water to expand knowledge for Stage 1 of global stormwater consent.

As outlined in Section 4, 're-purposing' of monitoring sites by either moving them within a sub-FMU or creating an entirely new site was considered when setting target attribute sites. Assessing water quality state and trends within the next 5 - 10 years at target attribute sites would most likely be through observed monitoring data, unless GWRC begin development (and updates) of water quality models. Some important considerations for GWRC that haven't been factored into this assessment include:

- A full cost benefit assessment of monitoring versus modelling. The cost of building whaitua specific water quality and flow models calibrated to a set 'baseline' time period, and used to predict water quality for accounting purposes should be compared against the costs of maintaining existing and new monitoring sites, as well as incorporating Mātauranga Māori monitoring practices (and resourcing).
    - Setting of target attribute sites and undertaking freshwater accounting at an FMU requires some level of monitoring, modelling or suitable proxies. Currently this assessment has focussed heavily on using monitoring data when a detailed water quality model with targeted monitoring may be cheaper. This is more relevant when considering monitoring requirements across the entire region.
- The additional monitoring requirements may mean a substantial cost and resource increase for GWRC, which could negate the '*re-purposed'* sites and rely increasingly on proxy monitoring catchments or models.
- Locations of current monitoring sites have been chosen carefully by GWRC, however in some situations, they are upstream of tidal influences and do not capture large landuse changes that occur downstream. Examples of this include Waiwhetū Stream, Hutt River at Boulcott and Horokiri at Snodgrass. This may mean freshwater accounting would be challenging without the use of a model or additional 'paired monitoring'.
- What coastal water quality monitoring GWRC will undertake for representing the 'receiving environment', and if target attribute sites are expressed in coastal locations, how you would assess changes in concentrations and loads (i.e., harbours, southwest coast). Is this going to be driven by summing of loads from major sub-FMUs that feed into appropriate receiving water bodies? If so, this would need suitable monitoring or modelling across all sub-FMUs.

5.1 Monitoring sites not used for setting target attribute states

The eight existing sites that were not used and the reasoning, are described briefly below:

1. **Porirua Stream at Glenside overhead cables** – mid catchment monitoring site, similar proportions of landuse exist at the downstream site (Porirua Stream at Milk Depot). Expect the same relative level of change in water quality across the catchment as a result of the plan change and RPS update.
2. **Pākuratahi River 50m Below Farm Creek** – upper Te Awa Kairangi catchment monitoring site. While it has different landuse proportions to Mangaroa (i.e., Pākuratahi has a lot more native forest), the target water quality states set by the Whaitua Committee would be the same as Mangaroa (defined as 'Te Awa Kairangi Rural Streams'). Mangaroa has poorer water quality and would continue to be monitored, and therefore could proxy for Pākuratahi. In addition, the downstream site 'Hutt River

at Te Marua' would remain and provide an indication of water quality trends from headwaters of Te Awa Kairangi prior to the confluence with Mangaroa.

3. **Wainuiomata River at Manuka Track –** little change in water quality is expected in the native catchments. In addition, this catchment is used for water supply by Wellington Water, so will have ongoing monitoring for drinking water standards and annual reporting. No proxy catchment is proposed however Whakatikei could be used if necessary, given the current and target attributes are all 'A state' for both sub-FMUs.
4. **Hutt River Opposite Manor Park Golf Club** – whilst this is an important site for the midstream reaches of Te Awa Kairangi/Hutt River between two TA boundaries, the downstream Boulcott monitoring site can provide sufficient representation of targets set for Te Awa Kairangi and water quality state and trends, allowing this site to be repurposed elsewhere.
5. **Ōrongorongo River at Ōrongorongo Station –** limited development is likely to occur in this catchment, which is primarily native. Re-purposing monitoring to catchments with no data, or are culturally significant (i.e., Korokoro, Parangārahu Lakes) would likely serve the community better. Setting of a target attribute site at this location could be proxied from Whakatikei, which has similar landuse proportions but would represent poorer water quality (due to forestry impacts) (see Section 4). Whakatikei and Ōrongorongo also have the same target attributes from the WIP, being an 'A state'.
6. **Akatarawa River at Hutt Confluence** – nearby Whakatikei River has similar catchment size and proportions of exotic forest and pasture, with similar water quality trends. While Whakatikei has a slightly greater proportion of exotic forest to total catchment area (than Akatarawa), impacts from RPS and NRP polices on forestry harvest and best practice would be echoed across both catchments. Setting of a target attribute site at this location could be proxied from Whakatikei, with both sub-FMUs having the same targets.
7. **Owhiro Stream at Mouth** – monitoring of this site is currently short term, as part of data collection to support Wellington Water's stage 1 global stormwater consent. Monitoring at this site could eventually be discontinued, and the setting of target attribute states can be proxied from Kaiwharawhara and Karori Streams which have a similar landuse and would be subject to the same development rules within the WCC TA boundary. Both proxy sites have similar or poorer water quality than Owhiro (see Table B2).
8. **Stokes Valley Stream at Eastern Hutt Road** – A short term record exists for this site as it is monitored to support Wellington Water's stage 1 global stormwater consent. Monitoring at this site could eventually be discontinued, as the Waiwhetū Stream and Black Creek within HCC TA boundary will continue to be monitored, and have similar catchment areas, landuse and NZEEM yields which are suitable to be used as a proxy for setting target attribute states. Hulls Creek adjacent Reynolds Bach Drive would instead be monitored to ensure an urban stream from UHCC can be compared against WCC and HCC in relation to water quality improvement.

See **Appendix B1** for a map of the monitoring sites that are to remain, be removed and be 're-purposed'.

5.2 Consideration of moving sites to lower points of the sub-FMU

A review of the landuse statistics for current monitoring sites at Mākara Stream at Kennels, Wainuiomata River Downstream of White Bridge and Kaiwharawhara Stream at Ngaio Gorge against their outlet landuse statistics showed little change in landuse proportions. Subsequently, the existing site remained suitable for setting target attribute states, assuming that flow and nutrient inputs would be relative downstream (i.e., concentrations should be similar). In addition, Mākara Stream at Kennels is upstream of the Mākara Estuary, allowing quantification of loads into the estuary.

Three additional sites were also considered to be moved, however following discussions with GWRC monitoring and science teams, these sites were kept at their existing locations and an additional target attribute site was suggested to be established downstream. They are:

Hutt River at Te Marua Intake Site - a NIWA NRWQN site exists in the headwaters of Te Awa Kairangi, ~4.5 km upstream which could be a suitable proxy. Moving the site downstream to the confluence with Mangaroa River was considered, which would ensure two of the larger headwater tributaries of Te Awa Kairangi are measured before they are impacted from downstream urban populations. However, this ~2.5 km move was considered unnecessary given the established record at this monitoring site and small landuse change over that reach.

Waiwhetū at Whites Line East - there is a significant increase in industrial land downstream of the existing monitoring site (~160 ha increase, changing proportions from 3% to 10% of total catchment area). Monitoring upstream would be unlikely to reflect the changes in water quality off industrial land, which may have different WSUD practices implemented than residential. Historical monitoring was ~0.9 km downstream, however this old site was decommissioned in 2011 due to tidal influences on water quality, with the current monitoring site representing the point above the tidal zone (Perrie and Conwell, 2011). Because of this, we recommend nominating target attribute states at an additional point at the outlet of Waiwhetū Stream to help establish the management of the landuse in the lower reaches. However, due to the tidal influence, information about this point may need to be estimated using modelling rather than monitoring.

Horokiri Stream at Snodgrass – this catchment has large sediment contributions to Pāuatahanui inlet. This would be driven by exotic forestry and pasture landuses. Between the outlet of the catchment and the upstream monitoring point, pasture increases by over 330 ha (~28%). Additional nutrients and lowland farming practices would likely mean the upstream monitoring site would underestimate the nutrient and sediment losses from these lower landuses. Historically, a monitoring site known as Horokiri Stream at Ongly was located ~ 1.1 km downstream, but this was decommissioned in early 2000's and moved to the current site due to the presence of a flow monitoring station at this location and continuous monitoring of other water quality parameters (i.e., temperature and dissolved oxygen) (Warr, 2002). Because of this, we recommend nominating target attribute states at an additional point at the outlet of Horokiri Stream to help establish the management of the landuse in the lower reaches. However, due to the tidal influence, information about this point may need to be estimated using modelling rather than monitoring.

5.3 Re-purposed (new) sites

A list of the suggested four new sites for setting target attribute states and potentially establishing monitoring sites is described below.

1. **Korokoro Stream** – this site was identified in both WIP's as an important sub-FMU or FMU (Te Mahere Wai) and is culturally significant. In addition, its landuse is relatively unique to other catchments meaning setting targets by proxy in another catchment would not be suitable.
2. **Parangārahu Lakes** – a culturally and biologically significant site and also the only two lakes within both Whaitua. Ongoing monitoring could be conducted in the primary tributary draining to Lake Kōhangatera, as this lake has a larger catchment than Lake Kōhangapiripiri (and should better reflect changing landuse practices). Re-purposing the monitoring site from Ōrongorongo River at Ōrongorongo Station.
3. **Duck Creek (Whitby)** – The WIP included this catchment within Takapū sub-FMU, though the catchment is unique with high proportions of pasture, exotic forest and residential landuses that was not represented by any other sub-FMUs. We recommend delineating a separate sub-FMU for this area and setting targets and monitoring at a new site.
4. **Rangituhi Catchment** – Currently not monitored. The stream is in close proximity to Takapūwahia and Hongoeka marae and was identified as a WMU in Te Awarua-o-Porirua WIP with more ambitious target attribute states assigned (than surrounding sub-FMUs such as Porirua Stream). Assigning targets and a monitoring site at this location should allow overlap with Matauranga Maori monitoring while also providing water quality data from a small mixed urban/forest catchment that could be applied elsewhere (for example, Te Awa Kairangi urban streams has a similar landuse proportion and NZEEM loads to Rangituhi). Suitability of monitoring this stream has not been considered (i.e., whether there is sufficient baseflow for SOE monitoring etc).

5.4 Modelling sites

As described in Section 4.1, Section 5.2 and Table B1, there are a number of suggested sites of which target attribute states are recommended to be applied, typically downstream of another target attribute (and monitoring site) within the same sub-FMU. Many of these sites are at the outlet of a catchment, such as the mouth of Te Awa Kairangi or Waiwhetū Stream, with the exception being the small urban streams in Eastbourne which are not suitably represented by potential proxy sites. The suggestion for modelling at these sites to predict water quality changes is based on their locations being relatively poor for water quality monitoring, due to tidal influences or hydrological drivers (i.e., short and steep streams). A suitable approach will need to be determined in how to model or predict water quality at these locations, using either existing models or establishing new methods.

6 FMUs

Background on FMUs and sub-FMUs

Regarding the spatial scale of an FMU, the following points relevant to this memo should be considered:

- The NPS-FM (2020) requires freshwater accounting[17] at each FMU, at a minimum of every five years (for detailed reporting on state, trends etc).
    - Should plan change outline a large number of FMUs, then GWRC would be required to report on this, and naturally this could lead to detailed assessments of each FMU. Scale is important, as by limiting the number of FMUs, this helps balance uncertainty in data (which could be misleading at too finer a scale) while also ensuring management and reporting obligations are simpler and potentially can be summarised easier.
- Within an FMU, sub-FMUs (or catchments) can be defined for locations such as where landuse changes significantly, a hydrological boundary is present or a catchment that may hold cultural significance. GWRC has proposed ~29 to start with.
- NPS-FM has a ki uta ki tai approach (mountains to sea) and consider the interconnectedness between freshwater catchments and landuse draining from headwaters, through rivers/streams/lakes and aquifers and discharging to the coast.
- Setting of target attribute states can occur at a site, or multiple sites within an FMU, but must have regard to environmental outcomes, connection between water bodies and to receiving environments.
- The mountains to sea approach was a consistent theme across all WIP's, specifically mentioned in Te Mahere Wai o Te Kāhui Taiao and Whaitua te Whanganui-a-Tara WIP.

In its simplest form, an FMU could be set at the highest level; the existing Whaitua boundary. This would mean GWRC have five FMUs for the entire region and when undertaking accounting, assess water quality and quantity and write a single report for each of the Whaitua at designated time intervals. However, the previous Whaitua programmes have interchangeably used the terminology FMUs (or WMU's in the case of Porirua) to define their preferred spatial boundaries for the management of catchments, following the NPS-FM. A lot of thought went into these 'FMUs', which needs to be considered by GWRC through the plan change process.

Moving to a single FMU for each Whaitua may frustrate previous committee members and mana whenua partners, while having numerous FMUs (aligning with the various WIP's) would result in increased reporting and assessments requirements (even if a single report is still

[17] "Freshwater quality accounting system" means a system that, for each freshwater management unit, records, aggregates and keeps regularly updated, information on the measured, modelled or estimated: a) loads and/or concentrations of relevant contaminants; b) sources of relevant contaminants; c) amount of each contaminant attributable to each source; and d) where limits have been set, proportion of the limit that is being used.

produced for each Whaitua boundary, you would have to specifically assess each FMU). The reason consideration of FMUs is relevant, is that this feeds into the number of target attribute sites that need to be defined and also the amount of monitoring (and modelling) that GWRC will need to conduct to assess the change over time.

An example could be a single FMU for all of Wellington Urban Streams. Accounting of the contaminants, loads, concentrations and flows could occur for the entire FMU, with optional specific mention of certain catchments/sub-FMUs such as Kaiwharawhara, which hold cultural significance to mana whenua. Alternatively, if GWRC broke this into three smaller FMUs, splitting out Karori Stream, Wellington Urban Streams and Kaiwharawhara Stream, then a commensurate level of detail for accounting and reporting on the many statistics would be required for each of these FMUs, increasing the effort required. If a regional water quality model isn't available, then it's likely that monitoring data would fill the gap to inform changes in water quality, subsequently requiring you to have a monitoring site at each FMU (aligning with your target attribute sites), or a suitable proxy catchment.

Delineated sub-FMUs

The maps in **Appendix B1** show a revised version of sub-FMUs that expanded on previous data sets provided by GWRC. While some are hydrologically correct, delineated by catchment boundaries, others still follow the original sub-FMU boundary which was presumably grouped by landuse. An example would be Mākara Stream, where the sub-FMU includes all streams draining to the southwest coast, or Horokiri Stream that has many small catchment which drain towards Pukerua Bay.

Further revisions could separate this out into hydrologically distinct catchments, but for the purpose of this exercise these have been appropriate to compare landuses, and where necessary (to inform target attribute sites and monitoring points), an 'outlet' assessment was conducted to reflect the streams actual hydrological catchment at the coast (rather than using the sub-FMU).

Some of the steps involved in the sub-FMU modifications are detailed below (for reference purposes only).

STEP 1

- Deleted the coastal sub-FMUs (retained the lake and Estuary FMUs)
- Disaggregated the merged sub-FMUs in Porirua and the Wellington Urban sub-FMU
- Further split the Wellington Urban sub-FMU to separate Karori Stream
- Fixed the two hydrological issues in Porirua (boundary alignments)

STEP 2

- Merged 2 Sub-FMUs around Titahi Bay, keeping Rangituhi separate
- Merged the 6 sub-FMUs around Plimmerton and Pukerua Bay
- Spilt out the Te Awa Kairangi small forested sub-FMU into 4 sub-FMUs
- Results in 31 sub-FMUs including the harbour and estuary sub-FMUs (25 if only considering freshwater stream and river catchments)

7 References

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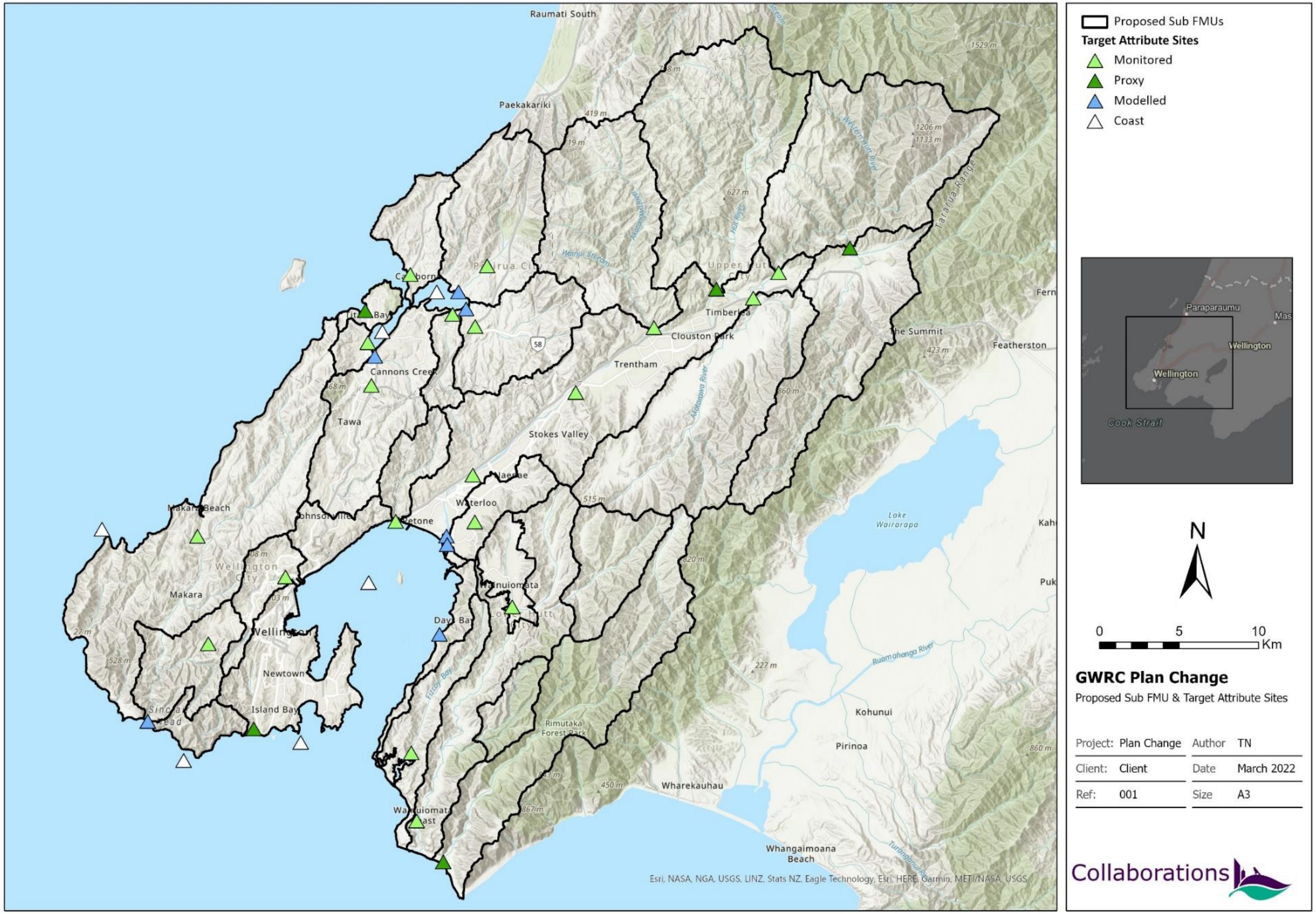
Appendix B1 - Target attribute and monitoring sites



Proposed Sub FMUs
Target Attribute Sites
Monitored
Proxy
Modelled
Coast
N
0
5
10
Km
GWRC Plan Change
Proposed Sub FMU & Target Attribute Sites
Project: Plan Change
Author TN
Client: Client
Date March 2022
Ref: 001
Size A3
Collaborations
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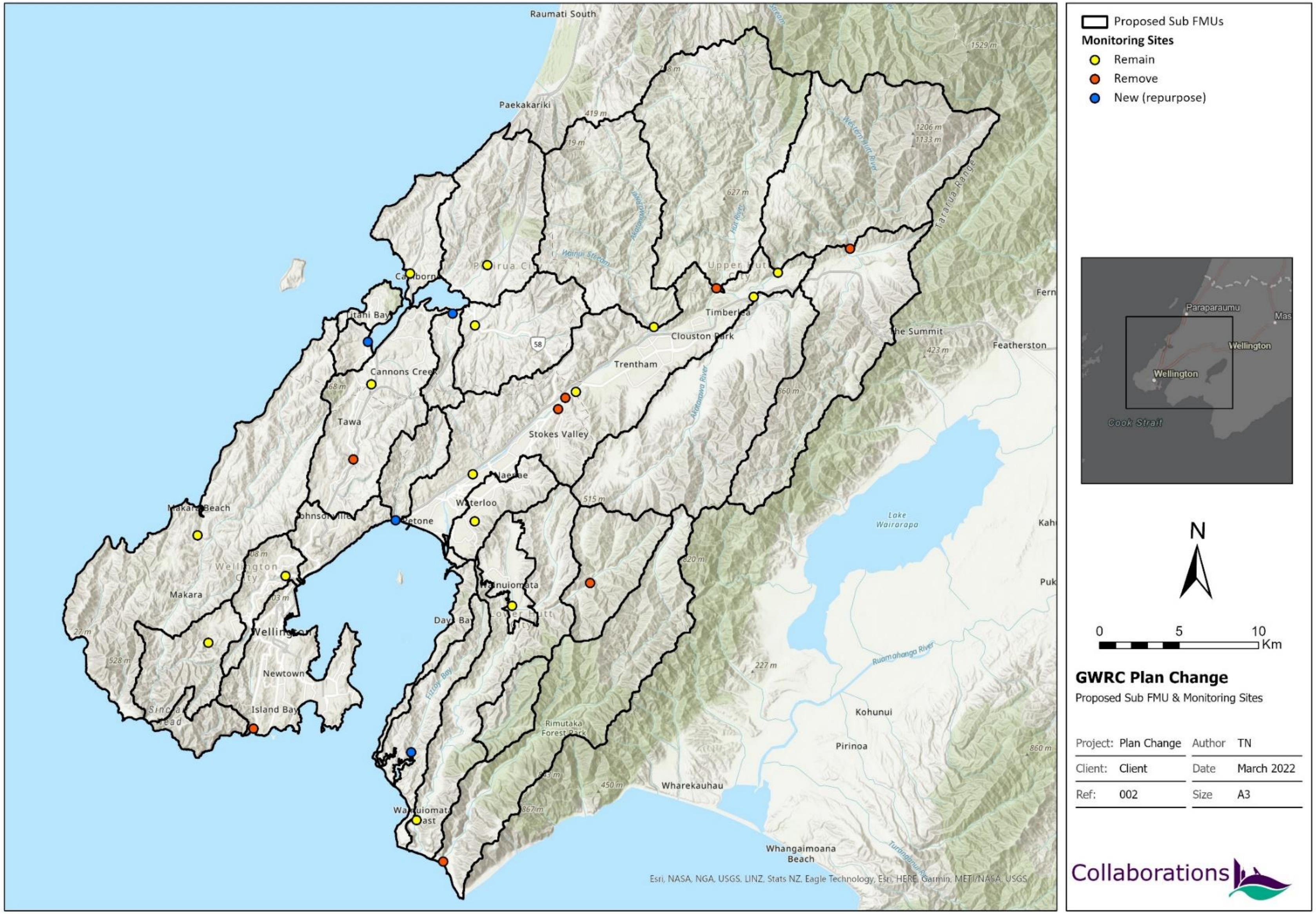
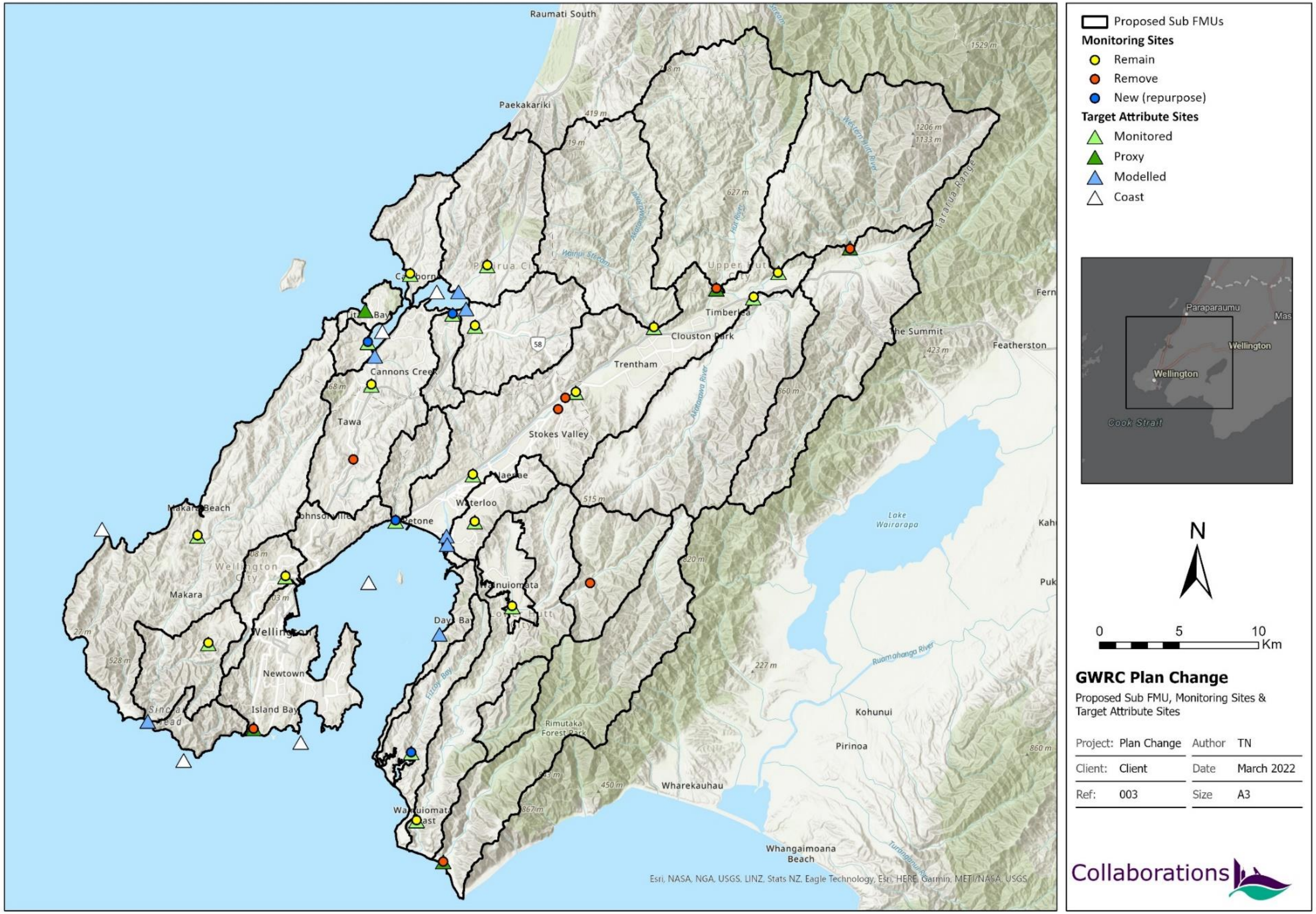
Paekakariki
Upper Hutt
Timberlea
Clouston Park
Trentham
Cannons Creek
Tawa
Stokes Valley
Makara Beach
Makara
Petone
Waterloo
Day's Bay
Newtown
Island Bay
Wainuiomata Coast
Featherston
The Summit
Lake Wairarapa
Kohunui
Pirinoa
Wharekauhau
Whangaimoana Beach
Rimutaka Forest Park
Tararua Range
Paraparaumu
Wellington
Cook Strait
Esri, NASA, NGA, USGS, LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS


Proposed Sub FMUs
Monitoring Sites
Remain
Remove
New (repurpose)
GWRC Plan Change
Proposed Sub FMU & Monitoring Sites
Project: Plan Change
Author TN
Client: Client
Date March 2022
Ref: 002
Size A3
Collaborations
Esri, NASA, NGA, USGS, LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS


Proposed Sub FMUs
Monitoring Sites
Remain
Remove
New (repurpose)
Target Attribute Sites
Monitored
Proxy
Modelled
Coast
N
0 5 10 Km
GWRC Plan Change
Proposed Sub FMU, Monitoring Sites & Target Attribute Sites
Project: Plan Change
Author TN
Client: Client
Date March 2022
Ref: 003
Size A3
Collaborations
Raumati South
Paekakariki
Trentham
Stokes Valley
Tawa
Makara
Newtown
Island Bay
Featherston
Kohunui
Pirinoa
Wharekauhau
Whangaimoana Beach
Lake Wairarapa
Esri, NASA, NGA, USGS, LINZ, Stats NZ, Eagle Technology, Esri, HERE, Garmin, METI/NASA, USGS

