Technical assessment of the impacts of the NPS-FM 2020 national bottom lines on sheep and beef farms

Report No. 2024-001

TORLESSE
ENVIRONMENTAL LTD

Authors

Michael Greer

Contact:

Dr Michael Greer
Principal Scientist, Director
Torlesse Environmental Ltd
M: +64 (27) 69 86 174
4 Ash Street, Christchurch 8011

Prepared for: Beef + Lamb New Zealand Ltd
Report No. 2024-001
Date: 22/07/2024

Quality Assurance (Report Status: Final)			
Role	**Responsibility**	**Date**	**Signature**
Prepared by	Michael Greer	22/07/2024	
Approved for issue by:			
Reviewed by (excluding Appendix A)	Duncan Gray	22/02/2024	

RECOMMENDED CITATION: Greer, M.J.C. 2024. Technical assessment of the impacts of the NPS-FM 2020 national bottom lines on sheep and beef farms. Prepared for Beef + Lamb New Zealand Ltd. Torlesse Environmental Report No. 2024-001. Christchurch, New Zealand.

Executive summary

Beef + Lamb New Zealand Ltd are interested in exploring the wider implications of the compulsory attribute state frameworks in Appendix 2A of the National Policy Statement for Freshwater Management (NPS-FM) 2020 for the sheep and beef sector. The purpose of this report is to review the relevant scientific literature to describe the compulsory attributes relevant to the sector, how they were developed, and the potential level of effort required by farmers to achieve the associated national bottom lines. This review is largely limited to the conglomeration and interpretation of the existing national scale models used to develop the NPS-FM 2020 attribute state frameworks and other national level policy. No new modelling has been undertaken and many of the conclusions drawn are based on expert opinion.

The key findings of this review are:

- Suspended fine sediment
    - The suspended fine sediment attribute state thresholds are not based on measured stressor-response relationships. Furthermore, they were set to achieve outcomes for a fish community health indicator not included as the compulsory fish attribute in the NPS-FM 2020. As a result, meeting the national bottom lines in many catchments:
        - May not result in the fish community health outcomes they were set for; and
        - May not be possible, even with the significant retirement of hill and high country sheep and beef farms. Indeed, some data sources indicate that they are not met in ~20% of monitored minimally disturbed rivers and may require an improvement beyond natural state across a substantive proportion of the river network.
    - The degree to which natural variability is accounted for in the national bottom lines is influenced by the number of sediment classes used, and it is for that reason that Franklin *et al.* (2019) originally recommended 12 sediment classes rather than the four adopted in the NPS-FM 2020.
- *Escherichia coli*
    - The inclusion of the ninety-fifth percentile statistic in the *Escherichia coli* (*E. coli*) attribute without allowing regional councils to exclude data collected during rainfall may make it difficult to achieve the compulsory minimum improvement in pastoral rivers where stormflow *E. coli* concentrations are currently high.
    - In those cases, the required improvement may necessitate a reduction in *E. coli* concentrations during rainfall conditions when losses are difficult to mitigate through stock exclusion and there is little health risk to recreational users.

Contents

Tables

Figures

Appendices

Glossary of terms used

Term	Meaning
Action planning	Developing and implementing an action plan in accordance with the NPS-FM 2020
Attribute	A water quality or ecology parameters listed in Appendix 2 of the NPS-FM 2020
Attribute state framework	The numeric and narrative thresholds specified for attributes listed in Appendix 2 of the NPS-FM 2020
B+LNZ survey farms	Farms included in the B+LNZ Sheep and Beef Farm Survey. The B+LNZ Sheep and Beef Farm Survey has been running continuously since 1950. It is a sample survey where a stratified sample of around 5% (500) of the sheep and beef farm population (representing the range in size, location and farm class) is surveyed for production, and financial data as well as physical characteristics of the property.
E. coli	*Escherichia coli, microorganism used to indicate faecal contamination*
FEP	Farm Environment Plan
LCDB	Land Cover Database version 5.0
LUC	Land Use Capability (class)
MfE	Ministry for the Environment
NBL	A national bottom line set for an attribute in in Appendix 2 of the NPS-FM 2020
NPS-FM	National Policy Statement for Freshwater Management
PC1	Proposed Waikato Regional Council Plan Change 1: Waikato and Waipā River Catchments
REC	River Environment Classification
SFS	Suspended Fine Sediment (as measured by visual clarity)
TAS	A target attribute state set by a regional council
The STAG	The Science and Technical Advisory Group for the Essential Freshwater reforms
Stock Exclusion Regulations	Resource Management (Stock Exclusion) Regulations 2020

1 Introduction

1.1 Background

Beef + Lamb New Zealand Ltd (B+LNZ) is the farmer-owned industry organisation that represents the sheep and beef farmers of New Zealand. Through recent regional planning processes B+LNZ have become increasingly aware of the uncertainty around the level of mitigation and land-use change required to meet the target attribute states (TASs) proposed by some regional councils; especially those for sediment. In light of this, B+LNZ have expressed an interest in exploring the wider implications of the national bottom lines (NBLs) in Appendix 2A of the National Policy Statement for Freshwater Management (NPS-FM) 2020[1] for the sheep and beef sector.

The primary purpose of this report is to answer the following question:

"What do the NBLs in the NPS-FM 2020 achieve in terms of environmental outcomes, and what is required from the sheep and beef sector to meet them".

This was achieved by reviewing and interrogating the relevant scientific literature to describe:

- The compulsory attributes for rivers in Appendix 2A of the NPS-FM 2020 that are relevant to the sheep and beef sector;
- Any uncertainties in NPS-FM 2020 attribute state frameworks that makes the achievement of the NBLs difficult and/or of questionable environmental benefit;
- The actions on sheep and beef farms required to achieve the NBLs in different regions; and
- The knowledge gaps that need to be filled to fully understand the effect of the NPS-FM 2020 NBLs on the sheep and beef sector.

1.2 Scope and limitations

- The focus of this report is primarily limited to those attributes in Appendix 2A (i.e., not 2B) of the NPS-FM 2020, as those attributes will drive the regulatory limits in regional plans and have the most immediate effect on the sheep and beef sector[2]. However, a detailed review of the phosphorus framework of the NPS-FM 2020 (including the Appendix 2B dissolved reactive phosphorus attribute) is also provided in Appendix A of this report.
- The intent of this report is to inform B+LNZ of the general scale of the challenge that sheep and beef farmers face in meeting the NPS-FM 2020 NBLs. As a review document it is generally limited to the conglomeration and interpretation of the existing national scale models used to develop the NPS-FM 2020 attribute state frameworks. Many of the conclusions in this report are based on expert opinion. Consequently, there would be benefit in confirming them through additional technical work (see Section 5).

---

[1] Including the minimum attribute state improvement for *E. coli*.

[2] As regional council can achieve the targets states for other attributes through non-regulatory action planning.

- No new modelling work has been conducted for this report. All modelling results presented have been drawn from the studies that informed the development of the policies and regulations included in the previous government's 'Essential Freshwater package'.
- While issues have been identified with the suspended fine sediment (SFS) attribute framework, this report is not intended to be a criticism of the authors of the technical reports behind that attribute, who:
    - Delivered a technical project as commissioned by the Ministry for the Environment (MfE);
    - Used a multiple lines of evidence approach to identify the most suitable attribute state framework for suspended sediment; and
    - Acknowledged most of the limitations identified in this report.

  Ultimately, the SFS attribute was adopted in the NPS-FM 2020 under the guidance of the Science and Technical Advisory Group (STAG) who defined "*bottom lines considering both [their] understanding of New Zealanders' views as to the bounds of acceptability and, from a technical perspective*" (STAG, 2019).

2 Review of the suspended fine sediment attribute

2.1 Technical issues with the attribute state framework and the national bottom lines

2.1.1 Background

The SFS attribute in Table 8 of the NPS-FM 2020 sets a four-band (A-D) framework for visual clarity (a measure of how far the human eye can see in water) that applies differently to rivers that fall within each of four sediment classes[3]. The attribute state framework was developed by Franklin *et al*. (2019) who built on earlier research by Depree *et al*. (2018). The STAG recommended the inclusion in the draft NPS-FM 2020 (STAG, 2019) before being further refined in the final version of the NPS-FM 2020 by Booker *et al*. (2020) and Franklin *et al*. (2020).

It is my understanding that the NBL for each sediment class reflects the modelled visual clarity at which point the pooled probability of capturing[4] six native fish species and brown trout (*Salmo trutta*) is reduced by 20% (compared to the probability of capturing those same fishes in a pristine river). The thresholds between the A/B and B/C states have then been evenly distributed between reference (natural) state visual clarity and the NBL[5]. The specific derivation of each attribute state compared to the NPS-FM 2020 narrative attribute states are provided in Table 1. Critically, the SFS attribute state framework was not developed to protect all instream biota, "*particularly sensitive macroinvertebrates*" as suggested by the NPS-FM 2020 narrative attribute states.

[3] The class framework is intended to account for the natural variability between rivers with different climates, source of flow and catchment geology.

[4] Through electric fishing.

[5] In terms of effect on fish.

Table 1: Specific details of outcomes the SFS attribute states were designed to achieve and their narrative description in the NPS-FM 2020.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	**Suspended fine sediment**	
Attribute Unit	Visual clarity (metres)	
Attribute State	**Attribute state designed to achieve**	**NPS-FM 2020 narrative attribute state**
A	Less than 7% reduction in probability of capturing: • Upland bully (*Gobiomorphus breviceps*); • Redfin bully (*G.huttoni*); • Koaro (*Galaxias brevipinnis*); • Banded kōkopu (*G. fasciatus*); • Longfin eel (*Anguilla dieffenbachii*); • Torrentfish (*Cheimarrichthys fosteri*); and • Brown trout, due to impact of suspended sediment	Minimal impact of suspended sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.
B	7% to 13%% reduction in probability of capturing aforementioned fish species due to impact of suspended sediment	Low to moderate impact of suspended sediment on instream biota. Abundance of sensitive fish species may be reduced.
C	13% to 20% reduction in probability of capturing aforementioned fish species due to impact of suspended sediment	Moderate to high impact of suspended sediment on instream biota. Sensitive fish species may be lost
NBL	**20% reduction in probability of capturing aforementioned fish species due to impact of suspended sediment**	
D	>20% reduction in probability of capturing aforementioned fish species due to impact of suspended sediment	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.

2.1.2 Identified issues with the attribute state framework

There are several sources of uncertainty associated with the technical work behind the SFS attribute state framework and the NBLs. Each of these are addressed individually in Sections 2.1.2.1 to 2.1.2.5 .

Most of the uncertainties discussed in Sections 2.1.2.1 to 2.1.2.5 are openly acknowledged in Franklin *et al*. (2019). Including:

- "*The absence of paired observations (in space and time) of fish and* [] *visual clarity*" (also scored as a negative in the 'Weight of evidence scoring tables' in Appendix L of the report); and
- That "*bias increases with aggregation of* [sediment] *classes*" (as was done in the final version of the NPS-FM 2020 (12 to 4)), "*resulting in more variable and potentially unachievable outcomes*".

However, the importance of these uncertainties appears to have been overlooked through the development of the NPS-FM 2020.

