Strategy & Planning Committee, 22 January 2020

Meeting is held in the Council Chamber, Level 2, Philip Laing House
144 Rattray Street, Dunedin

Members:

Hon Marian Hobbs, Chairperson	Cr Carmen Hope
Cr Michael Laws, Deputy Chairperson	Cr Gary Kelliher
Cr Hilary Calvert	Cr Kevin Malcolm
Dr Lyn Carter	Cr Andrew Noone
Cr Michael Deaker	Cr Gretchen Robertson
Mr Edward Ellison	Cr Bryan Scott
Cr Alexa Forbes	Cr Kate Wilson

Senior Officer: Sarah Gardner, Chief Executive

Meeting Support: Liz Spector, Committee Secretary

22 January 2020 01:00 PM - 03:00 PM

Agenda Topic — Page

1. APOLOGIES

Committee member Mr Edward Ellison has submitted his apologies.

2. ATTENDANCE

Staff in attendance will be noted.

3. CONFIRMATION OF AGENDA

Note: Any additions must be approved by resolution with an explanation as to why they cannot be delayed until a future meeting.

4. CONFLICT OF INTEREST

Members are reminded of the need to stand aside from decision-making when a conflict arises between their role as an elected representative and any private or other external interest they might have.

5. PUBLIC FORUM

Requests to speak must be made to the Committee Secretary on 0800 474 082 or liz.spector@orc.govt.nz at least 24 hours before the meeting; however, this requirement may be waived by the Chairperson.

6. ACTIONS

There are no outstanding actions of the Strategy and Planning Committee.

Minutes of the Strategy and Planning Committee held in the Council Chamber at on Wednesday 27 November 2019 at 3:00 pm

Membership

Hon Marian Hobbs	*(Co-Chair)*
Cr Michael Laws	*(Co-Chair)*
Cr Hilary Calvert	
Cr Michael Deaker	
Cr Alexa Forbes	
Cr Carmen Hope	
Cr Gary Kelliher	
Cr Kevin Malcolm	
Cr Andrew Noone	
Cr Gretchen Robertson	
Cr Bryan Scott	
Cr Kate Wilson	

Welcome

Chair Hobbs welcomed Councillors, members of the public and staff to the meeting at 3.00pm

1. APOLOGIES
There were no apologies.

2. LEAVE OF ABSENCE
There were no leave of absence.

3. ATTENDANCE
Sarah Gardner	*(Chief Executive)*
Nick Donnelly	*(General Manager Corporate Services and CFO)*
Gavin Palmer	*(General Manager Operations)*
Sally Giddens	*(General Manager People, Culture and Communications)*
Richard Saunders	(*General Manager Regulatory)*
Gwyneth Elsum	*(General Manager Strategy, Policy and Science)*
Amanda Vercoe	*(Executive Advisor)*
Dianne Railton	*(Executive Assistant, Minute taker)*
Eleanor Ross	*(Manager Communications Channels)*
Ryan Tippet	*(Media Communications Lead)*
Anita Dawe	*(Acting Policy Manager)*
Tom De Pelsemaeker	*(Team Leader Freshwater and Land)*

4. CONFIRMATION OF AGENDA
The agenda was confirmed as circulated.

5. CONFLICT OF INTEREST
No conflicts of interest were advised.

6. PUBLIC FORUM
No public forum was held.

7. PRESENTATIONS
No presentations were held.

8. ACTIONS
There are no outstanding actions.

9. MATTERS FOR COMMITTEE DECISION
9.1. Consideration of Draft Terms of Reference
The draft Terms of Reference for the Strategy and Planning Committee were discussed, and minor amendments were made.

- Amend quorum to eight
- Add 'to ensure consistency' to delegation
- Add delegations to carry out functions delegated by Council and may appoint working parties
- Amend key responsibilities and include 'identify strategic issues' and receive progress updates

Cr Kevin Malcolm left the meeting at 03:20 pm.

Resolution

That the Council:

1) ***Receives** this report.*

2) ***Refers**, following discussion, the proposed terms of reference for the Strategy and Planning Committee to Council for adoption on 11 December 2019 with the amendments.*

Moved: Cr Hope
Seconded: Cr Forbes
CARRIED

Cr Kevin Malcolm returned to the meeting at 03:35 pm.

10. MATTERS FOR NOTING

10.1. Manuherikia River Resource Assessment report

Chief Executive Sarah Gardner asked that this report attachment be withdrawn due to inconsistencies. The Councillors asked for an executive summary to be included with reports in the future and agreed that science reports should be made publicly available on the website.

Resolution

That the Council:

1) ***Receives** this report.*

2) ***Notes** that the report:*

   a. *Was released to the Manuherekia Technical Advisory Group (TAG) on the 26th November 2019.*

   b. *Will be available to the public following the Strategy and Planning Committee meeting on the 27th November 2019.*

3) ***Notes** that, in the future, ORC science reports will be made publicly available upon finalisation.*

The following amendment was made, that the Council:

4) ***Did not receive or note** the report attachment.*

Moved: Cr Calvert
Seconded: Cr Laws
CARRIED

11. NOTICES OF MOTION

No Notices of Motion were advised.

Cr Noone left the meeting at 03:49 pm.
Cr Noone returned to the meeting at 03:49 pm.

14. CLOSURE

The meeting was declared closed at 4:30 p.m.

_________________________________ _______________________

Hon Marian Hobbs, Chairperson Date

Minutes of the Public Excluded Strategy and Planning Committee held in the Council Chamber at on Wednesday 27 November 2019 at 3:00 pm

Membership

Hon Marian Hobbs	*(Co-Chair)*
Cr Michael Laws	*(Co-Chair)*
Cr Hilary Calvert	
Cr Michael Deaker	
Cr Alexa Forbes	
Cr Carmen Hope	
Cr Gary Kelliher	
Cr Kevin Malcolm	
Cr Andrew Noone	
Cr Gretchen Robertson	
Cr Bryan Scott	
Cr Kate Wilson	

Welcome

Chair Hobbs welcomed Councillors and staff to the meeting at 3.00pm

1. APOLOGIES

There were no apologies

2. ATTENDANCE

Sarah Gardner	*(Chief Executive)*
Nick Donnelly	*(General Manager Corporate Services and CFO)*
Gavin Palmer	*(General Manager Operations)*
Sally Giddens	*(General Manager People, Culture and Communications)*
Richard Saunders	(*General Manager Regulatory)*
Gwyneth Elsum	*(General Manager Strategy, Policy and Science)*
Amanda Vercoe	*(Executive Advisor)*
Dianne Railton	*(Executive Assistant, Minute-taker)*
Tom De Pelsemaeker	*(Team Leader, Freshwater and Land)*
Anita Dawe	*(Acting Policy Manager)*

3. CONFIRMATION OF AGENDA

The agenda was confirmed as circulated.

4. CONFLICT OF INTEREST

No conflicts of interest were advised.

5. MATTERS FOR NOTING

5.1. Plan Change 5A High Court Appeal

Following discussion, it was agreed that this report will lie on the table. Cr Laws made a motion:

Resolution
That the matter lies on the table.

Moved: Cr Laws
Seconded: Cr Kelliher
CARRIED

Cr Deaker left the meeting at 03:50 pm.
Cr Hope left the meeting at 03:52 pm.

6. CLOSURE

The meeting was declared closed at 04:30 pm.

Chairperson

8.1. Manuherekia River Resource Assessment report

Prepared for:	Strategy and Planning Committee
Report No.	P&S1812
Activity:	Governance Report
Author:	Julie Everett-Hincks, Manager Science
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	10 January 2020

PURPOSE

[1] NIWA was engaged by Otago Regional Council (ORC) to provide an assessment of selected water quality (2009-2019) and ecological data for the Manuherekia River catchment in Central Otago.

[2] The assessment provides an effective benchmark against which future ecological condition studies of the Manuherekia catchment can be compared.

[3] The assessment informs the Technical Advisory Group (TAG) who provide technical advice on the development and execution of a technical work programme and assist with the interpretation of the science information for policy development, as well as the Manuherekia Reference Group (MRG) who provide strategic advice to the ORC in support of the successful delivery of any relevant plan changes.

[4] The assessment also informs the development of the wider ORC Water Plan review that will align water management and central government policy.