Appendix B2 – Sub-FMU water quality

Main sub-catchment	Total Area (ha)	Dominant Landuse*	NZEEM t/ha/yr	Group Avg. (t/ha/yr)	Comment	WIP NOF current state (C) and Targets (T) for five selected attributes											
						E.coli		N		Zn		Cu		Periphyton		MCI	
						C	T	C	T	C	T	C	T	C	T	C	T
Karori Stream	3,103	Exotic Veg + Native + Urban Res	2.54			E	C	B	B	B	A	D	C	C	C	C	C
Wainuiomata small forested	4,924	Native	2.01	2.46	While split into two groupings (native versus native + exotic forest), all these sub-FMUs have the same current + future states. Could all be represented by a single monitoring and target site.	A	A	A	A	A	A	A	A	A	A	A	A
Kaitoke	10,938	Native	2.80			A	A	A	A	A	A	A	A	A	A	A	A
Ōrongorongo	9,579	Native + Exotic Veg	2.56			A	A	A	A	A	A	A	A	A	A	A	A
Akatarawa	11,651	Native + Exotic Forest	1.86	1.81		A	A	A	A	A	A	A	A	A	A	A	A
Whakatikei	8,077	Native + Exotic Forest	1.76		More pasture + forest as a proportion than Akatarawa	A	A	A	A	A	A	A	A	A	A	A	A
Parangārahu catchment streams	2,786	Native + Exotic Veg + Pastoral	1.10	1.29		E	C	A	A	A	A	A	A	C	B	C	B
Wainuiomata rural streams	7,116	Native + Exotic Veg + Pastoral	1.48			D	C	A	A	A	A	A	A	C	C	C	B
Eastbourne	1,011	Native + Exotic Veg + Urban Res	1.48			E	C	B	B	B	A	D	C	C	C	C	C
Korokoro Stream	1,673	Native + Pastoral + Exotic Forest/Veg	2.23			C	B	A	A	A	A	A	A	B	B	B	A
Mangaroa	10,371	Native + Pastoral + Exotic Forest	3.27			D	B	A	A	A	A	A	A	C	B	C	B
Pākuratahi	8,048	Native + Pastoral/Exotic Veg	2.83			D	B	A	A	A	A	A	A	C	B	C	B
Kaiwharawhara Stream	1,687	Native + Urban Res + Exotic Veg	1.28			E	C	B	B	B	A	C	B	C	C	C	C
Te Awa Kairangi urban streams	13,541	Native + Urban Res + Exotic Forest	0.94	0.80	Similar proportions, Rangituhi could proxy for Te Awa Kairangi Urban Streams	E	C	A	A	B	A	B	A	C	C	C	C
Rangituhi	649	Native + Urban Res + Pastoral	0.71			E	A	A	A	D	A	D	A	A	A	C	A
Wainuiomata urban streams	1,557	Urban Res + Native + Exotic Veg	0.77			E	C	A	A	B	A	B	B	C	C	D	D
Pouewe (Battle Hill)	5,640	Pastoral + Exotic Forest + Native	3.94		Similar to Southwest Coast Streams, except high % of exotic forest - not grouped for that reason	E	B	A	A	A	A	A	A	C	B	C/B	A
South-west coast rural streams	14,596	Pastoral + Exotic Veg	3.74		Could potentially be proxied off Pouewe	E	D	A	A	A	A	A	A	C	C	C	C
Takapū	4,252	Pastoral + Native + Exotic Forest	2.22			E	C	A	A	A	A	A	A	C	B	C/B	B
Plimmerton & Pukerua Bay	2,140	Pastoral + Native + Urban Res	2.26	2.41	Could be proxied off Duck Creek	E	B	A	A	C	A	D	B	C	B	C	B
Duck Creek	1,061	Pastoral + Urban Res + Exotic Forest	2.56		Similar to Plimmerton, except higher % of exotic forest. Current state probably incorrect as originally lumped with Takapū WMU (primarily pastural). I.e., likely similar to Plimmerton	E	C	A	A	A	A	A	A	C	B	C/B	B
Waiwhetū Stream	1,960	Urban Res + Native + Exotic Veg	0.63	0.67		E	C	A	A	D	B	C	A	C	C	D	C
Wellington Urban	6,242	Urban Res + Native + Exotic Veg	0.72			E	C	B	B	B	A	D	C	C	C	C	C
Te Rio o Porirua (Porirua Stream)	6,098	Urban Res + Pastoral	1.59	1.44		E	C	B	A	D	C	D	C	C/B	B	C	C
Titahi Bay	658	Urban Res + Pastoral + Other	1.29		Slightly different landuses but could be proxied off Porirua. Same target states.	E	C	B	A	D	C	D	C	C/B	B	C	C

Appendix B3 – Monitoring sites landuse statistics (from upstream catchment)

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
Akatarawa River at Hutt Confluence	Exotic Forest	2007.3	17%	11650.8
	Exotic Vegetation	75.1	1%	
	Native Forest	9158.7	79%	
	Other	3.7	0%	
	Pastoral	383.5	3%	
	Urban Commercial	6.1	0%	
	Urban Residential	13.9	0%	
	Water	2.5	0%	
Black Creek at Rowe Parade end	Exotic Forest	11.8	1%	1484.5
	Exotic Vegetation	197.2	13%	
	Native Forest	550.9	37%	
	Other	112.0	8%	
	Pastoral	137.8	9%	
	Urban Commercial	28.2	2%	
	Urban Industrial	16.9	1%	
	Urban Residential	429.8	29%	
Horokiri Stream at Snodgrass	Exotic Forest	871.4	30%	2884.8
	Exotic Vegetation	447.6	16%	
	Native Forest	392.4	14%	
	Other	0.0	0%	
	Pastoral	1173.4	41%	
Hulls Creek adjacent Reynolds Bach Drive	Exotic Forest	326.9	22%	1517.8
	Exotic Vegetation	90.4	6%	
	Native Forest	469.5	31%	
	Other	110.6	7%	
	Pastoral	18.0	1%	
	Urban Commercial	243.5	16%	
	Urban Industrial	4.6	0%	
	Urban Residential	254.2	17%	
	Water	0.1	0%	
Hutt River at Boulcott	Exotic Forest	7575.9	12%	61020.8
	Exotic Vegetation	2381.8	4%	
	Native Forest	40288.0	66%	
	Other	1163.9	2%	

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
	Pastoral	6412.4	11%	
	Urban Commercial	574.5	1%	
	Urban Industrial	156.8	0%	
	Urban Residential	2240.7	4%	
	Water	226.9	0%	
Hutt River at Te Marua Intake Site	Exotic Forest	681.9	4%	18985.7
	Exotic Vegetation	1045.4	6%	
	Native Forest	16311.3	86%	
	Other	27.2	0%	
	Pastoral	918.9	5%	
	Urban Residential	0.5	0%	
	Water	0.5	0%	
Hutt River Opposite Manor Park Golf Club	Exotic Forest	7485.5	13%	56285.4
	Exotic Vegetation	2008.3	4%	
	Native Forest	38186.1	68%	
	Other	827.1	1%	
	Pastoral	5551.7	10%	
	Urban Commercial	526.3	1%	
	Urban Industrial	79.1	0%	
	Urban Residential	1449.6	3%	
	Water	171.8	0%	
Kaiwharawhara Stream at Ngaio Gorge	Exotic Forest	87.8	6%	1581.7
	Exotic Vegetation	281.7	18%	
	Native Forest	552.8	35%	
	Other	51.7	3%	
	Pastoral	49.9	3%	
	Urban Commercial	25.0	2%	
	Urban Industrial	4.8	0%	
	Urban Residential	524.3	33%	
	Water	3.7	0%	
Karori Stream at Mākara Peak Mountain Bike Park	Exotic Forest	11.3	2%	695.5
	Exotic Vegetation	28.6	4%	
	Native Forest	287.7	41%	
	Other	29.5	4%	
	Pastoral	15.1	2%	
	Urban Commercial	6.8	1%	
	Urban Industrial	0.6	0%	
	Urban Residential	315.9	45%	

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
Mākara Stream at Kennels	Exotic Forest	556.9	8%	7203.2
	Exotic Vegetation	1434.9	20%	
	Native Forest	496.4	7%	
	Other	95.1	1%	
	Pastoral	4610.3	64%	
	Urban Commercial	2.9	0%	
	Urban Industrial	0.0	0%	
	Urban Residential	5.6	0%	
	Water	1.2	0%	
Mangaroa River at Te Marua	Exotic Forest	1649.1	16%	10370.5
	Exotic Vegetation	399.4	4%	
	Native Forest	5050.3	49%	
	Other	24.3	0%	
	Pastoral	3178.0	31%	
	Urban Commercial	0.9	0%	
	Urban Industrial	8.7	0%	
	Urban Residential	59.0	1%	
	Water	0.7	0%	
Ōrongorongo River at Station	Exotic Forest	20.8	0%	9578.6
	Exotic Vegetation	1288.8	13%	
	Native Forest	7722.2	81%	
	Other	326.0	3%	
	Pastoral	220.9	2%	
Owhiro Stream at Mouth	Exotic Forest	30.2	3%	965.2
	Exotic Vegetation	441.4	46%	
	Native Forest	249.4	26%	
	Other	85.1	9%	
	Pastoral	2.8	0%	
	Urban Commercial	3.9	0%	
	Urban Industrial	7.3	1%	
	Urban Residential	145.2	15%	
Pākuratahi River 50m Below Farm Creek	Exotic Forest	646.0	8%	8047.9
	Exotic Vegetation	852.5	11%	
	Native Forest	5613.6	70%	
	Other	26.0	0%	
	Pastoral	909.4	11%	
	Urban Residential	0.5	0%	
Pāuatahanui Stream at Elmwood Bridge	Exotic Forest	606.8	15%	3942.9

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
	Exotic Vegetation	148.3	4%	
	Native Forest	832.0	21%	
	Other	54.5	1%	
	Pastoral	2297.8	58%	
	Urban Commercial	1.9	0%	
	Urban Industrial	0.9	0%	
	Urban Residential	0.6	0%	
Porirua Stream at Glenside overhead cables	Exotic Forest	66.5	4%	1579.0
	Exotic Vegetation	160.2	10%	
	Native Forest	183.9	12%	
	Other	163.3	10%	
	Pastoral	537.6	34%	
	Urban Commercial	14.7	1%	
	Urban Industrial	19.4	1%	
	Urban Residential	433.5	27%	
Porirua Stream at Milk Depot	Exotic Forest	450.2	11%	4026.2
	Exotic Vegetation	363.4	9%	
	Native Forest	526.9	13%	
	Other	302.0	8%	
	Pastoral	1240.7	31%	
	Urban Commercial	136.3	3%	
	Urban Industrial	101.8	3%	
	Urban Residential	905.0	22%	
Stokes Valley Stream at Eastern Hutt Road	Exotic Forest	9.0	1%	1137.2
	Exotic Vegetation	107.7	9%	
	Native Forest	681.6	60%	
	Other	20.1	2%	
	Pastoral	15.0	1%	
	Urban Commercial	14.8	1%	
	Urban Industrial	2.7	0%	
	Urban Residential	285.5	25%	
	Water	0.8	0%	
Taupo Stream at Plimmerton Domain	Exotic Forest	36.1	3%	1147.8
	Exotic Vegetation	25.5	2%	
	Native Forest	164.5	14%	
	Other	13.1	1%	
	Pastoral	822.8	72%	
	Urban Commercial	13.3	1%	

Monitoring Point	Landuse	Area (ha)	Percent	Total (ha)
	Urban Industrial	6.6	1%	
	Urban Residential	65.7	6%	
Wainuiomata River at Manuka Track	Exotic Forest	2.6	0%	2699.5
	Native Forest	2690.5	100%	
	Pastoral	6.4	0%	
Wainuiomata River Downstream of White Bridge	Exotic Forest	368.3	3%	13221.7
	Exotic Vegetation	2375.2	18%	
	Native Forest	8549.4	65%	
	Other	230.6	2%	
	Pastoral	1110.5	8%	
	Urban Commercial	30.6	0%	
	Urban Industrial	18.7	0%	
	Urban Residential	537.1	4%	
	Water	1.2	0%	
Waiwhetū at Whites Line East	Exotic Forest	5.6	0%	1388.1
	Exotic Vegetation	283.1	20%	
	Native Forest	356.6	26%	
	Other	86.6	6%	
	Pastoral	12.1	1%	
	Urban Commercial	41.9	3%	
	Urban Industrial	19.1	1%	
	Urban Residential	583.0	42%	
Whakatikei River at Riverstone	Exotic Forest	1960.2	24%	8073.3
	Exotic Vegetation	169.0	2%	
	Native Forest	5398.3	67%	
	Other	7.1	0%	
	Pastoral	522.3	6%	
	Urban Residential	15.4	0%	
	Water	1.1	0%	

Appendix B4 – sub-FMU landuse statistics

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
Akatarawa	Exotic Forest	2007.2	17%	11650.7
	Exotic Vegetation	75.1	1%	
	Native Forest	9158.7	79%	
	Other	3.7	0%	
	Pastoral	383.5	3%	
	Urban Commercial	6.1	0%	
	Urban Residential	13.9	0%	
	Water	2.5	0%	
Duck Creek	Exotic Forest	137.9	13%	1061.2
	Exotic Vegetation	54.8	5%	
	Native Forest	76.5	7%	
	Other	87.5	8%	
	Pastoral	532.1	50%	
	Urban Commercial	10.9	1%	
	Urban Industrial	1.7	0%	
	Urban Residential	157.5	15%	
	Water	2.2	0%	
Eastbourne	Exotic Forest	8.6	1%	1010.7
	Exotic Vegetation	205.7	20%	
	Native Forest	605.0	60%	
	Other	27.4	3%	
	Pastoral	29.8	3%	
	Urban Commercial	5.2	1%	
	Urban Industrial	0.7	0%	
	Urban Residential	128.2	13%	
Kaitoke	Exotic Forest	36.0	0%	10937.8
	Exotic Vegetation	192.9	2%	
	Native Forest	10697.8	98%	
	Other	1.2	0%	
	Pastoral	9.5	0%	
	Water	0.5	0%	
Kaiwharawhara Estuary	Native Forest	0.4	71%	0.6
	Other	0.1	15%	
	Urban Commercial	0.1	14%	
Kaiwharawhara Stream	Exotic Forest	89.1	5%	1687.4
	Exotic Vegetation	281.7	17%	

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Native Forest	596.9	35%	
	Other	56.5	3%	
	Pastoral	49.9	3%	
	Urban Commercial	31.5	2%	
	Urban Industrial	10.3	1%	
	Urban Residential	567.7	34%	
	Water	3.7	0%	
Karori Stream	Exotic Forest	123.5	4%	3103.3
	Exotic Vegetation	1591.4	51%	
	Native Forest	674.1	22%	
	Other	41.7	1%	
	Pastoral	347.1	11%	
	Urban Commercial	6.9	0%	
	Urban Industrial	0.6	0%	
	Urban Residential	318.0	10%	
Korokoro Estuary	Native Forest	0.0	1%	0.2
	Other	0.1	93%	
	Urban Residential	0.0	7%	
Korokoro Stream	Exotic Forest	197.2	12%	1672.7
	Exotic Vegetation	193.8	12%	
	Native Forest	905.5	54%	
	Other	14.7	1%	
	Pastoral	300.1	18%	
	Urban Commercial	3.2	0%	
	Urban Industrial	12.0	1%	
	Urban Residential	46.2	3%	
Lake Kōhangapiripiri	Exotic Vegetation	0.7	3%	22.4
	Native Forest	9.7	43%	
	Other	1.2	5%	
	Water	10.8	48%	
Lake Kōhangatera	Exotic Vegetation	3.1	5%	67.2
	Native Forest	45.8	68%	
	Other	0.7	1%	
	Water	17.6	26%	
Mākara Estuary	Exotic Vegetation	0.0	1%	9.3
	Native Forest	3.9	41%	
	Other	0.2	3%	
	Pastoral	1.2	13%	

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Urban Residential	0.2	2%	
	Water	3.8	40%	
Mangaroa	Exotic Forest	1649.1	16%	10370.5
	Exotic Vegetation	399.3	4%	
	Native Forest	5050.4	49%	
	Other	24.3	0%	
	Pastoral	3178.0	31%	
	Urban Commercial	0.9	0%	
	Urban Industrial	8.7	0%	
	Urban Residential	59.0	1%	
	Water	0.8	0%	
Ōrongorongo	Exotic Forest	20.8	0%	9578.6
	Exotic Vegetation	1288.8	13%	
	Native Forest	7722.2	81%	
	Other	326.0	3%	
	Pastoral	220.9	2%	
Pākuratahi	Exotic Forest	646.0	8%	8048.0
	Exotic Vegetation	852.5	11%	
	Native Forest	5613.6	70%	
	Other	26.0	0%	
	Pastoral	909.4	11%	
	Urban Residential	0.5	0%	
Parangārahu catchment streams	Exotic Forest	2.1	0%	2785.7
	Exotic Vegetation	1058.3	38%	
	Native Forest	1205.6	43%	
	Other	48.1	2%	
	Pastoral	471.8	17%	
Plimmerton & Pukerua Bay	Exotic Forest	41.4	2%	2139.6
	Exotic Vegetation	242.7	11%	
	Native Forest	351.6	16%	
	Other	87.8	4%	
	Pastoral	1136.0	53%	
	Urban Commercial	28.4	1%	
	Urban Industrial	6.7	0%	
	Urban Residential	244.9	11%	
	Water	0.1	0%	
Pouewe (Battle Hill)	Exotic Forest	1503.4	27%	5639.6
	Exotic Vegetation	585.6	10%	

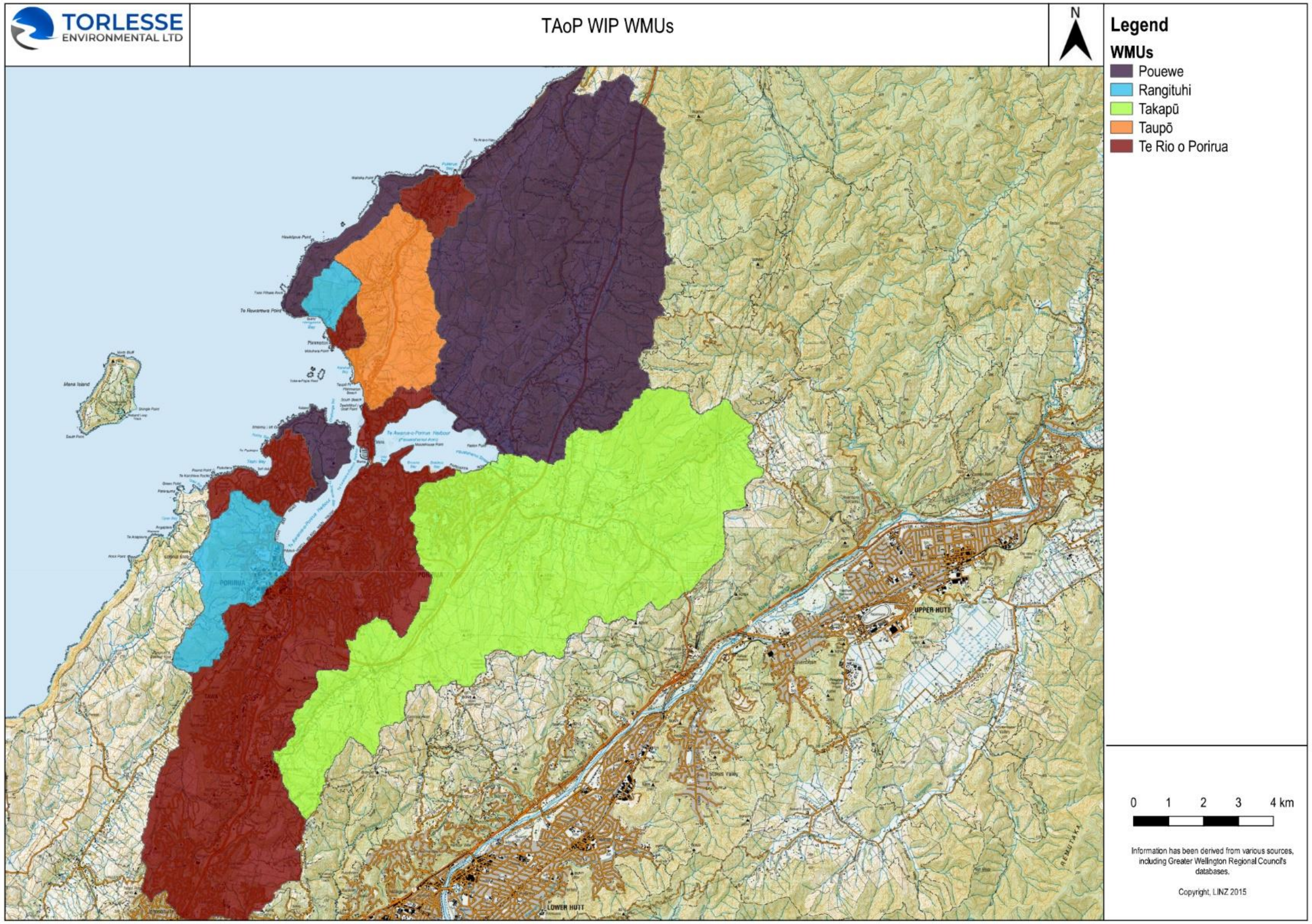
Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Native Forest	753.9	13%	
	Other	25.0	0%	
	Pastoral	2766.9	49%	
	Urban Residential	3.8	0%	
	Water	1.0	0%	
Rangituhi	Exotic Forest	5.1	1%	648.8
	Exotic Vegetation	63.6	10%	
	Native Forest	255.8	39%	
	Other	22.9	4%	
	Pastoral	87.2	13%	
	Urban Commercial	58.1	9%	
	Urban Industrial	35.5	5%	
	Urban Residential	120.6	19%	
South-west coast rural streams	Exotic Forest	630.6	4%	14596.3
	Exotic Vegetation	5373.7	37%	
	Native Forest	825.7	6%	
	Other	167.7	1%	
	Pastoral	7579.9	52%	
	Urban Commercial	3.1	0%	
	Urban Industrial	0.1	0%	
	Urban Residential	8.3	0%	
	Water	7.1	0%	
Takapū	Exotic Forest	612.6	14%	4251.9
	Exotic Vegetation	181.9	4%	
	Native Forest	870.3	20%	
	Other	87.3	2%	
	Pastoral	2439.4	57%	
	Urban Commercial	5.0	0%	
	Urban Industrial	1.9	0%	
	Urban Residential	53.1	1%	
	Water	0.4	0%	
Te Awa Kairangi Estuary	Native Forest	2.8	34%	8.4
	Other	0.1	2%	
	Urban Commercial	0.0	0%	
	Urban Industrial	0.1	1%	
	Water	5.3	63%	
Te Awa Kairangi urban streams	Exotic Forest	1280.8	9%	13541.3
	Exotic Vegetation	701.5	5%	

Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
	Native Forest	4712.3	35%	
	Other	1299.3	10%	
	Pastoral	1437.9	11%	
	Urban Commercial	695.0	5%	
	Urban Industrial	287.5	2%	
	Urban Residential	2822.8	21%	
	Water	304.4	2%	
Te Rio o Porirua (Porirua Stream)	Exotic Forest	518.2	8%	6098.3
	Exotic Vegetation	594.3	10%	
	Native Forest	697.5	11%	
	Other	602.3	10%	
	Pastoral	1594.5	26%	
	Urban Commercial	256.2	4%	
	Urban Industrial	111.1	2%	
	Urban Residential	1724.2	28%	
	Water	0.0	0%	
Titahi Bay	Exotic Forest	7.7	1%	657.5
	Exotic Vegetation	104.9	16%	
	Native Forest	36.1	5%	
	Other	117.9	18%	
	Pastoral	130.5	20%	
	Urban Commercial	7.7	1%	
	Urban Industrial	26.3	4%	
	Urban Residential	225.5	34%	
	Water	0.9	0%	
Wainuiomata rural streams	Exotic Forest	351.1	5%	7115.5
	Exotic Vegetation	2163.8	30%	
	Native Forest	3348.0	47%	
	Other	125.2	2%	
	Pastoral	1107.3	16%	
	Urban Commercial	0.1	0%	
	Urban Industrial	0.0	0%	
	Urban Residential	9.7	0%	
	Water	10.2	0%	
Wainuiomata small forested	Exotic Forest	5.6	0%	4923.6
	Exotic Vegetation	172.5	4%	
	Native Forest	4728.9	96%	
	Pastoral	16.6	0%	

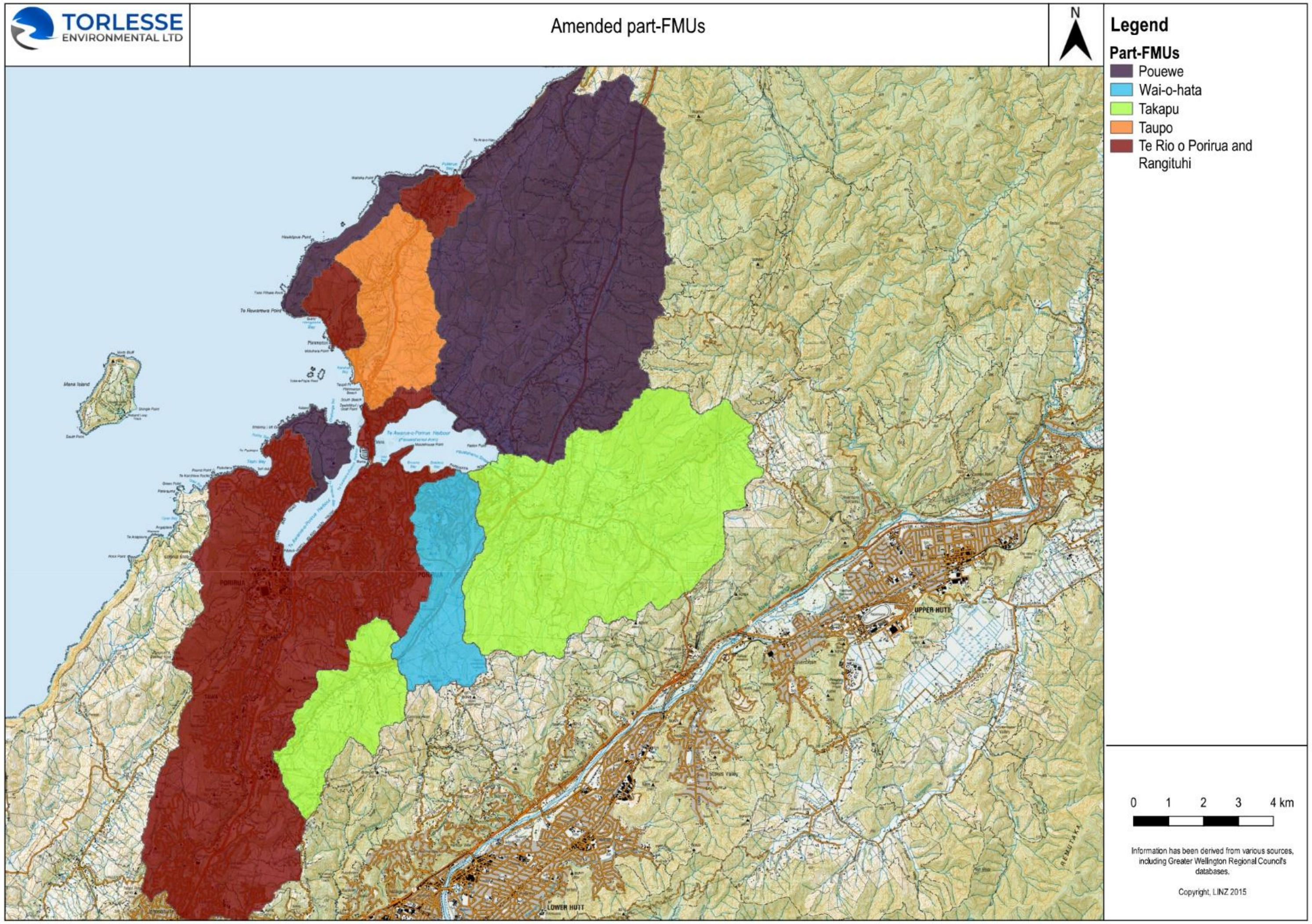
Sub-catchment name	Land Use	Area (ha)	Percentage	Total (ha)
Wainuiomata urban streams	Exotic Forest	11.6	1%	1557.0
	Exotic Vegetation	220.9	14%	
	Native Forest	474.3	30%	
	Other	130.6	8%	
	Pastoral	142.8	9%	
	Urban Commercial	30.5	2%	
	Urban Industrial	18.7	1%	
	Urban Residential	527.5	34%	
	Water	0.1	0%	
Waiwhetū Stream	Exotic Forest	8.9	0%	1959.6
	Exotic Vegetation	376.3	19%	
	Native Forest	473.3	24%	
	Other	135.3	7%	
	Pastoral	12.2	1%	
	Urban Commercial	54.8	3%	
	Urban Industrial	188.1	10%	
	Urban Residential	709.0	36%	
	Water	1.8	0%	
Wellington Urban	Exotic Forest	311.3	5%	6241.9
	Exotic Vegetation	646.4	10%	
	Native Forest	1365.2	22%	
	Other	614.0	10%	
	Pastoral	59.8	1%	
	Urban Commercial	435.3	7%	
	Urban Industrial	340.1	5%	
	Urban Residential	2469.8	40%	
Whakatikei	Exotic Forest	1960.2	24%	8077.1
	Exotic Vegetation	169.0	2%	
	Native Forest	5401.0	67%	
	Other	7.1	0%	
	Pastoral	522.6	6%	
	Urban Residential	15.4	0%	
	Water	1.7	0%	

