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 PRIMARY EVIDENCE OF DR CRAIG VERDUN DEPREE FOR DAIRYNZ LTD AND FONTERRA COOPERATIVE GROUP LTD

20 DECEMBER 2021

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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 appeals lodged by Fonterra Co-operative Group Ltd (**Fonterra**) and DairyNZ Ltd (**DairyNZ**) and collectively referred to as the '**dairy interests**'.

1.2 I understand that the planning provisions relating to farming activities have been largely agreed, and that these rely on having map/s of catchments in need of improvement. My understanding is that despite significant expert conferencing, no formal maps have been produced to date.

1.3 I have prepared two maps to define catchments in need of improvement for ecosystem and human health. These are set out in Appendix 1 to my evidence.

1.4 When developing the maps, my aim has been to produce the least number of maps to facilitate the connection to needed improvements and to aid interpretation / make it easier for plan users. I have taken into consideration the concept of hauora and prioritised an attribute that directly relates to aquatic life. The assessment of ecosystem health is based on modelled macroinvertebrate community index (MCI), the most widely used holistic indicator of stream biological health.

1.5 I have also developed a map showing human health values as indicated by the NPS-FM E.coli attribute. In my view, this is an appropriate indicator for suitability of water bodies for human contact recreation.

1.6 In my opinion, the methodology and approach taken to develop the maps, has a sound scientific base and is consistent with the agreed outcomes of the JWS.

2. INTRODUCTION

2.1 My full name is Craig Verdun Depree. I have been the principal water quality scientist at DairyNZ since November 2018. Prior to this I was a senior water quality scientist at NIWA for 18 years.

2.2 My research experience includes urban contaminants from road runoff, sediment/soil biogeochemical processes, nutrient attenuation process, eutrophication of water ways (streams and estuaries), dissolved oxygen and nutrient dynamics.

2.3 I have led several major consultancy projects relating to water quality and assessments of environmental effects (**AEE**) for industrial point source discharges and urban stormwater. I have had considerable experience with the National Policy Statement for Freshwater Management (**NPS-FM**) – including involvement in the development of attribute states in regional planning processes (e.g. dissolved oxygen, suspended and deposited sediment), technical guidance for implementation (e.g. co-author of the draft technical guide to the Periphyton Attribute Note) and providing technical advice to DairyNZ (primarily in respect of the proposed national objectives framework in the NPS-FM 2020) as part of DairyNZ's feedback on the Government's Essential Freshwater reform.

2.4 I am familiar with the national body of work around relationships between water quality drivers and biological responses (i.e. periphyton and macroinvertebrates). I have a good understanding of the impacts of anthropogenic nutrients on flowing waters, and the importance of considering potentially sensitive downstream receiving environments. In this regard, I have experience in assessing the nutrient susceptibility of lakes (via Vollenweider-type equations) and common classes of NZ estuaries (via the Estuarine Trophic Index, ETI). I have good knowledge of pressure, state and trend analysis/interpretation.

2.5 I am familiar with most of the technical reports produced as part of the new proposed plan change Tuatahi. This includes providing detailed technical review of the scale of nutrient reductions potentially required.

2.6 I have previously been seconded (2015-16) to the Water Directorate (Ministry for the Environment, MfE) to provide expertise in various areas of water quality – including nutrient trends across water quality monitoring sites throughout New Zealand. I have been a member of MfE's technical expert panels for sediment and dissolved oxygen, and I am currently a member of the Rotorua Lakes Technical Advisory Group, and the Our

Land and Water Technical Advisory Group for water quality monitoring projects.

2.7 I am currently a technical expert contracted to MfE to provide input and review of technical guidance documents for regional councils on implementing sediment attributes, and setting instream criteria consistent with the requirements of clause 3.13 in the NPS-FM.

2.8 I have involved in expert conferencing and evidence preparation (and presentation) in the Waikato Regional Council's Plan Change (**PC1**) and Manawatu-Whanganui Regional Council's proposed Plan Change 2 to the One Plan.

2.9 I have a good understanding of the derivation of thresholds for many of the national attributes (including nitrate and ammonia toxicity), and also other guidance values and triggers commonly used / proposed for limit-setting – for example; ANZECC trigger values, DIN thresholds for ecosystem health, and periphyton TN and DRP criteria.

2.10 I have had the opportunity to personally visit many Southland waterways, and estuaries including the New River Estuary, Jacobs River Estuary, Waiau Estuary and Toetoes Estuary.

2.11 I am familiar with monitoring literature on Southland estuaries from my time as a NIWA scientist working on a large eutrophication project (which partnered with Environment Southland), and via a project initiated at DairyNZ to get a better understanding of drivers of poor estuarine health in Southland's tidal lagoon estuaries.

3. BACKGROUND

Code of conduct

3.1 I have read the Environment Court's Code of Conduct for expert witnesses and I agree to comply with it. My qualifications as an expert are set out above. I confirm that the issues raised in this statement of evidence are within my area of expertise.

Scope of evidence

3.2 I have been asked by ‘the dairy interests’ to prepare evidence to derive maps to identify catchments of Southland waterbodies that are in need of improvement.

3.3 I understand that the planning provisions relating to farming activities have been largely agreed, and that these rely on having map/s of catchments (or subcatchments) in need of improvement. My understanding is that despite significant expert conferencing, no formal maps have been produced to date. I have prepared two maps to define catchments in need of improvement for ecosystem and human health. These are set out in Appendix 1 to my evidence.

3.4 For the avoidance of doubt, rather than using the term ‘degraded’, consistent with the planning evidence of Mr Willis (paragraph 5.14), I refer to these sites (or more accurately, subcatchments) as ‘in need of improvement’.

Background development from water quality expert conferencing

3.5 I have not been involved with prior expert conferencing, but I have read all five water quality joint witness statement (JWSs). In particular the 14-16 October and the 20-22 November 2019 JWSs. Throughout my evidence I refer to the JWSs, and where relevant to the matters discussed, outline my opinion in relation to conclusions reached.

3.6 The October 2019 JWS provides the attributes and corresponding threshold values proposed to differentiate ‘degraded’ and ‘non-degraded’ water bodies. The experts considered two compulsory values, ecosystem health and human health (or human contact). Receiving environments included rivers, lakes and estuaries. The list of attributes and thresholds are summarised in Table 1 (Oct 2019 JWS).

