Court File Reference: ENV-2018-CHC-38

BEFORE THE ENVIRONMENT COURT

I MUA I TE KOOTI TAIAO O AOTEAROA

UNDER	The Resource Management Act 1991 (RMA)
IN THE MATTER	Appeals under clause 14(1) of the First Schedule of the Act in relation to the Proposed Southland Water and Land Plan
BETWEEN	**MERIDIAN ENERGY LIMITED** **Appellants**
AND	**SOUTHLAND REGIONAL COUNCIL** **Respondent**

STATEMENT OF EVIDENCE OF KRISTY LYNN HOGSDEN

FOR

MERIDIAN ENERGY LIMITED

29 July 2022

Topic B6 – Infrastructure

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(ENV-2018-CHC-34 AND 35)

DIRECTOR-GENERAL OF CONSERVATION
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SOUTHWOOD EXPORT LTD, SOUTHLAND PLANTATION FOREST COMPANY OF NZ
(ENV-2018-CHC-46)

TE RUNANGA O NGAI TAHU, HOKONUI RUNAKA, WAIHOPAI RUNAKA, TE RUNANGA O AWARUA AND TE RUNANGA O ORAKA APARIMA
(ENV-2018-CHC-47)

PETER CHARTRES
(ENV-2018-CHC-48)

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

ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NZ INC
(ENV-2018-CHC-50)

Appellants

AND **SOUTHLAND REGIONAL COUNCIL**

Respondent

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QUALIFICATIONS AND EXPERIENCE

1 My name is Kristy Lynn Hogsden.

2 I hold the qualifications of BSc Honours from Trent University (Canada), MSc in Ecology and Environmental Biology from the University of Alberta (Canada), and PhD in Ecology from the University of Canterbury (New Zealand). I am a member of the New Zealand Freshwater Sciences Society.

3 I am a periphyton ecologist and group manager (Freshwater Ecology) at NIWA Taihoro Nukurangi, where I have worked since 2019. Prior to this, I worked in freshwater ecology as a research associate and postdoctoral fellow at the University of Canterbury (2013 to 2018) and as an Environmental Scientist at Fundy Engineering and Consulting (2007 to 2008). In total, I have over 10 years' experience as a freshwater ecologist.

4 My work involves assessing environmental impacts on water quality and aquatic communities (periphyton, macroinvertebrates and fish) in streams and lakes. I have worked across a range of environmental issues related to freshwater ecosystems, including mining, acidification and agriculture. I have authored 17 peer-reviewed scientific papers and numerous technical reports on river and lake water quality and ecology, including five in the Waiau Catchment in Southland.

5 In preparing this evidence I have read the evidence prepared on behalf of Meridian for this hearing by Dr Jennifer Purdie; Dr Jack McConchie, David

Hunt, Jane Whyte and Andrew Feierabend. I have also considered Mr Feierabend's earlier statement of evidence dated 15 February 2019.

6 I have also reviewed the following documents:

(a) Draft Joint Witness Statement (JWS) of the Expert Conference - Water Quality and Ecology (Rivers and Wetlands) for Topic: Proposed Southland Water and Land Plan - Southland Regional Council dated 13 May 2019;

(b) Joint Witness Statements (JWS) of the Expert Conference - Water Quality and Ecology (Rivers and Lakes) dated 4 September 2019, and the Expert Conference - Water Quality and Ecology (Rivers, Estuaries and Lakes) dated 16 October 2019.

CODE OF CONDUCT

7 I confirm that I have read the code of conduct for expert witnesses as contained in the Environment Court's Practice Note 2014[1]. I have complied with the practice note when preparing my written statement of evidence and will do so when I give oral evidence before the Environment Court.

8 The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence to follow. The reasons for the opinions expressed are also set out in the evidence to follow.

9 Unless I state otherwise, this evidence is within my knowledge and sphere of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

SCOPE OF THIS EVIDENCE

10 My evidence addresses the following matters:

(a) The current state of water quality and ecology in water bodies in the Waiau catchment, with a focus on water bodies affected by the operation of the Manapōuri Power Scheme (MPS).

(b) Trends in water quality and ecology at sites with sufficient information. My discussion of trends will include an evaluation of the degree of changes in water quality and ecology within the lower Waiau River

[1] https://environmentcourt.govt.nz/assets/Documents/Publications/Practice-Note-2014.pdf

during the operation of the MPS and identification of likely causes of changes, in particular changes that represent deteriorating conditions.

(c) Meridian's proposed exception from compliance with Appendix E standards for ancillary activities associated with the MPS.

EXECUTIVE SUMMARY

11 In the Waiau catchment, current water quality is generally better in the mainstem of the Waiau River, than in some lowland tributaries where water quality is poor. NO_3-N increases downstream from the upper catchment, with elevated concentrations in some lowland tributaries. Microbial contamination occurs throughout the catchment, with the highest concentration of *E. coli* in a lowland tributary. Water clarity decreases downstream with the lowest clarity (high suspended sediments) in lowland tributaries. Water quality in Lakes Manapōuri and Te Anau is currently very good.

12 Nuisance periphyton blooms occur at sites throughout the catchment. Macroinvertebrate community health (represented by the Macroinvertebrate Community Index, MCI) was generally moderate to poor at most sites relative to national standards. Deposited fine sediment was high at one mainstem site.

13 Over the past 10 years, there appears to have been an overall trend of increasing NO_3-N at sites downstream in the catchment but not at upstream sites. *E. coli* concentrations have changed little over this time period, except for deterioration in the Waiau at Sunnyside. Water clarity has also changed little over the past 10 years, except for deterioration in the upper catchment in the Mararoa at the Key and in the Whitestone River.

14 Since 2000, there has been an overall improving trend in water clarity at three sites along the mainstem of the Lower Waiau River, including the most downstream site at Tuatapere.

15 There were deteriorating trends in two indicators of river health, MCI and SQMCI, throughout the catchment from 2003 to 2018.

16 Agricultural land use activities that contribute contaminants (nutrients, sediment and microorganisms) from land to surface and ground water, nuisance periphyton and the invasion and spread of didymo are factors

driving deteriorating trends in water quality and macroinvertebrate community health in the Waiau catchment over the past 10 and 20 years.

17 The exception Meridian seeks regarding compliance with Appendix E standards in relation to ancillary activities associated with the MPS in my opinion is reasonable, given that water quality and ecological effects from these activities will be addressed through the resource consent process.

OVERVIEW OF WATER QUALITY AND ECOLOGY VARIABLES AND DATA

18 Water quality refers to a set of physical, chemical and biological properties of the water. Levels (or concentrations) of variables representing those properties are used to describe water quality at any particular location or time. The variables considered in my evidence are those for which attribute states have been set out in the National Policy Statement for Freshwater Management (NPS-FM) or for which recommended interim thresholds have been set out to identify degraded rivers in the JWS dated 16 October 2019.

19 The river water quality variables considered are nutrients (dissolved inorganic nitrogen (DIN), nitrate-nitrogen (NO_3-N), dissolved reactive phosphorus (DRP), total ammoniacal nitrogen (NH_4-N)), *Escherichia coli* (*E. coli*), and suspended fine sediments (visual clarity). The lake water quality variables considered are total nitrogen (TN), total phosphorus (TP) and phytoplankton (chlorophyll *a*). These three lake water quality variables are used to determine trophic state.

20 While all the nutrient attributes the NPS-FM provide for ecosystem health, those for ammonia (as NH_4-N) and NO_3-N refer to the toxic effects of high concentrations of these two forms of soluble nitrogen. However, soluble N is also an essential nutrient for plant growth. The JWS thresholds for DIN are therefore set at lower concentrations and define degraded rivers in terms of trophic state.

21 I interpret ecology as a part of ecosystem health, which includes water quality, water quantity, habitat quality, aquatic life and ecosystem processes, as outlined in the NPS-FM. The variables representing ecology are periphyton, macroinvertebrates and deposited fine sediment.

22 Periphyton comprises primarily algae that grows on the riverbed and is a natural part of freshwater ecosystems. Excessive periphyton can smother

substrates, adversely affect water quality (e.g., by increasing daily fluctuations in dissolved oxygen), and reduce or change habitat for macroinvertebrates. Certain types of periphyton are also linked to human health values (e.g., toxic cyanobacteria).

23 Periphyton is usually measured as chlorophyll *a*. Periphyton is also measured as weighted composite cover (WCC), which combines estimates of percentage cover of algal filaments and algal mats on the riverbed. WCC can be used to estimate levels of nuisance algae and provisional guidelines (thresholds) for WCC have been developed to indicate ecological condition[2].