2.1.2.1 Issue 1: The sediment-fish relationship used to establish the National Bottom Lines is not based on measured data

When establishing relationships between visual clarity and fish (probability of capture), Franklin *et al*. (2019) used:

- Modelled estimates of visual clarity based on the same inputs as Whitehead (2018) but bolstered with sediment yield estimates (Hicks *et al*., 2019); and
- Actual fish records collected[4] and entered into the New Zealand Freshwater Fish Database (NZFFD) between 1970 and 2019,

Those relationships were then used to predict the species present at a site based on modelled visual clarity and catchment characteristics.

In my opinion, there are a number of possible issues adopting and implementing an attribute state framework developed in this way. Potentially the most significant being that a restrictive piece of national regulation has been developed without paired measured data to support the stressor-response relationship upon which is it based.

The approach used by Franklin *et al*. (2019) attempts to establish causality based on stressor and response data collected/modelled over different time periods. Indeed, only 12% of the fish data used by Franklin *et al*. (2019) were collected during the five-year period in which their modelled estimates of visual clarity apply (2013-2017; (Whitehead, 2018)). Thus, it is uncertain whether the remaining 88% of the data used to develop the NBLs are suitable for this purpose, with Franklin *et al*. (2019) simply assuming that "*because the summary statistic of the suspended sediment [] was the long-term median, results would be compatible with existing state of the environment monitoring strategies for these variables*". Such an approach would be justified if neither visual clarity nor fish conservation status had not changed since 1970; however, there is evidence that this is not the case (Dunn *et al*., 2017; Julian *et al*., 2017). In their earlier reports the authors of Franklin *et al*. (2019) themselves acknowledged that "*it was not appropriate* *to pair the fish and deposited sediment* [] *observations from the same site when they were so far apart in time (e.g., >5 years)* (Depree *et al*., 2018) and it is unclear why this reasoning would apply to measured deposited sediment data, but not modelled visual clarity.

While the type of water quality models used by Franklin *et al*. (2019) to predict visual clarity at previously fished sites work well at large scales their performance reduces as spatial resolution increases. Thus, it is uncertain whether pairing modelled estimates of visual clarity to measured fish data collected at specific sites can yield robust relationships between the two, even for the 12% of NZFFD records collected during the period for which visual clarity was modelled. For example, the uncertainty analysis results provided in Whitehead (2018)[6] suggests that for each fish record used in the analysis by Franklin *et al*. (2019) there may only be a 50% probability that the paired estimate of visual clarity was within ± 25% of what actually occurred between 2013 and 2017. This means that a fish site modelled to be in the B attribute state by Franklin *et al*. (2019) was more than likely than not in either the A, C or D attribute state.

Models like those used by Franklin *et al*. (2019) also mainly predict visual clarity based on landscape factors (topography, geography and climate) and the percentage of the catchment in agriculture (Whitehead, 2018). Franklin *et al*. (2019) did account for the effects of such landscape factors when developing the sediment-fish relationships upon which the NBLs are based. However, they were open about not accounting for non-sediment confounding factors associated with agricultural development (e.g., effects on periphyton growth, macroinvertebrate community health, water quality, flows, habitat modification etc). Thus, the NBLs for SFS may not represent the direct adverse effects of sediment on fish. Rather degraded fish health and visual clarity may both simply be correlated with the extent of upstream agricultural development. In which case, the benefits of meeting the SFS NBL for fish will be vary between and within catchments based on the degree to which suspended sediment impacts fish. In catchments where the only effect of rural development is significantly reduced visual clarity, the benefits to fish may be significant. However, in catchments where fish are heavily impacted by periphyton blooms or water over-allocation, achieving the SFS NBL might have minimal impact.

---

[6] Expected to be comparable to Franklin *et al*. (2019) which used much the same model inputs but presents limited information on the uncertainty in their visual clarity model or and the importance of different predictor variables.

2.1.2.2 *Issue 2: The national bottom lines may not adequately account for natural variability and may be unachievable in many rivers as a result.*

Different SFS NBLs are set in the NPS-FM 2020, for each of four different sediment classes. However, the modelling upon which the NBLs are based was conducted at a much finer scale (Franklin *et al.*, 2019). Specifically:

1. The reference (natural) state of visual clarity in each segment of the River Environment Classification (REC)[7] segment was modelled;
2. Those modelled reference states for REC segments with similar climates, topographies and geologies were pooled and averaged to determine:
    a. The pooled fish probability of capture of each fish species in that climate-topography-geology class under reference conditions (based on the modelled relationship between visual clarity and fish); and
    b. The NBL for that climate-topography-geology class (the visual clarity at which the pooled fish probability of capture is <80% of that modelled at the average reference state).
3. A single NBL for each of the NPS-FM sediment classes was then calculated as the weighted (by relative river length) average of the NBLs for the REC climate-topography-geology classes contained within.

A result of the process described above is that the NBLs in the NPS-FM 2020 are skewed towards the modelled average reference states of the predominate climate-topography-geology classes in the REC network (Franklin *et al.*, 2019). Accordingly, the degree to which natural variability is accounted for in the NBLs is influenced by the number of sediment classes used; it is for that reason that Franklin *et al.* (2019) originally recommended 12 sediment classes rather than the four adopted in the NPS-FM 2020. Consequently, the current NBLs may not adequately account for natural variability and may be unachievable in some rivers.

The percentage of rivers in which the NPS-FM 2020 NBLs are unachievable cannot be directly determined from the data provided in Franklin *et al*. (2019), as the NBLs were further refined by Franklin *et al*. (2020) (a much shorter and less detailed memorandum) before their final adoption. However:

- Comparisons of the final NBLs with the reference state distributions presented in McDowell *et al*. (2013)[8] (Table 2) indicates that they are potentially more stringent than the reference state of ~38% of the REC network[9]. This is issue is greatest for sediment class 3, where the NBL is more stringent than the estimated reference state of 44% of included rivers (Table 2). However, it must be noted that these values are somewhat contradicted by the available modelled and measured

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

[8] Distribution of references state calculated from reported median concentrations, confidence intervals, sample sizes (from the REC) and derived standard deviations at Level 2 of the REC (Climate + topography). Percentile = $\text{Median}_{\log}$ + Z × Standard $\text{deviation}_{\log}$ **where** Standard $\text{deviation}_{\log}$ = $\text{CI}_{\log}$ / 3.92 ×√n **and** Z = $x_{\log}$ – $\text{median}_{\log}$ / Standard $\text{deviation}_{\log}$

[9] See Section 2.1.2.1 for discussion on limitations of national scale models such as those in McDowell *et al*. (2013)

current state data, which indicates that current non-compliance with the NBLs sits between 14% (Whitehead *et al.*, 2021) and 32% (Whitehead *et al.*, 2022).

- Nationally, 19% of minimally disturbed[10] water quality monitoring sites did not meet the SFS NBLs in 2020 (Whitehead *et al.*, 2022).
- Snelder *et al.* (2023) noted that NBLs are not met in many areas due to naturally occurring processes, observing that they require a reduction in sediment load across 63% of New Zealand including large areas of the Southern Alps.

Table 2: Estimated percentage of rivers in each sediment class with modelled reference state visual clarity less than the NPS-FM 2020 SFS NBL (McDowell *et al.* 2013).

Sediment class	% of rivers unable to meet NBL in reference state
1	41%
2	33%
3	44%
4	24%
Total	**38%**

2.1.2.3 Issue 3: The national bottom lines are linked to predicted response of a limited number of fish species to sediment

The SFS NBLs are based on the modelled impact of visual clarity on just seven fish species, including brown trout. Potential issues with this approach include:

- Six native fish species represents just ~10% of total freshwater fish diversity in New Zealand;
- Several of the species considered by Franklin *et al*. (2019) are not found in inland areas or at high elevations (i.e., banded kōkopu, redfin bully, and, to a lesser extent, torrentfish). Indeed, 52% of the REC is outside the known distribution of these three species (66% for banded kōkopu, 62 % redfin bully, 45% torrent fish) (Figure 1). Franklin *et al*. (2019) accounted for this in their modelling but did not provide an opinion on the appropriateness of setting NBLs that are largely based on the modelled response of the remaining four native fishes and brown trout to sediment.
- Two of the species considered (banded kōkopu and redfin bully) do not commonly occur across large areas of the east coast of New Zealand (Figure 1). Franklin *et al*. (2019) do not account for this biogeographic factor in their modelling, and this may have impacted their results (i.e., part of the modelled impact of visual clarity on the probability of capturing these species may have been due to the natural limits of their distribution).

---

[10] <5% of anthropogenic modified land-cover (urban, pastoral, and exotic forestry) in catchment (as percentage of the upstream catchment area) (McDowell *et al.*, 2013; Whitehead *et al.*, 2022)

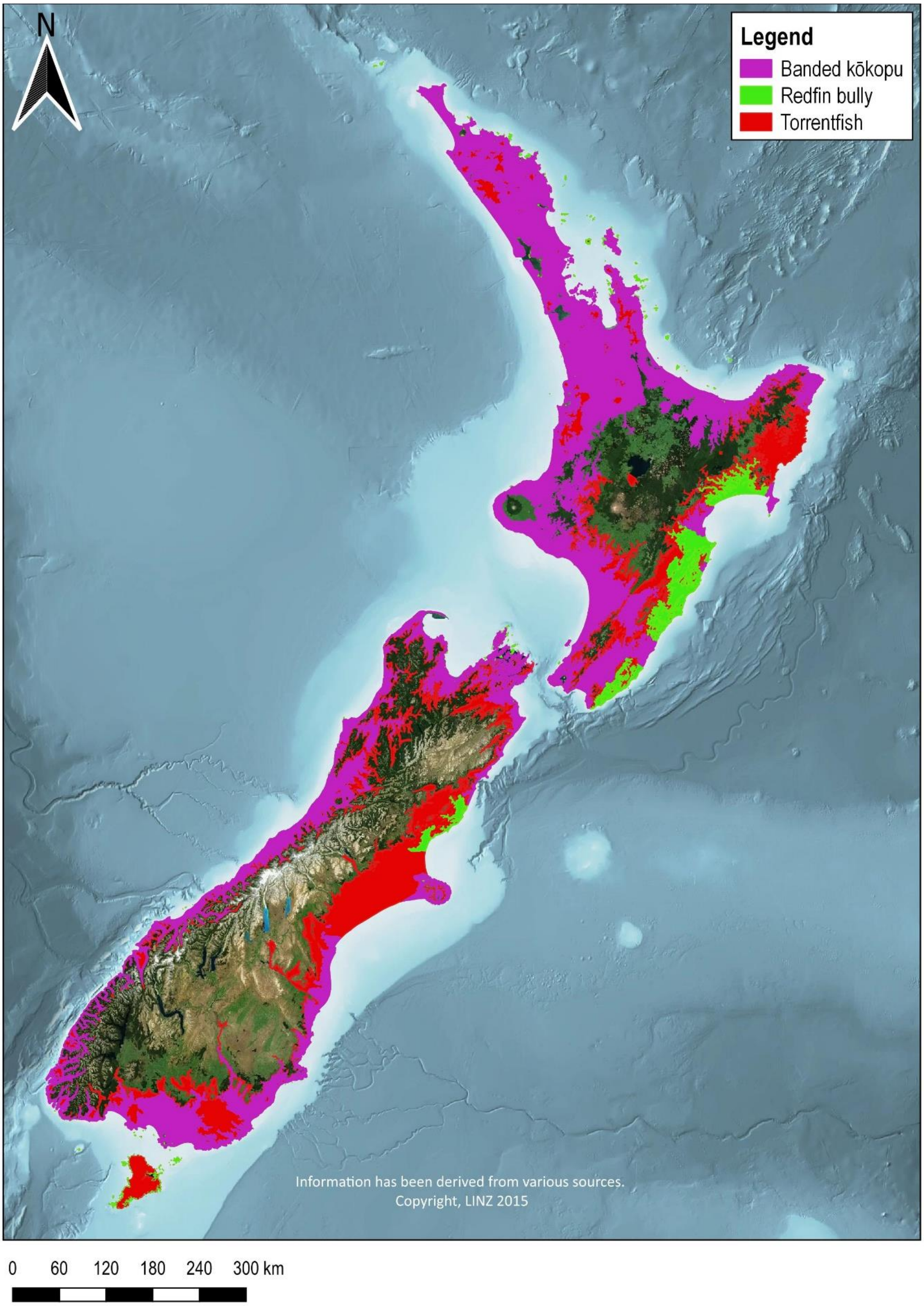

Figure 1: Distribution of banded kōkopu, redfin bully and torrentfish based on NZFFD records. Note – The distribution of redfin bully and torrentfish are partially obscured by the layers above (see legend for order).