3.7 Importantly, the experts adopted the concept that thresholds to define when a site is in need of improvement should be based on the “*national bottom-line”* (NBL) or *“minimum acceptable state from the NPS-FM as indicative of degraded state”*[1]. I agree. Despite adopting an approach based on NBL (or minimum state), within the same JWS (Table 1), more

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[1] Refer to paragraph 19 (p. 7) of the water quality JWS 14-16 October 2019 (originally from paragraphs 15 to 18 of the September 2019 JWS).

stringent thresholds were proposed for upland rivers, with B-band and even A-band thresholds being applied to these water bodies for some attributes. Several Table 1 footnotes highlight differing views on this decision to apply more stringent standards to upland rivers.

3.8 A total of 11 riverine attributes were defined:

a) Dissolved inorganic nitrogen (DIN)

b) Dissolved reactive phosphorus (DRP)

c) Ammoniacal-nitrogen (NH_4-N)

d) Macroinvertebrate community index (MCI)

e) Periphyton

f) Deposited fine sediment

g) Suspended sediment

h) Didymo

i) Fish index of biotic integrity (IBI)

j) E.coli (human health/contact)

k) Benthic cyanobacteria

3.9 The November 2019 JWS summarised the number of measured sites (measured data) or proportion of reaches (modelled data, where available) that were compliant / non-compliant with proposed thresholds[2].

3.10 There were three points of disagreement between the experts in relation to the methodology to define areas in need of improvement.

a) Whether it is more appropriate to classify lower reaches of main stem rivers as Lowland;

[2] Refer to tables in water quality expert conferencing JWS from 20-22 November 2019,

b) The use of national bottom-line or A-band for assessing nitrogen toxicity;

c) Disagreement as to whether a water body can be classified as in need of improvement if it fails DIN or DRP thresholds, but is compliant with aquatic life indicators (e.g. periphyton, MCI or fish IBI).

3.11 For the reasons outlined below, and based on the maps I have prepared, I do not consider it necessary to resolve the points of disagreement at this time, however these matters will likely need to be considered as part of preparing the Tuatahi Plan Change to give effect to the NPS-FM 2020.

4. THE APPROACH TAKEN TO MAP CATCHMENTS IN NEED OF IMPROVEMENT

4.1 In my opinion, the aims for developing the catchment maps should be:

a) To produce the least number of maps required to identify subcatchments in need of improvement for two of the compulsory values, ecosystem health and human contact. I believe that the use of multiple attributes (up to 11) for identifying catchments in need of improvement will be confusing and cumbersome.

b) Based on my understanding of synergies and complementarities between hauora and holistic measures of ecosystem health, prioritise science attributes that are actual measures (whether modelled or measured) of aquatic life; as opposed to indirect or proxy indicators. These are more likely, in my opinion, to be relevant within a hauora framework.

c) Generally consistent with the agreed technical work reported in water quality JWSs, including:

i. use of proposed thresholds for MCI and E.coli attributes[3], including higher thresholds for MCI applied to 'upland' river classes;

[3] Table 5 (MCI) of Nov 2019 JWS; and Table 9 (E.coli) of NPS-FM (C/D band thresholds) which is reproduced as Table 1 in this evidence.

ii. state assessments of lakes and estuaries (Nov 2019 JWS);

iii. utilise a combination of measured and modelled data;

iv. incorporate an integrated catchment approach, which incorporates ki uta kit tai by not just considering degraded sites or water bodies, but also identifies upstream catchments that do not have 'locally degraded' water quality but contribute contaminants to the degraded sites / water bodies (i.e., to manage cumulative effects of land use). Where estuarine receiving environments are identified as in need of improvement, the whole catchment must contribute to the improvement.

d) Consider the biophysical ecosystem health framework[4] that has been adopted by the NPS-FM (2020), which places greater emphasis on measures of aquatic life. And to also reflect current thinking regarding the non-inclusion of DIN as an attribute.

Selection of attributes for Ecosystem Health and Human Health values

Ecosystem health

4.2 To identify areas in need of improvement in 'ecosystem health' the single attribute I consider most relevant is macroinvertebrate community health via the commonly used macroinvertebrate community index (or MCI). The NPS-FM incorporates the ecosystem health monitoring framework[4] that comprises 5 components of ecosystem health, namely:

a) Water quality

b) Water quantity (note, my understanding is that this aspect of ecosystem health was not included in water quality expert conferencing)

c) Habitat quality

d) Aquatic life

[4] Clapcott J, Young R, Sinner J, Wilcox M, Storey R, Quinn J, Daughney C, Canning A, 2018. Freshwater biophysical ecosystem health framework. Prepared for Ministry for the Environment. Cawthra Report No. 3194. 89 p. plus appendices.

e) Ecosystem processes

4.3 In the context of the NPS-FM (2020), ‘ecosystem health’ refers to the “extent to which an FMU or part of an FMU supports an ecosystem appropriate to the type of water body”. While it may be useful to divide ‘ecosystem health’ into 5 components, **aquatic life**, in my opinion, effectively integrates (i.e. the response to) the other 4 components which can be viewed as ‘stressors’. Macroinvertebrates are reliable indicators of biological health, because they are relatively stationary and respond predictably to a variety of environmental stressors (e.g. water quantity, water quality and habitat quality). The macroinvertebrate community index (MCI) was developed for New Zealand conditions in the 1980s, and is used nationally as an index for macroinvertebrate community health in wadeable streams and rivers in New Zealand. Although I am not a stream ecologist, I believe there would be general consensus that macroinvertebrates are the most widely used indicator of stream ecosystem health. The 2020 NPS-FM included MCI as an attribute for monitoring.

4.4 The ability of macroinvertebrates to ‘integrate’ environmental stressors (i.e., water quality, quantity or habitat quality) is illustrated in Figure 1.

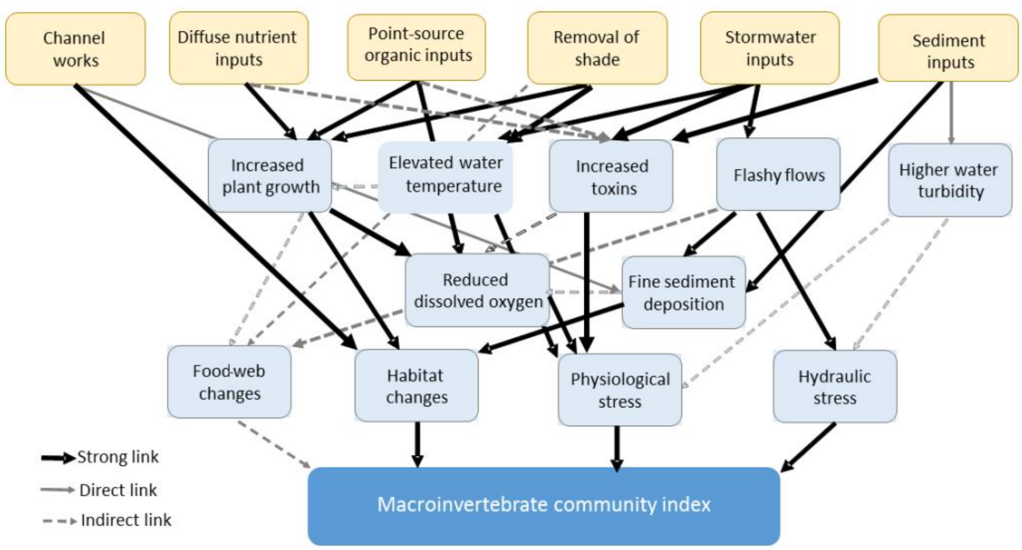

Figure 1. Pathways by which various stressors (orange boxes) influence a macroinvertebrate community index (Figure 14 taken from Clapcott et al. 2018).[4]

