IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER **appeals under clause 14(1) of Schedule 1 of the Act in respect of Proposed Southland Water and Land Plan**

between:

TRANSPOWER NEW ZEALAND LIMITED
(ENV-2018-CHC-26)

FONTERRA CO-OPERATIVE GROUP LIMITED
(ENV-2018-CHC-27)

HORTICULTURE NEW ZEALAND
(ENV-2018-CHC-28)

ARATIATIA LIVESTOCK LIMITED
(ENV-2018-CHC-29)

WILKINS FARMING CO
(ENV-2018-CHC-30)

(Continued on next page)

STATEMENT OF EVIDENCE OF DR CRAIG VERDUN DEPREE FOR DAIRYNZ LTD and FONTERRA COOPERATIVE GROUP LTD

4 FEBRUARY 2022

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GORE DISTRICT COUNCIL, SOUTHLAND DISTRICT COUNCIL & INVERCARGILL DISTRICT COUNCIL
(ENV-2018-CHC-31)

DAIRYNZ LIMITED
(ENV-2018-CHC-32)

H W RICHARDSON GROUP
(ENV-2018-CHC-33)

BEEF + LAMB NEW ZEALAND
(ENV-2018-CHC-34 & 35)

DIRECTOR-GENERAL OF CONSERVATION
(ENV-2018-CHC-36)

SOUTHLAND FISH AND GAME COUNCIL
(ENV-2018-CHC-37)

MERIDIAN ENERGY LIMITED Act 1991
(ENV-2018-CHC-38)

ALLIANCE GROUP LIMITED
(ENV-2018-CHC-39)

FEDERATED FARMERS OF NEW ZEALAND
(ENV-2018-CHC-40)

HERITAGE NEW ZEALAND POUHERE TAONGA
(ENV-2018-CHC-41)

STONEY CREEK STATION LIMITED
(ENV-2018-CHC-42)

THE TERRACES LIMITED
(ENV-2018-CHC-43)

CAMPBELL'S BLOCK LIMITED
(ENV-2018-CHC-44)

ROBERT GRANT
(ENV-2018-CHC-45)

SOUTHWOOD EXPORT LIMITED, SOUTHLAND PLANTATION FOREST COMPANY OF NZ, SOUTHWOOD EXPORT LIMITED
(ENV-2018-CHC-46)

TE RUNANGA O NGAI TAHU, HOKONUI RUNAKA, WAIHOPAI RUNAKA, TE

RUNANGA O AWARUA & TE RUNANGA O ORAKA APARIMA
(ENV-2018-CHC-47)

PETER CHARTRES
(ENV-2018-CHC-48)

RAYONIER NEW ZEALAND LIMITED
(ENV-2018-CHC-49)

ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NEW ZEALAND
(ENV-2018-CHC-50)

Appellants

and: **SOUTHLAND REGIONAL COUNCIL**
Respondent

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1. EXECUTIVE SUMMARY

1.1 This water quality evidence addresses the matters that were subject to the section 274 notices lodged by Fonterra Co-operative Group Ltd (Fonterra) and DairyNZ Ltd (DairyNZ) and collectively referred to as the 'dairy interests'.

1.2 When considering buffer widths, it is in my view important to recognise that several factors influence their performance. The sediment removal curve presented in figure 1 in my evidence, shows that increasing buffer widths from 5m to 10m leads to a relative increase in sediment removal of 14%. The corresponding increase when moving from 10m buffer width to a 20m buffer width, is less than 3%.

1.3 The 'heavy lifting' to reduce sediment loss from higher risk activities and concentrated overland flow paths is achieved by identifying and managing critical source areas (CSAs). Based on the reasons above, I do not support the wider, 20m buffer setback as proposed by Ms McArthur for Fish and Game.

1.4 I support the use of the ephemeral flow path terminology agreed in the planning JWS (and not 'ephemeral waterbodies' as per the Fish and Game proposal). In my opinion, international and national literature support a finding that ephemeral flow paths are terrestrial rather than aquatic environments.

1.5 Preliminary nutrient load reduction estimates were included in the November 2021 Science JWS (table 1 of the Science JWS) and referred to in Mr Farrell's evidence. Appendix 1 to this evidence identifies numerous technical issues that I have identified with the table 1 estimates. In my opinion the table 1 estimates are not based on robust relationships between nutrients and freshwater attributes for ecosystem health, are subject to change and further debate within the community and should not be relied upon in advance of Plan Change Tuatahi.

1.6 In my opinion, the phrase 'waterbodies in need of improvement' should be preferred over ' degraded waterbodies' as the former is more intuitive, more consistent with the NPSFM, and more flexible when referring to different sets of thresholds, including those that define hauora.

1.7 My understanding is that Ms McArthur and Mr Farrell are requesting that Appendix N should include 'attributes' that relate to ecosystem health and/or a state of hauora. I consider that a number of attributes will contribute water quality and ecosystem health improvements, but I agree with Mr Willis that these actions are captured elsewhere in Appendix N.

2. INTRODUCTION

2.1 My full name is Craig Verdun Depree. My qualifications are set out in my primary evidence dated 20 December 2021 and I do not repeat these here.

3. BACKGROUND

Code of conduct

3.1 I have read and am familiar with the Environment Court's Code of Conduct for expert witnesses and I agree to comply with it. Except where I state that I am relying on the specified evidence of another person, my evidence in this statement is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions which I express.

Scope of evidence

3.2 I have been asked by 'the dairy interests' to provide evidence relating to:

a) Buffer / setback widths

b) Ephemeral flow paths

c) The level of confidence that should be placed on the preliminary load reduction estimates included in the November 2021 Science JWS and referred to in Mr Farrell's evidence.

d) Terminology: waterbodies in need of improvement vs degraded water bodies.

e) The proposed inclusion of additional hauora/ ecosystem health attributes to Appendix N as outlined in Mr Farrell's evidence.

4. MINIMUM BUFFER WIDTHS FOR REDUCING CONTAMINANT CONCENTRATIONS IN SURFACE RUNOFF

4.1 My understanding is that in order to qualify as a permitted activity, the planning JWS (Dec 2021) provided that minimum setbacks for cultivation and intensive winter grazing were as follows:

a) 5m for cultivation on slopes of <10°

b) 10m for cultivation on slopes between 10 and 20°.

c) Either 5 or 10m for intensive winter grazing on slopes <10° (this setback was not agreed by the planners at conferencing).

4.2 I understand that Ms McArthur is recommending 10m minimum buffer widths everywhere, with wider buffer widths of at least 20m for cultivation on land >10° (para. 55) and for intensive winter grazing activities on all slopes (para. 61 of Ms McArthur's 20 December evidence). Although I note that Mr Farrell has not included this in his proposed provisions (his Appendix 1).

Target contaminant for setting minimum buffer width

4.3 Riparian buffers are generally better at removing sediment than nutrients and E.coli. This is because nutrients are either dissolved or concentrated in fine sediment fractions. Similarly E.coli when freely dissociated can behave more like a dissolved contaminant. The consequence of lower removals, is that wider buffers are required to achieve a target removal (compared to sediment). This appears to be one of the justifications for wider buffers used by Ms McArthur (para. 54).

4.4 I do not consider that the removal of nitrogen should be a justification for having buffers wider than what is necessary to effectively reduce suspended sediment. My reason for this position is that the load of nitrogen in surface runoff is a very small fraction of the total load[1] of

[1] Majority of nitrogen lost via movement through the soil profile (i.e. leaching).

nitrogen lost from the farm (the majority being via leaching through the soil profile).

4.5 For example, Monaghan et al (2000)[2] reported that on experimental plots in Southland receiving 400 kg of N fertiliser, less than 1% of the total N-loss was found in surface runoff. Based on this work, a maximum of 1% of total N loss from the paddock would be potentially removed via a buffer intercepting surface runoff.

4.6 Accordingly, increasing the buffer width to treat a very minor contaminant (nitrogen) pathway is very inefficient, and makes little sense. Instead, other nitrogen mitigations[3] that target the bulk of the nitrogen lost will be required to reduce N-losses from farm activities.