SUMMARY

[5] The Manuherekia River Resource Assessment Report (NIWA November 2019) is provided for discussion, a summary is provided.

a. Water quality trends: In some catchments, there is evidence of improving trends in several variables (DRP at Ophir and Galloway, NNN at Galloway). However, analysis revealed increasing trends in concentrations of some water quality variables at other sites, indicative of declining water quality over time (*E. coli* at Ophir, Galloway, Dunstan Creek and Thomsons Creek, NNN at Ophir and Dunstan Creek, NNN at Thomsons Creek)

b. Water quality state: Comparison against Schedule 15 (S15) of the Regional Plan Water showed that DRP S15 limits were exceeded at most mainstem and tributary sites, Thomsons Creek exceeded S15 limits for *E. coli* and turbidity, Chatto Creek and Manuherekia at Larkihill exceeded S15 limits for NNN. Comparison against the National Objective Framework (NOF) attribute states showed that monitoring sites were generally graded A for NH4-N and NNN, *E. coli* analysis was possible at five sites, of these sites four sites were graded below the national bottom line; Thomsons Creek (grade E) Dunstan Creek, Galloway and Ophir (grade D).

c. Nutrient loads: Nutrient loads were calculated for NNN and DRP using a regression modelling technique Median annual NNN and DRP load estimates were largest for the Manuherekia River at Ophir site. For tributaries, Dunstan Creek was the largest source of NNN, while Thomsons Creek was the largest source of DRP. These load estimates are likely to be useful when considering land use and changes in land use over time, and likely impact of nutrients on water quality and ecological condition.

d. Ecological condition: Macroinvertebrate community surveys indicate the main stem of the Manuherekia River was in fair to good condition with macroinvertebrate community index (MCI) values ranging from 90 to 120. Soluble inorganic nutrient concentrations appear to reflect periphyton growth, decreasing in response to uptake by periphyton during the summer months. Greatest periphyton cover was observed in the mid-to upper reaches of the Manuherekia River presumably as a consequence of regulated, relatively stable flows downstream of Falls Dam. Trout and various native fish species inhabit that Manuherekia River catchment and Dunstan Creek may provide a critical refuge for the roundhead galaxiid.

e. Flows: During the 2016/17 ecological survey period flows in the Manuherekia River were generally above what might be considered ‘low flow’ conditions, reflecting the high flows that extended into summer 2016/17, as well as several rainfall events. These ‘atypical’ flow conditions mean caution is required when evaluating the periphyton data (which may be more extensive in a period of lower flows), which in turn will also impact macroinvertebrate communities.

RECOMMENDATION

That the Council:

*1) **Notes** this report.*

ATTACHMENTS

1. Manuherikia River Resource Assessment 11(A B)_ FINAL REV 4 [**8.1.1** - 163 pages]

NIWA
Taihoro Nukurangi

Review of water quality and ecological data for the Manuherikia River catchment

Prepared for Otago Regional Council

June 2019

Prepared by:
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NIWA CLIENT REPORT No: HN2019151HN
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NIWA Project: ORC18202

Quality Assurance Statement		
	Reviewed by:	Juliet Milne
	Formatting checked by:	Alison Bartley
	Approved for release by:	Michael Bruce

Contents

Tables

Figures

Executive summary

NIWA was engaged by Otago Regional Council (ORC) to provide an assessment of selected water quality and ecological data for the Manuherikia River catchment in Central Otago. This study confirms that the information analysed provides an effective benchmark against which future ecological condition assessments of catchments can be compared.

The ORC had several specific requirements:

- A comparison of five physico-chemical and microbiological water quality variables from two time periods (~ 2009-2013 and 2016-2019).
- An assessment of trends over time in five water quality variables listed in the Regional Plan Water for Otago (RPW); nitrite plus nitrate-N (NNN), ammoniacal nitrogen, dissolved reactive phosphorus (DRP), turbidity and the faecal indicator bacterium *Escherichia coli (E. coli)*.
- A comparison of measured water quality values against both limits in Schedule 15 of the ORC's RPW and numeric attribute states in the National Objectives Framework (NOF) of the NPS-FM 2014 (amended 2017).
- An assessment of ecological condition based on the results of periphyton (streambed algae), physical habitat and macroinvertebrate community surveys carried out over 2016/17, together with fish population composition drawn from existing records and annual surveys of two catchment streams between 2015 and 2018 inclusive.

An additional task included estimation of loads for DRP and NNN at sites where both sufficient water quality data and flow estimates were available.

Water quality trends

In some catchments, there is evidence of improving trends in several variables. However, our analysis revealed increasing trends in concentrations of some water quality variables at other sites, indicative of declining water quality over time:

- Increasing trends in ammoniacal-N concentrations were observed, but these should be viewed with extreme caution because of the large number of results that were below or near the analytical detection limit, the gap in concentration data at many sites between 2012 and 2016, and changes in the laboratory detection limit from July 2014. To avoid inappropriate use of observed trends, we have removed them from the body of the report.
- Increasing concentrations of NNN and *E. coli* were evident in the Dunstan Creek catchment, but DRP concentrations appear to be decreasing.
- Decreasing DRP concentrations and decreasing turbidity was evident in the Manuherikia River at both the Ophir and Galloway monitoring sites.
- NNN concentrations at the Galloway site appear to be decreasing, but *E. coli* concentrations show an increasing trend.
- NNN and *E. coli* concentrations at the Ophir site are also on the increase.

- Concentrations of NNN are increasing in the Thomsons Creek catchment., as are *E. coli* concentrations and turbidity (at a lower rate). An improving trend in DRP concentration is evident in this catchment (DRP concentrations are declining).

Comparison of water quality data between the two time periods using an ANOVA parametric test revealed several statistically significant differences:

- Median *E. coli* concentrations at Dunstan Cr at Beattie Rd site increased from 23.5 *E. coli*/100 mL (pre 2013) to 40.5 *E. coli*/100 mL (post 2015).
- Median DRP concentrations at Dunstan Cr at Beattie Rd site decreased from 0.01 mg/L (pre 2013) to 0.004 mg/L (post 2015).
- Median DRP concentrations at Manuherikia R at Loop Rd site decreased from 0.005 mg/L (pre 2013) to 0.003 mg/L (post 2015).
- Median NNN concentrations at Manuherikia R at Loop Rd site decreased from 0.005 mg/L (pre 2013) to 0.002 mg/L (post 2015).
- Median NNN concentrations at Chatto Cr u/s Manuherikia R" site decreased from 0.15 mg/L (pre 2013) to 0.08 mg/L (post 2015).

Comparison against ORC RPW limits

Schedule 15 of the RPW sets out numeric limits for five water quality variables that apply to the results of water samples collected at river flows of median or less. The limits require 80% of these sample results to be less than the specified limits.

Water quality data for the period February 2009 to February 2019 were divided into a series of six 'rolling' five-year periods, and one period of four years and two months duration. After removal of data collected when river flows were above median flows, we found:

- Ammoniacal-N concentrations were generally low (mostly below analytical detection), and all sites complied with the limit of 0.1 mg/L.
- The Chatto Creek catchment exceeded the NNN limit of 0.075 mg/L in six of the seven five-year periods, and the Manuherikia River at Larkhill site exceeded the limit in each five-year period. Although they met the limit, a large proportion of NNN concentrations at both the Pool Burn and Thomsons Creek sites exceeded 0.075 mg/L.
- Most mainstem sites on the Manuherikia River and tributary streams – including Chatto Creek, Ida Burn, Lauder Creek, Pool Burn and Thomsons Creek – exceeded the DRP limit (0.01 mg/L) across multiple five-year periods.
- Thomsons Creek at SH 85 was the only site to exceed the *E. coli* limit of 260 cfu/100 mL. Although they met the limit, the Ida Burn at Auripo Road, Pool Burn at Auripo Road and the Manuherikia at Ophir sites all recorded some *E. coli* counts above 260 cfu/100 mL.
- Thomsons Creek at SH 85 was the only site to exceed the turbidity limit of 5 NTU, with this occurring in one five-year period. However, several turbidity values over 5 NTU were observed at this site, as well as the Ida Burn at Auripo Road, in other periods.

Comparison against the NOF attribute states of the NPS-FM 2014

The current NOF includes attribute state criteria for three of the five water quality variables of interest: ammoniacal-N, NNN and *E. coli.* The first two attributes are based on concentrations that relate to toxic effects on aquatic biota rather than adverse effects associated with eutrophication (e.g., excessive periphyton growth). The *E. coli* attribute relates to human health risk from primary contact recreation.

In accordance with the NPS-FM, we assessed each attribute on an annual basis (providing an assessment for 10 calendar years, 2009 to 2018), using the specified statistics. We found:

- Monitoring sites were generally graded in the A attribute state for the ammoniacal-N threshold, indicating that at most sites there will be no toxic effects on sensitive aquatic life. Where sites were graded in the B state, occasional adverse impacts on the 5% most sensitive species may be expected.
- With the exception of the Manuherikia at Larkhill site (graded B), all monitoring sites were consistently graded in the A attribute state for NNN, indicating that there are unlikely to be toxic effects on sensitive aquatic life.
- Robust assessment of *E. coli* attribute state was only possible at selected sites where sufficient data (60 measurements over a five-year period) were available [Manuherikia River at Galloway (six five-year periods), Manuherikia at Ophir (one), Dustan Creek at Beattie Road (one), and Thomsons Creek at SH85 (two periods)]. Data for these sites indicate attribute state varied from grade E or 'red' to A 'blue'.
  - These results indicate that an average infection risk to swimmers of up to 1% (grade A), to more than 7% (grade E) exists.
  - Consistently greatest illness risk occurs in Thomsons Creek (grade E), followed by Dunstan Creek and the Manuherikia at Galloway and Ophir sites (grade D).