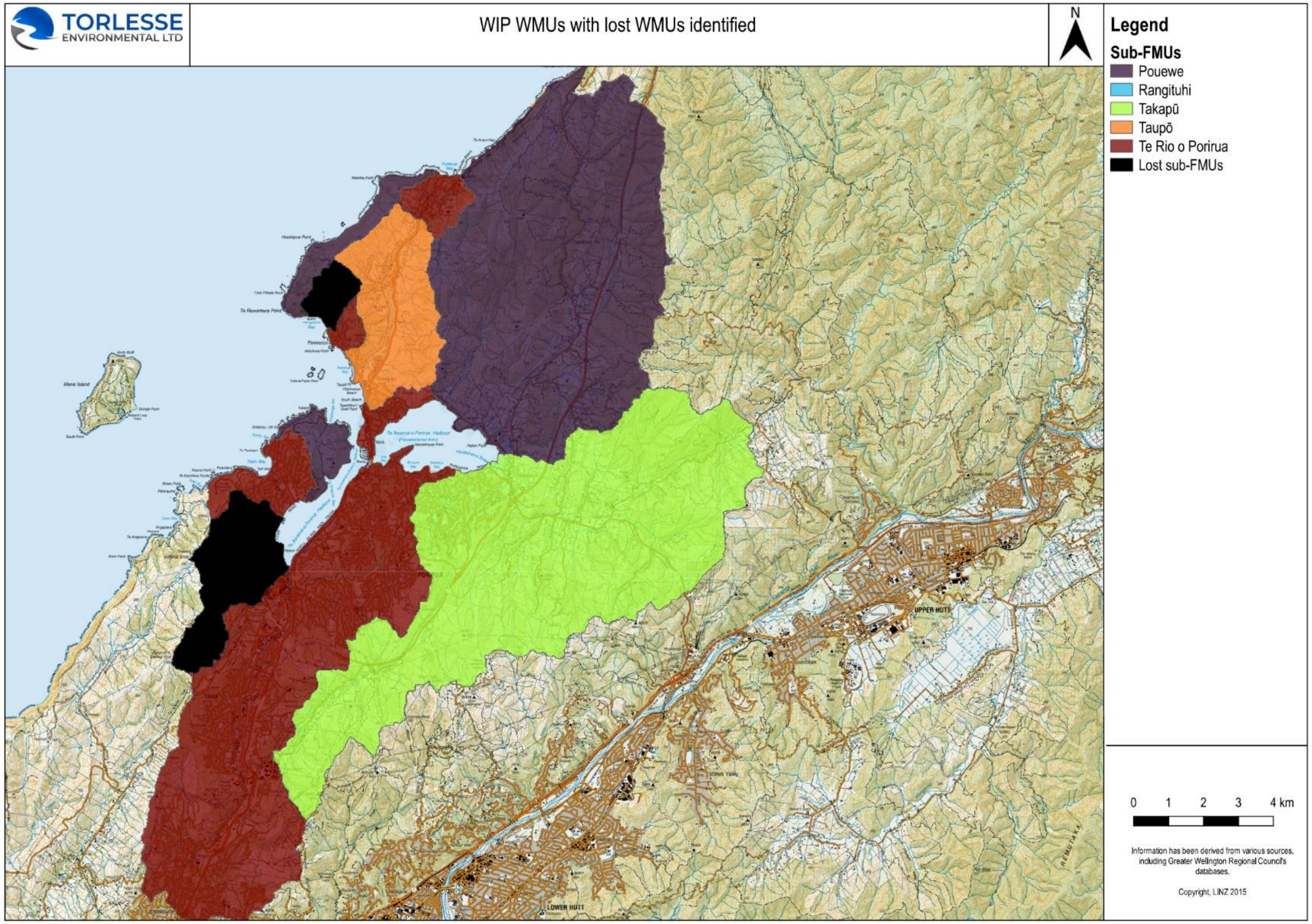
Appendix C – TAoP Whaitua part-FMU refinement process maps (Section 3)

TORLESSE ENVIRONMENTAL LTD



Amended part-FMUs




TORLESSE
ENVIRONMENTAL LTD
WIP WMUs with lost WMUs identified
N
Legend
Sub-FMUs
Pouewe
Rangituhi
Takapū
Taupō
Te Rio o Porirua
Lost sub-FMUs
UPPER HUTT
LOWER HUTT
0 1 2 3 4 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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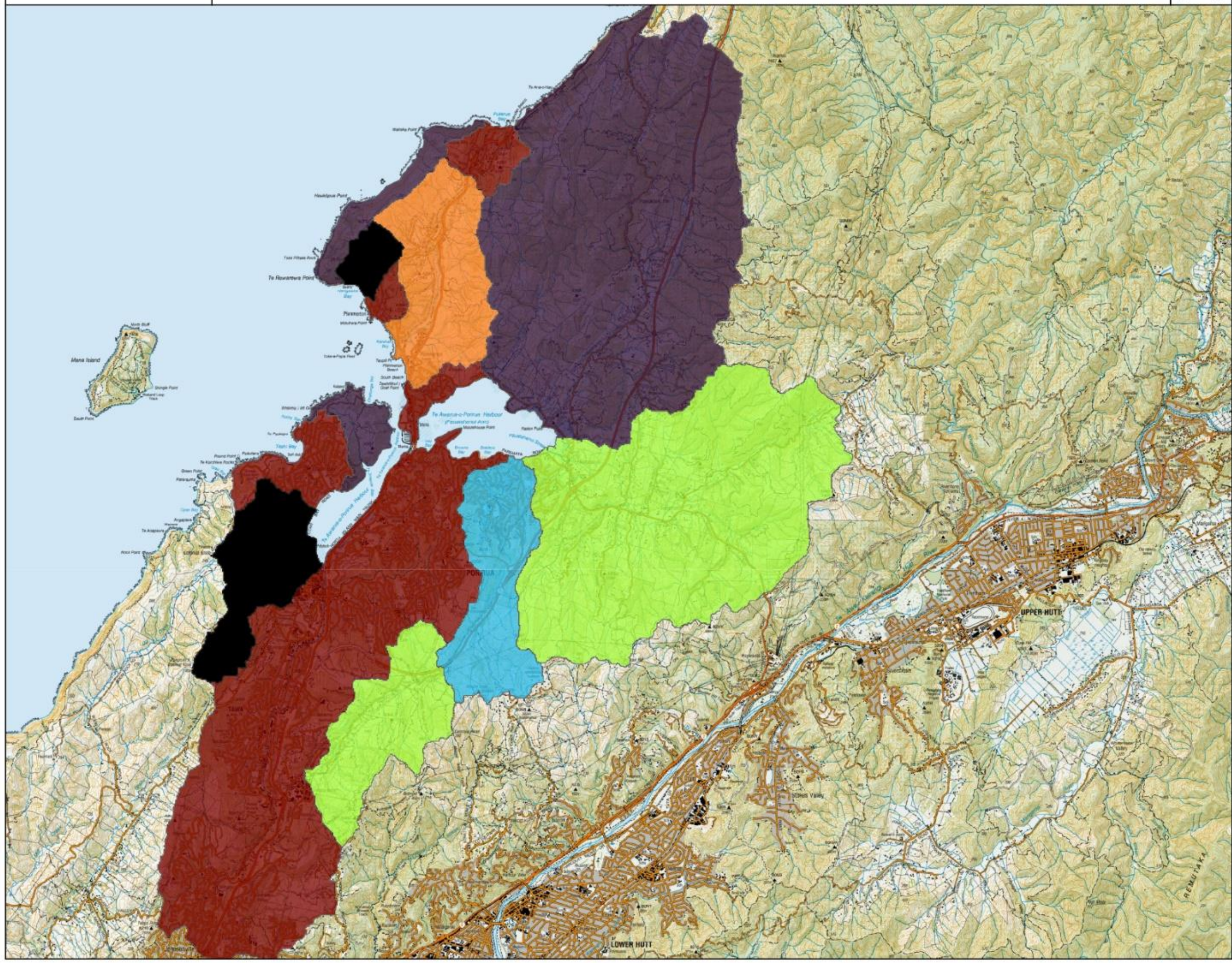
Amended part-FMUs with lost WIP WMUs identified



Legend

Part-FMUs

- Pouewe
- Wai-o-hata
- Takapu
- Taupo
- Te Rio o Porirua and Rangituhi
- Lost sub-FMUs

0 1 2 3 4 km

Information has been derived from various sources, including Greater Wellington Regional Council's databases.

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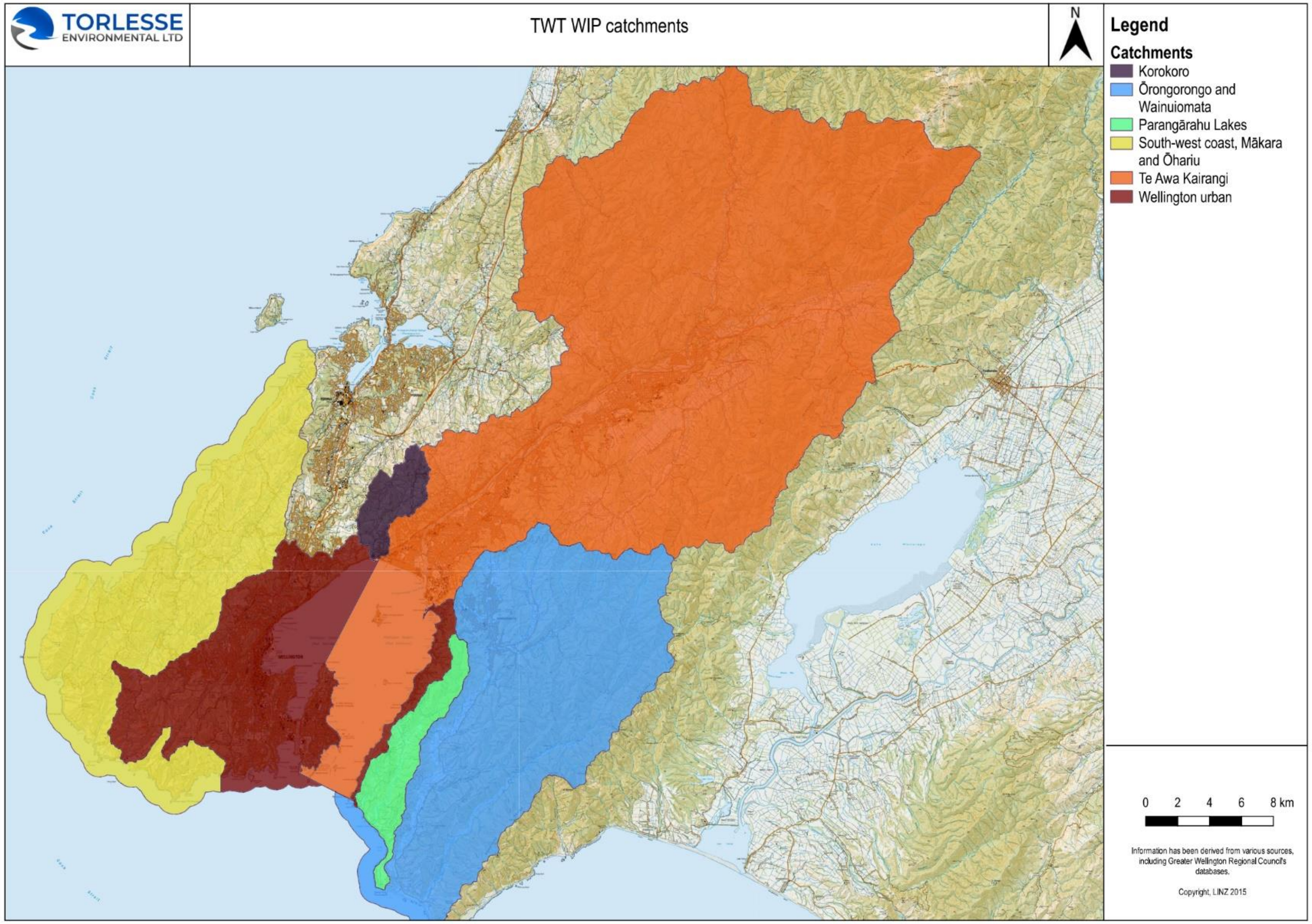
Appendix D – WTWT part-FMU refinement process maps (Section 3)


TORLESSE ENVIRONMENTAL LTD
TWT WIP catchments
N
Legend
Catchments
Korokoro
Ōrongorongo and Wainuiomata
Parangārahu Lakes
South-west coast, Mākara and Ōhariu
Te Awa Kairangi
Wellington urban
0 2 4 6 8 km
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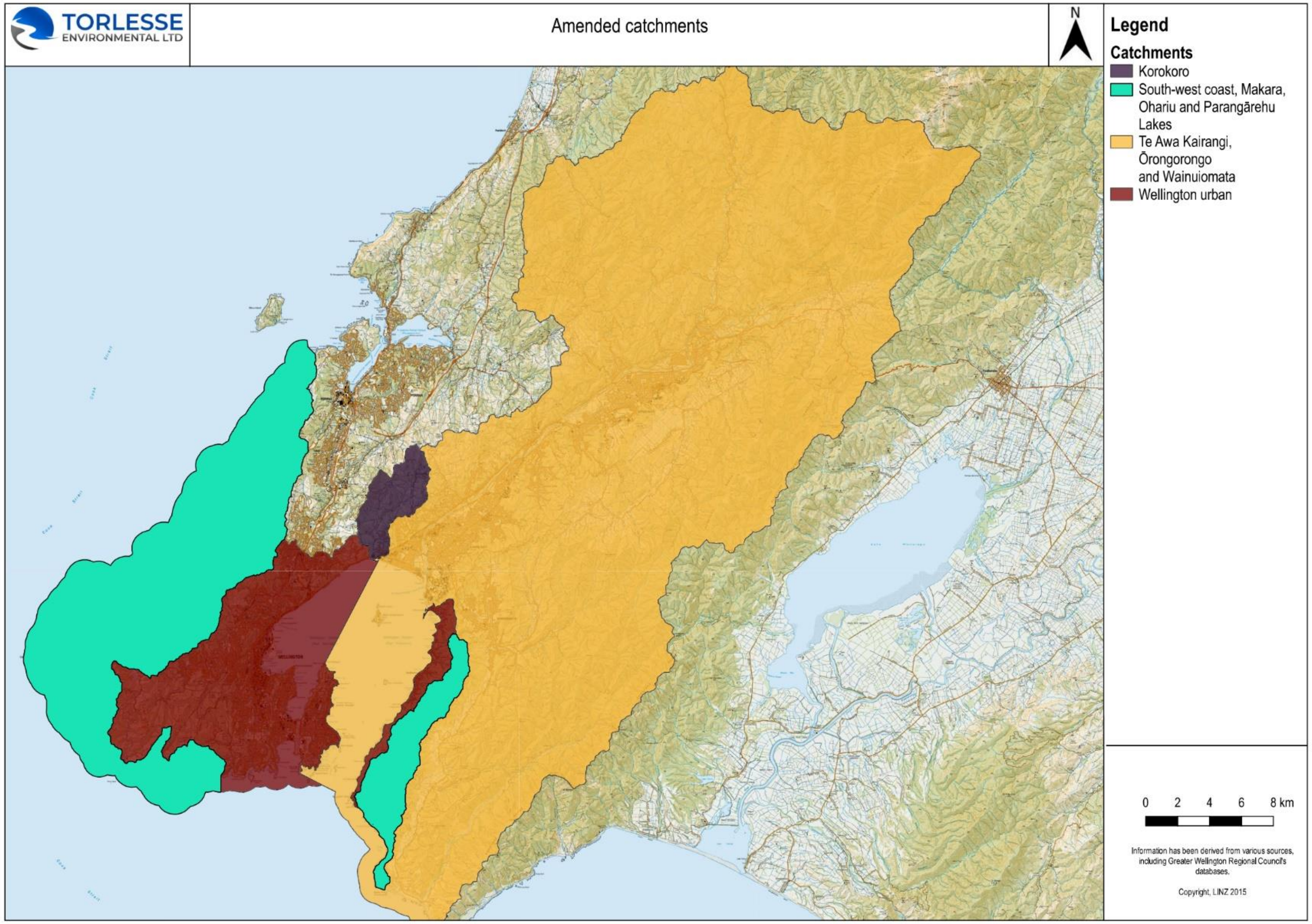
Amended catchments
N
Legend
Catchments
Korokoro
South-west coast, Makara, Ohariu and Parangārehu Lakes
Te Awa Kairangi, Ōrongorongo and Wainuiomata
Wellington urban
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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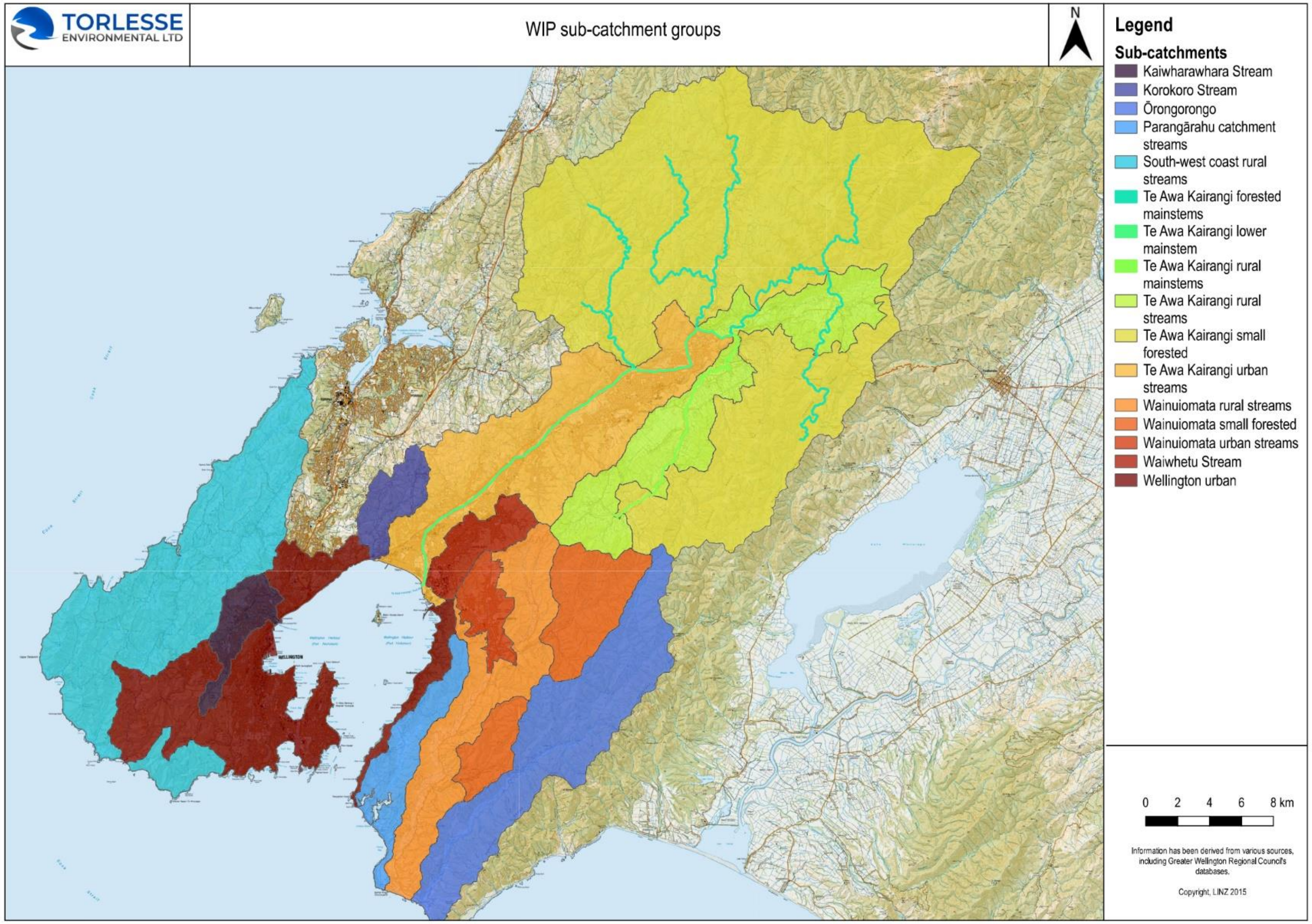
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WIP sub-catchment groups
N
Legend
Sub-catchments
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Korokoro Stream
Ōrongorongo
Parangārahu catchment streams
South-west coast rural streams
Te Awa Kairangi forested mainstems
Te Awa Kairangi lower mainstem
Te Awa Kairangi rural mainstems
Te Awa Kairangi rural streams
Te Awa Kairangi small forested
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata small forested
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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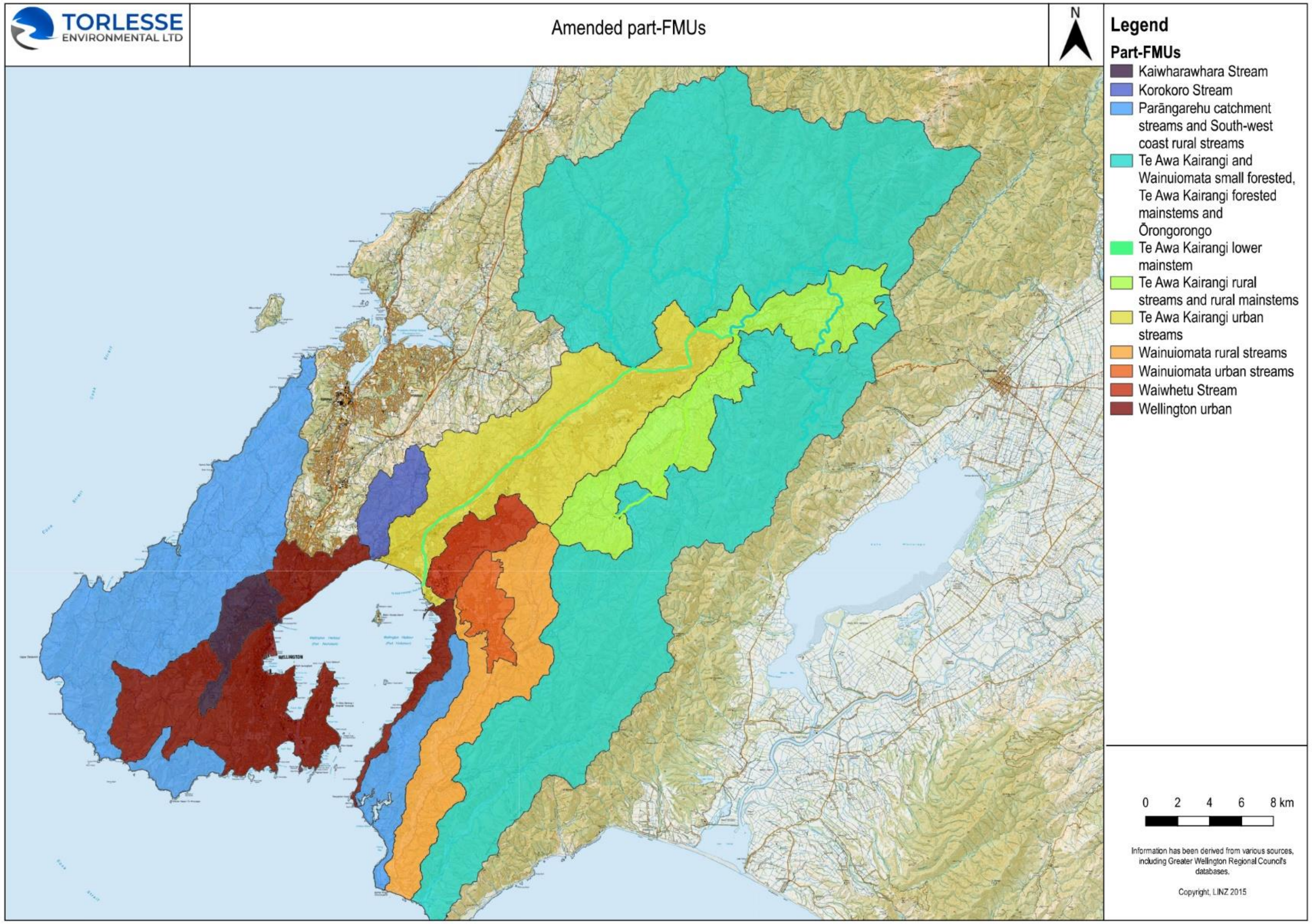
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Korokoro Stream
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Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Ōrongorongo
Te Awa Kairangi lower mainstem
Te Awa Kairangi rural streams and rural mainstems
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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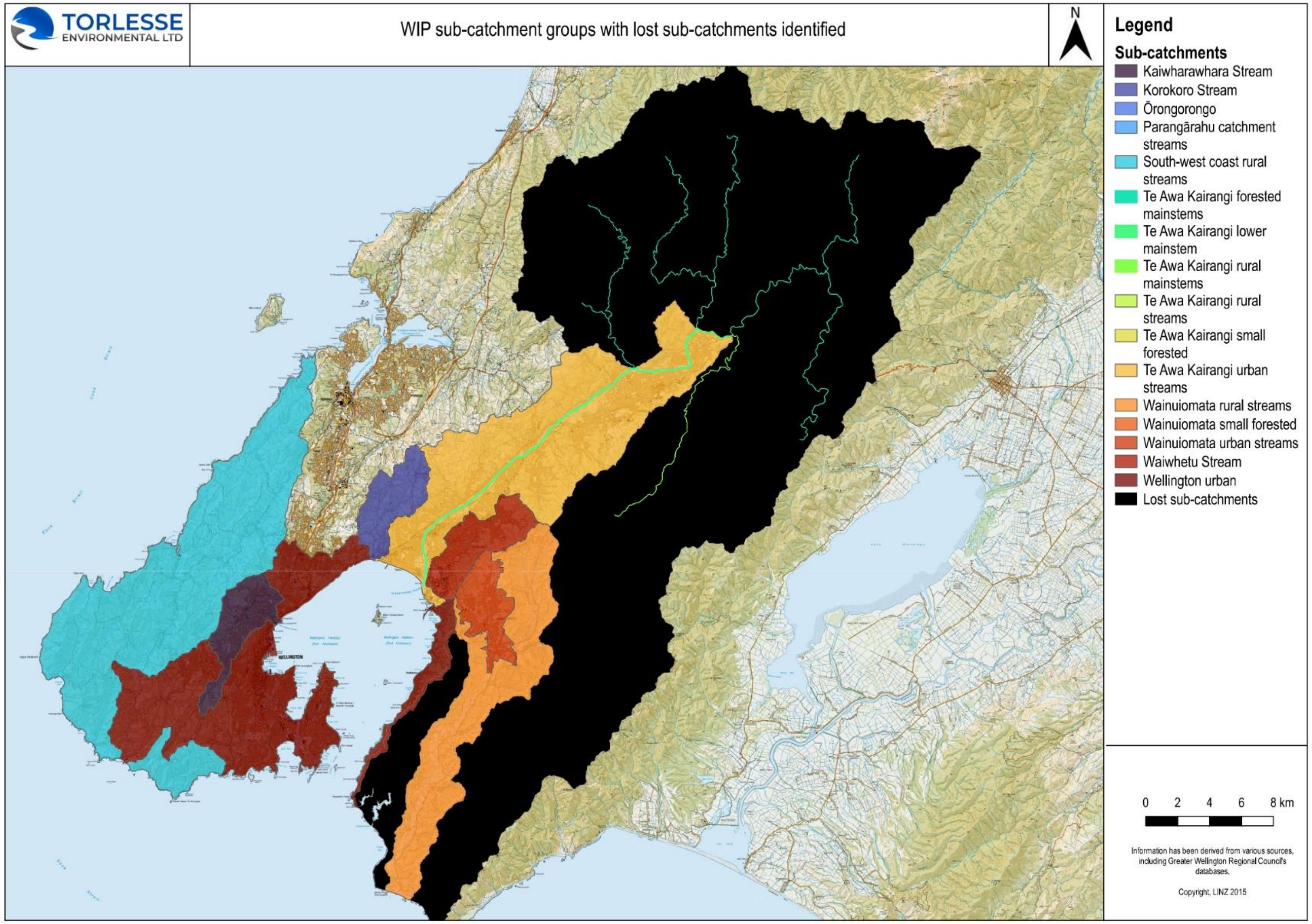
TORLESSE
ENVIRONMENTAL LTD
WIP sub-catchment groups with lost sub-catchments identified
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Legend
Sub-catchments
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Ōrongorongo
Parangārahu catchment streams
South-west coast rural streams
Te Awa Kairangi forested mainstems
Te Awa Kairangi lower mainstem
Te Awa Kairangi rural mainstems
Te Awa Kairangi rural streams
Te Awa Kairangi small forested
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata small forested
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
Lost sub-catchments
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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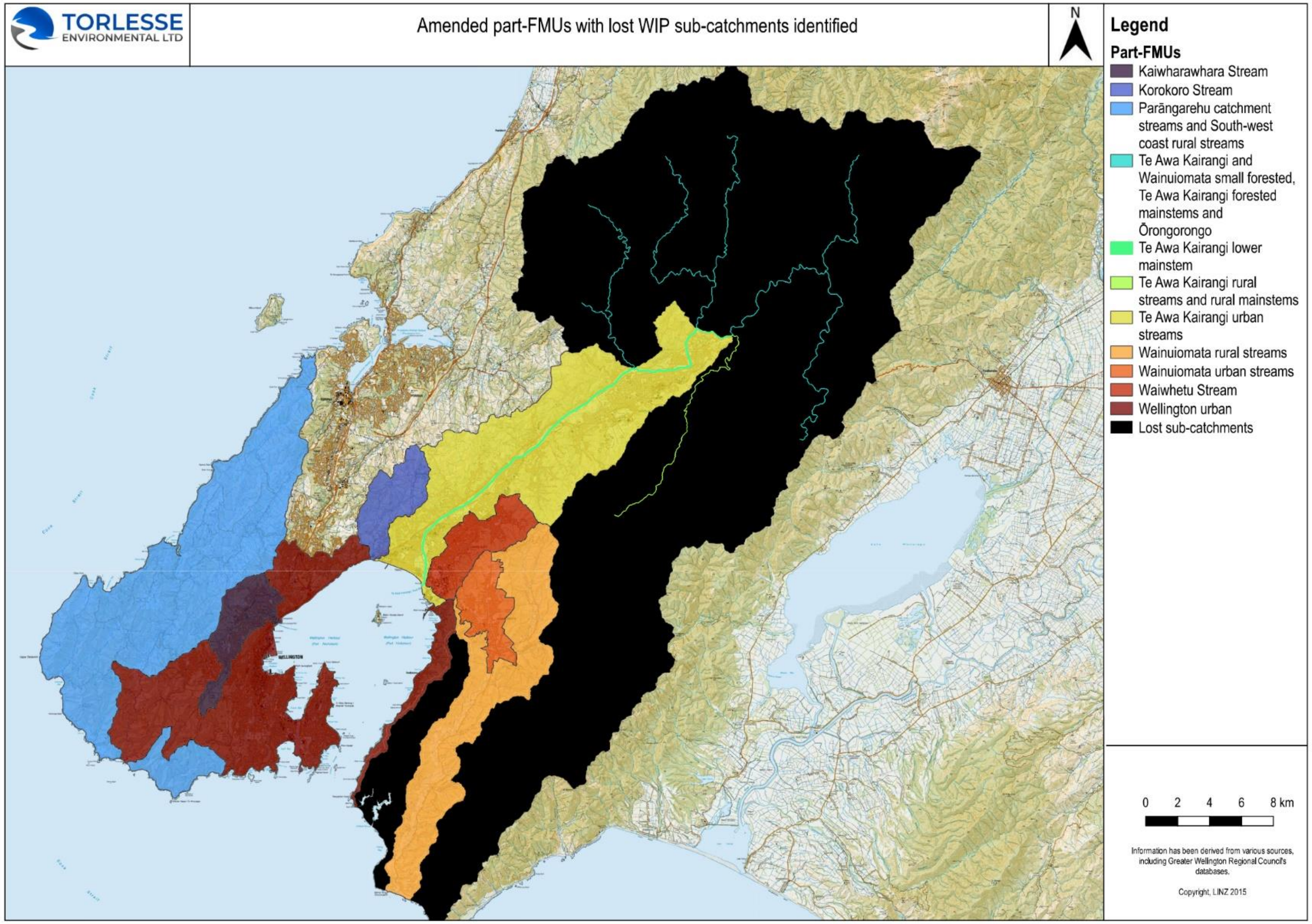
TORLESSE ENVIRONMENTAL LTD
Amended part-FMUs with lost WIP sub-catchments identified
N
Legend
Part-FMUs
Kaiwharawhara Stream
Korokoro Stream
Parāngarehu catchment streams and South-west coast rural streams
Te Awa Kairangi and Wainuiomata small forested, Te Awa Kairangi forested mainstems and Ōrongorongo
Te Awa Kairangi lower mainstem
Te Awa Kairangi rural streams and rural mainstems
Te Awa Kairangi urban streams
Wainuiomata rural streams
Wainuiomata urban streams
Waiwhetu Stream
Wellington urban
Lost sub-catchments
0 2 4 6 8 km
Information has been derived from various sources, including Greater Wellington Regional Council's databases.
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Appendix E – Validation of nutrient criteria to achieve periphyton target attribute states in the Greater Wellington Region (Section 6)