2.1.2.4 Issue 4: The national bottom lines are not set for the fish attribute in the NPS-FM 2020

It is my understanding the fish probability of capture metric used by Franklin *et al*. (2019) to establish the SFS NBLs was developed specifically for that purpose; it is not a commonly used measure of fish community health, nor is it a compulsory attribute in the NPS-FM 2020.

2.1.2.5 Summary

While the SFS NBLs are designed to protect a subset of native fish and brown trout from the adverse effects of sediment, the nature of the visual clarity data used by Franklin *et al*. (2019) means they may not be fit for that purpose. The implementation of the SFS NBLs is made more fraught as the available data suggests they may be unachievable in a significant number of rivers.

2.2 Potential level of effort to achieve the national bottom lines

2.2.1 Background

As stated in Section 2.1.2.2 , the process by which the SFS NBLs for visual clarity have been developed means that in many rivers they will be difficult to achieve, and in some catchments may not be achievable even with the re-establishment of natural landcover. This is supported by the modelling undertaken in support of the Resource Management (Stock Exclusion) Regulations 2020 (the 'Stock Exclusion Regulations') and the NPS-FM 2020 by NIWA.

2.2.2 Potential benefits of stock exclusion

2.2.2.1 Data sources and methods

As part of the development of the Stock Exclusion Regulations, Semadenis-Davies *et al*. (2020) modelled the impact of the four scenarios described in Table 3 on sediment loads in each segment of the REC. In this report, the following data sources have been used to determine the impact of those stock exclusion scenarios on the percentage of rivers (in total length) not meeting the SFS NBLs, to provide a general indication of the extent to which stock exclusion can contribute to their achievement:

- The modelled sediment load reductions in Semadenis-Davies *et al*. (2020),
- The modelled estimates of SFS baseline state in Whitehead (2018)[11]; and
- The relationship between sediment load and visual clarity change established by Hicks *et al*. (2019).

[11] This model was chosen over Whitehead *et al*. (2021) as the modelling period better aligns with definition of baseline state in the NPS-FM 2020 (i.e., state at 07/09/2017).

Table 3: Description of the stock exclusion scenarios tested by Semadenis-Davies *et al.* (2020). For context, the requirements of the Stock Exclusion Regulations are also provided and the most comparable scenario to those regulations(3) is highlighted.

Scenario descriptions				
Scenario number	**Stock type**	**Required setback (m)**	**Applies to rivers with a width greater than (#m)**	**Applies Slope**
1	Dairy	3	1	≤5°
		1		>5°
	Sheep, beef cattle and deer	1		≤5°
2	Dairy	3		≤5°
		1		>5°
	Sheep, beef cattle and deer	3		≤5°
		1		>5° (where degraded)
3	Dairy	3		≤10°
		1		>10°
	Sheep, beef cattle and deer	3		≤10°
4	Dairy	5		≤5°
		1		>5°
	Sheep, beef cattle and deer	5		≤5°
Stock Exclusion Regulations	Dairy (including support), intensive deer and beef cattle, pigs	3		All terrain
	Other deer and beef cattle			≤5°
	Sheep	N/A		

The general process by which visual clarity was calculated for each REC segment under the different stock exclusion scenarios is summarised by the equation below:

$$SFS_{future} = (1 - \Delta Load_{\%})^{\alpha} \times SFS_{baseline}$$

SFS_{future} = predicted future median visual clarity under the scenario

$\Delta Load_{\%}$ = predicted proportional reduction in sediment load under the scenario (from Semadenis-Davies *et al*. (2020))

α = Co-efficient used in national power law relationship between suspended sediment concentration and visual clarity established by Hicks *et al*. (2019) (-0.76).

$SFS_{baseline}$ = baseline median visual clarity from Whitehead (2018)

For each scenario, the length of the REC network meeting and not meeting the SFS NBLs has been calculated and summarised for:

- All rivers and those rivers where the dominant land cover upstream is pasture; and
- All of New Zealand and the five largest regions (by land area)[12].

2.2.2.2 Results

The modelling data from Semadenis-Davies *et al*. (2020) suggests that stock exclusion is unlikely to have a significant impact on the length of river meeting the SFS NBLs, with all scenarios tested predicted to reduce the length of failing pastoral rivers across the country by less than 25% (Table 4). Importantly, the scenario which best reflects the requirements of the Stock Exclusion Regulations (Scenario 4) was only predicted to decrease the length of pastoral river failing the NBL by 13% (nationally), despite assuming greater and more effective stock exclusion than required by those regulations (i.e., five metre setbacks + sheep excluded).

Table 4: Estimated impact of the stock exclusion scenarios tested by Semadenis-Davies *et al.* (2020) on percentage of rivers (by length) not meeting the NBL for visual clarity. Results are provided for all rivers and pastoral river at the national and regional scale (five largest regions only). Note, the results of scenario 2 have not been presented as they incorporate catchment specific additional mitigations that are not easily captured by general rules of thumb.

Region	Scenario	All rivers		Pastoral rivers	
		% of stream failing NBL	% reduction failing rivers NBL	% of stream failing NBL	% reduction failing rivers NBL
Waikato	Baseline	30%		43%	
	1	28%	5%	41%	5%
	3	26%	11%	38%	12%
	4	28%	5%	41%	5%
Manawatu	Baseline	24%		33%	
	1	23%	5%	32%	5%
	3	21%	13%	29%	14%
	4	23%	6%	31%	6%
Canterbury	Baseline	6%		8%	
	1	4%	28%	6%	32%
	3	3%	43%	4%	49%
	4	4%	32%	5%	36%
Otago	Baseline	18%		27%	
	1	16%	11%	23%	13%
	3	12%	31%	17%	36%
	4	15%	14%	22%	16%
Southland	Baseline	24%		52%	
	1	22%	10%	45%	12%
	3	18%	26%	36%	31%
	4	21%	13%	44%	16%
National	**Baseline**	**13%**		**22%**	
	1	**12%**	**9%**	**20%**	**11%**
	3	**11%**	**20%**	**17%**	**24%**
	4	**12%**	**11%**	**19%**	**13%**

[12] Excluding the West Coast given the lack of sheep and beef farming in that region.

2.2.3 Modelled benefits of erosion control measures

2.2.3.1 Data sources and methods

To determine the feasibility of achieving the NBLs for turbidity in the draft version of the NPS-FM 2020, Neverman *et al*. (2019) tested (through the New Zealand empirical erosion model (NZeem®)) the effects of the following mitigations on sediment loads in 583 REC catchments:

- Maturation of existing space planting (e.g., with poplars);
- Afforestation of grassland[13] in the Land Use Capability (LUC) 6e, 7e and 8e classes [14] (assumed to achieve 90% reduction in sediment losses from mitigated land);
- Space planting of grassland[13] in the LUC 6e, 7e and 8e classes (assumed to achieve 70% reduction in sediment losses from mitigated land); and
- Fencing of major streams (permanently flowing, >1m wide and >30cm deep) and the establishment of five-metre riparian buffers (assumed to achieve 14% reduction of catchment sediment loads (80% reduction in stream bank erosion which equated to 18% of catchment load).

In order to estimate the type and extent of mitigations required on B+LNZ survey farms[15] to achieve the SFS NBLs at the bottom (see note below) of each of the modelled catchments, the outputs of Neverman *et al*. (2019) have been interrogated by:

1. Calculating the visual clarity improvement achieved by each mitigation at the bottom of each catchment through:
    a. The modelled load reductions in Neverman *et al.* (2019);
    b. The modelled estimates of SFS baseline state in Whitehead (2018); and
    c. The relationship between sediment load and visual clarity change established by Hicks *et al.* (2019).
2. Identifying the level of mitigation required to achieve the NBL at the bottom of each catchment modelled by Neverman *et al.* (2019). Mitigation levels were tested in the following order (i.e., if two mitigations achieved the NBL, the one that appears first below was applied):
    a. Do nothing (where NBL currently met, or NBL predicted to be met through maturation of existing space planting;
    b. Riparian retirement and stock exclusion;
    c. Space planting of Class 6e, 7e and 8e land;
    d. Space planting of Class 6e, 7e and 8e land + Riparian retirement and stock exclusion;

---

[13] High producing grassland, low producing grassland and depleted grassland in the Land Cover Database version (LCDB) 5.0.

[14] New Zealand Land Resource Inventory (NZLRI) 2021

[15] Farms included in the B+LNZ Sheep and Beef Farm Survey. The B+LNZ Sheep and Beef Farm Survey has been running continuously since 1950. It is a sample survey where a stratified sample of around 5% (500) of the sheep and beef farm population (representing the range in size, location and farm class) is surveyed for production, and financial data as well as physical characteristics of the property.

e. Retirement of Class 6e, 7e and 8e land;
f. Retirement of Class 6e, 7e and 8e land + Riparian retirement and stock exclusion; and
g. Retirement of Class 6e, 7e and 8e land + Riparian retirement and stock exclusion + additional (where none of the mitigations above were predicted to achieve the NBL at the bottom of the catchment.

3. Using geospatial analysis tools to map and measure the area of required mitigation on each survey farm within the catchments modelled by Neverman *et al.* (2019) based on the land use, landcover and hydrological data contained in the NZLRI 2021, LCDB 5.0. and REC v2.5 respectively; and
4. Summarising the estimated required area of each mitigation type required on the survey farms to meet the SFS NBLs as a percentage of total grassland by farm class and region.

Important notes on methodology:

- No new modelling has been conducted for this section, instead it relies upon modelling work conducted to inform the development of the NPS-FM 2020. Specifically:
  - Neverman *et al*. (2019) and Hicks *et al*. (2019) are the two papers commissioned by MfE that assessed the feasibility of different iterations of the SFS NBLs;
  - The estimated sediment load reductions associated with the different mitigations tested were taken directly from Neverman *et al*. (2019); and
  - The approach used to estimate the resulting changes in visual clarity is taken from Hicks *et al*. (2019). While the assessment presented in this report does rely upon the modelled estimates of visual clarity in Whitehead (2018) (as opposed to those in Hicks *et al*. (2019)), this is unlikely to have substantively impacted the results with Hicks *et al*. (2019) noting "*Our results are generally consistent with those of Whitehead (2019)* [sic]*, with similar model structures (as indicated by the relative importance of predictor variables and directions of partial plots) and model performance*".
- Neverman *et al*. (2019) and Hicks *et al*. (2019) assessed the feasibility of the draft and final NPS-FM 2020 SFS NBLs by calculating the sediment load reductions required to achieve the NBLs in each REC segment, then averaging those values (including zero values) across the entire catchment. Importantly, those average load reduction estimates do not necessarily reflect the reductions needed to achieve the NBLs at the bottom of (or throughout) the catchment. Calculating the load reductions required to achieve the NBL at the bottom of each catchment provides an estimate of the minimum[16] level of mitigation required to manage the cumulative effects of sediment losses.