4.7 Accordingly, I have focussed on sediment removal in my assessment on effective minimum buffer widths.

How do riparian buffers work and what factors influence contaminant removal?

4.8 Riparian buffers work by slowing the velocity of overland flow as it travels through the buffer, removing contaminants by two main mechanisms:

a) Settling out (i.e., deposition) of particles suspended in runoff – this is the primary mechanism for removal of coarse particulates.

b) infiltration of runoff across the width of the buffer – this is the main mechanism for removal of dissolved nutrients and finely dispersed[4] contaminants (e.g. pathogens and clay particles).[5]

4.9 There are many factors that influence the performance of buffers, and hence the proportion of contaminants removed from a given width. These include sediment size, slope and slope length, soil type (i.e., infiltration properties), vegetation cover and flow distribution (McKergow et al. 2020).

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[2] Monaghan RM, Paton RJ, Smith LC, Binet c. (2000). Nutrient losses in drainage and surface runoff from a cattle-grazed pasture in Southland. Proceedings of the New Zealand Grassland Association. 62: 99-104.
[3] Combination of farm system (inputs / crop type / catch crop) and edge of field mitigations (i.e. constructed wetlands, or woodchip bioreactors intercepting artificial drainage)
[4] Particulate matter that is either not readily settleable or non-settleable
[5] For example, if 50% of the runoff volume entering a buffer is removed by infiltration, then c. 50% of associated non-settleable contaminant load will also be removed.

Sediment removal as a function of buffer width

4.10 Following a comprehensive literature review,[6] NIWA prepared a riparian buffer guideline document (McKergow et al. 2020), which included a sediment removal curve as a function of buffer width (Figure 1). The buffer width (x-axis) is the ratio of buffer width to hillslope length. The author determined an optimum ratio of 0.07, corresponding to 3.5m or 7m for a hillslope length of 50m and 100m, respectively. Assuming an upslope length of 100m, the widest buffer in Figure 1 would correspond to 20m.

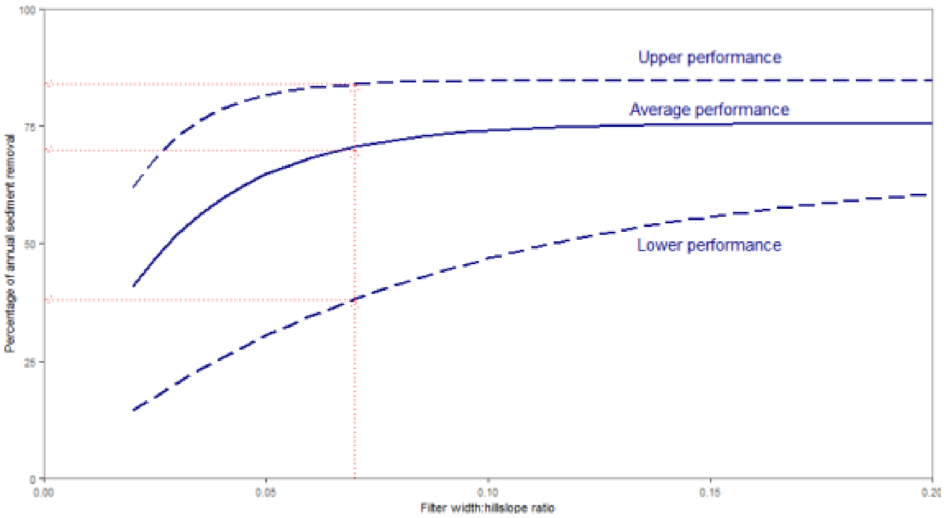

Figure 1. Sediment guideline curves for a well-designed and maintain grass riparian buffer with soils containing <30% clay. The lower and upper performance curves are the 95% confidence intervals around the fitted 'average performance' sediment removal curve (Figure 9 from McKergow et al. 2020).[7]

4.11 Measuring distances off the curve, and assuming a hillslope length of 100m and average removal performance, the estimated sediment removal for a 5m, 7m, 10m and 20m buffer was 65%, 71%, 74% and 76%. Based on these data, increasing buffer width from 5m to 10m increases the amount of sediment removed from 65 to 74% (14% relative increase). By contrast, increasing the riparian buffer width from 10m to 20m increases the amount of sediment removed from 74 to 76%; a relative increase of <3%.

[6] McKergow et al. 2020. Attenuation of diffuse-source agricultural sediment and nutrients by riparian buffer zones: A review to support guideline development. NIWA Client Report 2020037HN prepared for DairyNZ. 67 p.

[7] McKergow L, Matheson F, Goeller B, Woodward B. (2020). Preliminary riparian buffer guidelines Filtering surface runoff and nitrate removal from subsurface flow. NIWA Client Report 2020040HN prepared for DairyNZ. 49 p.

4.12 The findings by McKergow et al. (2020) identify marginal gains in sediment removal from doubling the buffer width from 10m to 20m. This finding was supported by the buffer performance model of Zhang et al. (2010).[8,9]

4.13 Irrespective of the Zhang et al. (2010) model used[10] for slopes up to 10°, the relative increase in sediment removal on going from a 10m to 20m buffer width was <3%. For a 10° slope, the estimated sediment removal for a 5, 10 and 20m buffer width (using the Zhang et al. model) was 63%, 72% and 74%, respectively, which were similar to predictions using the removal curve of McKergow et al. (2020) (Figure 1).

4.14 Based on small increases (i.e. <3%) in sediment removal when buffer width is increased from 10 to 20m predicted by both the NIWA guideline removal curve (McKergow et al. 2020) and the Zhang et al. (2010) model, I disagree with Ms McArthur's recommendation for 20m setbacks for intensive winter grazing and cropping on slopes between 10 and 20°.

4.15 Relative to a 5 m buffer, a 10m buffer removed 15% more sediment from runoff. Although this seems modest, if the "lower performance" curve is used (Figure 1, McKergow et al. 2020), the amount of sediment removed by a 5m and 10 m buffer is estimated to be 31 and 47% - which corresponds to a relative increase in sediment removal of 50%. Given the higher risk associated with intensive winter grazing[11,12] and cultivation on steeper slopes, I recommend a buffer set back of 10m for these activities. That said, I believe careful management of critical source areas (CSAs) is more important for reducing sediment loss from higher risk activities (as discussed in the following section).

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[8] Zhang et al. (2010). A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution. Journal of Environmental Quality. 39, January–February, 76-84.
[9] I have used the model of Zhang et al. (2010) as the output from this model was used by experts in the Science JWS (Nov 2021).
[10] Zhang et al. (2010) had several model equations to different slope categories, and riparian vegetation.
[11] A recent study showed that relative to 'normal' grazed pasture, intensive winter grazing increased soil erosion by a factor of around 10 (Donovan and Monaghan, 2021)
[12] Although intensive winter grazing generates higher sediment yields, at a regional scale, intensive wintering grazing (based on 2017 data) contributes to <4% of the total sediment load (Neverman et al. 2021: LandCare Report (es.govt.nz)).

4.16 For the avoidance of doubt, I recommend the following buffer widths for qualifying rivers:

a) 5m for cultivation on slopes <10°

b) 10m for cultivation on slopes between 10 and 20°

c) 10m for intensive winter grazing on slopes <10°

4.17 I disagree with Ms McArthur's recommendation (paragraph 54) that there should be a minimum 10m riparian buffer for all rivers in Southland. In the absence of cropping and intensive winter grazing, setbacks for rivers >1m wide should be in accordance with the Resource Management (Stock Exclusion) Regulations (2020).

Minimum buffer widths combined with Critical Source Area (CSA) management

4.18 'Flow distribution' is arguably the most important factor that affects buffer performance, and ultimately dictates whether wider, uniform width buffers is an efficient approach to reducing sediment losses.

4.19 Non-converging flows on relatively flat land reach the riparian buffer as shallow, low velocity, "sheets"[13] of water that are evenly (uniformly) dispersed across the entire length of the buffer (Figure 2a). Sediment removal is high when flows are non-convergent. This type of flow is what most studies use (or assume) to assess contaminant removal performance of buffers.