4.5 The ability of macroinvertebrates to integrate other ecosystem health components makes them 'holistic'[5] measures of stream ecosystem health. That is, if macroinvertebrate communities meet a target threshold, then it is reasonable to assume that other 'reductionist' measures (e.g. individual water quality indicator like nitrogen) are providing for stream ecosystem health. Ecosystem health is clearly more complex than macroinvertebrates, however, in my opinion, they are a convenient (and the best) single indicator / measure for stream ecosystem health.

4.6 My understanding[6] is that 'holistic' attributes like macroinvertebrate community health are more consistent with concepts such as ki uta ki tai and hauora.

Holistic vs reduction approach to identifying catchments in need of improvement

4.7 The approach to using a single holistic indicator is different to the reductionist approach that attempts to set thresholds for individual stressors. There is a perception that to be rigorous and technically robust we must set precise ('to the decimal place') thresholds that define, for example, how much sediment, nitrogen and phosphorus provides for (or compromises) stream ecosystem health. This approach reduces the complexity of the living world (as depicted by Figure 1) into simpler and more convenient relationships between individual stressors and ecosystem health outcomes (i.e., represented in Figure 2). I understand that this can be useful (in fact necessary) to implement highly developed regulatory systems (that is, where the ability to discharge is effectively 'allocated' to specific dischargers/land users).

[5] The term holistic is used to convey the concept that macroinvertebrate health incorporates multiple stressors as illustrated in Figure 1. This is in contrast to a 'reductionist' measure, that represents the concentration of a contaminant, that may or may not contribute significantly to aquatic life.

[6] Based on reading of water quality JWS November 2021, and the "Draft Murihiku Southland Freshwater Objectives" (Bartlett et al. 2020).

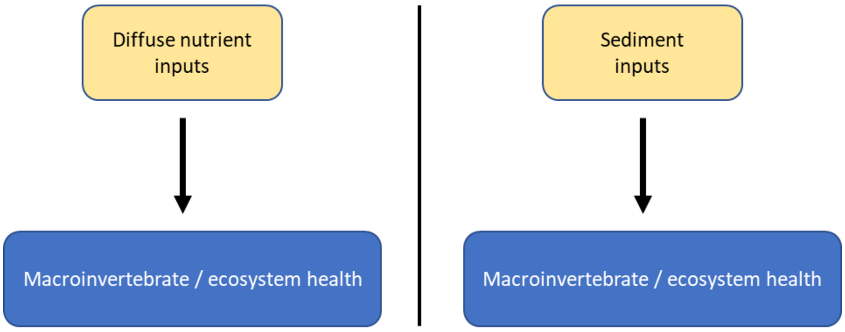

Figure 2. Example of the simplification of the complex world when defining relationships between single contaminant stressors and ecosystem health outcomes

4.8 The problem is that while convenient for setting thresholds and informing limit setting processes, often these 'relationships' are so far removed from the complex, interplay of multiple stressor (Figure 1) that the thresholds are poorly related to the holistic ecosystem health outcomes that they are trying to provide for.

4.9 An example of this is a recent study by Environment Southland[7] aiming to derive nutrient thresholds for periphyton biomass in Southland. Despite periphyton being considered a more directly related biological response to anthropogenic nutrient enrichment (compared with MCI - refer to Figure 1), Hodson and De Silva concluded that:

"Our analysis showed that relationships between Chla_92[8] and DIN or DRP were positive but weak, indicating that nutrient variables alone are poor predictors of chlorophyll a across the Southland region. This supports the consideration of the role of other environmental variables in controlling periphyton biomass in Southland rivers and streams."

4.10 This is not an uncommon finding for periphyton, and expectedly, the degree of complexity increases when trying to establish relationships between nutrients (or other contaminant stressors) and higher trophic responses like macroinvertebrates (or fish).

4.11 Despite the challenges, in June 2019 the Freshwater Science and Technical Advisory Group (or STAG) proposed DIN and DRP thresholds

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[7] De Silva N., Hodson R. (2020). Drivers of periphyton in Southland region. Environment Southland Technical Report 2020-05. 58 p. (PDF) Drivers of periphyton in Southland region (researchgate.net).
[8] Statistic related to assessment of periphyton biomass (92nd percentile).

for ecosystem health indicators (which included macroinvertebrates).[9] The water quality JWS (14-16 Oct 2019) indicates this work was the basis of proposed degradation thresholds for upland and lowland rivers.[10]. Since the initial STAG report, a subgroup of senior scientists (from NIWA, MfE, Horizons Regional Council and University of Waikato) on the STAG have stated that they do not support the introduction of DIN and DRP thresholds. They outlined a number of key reasons for their position,[11] as follows (underlining my emphasis):

"Sub-group members agree that nutrients assimilated into the food web through primary production (or microbial processes) can pass through and potentially influence higher trophic levels. These relationships are indirect, however, and are influenced by so many other factors as to potentially negate the derivation of a single, nationally applicable, set of nutrient criteria that could be used reliably and effectively in a management framework.

It is of significant concern to sub-group members, having reviewed the draft of the supplementary technical report, that the national bottom lines and thresholds proposed for DIN and DRP have been derived based on weak relationships that vary substantially from river to river. Sub-group members note that STAG has recommended spatially variable bottom lines and thresholds based on river classes for other 'stressor' attributes (suspended sediment, deposited sediment, and nutrients for periphyton control).

Sub-group members are also concerned that the proposed DIN and DRP bottom lines are 'blunt tools' that will result in a significant number of 'unders and overs' – meaning that the levels of DIN and DRP may not trigger a management response in rivers where this is necessary to protect ecosystem health and vice versa.

Similarly, although not being philosophically opposed to the concept of introducing limits on DIN & DRP, the members of the sub-group are of the opinion that the available evidence does not show a high probability that reducing DIN or DRP to the suggested levels will lead to improvement in ecosystem health.