[16] Greater mitigations may still be required in some parts of the catchment to meet NBL in upstream reaches.

2.2.3.2 Results

Neverman *et al*.'s (2019) outputs suggest that meeting the SFS NBLs may require the retirement of 44% of the total area of survey farms within the catchments modelled in that study, with space planting needed across a further 8%. Furthermore, 54% of that mitigation is predicted to be insufficient to achieve the SFS NBLs, meaning more effort will likely be required. Based on this it appears that widespread achievement of the SFS NBLs may depend on hill and high country farming ceasing across large areas of New Zealand.

Table 5: Estimated area of mitigation (as a percentage of grass land cover) required to achieve the SFS NBLs at the bottom of the catchments modelled by Neverman *et al.* (2019) by region and farm class. The final column denotes the percentage of that mitigation that is not estimated to result in the NBLs being met (i.e., more mitigation is needed).

Region	Farm class	Retire	Riparian retirement	Space planting	Total mitigated area	kms of stream fenced	% of mit. not resulting in NBL
Northland, Auckland, Waikato, BoP	N.I. Finishing	28%	0.03%	9%	37%	1.2	11%
	N.I. Hard Hill Country	65%	0.12%	8%	73%	21.2	55%
	N.I. Hill Country	50%	0.08%	12%	62%	14.4	20%
	Total	**54%**	**0.09%**	**10%**	**64%**	**36.9**	**34%**
East Coast	N.I. Finishing	3%	0.04%	2%	5%	3.4	1%
	N.I. Hard Hill Country	28%	0.20%	11%	40%	52.7	20%
	N.I. Hill Country	39%	0.16%	8%	47%	37.6	29%
	Total	**29%**	**0.16%**	**9%**	**37%**	**93.7**	**21%**
Taranaki, Manawatu, Wellington	N.I. Finishing	12%	0.62%	0%	13%	24.9	79%
	N.I. Hard Hill Country	70%	0.13%	0%	70%	24.8	91%
	N.I. Hill Country	37%	0.21%	0%	38%	31.6	56%
	Total	**51%**	**0.22%**	**0%**	**51%**	**81.2**	**76%**
Tasman, Marlborough, Canterbury	S.I. High Country	12%	0.00%	79%	92%	0.3	0%
	S.I. Hill Country	0%	0.00%	89%	89%	0.0	0%
	S.I. Finishing Breeding	7%	**0.50%**	28%	36%	17.5	0%
	Total	**9%**	0.11%	**70%**	**79%**	**17.8**	**0%**
South Canterbury, Otago, Southland	S.I. Finishing	3%	0.23%	1%	4%	17.6	49%
	S.I. High Country	62%	0.29%	0%	63%	205.4	70%
	S.I. Hill Country	51%	**0.26%**	0%	51%	100.3	82%
	S.I. Mixed Finishing	4%	0.38%	0%	5%	0.9	91%
	S.I. Finishing Breeding	26%	0.36%	8%	35%	85.4	75%
	Total	**50%**	0.29%	**2%**	**52%**	**409.6**	**73%**
National		**44%**	**0.22%**	**8%**	**52%**	**639.2**	**54%**

2.2.4 Potential to meet the national bottom lines through Whole of Farm Plans

There have been several instances recently where the ease with which target sediment losses can be achieved has been overstated. Specifically, the modelling conducted by the Waikato Regional Council for the appeals on PC1 suggested that farm environment plans (FEPs) can achieve 70% reductions in sediment losses at the farm scale (Olubode-Awosola, 2020). Similarly, when considering the impacts of feasible mitigations, the Our Land & Water National Science Challenge determined that a 70% reduction in sediment losses from hill slopes was achievable by 2035 (McDowell *et al.*, 2021) and went on to use this figure in their WebApp[17] for calculating mitigatable sediment loads.

It is my understanding that the assumption that sediment can be reduced by 70% at the farm scale comes from Dymond *et al*., (2010) where it is presented as an untested assumption around the efficacy of a Whole of Farm Plan that requires a high level of mitigation/land-use change, including:

- Space planting of all erosion prone slopes:
- Planting of all large gullies;
- Planting of all stream banks with willows.

Since Dymond *et al*., (2010) was published the definition of Whole of Farm Plan seems to have changed from encapsulating a suite of mitigations applied across the whole farm, to referring to space planting of LUC class 6e, 7e and 8e land (McDowell *et al.*, 2021; Neverman *et al.*, 2019). Despite this reduction in the scope of assumed mitigations, Whole of Farm Plans are still not comparable to FEPs which generally do not require such wide-spread space-planting.

To demonstrate the implications of Whole of Farm Plans on the sheep and beef farms, the area of grassland that would need to be space planted within the B+LNZ survey farms if they were adopted is presented in Table 6. Those figures suggest that, nationally, space planting would need to be undertaken across 61% of the total grassland area within the survey farms. The impact is generally consistent between regions and classes, except for the 'finishing' classes, where the required space planting would be much less (Table 6).

[17] https://www.monitoringfreshwater.co.nz/webapp

Table 6: Estimated area of B+LNZ survey farms (as a percentage of grassland) that would need to be space planted grassland if Whole of Farm Plans were adopted. Figures are summarised by region and farm class.

Region	Class	Area space planted (ha)	Area of grassland (ha)	Percent of grassland space planted
Northland, Auckland, Waikato, BoP	N.I. Finishing	1723	5424	32%
	N.I. Hard Hill Country	19518	22715	86%
	N.I. Hill Country	18854	28573	66%
	Total	**40095**	**56712**	**71%**
East Coast	N.I. Finishing	2178	10479	21%
	N.I. Hard Hill Country	28865	36805	78%
	N.I. Hill Country	23068	31513	73%
	Total	**54111**	**78797**	**69%**
Taranaki, Manawatu, Wellington	N.I. Finishing	878	4394	20%
	N.I. Hard Hill Country	14534	19450	75%
	N.I. Hill Country	10334	15126	68%
	Total	**25746**	**38970**	**66%**
Tasman, Marlborough, Canterbury	S.I. High Country	7809	9478	82%
	S.I. Hill Country	3854	4278	90%
	S.I. Finishing Breeding	2807	5708	49%
	Total	**14470**	**19464**	**74%**
South Canterbury, Otago, Southland	S.I. Finishing	616	8347	7%
	S.I. High Country	49373	77971	63%
	S.I. Hill Country	35821	59859	60%
	S.I. Mixed Finishing	45	1746	3%
	S.I. Finishing Breeding	13266	40947	32%
	Total	**99121**	**188871**	**52%**
National		**233543**	**382815**	**61%**

2.2.5 Summary

The available modelling indicates that the SFS NBLs are unlikely to be achieved in many pastoral rivers without significant retirement of hill and high-country sheep and beef farms. While Whole of Farm Plans have been discussed as a potential approach for mitigating sediment losses in these areas, the modelling results in Neverman *et al*. (2019) indicates that, despite requiring most of the grassland on sheep and beef farms (61%) to be completely space planted, they still do not universally achieve the SFS NBLs.

2.3 Concluding statements on the SFS attribute in the NPS-FM 2020

The SFS attribute state framework in the NPS-FM 2020 is not based on measured stressor-response relationships and were set to achieve outcomes for a novel fish community health indicator. Consequently, in many catchments there is a risk that achievement of the NBLs:

- May not result in the environmental outcomes they were set for; and
- May not be possible, even with the widespread retirement of hill and high country sheep and beef farms.

3 Review of the *E. coli* attribute

3.1 Technical issues with the *E. coli* attribute state framework

3.1.1 Background

The *E. coli* attribute framework was introduced with the 2017 amendments to the NPS-FM 2014. It is largely based on the Microbiological Assessment Categories in MfE/MoH (2003) which have been used by regional councils for the past 20 years to report on microbial health risk from faecal contamination. With the exception of the 95th percentile for attributes states B to D, the thresholds used in the NPS-FM 2020 correlate to a specific risk of *Campylobacter* infection to people undertaking activities which involve full immersion in water (MfE/MoH,' 2003).

3.1.2 Identified issues

The potential issues with the *E. coli* attribute state framework stem from:

- The inclusion of the 95th percentile assessment statistics without allowing regional councils to exclude data collected during rainfall or high flows; in combination with
- The requirement for regional councils to set target states at least one state higher than baseline state.

Stock exclusion has been shown to be effective at reducing *E. coli* concentrations in pastoral rivers during baseflows (i.e., when *E. coli* primarily enters the stream from animals defecating in close proximity to it) (Muirhead, 2019). However, there is evidence that it is less effective (62% in Sunohara *et al*. (2012)) during rainfall when:

- *E. coli* enters from the pasture via run-off (Muirhead, 2019); and
- Faecal material previously deposited on the bed (and the associated *E. coli*) is remobilised (Nagels *et al.*, 2002).

Thus, while mitigations like stock exclusion may significantly reduce *E. coli* concentrations in pastoral rivers during baseflows, it is uncertain how they will contribute to an attribute state improvement in waterways where that requires substantial reductions in storm-flow concentrations to achieve a specific 95th percentile concentration.

Recent studies have highlighted the limited evidence to support the commonly held view that *E. coli* concentrations are positively correlated with flows, and that 95th percentile concentrations generally reflect stormflow conditions (Muirhead *et al.*, 2023; Snelder *et al.*, 2016). Nevertheless, the inclusion of this assessment statistic in the NPS-FM 2020 does mean that reductions in stormflow *E. coli* concentrations will be needed in some rivers to achieve the required attribute state improvement.

When the data requirements of the *E. coli* attribute state are met, the 95th percentile assessment statistic is determined by the two samples with third and fourth highest *E. coli* concentrations in the data set. Accordingly, at sites where stormflow *E. coli* concentrations occasionally exceed the 95th percentile concentration of the attribute state above, concentrations will need to reduce across all flows to achieve the minimum required improvement, regardless of the flow-conditions under which current 95th percentile concentrations were recorded.

Such reductions in stormflow *E. coli* concentrations are both potentially challenging and, arguably, of limited benefit given:

- The difficulty in mitigating stormflow *E. coli* concentrations;
- People generally avoid full immersion activities during rainfall and/or high flows; and
- The 95th percentile thresholds set for all attribute states apart from 'A' do not relate to a risk of *Campylobacter* infection.

That is not to say, however, that minimising *E. coli* losses (not concentrations) during rainfall is not important nor that mitigation designed to achieve this have no value. Rather there may be limited human health benefit in designing mitigations to achieve a specific *E. coli* concentration during rainfall.

Note: In some rivers achieving an attribute state improvement will be difficult because of the scale of the E. coli reductions required. This is not considered in this section as it is not necessarily a structural issue with the attribute state framework.