Ecological condition

Limited sediment deposition was evident at the six sites surveyed on the mainstem of the Manuherikia River over 2016/17. Substrate across surveyed sites was varied and favourable for invertebrates. Algal cover was greatest in the upper Manuherikia River, presumably as a consequence of regulated, relatively stable flows downstream of Falls Dam, and low turbidity. Soluble inorganic nutrient concentrations appear to reflect periphyton growth, decreasing in response to uptake during the summer months. Periphyton species and abundance is consistent with nutrient and substrate conditions, with greatest periphyton cover observed in the mid-to upper reaches of the Manuherikia River. Flows in the river during the ecological monitoring campaigns were generally above what might be considered 'low flow' conditions, reflecting the high flows that extended into summer 2016/17, and several rainfall events that also occurred.

Macroinvertebrate community surveys indicate the main stem of the Manuherikia River was in fair to good condition over 2016/17, with macroinvertebrate community index (MCI) values ranging from 90 to 120. The semi-quantitative MCI (SQMCI) scores were greater than 4 (fair), with most samples (10 of 18) indicating good to excellent condition. The exception appears to be the Loop Road site, where lower MCI and semi-quantitative MCI (SQMCI) scores were consistent with greater periphyton growth.

Based on four annual fish surveys, the Dunstan Creek site indicated a productive habitat for the species observed, with a self-sustaining population of galaxiids. It is possible that this catchment forms a refuge for galaxiids, because conditions discourage trout during periods of low flow and elevated water temperature. The Thomsons Creek surveys indicate a greater influence of trout.

Soluble inorganic nutrient loads

Nutrient loads were calculated for NNN and DRP using a regression modelling technique. Nutrient loads are seasonal, with largest loads estimated in the winter, roughly equivalent loads in spring and autumn, and smallest loads in summer. Median annual NNN and DRP load estimates were largest for the Manuherikia River at Ophir site – 66.6 kg/d and 9.6 kg/d, respectively. For tributaries where it was possible to estimate loads, Dunstan Creek was the largest source of NNN (11.2 kg/d), while Thomsons Creek was the largest source of DRP (1.5 kg/d). These load estimates are likely to be useful when considering land use and changes in land use over time, and likely impact of nutrients on water quality and ecological condition.

1 Introduction

To support implementation of the National Policy Statement for Freshwater Management 2014 (NPS-FM), Otago Regional Council (ORC) engaged NIWA to assess water quality and ecological condition of the Manuherikia River catchment in Central Otago. Routine (typically monthly) monitoring of physical-chemical and microbiological water quality, and annual assessments of periphyton and macroinvertebrate community composition, have been carried out at a small selection of sites for many years. Around 2011 and over 2016/17, additional monitoring was carried out across a wider range of sites and encompassing a wider suite of measurements – including, in 2016/17, assessments of stream habitat quality, deposited sediment and fish diversity.

The primary purpose of this assessment is to provide a benchmark against which future water quality and ecological condition may be compared. The period of interest to ORC dates from early 2009.

Specially, the ORC required:

- A comparison of physico-chemical and microbiological water quality data from two time periods (part of 2009-2013 and 2016-2019).
- An assessment of trends over time in five water quality variables listed in the Regional Plan Water for Otago (RPW); nitrite plus nitrate nitrogen (NNN), ammoniacal nitrogen, dissolved reactive phosphorus (DRP), turbidity and the faecal indicator bacterium *Escherichia coli (E. coli)*.
- A comparison of measured water quality values against both limits in Schedule 15 of the ORC's Regional Plan Water for Otago (RPW, (ORC 2004, as updated) and numeric attribute states in the National Objectives Framework (NOF) of the NPS-FM 2014 (amended 2017, (New Zealand Government 2017)).
- An assessment of ecological condition that considered the results of recent surveys of periphyton (streambed algae), physical habitat quality, macroinvertebrate community health, and fish population composition.
- Estimation of loads for DRP and NNN at sites where both sufficient water quality data and flow estimates were available.

1.1 Report outline

The report reviews physico-chemical and biological data, and has been structured as follows:

- Section 2 describes the materials and methods used.
- Section 3 summarises the results of the various assessments, with
  - Section 3.2 to 3.5 focussing on physico-chemical water quality, trends in concentration over time, comparison between two periods of time, compliance with ORC RPW limits and comparison with NPS-FM attribute states (where appropriate), respectively.
  - Section 3.7 provides estimates of loads of NNN and DRP for sites where sufficient data are available.

- Section 4 considers ecological condition, subdivided as follows:
  - Section 4 considers habitat quality
  - Section 4.1.4 focuses on sediment, and
  - Sections 4.3, 4.4 and 4.5 address periphyton cover, macroinvertebrate abundance and fishery data, respectively.
- Section 5 is a discussion that integrates the results of the earlier separate assessments as far as possible.

2 Methods

The data were provided by ORC and comprise a combination of ongoing routine State of the Environment, semi-regular and episodic sampling campaigns. This section provides broad descriptions of the collection methods used and the periods of time represented by the data, along with an overview of our methods of analysis.

2.1 Physico-chemical water quality data

Grab sample water quality data were provided for sites across the Manuherikia River catchment – these are summarised in Table 2-1, and the locations of these sites are indicated in Figure 2-1. The sites are also shown in schematic form in Figure 2-2, along with flow monitoring sites. Water quality sites were divided into two groups – those identified by ORC as primary sites for this assessment, and an additional group of sites included in the overall assessment for completeness. Primary sites are identified in Table 2-1 with bold text. The "Flow reference site" column indicates the sites identified in the ORC's RPW for determining whether flows across the Manuherikia River catchment are deemed to be below or above median flow conditions. Use of these values is described further in Section 3.1.

Table 2-1: Summary of number of data available for each site and water quality variable combination. Note that for some variables a gap exists between approximately 2010-2015 (this is evident from time-series plots summarised in Appendix E). Primary sites identified by ORC are shown in bold.

Site name	Period of record		Number of measurements					Flow ref. site
	Start	End	Ammon.-N (mg/L)	DRP (mg/L)	*E. coli* (cfu/100 mL)	NNN (mg/L)	Turbidity (NTU)	
Chatto Cr at Manuherikia	**09/09**	**09/17**	**38**	**38**	**12**	**38**	**13**	A
Dunstan Cr at Beattie Rd	**07/09**	**02/19**	**108**	**107**	**107**	**107**	**88**	B
Hills Cr at SH85	08/18	02/19	7	7	7	7	7	B
Ida Burn at Auripo Rd	07/09	05/13	32	32	31	32	13	B
Ida Burn at Blackstone Hill	09/09	09/10	26	26		26	1	B
Ida Burn at SH85	07/09	05/13	32	32	31	32	13	B
Lauder Cr at Cattle Yards	**10/16**	**08/17**	**10**	**10**	**10**	**10**	**10**	B
Lauder Cr at Rail Trail	**09/09**	**09/17**	**38**	**38**	**12**	**38**	**13**	B
Manuherikia 20m u/s Thomsons Cr	**01/18**	**05/18**	**5**	**5**	**5**	**5**	**5**	A
Manuherikia 80m u/s Thomsons Cr	**11/17**	**12/17**	**1**	**1**	**2**	**1**	**1**	A
Manuherikia at Blackstone Hill	**07/09**	**02/19**	**89**	**89**	**88**	**89**	**69**	B
Manuherikia at Galloway	**01/08**	**02/19**	**124**	**124**	**205**	**124**	**107**	A
Manuherikia at Larkhill	07/11	03/16	32	32	2	29		B
Manuherikia at Loop Rd	**09/09**	**05/18**	**46**	**46**	**20**	**46**	**21**	B
Manuherikia at Omakau	**09/09**	**05/18**	**46**	**46**	**20**	**46**	**21**	B
Manuherikia at Ophir	**01/08**	**02/19**	**118**	**118**	**117**	**118**	**101**	B
Manuherikia d/s Fork	**10/16**	**02/19**	**19**	**19**	**19**	**19**	**19**	B
Manuherikia u/s Chatto Cr	**09/09**	**05/18**	**46**	**46**	**20**	**46**	**21**	B
Manuherikia u/s Ida Burn	09/09	09/10	26	26		26	1	B
Pool Burn at Auripo Rd	07/09	05/13	33	33	32	33	13	B
Poolburn at Cob Cottage	**10/16**	**02/19**	**19**	**19**	**19**	**19**	**19**	B
Thomsons Cr at Race	**10/16**	**02/19**	**31**	**31**	**36**	**31**	**31**	A
Thomsons Cr at SH85	**09/09**	**02/19**	**102**	**102**	**106**	**102**	**78**	A