24 Didymo (*Didymosphenia geminata)* is a non-indigenous, bloom-forming diatom which was first found in the Waiau River in 2004[3]. Didymo has been a prominent part of the periphyton in both the Upper and Lower Waiau Rivers since 2004[4][5]. Didymo blooms tend to occur in low nutrient waters (which is atypical of most periphyton) and can tolerate a wide range of flow conditions. Didymo caused notable changes to the periphyton in Waiau catchment, forming thick mats on the substrate and increasing biomass to unprecedented levels. Didymo mats impact the benthic ecology of rivers, by altering habitat conditions, water quality and macroinvertebrate communities[6]. As Mr Feierabend describes in his evidence, Meridian works with local stakeholders to monitor and manage didymo with supplementary (flushing) flows in the Lower Waiau River.

25 Macroinvertebrates are aquatic invertebrates living in a river or other water body that are retained by a 500 µm sieve and include insect larvae, snails, worms and crustaceans. Macroinvertebrates are widely used as indicators

[2] Matheson, F., Quinn, J. Hickey, C. (2012). Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision-making framework: Phases 1 and 2 final report. NIWA Client Report HAM2012-081. Prepared for the Ministry of Science & Innovation Envirolink Fund.

[3] Kilroy, C., Unwin, M. (2011). The arrival and spread of the bloom-forming, freshwater diatom, *Didymosphenia geminata*, in New Zealand. Aquatic Invasions 6:249-262.

[4] Kilroy et al. 2012. Manapouri Power Scheme resource consent monitoring programme: periphyton and macrophytes in the Upper Waiau River, 2012. NIWA Client Report CH2012-039. Prepared for Meridian Energy Ltd.

[5] Kilroy, C. 2021. Managing nuisance periphyton in the Lower Waiau River Monitoring and management 2020-21. NIWA Client Report 2021257CH. Prepared for Meridian Energy Ltd.

[6] Kilroy, C., Larned, S.T., Biggs, B.J.F. (2009) The non-indigenous diatom *Didymosphenia geminata* alters benthic communities in New Zealand rivers. Freshwater Biology 54: 1990–2002.

of river health because many taxa have known sensitivity or tolerance to water quality or habitat conditions.

26 The NPS-FM sets numeric attribute states for the Macroinvertebrate Community Index, its quantitative variant (QMCI) and for Average Score Per Metric (ASPM). The MCI and QMCI metrics are based on the tolerance of different macroinvertebrate taxa to organic enrichment, with the former based on taxa presence and the latter on taxa abundance. The ASPM has broader application and refers to ecological integrity. The SQMCI is a semi-quantitative variant of the MCI and is calculated using abundance categories. SQMCI reflects changes in community dominance, in a similar way as QMCI, but reduces sample processing effort and associated costs while improving monitoring programmes with the inclusion of semi-quantitative information. In my assessment, I have used MCI for current state and MCI and SQMCI for trend analysis, based on available data.

27 Deposited fine sediment represents a physical habitat component of ecosystem health. High or increased levels of deposited fine sediment can smother streambeds, fill interstitial spaces between substrate and reduce habitat availability. Deposited fine sediment is measured as percent cover.

28 Data on the variables mentioned above are collected by Environment Southland as part of their State of the Environment (SOE) monitoring programme. The SOE programme includes data collection at river and lake sites in the Waiau catchment. Since 2018, additional data has been collected at six river sites on the mainstem of the Lower Waiau River, funded by Meridian. Data are also collected by NIWA at one National River Water Quality Network (NRWQN) site in the catchment. I used these three sources of data to make the assessments that follow. Site locations and details of data used in my assessment are shown in the map and table in Appendix 1 of this evidence.

CURRENT STATE OF WATER QUALITY AND ECOLOGY

Approach

29 In my assessment, current state refers to the most recent three to five years up to November 2021. Water quality and ecology data were compared with relevant states set out in the NPS-FM and interim numeric thresholds in the JWS for sites listed in Table A1-1 in Appendix 1 of this evidence. Sites were assigned to attribute bands as set out in Appendix 2A and 2B of the

NPS-FM. The bands, which are designated A to D (or A to E, for the *E. coli* attribute) represent a range of support for environmental values from high (A band) to low (D or E band). The threshold between band C and D (or band B and C in some cases[7]) is referred to as the National bottom line. In the NPS-FM an attribute that is below a national bottom line is generally considered to be in an unacceptable condition[8]. Attribute state bands (from the NPS-FM) and recommended numeric thresholds (from the JWS) are shown in Tables 2-1 and 2-2 of Appendix 2 of this evidence.

30 Deposited fine sediment cover was estimated during visual assessments at periphyton sites from 2014 to 2021. NPS-FM band assignments are provisional only because fewer than the required 60 observations were available.

31 DIN is a combination of nitrite (NO_2-N), NO_3-N, and NH_4-N. In the assessment of DIN concentrations, I used data on NO_2-N + NO_3-N concentrations to represent DIN because NO_3-N is the major form of dissolved nitrogen in the Waiau catchment. Concentrations of NH_4-N were below analytical detection limits for a high percentage of samples (i.e., 63 to 100%).

32 For assessment of DIN, DRP and periphyton attributes against the numeric thresholds defined in the JWS, I followed the classification of rivers into upland and lowland classes (provided in Figure 1 in the JWS). I have assumed that all sites are classified as upland, except for three (Home Creek, Orauea River, and Lill Burn) that are lowland. For the macroinvertebrate attribute in the JWS (MCI only), I followed the Appendix E categories for upland (hill) and lowland (lake fed, spring fed, lowland) provided in Table 1 of the JWS dated 16 October 2019.

33 It is noted that a water body exceeding any one of the criteria in the Draft JWS was considered degraded.

34 The three-year period of 2018 to 2021 was used, unless a minimum of five years data was required for assessment, in which case the period was 2016 to 2020. Annual values (median and maximum) were calculated for most recent 12 months of data available.

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[7] NH4-N (toxicity) and NO3-N (toxicity)

[8] With exceptions made for large hydroelectric generation schemes, specified vegetable growing areas and naturally occurring processes (clauses 3.31 – 3.33; NPS-FM 2020).

35 MCI scores were used for assessment of macroinvertebrate attributes in the NPS-FM and JWS. Macroinvertebrate data from ES was provided as MCI and SQMCI scores and therefore not suitable for calculation or assessment of QMCI or ASPM metrics in the NPS-FM.

36 I have mapped the current state of selected water quality and ecology variables to show spatial patterns in numerical concentrations, MCI scores, and NPS-FM bands across sites in the catchment. Maps are shown for the most recent three-year period (2018 to 2021) to include six monitoring sites added in 2018 and for the five-year period (2016 to 2020) for evaluation of the NPS-FM attributes that require longer assessment periods (*E. coli*, suspended fine sediment).

Water Quality – Rivers

Ammonia (Toxicity)

37 All 17 sites were placed in NPS-FM band A for the ammonia toxicity attribute[9] and were below (better than) the threshold for the JWS ammonia toxicity attribute.

NO_3-N

38 Median NO_3-N was highest in a lowland tributary (Orauea River), with concentrations also moderately high in a cluster of sites in the upper mainstem of the Waiau River (Waiau Arm) and on three upstream tributaries (Whitestone, Home Creek, Mararoa at Weir Rd). Median NO3-N was lowest in the most upstream sites (Mararoa River at South Mavora Lake, Upper Waiau at Queens Reach) and in a lowland tributary (Lill Burn), with more moderate concentrations at sites on the mainstem of the Waiau from Sunnyside to Clifden Bridge. Three-year median NO_3-N concentrations in sites across the catchment are shown in Figure 1.

39 Median NO_3-N increases downstream at sites along the Mararoa River from South Mavora Lake to Weir Rd.

40 All 17 sites were placed in NPS-FM band A for the NO_3-N toxicity attribute[10].

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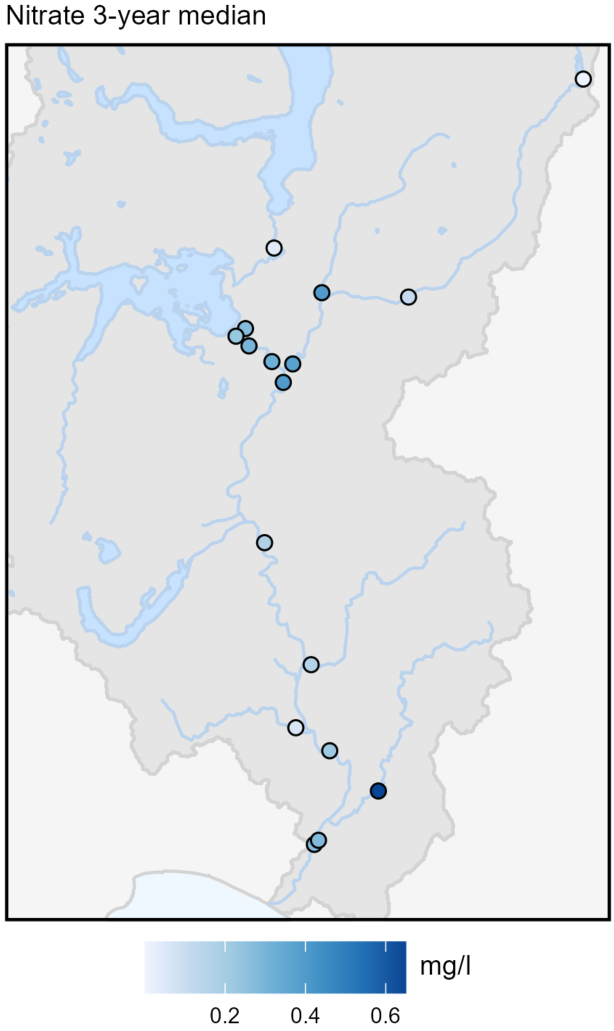
[9] The grading of the Upukerora River site is provisional as only 7 months of were data available.
[10] The grading of the Upukerora River site is provisional as only 7 months of were data available.