3.2 Potential level of effort to achieve the minimum improvements for *E. coli*

3.2.1 Modelled benefits of stock exclusion

<u>*3.2.1.1 Data sources and methods*</u>

In addition to modelling sediment loads under the four stock exclusion scenarios in Table 3 (see Section 2.2.2), Semadenis-Davies *et al*. (2020) also generated predictions of how *E. coli* attribute state will change in each REC segment under those scenarios. For the purposes of this report, those outputs have been used to calculate the percentage of REC segments (in terms of length) in which the minimum required improvement for *E. coli* is achieved under each scenario. These results were then summarised for:

- All rivers and those rivers where the dominant land cover upstream is pasture; and
- All of New Zealand and the five largest regions (by land area)[12].

<u>*3.2.1.2 Results*</u>

Semadenis-Davies *et al.'s* (2020) modelling results suggest that stock exclusion may contribute meaningfully, but not wholly to the achievement of the NPS-FM 2020 requirement for all rivers to improve at least one attribute state. Specifically, close to or more than 40% of the pastoral rivers (by length) were predicted to improve an attribute state under all tested scenarios (Table 7). However, this may be an over-estimation of the benefits of the current stock exclusion requirements as:

- Semadenis-Davies *et al*. (2020) applied a constant load reduction factor to both median and 95th percentile concentrations when calculating *E. coli* attribute state under the different scenarios. This may have resulted in the impact of stock exclusion on 95th percentile concentrations being over-estimated in streams where those concentrations are recorded during rainfall (see Section 3.1.2); and

- The scenario which best reflects the requirements of the Stock Exclusion Regulations (Scenario 4) still assumes greater and more effective (~10% Semadenis-Davies *et al*. (2020) stock exclusion than required by those regulations (i.e., five metre setbacks + sheep excluded).

3.2.2 Potential additional benefits of farm environment plans and other mitigations

A review of the available scientific literature indicates that there is limited potential to mitigate *E. coli* losses from sheep and beef farms through methods other than stock exclusion and/or destocking. National modelling of mitigatable *E. coli* load by Elliot *et al*. (2020) assumed that even with stock exclusion 0% and 14% of *E. coli* losses can be mitigated from hill country sheep and beef farms and intensive sheep and beef farms respectively. While the Our Land & Water National Science Challenge has assumed that a greater load reduction (35%) is achievable on sheep and beef farms by 2035 in their WebApp[17], the source of that figure is unclear.

Table 7: Estimated impact of the stock exclusion scenarios tested by Semadenis-Davies *et al.* (2020) on percentage of rivers (by length) meeting the minimum required improvements for *E. coli*. Results are provided for all rivers and pastoral river at the national and regional scale (five largest regions only). Note, the results of Scenario 2 have not been presented as they incorporate catchment specific additional mitigations that are not easily captured by general rules of thumb.

Region	Scenario	% meeting NPS-FM requirements	
		All rivers	Pastoral rivers
Waikato	1	24%	33%
	3	29%	39%
	4	25%	33%
Manawatu	1	13%	18%
	3	17%	23%
	4	14%	20%
Canterbury	1	41%	60%
	3	41%	61%
	4	43%	64%
Otago	1	13%	19%
	3	19%	29%
	4	13%	21%
Southland	1	8%	19%
	3	14%	31%
	4	10%	22%
National	1	23%	39%
	3	26%	44%
	4	24%	41%

3.2.3 Summary

- The stock exclusion modelling by Semadenis-Davies *et al*. (2020) indicates that the minimum *E. coli* requirements of the NPS-FM 2020 (a one attribute state improvement) can be achieved in a significant minority of pastoral rivers through stock exclusion alone. However, on sheep and beef farms, the stock exclusion required to achieve those improvements may have to go beyond that required by the Stock Exclusion Regulations and include sheep.
- Nevertheless, even with widespread stock exclusions, most pastoral rivers nationally are not predicted to achieve the minimum *E. coli* requirements of the NPS-FM 2020. Furthermore, the sheep and beef sector may have limited ability to address this through means other than de-stocking.

3.3 Concluding statements on the *E. coli* attribute in the NPS-FM 2020

The *E. coli* attribute in the NPS-FM 2020 is largely based on commonly used guidelines that have been applied by regional councils for 20 years. The primary issues with the *E. coli* framework are the inclusion of the 95th percentile assessment statistic without a flow cut-off and the requirement for regional councils to set TASs at least one state higher than the baseline. In combination, those two factors may require that *E. coli* concentrations be improved during rainfall conditions when *E. coli* losses from farmland are difficult to mitigate and there is a low level of recreational use. As a result, stock exclusion on sheep and beef farms may need to go beyond that required by the Stock Exclusion Regulations to meet the TASs that regional councils will set under the current NPS-FM. Importantly, even with this level of stock exclusion, many pastoral rivers are unlikely to achieve the minimum *E. coli* requirements of the NPS-FM 2020.

4 Review of nutrient related attributes

4.1 Technical issues with the attribute state frameworks and the national bottom lines

4.1.1 Background

The NPS-FM 2020 requires regional councils to (at a minimum) set limits to achieve:

- The NBLs for the following attributes
  - Total nitrogen (trophic state) – Lakes;
  - Total phosphorus (trophic state) – Lakes;
  - Ammonia (toxicity) – Lakes and rivers; and
  - Nitrate (toxicity) – Rivers.
- Nutrient outcomes set to achieve the NBLs for the at least the following attributes:
  - Phytoplankton (trophic state) – Lakes; and
  - Periphyton (trophic state) – Rivers.

The attribute state framework for each of the attributes listed above are well established, based on sound science and have been in the NPS-FM since 2014.

Note: A separate detailed review of the phosphorus framework of the NPS-FM 2020 is provided in Appendix A.

4.1.2 Identified issues

The only issue worth noting in relation to the NPS-FM 2020 Appendix 2A nutrient attributes is that the NBLs for nitrate and ammonia toxicity were shifted from the C/D state thresholds to the B/C state thresholds with the release of the NPS-FM 2020. Notably, this change was not made to manage the toxicity effects of these attributes. Consequently, the NBLs no longer reflect the level at which these attributes start to have significant adverse toxicity effects.

In combination ammonia and nitrate make up the vast majority of the plant available nitrogen in rivers (known as dissolved inorganic nitrogen (DIN)), and the change to the NBLs of these attributes was made to reflect the STAG's view that the C/D attribute state thresholds were generally inconsistent with the achievement of the periphyton NBL (STAG, 2019). However, this change does not appear to have been necessary as:

- It is uncommon to find nitrate concentrations exceeding the current NBLs, let alone the NBLs in the NPS-FM 2014, with:
  - Less than 6% and 0.6% of the monitoring sites on Land Air Water Aotearoa (LAWA)[18] not meeting the current NBL and previous NBL respectively; and
  - Less than 5.6% of the REC network predicted not to meet the current NBL (Whitehead *et al.*, 2021).
- The highest nitrate concentrations are often found in groundwater fed streams in areas with catchments containing intensive agriculture and/or light soils (e.g., the Canterbury plains (Table 8)). These rivers frequently do not support periphyton growth, rather they are dominated by rooted plants known as macrophytes. This is evident from Table 8, which shows that 70% of the sites on LAWA with nitrate concentrations exceeding the current NBL (and available plant community data) are macrophyte dominated streams.
- The requirements for regional councils to set nutrient outcomes in accordance with Clause 3.13 of the NPS-FM 2020 should prevent regional councils setting a nitrate toxicity target state of C in a river that can support periphyton growth as it would likely fail to achieve the periphyton target attribute state. For example, if using the lookup tables in Snelder *et al.* (2022) councils should not set outcomes for DIN greater than 1 mg/L (as a median) in rivers where an improvement in periphyton biomass is required, as that is the 'saturating concentration' (MfE, 2022)

In some catchments (especially in Southland and Canterbury) the reduction in the nitrate NBL will likely necessitate substantive land use changes if it is to be achieved. However, in my experience those catchments are not normally dominated by hill and high-country sheep and beef farming.

[18] https://www.lawa.org.nz/

Table 8: Assessment of whether the sites on LAWA with nitrate concentrations below the NBL are macrophyte dominated or not. The plant community of a given site was determined from the LAWA site description, Regional Council monitoring data (Canterbury only) or published reports. The number of sites in each region where the NBL is not met, but the plant community is not documented online are denoted in parentheses next to the region name

<table>
<tr><th>Region</th><th>Site</th><th>Median nitrate concentration (mg/L)</th><th>Macrophyte dominated (N= no; Y=yes)</th></tr>
<tr><td rowspan="2">Auckland (1)</td><td>Ngakaroa</td><td>3.1</td><td>N</td></tr>
<tr><td>Whangamarie Stream</td><td>12.9</td><td>Y</td></tr>
<tr><td rowspan="25">Canterbury</td><td>Curletts Road Stream Upstream of Heathcote River</td><td>0.8</td><td rowspan="3">N</td></tr>
<tr><td>Riccarton Main Drain</td><td>2.5</td></tr>
<tr><td>Knights Stream at Sabys Road</td><td>3.8</td></tr>
<tr><td>Heathcote River at Rose Street</td><td>2.5</td><td rowspan="2">Y</td></tr>
<tr><td>Halswell River at Akaroa Highway (Tai Tapu Road)</td><td>3.15</td></tr>
<tr><td>Hook River Beach Road</td><td>1.93</td><td rowspan="5">N</td></tr>
<tr><td>Cust River u/s Skewbridge Road</td><td>4.5</td></tr>
<tr><td>St Leonards Drain at recorder</td><td>6.4</td></tr>
<tr><td>Selwyn River u/s Coes Ford bridge</td><td>6.6</td></tr>
<tr><td>Hinds River Lower Beach Road</td><td>7.1</td></tr>
<tr><td>Penticotico Stream SH83</td><td>1.695</td><td rowspan="15">Y</td></tr>
<tr><td>Halswell River u/s McCartneys bridge</td><td>2.75</td></tr>
<tr><td>LII Stream u/s Pannetts Rd</td><td>3.3</td></tr>
<tr><td>Lee River u/s Brooklands Farm bridge</td><td>3.4</td></tr>
<tr><td>Waikakahi Stream Cock & Hen Road</td><td>3.7</td></tr>
<tr><td>Waikakahi Stream Te Maiharoa Road</td><td>3.8</td></tr>
<tr><td>Waikakahi Stream Old Ferry Road</td><td>4.2</td></tr>
<tr><td>McKinnons Stream Wallaces Bridge</td><td>4.4</td></tr>
<tr><td>Smithfield Creek Te Awa Rd</td><td>4.4</td></tr>
<tr><td>Waikekewai Creek u/s Gullivers Rd</td><td>4.8</td></tr>
<tr><td>Kaiapoi River u/s Island Rd</td><td>5.1</td></tr>
<tr><td>Harts Creek d/s Lower Lake Rd</td><td>7.6</td></tr>
<tr><td>Rhodes Stream Parke Road</td><td>8.3</td></tr>
<tr><td>Kaiapoi River u/s Harpers Road</td><td>9.1</td></tr>
<tr><td>Boundary Drain Trigpole Road</td><td>12.4</td></tr>
<tr><td rowspan="8">Southland (1)</td><td>Winton Stream at Lochiel</td><td>1.5</td><td rowspan="2">N</td></tr>
<tr><td>Longridge Stream at Sandstone</td><td>3.7</td></tr>
<tr><td>Waituna Creek at Marshall Road</td><td>1.61</td><td rowspan="6">Y</td></tr>
<tr><td>Sandstone Stream at Kingston Crossing Rd</td><td>1.78</td></tr>
<tr><td>Oteramika Stream at Seaward Downs</td><td>2.05</td></tr>
<tr><td>Waihopai River u/s Queens Drive</td><td>2.4</td></tr>
<tr><td>Waikiwi Stream at North Road</td><td>2.8</td></tr>
<tr><td>Waimea Stream at Mandeville</td><td>3.6</td></tr>
<tr><td>Gisborne (1)</td><td colspan="3">N/A</td></tr>
<tr><td>Wellington</td><td>Parkvale Stream at Renalls Weir</td><td>1.56</td><td>N</td></tr>
<tr><td>Hawke's Bay (4)</td><td>Kahahakuri Stream U/S Tukituki Confl</td><td>2.9</td><td>Y</td></tr>
<tr><td rowspan="2">Horizons (1)</td><td>Unnamed Trib of Waipu at ds Ratana STP*</td><td>1.36</td><td rowspan="2">Y</td></tr>
<tr><td>Tutaenui Stream at d/s Marton STP</td><td>1.69</td></tr>
<tr><td>Otago (1)</td><td colspan="3">N/A</td></tr>
<tr><td>Tasman (2)</td><td>Neimann at 600m u-s Lansdowne Rd</td><td>2.6</td><td>Y</td></tr>
<tr><td>Waikato (3)</td><td>Waitoa River at Mellon Rd Recorder</td><td>2.1</td><td>Y</td></tr>
</table>