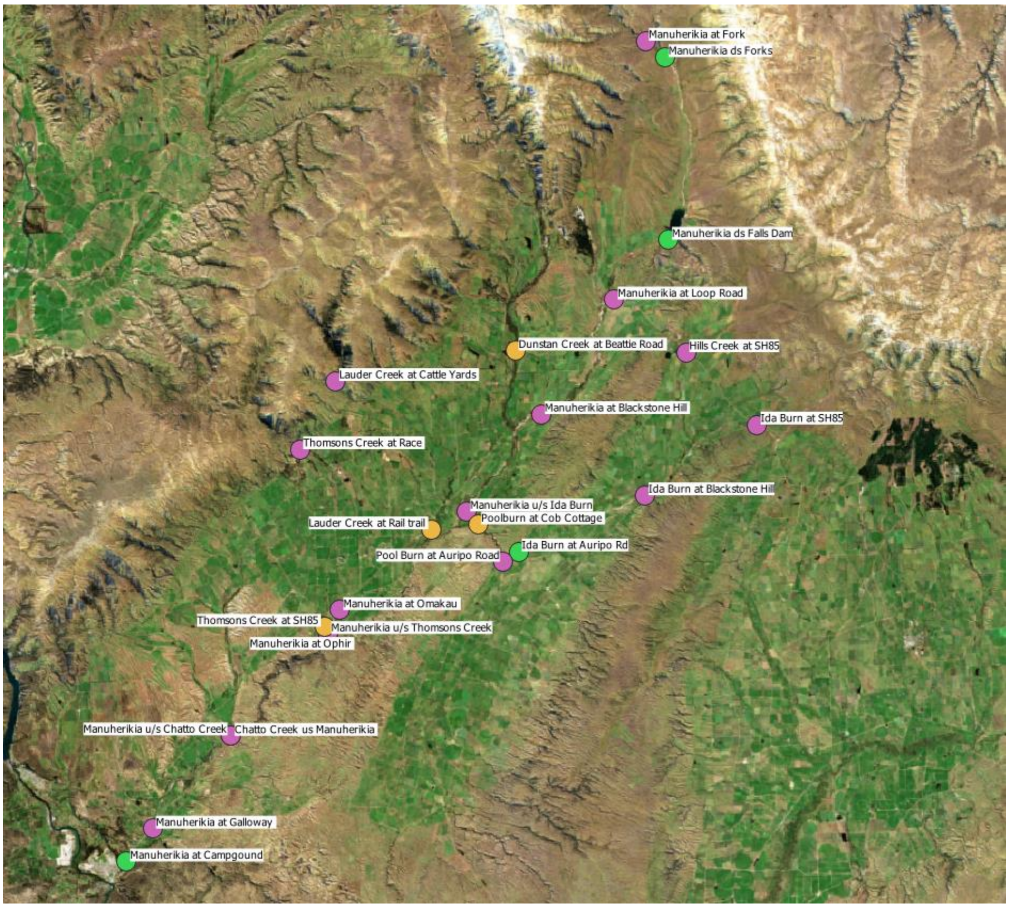


Figure 2-1: Location of water quality and biological monitoring sites, Manuherikia River catchment. Green circles indicate flow monitoring only, magenta circles indicate water quality monitoring only, and orange circles indicate both flow, ecological and water quality monitoring.

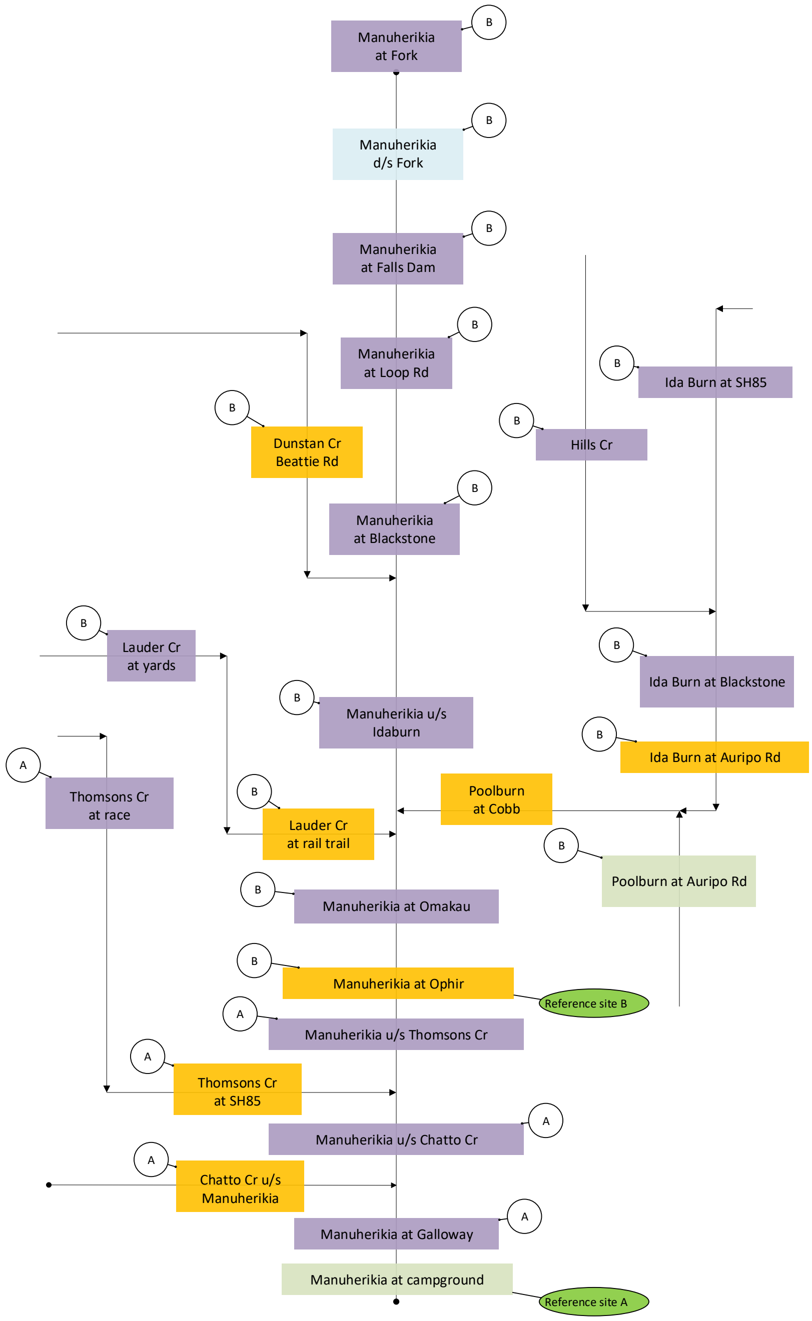


Figure 2-2: Schematic of flow and water quality monitoring sites, Manuherikia River catchment. Green rectangles indicate flow monitoring only, mauve rectangles indicate water quality monitoring only, and orange rectangles indicate both flow, ecological monitoring and water quality monitoring. Reference sites are labelled with green oval shapes, and associated water quality sites are labelled with letters in circles.

Data for five water quality variables of interest to ORC – ammoniacal nitrogen, nitrite plus nitrate nitrogen (NNN), dissolved reactive phosphorus (DRP), *E. coli* and turbidity – were provided in Microsoft Excel spreadsheets, and were used as received. The data were manipulated in Excel (to combine flow data with the associated grab sample water quality record, using the VLOOKUP function to match dates in each record), and to combine these data into a single database. Data analysis was undertaken in several different software packages:

- LOADEST was used for load estimation.
- Trends were estimated using the TimeTrend software (v6.30).
- Systat v13.2 was used for all other analyses and to prepare most of the figures and compliance-exceedance tables. A description of a boxplot derived from Systat is included in Appendix A.

2.1.1 Trend analysis

Where possible trend was assessed using the Seasonal Mann-Kendall procedure in the TimeTrends software.[1] For sites where flow data were available, flow was used as a covariate. Trends were also de-seasonalised. The data record for several sites was broken, which limits application of trend analysis methods.

2.1.2 Assessment against Regional Plan Water limits

Water quality data were assessed against 'Receiving Water Group 2' water quality limits specified in Schedule 15 of the RPW (Table 2-2).[2] These limits are met at a site when the results of 80% or more of water samples collected at or below median flow over a five-year period are lower than the numeric limit. Table 16B of Schedule 15 of the RPW identifies that the median flow status of all catchment sites is determined from two reference sites on the Manuherikia River mainstem – the Manuherikia River at Campground and the Manuherikia River at Ophir.

[1] TimeTrends software, available from http://www.jowettconsulting.co.nz/home/software
[2] https://www.orc.govt.nz/plans-policies-reports/regional-plans-and-polices/water

Table 2-2: Water quality limits and target dates for their achievement, as defined in the ORC's Regional Plan Water (RPW). [A] cfu indicates "colony forming units". [B] NTU = Nephelometric Turbidity Units, a measure of the "cloudiness" of water arising from light-scattering particles. DRP is shaded to indicate the different target date.