4.20 By contrast, on rolling / undulating typography, runoff tends to converge resulting in concentrated flows entering only a small fraction of the buffer length[14] (Figure 2b). The combination of high velocities and deep flows 'swamp' the riparian vegetation, resulting in much lower removal of sediment (and associated contaminants).

[13] Uniform sheet flow is relatively uncommon, and normally comprises a series of micro-channels (or 'fingers'). Riparian buffers perform well if there are many of these 'finger' flows that are well dispersed across the length of the buffer (McKergow et al. 2020).
[14] Most of the buffer face receives little or not runoff, and is therefore only a small fraction of the buffer area is involved in treating the runoff.

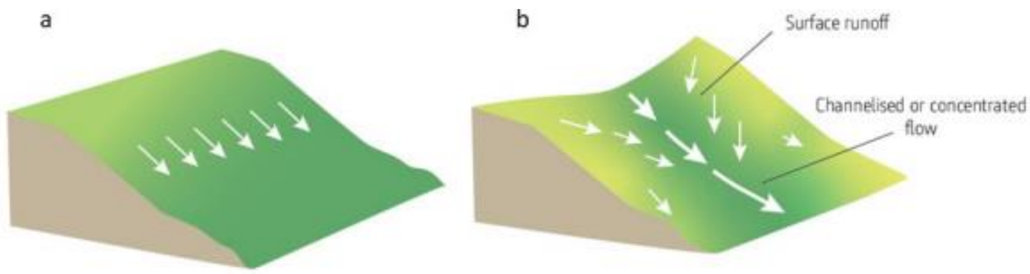

Figure 2. flow distribution – idealised uniform, non-converging flow on a planar slope (left) and convergent flow on rolling topography (right). (Figure 8 from McKergow et al. 2020).

4.21 In general, as slopes get steeper runoff flows become more concentrated, which means contaminant removal by buffers positioned along waterways (i.e., running parallel to ground contours) become increasing ineffective as the proportion of runoff entering the buffer face as concentrated flow increases.

4.22 Modelling by Dosskey et at. (2002)[15] highlighted the importance of considering concentrated flows when assessing real-world buffer performance. At three field sites discussed by Dosskey et al. (2002), when concentrated flows were taken into account, sediment removal performance reduced by 60 to 80% (relative to scenario where runoff was uniformly distributed across the buffer face). For example, at one of the sites, the proportion of sediment removed by the buffer reduced from 67%, under non-convergent (uniformly distributed) flow, to just 15% under a real-world convergent flow scenario. The reason for this large reduction in performance is that the concentrated flow path(s) run through only 12% of the total buffer area. This means that almost 90% of the riparian buffer was not involved in treating runoff (i.e. redundant area).

4.23 Concentrated flows are more pronounced on steeper topography. The Dosskey et al. (2002) examples had average slopes of around 2° (i.e. relatively flat). Based on this, it seems reasonable to expect that as slope increases, concentrated flows are likely to comprise a greater proportion of total surface runoff, reducing the efficacy of uniformly wide riparian buffers. Based on the work of Dosskey et al (2001), which showed marked

[15] Dosskey MG, Helmers MJ, Eisenhauer D, Franti T, Hoagland KD. (2002). Journal of Soil and Water Conservation (November) p.336-343. https://www.researchgate.net/publication/245508735_Assessment_of_Concentrated_Flow_Through_Riparian_Buffers/link/53e3baa30cf2fb74870db8d7/download

performance reductions from channelised flow on flat topography, it seems reasonable to expect that concentrated flow may reduce the theoretical[16] performance of riparian buffers by around 80%.

4.24 In my opinion, while it is good management practice to have a minimum riparian buffer width, the 'heavy lifting' to reduce sediment loss from higher risk activities and concentrated overland flow is done by identifying and managing CSAs. For example, non-cultivation of major surface flow paths will provide longitudinal grassed 'buffers' (or swales) for pre-treatment before intersecting with a 'transverse' minimum riparian buffer. Examples of critical source areas from cropping/grazing are shown in Figure 3.

Figure 3. Examples of critical source areas that do not have buffer zones along the convergent flow path (i.e.. swale, gully or depression landforms).

4.25 It has been shown that good management of CSAs can reduce the loss of sediment, phosphorus and *E.coli* by 80 to >90% (Monaghan et al. 2017)[17]. As such, it is unnecessary (and certainly inefficient) to set very wide 'transverse' riparian buffers when the buffer treatment area relative to that of well managed CSAs is very small. I have attempted to illustrate the landscape connection between the CSA management zones (orange) with the minimum riparian buffer (green) in Figure 4. This highlights how much more treatment area and length (blue arrows) is available from

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[16] Theoretical refers to assuming that surface runoff is evening distributed across 100% of the buffer face length and width.
[17] Monaghan RM, Laurenson S, Dalley, DE, Orchiston TS (2017). Grazing strategies for reducing contaminant losses to water from forage crop fields grazed by cattle during winter. New Zealand Journal of Agricultural Research. 60 (3), 333-348.

within the managed CSAs compared with the riparian buffer receiving concentrated flow from this area (red arrow).

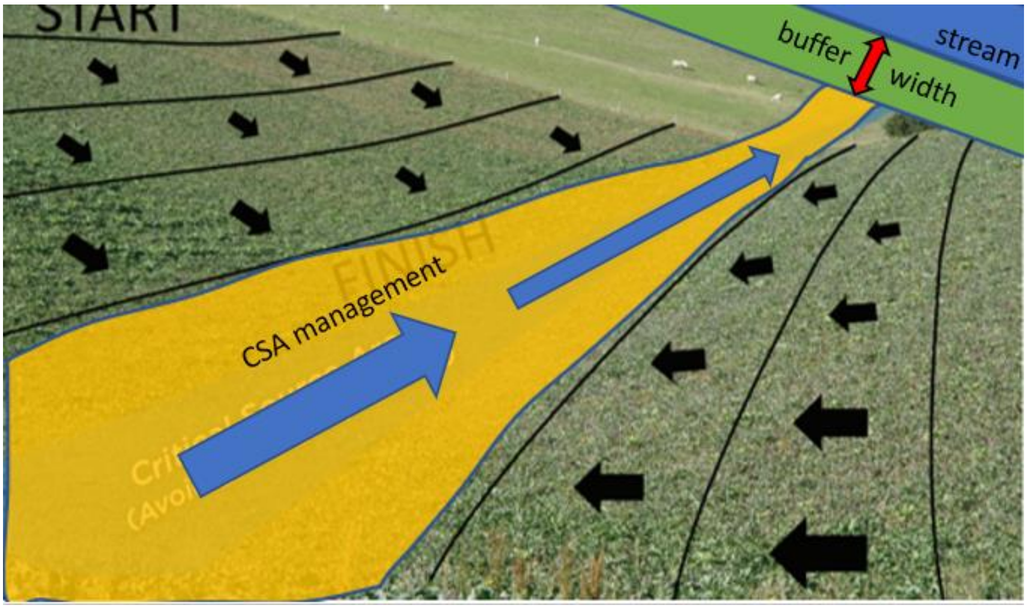

Figure 4. Illustration of area used to manage contaminant generation and transport within a CSA (where a higher risk activity is occurring), and connections with a minimum width riparian buffer adjacent to a waterbody (the location of the stream and riparian buffer have been added for illustrative purposes) . The black arrows depict overland flow from grazed/cropped hillslopes into the CSA buffer, sediment is removed, and treated runoff converges to form channelised flow (blue arrows) that is conveyed to a riparian buffer (green) before discharge to the waterbody. Relative to the length-wise 'filtration' within the CSA buffer, additional treatment provided by the riparian buffer is likely to be minor.

4.26 Accordingly, the identification of major flow paths and committing more area for managing contaminant loss from CSAs, in my opinion, is a more efficient and targeted approach to achieve target freshwater outcomes. Figure 5 shows examples of where significant areas of land are taken out of production (while a higher risk farming activity such as intensive wintering grazing is occurring) as part of managing contaminant generation and transport from CSAs.