41 Eleven sites with sufficient data for assessment against the JWS DIN attribute were below (better than) the thresholds (nine upland and two lowland sites).

Figure 1 – Median NO_3-N concentrations at sites from 2018 to 2021



DRP

42 DRP was very low to low at most sites across the catchment, with a high percentage of samples below analytical detection (49 to 100% across sites over the 5-year period). The exception was at sites in two tributaries (Home Creek at Manapouri and Orauea River at Orawia Pukemaori Rd) where 3-year median concentrations were relatively high (~ 0.01 mg/L).

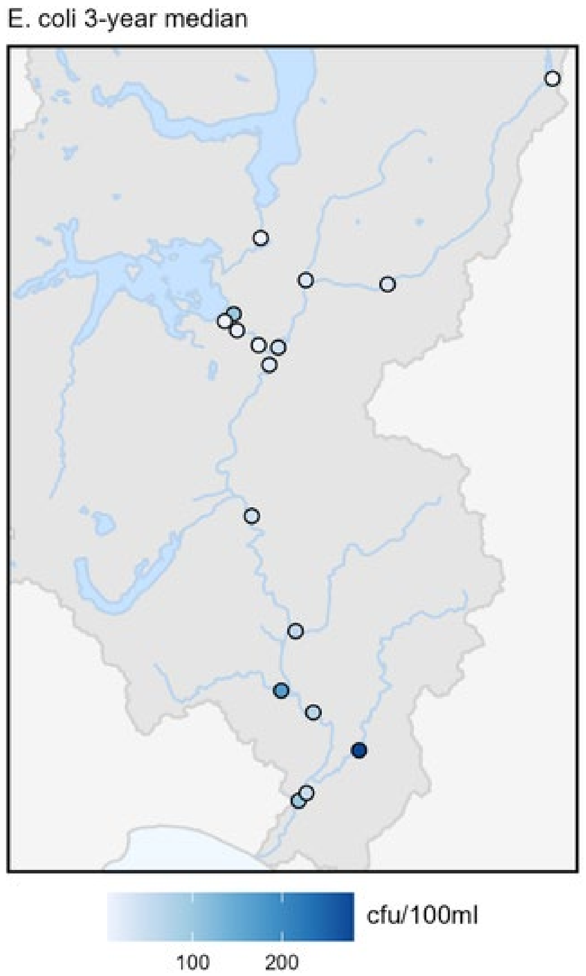
43 Ten of eleven sites were placed in band A of the NPS-FM attribute for DRP and one site was placed in band B (Orauea River at Orawia Pukemaori Rd). All sites assessed were below (better than) the JWS threshold for degradation.

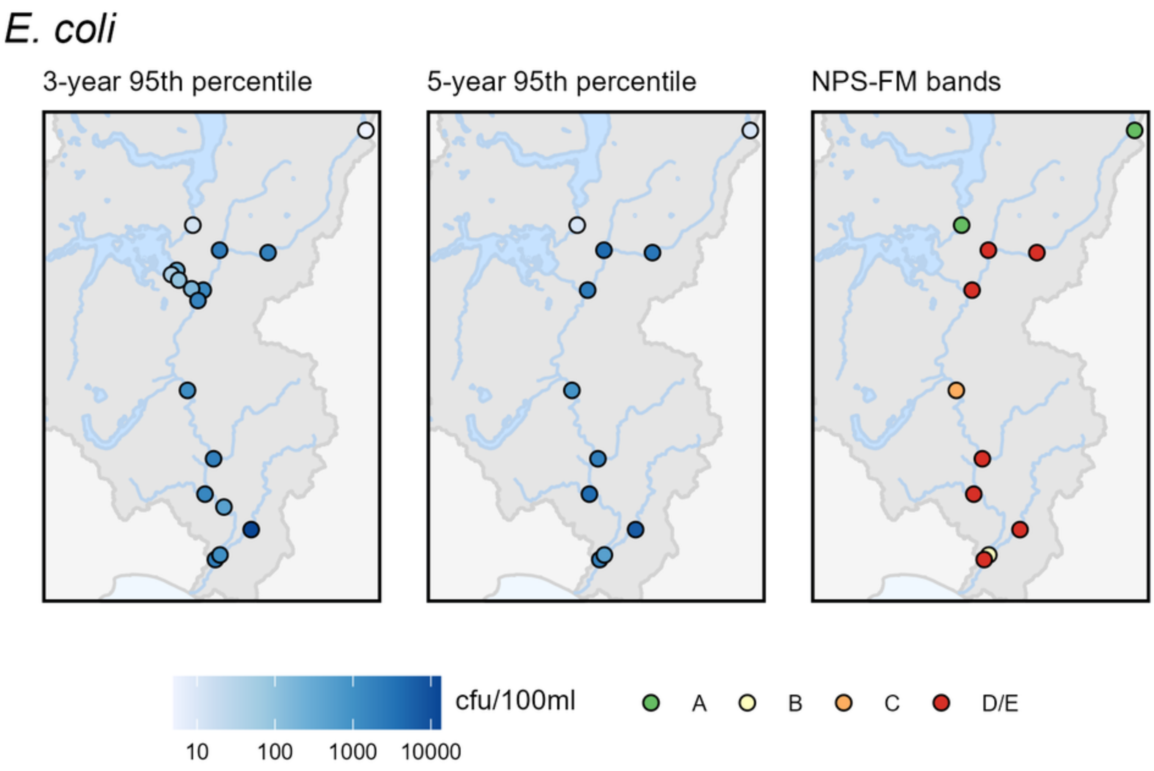
E. coli

44 Median *E. coli* concentrations were generally low (<130 CFU/100 ml) at all sites except in two lowland tributaries (Lill Burn, Orauea River) which were higher (170 and 250 CFU/100 ml, respectively), as shown in Figure 2.

45 Assessment against the NPS-FM *E. coli* attribute requires that all four numeric states be met for a particular band. Owing to high 95th percentile values of *E. coli*, seven of the ten sites assessed were placed in band D/E for the NPS-FM *E. coli* attribute, with one site in band C (Waiau River at Sunnyside) and one site in band B (Waiau River at Tuatapere - NRWQN) based on exceedances > 540 CFU/ 100 ml, and two sites in band A (Upper Waiau River at Queens Reach, Mararoa at South Mavora Lake), as shown in Figure 2.