Water quality variable	RPW limit (units)	Target date
Ammoniacal-N	0.1 (mg/L)	31 March 2012
Dissolved reactive phosphate (DRP)	0.01 (mg/L)	31 March 2025
E. coli	260 (cfu/100 mL)[A]	31 March 2012
NNN	0.075 (mg/L)	31 March 2012
Turbidity	5.0 (NTU)[B]	31 March 2012

2.1.3 Assessment against NPS-FM NOF attribute states

Ammoniacal-N, NNN and *E. coli* data were assessed against their respective numeric attributes states specified in the National Objective Framework (NOF) of the NPS-FM. These attribute states are summarised in Table 2-3, Table 2-4 and Table 2-5 for ammoniacal-N, NNN and *E. coli,* respectively. The attribute thresholds for ammoniacal-N and NNN relate to ecosystem health and the potential for toxic effects on a range of test organisms, whereas the classification in terms of *E. coli* concentrations provides a direct estimate of human health risk (risk of infection). The NPS-FM notes that for NNN more stringent thresholds will be required when managing a catchment in terms of trophic state.

Table 2-3: Ammoniacal-N attribute state thresholds defined in the National Objective Framework of the NPS-FM. The colour codes align with the assessment results presented in Section 3 (New Zealand Government 2017).

Attribute state	Numeric attribute state thresholds (mg/L as ammoniacal-N) [based on pH 8.0 and 20°C]		Colour code
	Annual median	Annual maximum	
A	≤ 0.03	≤ 0.05	Blue
B	>0.03 and ≤0.24	>0.05 and ≤0.04	Green
C	>0.24 and ≤1.30	>0.40 and ≤2.2	Orange
D	>1.30	>2.20	Red

Table 2-4: NNN attribute state thresholds defined in the National Objective Framework of the NPS-FM. The colour codes align with the assessment results presented in Section 3 (New Zealand Government 2017).

Attribute state	Numeric attribute state thresholds (mg/L as NNN)		Colour code
	Annual median	Annual 95th percentile	
A	≤ 1.0	≤ 1.5	Blue
B	>1.0 and ≤2.4	>1.5 and ≤3.5	Green
C	>2.40 and ≤6.9	>3.5 and ≤9.8	Orange
D	>6.9	>9.8	Red

Table 2-5: Microbiological attribute state thresholds defined in the National Objective Framework of the NPS-FM in terms of *E. coli* concentrations. The colour codes align with the assessment results presented in Section 3 (New Zealand Government 2017).

Attribute state	Numeric attribute state thresholds (n/100 mL as *E. coli*) [requires 60 samples/five-year period]				Colour code	Infection risk (%)
	Exceedances (%)		Concentration (cfu/100 mL)			
	No samples >540 cfu/100 mL	No samples >260 cfu/100 mL	Median	95th percentile		
A	<5%	<20%	≤130	≤540	Blue	1
B	5-10%	20-30%	≤130	≤1000	Green	2
C	10-20%	20-34%	≤130	≤1200	Yellow	3
D	20-30%	>34%	>130	>1200	Orange	>3
E	>30%	>50%	>260	>1200	Red	>7

2.1.4 Water quality loads

Initially it was anticipated that trends in water quality loads would be considered in parallel with land use change. However, land use data representative of the two periods were not available so the emphasis of the assessment was shifted to include estimation of loads of two key water quality variables – NNN and DRP.[3]

DRP and NNN flux was estimated using the LOADEST software (Runkel et al. 2004). In brief, the software is described as:

> *"LOAD ESTimator (LOADEST) is a FORTRAN program for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables, and constituent concentration, LOADEST assists the user in developing a regression model for the estimation of constituent load (calibration). Explanatory variables within the regression model include various functions of streamflow, decimal time, and additional user-specified data variables. The formulated regression model then is used to estimate loads over a user-specified time interval (estimation). Mean load estimates, standard errors, and 95 percent confidence intervals are developed on a monthly and(or) seasonal basis. The calibration and estimation procedures within LOADEST are based on three statistical estimation methods. LOADEST output includes diagnostic tests and warnings to assist the user in determining the appropriate estimation method and in interpreting the estimated loads."*

Results from the load estimation were provided as a daily flux or mass load estimate, as well as seasonal and monthly average values (for each month of the estimation period). Flow data were not available for all sites, so the number of sites at which loads could be estimated was limited.

[3] Estimation of ammoniacal-N loads at most sites was limited by the large number of results at or below the laboratory analytical limit of detection. This constraint was exacerbated by the change in detection limit over time. In any case, the majority of inorganic N in surface waters is usually present as NNN.

2.2 Ecological condition

Ecological condition was assessed using data collected for the purposes indicated in Table 2-6, the sites, and survey dates are defined in the table as well.

Table 2-6: Sites and ecological condition characteristics surveyed in the Manuherikia River catchment.

Survey site	Ecological characteristic and survey dates				
	Habitat condition	Sediment cover/ embeddedness	Periphyton cover and community composition	Macroinvertebrate data	Fish species and abundance
Manuherikia River downstream of Fork	Yes	Yes	Yes	Yes	-
Manuherikia River at Loop Road	Yes	Yes	Yes	Yes	-
Manuherikia River at Blackstone Hill	Yes	Yes	Yes	Yes	-
Manuherikia River at Omakau	Yes	Yes	Yes	Yes	-
Manuherikia River at Ophir	Yes	Yes	Yes	Yes	-
Manuherikia River at Galloway	Yes	Yes	Yes	Yes	-
Dunstan Creek at Beattie Rd	-	-	-	-	Yes
Thomsons Creek at SH85	-	-	-	-	Yes
Survey dates	20–21/2/17	17/12/16; 20–21/2/17; 30–31/03/17 26/04/17	17/12/16; 20–21/2/17; 30–31/03/17 26/04/17	17/12/16; 20–21/2/17; 26/04/17	12/2/15; 14/01/16; 08/02/17; 25/01/18

2.2.1 Habitat quality

One-off stream habitat assessments were undertaken at each site indicated in Table 2-6 according to the National Rapid Habitat Assessment Protocol Development for Streams and Rivers (Clapcott 2015). This assessment covered ten parameters: deposited sediment, invertebrate habitat diversity, invertebrate habitat abundance, fish cover diversity, fish cover abundance, hydraulic heterogeneity, bank erosion, bank vegetation, riparian width, and riparian shade.

2.2.2 Sediment cover

Sediment cover assessments were undertaken at the sites and on the dates indicated in Table 2-6 according to Sediment Assessment Method 2 (SAM2): "In-stream visual estimate of percentage sediment cover", outlined by Clapcott et al. (2011). This provides for a semi-quantitative assessment of the surface area of the streambed covered by sediment, with at least 20 readings made within a single habitat using an underwater viewer.

2.2.3 Periphyton

Periphyton cover assessments were undertaken at the sites and on the dates indicated in Table 2-6 using a modified version of the Rapid Assessment Method 2 (RAM-2): "Line transect – point method" outlined in (Biggs and Kilroy 2002). The width of the wadeable streambed at four locations was divided into five equally spaced points (which were surveyed as transects). At the first point across the transect an underwater viewer was used to view the substrate and the percentage of the bed within the field of view covered by each periphyton cover category was estimated. The estimation was continued across the stream width and repeated moving upstream. The periphyton cover was then categorised in line with Biggs and Kilroy (2002) and assessed against the guidelines for mat and filamentous algal cover provided in the New Zealand Periphyton Guidelines (Biggs 2000).

In addition to periphyton cover, periphyton biomass – as concentrations of chlorophyll *a* – were assessed. Insufficient data exists for comparison against the relevant numeric attributes states specified in the National Objective Framework (NOF) of the NPS-FM (New Zealand Government 2017) – data are required for a period of at least three years.

Biggs and Kilroy (2002) include a periphyton index designed to provide a general assessment of periphyton cover and the community composition that enables a general assessment of stream enrichment. The index recognises 12 main types of periphyton based on colour and thickness. In general, periphyton communities dominated by thin mat algae are typical of clean streams with higher stream water flow and low concentrations of nutrients, while thicker mats of algae and long filamentous algae are typical of increasingly enriched conditions, low flows, increasing water temperatures and/or diffuse or point-source nutrient inputs. Scores of up to 1.9 are classified as 'very poor', those of 2–3.9 as 'poor to moderate', those of 4–5.9 as 'moderate', those of 6–7.9 as 'good', and those of 8–10 as 'very good' (Biggs and Kilroy 2002).