4.2 Potential level of effort to achieve the national bottom lines

Based on modelling by Snelder *et al*. (2023) a ~25% reduction in total nitrogen and total phosphorus loads is required nationally to achieve the NBLs for all the following nutrient related attributes:

- Phytoplankton (trophic state) – Lakes;
- Periphyton (trophic state) – Rivers
- Total nitrogen (trophic state) – Lakes;
- Total phosphorus (trophic state) – Lakes;
- Ammonia (toxicity) – Lakes and rivers; and
- Nitrate (toxicity) – Rivers.

While there will undoubtedly be areas where larger improvements are required, the general level of nutrient reduction required, combined with the source of these contaminants, suggests that in most regions the NBLs for the attributes listed above do not pose as large a hurdle to the sheep and beef sector as the SFS NBLs in the NPS-FM 2020 or the minimum required improvements for *E. coli*. Specifically, the ability for sheep and beef farms to reduce their nitrogen and phosphorus losses through mitigations appears to be generally limited when compared to dairy land given the paucity of effective mitigations and generally lower yields, especially for nitrogen (10–15% in Elliot *et al*. (2020) and McDowell *et al*. (2021)).

5 Recommended next steps

1. Confirm the difficulty of achieving the SFS NBLs through mechanistic sediment modelling for a specific case study catchment (i.e., use a dSedNet model (or similar) to calculate the sediment load reductions needed to meet the SFS NBL in the catchment and compare the results to those generated for the purposes of this report).
2. Develop alternative approaches to managing sediment outside of the SFS attribute state framework. Given the current NPS-FM 2020 approach represents the best of a number of options tested, this is unlikely to take the form of a revised sediment attribute. Rather it could be a process that can be employed by regional council's to determine the impact sediment is having on key ecological attributes within a specific catchment, so that environmentally meaningful targets can be set that also account for natural variation in sediment concentrations/loads.

   Note: This is similar to the nutrient outcome approach in the NPS-FM 2020.

3. Develop a framework that regional councils can use to identify where the minimum required improvement set for *E. coli* in the NPS-FM 2020 should not apply as there is no meaningful impact on the recreational value of a river: i.e.:
   a. Because no one swims or wants to swim there; or
   b. Where improving an attribute state would not reduce health risk at times when people swim (e.g., it would only result in an improvement in 95^{th} percentile concentrations during rainfall when people do not swim).

6 References

Booker, D.J., Franklin, P.A., Stoffels, R., 2020. Contract 23184: Task 1 - Mapping CTG classes with few data to sediment classes (NIWA memorandum). NIWA, Christchurch, N.Z.

Depree, C., Clapcott, J.E., Booker, D.J., Franklin, P.A., Hickey, C.W., Wagenhoff, A., Matheson, F., Shelley, J., Unwin, M., Wadhwa, S., Goodwin, E., Mackman, J., Rabel, H., 2018. Development of ecosystem health bottom-line thresholds for suspended and deposited sediment in New Zealand rivers and streams (Client Report No. 2017076HN). NIWA, Hamilton, New Zealand.

Dunn, N.R., Allibone, R.M., Closs, G.P., Crow, S.K., David, B.O., Goodman, J.M., Griffiths, M., Jack, D.C., Ling, N., Waters, J.M., Jeremy R Rolfe, 2017. Conservation status of New Zealand freshwater fish, 2017. New Zealand Threat Classification Series 24, 15.

Dymond, J.R., Betts, H.D., Schierlitz, C.S., 2010. An erosion model for evaluating regional land-use scenarios. Environmental Modelling & Software 25, 289–298.

Elliott, A.H., Snelder, T.H., Muirhead, R.W., Monaghan, R.M., Whitehead, A.L., Bermeo-Alvear, S.A., Howarth, C.J., 2020. A Heuristic Method for Determining Changes of Source Loads to Comply with Water Quality Limits in Catchments. Environmental Management 65, 272–285.

Franklin, P.A., Booker, D.J., Stoffels, R., 2020. Contract 23184: Task 7 - Turbidity and visual clarity thresholds at SSC Level 2 (NIWA memorandum). NIWA, Christchurch, New Zealand.

Franklin, P.A., Stoffels, R., Clapcott, J.E., Booker, D.J., Wagenhoff, A., Hickey, C.W., 2019. Deriving potential fine sediment attribute thresholds for theNational Objectives Framework (Client Report No. 2019039HN). NIWA, Hamilton, New Zealand.

Hicks, M., Haddadchi, A., Whitehead, A.L., Shankar, U., 2019. Sediment load reductions to meet suspended and deposited sediment thresholds (NIWA Client Report No. 2019100CH). NIWA, Christchurch, New Zealand.

Julian, J.P., de Beurs, K.M., Owsley, B., Davies-Colley, R.J., Ausseil, A.-G.E., 2017. River water quality changes in New Zealand over 26 years: response to land use intensity. Hydrology and Earth System Sciences 21, 1149–1171.

McDowell, R.W., Monaghan, R.M., Smith, C., Manderson, A., Basher, L., Burger, D.F., Laurenson, S., Pletnyakov, P., Spiekermann, R., Depree, C., 2021. Quantifying contaminant losses to water from pastoral land uses in New Zealand III. What could be achieved by 2035? New Zealand Journal of Agricultural Research 64, 390–410.

McDowell, R.W., Snelder, T.H., Cox, N., Booker, D.J., Wilcock, R.J., 2013. Establishment of reference or baseline conditions of chemical indicators in New Zealand streams and rivers relative to present conditions. Marine and Freshwater Research 64, 387–400.

Ministry for the Environment and Ministry of Health (MfE/MoH), 2003. Microbiological water quality guidelines for marine and freshwater recreational areas. Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment (MfE), 2022. Guidance on look-up tables for setting nutrient targets for periphyton: second edition. (No. MFE 1644). Ministry for the Environment, Wellington, New Zealand.

Muirhead, R.W., 2019. The effectiveness of streambank fencing to improve microbial water quality: A review. Agricultural Water Management 223, 105684.

Muirhead, R.W., Hudson, R., Cookson, A., 2023. A review of river microbial water quality data in the Northland region (agresearch report No. RE450/2023/029). agresearch, New Zealand.

Nagels, J.W., Davies-Colley, R.J., Donnison, A.M., Muirhead, R.W., 2002. Faecal contamination over flood events in a pastoral agricultural stream in New Zealand. Water Science and Technology 45, 45–52.

Neverman, A.J., Djanibekov, U., Soliman, T., Walsh, P., Speikermann, R., Basher, L., 2019. Impact testing of a proposed suspended sediment attribute: identifying erosion and sediment control mitigations to meet proposed sediment attribute bottom lines and the costs and benefits of those mitigations (Contract Report No. LC3574).

Science and Technical Advisory Group (STAG), 2019. Freshwater Science and Technical Advisory Group: Report to the Minister for the Environment (No. CR 372). Wellington, New Zealand.

Semadenis-Davies, A., Haddadchi, A., Booker, D.J., 2020. Modelling the impacts of the Draft Stock Exclusion Section 360 Regulations on river water quality: E. coli and Sediment (NIWA Client Report No. 2020052AK). NIWA, Auckland, New Zealand.

Snelder, T., Kilroy, C., Booker, D.J., 2022. Derivation of nutrient criteria for periphyton biomass objectives: Using regional council monitoring data. LWP Limited, Christchurch, New Zealand.

Snelder, T., Smith, H., Plew, D., Fraser, C., 2023. Nitrogen, phosphorus, sediment and *Escherichia coli* in New Zealand's aquatic receiving environments: Comparison of current state to national bottom lines (LWP Client Report No. 2023–06). LWP Limited, Christchurch, New Zealand.

Snelder, T.H., Wood, S.A., Atalah, J., 2016. Strategic assessment of New Zealand's freshwaters for recreational use: a human health perspective: *Escherichia coli* in rivers and planktonic cyanobacteria in lakes (LWP Client Report No. 2016–011). Land Water People, Christchurch, New Zealand.

Sunohara, M.D., Topp, E., Wilkes, G., Gottschall, N., Neumann, N., Ruecker, N., Jones, T.H., Edge, T.A., Marti, R., Lapen, D.R., 2012. Impact of Riparian Zone Protection from Cattle on Nutrient, Bacteria, F-coliphage, *Cryptosporidium* , and *Giardia* Loading of an Intermittent Stream. Journal of Environmental Quality 41, 1301–1314.

Whitehead, A., Fraser, C., Snelder, T.H., 2021. Spatial modelling of river water quality state Incorporating monitoring data from 2016 to 2020 (NIWA Client Report No. 2021303CH). NIWA, Christchurch, New Zealand.

Whitehead, A., Fraser, C., Snelder, T.H., Walter, K., Woodward, S., Zammit, C., 2022. Water quality state and trends in New Zealand Rivers: Analyses of national data ending in 2020 (NIWA Client Report No. 2021296CH). NIWA, Christchurch, New Zealand.

Whitehead, A.L., 2018. Spatial modelling of river water-quality state: Incorporating monitoring data from 2013 to 2017 (NIWA Client Report No. 2018360CH). NIWA, Christchurch, New Zealand.

.

Appendices

Appendix A: Potential implications of the phosphorus management framework in the NPS-FM 2020 on the sheep and beef sector

Executive summary

Torlesse Environmental previously provided (B+LNZ) with a memorandum (now the body of this report) describing:

- The compulsory attributes in the National Policy Statement for Freshwater Management (NPS-FM) 2020 relevant to the sheep and beef sector;
- How they were developed; and
- The level of effort required to achieve the associated national bottom lines.

That memorandum was primarily focused on the impacts of the sediment and *E. coli* requirements of the NPS-FM 2020, as those attributes were identified as posing the largest risk to the sheep and beef sector. However, B+LNZ have indicated that they would like additional detail provided around the phosphorus aspects of the NPS-FM 2020.