4.27 In summary, the technical evidence clearly shows the importance of not fixating on wider transverse riparian buffers as a means of reducing sediment to surface waters, and the importance of good CSA management.

Grassy swale protecting CSA

Grass swale capturing sediment protecting CSA

Figure 5. Examples of 'longitudinal' grassed buffers for reducing contaminant loss from critical source areas during intensive wintering grazing (Landcare NZ). In the left image, the result of deeper, higher velocities in channelised flows is evident from the flattened grass. The longitudinal nature of these CSA buffer areas is evident, and with the potential to combine with silt fences (left image), the treatment potential of these targeted buffers (located close to the source of contaminant generation) is much greater than that provided by untargeted, uniformly wide riparian buffers.

5. EPHEMERAL RIVERS

5.1 With respect to ephemeral flow paths, I support the agreed terminology in the December 2021 planning JWS, as based on international and national definitions and field criteria, these are terrestrial flow paths characterised by absence of a discernible bed and channel, only flow in response to runoff events, and the areas do not comprise aquatic plants or animals. The reasons for my position are described below.

5.2 Acknowledging the river continuum, and that the flow of water from mountains to sea is connected, it is important to be able to differentiate terrestrial from aquatic environments.

5.3 Runoff in the landscape flows perpendicular to contour lines, forming concentrated flows in areas characterised by ‘convergent’ contours, such as gullies and swales. These concentrated flows move along ephemeral flow paths and discharge nearby aquatic receiving environments (e.g. intermittently flowing or low-order perennial rivers).

5.4 The RMA defines the terrestrial to aquatic (i.e. riverine environment) transformation as starting with intermittent rivers. The RMA definition of a river is:

"*A continually or intermittently flowing body of fresh water; and includes a stream and modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal).*"

5.5 Auckland Council has developed guidelines for differentiating intermittent rivers (or streams) and ephemeral flow paths. If a 'stream' meets 3 of the 6 intermittent river criteria (a-f), then it is classified as an intermittent river (and a 'river' for the purpose of the Act) , if not, it is an ephemeral flow path.

a) it has natural pools

b) it has a well-defined channel, such that the bed and banks can be distinguished

c) it contains surface water more than 48 hours after a rain event which results in stream flow

d) rooted terrestrial vegetation is not established across the entire cross-sectional width of the channel

e) organic debris resulting from flood can be seen on the floodplain or

f) there is evidence of substrate sorting process, including scour and deposition.

5.6 The Auckland Council criteria are similar to those reported by Hansen (2001)[18] (Table 1), although importantly, from his criteria (in my opinion) it is implicit that ephemeral flow paths are terrestrial environments given that they contain no aquatic insects.

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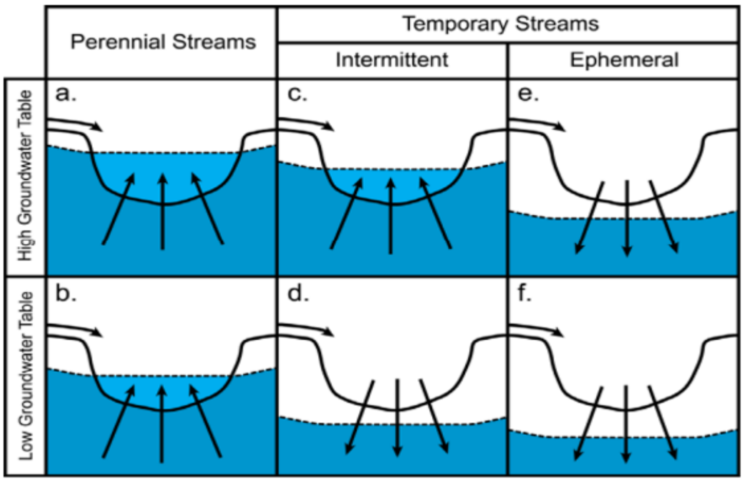
[18] Hansen HF. (2001). Identifying stream types and management implications. Forest Ecology and Management. 143 (2001) 39-46.

Table 1. Field criteria used for determining river type (from Hansen 2001)[18]

Criteria	Stream type		
	Perennial	Intermittent	Ephemeral[a]
Channel	Defined	Defined	Not defined
Flow duration (estimated)	Almost always	Extended, but interrupted	Stormflow only
Bed water level	Above channel	Near channel surface	Below channel
Aquatic insects	Present	Few, if any	None
Material movement	Present	Present, less obvious	Lacking or limited
Channel materials	Scoured, flow sorted No organic buildup	Scoured or flow sorted Lacks organic buildup	Mostly soil materials Organic buildup

5.7 *Figure 6* (from McDonough et al. 2011)[19] provides a useful illustration of the difference between perennial, intermittent and ephemeral flow paths under high and low groundwater table conditions. This highlights that the downstream extent of intermittent rivers will expand when ground water is increasing, and contract when ground water levels are decreasing. The extent of intermittent rivers should be based on a high groundwater table. That is, during summer, dry intermittent rivers are still intermittent rivers – they do not become ephemeral because there is no water in the channel.

5.8 In contrast to intermittent rivers, the 'bed' of ephemeral flow path is always above the groundwater table. This is why these landscape features only flow during, or shortly after, rainfall events.



Channel cross-sectional schematic showing perennial, intermittent, and ephemeral streams under high and low groundwater table conditions. Dashed line indicates groundwater table elevation. Arrows indicate surface water and groundwater flowpaths. a) Perennial – High Groundwater: gaining stream. b) Perennial – Low Groundwater: gaining stream. c) Intermittent – High Groundwater: gaining stream. d) Intermittent – Low Groundwater: losing stream. e) Ephemeral – High Groundwater: losing stream. f) Ephemeral – Low Groundwater: losing stream.

Figure 6. Schematic from McDonough et al. (Figure 1) showing the different hydrology of perennial, intermittent and ephemeral rivers under higher groundwater tables (a, c and e, respectively) and low ground water tables (b, d and f, respectively).Although the ephemeral rivers (e and f) show a defined channel (for illustrative purposes) this is typically not a characteristic of ephemeral flow paths (Hansen 2001).[18]

[19] McDonough OT, Hosen JD, Palmer MA. (2011). Temporary streams: the hydrology, geography and ecology of non-perennially flowing waters. Chapter 7 in: River Ecosystems, dynamics, management and conservation. Eds. Elliot HS, and Martin LE.

5.9 I note that Parkyn and Wilding (2006)[20] emphasised the inconsistent use of terminology to describe non-perennial flowing rivers, stating:

"There is considerable inconsistency in the terminology for rivers that only flow for part of the year. Temporary, intermittent, and ephemeral are all terms used to describe rivers and ponds with irregular flow." (Parkyn and Wilding, 2006).[20]

5.10 The inconsistent use of terminology is apparent in Ms McArthur's evidence on the ecological importance of ephemeral flow paths[21]. Ms McArthur refers to the study of Story et al. (2011)[22] (which I understand is the same study as Parkyn et al., 2006)[23] as evidence of ephemeral flow paths having as many, or more invertebrates, as perennial rivers. I disagree with this assessment. My understanding is that the authors only sampled macroinvertebrates from channels containing water, isolated pools or relatively fluid mud. No dry channels were sampled for macroinvertebrates.

5.11 In my opinion, habitats defined by pools and the mud of residual pools, are examples of intermittent rivers (i.e. contracting reaches due to falling water table). Accordingly, I do not believe that the macroinvertebrates reported by Story et al.[22] are evidence of the value of ephemeral flow paths.

5.12 In addition, Ms McArthur refers to the results of Collier and Smith (2005)[24], as further evidence of the ecological value of ephemeral flow paths. However, I disagree with Ms McArthur on this point also, as the study looked at invertebrates sampled from rockface seepages. In my opinion, these environments have little relevance to ephemeral flow paths.

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[20] Parkyn S. and Wilding TK (2006).Small headwater streams of the Auckland Region Vol. 1: Spatial extent. NIWA Client Report HAM2006-064 prepared for Auckland Regional Council (ARC). 82 p.