Memorandum: Validation of nutrient criteria to achieve periphyton target attribute states in the Greater Wellington Region

Author: Ton Snelder LWP Ltd

Date: 14 November 2022

Introduction

The NPS-FM 2020 requires that regional councils set instream concentrations and exceedance criteria for nutrients to achieve target attribute states for periphyton biomass. The NPS-FM periphyton attribute is defined as the algal component of periphyton as chlorophyll *a*, mg m^{-2}. Exceedances of specified biomass thresholds are allowed in no more than one in 12 samples (based on monthly monitoring), which is the 92nd percentile of the distribution of monthly periphyton biomass observations. The NPS-FM specifies that the 92nd percentile is assessed from monthly observations made over at least three years. Thresholds of 50, 120 and 200 mg m^{-2} define the upper boundaries of the NPS-FM A, B and C bands, which indicate a scale of potential target attribute states from very high to minimum acceptable levels of environmental protection.

To assist councils, the Ministry for the Environment (MFE) commissioned the development of nutrient criteria to achieve a range of target attribute states based on modelling that was informed by a national dataset of 251 sites located across New Zealand (T Snelder *et al.*, 2022). Snelder *et al.* (2022) provide nutrient criteria in a series of look-up tables that apply to all hard-bottomed (i.e., cobble- or gravel-bed) streams and rivers, which are classified into one of 21 River Environment Classification (REC) Source-of-flow classes. Criteria were derived to apply to both shaded and unshaded sites.

An important feature of the criteria provided by Snelder *et al.* (2022) is the inclusion of under-protection risk. The under-protection risk concept arises due to the uncertainty associated with the statistical models underlying the nutrient criteria in the look-up tables. The models predict the periphyton biomass given the nutrient concentration, but they are uncertain at the level of individual sites. The models are more reliably used to predict the proportion of sites that exceed a given periphyton biomass. The criteria therefore require the user to choose both the target periphyton biomass (i.e., target attribute state) and the acceptable proportion of sites that can exceed this level of biomass. The proportion of sites that can exceed the target periphyton biomass is referred to as the under-protection risk because it is the probability that a randomly chosen site will exceed the target biomass despite having nutrient concentrations equal to, or lower than, the criterion for that site.

The derived criteria are intended to provide default values that can be used in the absence of other more appropriate criteria (e.g., potentially from locally derived observations and modelling). Guidance provided by MFE (2022) suggests that use of the look-up tables to define criteria, for example within a region, should be accompanied by a verification that considers whether the nutrient criteria are reasonably consistent with local observations of relationships between periphyton abundance and nutrient concentrations. There are limited ways to assess confidence in the criteria. However, where a monitoring network for periphyton and nutrients exists within a region, a validation analysis can be performed with the following seven steps:

Obtain the median concentration of each nutrient and 92nd percentile biomass from the observations at each monitoring site.

Obtain the REC source-of-flow class and shade status for each site.

For a fixed nutrient and level of under-protection risk, obtain the criteria for the A, B and C bands for each site based on the site's REC source-of-flow class and shade status.

For each nutrient and site, interpolate the biomass from the criteria by:

a) treating the biomass thresholds (upper limits) for A, B and C bands of 50, 120 and 200 mg m^{-2} as the variable Y and nutrient criteria from the look-up tables for each band as the variable X

b) interpolating the biomass from the above Y values for the value of X defined by the observed site nutrient concentration

c) treating the interpolated biomass as a prediction.

Calculate, over all sites, the proportion of observed values that exceed the above predicted values.

Repeat this process for each nutrient and level of under-protection risk.

Assess whether the nutrient criteria are consistent with the observations by comparing the proportion of sites for which observations exceed the predictions with the levels of under-protection risk.

MFE (2022) suggests that reasonable agreement between the observed proportion of sites and level of under-protection risk can be interpreted as evidence that the nutrient criteria are valid for the sites represented by the monitoring network. MFE (2022) notes that perfect agreement should not be expected and that divergence between the proportion of observations that exceed the predictions, and the under-protection risk can be expected to decrease as the sample size increases. This memo reports on a verification analysis that was performed using periphyton and nutrient data collected by Greater Wellington Region Council (GWRC).

Data

For 16 sites located across the region (Figure E1), GWRC provided monthly observations of concentrations of four forms of nutrient: total nitrogen (TN), nitrate-nitrogen (NO3N), total phosphorus (TP) and dissolved reactive phosphorus (DRP). In addition, there were monthly observations of periphyton biomass as chlorophyll-a (CHLA). The majority of the 16 sites (11) belonged to the CW/L REC Source-of-flow class (Figure E1). The number of observations of CHLA at these sites varied between 40 and 62.

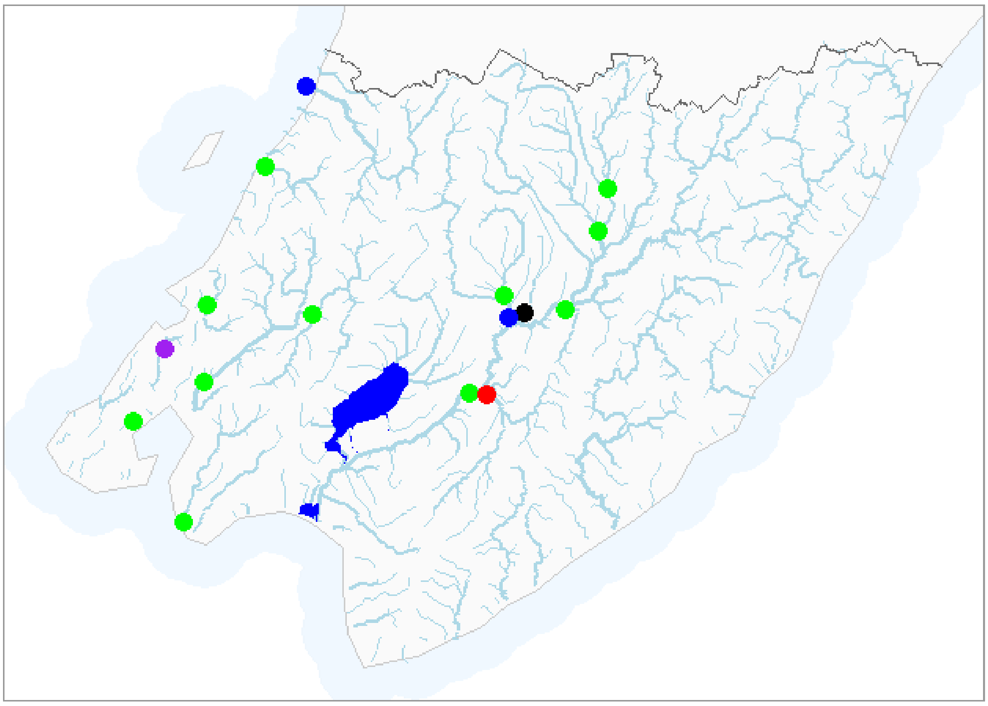

Figure E1. Location of the 16 periphyton monitoring sites in the Wellington region. Sites are colour coded by their Source-of-flow class.

The median values of TN, NO3N, TP and DRP and the mean and 92nd percentile of CHLA (CHLA92) were calculated for each site from the dataset. The standard error of estimate of the mean of CHLA was calculated and the precision of the estimated CHLA92 at each site was calculated based on the method of Wilson (1927) as recommended by Brown *et al.* (2001) and was expressed as the 95% confidence interval.

Validation analysis

The monthly CHLA observations at each site were mainly low values with occasional high values. CHLA92 exceeded 200 mg m^{-2} at three sites (Figure E2).

The distributions at each site approximately followed the theoretical exponential distribution (Figure E2). See Snelder *et al.* (2022) Section 5.1 for an explanation of the exponential distribution and how CHLA92 is estimated from the mean of the observed values based on the exponential distribution.

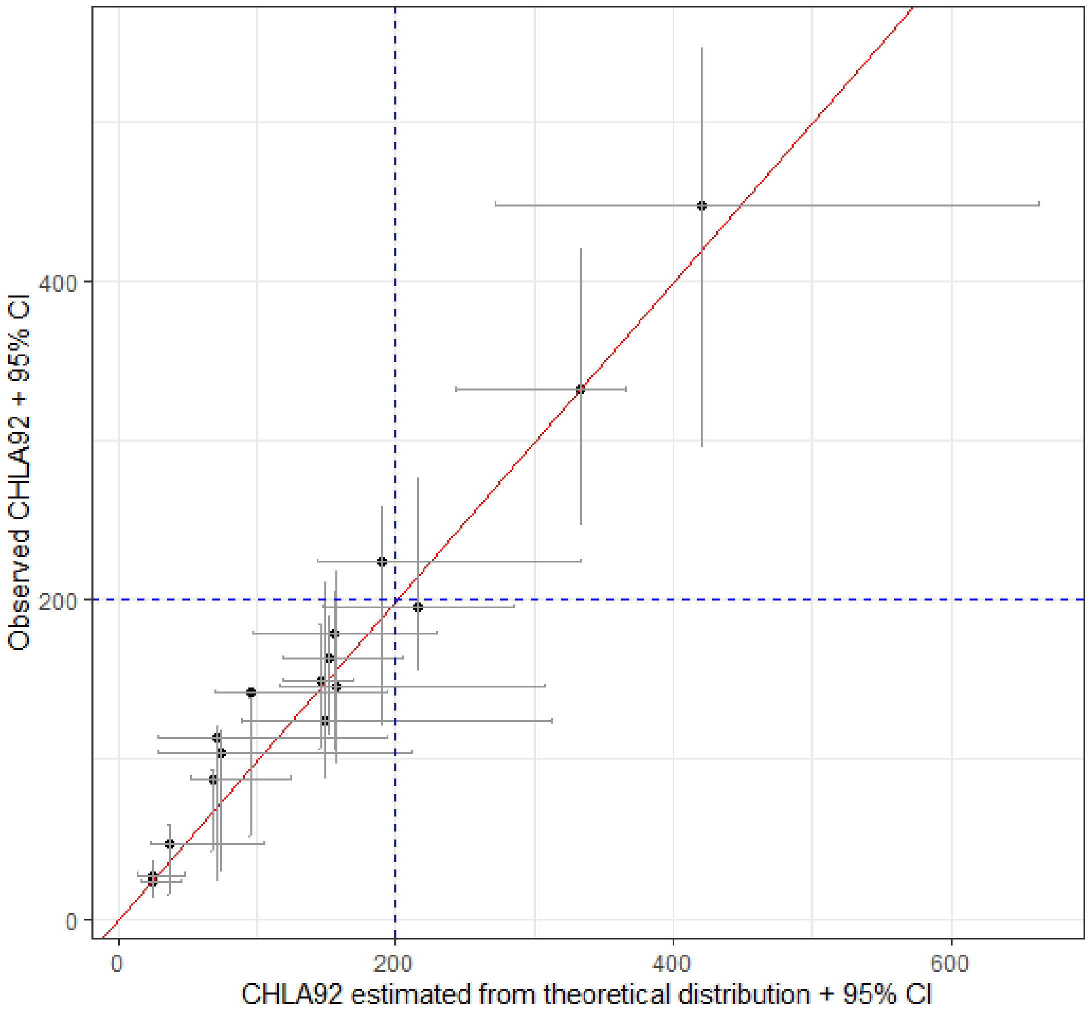

Figure E2. Relationship between observed CHLA92 for each site and the same value calculated from the mean of the observed values based on the theoretical (exponential) distribution. The error bars indicate the 95% confidence interval for both sets of estimates of CHLA92. The red dashed line is one to one. The blue dashed lines indicate CHLA92 values of 200 mg m^{-2}.

Predicted values of CHLA92 were derived for each site by interpolation of the nutrient criteria look-up tables (i.e., the observed median nutrient concentration at each site was used to evaluate CHLA92 from the look-up tables – see step 4 of validation procedure described above). The observed and predicted values of CHLA92 at the 16 sites in the Wellington region based on the four nutrient forms are shown as scatter plots in Figure E3. Theoretically, 5%, 10%, 15%, 20%, 30% and 50% of the sites should have observed biomass that exceeds the predicted biomass when the predictions are made based on the corresponding levels of under-protection risk (i.e., should lie above the red lines on Figure E3).

The data shown in Figure E3 indicate that the proportions of sites for which observed CHLA92 exceeds predicted CHLA92 increases systematically as the under-protection risk increases for all four nutrient forms. However, Table E1 indicates that the proportion of sites for which observed CHLA92 exceeds the predicted is higher than expected according to the level of under-protection risk for all four nutrient forms and for all levels of under protection risk. This indicates that the criteria are too permissive (i.e., the criteria concentrations are too high).

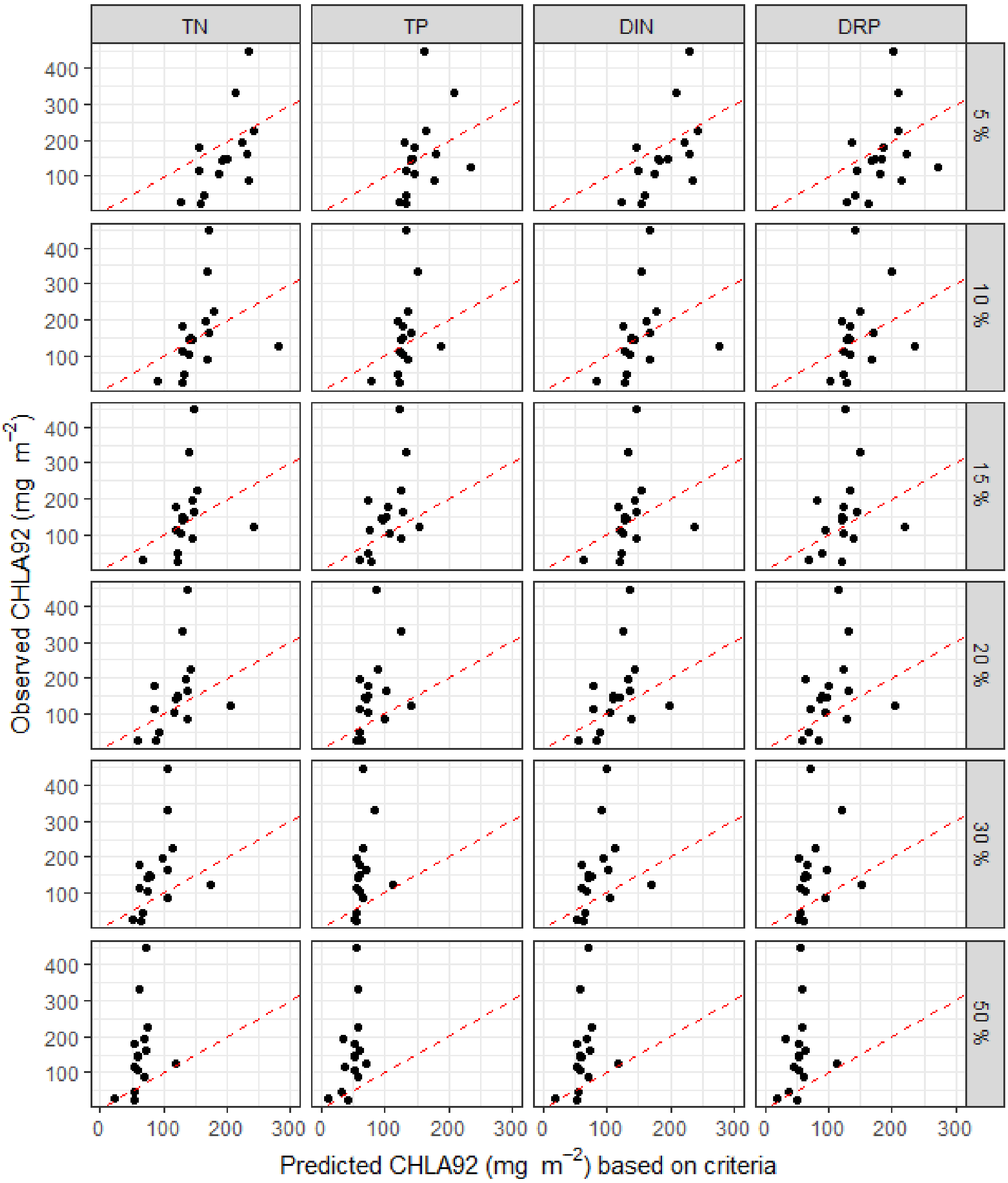

Figure E3. The observed and predicted values of CHLA92 at the 16 sites in the Wellington region where predicted values are derived from the nutrient criteria for under-protection risks of 5, 10,15, 20, 30 and 50%. Panel labels indicate the under-protection risks and the nutrient form (TN, DIN, TP and DRP). The dashed red diagonal (one to one) line represents agreement between the predictions and observations. The points lying below the red line indicate sites for which the observed biomass was less than that predicted by the targets and vice versa.

Table E1. Proportion of sites (%) for which observed biomass exceeds that predicted for the four levels of under-protection risk.

Under protection risk (%)	Nutrient form			
	TN	DIN	TP	DRP
5	19	19	50	25
10	50	50	56	50
15	56	56	62	62
20	62	69	69	69
30	69	69	81	69
50	88	88	94	94

Uncertainty of validation analysis

Because the observed values of CHLA92 are imprecise (i.e., are estimates of the population value calculated from the monthly samples), the above analysis is uncertain. A second analysis was undertaken to estimate the uncertainty of the first analysis. The second analysis repeated the first analysis but used a Monte Carlo simulation to generate 1000 “realisations” of the observed CHLA92 observations. For each site, a random error was added to the observed mean CHLA and then this “perturbed” mean was used to estimate CHLA92 based on theoretical empirical distribution (see Figure E2). The random error was derived by drawing from a normal distribution with a standard deviation equal to the standard error of the observed mean CHLA.

Figure E4 summarises the results of the Monte-Carlo procedure and shows the proportion of “exceeding” sites and the 95% confidence interval for each level of under-protection risk. In Figure E4, for all levels of under protection risk and all nutrient forms, the lower confidence limit is greater than the associated level of under-protection risk (indicated by horizontal lines). For example, for TN and the 15% under-protection risk, the 95% CI for the proportion of “exceeding” sites extends between 32% and 60% with a best estimate of 40%. This confirms the results of the first validation analysis and means that, globally, we are confident that the observations are inconsistent with the criteria (i.e., the criteria are too permissive, which means the criteria concentrations are too high).

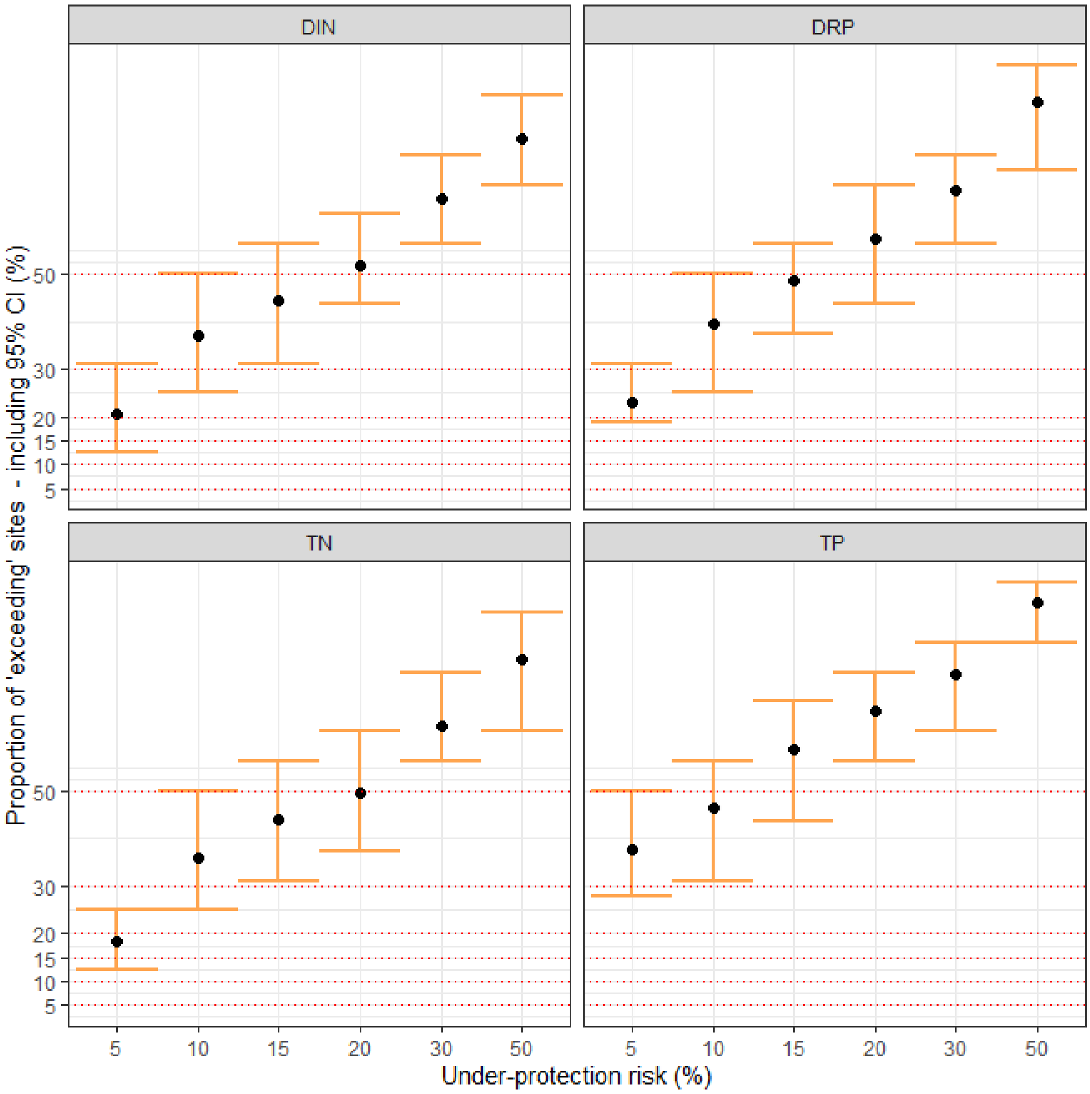

Figure E4. Proportion of "exceeding" sites (i.e., sites that are under-protected) for each level of under-protection risk (x-axis). The error bars indicate the 95% confidence interval of the observed "exceeding" sites, which was generated from a Monte Carlo analysis.