The phosphorus management framework of the NPS-FM 2020 requires councils to set:

- Nutrient outcomes (NOs) for phosphorus in rivers;
- Target attribute states (TASs) for dissolved reactive phosphorus (DRP) in rivers;
- TASs for periphyton (algae) in rivers;
- TASs for total phosphorus (TP) in lakes;
- TASs for phytoplankton (algae) in lakes;
- Limits to achieve the phosphorus NOs and the TASs for periphyton (rivers), TP (lakes) and phytoplankton (lakes); and
- Action plans to achieve the DRP TASs for rivers.

From a scientific perspective, the approach described above is a sensible method of managing phosphorus. The periphyton, TP and phytoplankton attribute state frameworks are well established and based on commonly used and accepted guideline values. Furthermore, a national approach has been developed for setting Phosphorus NOs to achieve various periphyton attribute states. However, there is a risk to sheep and beef farmers arising from the potential for regional councils to set NOs and associate limits to achieve the target states for attributes other than periphyton.

Acknowledging that this is very much a live debate, it is my opinion that setting phosphorus NOs in rivers to achieve TASs for non-periphyton attributes (e.g., macroinvertebrate community health) is unnecessary; in most rivers the primary mechanism through which DRPs affects such attributes is indirectly through periphyton growth. Furthermore, there are no national guideline values that can be adopted for this purpose apart from the DRP attribute state thresholds in the NPS-FM 2020. Thus, if councils decide to set phosphorus NOs for attributes other than periphyton, they may well use those attribute state thresholds to do so. Unfortunately, there are several technical issues with the NPS-FM 2020 attribute. Specifically, it was developed under the implied assumption that the ecological effects of agriculture all stem from associated nutrient losses. Consequently, adoption of this framework could result in regional councils imposing limits to achieve NOs with limited environmental relevance.

1 Introduction

Torlesse Environment Ltd (Torlesse) previously provided Beef + Lamb New Zealand Ltd (B+LNZ) with a memorandum (now the body of this report) that answered the following question:

What do the national bottom lines in the National Policy Statement for Freshwater Management (NPS-FM) 2020 achieve in terms of environmental outcomes, and what is required from the sheep and beef sector to meet them".

That memorandum was primarily focused on the impacts of the sediment and *E. coli* requirements of the NPS-FM 2020, as those attributes were identified as posing the largest risk to the sheep and beef sector. However, B+LNZ have since indicated that they would like additional detail provided around the phosphorus management framework in the NPS-FM 2020.

2 NPS-FM 2020 phosphorus management framework

The NPS-FM 2020 requires regional councils to manage phosphorus by setting:

- Nutrient outcomes (NOs) for phosphorus in rivers;
- Target attribute states (TASs) for dissolved reactive phosphorus (DRP) in rivers;
- TASs for periphyton (algae) in rivers (increased DRP generally increases the risk of periphyton growth);
- TASs for total phosphorus (TP) in lakes;
- TASs for phytoplankton (algae) in lakes (increased TP generally increases the risk of periphyton growth);
- Limits to achieve the phosphorus NOs and the TASs for periphyton (rivers), TP (lakes) and phytoplankton (lakes); and
- Action plans to achieve the DRP TASs for rivers.

This process is described in more detail in Sections 2.1 to 2.4

2.1 Setting and achieving target attribute states for phosphorus related lake attributes in Appendix 2A of the NPS-FM 2020

- The NPS-FM 2020 requires regional councils to set TASs for phytoplankton in lakes below the national bottom line (NBL) of 12/60 (median/maximum) mg chl-*a*/ m^3. These TASs have to be achieved through limits on resource use; defined as rules in a regional plan that act as any of the following:
    - a land-use control (such as a control on the extent of an activity)
    - an input control (such as an amount of fertiliser that may be applied)
    - an output control (such as a volume or rate of discharge).
- In lake catchments where phytoplankton growth is heavily influenced by TP concentrations, it is likely that these limits will be designed to control phosphorus losses.
- Regional councils also have to set specific TASs for TP below the NBL of 0.05 mg/L (as a median). Ideally, the TASs for TP will be set at the level needed to achieve the phytoplankton

TASs. However, the inclusion of an NBL for TP means in some lakes TP may have to improve despite a commensurate improvement not being required for phytoplankton (further detail provided in Section 3.1.1.2). As with phytoplankton, regional councils must set limits in regional plans to achieve the TP TASs.

2.2 Setting and achieving target attribute states for periphyton in rivers

Regional councils are required to set TASs for periphyton in rivers below the NBL of 200 mg chl-*a*/ m^2 (as a 92nd percentile). These TASs must be achieved by limits, and in catchments where periphyton growth is driven by DRP concentrations, these limits will likely be set to control phosphorus losses.

2.3 Setting and achieving nutrient outcomes in rivers

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 NOs; and
- Identify limits on resource use that will achieve any nutrient outcomes.

On that basis NOs effectively act as NPS-FM 2020 Appendix 2A attributes (i.e., compulsory attributes that must be achieved through limits). However, unlike Appendix 2A attributes, the NPS-FM 2020 does not define a state framework through 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.

In short phosphorus NOs are an intermediate step between the periphyton, TP and phytoplankton TASs and the limits set to achieve them (see Figure A1).

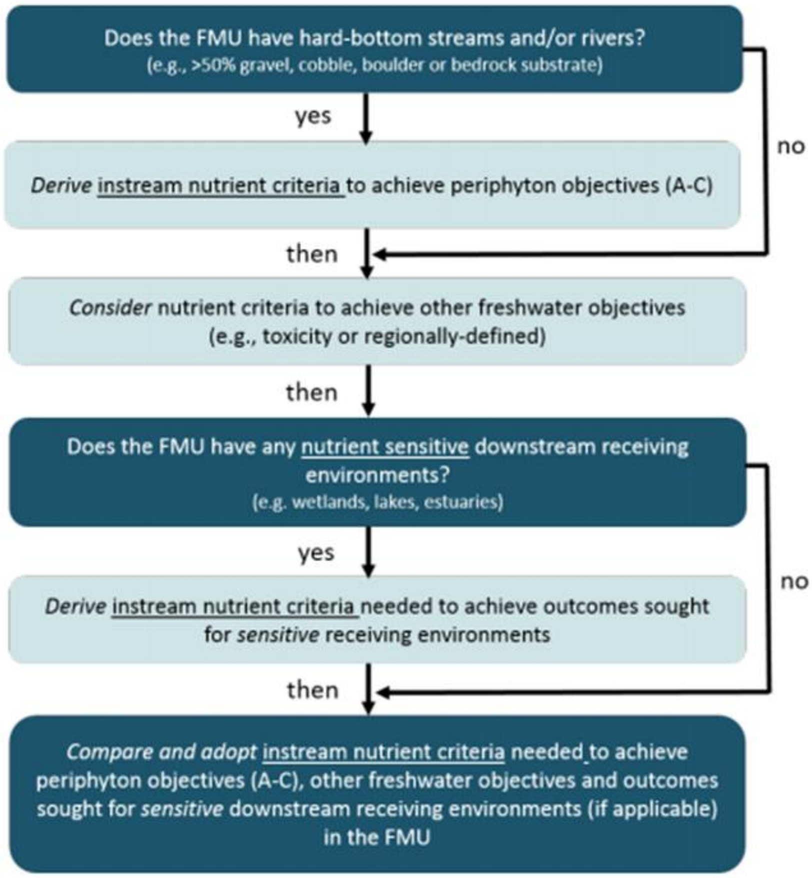

Figure A1: Flow diagram of the process outlined by clause 3.13(3) of the NPS-FM 2020. Adapted from MfE (2021).

2.4 Setting and achieving target attribute states for dissolved reactive phosphorus in rivers

In addition to setting phosphorus NOs in rivers, regional councils are required to set TASs for DRP in accordance with the attribute state framework in Table 20 of that document. In general, TASs set in this manner will have less of an impact on the sheep and beef sector than the phosphorus NOs as:

- They do not have to be achieved through limits. Rather it is the regional councils responsibility to ensure they are achieved through Action Plans; and
- There is no NBL, whereas the NOs have to be set to at least achieve the periphyton (rivers), phytoplankton (lakes) and TP (lakes) NBLs.

3 Background and potential issues with the NPS-FM 2020 phosphorus management framework

3.1 Compulsory attributes in Appendix 2 of the NPS-FM 2020

3.1.1 Total phosphorus and phytoplankton in lakes

3.1.1.1 Background to the attributes

The TP and phytoplankton attribute state frameworks in the NPS-FM 2020 are based on the Trophic Lake Index (TLI) developed by Burns *et al*. (2000). The TLI is an integrated measure that characterises how enriched a lake is by nutrients based on nitrogen, phosphorus and phytoplankton concentrations[19]. The lower the TLI the better the condition of the lake.

The TP and phytoplankton attribute state thresholds in the NPS-FM 2020 are rounded values drawn directly from Burns *et al*. (2000). The boundaries between:

- A/B attribute states are set at a level that reflects a shift from oligotrophic (low levels of nutrients and algae) to mesotrophic conditions (moderate levels of nutrients and algae);
- The B/C attribute states are set at a level that reflects a shift to eutrophic conditions (high amounts of nutrients and algae); and
- The C/D attribute states are set at a level that reflects a shift to supertrophic conditions (very high amounts of phosphorus and nitrogen and excessive algal growths).

3.1.1.2 Identified issues with the attributes

The attribute state framework described above in Section 3.1.1.1 is well established, based on robust science and has been in the NPS-FM since 2014. However, there is a small issue with the how the NPS-FM 2020 TP and phytoplankton attributes interact with each other.

By treating TP and phytoplankton separately, the NPS-FM 2020 requires phosphorus losses to be managed to control TP concentrations in themselves, not just the ecological effects associated of those concentrations (i.e., phytoplankton). There will be some lakes where TP concentrations exceed the NBL, but phytoplankton concentrations do not due to factors such as nitrogen limitation (i.e. nitrogen concentrations are sufficiently low that algae cannot proliferate despite elevated TP concentrations). In such cases, it could be argued that the requirement to reduce TP concentrations to the NBL is of limited value unless the phytoplankton TAS also requires an improvement from current state.

This issue is unlikely to have large implications for sheep and beef famers given the NBLs for all lake attributes represent a significantly degraded state and only 3% of the monitored lakes in the country have TP concentrations above the NBL and phytoplankton concentration below the NBL[20].

[19] Just these three parameters are considered in the TLI3 which forms the basis of the NPS-FM 2020 attribute states. There is also a TLI4 which which incorporates a measure of water clarity (Burns *et al.*, 2000).
[20] Based on state data extracted from lawa.org.nz.

3.1.2 Periphyton in rivers

3.1.2.1 Background to the attribute

The periphyton attribute states in the NPS-FM 2020 were selected by Snelder *et al.* (2013), and are underpinned by:

- The *New Zealand Periphyton Guideline* developed by Biggs (2000); and
- Matheson *et al*.'s (2012) review of the New Zealand instream plant and nutrient guidelines.

The boundaries between the:

- A/B attribute states correspond with the guideline value recommended by Biggs (2000) for the protection of benthic biodiversity. Below this threshold there are only "*rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat*".
- The B/C attribute states corresponds with the filamentous periphyton biomass guideline recommended by Biggs (2000) for the protection of aesthetic/recreational values and trout habitat/angling values. Below this threshold there are only "*occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat*"; and
- The C/D attribute states corresponds with the diatoms/cyanobacteria (mat) biomass guideline recommended by Biggs (2000) for the protection of trout habitat/angling values. Below this threshold there are only "*periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or moderate alteration of the natural flow regime or habitat*". Above it there are *"regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat*".