[21] Evidence in chief, paragraphs 63 to 70.

[22] Storey RG, Parkyn S, Neale MW, Wilding T, Croker G 2011. Biodiversity values of small headwater streams in contrasting land uses in the Auckland region. New Zealand Journal of Marine and Freshwater Research 45 (2): 231-248

[23] Parkyn S, Wilding TK and Croker G. (2006).Small headwater streams of the Auckland Region Vol. 4:Natural values. NIWA Client Report HAM2006-134 prepared for Auckland Regional Council (ARC). 57 p

[24] Collier K, Smith B 2006. Distinctive invertebrate assemblages in rockface seepages enhance lotic biodiversity in northern New Zealand. Biodiversity and Conservation 15: 3591-3616.

5.13 For the avoidance of doubt, in my opinion, the macroinvertebrate evidence of Ms McArthur (para. 64, 65 and 70) relates to intermittent rivers (and seeps), and it is incorrect to 'extend' these ecological values to ephemeral flow paths.

5.14 My interpretation of the delineation between 'terrestrial' and 'aquatic' environments is shown in Figure 7.

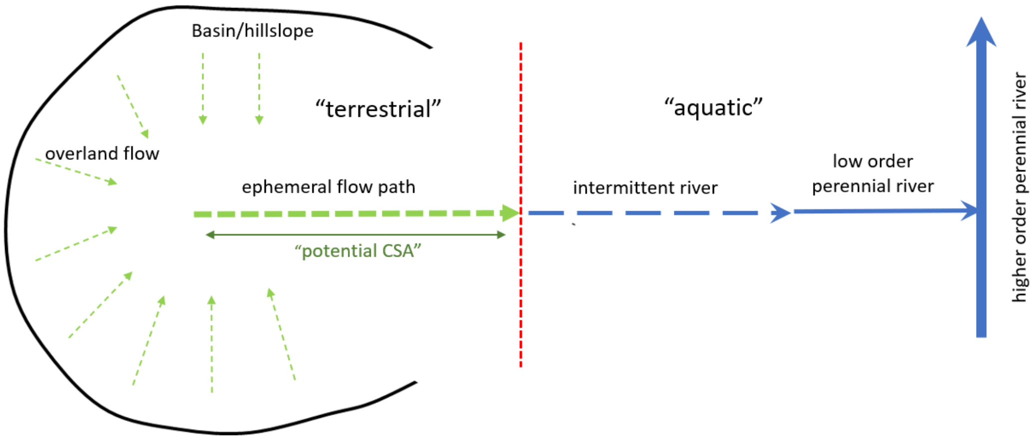

Figure 7. Proposed delineation between terrestrial and aquatic environments along the river continuation. The division between terrestrial and aquatic environments (vertical red dashed line) is consistent with the RMA definition of a river. Note some intermittent rivers may also be characterised as seepage wetlands, especially where the channel is poorly defined or spread-out.

5.15 Figure 7 proposes that ephemeral flow paths are terrestrial environments.

5.16 For the avoidance of doubt, and being consistent with the criteria of Hansen (2001), and other ecological assessments[22,23] I do not agree that ephemeral flow paths should be considered (or classified) as rivers. They are terrestrial environments.

5.17 However, being overland flow paths, these are potential CSAs, and should be assessed by a certified professional to determine if they are, in whole or in part CSAs (for a given farm activity).

5.18 I support that, where practicable, stock should be excluded from small rivers (including intermittent rivers) because these environments do contain / support aquatic life. It is my understanding that this is already included in the plan.

6. RELEVANCE OF PRELIMINARY SCIENCE ARISING FROM THE NPSFM 2020 LIMIT-SETTING PROCESS

6.1 The Science 2021 JWS and the evidence in chief of Ms McArthur refer to the magnitude of modelled contaminant load reductions required to meet possible freshwater objectives (including the minimum hauora state – Ms McArthur's evidence, para. 25) as a reason for the pSWLP to 'do more' with respect to improving water quality.

6.2 It is not clear to me why that information is relevant to the provisions to be included in the pSWLP at this time given this is a matter of on-going deliberation amongst scientists in another forum (the Plan Change Tuatahi development process). Nevertheless, I have been asked to provide comment on the relevance of proposed load reductions, in particular, the percentage load reductions in nutrients presented in Table 1 of the Science JWS (Nov 2021). This table is shown below (Table 2).

Table 2. Net estimated load reductions for TN and TP to achieve trophic outcomes in rivers, lakes and estuaries of Southland (excluding Fiordland and off-shore island). [Table 1 from the Science JWS 2021, but original values from Snelder (2021)[25]]

Outcomes	TN reduction (%)	TP reduction (%)
Hauora*	70 (61-78)	70 (62-77)
pSWLP	66 (58-74)	69 (59-77)
NBL (C/D)	47 (33 – 61)	21 (13 -33)

6.3 The load reductions shown in Table 2 have been derived as part of the Plan Change Tuatahi workstream to inform the regional forum process. Plan Change Tuatahi is scheduled to be notified in 2023.

6.4 Importantly, the load reductions have no formal regulatory status. They represent a preliminary desktop assessment of the load reductions required to meet a series of environmental nutrient targets, some of which are poorly related to measured attribute states at Environment Southland monitoring sites.

6.5 I am very familiar with Environment Southland's nutrient load reduction work. In February 2021 I provided a comprehensive technical review to

[25] Snelder T. (2021). *Assessment of Nutrient Load Reductions to Achieve Freshwater Objectives in the Rivers, Lakes and Estuaries of Southland Including Uncertainties: To inform the Southland Regional Forum process. 113 p.* Type Topic Title (datacomsphere.com.au)

Environment Southland outlining numerous technical issues with the estimated load reductions (focusing on nitrogen). Furthermore, while at NIWA, I was co-author of MfE's *A draft technical guide to the Periphyton Attribute Note*[26], which has now been updated and finalised as "*A guide to setting instream nutrient concentrations under clause 3.13 of the National Policy Statement for Freshwater Management 2020.*"[27]

6.6 In these reports, I authored:

a) *Section 3.2: Are there sensitive downstream receiving environments?*

b) Section 3.3: *How are nutrient criteria reconciled across the FMU and downstream receiving environments?*

6.7 Accordingly, I believe that I am suitably qualified to technically evaluate the nutrient limit setting work that sits behind the preliminary load reduction targets in Table 2.

6.8 In broad terms, I do not consider that the approach used to derive the nutrient load reductions set out in Table 2 above is based on a certain enough understanding of the relationship between nutrient concentrations and trophic outcomes (e.g., periphyton) in Southland's rivers and estuaries.

6.9 I set out a summary of my reasoning for that opinion in Appendix 1.

6.10 From that discussion, although some parties appear to have accepted the numbers in Table 2 as 'firm and final' that is not the case. While I agree that significant reductions in nutrients will be required to achieve the outcomes the Southland community is likely to want[28], based on my involvement in this issue to date, I would anticipate that there is significant

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[26] Ministry for the Environment (2018). A draft technical guide to the Periphyton Attribute Note. Freshwater guidance under the NPSFM 2014 (as amended 2017). 69 p. FORMATTED Gas guidance NZ ETSto formatter (environment.govt.nz)

[27] Ministry for the Environment. 2021. A guide to setting instream nutrient concentrations under clause 3.13 of the National Policy Statement for Freshwater Management 2020. Wellington: Ministry for the Environment. Guidance-for-setting-instream-nutrient-concentrations-under-Clause-3.13-FINAL.pdf (environment.govt.nz)

[28] It is important to emphasise that the communities values and corresponding target freshwater water attribute states (or freshwater objectives, FWOs) have yet to be finalised.

technical analysis and discussion to be had before the final reduction targets are agreed. For the reasons set out in Appendix 1, while reductions required will be significant I don't expect the final numbers to be as high as those set out in Table 2.