Figure 2 – Median E. coli concentrations from 2018 to 2021 (top) and 95th percentile of E. coli concentrations for the 3- and 5-year periods, including NPS-FM bands for the 5-year period (bottom)



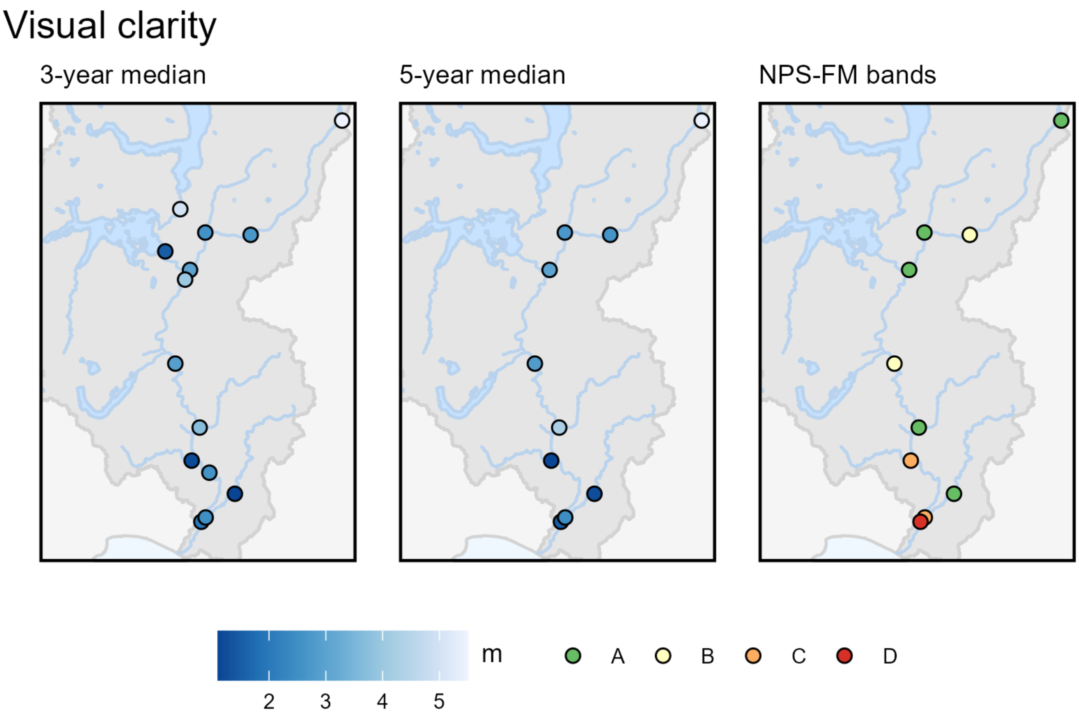


Suspended Fine Sediment (Visual Clarity)

46 Median water clarity was highest in two tributary sites in the upper catchment (Upper Waiau at Queens Reach and Mararoa River at South Mavora Lake) and lowest in two lowland tributaries (Lill Burn and Orauea River) and at Home Creek at Manapōuri (Figure 3). The Waiau River downstream of the Manapōuri Lake Control structure (MLC) receives inputs of clear water from western tributaries (e.g., Monowai) which improves water clarity in the mainstem until the most downstream site at Tuatapere, where clarity is low and reflects turbid inputs from lowland tributaries.

47 Six of the eleven sites assessed for the NPS-FM suspended fine sediment (visual clarity) attribute were placed in band A, two sites in band B, two sites in band C, and one site (Waiau River at Tuatapere - ES) in band D (i.e., below the National bottom line) as shown in Figure 3.

Figure 3 – Median visual clarity (m) for the most recent 3- and 5-year periods and NPS-FM bands for the 5-year period



Water Quality – Lakes

48 Low nutrient concentrations (TN, TP) and phytoplankton biomass (chlorophyll *a*) were recorded at all sites in Lake Manapōuri and Lake Te Anau from 2018 to 2021. Both lakes were classified as microtrophic based on median Trophic Lake Index (TLI) scores, which indicates very good water quality.

49 Lake Manapōuri and Lake Te Anau were both placed in band A for the NPS-FM phytoplankton, TN and TP attributes, indicating healthy ecological communities similar to reference conditions.

Ecology – Periphyton, Macroinvertebrates and Deposited Fine Sediment

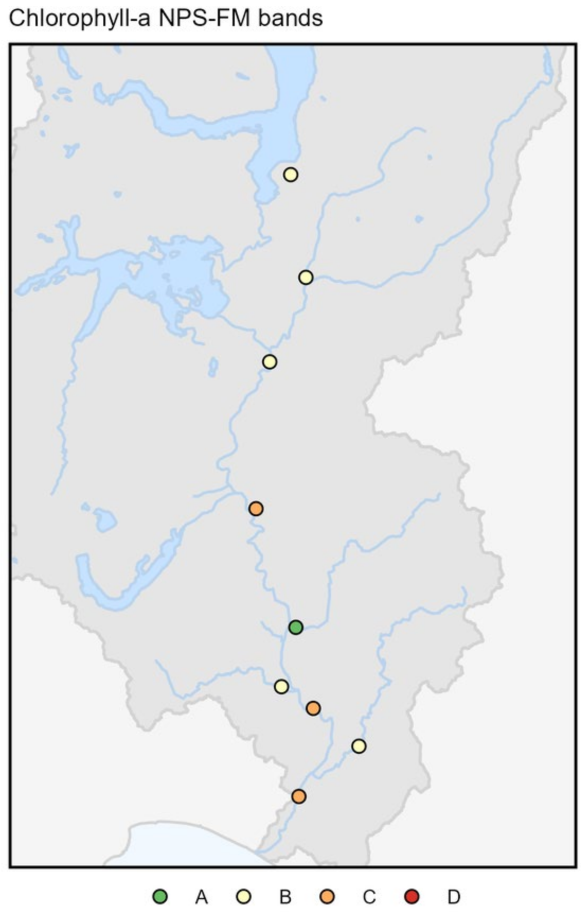
Periphyton

50 Of the nine sites assessed for the NPS-FM periphyton attribute, all were within the bands A to C, indicating rare to periodic short-term nuisance blooms. Eight sites in the default[11] class were placed in band A (one), B (four) and C (three) and one site in the productive class was placed in band

[11] The NPS-FM periphyton attribute allows for sites where biomass is expected to be naturally high because of climate and geological characteristics. Such sites are classed as "productive" and use a different metric for assessing sites. All other sites are in the default class. See Table 2-1 in Appendix 2.

B (Orauea River), as shown in Figure 4. I note all sites had missing data mostly due to sampling events missed because of high flow conditions[12].

Figure 4 – NPS-FM bands for the periphyton attribute assessed from 2018 to 2021



51 Individual exceedances of the NPS-FM national bottom line value (200 mg/m^2) for periphyton attribute at one mainstem site (Waiau River at Sunnyside) and one tributary site (Lill Burn at Lill Burn Monowai Rd) indicated the potential for high periphyton at these sites. However, I note that assessment of the NPS-FM periphyton attribute requires a minimum of three years of monthly data and these exceedances are indicative only.

52 For the seven upland sites assessed, three exceeded (worse than) the JWS threshold for chlorophyll *a* (Lower Waiau River from Sunnyside to Tuatapere) and all seven exceeded (worse than) the JWS threshold for WCC. For the two lowland sites assessed, both were below (better than) the JWS threshold for chlorophyll *a*, but exceeded (worse than) the JWS threshold for WCC.

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[12] DeSilva, N., Hodson, R. (2021) Drivers of Periphyton in Southland. Environment Southland Technical Report. Publication No 2020-05.

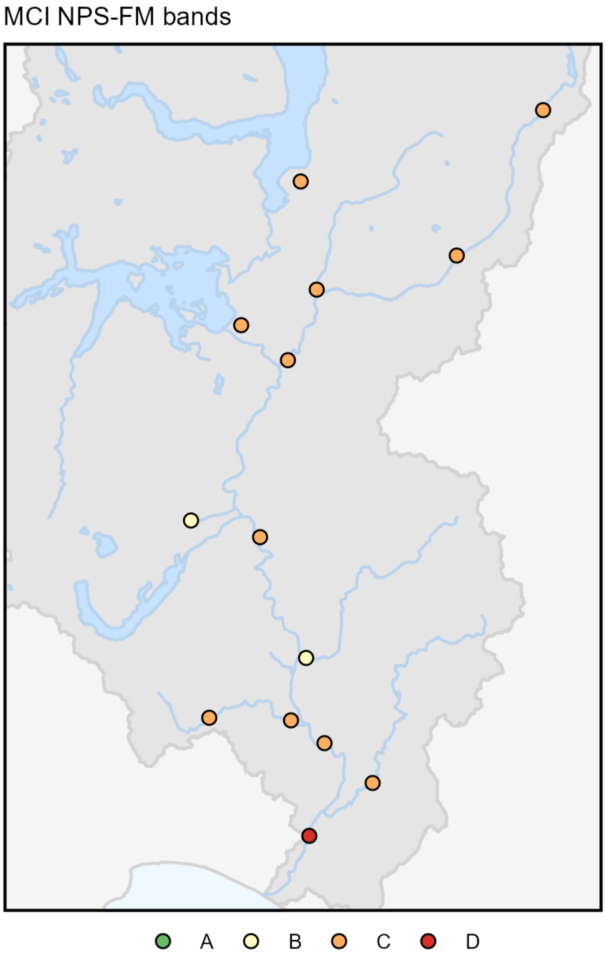
53 Didymo was present in all sites monitored for periphyton, except the Orauea River. High didymo cover[13] (> 60%) was not frequently observed (i.e., in 2% of records) during 2018 to 2021.

Macroinvertebrates

54 Of the fourteen sites assessed for the NPS-FM MCI attribute, two were placed in band B (Pig Creek, Wairaki River), eleven were placed in band C and one was placed in band D (i.e., below the national bottom line; Waiau at Tuatapere) as shown in Figure 5. Median MCI equalled the bottom line at Waiau River 100 m u/s Clifden Bridge and approached the bottom line on one tributary (Orauea River).