[9] Freshwater Science and Technical Advisory Group Report to the Minister for the Environment (June 2019). freshwater-science-and-technical-advisory-group-report.pdf (environment.govt.nz)
[10] Refer to Table 1 (pg 21) Water quality JWS (14-16 October 2019) – bottom of B-band for *upland*, and bottom of C-band for *lowland* rivers.
[11] Freshwater Science and Technical Advisory Group (STAG) (2020) Supplementary report to the Minister.freshwater-science-and-technical-advisory-group-supplementary-report.pdf (environment.govt.nz)

4.12 In my opinion, that last point is the most important, that is, that available evidence does not show a high probability that reducing DIN or DRP to suggested threshold levels will lead to improvements in ecosystem health.

4.13 I believe that an approach based on a direct measure of macroinvertebrate aquatic life (a good holistic proxy for stream ecosystem health) is the most robust and meaningful way to identify and manage catchments in need of improvement.

4.14 In catchments identified as in need of improvement for ecosystem health (MCI), it is implicit that this will involve management of fine sediment and nutrients because these are known drivers/stressors of macroinvertebrates in productive catchments.[12]

4.15 A strength, I believe, of focussing on MCI to establish catchments in need of improvement is that experts (NIWA/Cawthron/Councils)[12] agree that one of the three main stressors of macroinvertebrates is loss of riparian habitat. Accordingly, this should direct actions in catchments in need of improvement that target 'habitat quality' which would (could) be overlooked, in my opinion, if focussing on individual contaminants thresholds.

Human health value[13]

4.16 Macroinvertebrates are good holistic indicators of stream ecosystem health, however, they do not provide information on the suitability of water bodies for human contact recreation. Accordingly, I have used the NPS-FM *E.coli* attribute (Table 1) to map areas in need of improvement for the reasons outlined below.

a) In my opinion, *E.coli,* is the most widely applicable attribute for assessing regional-scale suitability of water bodies for human contact.

b) Benthic cyanobacteria is not a compulsory attribute for the human health value in the NPS-FM (2020). My understanding is that benthic cyanobacteria represents a risk to dogs, as humans are unlikely to

[12] Greenwood, M., Graham, E. and Wagenhoff, A. (2021). Macroinvertebrate action plan workshop. NIWA Client Report 2021139CH prepared for DairyNZ. 62 p.
[13] NPS-FM (2020) refers to this value as *human contact*

ingest the quantities required to get ill, and that benthic cyanobacteria generally do not result in toxic water column concentrations.

c) Planktonic cyanobacteria are a NPS-FM (2020) compulsory attribute for human health, but this attribute is only applicable to lakes and lake-fed rivers. Hence this attribute is not suitable for assessing region-wide risk to human health outside the Waiau catchment (and even then, it is debateable whether this should be classified as a lake fed catchment due to the Manapouri power scheme that diverts the majority of the water from the Waiau mainstem).

Method to identify areas in need of improvement

4.17 I have prepared maps using the River Environment Classification (REC2) and have adopted modelled data for every stream / river reach taken from the publicly available model output from NZ RiverMaps website.[14] The modelled water quality data is used by MfE and StatsNZ to report on the state of national water quality and ecosystem health. Model derivation and performance are described elsewhere (Whitehead 2018[15]).

4.18 Briefly, modelled water quality data for Southland were retrieved from *NZ River Maps*[14] and linked to the REC 2.4 using the NZsegment attribute common to both datasets. Local compliance at reach level was assessed by comparing modelled medians to relevant targets and rendered in GIS software. Thresholds used for macroinvertebrate community index (MCI) were 90 and 100 for lowland and upland streams,[16] respectively. The threshold used for human health (*E.coli*) was the NOF's C-band (consistent with the Science JWS agreement), which, in-turn, is determined via four different statistics and their corresponding C-band thresholds (Table 1).[17]

[14] NZ River Maps (niwa.co.nz). Note that this dataset is the same as that provided by Ministry of the Environment dataservice (https://data.mfe.govt.nz/table/99871-river-water-quality-modelled-state-20132017/) except that it has a large suite of modelled variables, which includes the E.coli statistics required to grade the suitability of a site for primary contact recreation.
[15] Whitehead, A. 2018. Spatial Modelling of River Water-Quality State. Incorporating Monitoring Data from 201 3- 2017. NIWA Client Report, NIWA, Christchurch, New Zealand.
[16] Refer to Table 5 (para. 38) in the 20-22 Nov 2019 water quality JWS.
[17] Thresholds taken from Table 9 (Appendix 2a) of the NPS-FM (2020). Threshold correspond to the upper limit defining the C (yellow) band.

Table 1. E.coli thresholds used for identifying catchments in need of improvement for human health

***E.coli* statistic**	**C-band threshold**
median	130
% Exceedance of >540 *e.coli*/100ml	20%
% Exceedance of >260 *e.coli*/100ml	34%
95^{th} percentile	1200

Catchments in need of improvement: 'local' vs 'downstream' water quality issues

4.19 For MCI and E.*coli*, where the modelled stream reach value exceeded the threshold concentration, the reach (and contributing land area) was identified as in need of improvement. At these sites / areas, the need to improve is based on *local* water quality state.

4.20 Water quality experts in response to Question 8 (November 2021 water quality JWS) emphasised that "all resource users within catchments upstream of sites (and/or water bodies) in need of improvement should be managed to an extent that considers cumulative impacts, contaminant loss risk, and amount of contaminant loss". As I understand it, this approach incorporates aspects of ki uta ki tai, recognising the connectedness of water and land in catchments.

4.21 To identify all upstream catchment areas contributing to local degradation, the requirement to improve water quality at identified locations was extended (or 'propagated' – Figure 3) to include all upstream contributing stream reaches (and hence catchment area) by following the REC network. These areas do not have local water quality degradation, but they are identified as 'in need of improvement' because they contribute to poor water quality outcomes at a downstream site.

Figure 3. Explanation of process to identify local exceedances within the stream network (left), the area associated with local exceedance (dark red, middle), and the area upstream is contributing to the local exceedance, but not having local water quality that requires improvement (light red area, right)

4.22 Although not shown in the Appendix 1 maps of *Catchments In Need Of Improvement*, I have differentiated areas with local water quality issues and those that do not, but contribute to downstream issues. In the figure presented below, these are referred to as "in need of improvement – local" and "in need of improvement – upstream" (i.e. a propagated exceedance), and are identified using dark red and light red shading, respectively.