Comparison of site data with the models underlying the criteria

The observed CHLA92 was compared with predictions made using the models underlying the criteria, which are fully described by Snelder *et al.* (2022). There are four linear regression models each including one of the four nutrient forms as a predictor. Each model also includes several other predictors describing the hydrological regime, electrical conductivity, turbidity and shade at each site. The predictor values for all 16 GWRC sites are available from the dataset described by Snelder *et al.* (2022) and together with the observed nutrient concentrations were used to predict CHLA92 at each site.

Predictions of CHLA92 for the 16 GWRC sites generally under-estimated[18] the observed values (Figure E5). This is indicated by most points being above the red

[18] Note that under-estimation means the model is positively biased (Moriasi *et al.*, 2015).

dashed one-to-one lines in Figure E5. The average discrepancy between the observations and predictions was similar across all four nutrient forms and ranged from 38% to 47% (relative to the observed values).

Under-estimation by the model is consistent with the criteria being too permissive. This is most easily understood by considering a site at which the observed CHLA92 is just equal to a threshold (e.g., 200 mg m^{-2}, which defines the upper limit of the C band).

- The model will tend to under-estimate CHLA92 based on the observed nutrient concentration and will predict that the CHLA92 threshold has not been reached.
- The nutrient criterion derived from the model for a threshold of 200 mg m^{-2} will be higher than the observed nutrient concentration and therefore this will be too permissive because the (observed) CHLA92 threshold has been reached.

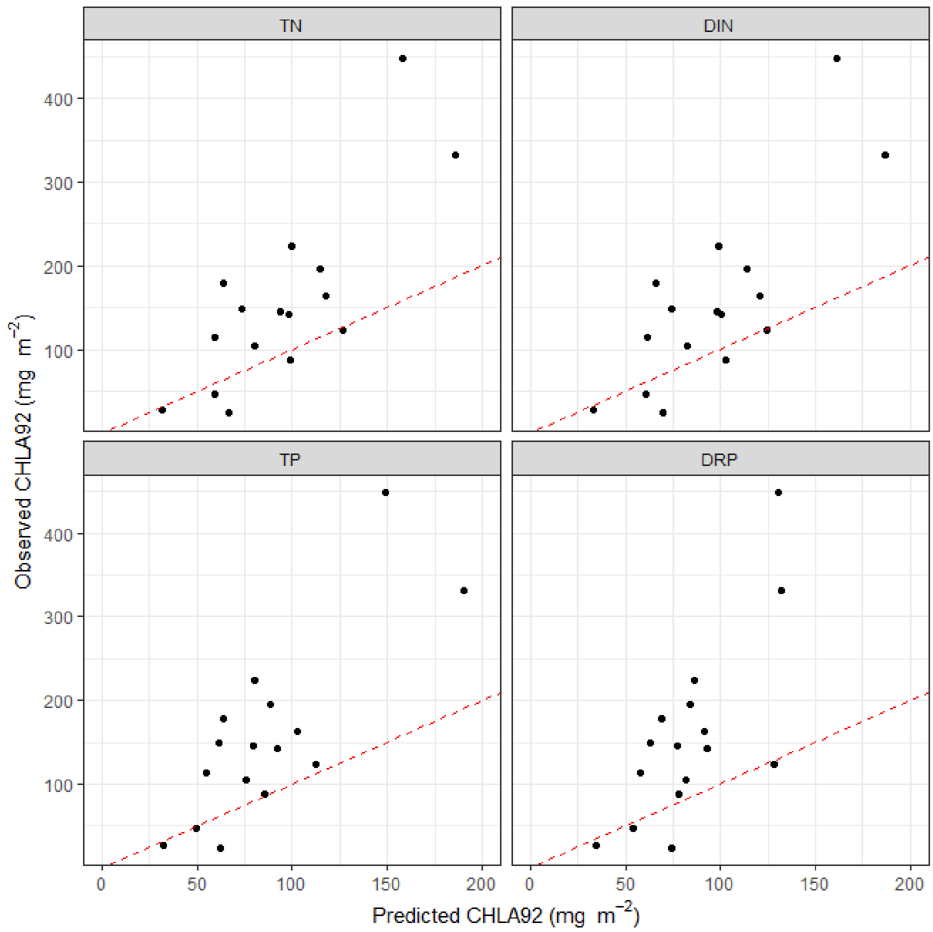

Figure E5. Predicted versus observed CHLA92 at each of the 16 sites. The dashed red diagonal (one to one) line represents agreement between the predictions and observations.

There are three potential contributing factors to the under-estimation of CHLA92 at most of the 16 GWRC site. First, the sampling sites in the Wellington region may be atypical compared to the 256 national sites that were used to fit the models underlying the criteria. Evidence that this may be the case is that the dataset used by Snelder *et al.* (2022) to derive the nutrient criteria had 20 sites (out of 251; i.e., 8%) with CHLA92 > 200 mg m^{-2}. However, of the 16 sites used in this validation study, three had CHLA92

> 200 mg m^{-2} (i.e., 19%) suggesting that high-biomass sites were over-represented. The risk the validation dataset is poorly representative increases as the sample size used to validate the criteria decreases. In addition, the small size of the sample (16 sites) could cause a validation result (i.e., that the criteria are too permissive) that is specific to this sample.

A second reason could be that the 16 sampled sites are representative of the region's rivers but the 256 sites that were used to derive the criteria were not. In other words, the biomass – nutrient relationship in rivers in the Wellington region differs appreciably from that represented by the 256 national sites. This risk increases as the sample size used to validate the criteria decreases, and the sample size of only 16 sites in this study is likely to be inadequate for inferring that that biomass – nutrient relationship in Wellington region's rivers differ from the modelled relationship.

Third, the models underlying the criteria were unable to explain "high" values of CHLA92 (Snelder *et al.* 2022) and this means that model predictions tended to under-estimate the observations). The models used by Snelder *et al.* (2022) to derive the nutrient criteria do not produce CHLA92 predictions appreciably greater than 200 mg m^{-2} at nutrient concentrations that are within the overall observed range. However, there were sites with CHLA92 > 200 mg m^{-2} in the data Snelder *et al.* (2022) used to derive the models. This indicates that sites with biomass greater than 200 mg m^{-2} were associated with factors that were not represented by the models[19]. The combination of the inability to predict CHLA92 > 200 mg m^{-2} and some observations in the dataset that exceeded this value led to the tendency for the model predictions to under-estimate the observations, which is referred to as positive bias (Moriasi *et al.*, 2015).

Snelder *et al.* (2022) corrected for retransformation bias[20] when deriving the criteria. However, there was no attempt to compensate for the positive bias of the underlying models. Therefore, as a further step in this validation exercise, the criteria were re-derived with an explicit correction for positive bias of the models and the validation for GWRC sites was repeated with the bias-corrected criteria[21]. The details and results are set out in the Appendix E1 to this memo. Although accounting for the bias did reduce the extent to which the validation indicates the criteria were too permissive, the

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[19] Snelder *et al.*. (2022) concluded that there are unknown factors that cause high biomass at some sites. High biomass sites were not generally associated with high nutrient concentrations which suggests that some factor or combination of factors produces high biomass, and that nutrient control is a necessary but not sufficient requirement for achieving biomass targets at these sites. The work was unable to determine what these factors are.

[20] A non-linear transformation of the response variable (e.g., fourth root transformation of CHLA92 in the models defined by Snelder *et al.*. 2022) is required to satisfy the assumption of normality for linear regression models. However, it introduces a bias when predictions made using this model are retransformed to the original units (e.g., by raising to the power of four in the models defined by Snelder *et al.*. 2022). A factor must be applied to correct for retransformation bias; Snelder *et al.*. (2022) used the method of Duan (1983).

[21] It is not entirely clear that correcting for the bias in this global manner (i.e., by adding an amount equal to the mean difference between observations and predictions) and then using the corrected predictions to generate criteria is appropriate. In this study, this approach was applied, but it did not appreciably improve the validation.

improvement was modest, and the validation still indicated that the bias-corrected criteria are too permissive.

Conclusions

The validation of the criteria of Snelder *et al.* (2022) for the Wellington region, based on 16 monitoring sites, indicates that the criteria are too permissive (i.e., biomass thresholds will be exceeded at more sites than expected given the selected under-protection risk even when nutrient criteria are complied with).

Snelder *et al.* (2022) derived the criteria from the best available dataset and based on models that were consistent with the conceptual understanding of nutrient – periphyton biomass relationships. The models and associated criteria account for variation in factors such as hydrological regime, electrical conductivity, turbidity and shade that mediate nutrient – periphyton biomass relationships. There is no reason to expect that the models and criteria are not reasonably applicable to rivers in the Wellington region. It is noted that the correlation between the model predictions and observations shown in Figure E5 indicate that the models correctly represent the direction of the relationships between biomass and the various explanatory variables that are included in the models.

Conceptually the procedure outlined in the MFE guidance is an appropriate way to validate the criteria, however, the results are influenced by biases that can arise for three reasons. First, the 16 monitoring sites may be atypical compared to the 256 national sites that were used to derive the criteria. There is no statistical approach that can confirm that the validation result obtained by this study is influenced by this type of bias other than by increasing the number of validation sites. Second, the sampled sites may be representative of the region's rivers but the 256 sites that were used to derive the criteria were not. Again, there is no statistical approach that that can confirm that the validation result obtained by this study is influenced by this type of bias other than by increasing the number of validation sites.

The third potential cause of bias is that the criteria themselves are derived from biased models. In this study, repeating the validation procedure using criteria re-derived with an explicit correction of the model predictions for this bias made only a modest reduction in the extent to which the validation indicated the criteria were too permissive. At this point, the options for improving the approach to defining the criteria have been exhausted.

A reasonable conclusion is that the criteria are the best available and are appropriate to use, but that they are uncertain. In addition, the best available evidence is the criteria are too permissive. These two points need to be considered if the criteria are to be used to set instream nutrient concentration requirements. For example, ideally any regulation would include the ability to update the instream nutrient concentration requirements in the future should the criteria be revised.

An alternative conclusion is that different criteria should be used or derived, perhaps based on a region-specific analysis. The problem with this is that it is unlikely that more certain criteria can be derived given the small number of regional sites for which there is data.

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Appendix E1: Explicit inclusion of bias in derivation of the criteria

The regression models used by Snelder *et al.* (2022) to derive the nutrient criteria were positively biased (i.e., under-estimated biomass). Although Snelder *et al.* (2022) corrected for retransformation bias when deriving the criteria, the remaining small positive bias was not corrected. Because the results of this study indicated that the criteria were too permissive and that this was associated with positive model bias, the criteria were re-derived with an explicit correction for positive bias.

The first step was to calculate the model bias as the mean of the difference between the observed minus the predicted values. This was performed after back-transforming the predictions to the original units by raising the model predictions to the power of four (because the observations were fourth-root transformed in the model). The bias for each model is shown in Table E2.

Table E2. Bias (in original units of CHLA92 mg m^{-2}) for the model used by Snelder et al. (2022) to derive the nutrient criteria. The bias for predictions made for the GWRC sites using the models of Snelder et al. (2022) are shown. Note that the predictions and observations for the GWRC sites are shown in Figure E5.

Nutrient	**Bias (Snelder *et al.* 2022)**	**Bias GWRC sites (this study)**
TN	13	61
DIN	14	59
TP	14	70
DRP	16	73

The second step was to rederive the criteria as described by Snelder *et al.* (2022) with one modification. Rather than adding the retransformation correction factor (CF) to the predictions (see Equation 3 Snelder *et al.* 2022), the bias values shown in Table E2 were added to the back-transformed model predictions. The derivation process was then as described by Snelder *et al.* (2022). A comparison of the criteria produced by both derivation procedures is shown in Figure E7. As expected, the bias corrected criteria are slightly more stringent (i.e., lower concentrations).

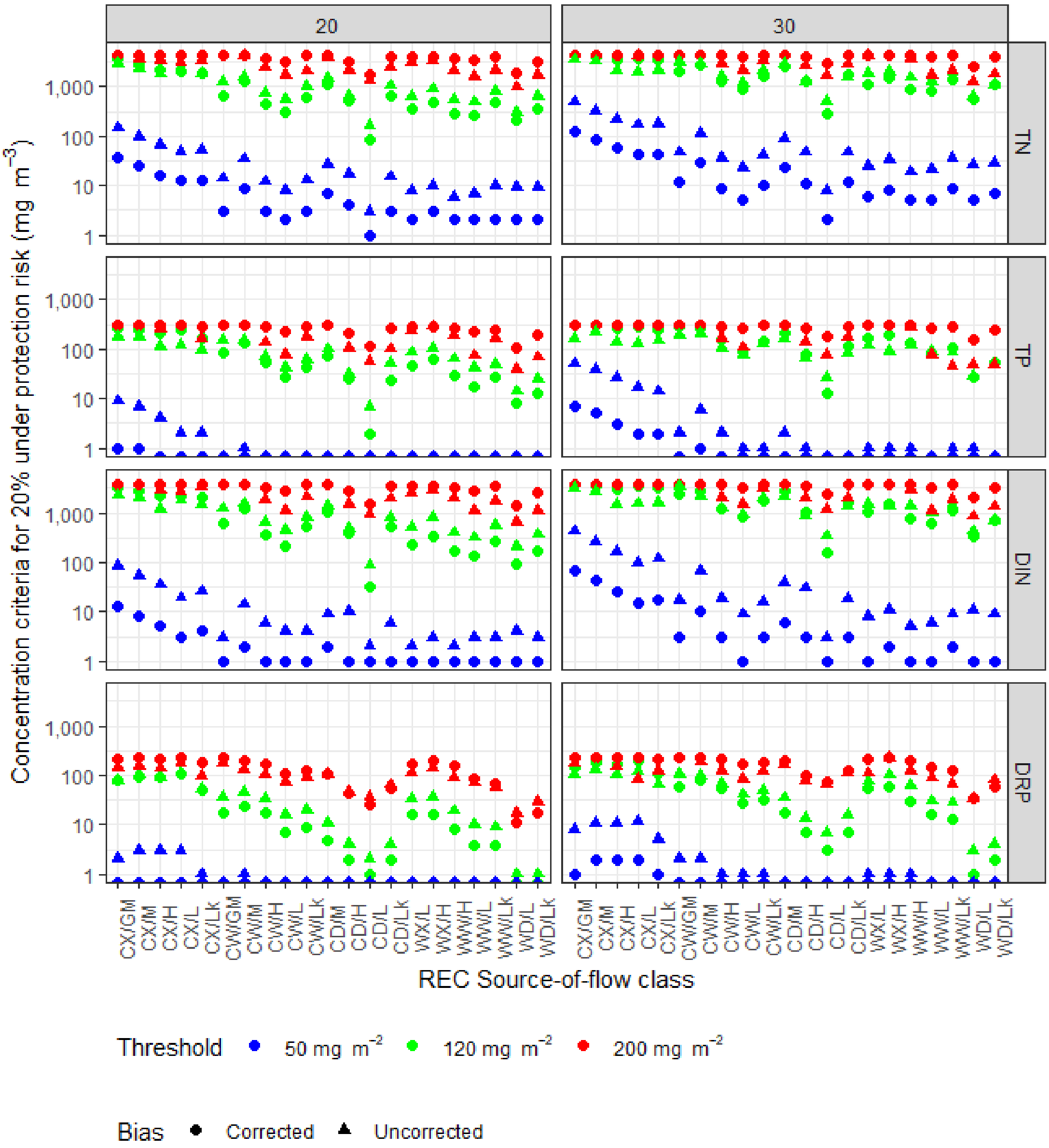

Figure E7. Nutrient criteria for REC Source-of-flow classes and 20% and 30% under protection risk.For each nutrient, the maximum possible value for a criterion is the maximum observed nutrient concentration (i.e., 4,500, 3,800, 300 and 230 mg m^{-3} for TN, DIN, TP and DRP, respectively). Note that the y-axes are log transformed and therefore accentuate the differences between corrected and uncorrected values for the lower thresholds compared to the higher thresholds.

The next step was to re-apply the validation procedures described above using the bias-corrected criteria. The results are shown in Table E3 and Figure E8 below.

The results based on the corrected criteria indicate they are too permissive. For example, Table E3 indicates that the proportion of sites for which observed CHLA92 exceeds the predicted is higher than expected according to the level of under-protection risk for all four nutrient forms and for all levels of under protection risk. However, comparison of the results based on the bias-corrected criteria with the original (uncorrected) criteria (shown in Table E1 and Figure E3) indicate a small reduction in the extent to which the bias-corrected criteria are too permissive. The reduction is relatively small, and the overall conclusion remains that the criteria are too permissive.

Table E3. Proportion of GWRC sites (%) for which observed biomass exceeds that predicted for the four levels of under-protection risk for validation based on the bias-corrected criteria. Results are comparable to Table E1.

Under protection risk (%)	**Nutrient form**			
	TN	**DIN**	**TP**	**DRP**
5	19	19	31	25
10	31	38	56	50
15	56	56	56	56
20	56	56	69	62
30	69	69	75	69
50	75	75	81	75

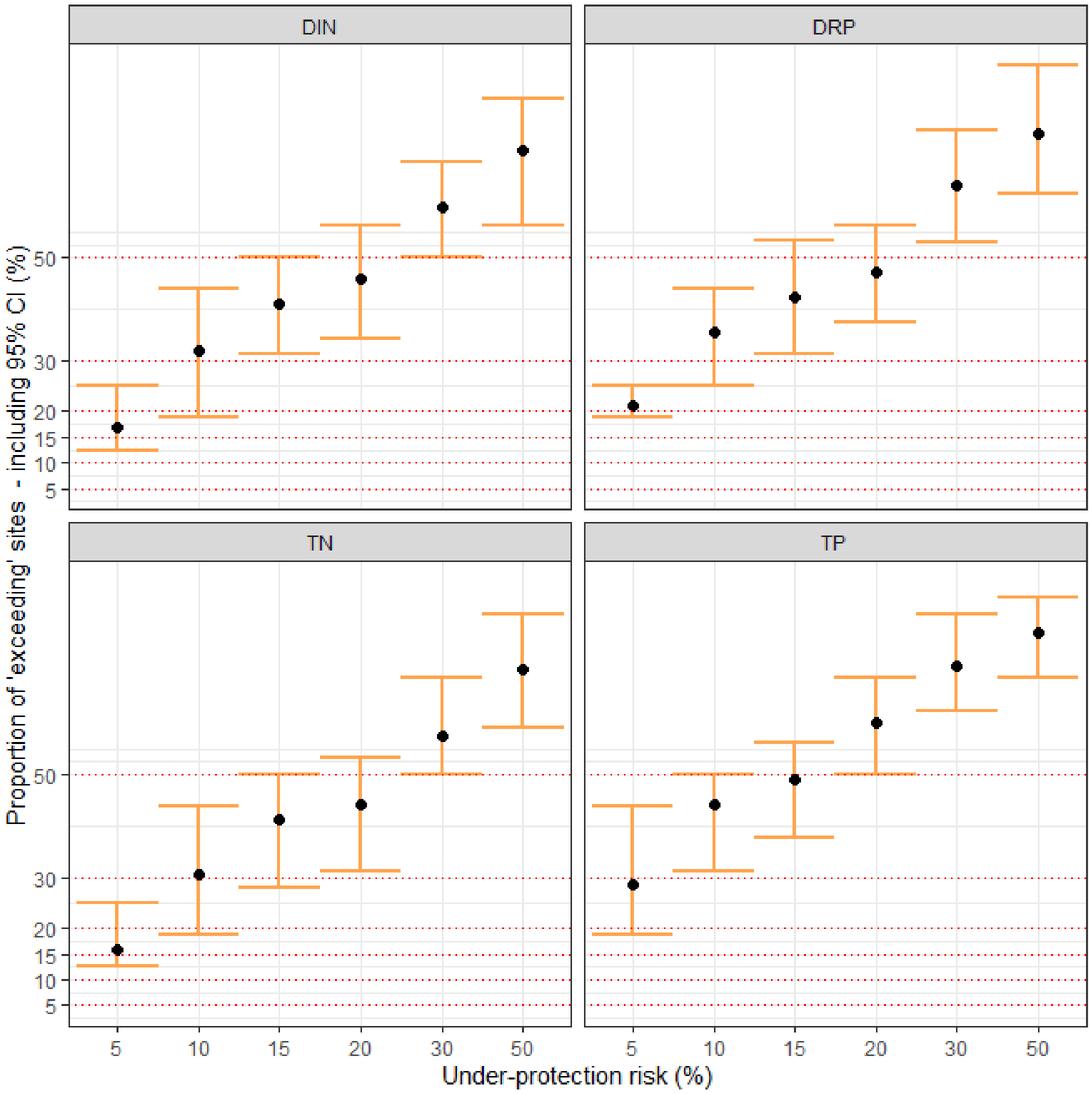

Figure E8. Proportion of "exceeding" sites (i.e., sites that are under-protected) for each level of under-protection risk (x-axis) for validation based on the bias-corrected criteria. The error bars indicate the 95% confidence interval of the observed "exceeding" sites, which was generated from a Monte Carlo analysis. These results are comparable to Figure E4.

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Appendix F – Update of nutrient criteria to achieve periphyton target attribute states in the Greater Wellington Region (Section 6)

Test of periphyton nutrient criteria based on GLM models and assuming gamma distribution for Wellington Region

Version 1, 22 March 2023

Ton Snelder, LWP Ltd

The study by Snelder *et al.* (2022) fitted OLS models to chlorophyll observations at a national dataset comprising 251 monitoring sites (summarized as the 92nd percentile of the observations and referred to hereafter as Chla92) using several predictors that include nutrient concentrations (typically summarized as median values of the observations of dissolved inorganic nitrogen (DIN), dissolved reactive phosphorus (DRP), total nitrogen (TN) and total phosphorus (TP)) and other environmental observations at the sites including substrate composition, shade and hydrological indices. These fitted models were subsequently used to defined criteria for DIN, DRP, TN and TP to achieve fixed Chla92 values (50, 120 and 200 mg m^{-2}).

A validation of the criteria for the Wellington Region based on 16 sites concluded that derived criteria were too permissive. Without getting into a lot of detail, the reason for this is that the model is unable to predict the highest site values of Chla92 (values >> 200 mg m^{-2}).

When the OLS models were fitted, the site values of Chla92 were forth root transformed to approximate normality. Despite the transformation to normality, the high Chla92 values were not well described by the normal distribution (Figure F1). In effect the tail of the actual distribution is fatter than represented by the normal distribution. In addition, the normal distribution does not reflect the zero lower-bound of the Chla92 values (Figure F1). These violations of statistical assumptions probably don't have an appreciable effect on estimates of the central tendency (conditional mean) but will have a relatively greater influence on predictions associated with the edges of the data distribution such as the predicted 70th, 80th and 90th percentile values. This is important to the criteria because these predicted percentile values are used to derive the criteria for 30%, 20% and 10% under protection risk (UPR); respectively. The OLS model will under-predict these values and this leads to defining criteria that are too permissive.

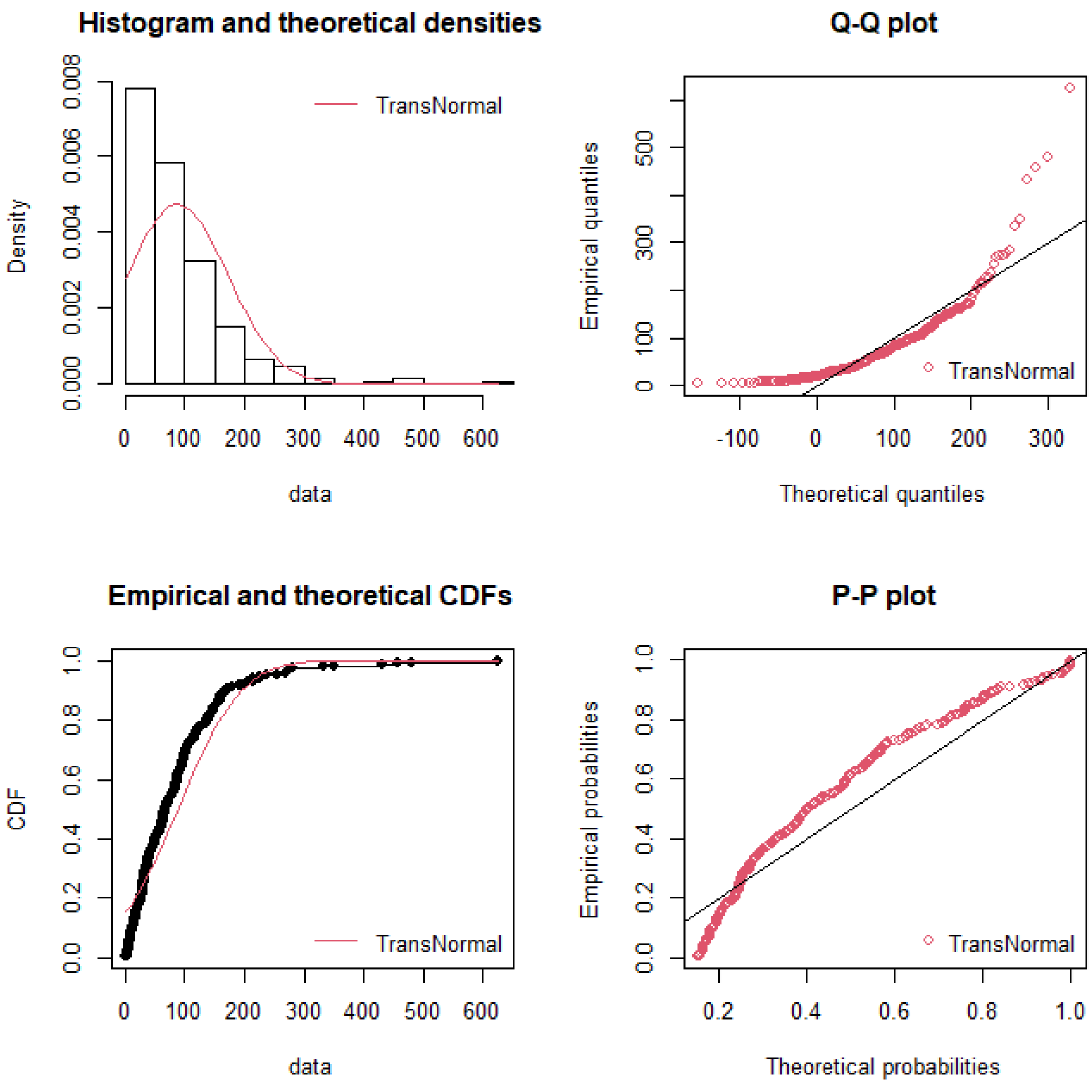

Figure F1. Normal distribution fitted to the fourth root transformed Chla92 values at 251 monitoring sites.

The gamma distribution more accurately represents the actual distribution of the Chla92 values (Figure F2). The gamma distribution is zero-bounded and allows for a fatter tail than the normal distribution. The better fit of the gamma distribution indicates that modelling Chla92 using the same methods as the Snelder *et al.* (2022), but based on a generalized linear model (GLM) may achieve better results.