55 All sites were above (better than) the JWS macroinvertebrate attribute (MCI) thresholds for upland and lowland sites, respectively.

Figure 5 – NPS-FM bands for the MCI attribute assessed from 2016 to 2020



[13] Biggs, BJF, 2000: New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams. Ministry for the Environment, Wellington.

Deposited Fine Sediment

56 Eight of the periphyton sites were provisionally placed into NPS-FM band A for deposited fine sediment cover. Exceptions were Waiau River 100 m u/s Clifden Bridge (band B) and Waiau River u/s Excelsior Creek (band D i.e., below the National bottom line). The band assignments are provisional because fewer than the required 60 observations were available (N = 24 – 49).

Summary – Current State

57 NO_3-N increases downstream from sites in the upper catchment, with elevated concentrations in some lowland tributaries. All sites met ammonia (toxicity), NO_3-N (toxicity) and DIN standards. Microbial contamination occurs throughout the catchment, with the highest concentration of *E. coli* in the Orauea River. Due to high 95% percentile concentrations, most sites were placed in band D/E for the NPS-FM *E. coli* attribute. Water clarity tends to decrease downstream with the lowest clarity (high suspended sediments) in lowland tributaries. Water quality in Lakes Manapōuri and Te Anau is currently very good.

58 Periphyton blooms occurred at sites throughout the catchment, with cover by nuisance algae (filaments and mats) indicative of fair to poor ecological condition at all sites. All sites were above (better than) the national bottom line for periphyton. Didymo was present at all sites (except Orauea River) although high cover was not frequently recorded in the last three years of monitoring.

59 Macroinvertebrate community health (as MCI) was moderate to poor at most sites relative to national standards, with the exception of two tributary sites (Pig Creek, Wairaki River) where MCI was good. The national bottom line was not met at one mainstem site (Waiau River at Tuatapere) and was equalled at one site (Waiau River 100 m u/s Clifden Bridge).

60 Deposited fine sediment cover was low at most sites, suggesting minimal impacts to instream biota. The exception was high cover at one mainstem site on the Lower Waiau River (u/s Excelsior Creek) which was provisionally placed below the national bottom line and may indicate potential issues with high deposited fine sediment for biota at this site.

TRENDS IN WATER QUALITY AND ECOLOGY

Approach Overview

61 In my evidence, I focus on 10-year water quality trends in rivers for the most recent period (years) at sites with suitable time series data. I provide 21-year trends for water quality at three river sites with a longer record. Trends for macroinvertebrates (as MCI and SQMCI) are provided for an 18-year period (2003 to 2020).

62 River flow can influence some water quality variables. Therefore, water quality data were flow-adjusted prior to trend analyses, where possible and appropriate, to take fluctuating river flows into account. When flows have a strong effect on water quality, use of flow-adjusted water quality data indicates whether there are underlying trends that are independent of flows[14].

63 Trends are reported on flow-adjusted data, where flow data were available and if flow was strongly correlated with the variable being considered (i.e., the correlation coefficient R was greater than 0.7). Where flow data were not available, unadjusted trends are shown.

64 Trends in periphyton and deposited fine sediment cover were not assessed due to insufficient data (short time series).

65 All trend analyses were carried out following recommendations in recent guidance (Snelder et al. 2021). Trends are reported using narratives describing the level of confidence shown in the table below. Trends were interpreted as "improving" or "deteriorating" because improving implies a decreasing trend for most water quality variables but is an increasing trend for water clarity, and vice versa for deteriorating.

Narrative	**Confidence**
Highly likely	0.95 - 1.0
Very likely	0.9 - 0.95
Likely	0.67 - 0.9
As likely as not	0.5 - 0.67

[14] Snelder, T., Fraser, C., Larned, S., Whitehead, A. (2021) Guidance for the analysis of temporal trends in environmental data. NIWA Client Report 2021017WN. Prepared for Horizons Regional Council and MBIE Envirolink.

66 For lakes, data on the three key variables (chlorophyll a, TN and TP) have been collected in surface waters at the three sites in Lake Manapōuri and two sites in Lake Te Anau since at least 2002, often monthly up to about 2007. However, long periods when all results returned were below detection, and varying levels of detection, has meant that robust trend analyses were not possible.

Trends in Water Quality

NO_3-N

67 Over the 10 years since 2011, NO_3-N has shown a very likely improving trend in the Mararoa River at South Mavora Lake, a highly likely improving trend in the Whitestone River, trends of indeterminate direction at a site farther downstream in the Mararoa River (at the Key) and in the Lill Burn, and deteriorating trends at all other sites. The spatial pattern of these trends is shown in Figure 6.

68 All three sites with 21 years of data – Mararoa at Weir Road, Waiau River at Sunnyside and Waiau River at Tuatapere (the most downstream site) – showed highly likely trends of deteriorating (i.e., increasing) NO_3-N concentrations since 2000.

*E. co*li

69 Since 2011, *E. coli* concentrations have deteriorated (i.e., increased) at five of the eight sites with data. There were indeterminate trends (i.e., as likely as not increasing or decreasing) in the Lill Burn and Orauea River, and a likely improving trend in the Mararoa River at Weir Road (using flow-adjusted data). These trends are shown in Figure 6. The deteriorating trend with highest certainty was in the Waiau River at Sunnyside.

70 Two sites had 21 years of *E. coli* data. *E. coli* concentrations have improved since 2000 in Mararoa River at Weir Road and have deteriorated since 2000 in the Waiau River at Sunnyside.

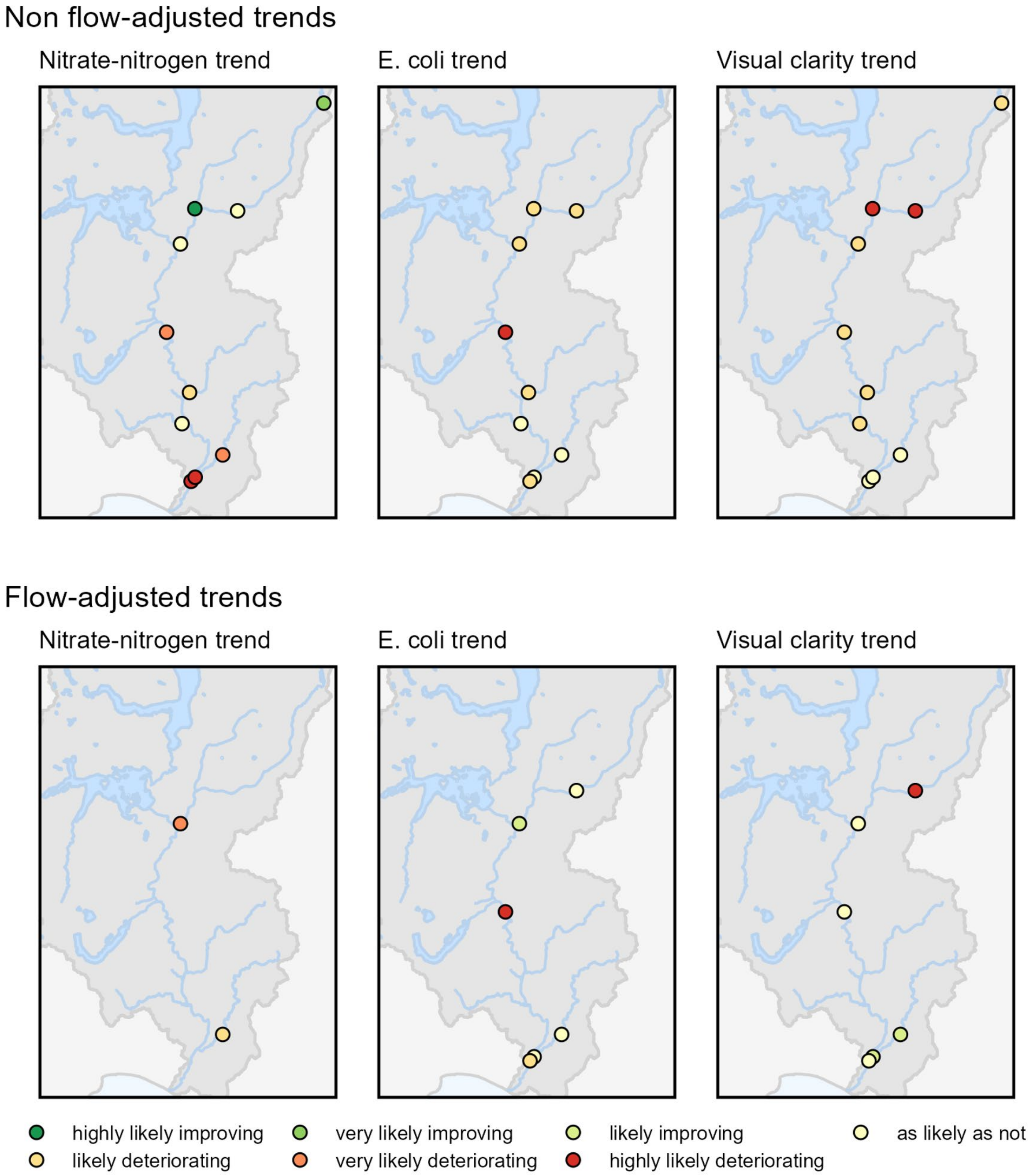
Visual Clarity

71 Since 2011, trends determined without taking flow into account suggested that visual clarity has deteriorated (i.e., decreased) at seven of the nine sites with data, with highly likely deteriorating trends in the Whitestone River and the Mararoa River at the Key (Figure 6). The trend was indeterminate at the two remaining sites (Oruaea and Waiau at Tuatapere).