2.2.4 Macroinvertebrates

One macroinvertebrate sample was collected from each of six sites on the Manuherikia River on three sampling occasions (indicated in Table 2-6). Samples were collected with a kick net according to collection protocol 'C1: hard-bottomed semi-quantitative', as described in the Ministry for the Environment's protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001). Protocol 'P1: Coded abundance' was used to enumerate macroinvertebrate taxa.

Macroinvertebrate community composition was assessed through calculation of a series of commonly reported indices:

- Total taxa richness – describes the total number of different types of macroinvertebrates present at a site. In general, high total taxa richness scores indicate higher quality and more diverse habitat.
- EPT richness and % – the presence and abundance of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), collectively known by the acronym EPT. EPT taxa are widely used bio-indicators of freshwater ecosystem health due to their 'heightened sensitivity' to habitat degradation or pollution.

- Macroinvertebrate Community Index (MCI) – an indicator of the tolerance of macroinvertebrate communities to organic pollution, although it may also respond to an interacting complex of other environmental variables, and it provides a complementary measure of stream health. Sites with scores less than 80 are classified as poor, those scoring 80-100 as fair, those scoring 100-120 as good, and those scoring higher than 120 as excellent (Stark and Maxted 2007).
- Semi-Quantitative Macroinvertebrate Community Index (SQMCI) – a variant of the MCI that incorporates a rapid assessment of taxa abundance in its measure of stream health, where each taxon is coded as Rare, Common, Abundant, Very Abundant, or Very Abundant. Stream health at sites with scores less than 4.00 is classified as poor, those scoring 4.00-4.99 as fair, scores of 5.00-5.99 as good, and scores greater than 5.99 indicate excellent stream health (Stark and Maxted 2007).

The indices were calculated according to the methods and requirements of Collier and Kelly (2005).

2.2.5 Fish

Two forms of fish data were available; existing records in the New Zealand Freshwater Fish Database (Crow 2018) and annual fish surveys carried out between 2015 and 2018 inclusive (indicated in Table 2-6).

Fish surveys were carried out on two tributaries of the Manuherikia River – Dunstan Creek and Thomson Creek – by electric fishing using the standardised methods outlined by Waikato Regional Council (David and Hamar 2010). At each site, a 150 m reach was surveyed by single pass electric fishing. The number of each species captured, along with fish lengths, was recorded for every 15 m sub-reach. This survey approach is designed to maximise the likelihood of capturing the full diversity of species present by encompassing the full range of habitats within a stream reach. Results are presented as relative abundance standardised by survey area (number of fish divided by total area sampled).[4] Interpretation of the relative abundance estimates is restricted to temporal comparisons at the same site, assuming the same reach is sampled, with the same level of effort and sampling efficiency on each sampling occasion.

[4] Single pass electric fishing is a semi-quantitative method so abundance data are not equivalent to fish density and should not be used for comparison between sites.

3 Results – physico-chemical water quality variables

3.1 Hydrological conditions

Available discharge data are summarised graphically in Appendix B, where summary statistics are provided. The latter should be used with caution because of the large duration of missing record for six of the available sites. Summary statistics for the two reference sites are provided below to allow comparison between recent flow characteristics and those since January 2016. A graphical comparison of monthly median flows and the flows at the time of biological surveys is provided in Figure 3-1.

Table 3-1: Discharge characteristics for the two reference sites identified in the Manuherikia River catchment. The relationship between flow conditions and biological monitoring conditions is described in more detail in Section 4.3.

Statistic	Discharge characteristics by site and period					
	Campground site			Ophir site		
	All	Pre-2013	Post-2016	All	Pre-2013	Post-2016
N of Cases	3787	1521	1173	4093	1827	1171
Minimum	406	522	548	1131	1131	1564
Maximum	465457	465457	321192	285884	260641	285884
Median	11783	12105	12388	10097	9944	10918
Mean	16325	17349	15917	13983	14059	14857
Std Dev.	26240	27079	24167	19252	17338	22291
Cleveland ptiles						
1 %	621	693	697	1448	1417	1744
5%	892	1036	854	1930	2152	2000
10%	1130	1341	1017	2276	2605	2194
20%	1881	2733	1628	2954	3249	2587
25%	2645	4134	2260	3388	3881	3122
30%	3913	5538	3051	4185	4977	3832
40%	7853	9254	8006	7103	7805	8081
50%	11783	12105	12388	10097	9944	10918
60%	14653	14563	14984	12037	11946	12877
70%	17719	17856	17889	15121	14972	16208
75%	19863	19775	20370	17247	17386	17726
80%	22259	22604	22514	19533	19757	19773
90%	32390	34928	31179	27643	28717	28559
95%	45106	48662	41984	38204	40112	38338
99%	126129	127608	105408	96305	82829	114151

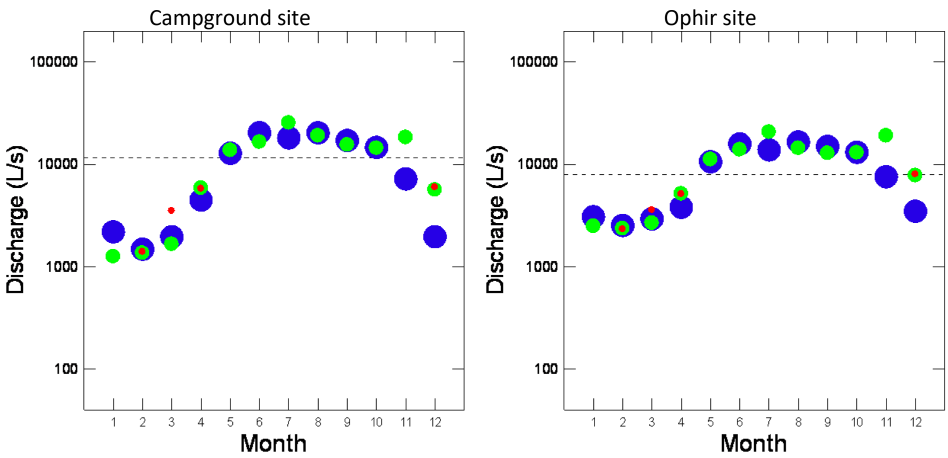


Figure 3-1: Comparison of discharge conditions during biological surveys (red dot), long term median flow (2009-2019, blue), median flow post-2016 (green). The broken horizontal line is the median flow defined for each site in the ORC Water Plan (Schedule 15, Table 16B). note the logarithmic scale.

3.2 Physico-chemical water quality

The data for each key site identified and water quality variable identified in Table 2-1 over the period 2009-2019 inclusive is summarised in box and whisker format in Figure 3-3 (additional sites are included in box and whisker plots in Appendix B). In each figure, the sites are arranged in descending order (from upper catchment to lower catchment) along the Manuherikia River main stem. The stippled vertical lines indicate the relevant ORC Regional Plan Water (RPW) limit. These limits have been added for reference purposes only; as outlined in Section 2.1.2, the limits apply only to data collected at median or lower river flows. Compliance with these limits is assessed in Section 3.6.1.

The ammoniacal-N data requires special attention. Examination of the time series records for most sites indicates a step-change from July 2014 arising from an improvement in the laboratory detection limit. The significance of this change is evident from data for the Manuherikia River at Galloway site, which has the longest and largest available record for both ammoniacal-N and NNN (Figure 3-2). Prior to July 2014, all but three ammoniacal-N results were reported as being below detection limit, whereas after July 2014 a more substantial proportion were reported as values above the detection limit. This effect is not evident in the NNN record for the same site and period, reflecting the fact that NNN is consistently present in measurable concentrations in most natural surface waters. This has significance in terms of trend detection, or when comparing data between two periods, and caution is required when considering the results of trend detection.

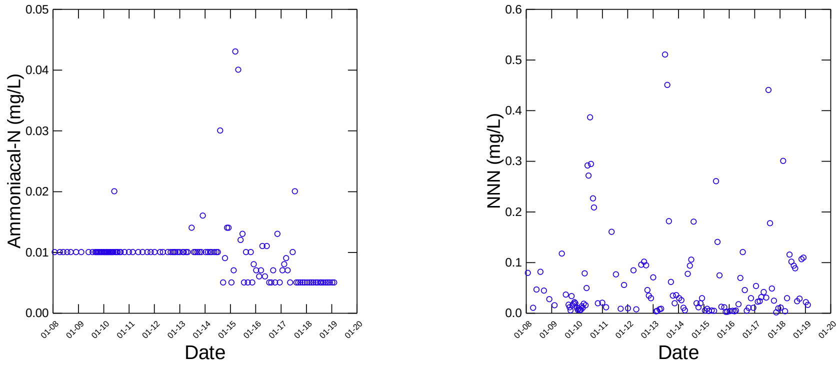


Figure 3-2: Influence of change in laboratory analytical procedures on reported results for ammoniacal nitrogen (left) and NNN. Data are for the Manuherikia River at Galloway site, which has the longest record for these variables. Note effect of change in laboratory method/detection limit in July 2014.