7. DEGRADED WATERBIODIES VS. WATERBODIES IN NEED OF IMPROVEMENT

7.1 My understanding from the Planning JWS is that the planners had agreed to refer to catchments that needed to be improved as *waterbodies in need of improvement*, as opposed to *degraded waterbodies*.

7.2 I do not support the use of the term *degraded waterbodies* for the reasons outlined in paragraphs 7.3 to 7.10.

7.3 I understand that the term **degraded** (FMU/part FMU or site) has specific meaning in the NPSFM (2020). In the absence of target attributes states having been set, the failure to comply with national bottom-lines is the only 'threshold' test that should be used to assess whether a site (FMU/part FMU) is degraded (according to the NPSFM's definition). Accordingly, I consider it reasonable to refer to catchments as 'degraded' if they fail to meet a threshold that corresponds to a NPSFM national bottom-line.

7.4 The use of national bottom-lines (i.e. minimum acceptable state) from the NPSFM as being indicative of a degraded state was agreed by the science experts (para. 19. JWS Oct 2019). I agree with that but the thresholds recommended by the Science JWS (Oct 2019, Table 1) for the purpose of identifying degraded waterbodies often do not correspond to national bottom-lines.[29] Given that many of the thresholds identified in Table 1 of the Oct 2019 JWS are 'better' than the national bottom-line (also referred to as the minimum acceptable state), in my opinion, it is inconsistent with NPSFM terminology to refer to these as *degraded waterbodies*.

7.5 Perhaps the most important reason for avoiding 'degraded' terminology is the requirement to provide for hauora. Using six guiding hauora principles, Bartlett et al. (2020) defined NPSFM (and other regional attributes) target attribute states that corresponded to a minimum state of hauora. The

[29] Refer to Table 1 of Science JWS (14-16 October 2019)

hauora target attributes states are dominated by A and B band grades. As such, hauora thresholds often reflect a much higher environmental standard than a minimum acceptable state agreed by the experts to define ‘degraded waterbodies’.

7.6 Consequently, the process now has two sets thresholds, one that defines degraded relative to a minimum acceptable state, and a second that defines haoura, with several attributes requiring very high quality outcomes (i.e., A-band). The separation of ‘degraded’ from ‘hauora’ was apparent in the answer to question two in the Science JWS (Nov 2021), where the experts state *“:… the previous work for the water quality JWS was focussed on defining degradation rather than hauora*.”

7.7 I interpret this as meaning that a waterbody not meeting hauora, is not necessarily degraded – they are different assessments. However, regardless of the assessment, exceeding either a degraded threshold , or a hauora threshold, the terminology of “waterbody in need of improvement” is appropriate.

7.8 For the avoidance of doubt, I agree with the planning JWS decision to refer to *waterbodies in need of improvement* rather than ‘degraded waterbodies’. I consider the former to be inherently more intuitive (i.e. with respect to objectives and intended outcomes) and avoids conflicts with NPSFM definitions regarding ‘degraded’ waterbodies and/or catchments. Furthermore, ‘in need of improvement’ avoids the subtle (but meaningful) difference in the NPSFM terms ‘degraded’ (referring to state) and ‘degrading’ (referring to trend).

7.9 Below I give specific examples of where Table 1 thresholds (Science JWS Oct 2019) do not correspond to national bottom-lines set out in the NPSFM (2020). Accordingly, assessing degraded waterbodies with Table 1 thresholds is not consistent with the NPSFM definition of degraded, which states a waterbody is degraded when its state is “*below a national bottom line*”.

7.10 These include:

a) Macroinvertebrate community index (MCI) threshold of 100 applied to upland rivers is better than the national bottom-line of 90. For the avoidance of doubt, these threshold were used in the ecosystem health map of waterbodies in need of improvement in my primary evidence.

b) Periphyton biomass thresholds used to identified ‘degraded’ upland rivers of 120 mg chla/m^2 is significantly better than the national bottom-line value of 200 mg chla/m^2.

c) DIN (and DRP) thresholds are problematic for defining ‘degraded’ waterbodies.[30] Moreover, DIN is not a NPSFM attribute[31], and DRP, while an attribute has no national bottom-line because the current threshold is known to be exceeded naturally

d) The threshold for ammonia toxicity corresponds to an A-band attribute state, which is better than the national bottom-line (B-band).

7.11 To conclude, for reasons outlined above, I disagree with Mr Farrell’s recommendation to refer to *waterbodies in need of improvement* as degrade waterbodies. The latter is less intuitive, less consistent with the NPSFM, and less flexible when referring to different sets of thresholds, including those that define hauora.

8. INCLUSION OF ADDITIONAL HAUORA AND ECOSYSTEM HEALTH ATTRIBUTES TO APPENDIX N

8.1 My understanding is that Ms McArthur and Mr Farrell are requesting that Appendix N should include ‘attributes’ that relate to ecosystem health and/or a state of hauora. The Science JWS (Nov 2021) identified a number of potential “other attributes of relevance to improving hauora including ecosystem health”. These are described in Table 2 of the Science JWS (Nov 2021).

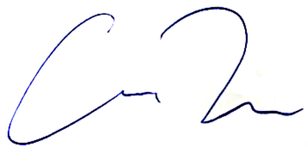
8.2 As a water quality scientist, I understand the importance of catchment context. Furthermore, while a number of the attributes[32] will contribute

[30] Refer to Appendix 1, para. 9.11 to 9.16.

[31] As discussed in my 20 December evidence, a subgroup of the Science Technical Advisory Group (STAG) concluded that nutrients (DIN and DRP) were generally poor predictors of ecosystem health. Accordingly, DIN and DRP thresholds are, at best, highly uncertain ‘proxy’ measures for trophic attributes (e.g. periphyton biomass in hard-bottom streams). In my opinion, these thresholds are cannot be used to assess whether a site/catchment is degraded with respect to a bottom-line trophic attribute state.

water quality and ecosystem health improvements, I agree with Mr Willis at paragraph 9.4 of his evidence that these actions are captured elsewhere in Appendix N (irrigation design, installation and management, collected effluent management, nutrient management , drain maintenance etc) and therefore would not appear to warrant separate inclusion.

8.3 I also agree with the evidence of Mr Duncan that it is important to ensure the FEMP remains a targeted document that can be easily applied (and understood) to have the best chance of achieving its purpose – water quality improvements. However, given the technical complexity of some of issues included in Table 2, I consider that it may be impractical to meaningfully include some of the "attributes" in table 2 (Science JWS, Nov 2021) in a farm plan.



DR CRAIG VERDUN DEPREE

20 December 2021

9. APPENDIX 1: SUMMARY OF TECHNICAL ISSUES WITH NUTRIENT LOAD REDUCTION TARGETS

9.1 The Science JWS (Nov 2021) and the evidence in chief of Ms McArthur refer to the magnitude of modelled contaminant load reductions required to meet possible freshwater objectives (including the minimum hauora state – Ms McArthur's evidence, para. 25) as a reason for the pSWLP to 'do more' with respect to improving water quality.

9.2 I do not agree that the information is relevant to the provisions to be included in the pSWLP at this time given this is a matter of on-going deliberation amongst scientists in another forum (the Plan Change Tuatahi development process). Nevertheless, I have been asked to provide comment on the relevance of proposed load reductions, in particular, the percentage load reductions in nutrients presented in Table 1 of the Science JWS (Nov 2021). This table is shown below (Table A1).

Table A1. Net estimated load reductions for TN and TP to achieve trophic outcomes in rivers, lakes and estuaries of Southland (excluding Fiordland and off-shore island). [Table 1 from the Science JWS 2021, but original values from Snelder (2021)[33]]

Outcomes	TN reduction (%)	TP reduction (%)
Hauora*	70 (61-78)	70 (62-77)
pSWLP	66 (58-74)	69 (59-77)
NBL (C/D)	47 (33 – 61)	21 (13 -33)

9.3 The load reductions shown in Table A1 have been derived as part of the Plan Change Tuatahi workstream to inform the regional forum process. Plan Change Tuatahi is schedule to be notified in 2023, and my understanding is that Environment Southland have only just started the community consultation process.