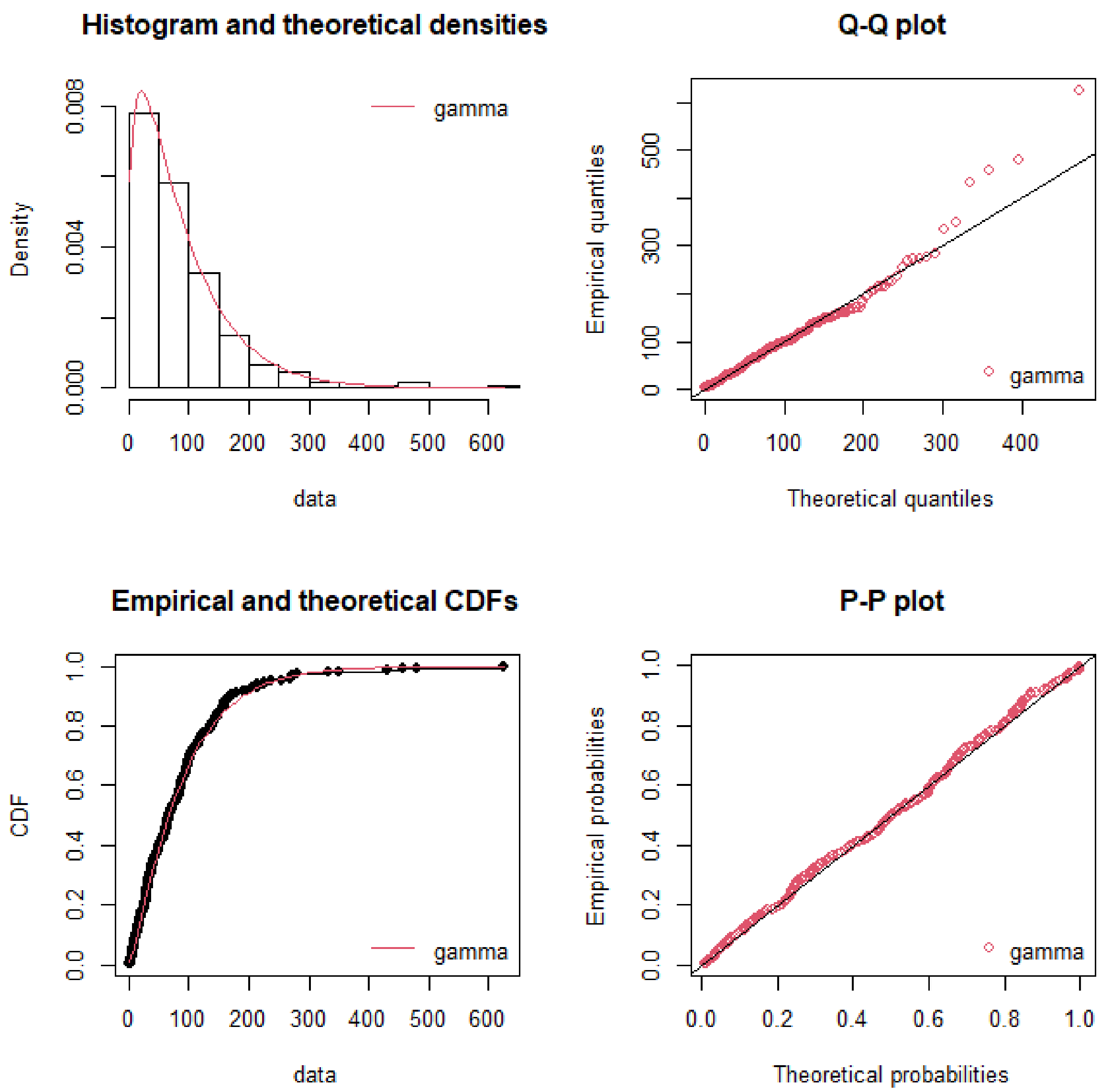

Figure F2. Gamma distribution fitted to the Chla92 values.

GLM models were fitted using the same procedures as Snelder *et al.* (2022). A very similar set of fitted models to Snelder *et al.* (2022) was obtained – see Table F1.

Table F1. Fitted coefficients for GLM regression models pertaining to each nutrient variable.

Nutrient	Intercept.	log10.Nutrient.	Temp95	FRE3	Shade	EC	Turb	Reversals	sdQ	FineSed	nNeg
TN	3.42	0.46	0.04	-0.03	-0.2	0	-0.06	-0.01	1.57	NA	NA
DIN	3.56	0.34	0.04	-0.03	-0.22	0	-0.06	-0.01	1.72	NA	NA
TP	10.07	0.54	0.05	-0.04	-0.16	NA	-0.05	-0.02	3.37	-0.01	-0.02
DRP	11.38	0.39	0.05	-0.03	-0.15	NA	NA	-0.02	3.27	-0.01	-0.03

The four GLM models were able to represent the values of Chal92 in excess of 300 mg m^{-2} (Figure F3), whereas the OLS models derived by Snelder *et al.* (2022) were not (see Figure 17 of Snelder *et al.* 2022). Note however that the mean (indicated in Figure F3 by the lower line of points is indicating a biomass ceiling at a Chla92 value less than 200 mg m^{-2}. This is consistent with the findings of a "biomass ceiling" and a "saturating concentration" by Snelder *et al.* (2022). At this stage, it does not appear that the GLM models would change those conclusions but further work on this is desirable.

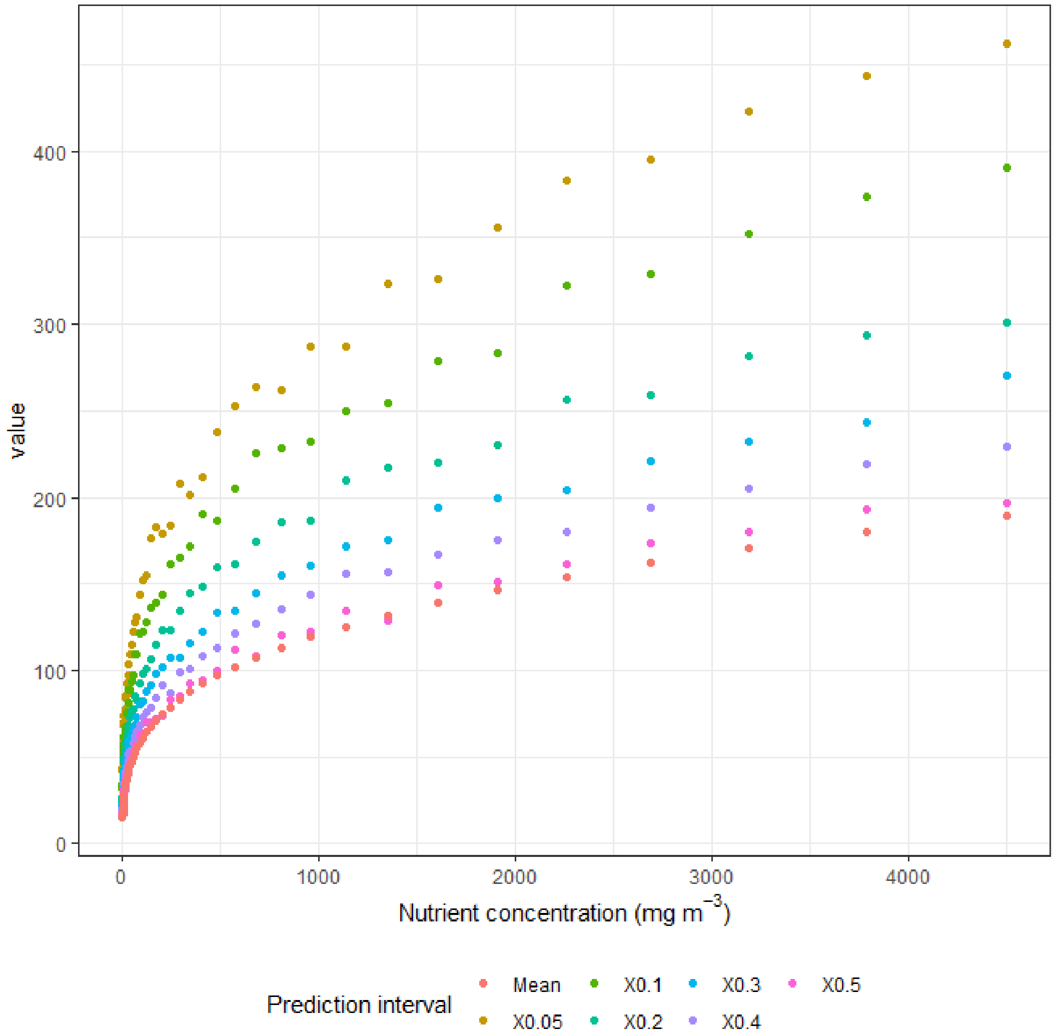

Figure F3. Predictions of Chla92 for the 95%, 90%, 20%, 30%, 40% and 50% prediction intervals over a range of TN concentrations made using the GLM based on gamma distribution. The curves represent the prediction intervals for varying TN concentration at a site that has mean values for all predictors fitted in the GLM model.

The four GLM models were used to derive nutrient criteria in approximately the same manner as Snelder *et al.* (2022). There are some additional details that are omitted here about the derivation of prediction intervals from the GLM models – which are not as for OLS models, but the principles are the same. Note that the criteria presented here are based on the method deployed by Snelder *et al.* (2022) with two modifications. First, the criteria were derived from a sub-sample of 500 randomly selected segments of stream order > 3 in each REC class. This was because the derivation of prediction intervals from the GLM models is numerically intensive and this approach made the processing time more tractable. Tests indicate that 500 random segments produces the same results as would the all segments in each REC class. Second, the criteria for each REC class were derived as the geometric mean (not the ordinary mean) of the individual nutrient concentrations derived for each segment (for more details see Section 4.71 of Snelder *et al.* 2022). The geometric mean was calculated as the exponentiated mean of the log of the individual nutrient concentrations. The exponentiated standard deviation of the log of the individual nutrient concentrations was also obtained as a measure of the within-class variability. The measure of the within-class variability was used in the validation procedure to account for within-class variation in the criteria. It is desirable to account for this variation in the validation because it is based on a small sample of specific sites but the method produces a mean criteria for an entire REC class. The "best" estimate of the criteria for a specific site is the criteria produced for the specific segment that the site is located on. Using the mean for that segment's class means there is some uncertainty in the criteria that are used; because the best criteria will be different to the mean. The measure of the within-class variability can be incorporated in a Monte Carlo analysis so that the validation accounts for this uncertainty.

The criteria derived using the GLM models were generally less permissive (i.e., lower concentrations) than those derived by (T Snelder *et al.*, 2022). This is consistent with the GLM models being better able to represent the high Chla92 values.

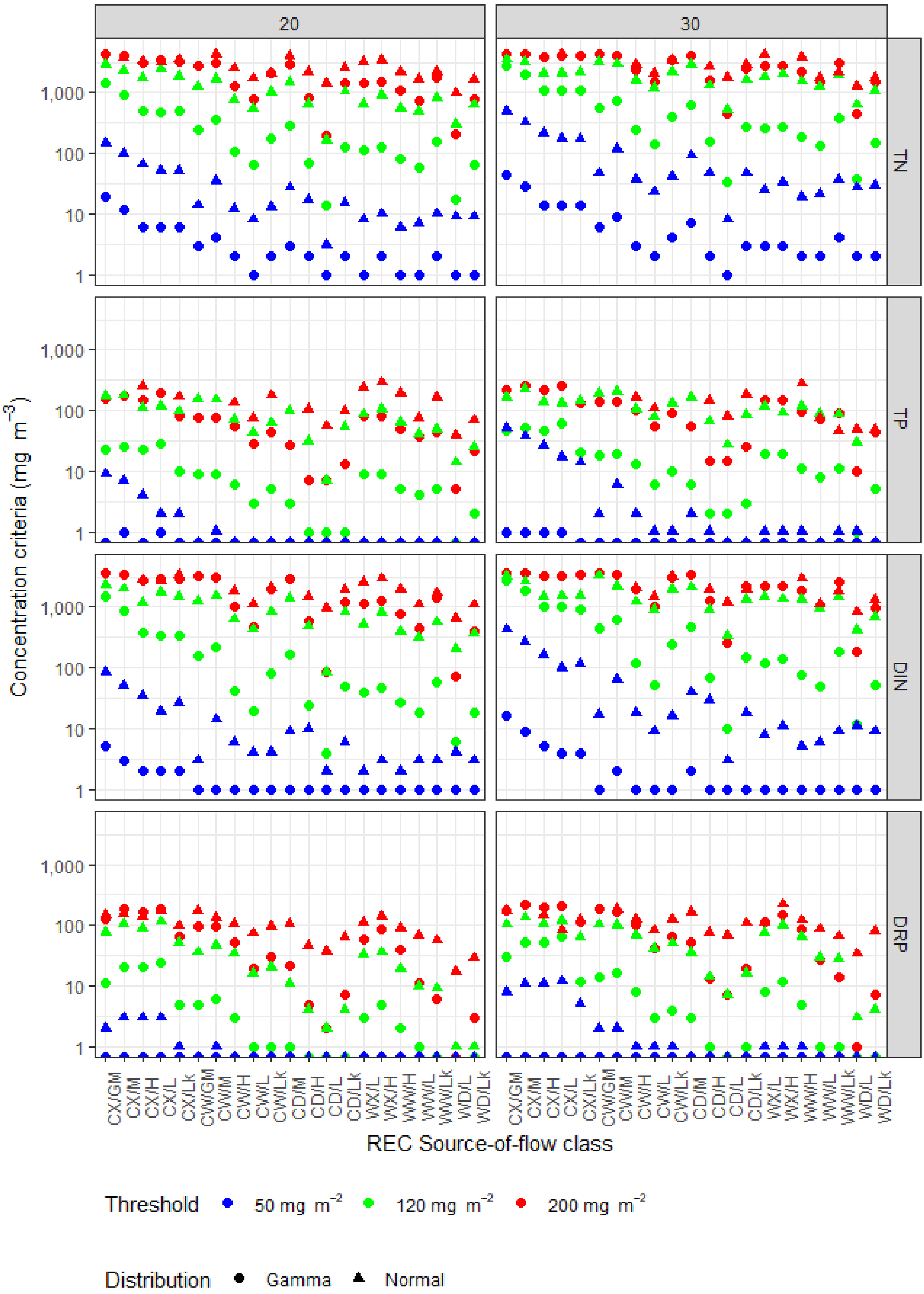

Figure F4. Comparison of nutrient criteria derived based on the normal distribution (OLS models) and gamma distribution (GLM models) for unshaded sites and the 20% and 30% UPR and for three Chla92 thresholds.

The criteria derived using the GLM (gamma distribution) were validated using dataset pertaining to 19 sites in the Wellington Region. The GLM results presented below can be compared with results based on the OLS models provided in a memo from Ton Snelder to GWRC dated 14 November 2022.

Predicted values of CHLA92 were derived for each site by interpolation of the GLM-based nutrient criteria look-up tables (i.e., the observed median nutrient concentration at each site was used to evaluate CHLA92 from the look-up tables – see step 4 of validation procedure described by a memo from GWRC dated 14 November 2022). The observed and predicted values of CHLA92 at the 19 sites in the region based on the four nutrient forms (TN, DIN, TP and DRP) are shown as scatter plots in Figure F5. Theoretically, 5%, 10%, 15%, 20%, 25%, 30% and 50% of the sites should have observed biomass that exceeds the predicted biomass when the predictions are made based on the corresponding levels of under-protection risk (i.e., should lie above the red lines on Figure F5).

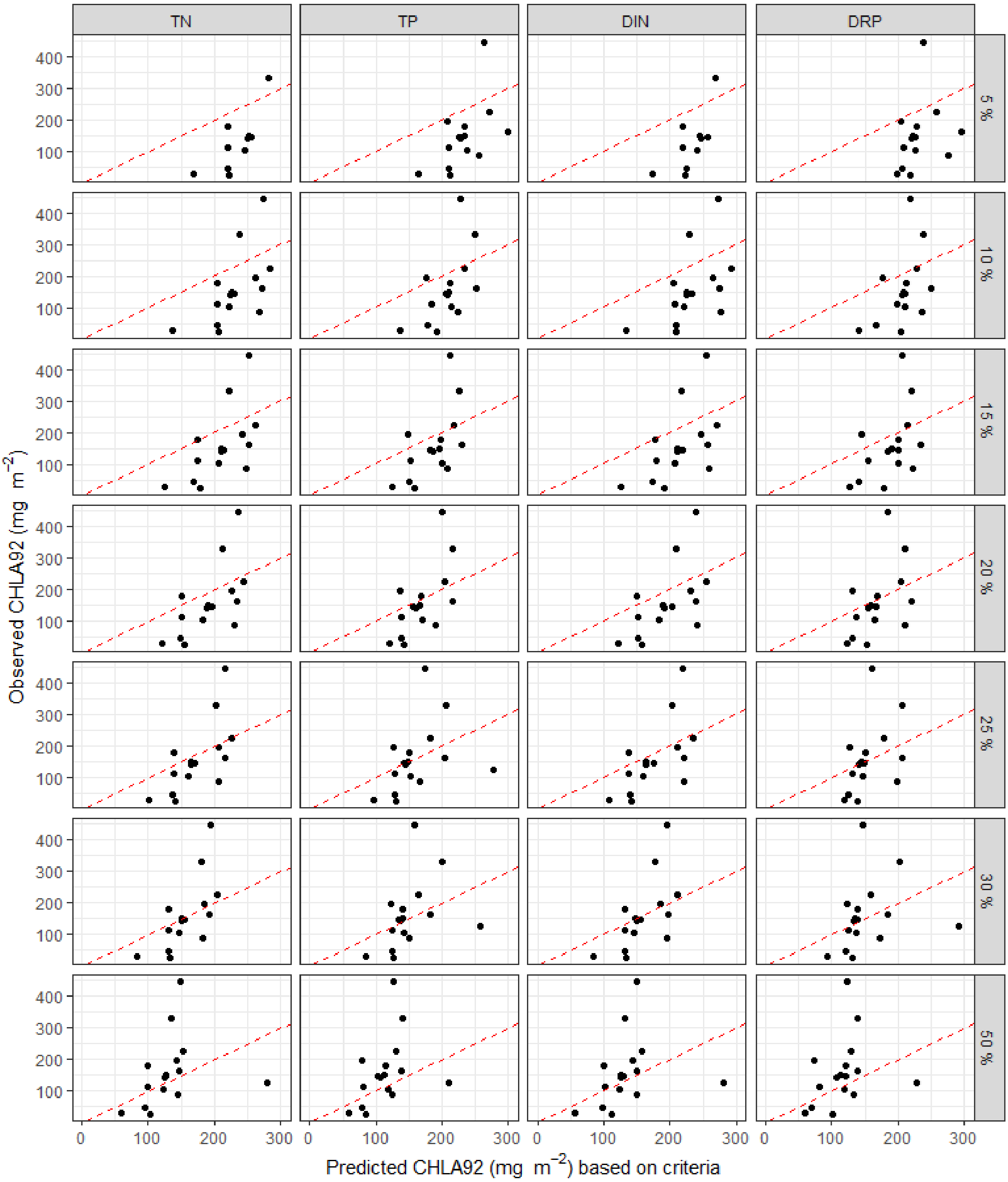

Figure 5. The observed and predicted values of CHLA92 at the 19 sites in the Wellington region where predicted values are derived from the nutrient criteria for under-protection risks of 5, 10,15, 20, 25%, 30% and 50%. Panel labels indicate the under-protection risks and the nutrient form (TN and TP). The dashed red diagonal (one to one) line represents agreement between the predictions and observations. The points lying below the red line indicate sites for which the observed biomass was less than that predicted by the targets and vice versa. Note that the GLM-based criteria include the 25% UPR.

The data shown in Figure F5 indicate that the proportions of sites for which observed CHLA92 exceeds predicted CHLA92 increases systematically as the under-protection risk increases for all four nutrient forms. Table F2 indicates that the proportion of sites for which observed CHLA92 exceeds the predicted is close to the expected for the 15%, 20%, 30% and 50% levels of under-protection risk for TN and TP and is slightly higher than expected for the 5% and 10% levels. The column headed "discrepancy" is the difference (for each nutrient) in the UPR and the observed proportion of sites exceeding the threshold. These validation results are considerably better than those for the OLS models (Table F3) reported in the memo from Ton Snelder to ORC dated 22 Feb 2023.

Table F2. Validation results for GLM-based criteria. Proportion of sites (%) for which observed biomass exceeds that predicted for the six levels of under-protection risk and two forms of nutrient (TN and TP). The discrepancy is the difference between the UPR and the observed proportion of sites exceeding the threshold (%). Note that the GLM-based criteria include the 25% UPR.

Under protection risk (%)	Proportion exceeding (%)				Discrepancy (%)			
	TN	TP	DIN	DRP	TN	TP	DIN	DRP
5	12	12	12	12	-7	-7	-7	-7
10	12	19	12	19	-2	-9	-2	-9
15	19	25	19	25	-4	-10	-4	-10
20	19	31	19	31	1	-11	1	-11
25	19	44	19	44	6	-19	6	-19
30	31	50	38	50	-1	-20	-8	-20
50	62	62	62	62	-12	-12	-12	-12

Table F3. Validation results for OLS-based criteria reported in memo from Ton Snelder to GWRC dated 14 November 2022. Proportion of sites (%) for which observed biomass exceeds that predicted for the six levels of under-protection risk and two forms of nutrient (TN and TP). The discrepancy is the difference between the UPR and the observed proportion of sites exceeding the threshold (%).

Under protection risk (%)	Proportion exceeding (%)				Discrepancy (%)			
	TN	TP	DIN	DRP	TN	TP	DIN	DRP
5	19	50	19	25	-14	-45	-14	-20
10	50	56	50	50	-40	-46	-40	-40
15	56	62	56	62	-41	-47	-41	-47
20	62	69	69	69	-42	-49	-49	-49
30	69	81	69	69	-39	-51	-39	-39
50	88	94	88	94	-38	-44	-38	-44

The above analysis is uncertain for two reasons. First, the observed values of CHLA92 are imprecise (i.e., are estimates of the population value calculated from the monthly samples). Second, there is within-class variability in the “best” estimate of the criteria for each site. This within-class variability is quantified by the measure of within-class variability in the criteria explained above. Therefore, a second analysis was undertaken to estimate the uncertainty of the first analysis. The second analysis repeated the first analysis but used a Monte Carlo simulation to generate 1000 “realisations” of the observed and predicted CHLA92 for each site. For each site, a random error was added to the observed mean CHLA and then this “perturbed” mean was used to produce a realisation of the observed CHLA92 based on theoretical empirical distribution (see Figure F2 of the memo from Ton Snelder to ORC dated 22 Feb 2023). The random error was derived by drawing from a normal distribution with a standard deviation equal to the standard error of the observed mean CHLA. In addition, for each site, a random error was added to the criteria and then this “perturbed” criteria was used to produce a realisation of the predicted CHLA92.

Figure F6 summarises the results of the Monte-Carlo procedure and shows the proportion of “exceeding” sites and the 95% confidence interval for each level of under-protection risk. In Figure F6, for most of the levels of under protection risk, the confidence bound includes the associated level of under-protection risk (indicated by horizontal lines). This indicates that the new criteria are consistent with the monitoring data within the inherent uncertainty in both the observations of CHLA92 and the uncertainty in the criteria themselves. At the least, this analysis allows us to understand why the validations have consistently indicated that the criteria derived by (T Snelder *et al.*, 2022) are too permissive.

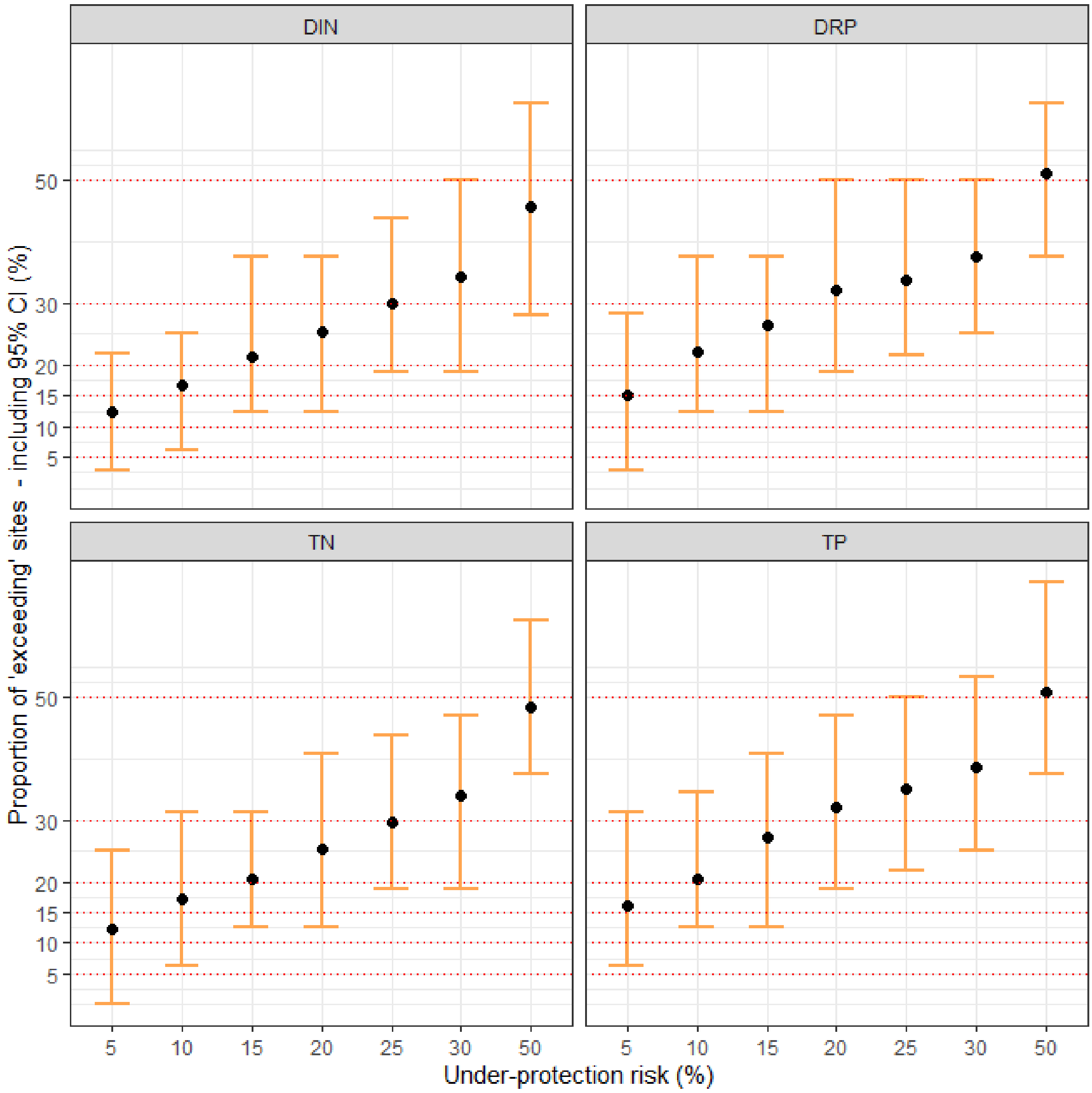

Figure F6. Proportion of "exceeding" sites (i.e., sites that are under-protected) for each level of under-protection risk (x-axis) and the two nutrients. The error bars indicate the 95% confidence interval of the observed "exceeding" sites, which was generated from a Monte Carlo analysis.