72 Water clarity typically declines following heavy rainfall and, as expected, was strongly negatively correlated with flow at five sites for which flow data were available (R ~ -0.7). At four of these sites, using flow-adjusted data changed the deteriorating trend to indeterminate or improving. At the fifth site with flow data (Mararoa River at the Key), flow-adjustment of water clarity data reduced the certainty of the deteriorating trend there. Therefore, it is assumed that worsening water clarity since 2011 at the sites with no flow data (such as the Whitestone River) was at least partly related to flow conditions.

73 Water clarity data at all three sites with 21 years of data indicated a very likely improving trend since 2000, especially using flow-adjusted data.

Figure 6 – Non-flow adjusted (top three panels) and flow adjusted (bottom three panels) trends in nitrate, E. coli, and visual clarity from 2011 to 2021



Summary of Trends in Water Quality

74 In summary, there appears to have been an overall trend of increasing NO_3-N at sites downstream in the catchment (with varying degrees of certainty), but not at upstream sites. *E. coli* concentrations have changed little over the past 10 years except for deterioration in the Waiau at Sunnyside. Water clarity has also changed little over the past 10 years,

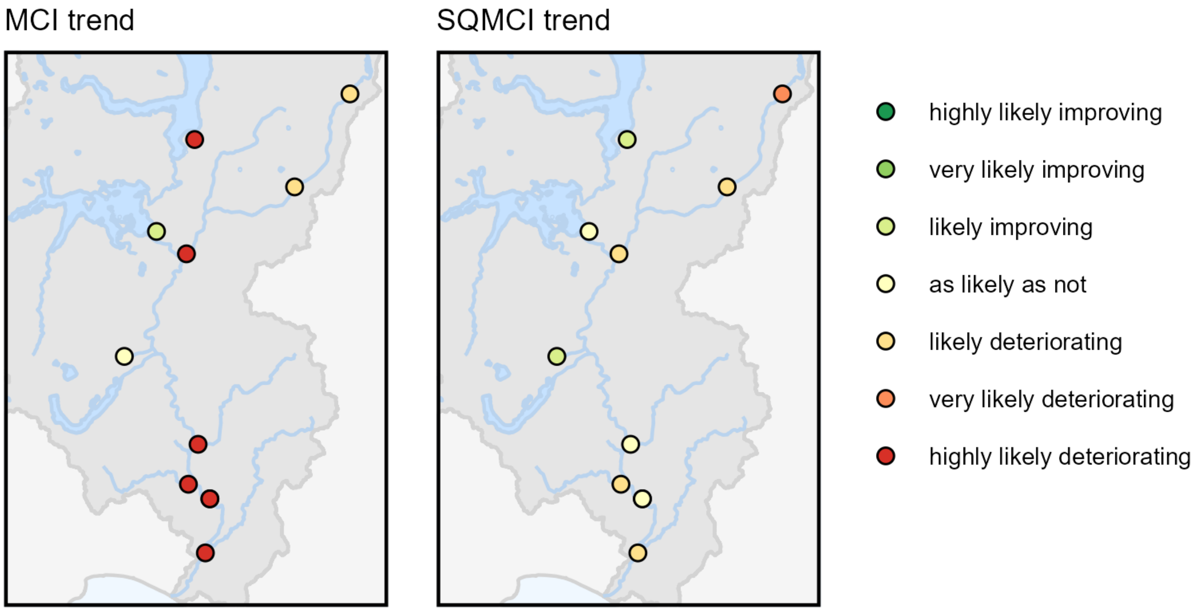
except for some deterioration in the Mararoa River at the Key and in the Whitestone River which appears to be independent of flow conditions. There may have been an improving overall trend over the longer term in the main stem of the Lower Waiau River based on data from three sites since 2000, including the most downstream site (Waiau at Tuatapere).

Macroinvertebrates

75 For MCI, there was a highly likely deteriorating trend at six sites, a likely deteriorating trend at two sites, a likely improving trend at one site and an as likely as not trend at one site from 2003 to 2018. The deteriorating trends in MCI occurred throughout the catchment, as shown in Figure 7.

76 For SQMCI, there was a very likely deteriorating trend at one site, likely deteriorating trends at four sites, a likely improving trend at two sites, and an as likely as not trend at three sites from 2003 to 2018. Again, deteriorating trends occurred through the catchment, as shown in Figure 7.

Figure 7 – Trends in MCI and SQMCI from 2003 to 2018



Trends in Water Quality in Lake Te Anau and Lake Manapōuri

77 Data on chlorophyll a, TN and TP from two sites in Lake Te Anau and three sites in Lake Manapōuri were inadequate for robust trend analysis for the reasons outlined in paragraph 66 above. However visual assessments of simple plots of the available data over time do not suggest any consistent increases over time.

Summary of Deteriorating Trends

78 In the analysis above I identified the following key deteriorating trends in water quality and ecology (macroinvertebrates) which I will discuss further below in paragraphs 79 to 87:

(a) Increasing NO_3-N at sites from the lower Mararoa River, throughout the Lower Waiau River, and in two tributaries of the Lower Waiau River (the Wairaki River and the Orauea River). I note the increase in NO_3-N has been occurring since at least 2000.

(b) Increasing *E. coli* concentrations in the Waiau River at Sunnyside.

(c) Deteriorating water clarity in the Mararoa River at the Key and in Whitestone River.

(d) Deteriorating MCI at sites throughout the catchment (from the Upukerora River and Mararoa River at Kiwiburn to the Lill Burn and Lower Waiau at Tuatapere), with highest certainty in the trend in the Waiau River upstream of Clifden Bridge.

(e) Deteriorating SQMCI at several sites from the Mararoa River at Kiwiburn to the Lower Waiau River at Tuatapere.

FACTORS DRIVING TRENDS IN WATER QUALITY AND ECOLOGY

79 Nutrients, fine sediment, microorganisms, and nuisance periphyton (primarily didymo) are recognised as the main contaminants or stressors affecting water quality and ecology in the Waiau catchment.

80 The deteriorating trend in NO_3-N, which extends from the Lower Mararoa River throughout the Lower Waiau River and including two lowland tributaries, primarily reflects land use in the catchment, particularly agricultural intensification and associated activities that contribute nutrients (and sediment) to waterways through overland runoff, effluent discharges, fertilisers, and soil loss. Home Creek is a known source of nutrient inputs to the Upper Waiau River, where it enters the river just downstream of Lake Manapōuri. In the Orauea sub-catchment, 66% of the land is classified by high intensity nitrogen (N) loss land use types, which contribute to high N loads in the in the lowland river[15].

[15] Lowe Environmental Impact (2021). Waiau River Catchment – Land Use Assessment. Prepared for Meridian Energy Limited.

81 The downstream effect of NO_3-N inputs throughout the catchment, is captured in the deteriorating water quality trend at the most downstream site on the Waiau at Tuatapere.

82 The deteriorating trend in *E. coli* in the Waiau River at Sunnyside is most likely due to contamination from grazing livestock along the river. Land use in the sub-catchment around Sunnyside is primarily conservation land, with 5% used for agriculture. Faecal contaminants can enter rivers directly where stock have access, as effluent discharge or as runoff from adjacent land/overland flow following rainfall. Sheep and cattle (ruminant animals) have been identified as the dominant source of faecal contamination in the Waiau at Sunnyside following rainfall[16]. The type and density of livestock or effluent management upstream of Sunnyside may be contributing to the deteriorating trend over time.

83 Declining water clarity in the lower Mararoa (at the Key) and Whitestone is likely related to land use and land cover changes in the upper catchment associated with increased erosion and runoff.