4.23 With respect to other aquatic receiving environments – lakes and estuaries. Based on 'state summaries' presented in the water quality JWS (Nov 2019): lakes were assumed to be of generally good quality (relative to national bottom-lines)[18]; the ICOLL[19] Waituna Lagoon is in need of improvement; and the two tidal lagoons, Jacob River Estuary (JRE, Aparima catchment) and New River Estuary (NRE, Oreti Catchment) were also identified as in need of improvement.[20]

5. MAPS IDENTIFYING CATCHMENTS IN NEED OF IMPROVEMENT FOR ECOSYSTEM HEALTH

Riverine receiving environments via MCI

5.1 Catchments identified as in need of improvement with respect to ecosystem health are shown in Figure 4. As discussed, this assessment is based on modelled macroinvertebrate community index (MCI), which is

[18] Refer to Figure 17 and Table 24 of the water quality JWS (Nov 2019).
[19] ICOLL = Intermittently closed and open lake and lagoons
[20] Refer Table 31 of the water quality JWS (Nov 2019).

the most widely used index for monitoring the health of macroinvertebrate communities in NZ streams. The MCI integrates multiple environmental stressors, including water quality (e.g., sediment, nutrients, dissolved oxygen, periphyton), and hence is a holistic indicator of stream ecosystem health.

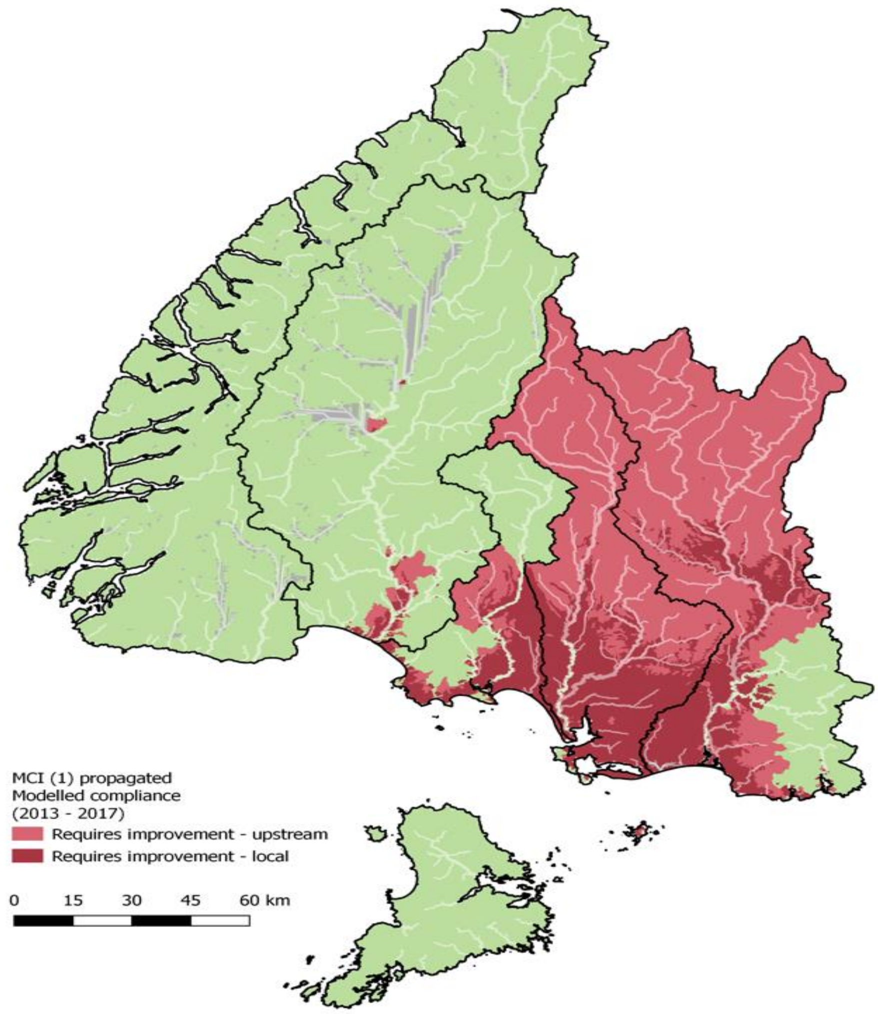


Figure 4.Catchments in need of improvement in ecosystem health outcome for freshwater. Assessment is based on modelled MCI scores, a holistic indicator of stream biological health. Red shading indicates catchments in need of improvement, either because of local exceedance of thresholds (dark red) or because area is located upstream and contributes to downstream exceedance (light red).

5.2 The national random-forest water quality models used to predict MCI (and *E.coli*) have been shown to perform well based on accepted criteria for assessing model performance (e.g. coefficient of determination and Nash-Sutcliffe efficiency values).[21]

[21] Whitehead, A. 2018. Spatial Modelling of River Water-Quality State. Incorporating Monitoring Data from 2013- 2017. NIWA Client Report, NIWA, Christchurch, New Zealand.

5.3 The catchment area identified as in need of improvement in ecosystem health for each FMU and region are summarised in Excluding Fiordland and Stewart Island, of the remaining 2.12 million ha, 16% (339,400 ha) are estimated to have water bodies that are in need of improvement, with an additional 34% (721,100 ha) contributing to those areas in need of improvement. It is important to emphasise that upstream areas do not have local water quality issues that are in need of improvement, rather they are contributing (to an unknown extent) to exceedances of thresholds in downstream water bodies.

5.4 Catchment areas in need of improvement in pastoral FMUs because of local exceedances were 1%, 28%, 36% and 19%, for Waiau, Aparima, Oretii and Matura respectively. When upstream contributing areas are included, the respective areas increased to 3%, 44%, 99% and 84% (Table 2).

Table 2. Summary of areal extent of catchments in need of improvement to achieve riverine ecosystem health (based on modelled MCI scores).

		% of land area in need of improvement in ecosystem health		
Spatial unit	**Total area (ha)**	**“local” (%)**	**“upstream” (%)**	**“total” (%)**
Fiordland	1,014,327	0.0%	0.0%	0.0%
Waiau	861,015	1%	2%	3%
Aparima	207,182	28%	16%	44%
Oreti	407,182	36%	64%	99%
Mataura	645,619	19%	64%	84%
Region	**3,135,325**	**11%**	**23%**	**34%**
Region (excl Fiordland/islands)	**2,120,999**	**16%**	**34%**	**50%**

5.5 The incorporation of a large amount of upstream contributing catchment area, which themselves do not have locally ‘degraded’ water quality, emphasises the precautionary approach taken in mapping areas using modelled MCI to identify catchments in need of improvement, and by extension up the catchment, those areas that are contributing to water quality issues downstream.