Appendix G – Site-specific TSS : Clarity plots (Section 9)

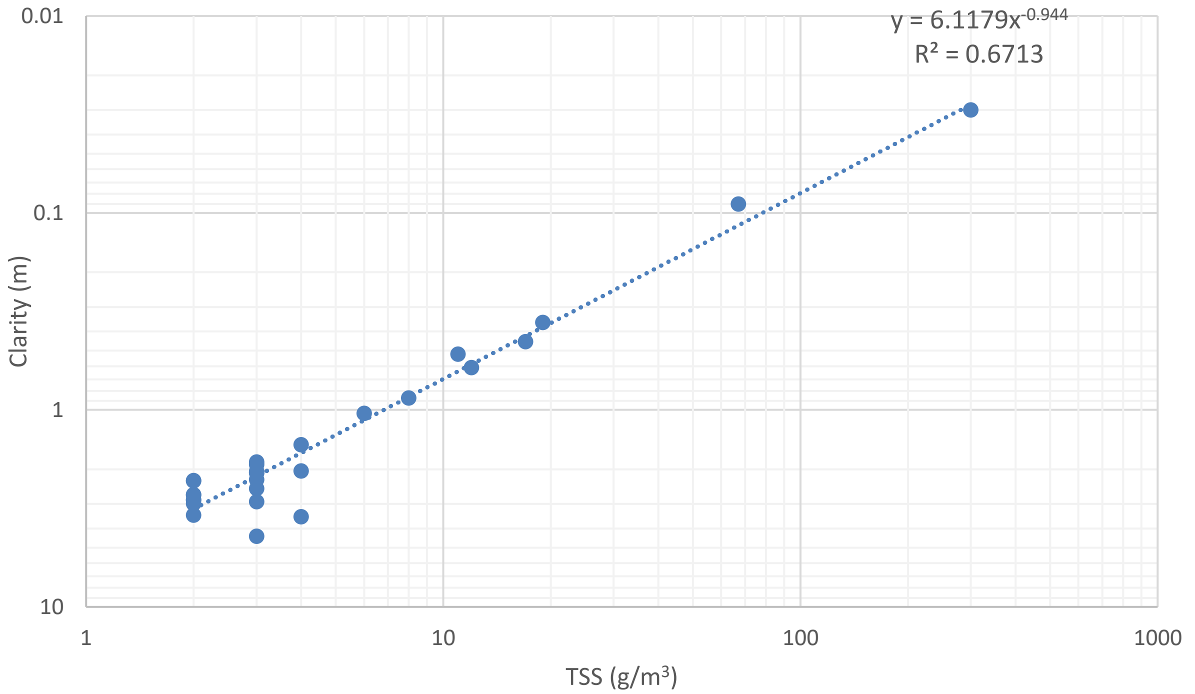

Figure G1 Horokiri at Snodgrass TSS - Clarity relationship

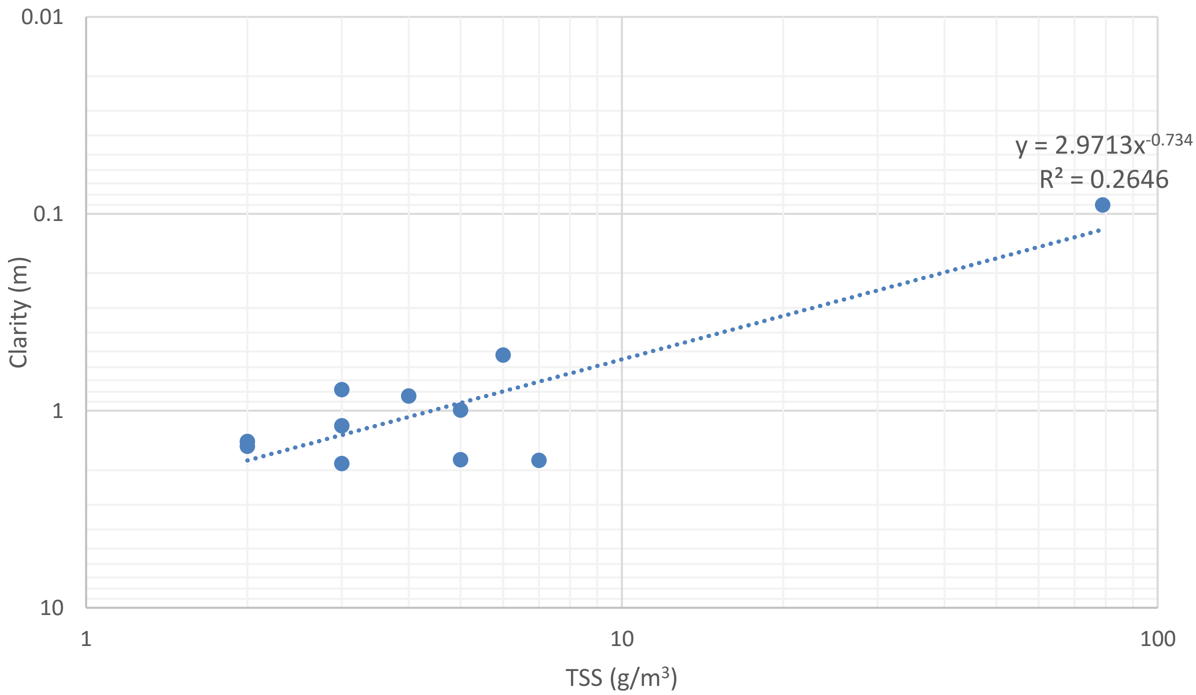

Figure G2 Taupo Stream at Plimmerton Domain TSS - Clarity relationship

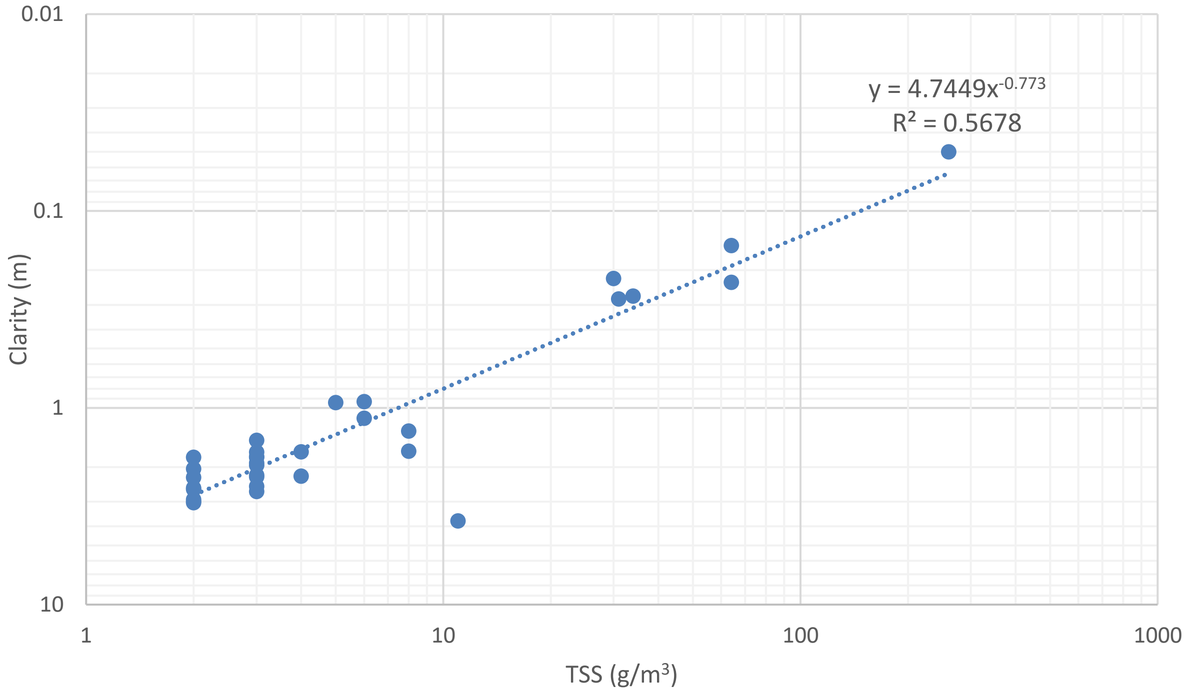

Figure G3 Pāuatahanui Stream at Elmwood Bridge TSS - Clarity relationship

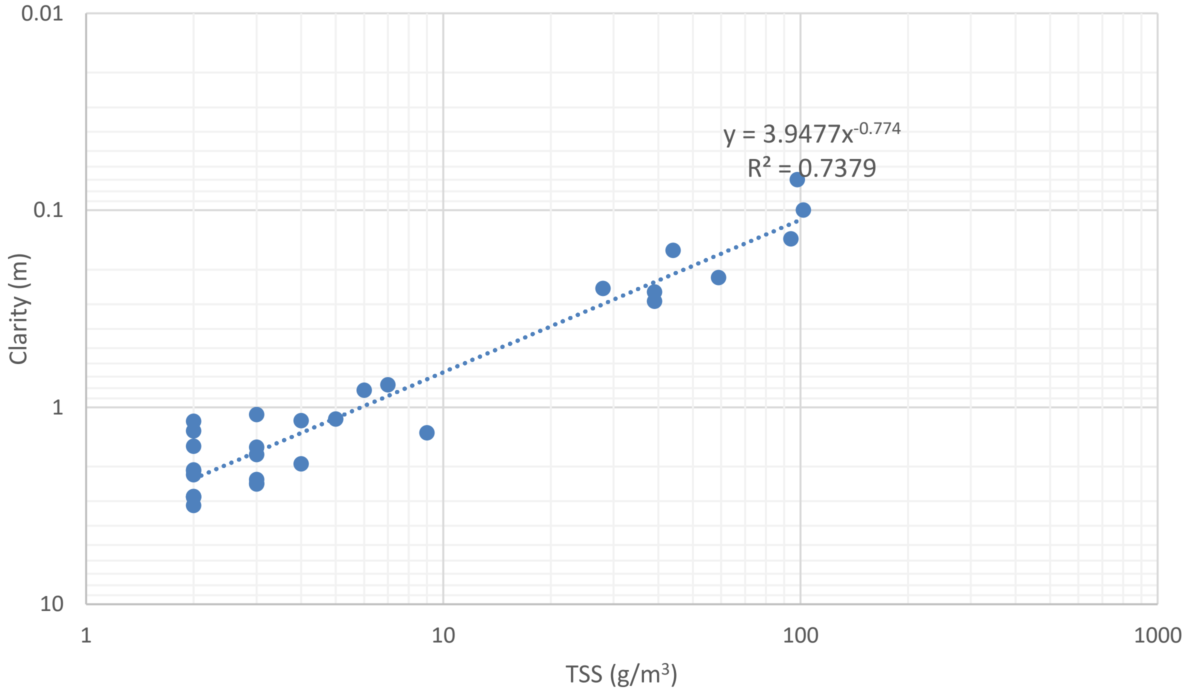

Figure G4 Porirua Stream at Milk Depot TSS - Clarity relationship

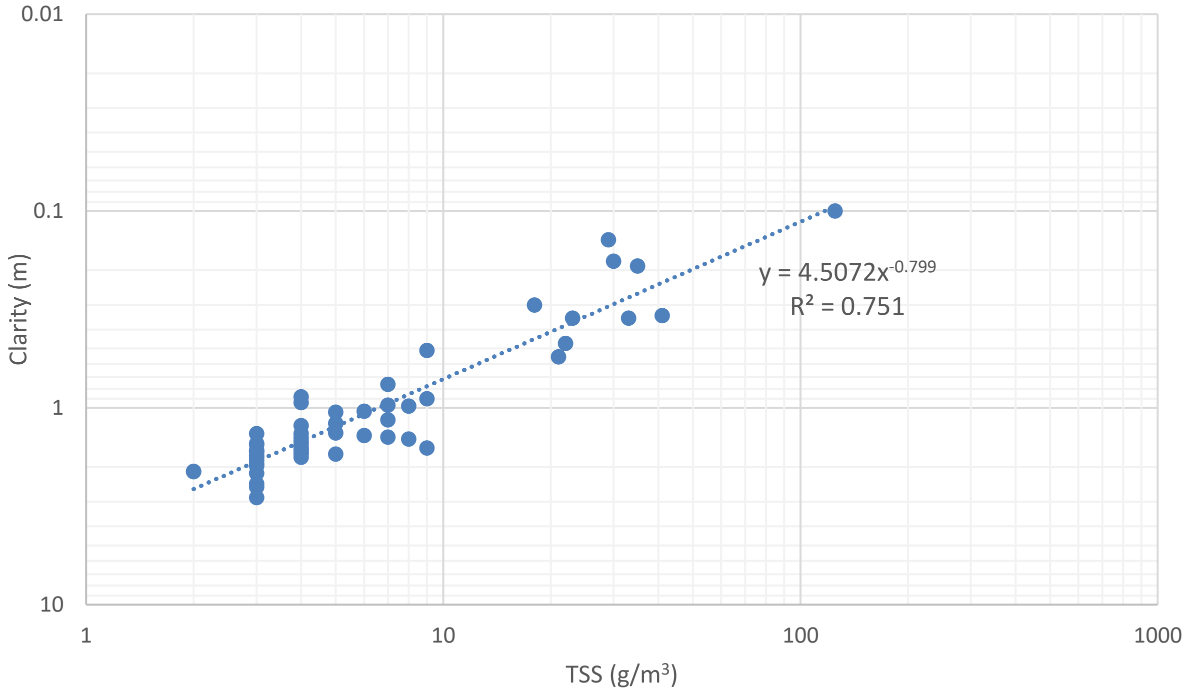

Figure G5 Mākara Stream at Kennels TSS - Clarity relationship

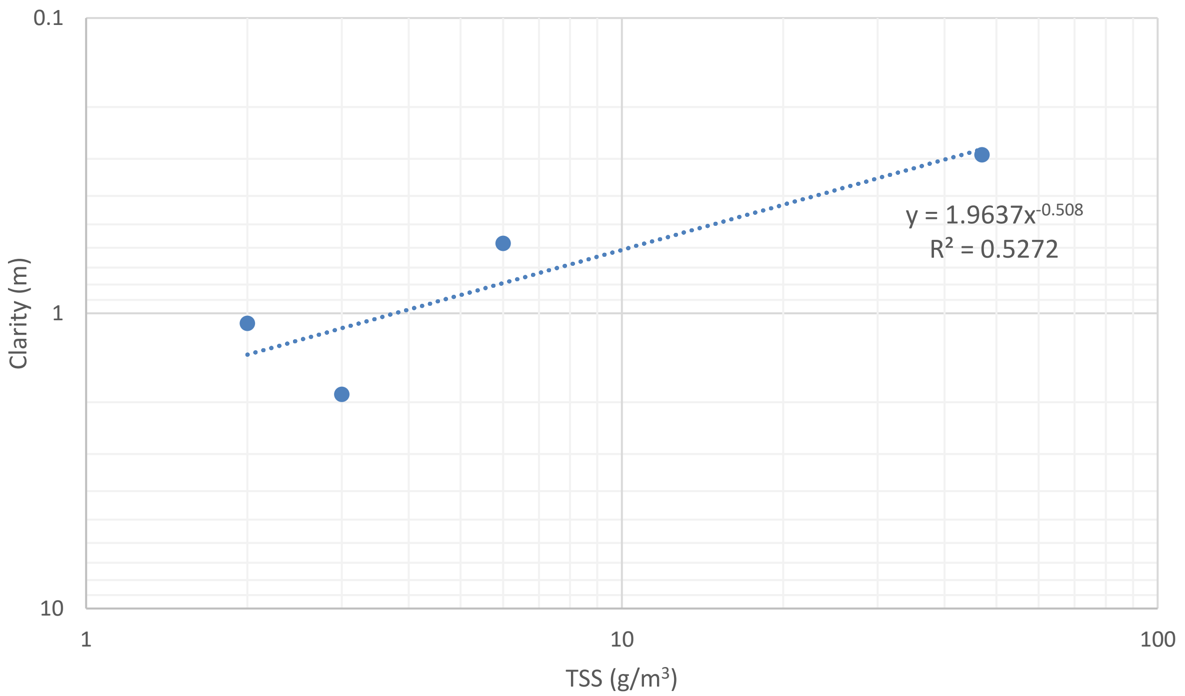

Figure G6 Karori Stream at Mākara Peak Mountain Bike Park TSS - Clarity relationship