From Figure 3-3 it can be seen that:

- The bulk of ammoniacal-N data (Figure 3-3 A) were at or near the analytical limit of detection, with little indication of spatial trend.
- NNN concentrations (Figure 3-3 B) increased in a downstream direction at all sites where multiple sample sites exist (a spatial trend typical of most catchments). The highest median concentrations were recorded at sites on two tributaries to the Manuherikia River; Thomsons Creek at SH 85 and Chatto Creek at confluence).
- DRP concentrations (Figure 3-3 C) were low in all upper catchment sites (Manuherikia mainstem and tributary streams). Median concentrations were above 0.01 mg/L in mid-catchment reaches of the Manuherikia River, and in lower catchment tributaries.
- A relatively clear distinction between upper tributary-, mid- and lower catchment turbidity values (Figure 3-3 D). Median mid-catchment turbidity values were similar, with the Manuherikia River upstream of Thomsons Creek recording the most values over 5 NTU.
- *E. coli* concentrations generally increased in a downstream direction (Figure 3-3 E) in a similar manner to nutrient concentrations. The Thomsons Creek at SH 85 and Chatto Creek at confluence sites recorded the highest median concentrations, with the former recording a median over 260 *E. coli*/100 mL (the commonly applied 'amber/alert' threshold for contact recreation).

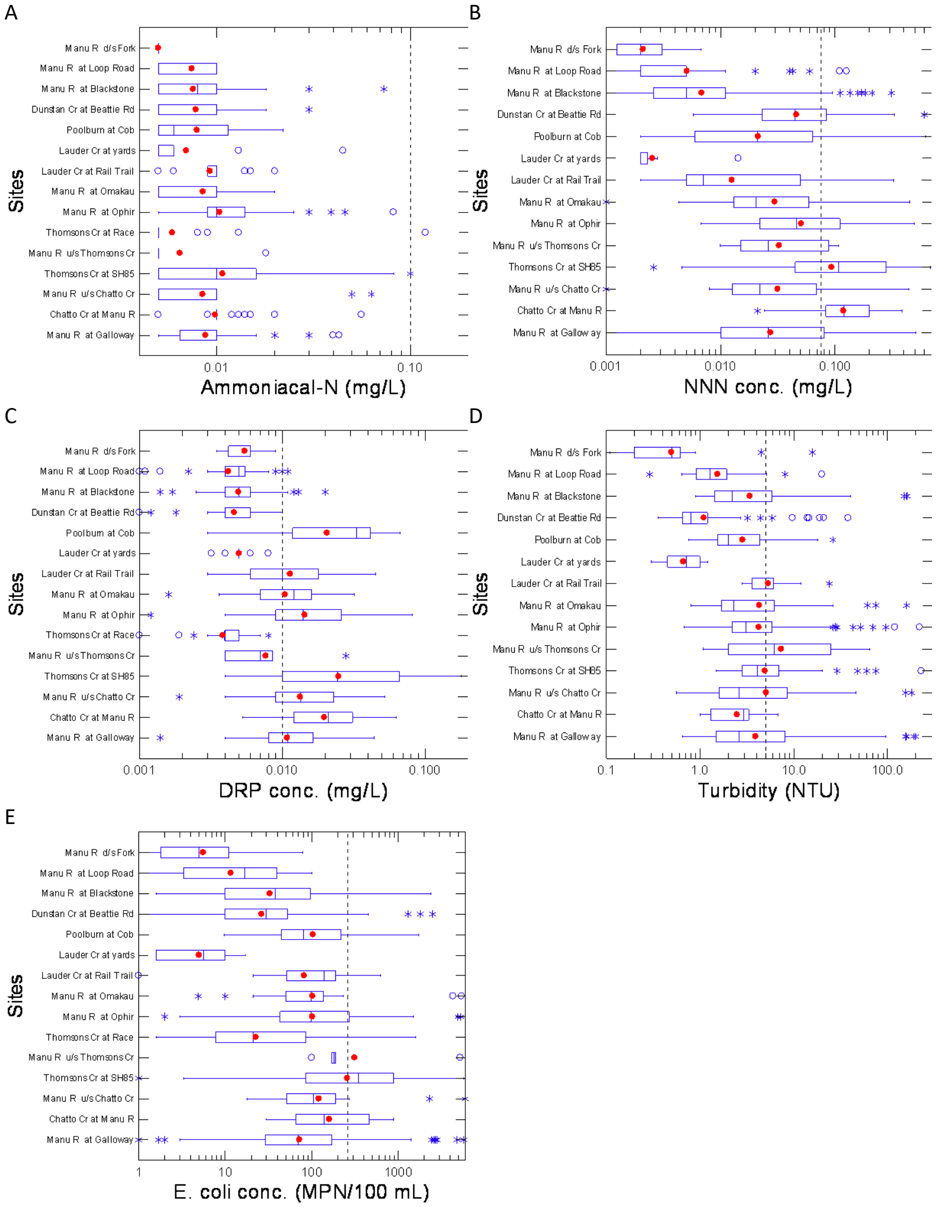


Figure 3-3: Box and whisker plots for five water quality variables measured at sites in the Manuherikia River catchment over the period January 2008–February 2019 inclusive. (Note that data available for specific variables at some sites may be for a shorter period – refer to Table 2-1). The red dot is the average value for the data set. Note *x*-axis scales have a $\log_{10}$ scale. For A-E, the black broken line represents the ORC's RPW limit, provided for reference purposes only.

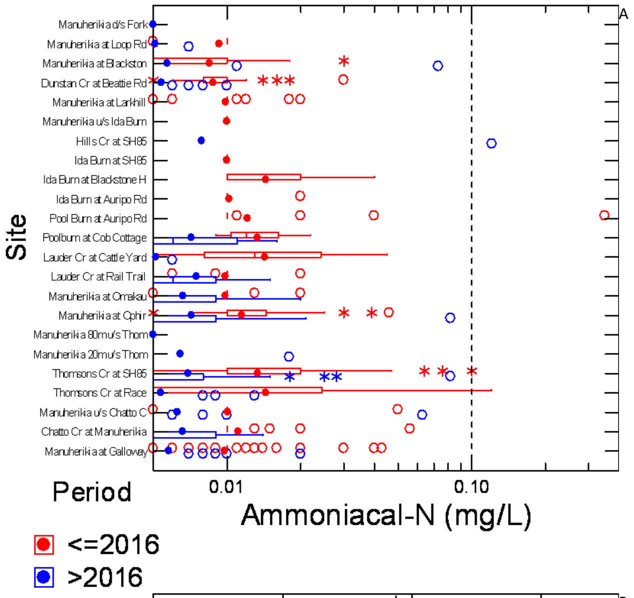
3.3 Difference in water quality between 2012 and 2017

Here we compare measured water quality values between two periods of interest to the ORC – data for the period post-2016 *versus* data derived from an assessment carried out around 2011. The available data spanned periods that extended outside of these two calendar years. Accordingly, data were classified into a "pre-2013 period", and a "post-2016 period". These defined periods were also consistent with available flow data for several sites. The number of data in each period is reported together with the statistical test results in Appendix H. The extent of data for each variable and the gap between periods is evident in the time series figures for each site and variable in Appendix E.

Data were $\log_{10}$ transformed and a concentration data between the two periods were assessed using a two-side ANOVA. The likelihood that the arithmetic means were not indistinguishable at the 95% significance level were estimated. The results are summarised in Appendix H. Statistically significant differences are summarised in Table 3-2. For several sites and water quality variables, insufficient data existed for comparison. Available data for the two periods are summarised in Figure 3-4 for visual comparison. The results are broadly consistent with those for the temporal trend tests.

Table 3-2: ANOVA comparison of independent samples indicating statistically significant differences between sample subsets for two times periods. Data were lo_{10} transformed prior to analysis. Results for all variables where adequate data exist are summarised in Appendix H. Green indicates decrease in concentration between the two periods, and magenta indicates an increase in concentration.