Comparison of MCI assessment with key individual stressors

5.6 Table 3 compares the area of total riverine catchments identified as in need of improvement using assessments of MCI, DRP and DIN. The areal extent of subcatchments 'in need of improvement' using modelled MCI is comparable to that assessed using modelled DIN and greater than that from modelled DRP.

Table 3. Comparison of the proportion (%) of catchments identified as in need of improvement based on modelled values of MCI and individual modelled stressors (DRP and DIN).

Spatial unit	MCI	DRP	DIN
Fiordland	0	1	0
Waiau	3	12	2
Aparima	44	51	62
Oreti	99	56	82
Mataura	84	52	88
Region	**34**	**25**	**34**
Region (excl. Fiordland/islands)	**50**	**36**	**50**

5.7 Excluding Fiordland and Stewart Island, of the remaining 2.12 million ha, 16% (339,400 ha) are estimated to have water bodies that are in need of improvement, with an additional 34% (721,100 ha) contributing to those areas in need of improvement. It is important to emphasise that upstream areas do not have local water quality issues that are in need of improvement, rather they are contributing (to an unknown extent) to exceedances of thresholds in downstream water bodies.

5.8 Catchment areas in need of improvement in pastoral FMUs because of local exceedances were 1%, 28%, 36% and 19%, for Waiau, Aparima, Oretii and Matura respectively. When upstream contributing areas are included, the respective areas increased to 3%, 44%, 99% and 84% (Table 4).

Table 4. Summary of areal extent of catchments in need of improvement to achieve riverine ecosystem health (based on modelled MCI scores).

		% of land area in need of improvement in ecosystem health		
Spatial unit	**Total area (ha)**	**“local” (%)**	**“upstream” (%)**	**“total” (%)**
Fiordland	1,014,327	0.0%	0.0%	0.0%
Waiau	861,015	1%	2%	3%
Aparima	207,182	28%	16%	44%
Oreti	407,182	36%	64%	99%
Mataura	645,619	19%	64%	84%
Region	**3,135,325**	**11%**	**23%**	**34%**
Region (excl Fiordland/islands)	**2,120,999**	**16%**	**34%**	**50%**

5.9 The incorporation of a large amount of upstream contributing catchment area, which themselves do not have locally ‘degraded’ water quality, emphasises the precautionary approach taken in mapping areas using modelled MCI to identify catchments in need of improvement, and by extension up the catchment, those areas that are contributing to water quality issues downstream.

Estuarine receiving environments

5.10 Estuaries identified as in need of improvement in ecosystem health are the tidal lagoons Jacobs River Estuary and New River Estuary, and the ICOLL, Waituna Lagoon. Estuaries being terminal receiving environments mean that reductions in contaminant load / concentrations required to improve ecosystem health outcomes are borne by the entire catchment. These areas / catchments (i.e., Aparima, Oreti and Waituna) are shown in Figure 5.

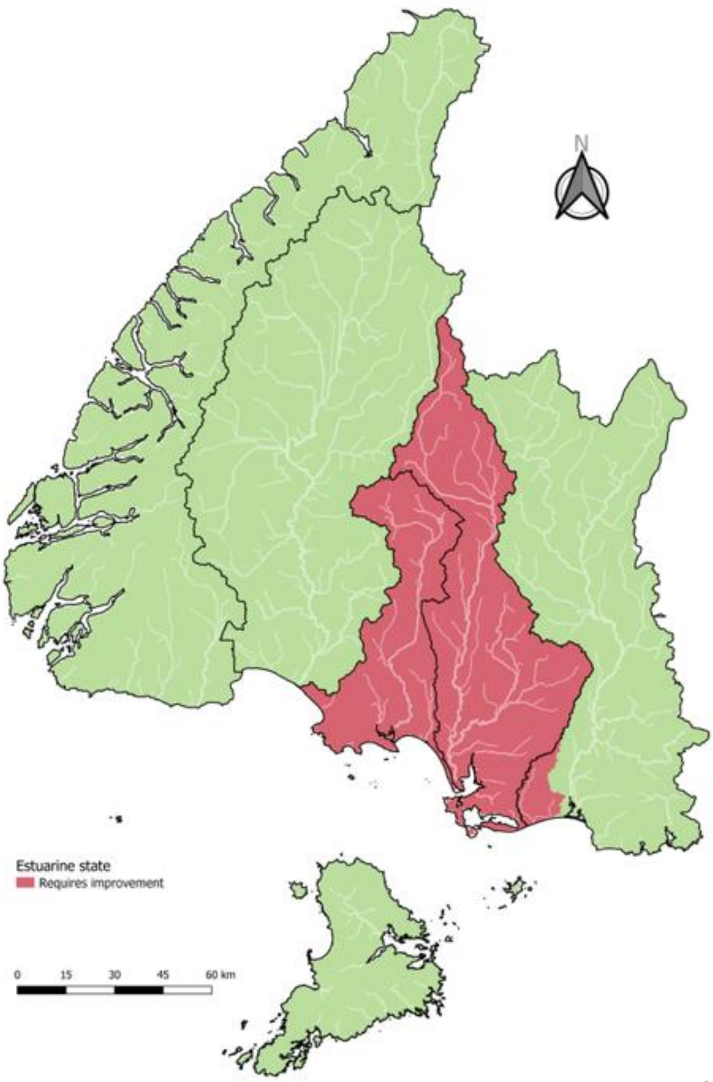


Figure 5. Catchments 'in need of improvement' to provide for ecosystem health outcomes for estuaries

Combined riverine and estuarine receiving environments

5.11 Combining the macroinvertebrate riverine and estuarine areas identified as in need of improvement results in a total area of around 1.18 million ha, which is shown in Figure 6 (reproduced as Map 1 in Appendix 1). This represents 38% of the southland region, and 56% if Fiordland and offshore islands are excluded (Table 5). This is comparable to (or even greater than) the spatial extent of areas requiring improving if assessed by DIN criteria.