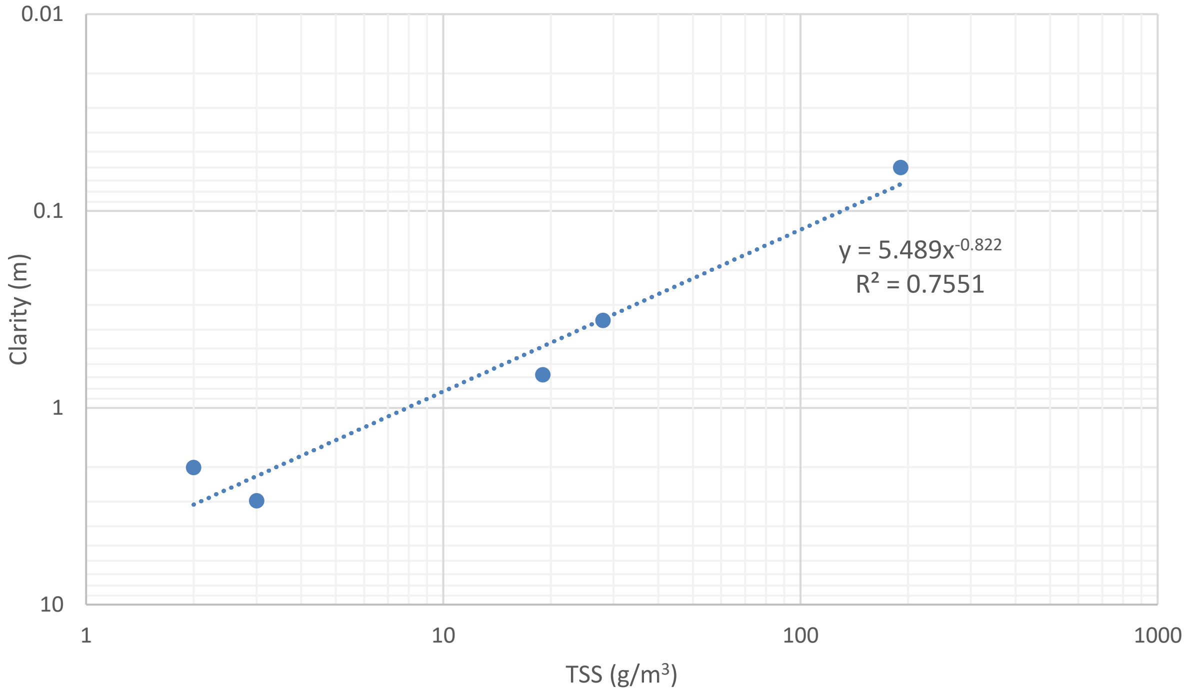

Figure G7 Kaiwharawhara Stream at Ngaio Gorge TSS - Clarity relationship

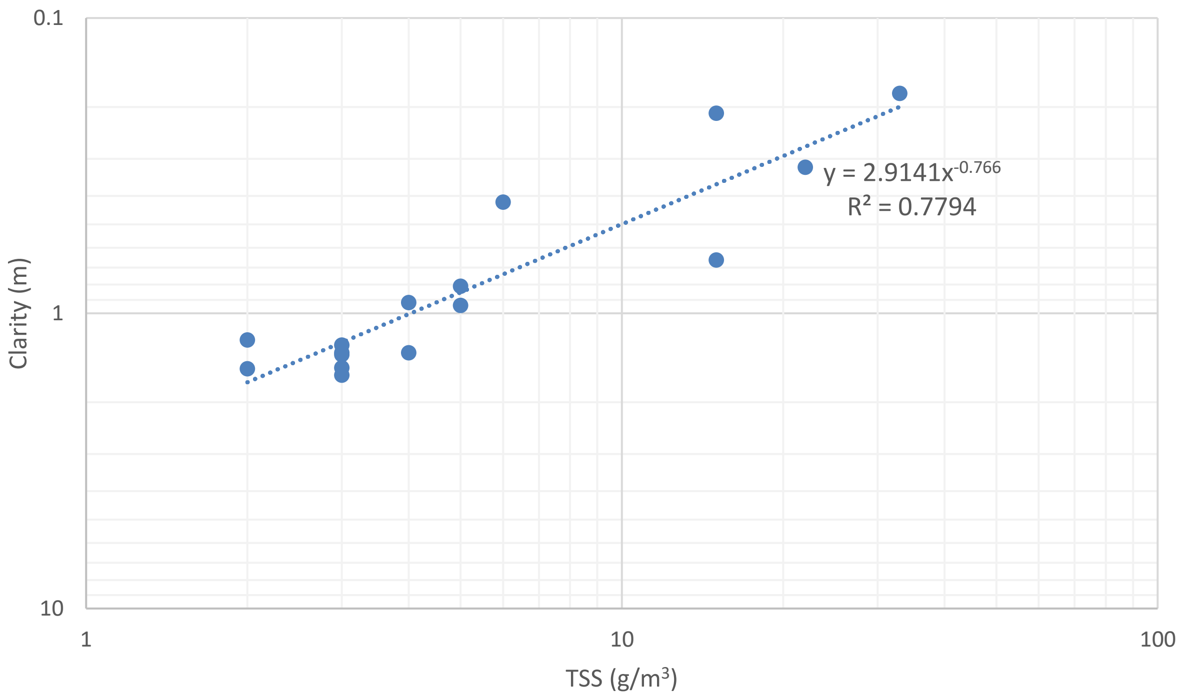

Figure G8 Black Creek at Rowe Parade end TSS - Clarity relationship

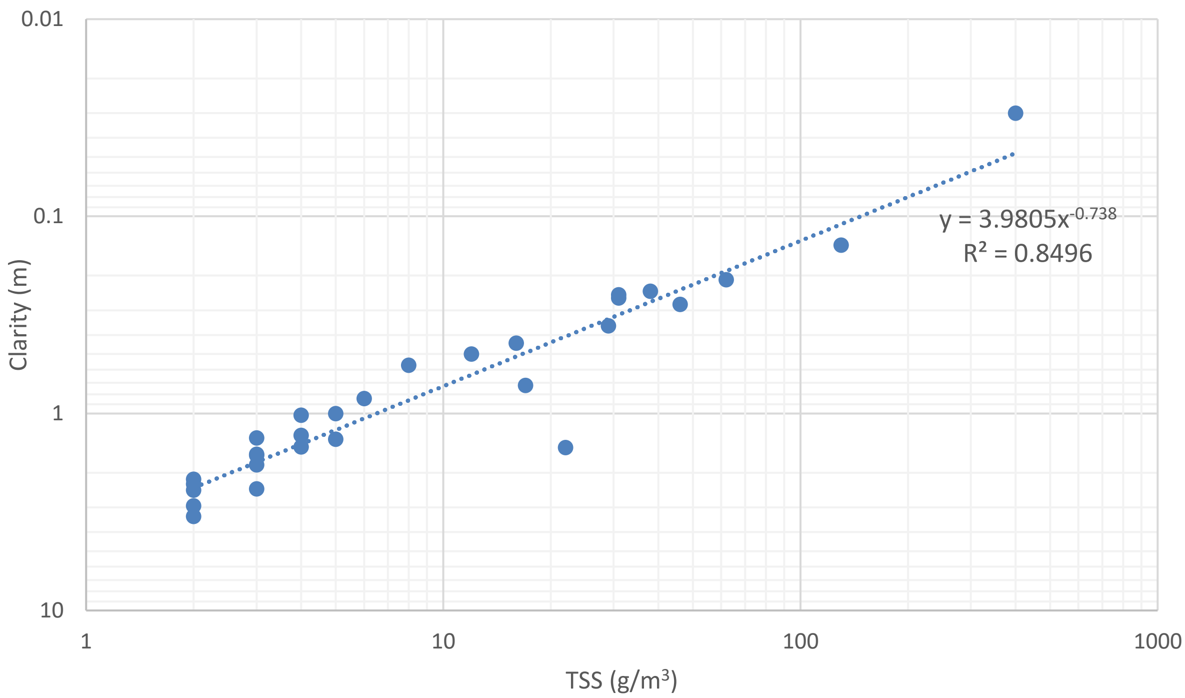

Figure G9 Hutt River at Boulcott TSS - Clarity relationship

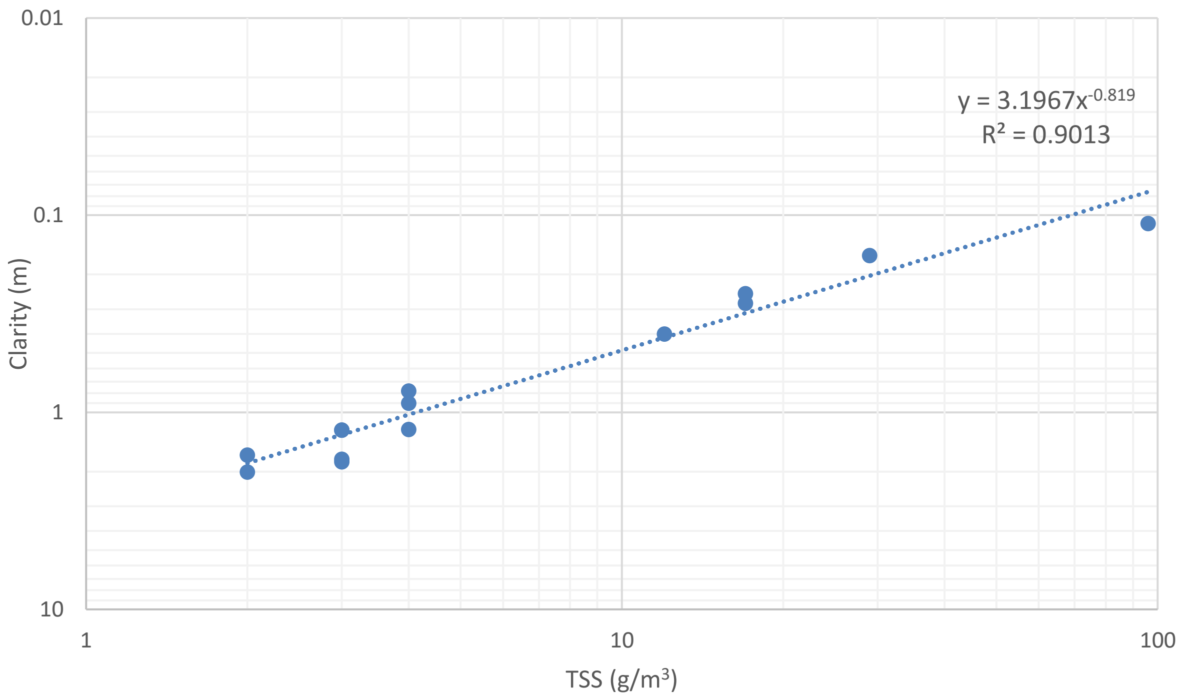

Figure G10 Hulls Creek adjacent Reynolds Bach Drive TSS - Clarity relationship

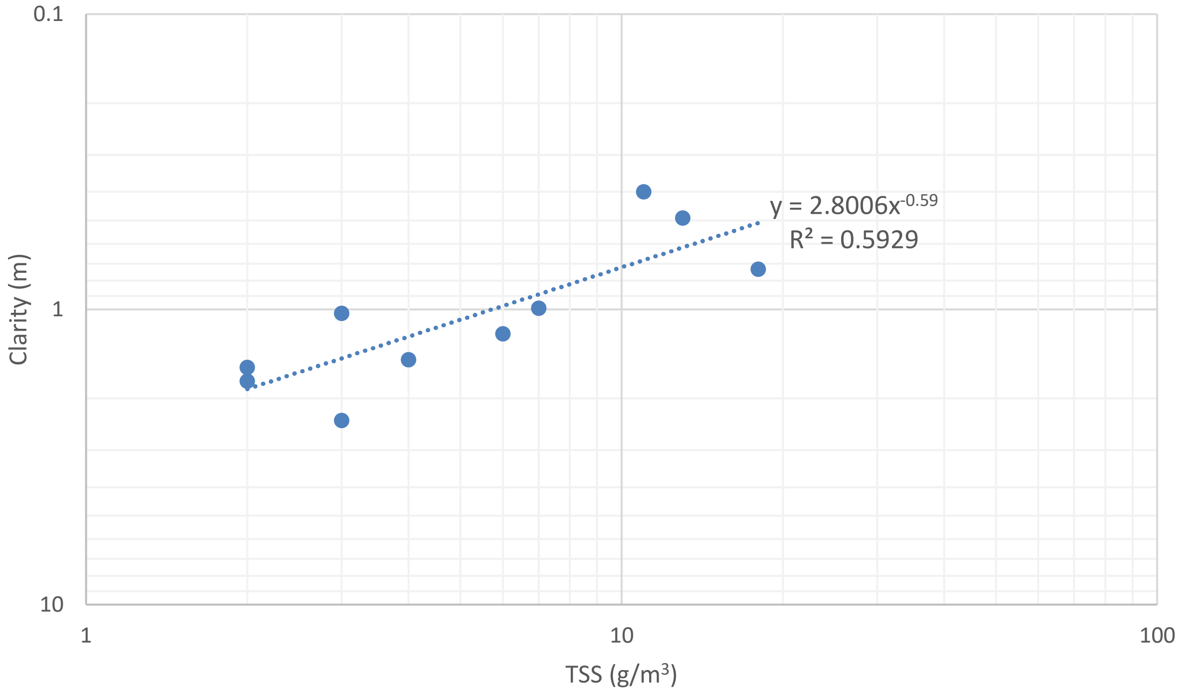

Figure G11 Whakatikei River at Riverstone TSS - Clarity relationship

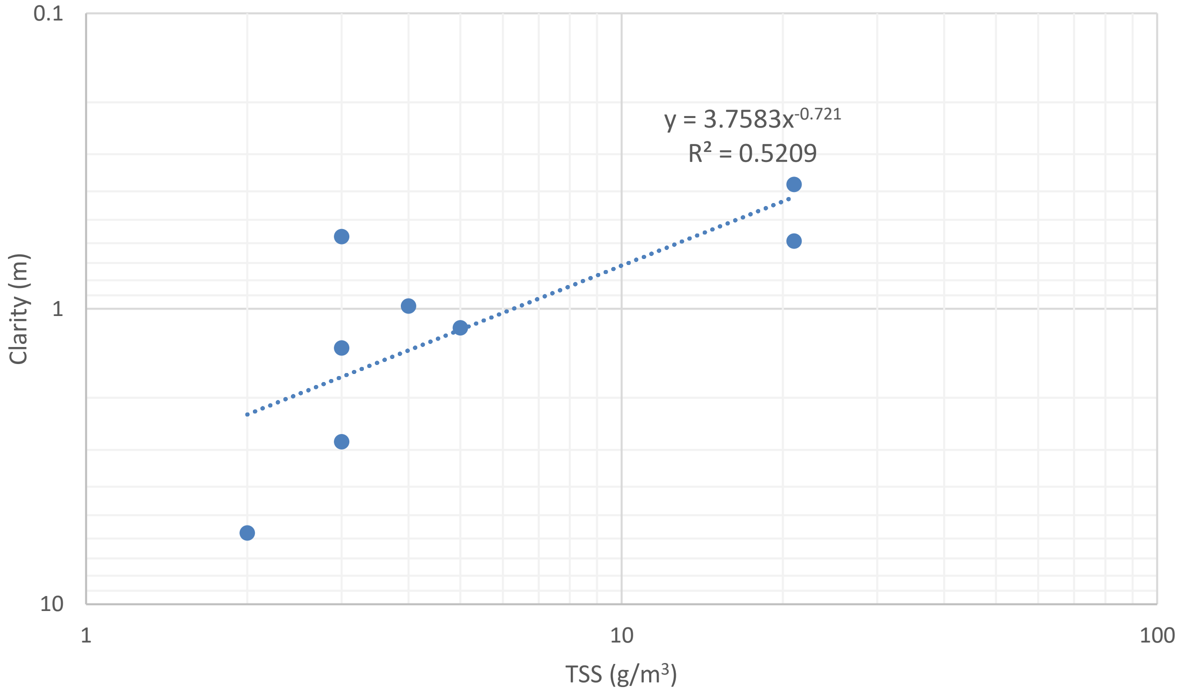

Figure G12 Hutt River at Te Marua Intake Site TSS - Clarity relationship

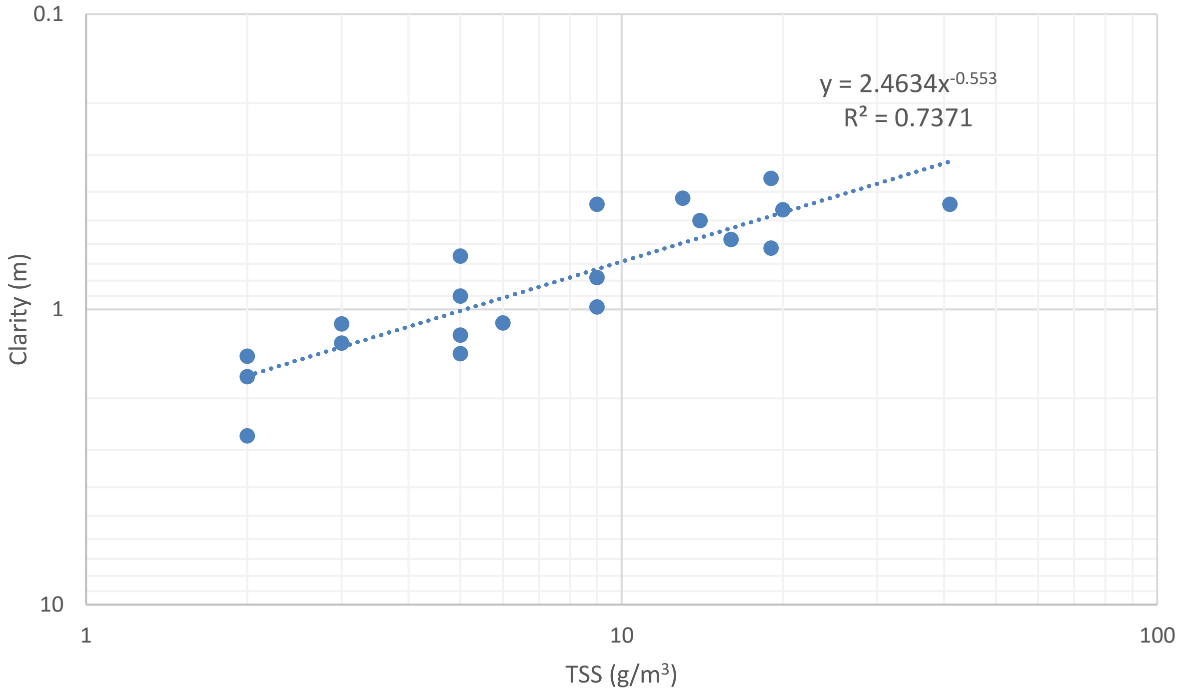

Figure G13 Mangaroa River at Te Marua TSS - Clarity relationship

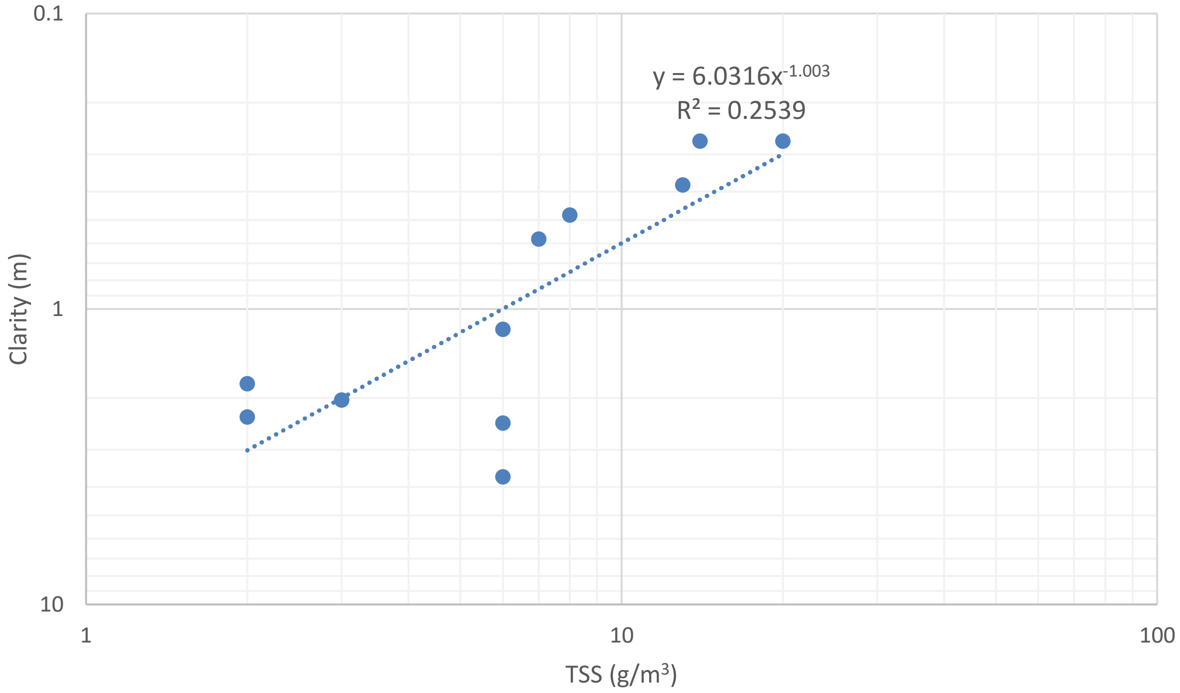

Figure G14 Waiwhetū Stream at Whites Line East TSS - Clarity relationship

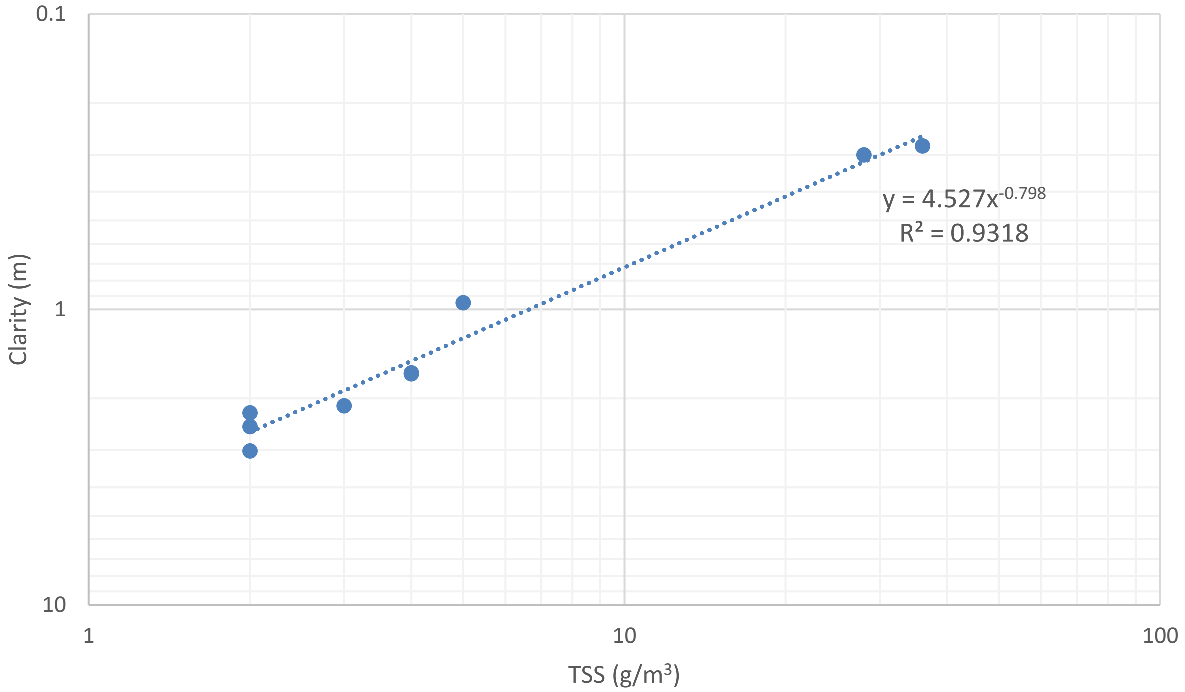

Figure G15 Wainuiomata River Dnstr of White Bridge TSS - Clarity relationship

Appendix H – Regional TSS : Clarity plots (Section 9)

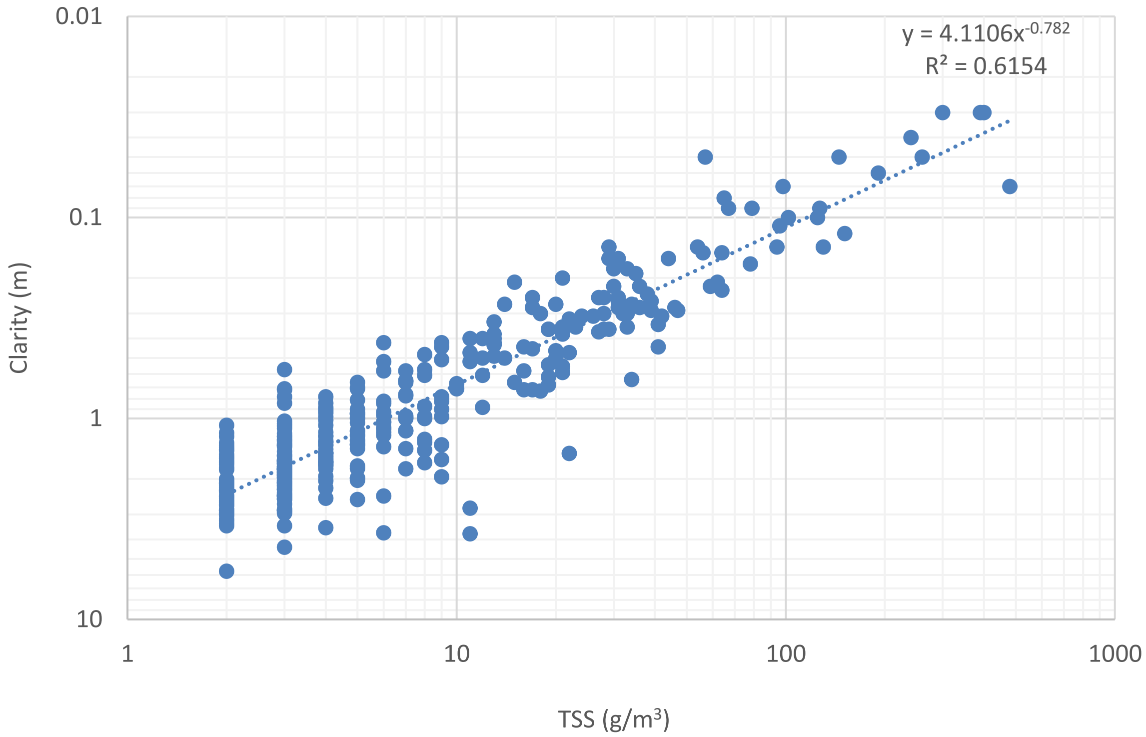

Figure H1 Paired Clarity measurements and TSS samples for all sites (n=373). Log10 scale.

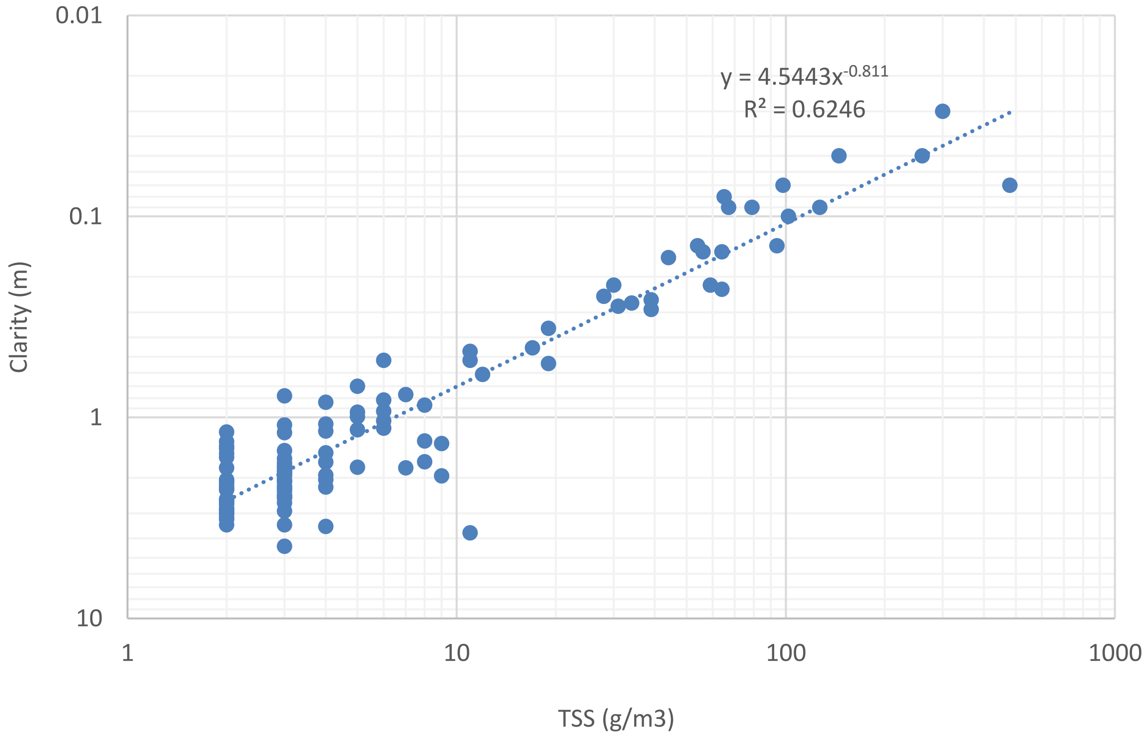

Figure H2 Paired Clarity measurements and TSS samples for all Te Awarua-o-Porirua sites (n=116). Log10 scale.

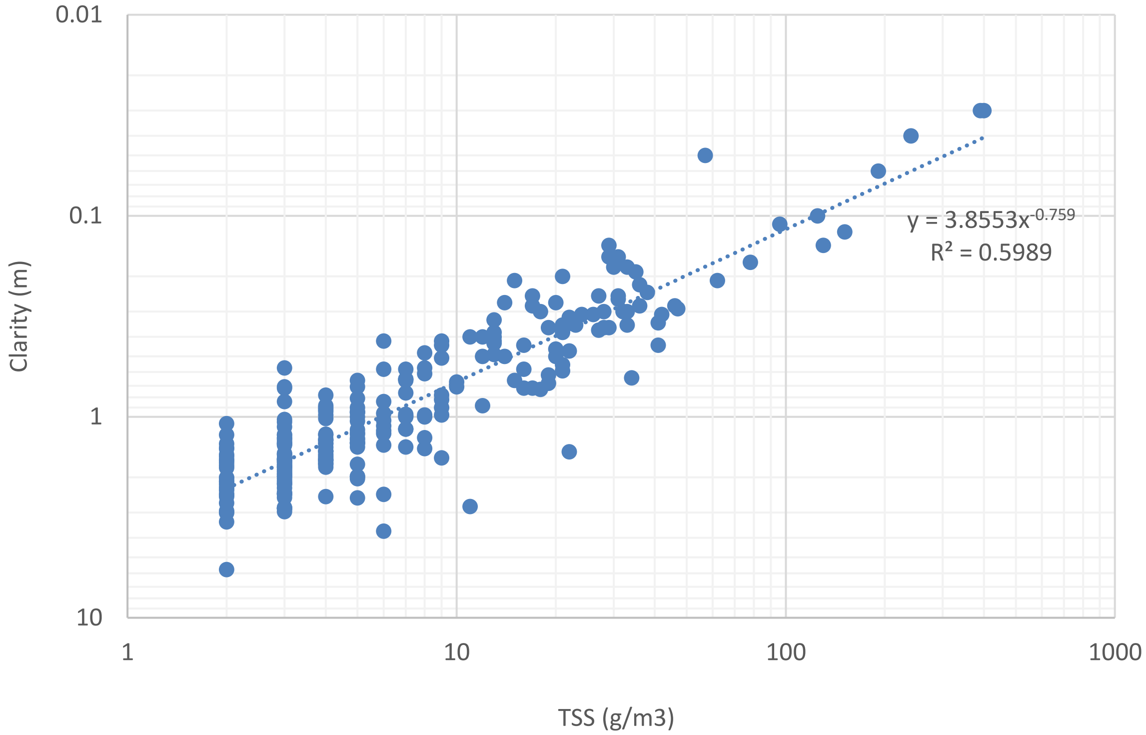

Figure H3 Paired Clarity measurements and TSS samples for all Te Whanganui-a-Tara sites (n=257). Log10 scale.

Appendix I – Sediment load reduction range (Section 9)

Table I1. Estimated load reduction required to achieve clarity targets and ranges for monitored TAS. Current clarity medians below the target are in bold.

Target Attribute Site (TAS)	Sub-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target (site-specific exponent)	Site Exponent	R^2	Load reduction (regional exponent)	Load reduction range	
										+1 Std. Dev.	-1 Std. Dev.
Te Whanganui-a-Tara TAS											
Whakatikei River	Whakatikei	Whakatikei River at Riverstone	4	4	3,189	0%	-0.59	0.59	0%	0%	0%
Akatarawa River	Akatarawa	Akatarawa River at Hutt Confluence	4.8	4.8	8,147	0%	-0.74	0.56	0%	0%	0%
Te Awa Kairangi Upstream	Kaitoke	Hutt River at Te Marua Intake Site	4.6	4.6	70,950	0%	-0.72	0.52	0%	0%	0%
Pākuratahi River	Pākuratahi	Pākuratahi River 50m Below Farm Creek	4.5	4.5	10,896	0%	-0.82	0.52	0%	0%	0%
Mangaroa River	Mangaroa	Mangaroa River at Te Marua	**1.6**	**2.22**	**10,965**	**-45%**	**-0.55**	**0.74**	**-34%**	**-38%**	**-31%**
Hulls Creek	Te Awa Kairangi Urban Streams	Hulls Creek adjacent Reynolds Bach Drive	1.2	1.2	181	0%	-0.82	0.90	0%	0%	0%
Te Awa Kairangi Downstream	Te Awa Kairangi mainstem	Hutt River at Boulcott	**2.8**	**2.95**	**102,303**	**-7%**	**-0.74**	**0.85**	**-6%**	**-7%**	**-6%**
Waiwhetū Stream	Waiwhetū	Waiwhetū Stream at Whites Line East	1.4	1.4	228	0%	-1.00	0.25	0%	0%	0%
Wainuiomata River Upstream	Wainuiomata Urban Streams	Black Creek at Rowe Parade end	**1.3**	**2.22**	**382**	**-50%**	**-0.77**	**0.78**	**-50%**	**-55%**	**-45%**
Wainuiomata River Downstream	Wainuiomata Rural Streams	Wainuiomata River Downstream of White Bridge	2.2	2.2	12,243	0%	-0.80	0.93	0%	0%	0%
Kaiwharawhara Stream	Kaiwharawhara	Kaiwharawhara Stream at Ngaio Gorge	3.6	3.6	290	0%	-0.82	0.75	0%	0%	0%
Karori Stream Upstream	Wellington Urban	Karori Stream at Mākara Peak Mountain Bike Park	3.2	3.2	2,159	0%	-0.51	0.53	0%	0%	0%

Target Attribute Site (TAS)	Sub-FMU	Monitoring Site	Baseline clarity median (m)	Clarity target (m)	Baseline dSedNet mean annual load (t/year)	Load reduction required to meet clarity target (site-specific exponent)	Site Exponent	R^2	Load reduction (regional exponent)	Load reduction range	
										+1 Std. Dev.	**-1 Std. Dev.**
Mākara Stream	South-west coast rural streams	Mākara Stream at Kennels	**1.6**	**2.22**	**4,437**	**-34%**	**-0.80**	**0.75**	**-34%**	**-38%**	**-31%**
Te Awarua-o-Porirua TAS											
Horokiri Stream	Pouewe (Battle Hill)	Horokiri Stream at Snodgrass	2.8	2.8	764	0%	-0.94	0.67	0%	0%	0%
Pāuatahanui Stream	Takapū	Pāuatahanui Stream at Elmwood Bridge	**2**	**2.22**	**2311**	**-13%**	**-0.77**	**0.57**	**-12%**	**-14%**	**-11%**
Porirua Stream	Te Riu o Porirua	Porirua Stream at Milk Depot	2.4	2.4	124	0%	-0.77	0.74	0%	0%	0%

Appendix J – Peer review of sediment load target setting process for TAoP (Section 11)

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Ref:	Init:	Date:
44801481/01	JWO	1st December 2021

1) Concerning – Review of Whaitua Sediment Model Outputs

Dear Brent

I have reviewed your memo relating to the derivation of sediment loads in relation to sedimentation rate reduction targets that were set out in the Te Awarua-o-Porirua Whaitua Implementation Plan[22].

Your memo uses a combination of sediment plate data, harbour wide survey data, outputs from the sediment modelling we undertook for the Whaitua in 2019 and the temporal variability of sediment loads entering the harbour to derive an appropriate baseline sediment load for consideration of sediment load reduction targets for the Whaitua Implementation Plan.

As we discussed in DHI (2019), the majority of sediments are delivered during individual storm events which is why we chose to model a range of individual storm events in addition to the annual 2010 simulation. The purpose of the annual simulation was to quantify the subsequent movement of sediments between storm events and allow a more direct comparison of model result with both the survey and sediment plate data (both of which provide estimates of annual sedimentation rates). That modelling showed that the primary pattern of deposition is established during storm events with only relatively minor changes to sedimentation patterns and rates between storms.

The ten year period from 2005-2014 was used for the Whaitua catchment modelling because it was deemed to be representative of the climatic conditions within the Porirua catchment.

The 2010 annual simulation that we carried out provided representative estimates of 'average' sedimentation rates for the period 2005-2014 primarily because the sediment load delivered in 2010

[22] Te Awarua-o-Porirua Whaitua Committee, 2019. Te Awarua-o-Porirua Whaitua Implementation Programme

(8839 tonnes/yr) was very similar to the average sediment load delivered between 2005-2014 (7971 tonnes/yr).

However, in the context of longer term historic loads delivered to the harbour (and as we discussed in DHI, 2019), 2010 could be considered a relatively low sediment load year. This is primarily why we opted to include the simulation of the 2004 storm event (which delivered over five times the average sediment load delivered between 2005-2014).

As you conclude in your memo, using the period 2004-2014 to define a baseline sediment load is therefore more appropriate when considering the sediment load reduction targets for the Whaitua Implementation Plan since the mean load over this period is more representative of the historical sediment loads delivered to the harbour.

Your methodology for estimating the sediment loads required to meet the Whaitua Implementation Plan target sedimentation rates uses the same approach that we have adopted for Catchment Receiving Environment Scenario Tool that we have developed for both Auckland Council and the Bay of Plenty Regional Council. That is, we take results from a number of representative model simulations (which can be event based or annual simulations) and manipulate the underlying data to determine the what-if outcomes of sediment load reductions without the need for rerunning the underlying sediment transport model.

I am not sure that the event based estimates of basin wide sedimentation rates (as opposed to the true annual estimates from an annual model run) will overstate the longer-term sedimentation rate (paragraph 1, pg. 6 of your memo). The subsequent reworking of sediments and the relatively small input of sediments between storm events will result in relatively small changes in deposition patterns and rates at a subestuary level, but I believe that basin wide deposition rates will be primarily driven by the event based deposition. Importantly however, your conclusion that not accounting for sediment dynamics and inputs outside the period of the storm events would result in relatively small changes in the sediment load/deposition relationship (from your Figure 4 repeated below) is correct. I'm happy to discuss this further and assist you with rewording this paragraph if required.

The only editorial comment I have is that the caption on Figure 2 should refer to “adapted from DML, 2019”.

Thanks for the opportunity to review this work.

Best regards
John Oldman
Principal Coastal Scientist

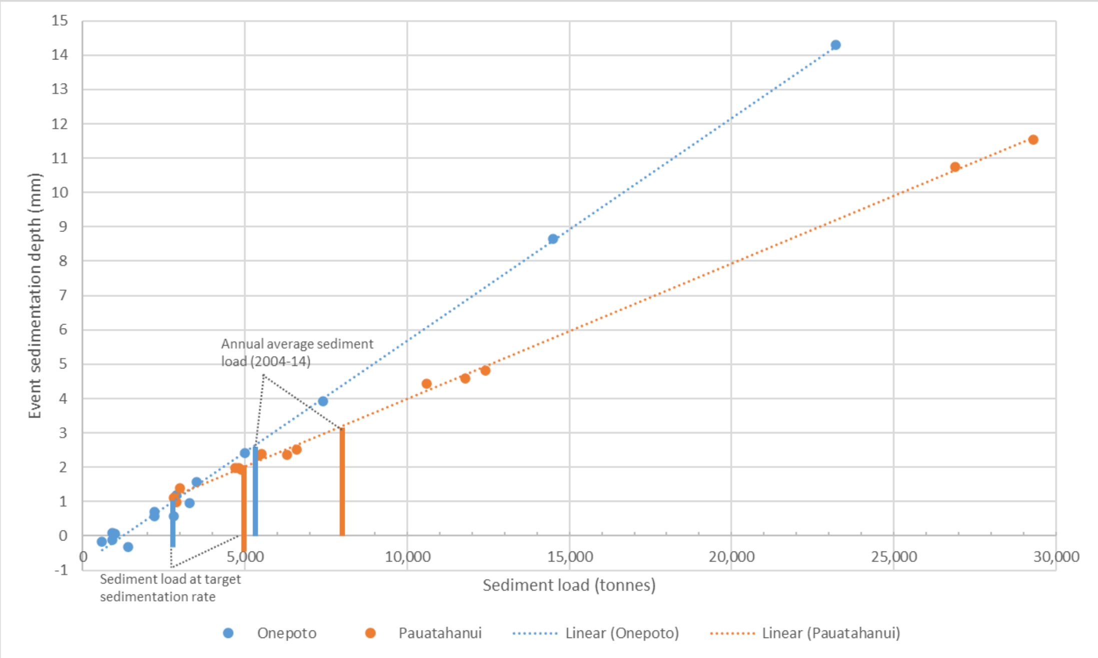

Figure 4 - Simulated sedimentation events in Te Awarua-o-Porirua

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