9.4 Importantly, the load reductions specified only represent a preliminary desktop assessment of the load reductions required to meet a series of

[33] Snelder T. (2021). *Assessment of Nutrient Load Reductions to Achieve Freshwater Objectives in the Rivers, Lakes and Estuaries of Southland Including Uncertainties: To inform the Southland Regional Forum process. 113 p.* Type Topic Title (datacomsphere.com.au)

environmental nutrient targets reductions required to meet load reduction work considered riverine, lake and estuarine receiving environments.

9.5 The freshwater objectives (attribute states) applied to the receiving environments were:

a) Riverine = periphyton biomass (Table 2, NPSFM 2020)

b) Lakes = phytoplankton - using TN and TP attribute states (Table 3 and 4, respectively of NPSFM 2020)

c) Estuaries = macroalgal and/or phytoplankton (Estuarine Trophic Index)[34]

9.6 Importantly, the load reductions in Table A1 are not based on meeting the relevant 'trophic' attribute state[35], but rather meeting nutrient target/s that may relate to the target attribute state. For example, in rivers TN targets the Ministry's default national 'look up tables' (MfE 2020)[36] are used as proxies for periphyton biomass. In this way, if a river type has a TN target of 0.5 mg/L, and the current state concentration is 1 mg/L; then the load reduction required to meet the periphyton attribute state is calculated as 50%.

9.7 This approach is justified assuming there is a robust relationship between TN and periphyton biomass. Unfortunately this is not the case for Southland. For example, in a recent analysis by Environment Southland, the authors concluded that nutrients alone were poor predictors of

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[34] Zeldis, J., Plew, D., Whitehead, A., Madarasz-Smith, A., Oliver, M., Stevens, L., Robertson, B., Burge, O., Dudley, B. (2017). The New Zealand Estuary Trophic Index (ETI) Tools: Web Tool 1 - Determining Eutrophication Susceptibility using Physical and Nutrient Load Data. Ministry of Business, Innovation and Employment Envirolink Tools: C01X1420. https://shiny.niwa.co.nz/Estuaries-Screening-Tool-1/

[35] Trophic attributes relate to the biological response of aquatic receiving environments to anthropogenic nutrient enrichment. The primary trophic response is excess primary production (i.e. growth of plants). For stoney bottom rivers the key trophic response (and hence attribute) is periphyton biomass; in lakes it is phytoplankton growth and in estuaries, it is macroalgal biomass or phytoplankton (depending on the estuary type).

[36] Ministry for the Environment. 2020. Action for healthy waterways: Guidance on look-up tables for setting nutrient targets for periphyton. Wellington: Ministry for the Environment. Action for healthy waterways: Guidance on look-up tables for setting nutrient targets for periphyton (environment.govt.nz)

periphyton biomass across the Southland region (DeSilva and Hodson, 2020).[37]

9.8 I do not agree that TN targets can be used as a proxy measure for assessing compliance of Southland rivers against target periphyton attribute states given that there is not an adequately robust relationship between the attribute state (i.e. periphyton biomass) and instream nutrient concentrations.

9.9 The uncertainty of nutrient targets, and the need for measured data to confirm non-compliance of periphyton biomass, is emphasised in the Ministry's guidance document for using periphyton "look up" tables for nutrient targets. This document states:

> *"Exceeding the target, however, does not mean that the site is exceeding the biological threshold, because the nutrient targets are uncertain and only monitoring of periphyton can confirm the actual biomass. However, in the absence of biological information, the manager would interpret failing the target as evidence that there is an issue and may decide to act accordingly." (MfE 2020).*[36]

9.10 Importantly the guidance emphasises that "only monitoring can confirm the actual biomass" (of periphyton). This is consistent with Clause 1.6[38] of the NPSFM (2020), which prioritises robust measured data over modelled data, and requires steps be taken to reduce the level of uncertainty – for example, by validating model output.

9.11 The poor performance of TN targets for predicting periphyton biomass is highlighted in Figure. Based on the measured data at 30 Southland sites, 27 (90%) of sites were meeting periphyton biomass targets (blue markers), but when using TN criteria as a proxy for periphyton compliance, the number of compliant sites decreased to 7 (23%). In other words, the use of TN targets resulted in 20 sites with measured

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[37] DeSilva N. Hodson R. (2020). Drivers of periphyton in the Southland Region. Publication N. 2020-05. 59 p. DriversofperiphytoninSouthland (2).pdf

[38] Clause 1.6 of the NPSFM (2020) states: *In the absence of complete and scientifically robust data, the best information may include information obtained from modelling, as well as partial data, local knowledge, and information obtained from other sources, but in this case local authorities must: (a) prefer sources of information that provide the greatest level of certainty; and (b) take all practicable steps to reduce uncertainty (such as through improvements to monitoring or the validation of models used)*

compliance being incorrectly classified as non-compliant (orange markers).

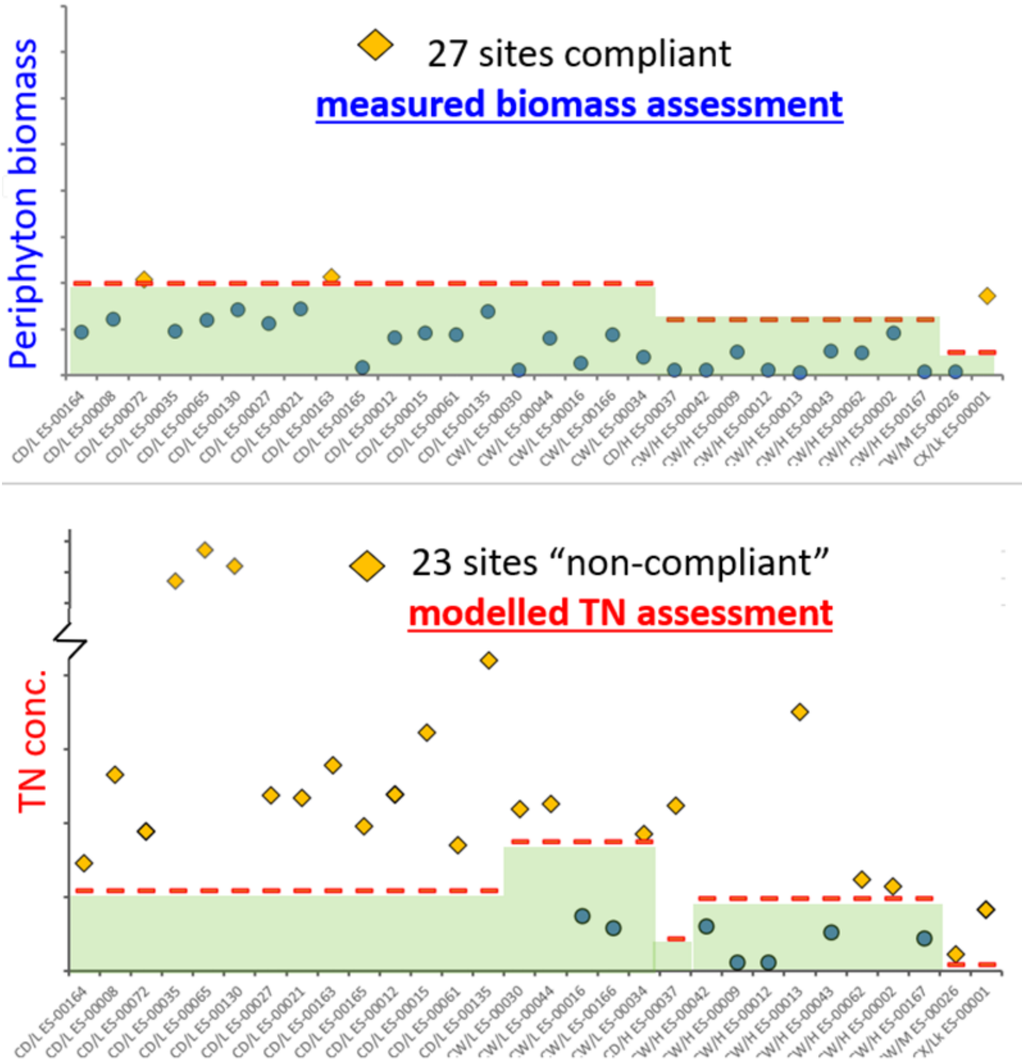

Figure A1. Comparison of compliance based on: measured periphyton biomass data (top) and exceedance of TN targets (an uncertain proxy for periphyton biomass) (bottom).