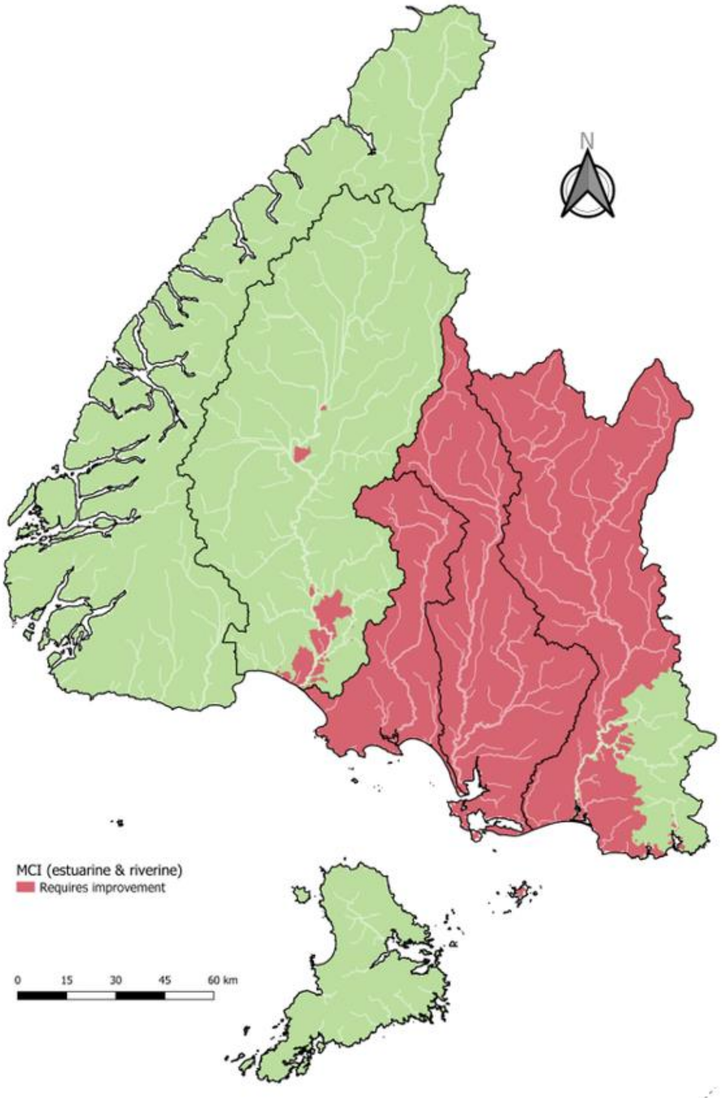


Figure 6. Combined catchment in need of improvement for ecosystem health that considers riverine and estuarine receiving environments.

Table 5. Summary of areal extent of catchments in need of improvement to achieve ecosystem health in riverine and estuarine receiving environments

Spatial unit	Total area (ha)	Total[a] area in need of improvement (ha)	% of total
Fiordland	1,014,327	501	0%
Waiau	861,014	23,860	3%
Aparima	207,182	207,182	100%
Oreti	407,183	407,183	100%
Mataura	645,621	539,780	84%
Region	**3,135,327**	**1,178,506**	**38%**
Region (excl Fiordland/islands)	**2,121,000**	**1,178,005**	**56%**

[a] *includes riverine 'local', riverine 'upstream' and estuaries*

Human health

5.12 The spatial extent of the Southland region in need of improvement for human health (based on modelled *E.coli* data) is shown in Figure 7, with summary statistics provided in Table 6. An estimated 996,000 ha (32%) of catchment area in need of improvement based on local modelled water quality (dark red shading in Figure 7). Although probably overly precautionary, extending (i.e., propagating) these exceedances to upstream contributing catchments, increases the total area in need of improvement (human health) to an estimated 1.6 million ha (50% of the region).

5.13 Excluding Fiordland and off-shore islands (largely in conservation estate) the number of catchments in need of improvement for 'local' exceedance is 47%, with this increasing to 74% when extended to including contributing upstream catchment areas. The Waiau is the only modified FMU that is not dominated (i.e., 36%) by subcatchments in need of improvement for human health. The Aparima, Oreti and Mataura FMUs have 100% of their area identified as in need of improvement for human health.

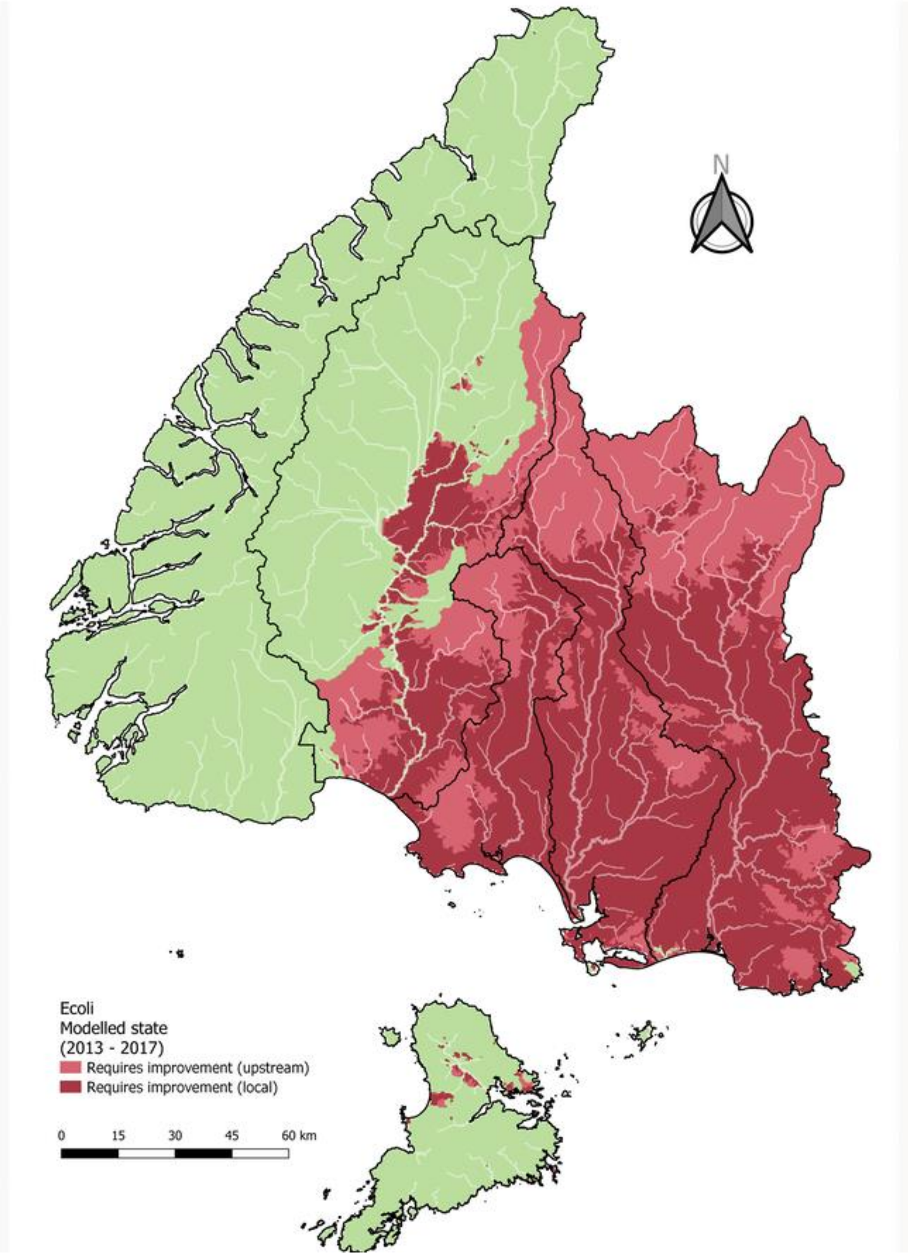
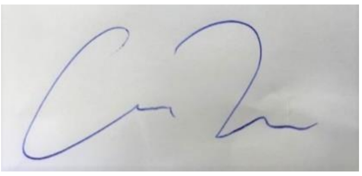


Figure 7. Catchments in need of improvement for human health based on modelled E.coli concentrations. Red shading indicates catchments in need of improvement, either because of local exceedance of thresholds (dark red) or because area is located upstream and contributes to downstream exceedance (light red).