84 A wide range of factors directly affect macroinvertebrate communities, including substrate, flow regime, deposited fine sediment, dissolved oxygen, periphyton biomass, and food availability. Habitat quality has been identified as a key factor explaining MCI scores in rivers across Southland[17].

85 Nuisance periphyton (filaments and mats), particularly didymo have a strong effect on macroinvertebrate habitat. Didymo mats cover benthic substrate and modify local hydraulics and water chemistry. Within areas affected by didymo mats, habitat availability and flow conditions are reduced, and fluctuations in dissolved oxygen levels can increase, all of which can adversely affect macroinvertebrate communities[18].

86 Didymo changes the composition of the macroinvertebrate community, to one dominated by chironomids, snails, cladocerans and worms (tolerant taxa) rather than one comprised primarily of sensitive mayflies, stoneflies

[16] Moriarty et al. (2019) Sources of pollution in the Waiau Freshwater Management Unit. ESR Client report CSC 19006. Prepared for Environment Southland.
[17] DeSilva, N., Hodson, R. (2021) Freshwater macroinvertebrates in the Southland Region: updating state and trend; predicting reference condition; and investigating drivers of macroinvertebrate community health. Environment Southland Technical Report Publication No 2021-05.
[18] Larned, S.T., Kilroy, C. (2014). Effects of *Didymosphenia geminata* removal on river macroinvertebrate communities. Journal of Freshwater Ecology 29: 345–362.

and caddisflies[19]. The declining trends in SQMCI scores throughout the catchment likely partially reflect the change in community dominance to low-scoring taxa as a result of didymo effects on habitat.

87 The MPS diverts a substantial proportion of natural outflows from Lake Manapōuri to Doubtful Sound for hydroelectric power generation. However, despite changes in operations through four key phases (pre-minimum flow, post minimum flow but pre-second tailrace; pre-MTAD and post-MTAD), the long-term mean flow in the Lower Waiau River has remained relatively constant[20]. As noted in paragraphs 91 and 92 of Mr McConchie's evidence, since 1996 and the implementation of the minimum flow regime there has been little change in the various hydrometric indices, except that caused by natural climatic variability. Differences in the flow regime in the Lower Waiau River reflect short-term spills, releases and flushes from the operation of the MPS. Therefore, it is unlikely that the MPS flow regime is contributing to deteriorating 10- and 21-year water quality trends described above.

PROPOSED EXCEPTION TO APPENDIX E STANDARDS

88 I understand that at times there are activities that Meridian must undertake to maintain or improve infrastructure and instream works to manage flows to ensure the continued operation of the MPS. Examples of these works include maintenance of the MLC, construction of new jetty structures, or channel excavation in the Waiau Arm to improve flushing flows, as described in Mr Feierabend's evidence in paragraphs 31 and 37.

89 I consider that many of these activities will have short-term effects on downstream water quality and ecology (e.g., increased turbidity, habitat disturbance) that will cause exceedances of Appendix E standards as currently provided in the proposed Southland Water and Land Plan (pSWLP), noting that the extent and magnitude of effects will depend on the activity, its location and duration. I also note the standards in Appendix E apply to discharges following reasonable mixing with the receiving waters unless otherwise stated. I understand a number of the ancillary activities take place in lake environments where a reasonable mixing zone is not defined in the pSWLP as it is for rivers. Mixing zones for lakes can be considered based on distance or area from the discharge point and should

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[19] Kilroy et al. (2009), Larned et al. (2014) as above

[20] Statement of Evidence of Andrew Bazel Conrad Feierabend on behalf Meridian Energy dated 15 February 2019.

take into account current speed and direction, mixing rates and the nature of the contaminant.

90 I expect that such activities will be managed on a case-by-case basis so that any adverse effects on ecosystem health are mitigated and temporary in nature, such that ecological communities can recover if impacted. In this regard, I consider the exception proposed by Meridian to Appendix E standards for such activities to be managed through the consenting process appropriate.

CONCLUSIONS

91 In conclusion, the current state of water quality in the Waiau catchment is generally better in the mainstem of the Waiau River with poorer water quality in some lowland tributaries. The pattern down the catchment generally reflects the influence of the tributaries on the mainstem, with either improving or degrading conditions depending on the water quality variable, (e.g., clear water from the Monowai increases water clarity vs high nutrient water from the Oraeau which increases NO_3-N concentrations). Water quality in Lakes Manapōuri and Te Anau is currently very good.

92 Nuisance periphyton blooms occur at sites throughout the catchment. Macroinvertebrate community health (as MCI) was generally moderate to poor at most sites relative to national standards.

93 Deteriorating trends in water quality and river health, as indicated by macroinvertebrate community indices, in the Waiau catchment over the past 10 and 20 years have been driven by agricultural land use activities that contribute contaminants (nutrients, sediment and microorganisms) to rivers and the presence of nuisance periphyton, including didymo, throughout the catchment.

94 The exception Meridian seeks regarding compliance with Appendix E standards in relation to ancillary activities associated with the MPS in my opinion is reasonable, given that water quality and ecological effects from these activities will be addressed through the resource consent process.

Kristy Hogsden
Periphyton Ecologist
29 July 2022

Appendix 1

Site Locations and Data Collected

Figure A1-1. *Map showing the approximate locations of water quality (WQ), periphyton (Peri) and macroinvertebrate (MCI) sampling sites in the Waiau catchment. Data was collected by Environment Southland (circles) and at a National River Water Quality Monitoring Network (NRWQN) site (square). Data at Meridian-funded sites (triangles) were collected by Environment Southland. Site numbers and letters refer to site names listed in Table A1-1.*

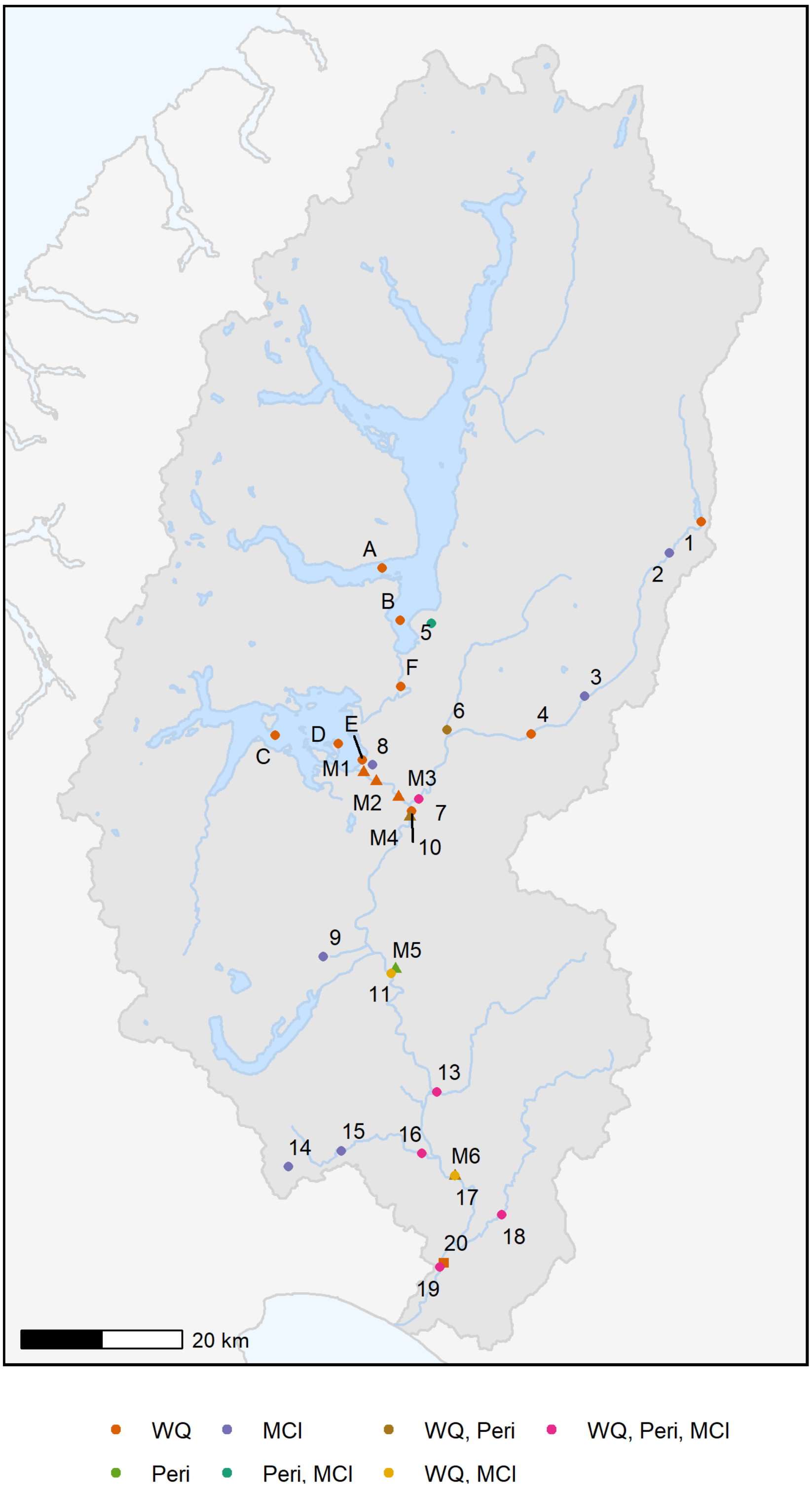

Table A1-1: *List of sites included in this assessment for which water quality (WQ), periphyton (Peri) and / or macroinvertebrate (MCI) data were collected by ES, Meridian or NIWA at the NRWQN site. Site number refers to numbers on Figure A1-1. M denotes site with Meridian-funded monitoring of WQ and/or Peri that began in July 2018. Waterbody class was assigned by ES. River sites are classified as a tributary or mainstem on the Lower Waiau River.*