9.12 Based on guidance for the use of nutrient targets (TN in this case), exceedance of TN at these 20 sites should have been ‘sense checked’ against measured data. However the load reductions have been based exclusively on compliance assessments using TN targets. In my opinion, this has markedly over-estimated the TN load reductions required to meet periphyton target attribute states.

9.13 To further highlight the problem, Table A2 (below) shows a comparison periphyton attribute state compliance using TN targets vs. measured periphyton biomass for nine Environment Southland monitoring sites in the Mataura catchment. Non-compliance and compliance is shown in red and green, respectively. The assessments using TN targets require reduction in TN at 8 of the 9 sites ranging from 23 to 88%. Based on measured periphyton biomass, all 9 sites are currently compliant with periphyton biomass attribute states.

9.14 I note that according to the latest MfE guidance (for setting instream nutrient targets), at these Mataura catchments sites where the periphyton target attribute is being met, a reasonable approach to setting instream nutrient criteria is to apply current state concentrations. The guidance document states:

"For hard-bottom stream and river sites and segments across the FMU where the periphyton objective is currently being achieved (ie, periphyton state = periphyton objective), a reasonable approach would be to set instream nutrient criteria at current concentrations, provided these concentrations also ensure other freshwater objectives for compulsory or regionally-defined attributes are met. We recommend using annual median or geometric mean concentrations of DIN and DRP as the nutrient criteria." (MfE 2021, Section 3.1.1 "How to derive nutrient criteria").

9.15 Note that the final "% load reduction" column in Table A2 does not imply that reductions in nutrients are not required in those catchments. Reductions are required (approximately 50%) for two sites to comply with national bottom-line for nitrate-N toxicity, and also load reductions for the entire catchment can be driven by the need to reduce nutrient loads in the estuaries.

9.16 The TN nutrient load reductions shown in Table A2 are based on riverine assessments that use TN targets as a proxy for periphyton biomass. The result of this, in my opinion, is the significant over-estimation of load reductions required.

Table A2. Comparison of periphyton compliance based on TN targets (proxy attribute) and measured periphyton biomass (actual attribute) at all monitored sites in the Mataura catchment.

description	REC class	TN target conc. (mg/L)	Current TN conc. (mg/L)	% reduct-ion to meet TN target	Periphyton target attribute state (mg/m²)	measured periphyton biomass (mg/m²)	% reduction to meet periphyton biomass target
Longridge Stm at Sandstone	CD/L	0.542	4.35*	88%	200	119	0%
Waimea Stm at Mandeville	CD/L	0.542	4.10*	87%	200	141	0%
Waikaka Stm at Gore	CD/L	0.542	1.19	54%	200	112	0%
Mataura Ry at Mataura Is. Brdg	CD/L	0.542	1.17	54%	200	143	0%
Otamita Stm at Mandeville	CW/L	0.874	1.10	20%	200	11	0%
Mimihau Strm at Wyndham	CW/L	0.874	1.13	23%	200	81	0%
Mataura Ry at Gore	CD/H	0.217	1.12	81%	120	11	0%
Waikaia Ry at Waikaia	CW/H	0.488	0.30	0%	120	12	0%
Waikaia Ry u/s Piano Flat	CW/M	0.044	0.11	60%	50	7	0%

* Longridge and Sandstone need 50% reductions in nitrate-N to meet NBL of 2.4 mg/L

9.17 Other unresolved issues that contribute to high levels of uncertainty in the proposed nutrient load reductions in Table A1:

a) Table A1 indicates that a 47% reduction in TN load across the Southland region is required to meet national bottom-line attribute states. However a 2020 peer-reviewed publication (Snelder et al. 2020)[39] estimated a significantly smaller TN load reduction of 20% to reach national bottom-lines, although this study included Fiordland and off-shore Islands. Taking into account the estimated proportion of TN load from Fiordland, Manapouri[40] and off-shore islands, by my calculations, this corresponds to a 24% reduction. A factor of two lower than the 47% figure in Table A1. I have not been able to reconcile the difference in these two estimates of the load reduction to achieve the same trophic attribute states.

[39] Snelder T, Whitehead A, Fraser C, Larned S & Schallenberg M. (2020b): Nitrogen loads to New Zealand aquatic receiving environments: comparison with regulatory criteria, New Zealand Journal of Marine and Freshwater Research, DOI 10.1080/00288330.2020.1758168.
[40] It was assumed that approximately 90% of the Waiau catchment N load upstream of Lake Manapouri is discharged out of catchment via the Manapouri power station.

b) Periphyton TN criteria are applied to rivers classified as lowland soft-bottom. Soft bottom rivers are generally considered not to support nuisance growths of periphyton biomass. This potentially applies overly stringent TN criteria to >30,000 km of Southland rivers. Previous national load reduction work excluded soft-bottom rivers.[39]

c) The nutrient load reductions in Table A1 are the regional average (excluding Fiordland and off-shore Islands). They include nutrient load reductions that are driven by **estuaries –** the terminal receiving environments for catchments. In addition to the high level of uncertainty estimating load reductions for riverine environments, I am aware of a several issues in the assessment of nutrient load reductions for individual estuaries. In the following paragraphs, I provide examples for the Waituna, Aparima, Oreti and Mataura estuaries.

d) The Waituna catchment requires a 90% reduction in TN load based on modelled concentrations of phytoplankton exceeding a threshold of 25 mg/m^3. The Estuarine Trophic Index (ETI) phytoplankton model predicted a concentration of 74 mg/m3. However, 7 years of monthly monitoring at 4 locations in the lagoon show measured concentrations[41] of between 13 and 19 mg/m3 (LAWA[42]). National and international experts estimated TN reductions of closer to 50% for lagoon ecosystem health.[43,44]

e) Aparima and Oreti estuaries have calculated TN load reductions of 42 and 52%, respectively when riverine TN concentrations are estimated using the CLUEs catchment model. Using measured concentrations (ES monitoring), the reductions in TN to meet estuarine TN targets for the Aparima and Oreti decrease to 18 and 24%, respectively..

f) Mataura (Toetoes) estuary is a tidal river-type estuary which are classified as having *low to very low* 'susceptibility' to nitrogen

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[41] 90% percentile concentrations are used for the assessment.
[42] Land Air Water Aotearoa (LAWA). Land, Air, Water Aotearoa (LAWA) - Waituna Lagoon
[43] Waituna lagoon Guidelines v6-final.pages
[44] Scanes, P (2012). Nutrient loads to protect environmental values in Waituna Lagoon. Report prepared for Environment Southland. 11 p.

enrichment. In comparison, tidal lagoon estuaries like New River and Jacobs River have *moderate to high* susceptibility to nitrogen. Despite this well-known difference, the ES load reduction work applied the same nitrogen targets to the Toetoes estuary, resulting in a calculated 80% reduction in nitrogen load. Estuarine ecologists (Stevens 2018)[45], and experts (Science JWS) conclude that Toetoes is approaching a degraded state (but is not degraded based on trophic criteria). Accordingly, I do not agree it is appropriate to apply TN thresholds derived for estuaries with high susceptibility to nutrients, to an estuary type that is known to have at least an order of magnitude lower susceptibility to nitrogen.

9.18 These issues highlight the preliminary and untested 'nature' of the nutrient load reductions shown in Table 2. The gaps/uncertainty in the science provide ample scope for those involved in the plan change Tuatahi development process to seek quite different reduction targets". In my opinion, the numbers generated to date will not be able to be supported when robustly challenged.

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[45] Stevens, L.M. 2018. Fortrose (Toetoes) Estuary 2018: Broad Scale Habitat Mapping. Report prepared by Wriggle Coastal Management for Environment Southland. 50p.