Table 6. Summary of areal extent of catchments in need of improvement for human health. Includes catchment that exceed thresholds ("local") and those that are "upstream" of local exceedances.

		In need of improvement for Human Health		
Spatial unit	**Total area (ha)**	**"local" (%)**	**"upstream" (%)**	**"total" (%)**
Fiordland	1,014,322	0.4%	0.2%	0.6%
Waiau	861,015	18%	18%	36%
Aparima	207,182	68%	32%	100%
Oreti	407,183	71%	29%	100%
Mataura	645,620	62%	37%	100%
Region	3,135,321	**32%**	**18%**	**50%**
Region (excl. Fiordland/islands)	2,121,000	**47%**	**27%**	**74%**

5.14 The E.*coli* assessment likely significantly over-estimates the areas in need of improvement because it is well known that microbes will die-off as they travel downstream.[22] For example, Muirhead and Doole, estimated that in a stream with a flow of 250 l/s, that a 50% die-off of E.*coli* could occur over a 5 km distance. Given the non-conservative nature of E.*coli* (and my understanding is that pathogens generally die-off quicker than E.*coli* in the environment), it is most likely overly precautious to assume by default that upstream areas are contributing significantly to non-compliant downstream sites.



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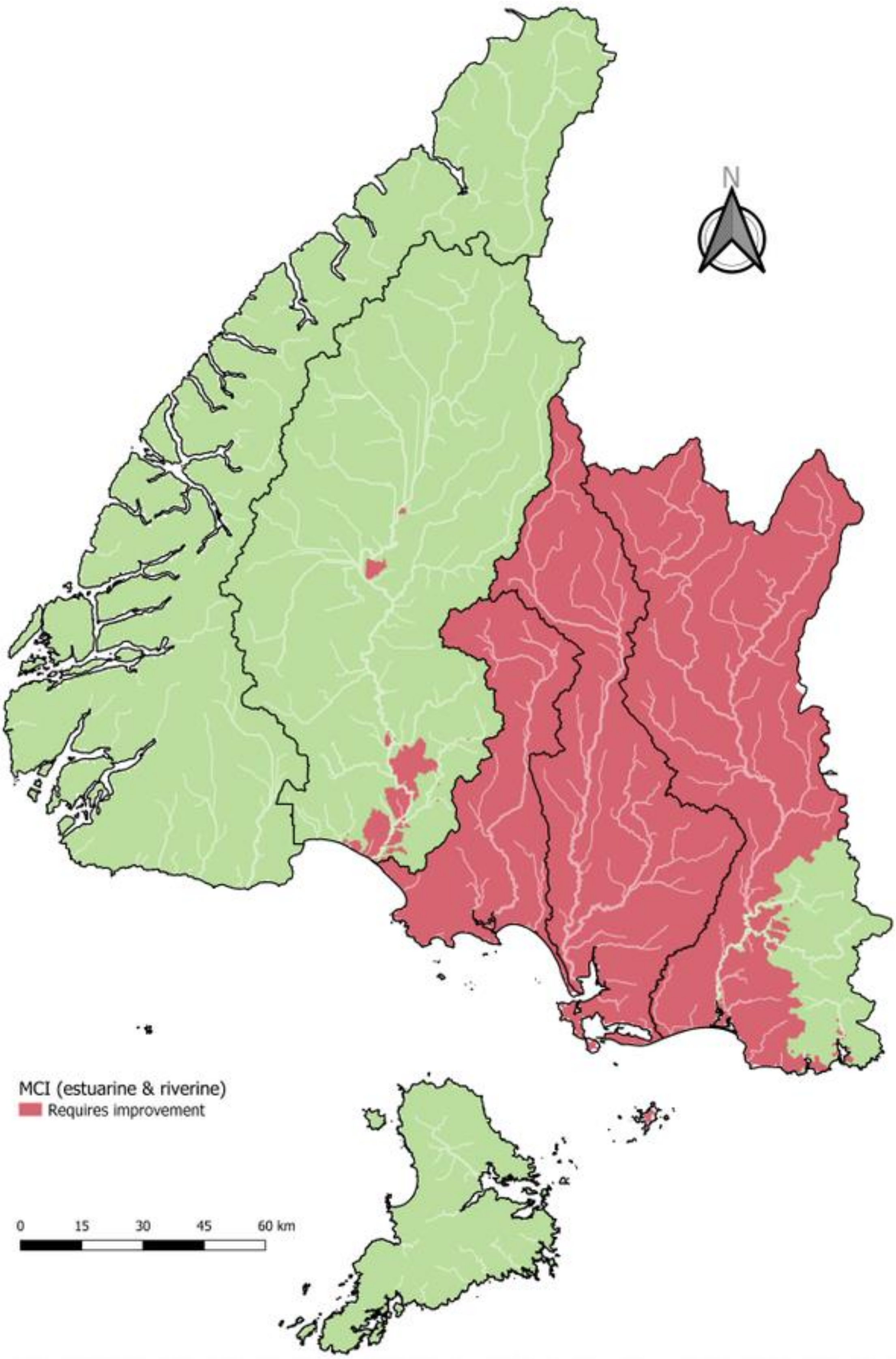
20 December 2021

[22] Muirhead R. and Doole G. (2017). A Farm-scale E. coli model for Gisborne District Council. AgResearch Report RE450/2017/025 prepared for Gisborne District Council (35 p.).

6. APPENDIX 1 – MAPS OF CATCHMENTS IN NEED OF IMPROVEMENT FOR ECOSYSTEM HEALTH (MAPS 1) AND HUMAN HEALTH (MAP 2)

Map 1: Catchment area in need of improvement for ecosystem health – combined riverine and estuarine receiving environments



Map 2: Catchment area in need of improvement for human health / contact