Site number	Waterbody class	Site name	Location	Data collected
1	Lake fed	Mararoa River at South Mavora Lake	Tributary	WQ
2	Lake fed	Mararoa River at Kiwiburn	Tributary	MCI
3	Hill	Mararoa River at Mararoa Rd Bridge	Tributary	MCI
4	Hill	Mararoa River at The Key	Tributary	WQ
5	Hill	Upukerora River at Te Anau Milford Road	Tributary	Peri, MCI
F	Lake fed	Upper Waiau River at Queens Reach	Tributary	WQ
6	Hill	Whitestone River d/s Manapouri-Hillside	Tributary	WQ, Peri
7	Hill	Mararoa River at Weir Road	Tributary	WQ, Peri, MCI
M1	Lake fed	Waiau River d/s Pearl Harbour	Mainstem	WQ
M2	Lake fed	Waiau River 2.8 km d/s Pearl Harbour	Mainstem	WQ
M3	Lake fed	Waiau River 2.3 km u/s Mararoa Weir	Mainstem	WQ
M4	Lake fed	Waiau River u/s Excelsior Creek	Mainstem	WQ, Peri
8	Spring fed	Home Creek 100 m u/s Waiau River/ at Manapouri	Tributary	WQ/ MCI
9	Natural state	Pig Creek at Borland Lodge	Tributary	MCI
10	Lake fed	Waiau River at Duncraigen Road	Mainstem	WQ
11/M5	Lake fed	Waiau River at Sunnyside	Mainstem	WQ, Peri, MCI
13	Hill	Wairaki River d/s Blackmount Road	Mainstem	WQ, Peri, MCI
14	Natural state	Thicket Burn at Lake Hauroko Road	Tributary	MCI
15	Lowland soft bed	Lill Burn at Hindley Rd	Tributary	MCI
16	Lowland soft bed	Lill Burn at Lill Burn-Monowai Road	Tributary	WQ, Peri, MCI
17/M6	Lake fed	Waiau River 100m u/s Clifden Bridge	Mainstem	WQ, Peri, MCI
18	Lowland soft bed	Orauea River at Orawia Pukemaori Road	Tributary	WQ, Peri, MCI
19	Lake fed	Waiau River at Tuatapere (ES)	Mainstem	WQ, Peri, MCI

Site number	Waterbody class	Site name	Location	Data collected
20	Lake fed	Waiau River at Tuatapere (NRWQN)	Mainstem	WQ
A	Natural state	Lake Te Anau at South Fiord		WQ
B	Natural state	Lake Te Anau at Blue Gum Point		WQ
B	Natural state	Lake Manapouri at Pomona Island		WQ
D	Natural state	Lake Manapouri at Stony Point		WQ
E	Natural state	Lake Manapouri near Frazers Beach		WQ

Appendix 2

Tables of NPS-FM Attribute State/Bands and JWS Recommended Thresholds

Table 2-1: Attribute and state (band) definitions for variables included as attributes in the NPS-FM (2020).*Attributes are listed in the order in which they appear in the NPS-FM. Sites are classified into default or productive classes for NPS-FM based on the River Environment Classification (REC) for assessment of the periphyton attribute.*[21] *Numeric attribute states for suspended and deposited sediment vary according to the REC classification at each site; band definitions are shown for REC groups defined in Appendix 2C in the NPS-FM (2020) for RECs represented by the sites in the Waiau catchment. REC groups are summarised as suspended sediment and deposited sediment classes (1 – 4), shown in the right-hand column.*

NPS-FM attribute	Unit	Metric	Band A	Band B	Band C	Band D	Band E (or class)
Applicable to lakes							
Phytoplankton chlorophyll *a*	mg/m³	annual median	≤2	>2 and ≤5	>5 and ≤12	>12	
		annual maximum	≤10	>10 and ≤25	>25 and ≤60	>60	
Total nitrogen	mg/m³	annual median (stratified seasonally)	≤160	>160 and ≤350	>350 and ≤750	>750	
		annual median (polymictic)	≤300	>300 and ≤500	>500 and ≤800	>800	
Total phosphorus	mg/m³	annual median	≤10	>10 and ≤20	>20 and ≤50	>50	
Applicable to rivers							
Periphyton chlorophyll *a*	mg/m²	exceeded in ≤8% samples (default class) or in ≤17% samples (productive class)	≤50	>50 and ≤120	>120 and ≤200	>200	
NO_3-N (for nitrate toxicity)	mg/L	annual median	≤1	>1 and ≤2.4	>2.4 and ≤6.9	>6.9	
		annual 95th %tile	≤1.5	>1.5 and ≤3.5	>3.5 and ≤9.8	>9.8	
Suspended fine sediment (water clarity) (Requires median of ≥ 60 samples taken over ≥ 5 years)	m	median	≥1.78	<1.78 and ≥1.55	<1.55 and ≥1.34	<1.34	1
			≥0.93	<0.93 and ≥0.76	<0.76 and ≥0.61	<0.61	2
			≥2.95	<2.95 and ≥2.57	<2.57 and ≥2.22	<2.22	3
			≥1.38	<1.38 and ≥1.17	<1.17 and ≥0.98	<0.98	4
Macroinvertebrates	MCI	5-year median	≥130	≥110 and <130	≥90 and <110	<90	

[21] Productive sites have “dry” climate categories combined with geology categories that reflect naturally high nutrient enrichment due to the underlying catchment geology. Sites with all other REC types (not in the Productive class) are classified as default.

NPS-FM attribute	Unit	Metric	Band A	Band B	Band C	Band D	Band E (or class)
Deposited fine sediment (Requires median of ≥ 60 samples taken over ≥ 5 years)	%	median	≤10	>10 and ≤19	>19 and ≤29	>29	2
			≤9	>9 and ≤18	>18 and ≤27	>27	3
			≤13	>13 and ≤19	>19 and ≤27	>27	4
Applicable to lakes and rivers							
NH_4-N (for ammonia toxicity; at pH 8 and 20 °C)	mg/L	annual median	≤0.03	>0.03 and ≤0.24	>0.24 and ≤1.30	>1.30	
		annual maximum	≤0.05	>0.05 and ≤0.40	>0.40 and ≤2.20	>2.20	
E. coli (Requires minimum of 60 samples over maximum of 5 y)	cfu/ 100 ml	% exceedance 540	<5%	5-10%	10-20%	20-30%	>30%
		% exceedance 260	<20%	20-30%	20-34%	>34%	>50%
		median	<130	<130	<130	>130	>260
		95th percentile	≤540	≤1000	≤1200	>1200	>1200

Table 2-2: Recommended thresholds set out to identify degraded rivers in the JWS (as in Table 1).

Attribute	Spatial area	Metric	Numeric threshold	Compliance statistic
Dissolved inorganic nitrogen (DIN)	Upland*	DIN	>0.5 mg/L	5 year median
	Region	DIN	>1.0 mg/L	5 year median
Dissolved reactive phosphorus (DRP)	Upland*	DRP	>0.01 mg/L	5 year median
	Region	DRP	>0.018 mg/L	5 year median
Macroinvertebrates	Upland	MCI	<100	5 year mean
	Lowland	MCI	<90	5 year mean
Periphyton	Upland*	Chlorophyll *a*	>120 mg/m^2	92%ile over 3 years for monthly sampling
		% weighted composite cover (WCC)	>40%	92%ile over 3 years for monthly sampling
	Region	Chlorophyll *a*	>200 mg/m^2	92%ile over 3 years for monthly sampling
		% weighted composite cover (WCC)	>55%	92%ile over 3 years for monthly sampling

* to be confirmed