3.1.2.2 Identified issues with the attribute

The periphyton attribute state thresholds in the NPS-FM 2020

- Have been used as national guidelines for over 20 years;
- Are well accepted by the scientific community;
- Represent the best available guidelines for the protection of aquatic ecosystem health.

Nevertheless, Matheson *et al*. (2016) did find that the A/B and B/C thresholds are not well aligned with the macroinvertebrate community health attribute states.

3.1.3 Dissolved reactive phosphorus attribute

3.1.3.1 Background to the attribute

The DRP attribute state thresholds in the NPS-FM 2020 were developed by Canning (2020) and are based on correlations between modelled nutrient concentrations and measured values for the following compulsory attributes in the NPS-FM 2020:

- Periphyton
- Fish index of biotic integrity (IBI);
- Macroinvertebrate community index (MCI);
- Quantitative macroinvertebrate community index (QMCI);

- Average score per macroinvertebrate metric (ASPM); and
- Ecosystem metabolism.

For each of the above attributes, Canning (2020) used the correlations between modelled DRP and the measured attribute data to derive the DRP concentration that would be expected at the A/B, B/C and C/D attribute state thresholds for that attribute. These values were then weighted and averaged across all attributes to provide the equivalent DRP thresholds.

3.1.3.2 Identified issues with the attribute

The approach described above does not acknowledge that while elevated nutrients and degraded ecological health often co-occur, this can be because both are driven by an increase in intensive land-use (which affects a range of environmental factors), and that any causative link is generally indirect and complex. As such, setting DRP targets based on such correlative relationships will not necessarily achieve the desired objective in terms of ecosystem health.

Macroinvertebrate community health, fish health and nutrient concentrations are all impacted by a decrease in catchment indigenous vegetation cover and an increase in catchment pastoral cover (Clapcott *et al.*, 2013; Clapcott & Goodwin, 2014; Larned *et al.*, 2017; Unwin & Larned, 2013). Such changes in land use also commonly result in:

- Reduced shading from riparian vegetation which:
  - Increases light availability thereby promoting periphyton growth;
  - Increases water temperatures;
  - Reduces habitat availability; and
  - Reduced terrestrial organic matter input.
- Increased sediment loads;
- Reduced in-stream habitat complexity; and
- Flow alterations.

All of the factors listed above affect macroinvertebrate and fish community health. Thus, while land use intensification can both increase nutrient concentrations and impact aquatic communities, the change in the latter is not always caused by the former. Therefore, it is doubtful that simply managing nutrient concentrations to a certain level based on correlative relationships with the attributes listed will be effective in achieving a specified state for those attributes as nutrient management will not necessarily control those stressors having the greatest impact.

In most rivers, the primary mechanism through which DRP affects macroinvertebrates and fish is through periphyton growth (Clapcott *et al.*, 2017) the effects of which regional councils are already required to manage through periphyton TASs and phosphorus NOs (see Section 3.4 below). Consequently, it does not appear that the DRP attribute state framework in the NPS-FM 2020 is needed to fulfil the purpose it was designed to achieve.

As discussed in Section 2.2, the issues with the DRP attribute state will be of limited consequences in regions where councils set them to be consistent with phosphorus NOs aimed at achieving TASs for periphyton in rivers and TP/ phytoplankton in any downstream lakes. However, they may pose a problem if regional councils:

- Adopted the DRP attributes states as phosphorus NOs that must be achieved through limits; or
- Choose to interpret the C/D state threshold as a national bottom line and achieve them through limits rather than action plans.

3.2 Phosphorus nutrient outcomes set under Section 3.13 of the NPS-FM 2020

3.2.1 Phosphorus nutrient outcomes set to achieve periphyton, total phosphorus and phytoplankton TASs

Setting nutrient outcomes in hard-bottom rivers to achieve periphyton TASs is tested method, and there is an established national approach for doing this. While MfE (2022) proposed four possible strategies that regional councils could use to set NOs (Table A1), the only one that is currently feasible (Strategy 1) is to use 'off the shelf' numbers to achieve different levels of periphyton biomass. All the other available strategies are based on as yet unavailable modelling

Setting phosphorus NOs for periphyton involves:

- Selecting a TAS for periphyton (while an option does exist to set the NOs to achieve the macroinvertebrate community health TASs (as per Canning *et al*. (2021)) there a number of weaknesses in this approach that makes it less appealing than the periphyton based approach set out in Snelder *et al.* (2022) – See Sections 3.1.3.2 and 3.2.2);
- Selecting an under-protection risk threshold (i.e., the acceptable risk of not meeting the periphyton biomass target);
- Obtaining phosphorus NOs outcomes from look up tables in Snelder & Kilroy (2023) (previously Snelder *et al*. (2022));
- Assessing confidence in the NOSs; and
- Applying the Phosphorus NOs or alternative criteria (i.e., more stringent values if necessary to meet other phosphorus related TASs or maintain current state).

Ultimately the aim of this strategy is to select nutrient outcomes that maintain current state, achieve the periphyton TASs for the river and achieve the TASs for phytoplankton, and TP in any downstream lakes.

Table A1: Description of the four strategies proposed in MfE (2022) 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

3.2.2 Phosphorus nutrient outcomes set to achieve other attributes

Prior to 2023 regional councils were only required to consider periphyton when setting NOs for hard-bottomed rivers; the requirement to consider other nutrient affected attributes[21] was limited to naturally soft-bottomed systems. However, this changed with the February 2023 amendments to the NPS-FM 2020, and now regional councils can consider all nutrient effected attributes when developing NOs for hard-bottomed rivers. In an ideal world, this would still have NOs in hard-bottomed rivers set to manage periphyton growth, as that is the mechanism through which phosphorus primarily impacts most other attributes in hard-bottomed rivers. However, there is a risk that regional councils will set phosphorus NOs for the achievement of macroinvertebrate or fish TASs.

As set out in Section 3.1.3 it is my opinion that setting phosphorus NOs to directly achieve the target states of river attributes other than periphyton is problematic. Furthermore, there is currently no nationally

[21] Dissolved oxygen, submerged plants, fish, macroinvertebrates, and ecosystem metabolism

accepted thresholds for which this can be accomplished. While Canning *et al*. (2021) does recommend NOs for macroinvertebrate community health, they only apply to the NBLs for Q/MCI and ASPM. Canning *et al*. (2021) provides no numbers relevant to the A/B or B/C attribute state thresholds (although work is ongoing in this space – see Canning & Death (2023)). Consequently, it is possible that councils who decided to set NOs for nutrient affected attributes other than periphyton will revert back to the DRP attribute state framework.

3.3 Other potential issues

3.3.1 Uncertainty in need for and effectiveness of required actions to meet TASs

Regardless of what how the phosphorus NOs are set, there is always potential for the associated limits to be stringent or too permissive if the current state and source of phosphorus is poorly understood, and/or the impacts of the specific actions required by the limits have not been robustly assessed.

3.3.2 Target states and/or nutrient outcomes set at a level that requires significant phosphorus mitigation and/or land use change

Even when the link between land-use and in-river/lake concentrations are well understood, there is potential for TASs for periphyton (rivers), TP (lakes) and phytoplankton (lakes) to be set at a level that requires requires significant mitigations or land-use change even in areas where the NBLs are currently met. Whether such mitigations are justified is subjective. However, it is a possible outcome for the sheep and beef sector and has already occurred in some places (i.e., the 80 year targets in Proposed Waikato Regional Plan Change 1)

4 References

Biggs, B.J.F., 2000. New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams. Ministry for the Environment, Wellington, New Zealand.

Burns, N., Bryers, G., Bowman, E., 2000. Protocols for monitoring trophic levels of New Zealand lakes and reservoirs (Lakes Consulting report). Lakes Consulting, Pauanui, New Zealand.

Canning, A., 2020. Nutrients in New Zealand Rivers and Streams: An exploration and derivation of national nutrient criteria. (Report to the Minister for the Environment). Essential Freshwater Science and Technical Advisory Group, Wellington, New Zealand.

Canning, A.D., Death, R.G., 2023. Establishing riverine nutrient criteria using individual taxa thresholds. Water Research 246, 120731.

Canning, A.D., Joy, M.K., Death, R.G., 2021. Nutrient criteria to achieve New Zealand's riverine macroinvertebrate targets. PeerJ 9, e11556.

Clapcott, J.E., Goodwin, E., 2014. Technical report of Macroinvertebrate Community Index predictions for the Wellington Region (Cawthron Report No. 2503). Cawthron Institute, Nelson, New Zealand.

Clapcott, J.E., Goodwin, E., Snelder, T.H., 2013. Predictive models of benthic macroinvertebrate metrics (Cawthron Report No. 2301). Cawthron Institute, Nelson, New Zealand.

Clapcott, J.E., Wagenhoff, A., Neale, M.W., Storey, R.G., Smith, B.J., Death, R.G., Harding, J.S., Matthaei, C.D., Quinn, J., Collier, K.J., Atalah, J., Goodwin, E., Rabel, H., Mackman, J., Young, R.G., 2017. Macroinvertebrate metrics for the National Policy Statement for Freshwater Management (Cawthron Report No. 3073). Cawthron Institute, Nelson, New Zealand.

Larned, S.T., Snelder, T.H., Unwin, M., 2017. Water Quality in New Zealand Rivers: Modelled water quality state (NIWA Client Report No. CHC2016-070). NIWA, Christchurch, New Zealand.

Matheson, F., Quinn, J., Hickey, C., 2012. Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phases 1 and 2 final report (Client Report No. HAM2012-081). NIWA, Hamilton, New Zealand.

Matheson, F., Quinn, J., Unwin, M., 2016. Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phase 3 (Client Report No. HAM2015-064). NIWA, Hamilton, New Zealand.

Ministry for the Environment (MfE), 2021. A guide to setting instream nutrient concentrations under clause 3.13 of the National Policy Statement for Freshwater Management 2020 (No. ME 1569). Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment (MfE), 2022. Setting instream nutrient concentration thresholds for nutrient-affected attributes in rivers: Guidance on implementing Clause 3.13 of the NPS-FM (No. MFE 1662). Ministry for the Environment, Wellington, New Zealand.

Snelder, T., Kilroy, C., 2023. Revised Nutrient Criteria for Periphyton Biomass Objectives: Updating criteria referred to in Ministry for Environment 2022 guidance (LWP Client Report No. 2023–08). LWP Limited, Christchurch, New Zealand.

Snelder, T., Kilroy, C., Booker, D.J., 2022. Derivation of nutrient criteria for periphyton biomass objectives: Using regional council monitoring data. LWP Limited, Christchurch, New Zealand.

Snelder, T.H., Biggs, B.J.F., Kilroy, C., Booker, D.J., 2013. National Objective Framework for periphyton (Client Report No. CHC2013-122). NIWA, Christchurch, New Zealand.

Unwin, M., Larned, S.T., 2013. Statistical models, indicators and trend analyses for reporting national-scale river water quality (NEMAR Phase 3) (Client Report No. CHC2013-033). NIWA, Christchurch, New Zealand.

TORLESSE
ENVIRONMENTAL LTD