Site	Variable (unit)	Median conc. (mg/L)		Probability at 95% significance level
		Pre-2013	Post-2016	
Dunstan Creek at Beattie Rd	*E. coli* (n/100 mL)	23.5	40.5	0.002
Dunstan Creek at Beattie Rd	DRP (mg/L)	0.01	0.004	<0.001
Manu R at Blackstone	NNN (mg/L)	0.005	0.002	<0.001
Manuherikia R at Loop Rd	DRP (mg/L)	0.005	0.003	<0.001
Manuherikia R at Loop Rd	NNN (mg/L)	0.005	0.002	<0.001
Chatto Cr at Manu R	NNN (mg/L)	0.15	0.88	0.004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Ida Burn at Auripo Rd
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Poolburn at Cob Cottage
Lauder Cr at Cattle Yard
Lauder Cr at Rail Trail
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Manuherikia at Ophir
Manuherikia 80m u/s Thom
Manuherikia 20m u/s Thom
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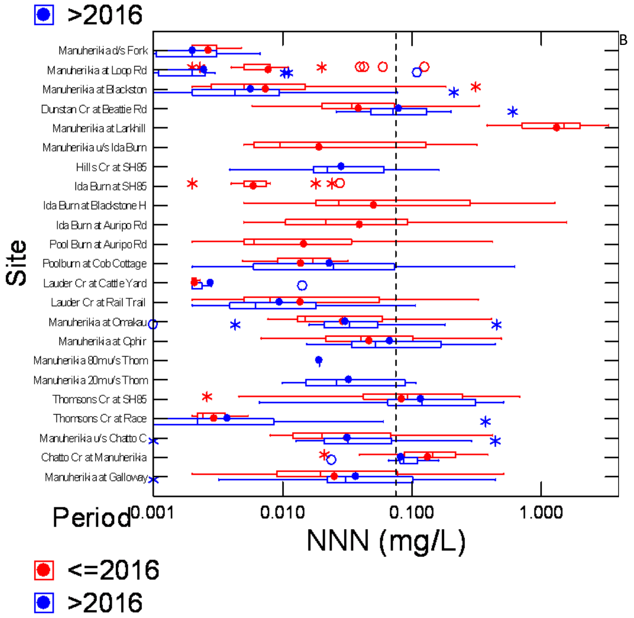
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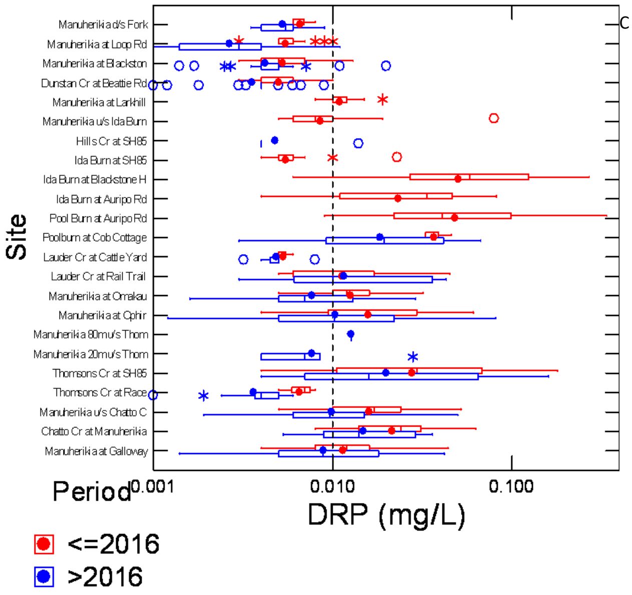
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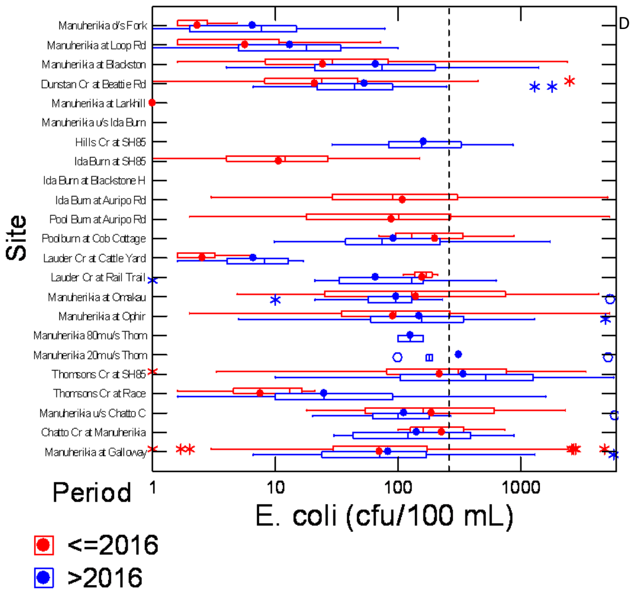
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Pool Burn at Auripo Rd
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Manuherikia 20m u/s Thom
Thomsons Cr at SH85
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E. coli (cfu/100 mL)
<=2016
>2016

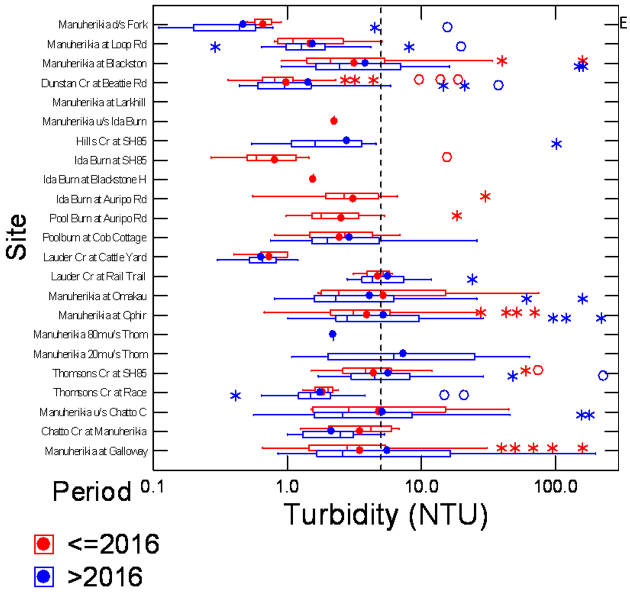

Figure 3-4: Comparison of data by site between pre-January 2016 and post-December 2015 period. The blue and red dots are the average value for each period, respectively. The symbology used in the box and whisker plot is explained in Appendix A. The horizontal black dashed lines indicate the ORC RPW limits (for reference purposes only). Note the *y*-axis scales vary, and have a $\log_{10}$ scale.

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3.4 Temporal trends

Seasonal and flow-adjusted trend assessments provided similar outcomes. The results for all sites are provided in Appendix G. Test results that indicated several, statistically significant increasing or decreasing trend are listed in Table 3-3.

Table 3-3: Summary of Kruskall-Wallis tests indicating trend. Positive and negative percent annual change (PAC) values indicate increasing or decreasing trend respectively. Values in parentheses are probability. Values in non-bold font were estimated using seasonal median values, and values in bold are for all values in each season. Definitions of likelihood of trend direction and confidence are as used in the TimeTrends software.

Site	Var.	Percent annual change					
		Decreasing trend possible	Decreasing trend very likely	Decreasing trend virtually certain	Increasing trend possible	Increasing trend very likely	Increasing trend virtually certain
Dunstan Creek at Beattie Road	DRP			-4.43 (1.00) **-6.37 (1.00)**			
	E. coli				6.04 (0.95) **4.2 (0.95)**		
	NNN					5.42 (0.98) **6.75 (0.99)**	
Manuherikia at Galloway	*E. coli*				1.72 (0.64)	**5.09 (0.98)**	
	DRP			-2.88 (0.99) **-3.6 (1.0)**			
	NNN	-2.68 (0.82) **-2.91 (0.79)**					
	Turb	Unlikely **-1.12 (0.8)**					
Manuherikia at Ophir	*E. coli*				Unlikely **3.06 (0.9)**		
	DRP		-4.14 (0.99) -2.67 (0.99)				
	NNN				1.05 (0.70) **1.06 (0.79)**		
	Turb	-1.04 (0.73) **-1.89 (0.76)**					
Thomsons Creek at SH85	*E. coli*				4.59 (0.68) **5.06 (0.87)**		
	DRP	-1.84 (0.71) **-1.32 (0.71)**					
	NNN						13.39 (1.00) **13.66 (1.00)**
	Turb				6.56 (0.77) **6.59 (0.65)**		

3.5 Compliance with numeric water quality limits

3.5.1 ORC limits

The ORC RPW requires 80% of samples collected at a site, when flows are at or below median flow, over a rolling 5-year period, to meet or be better than the limits specified in Schedule 15. Given the discontinuous nature of the data for several sites, we assessed compliance with the five ORC numeric thresholds as follows:

i. The assessment period was categorised into six ‘rolling’ five-year periods (2009-2013; 2010-2014; 2011-2015; 2012-2016; 2013-2017; 2014-2018). A seventh period (2015-2019) represented data for a shorter period (approximately four years and two months).

ii. Each site was associated with one of the reference sites defined in Schedule 15 of the ORC Water Plan – as indicated in Table 2-1.

iii. Where the flow at the reference site was less than the median flow, each sample result was compared with the numeric limit, and classified as “Pass” or “Fail”.

iv. For each water quality sample date, the flow at the relevant reference site was compared with the reference median flow, and classified as above or below median.

v. Where the flow was below median and the concentration of a given water quality variable exceeded its specified limit, the result was classified “non-compliant”. For each five-year period the total number of results (all flow conditions), the number of sample results when $Q<Q_{50}$, and the number of “Comply”/”Non-comply” results were calculated.

vi. The number of sample results classified as “Non-comply” in each period was expressed as the proportion of results obtained when $Q< Q_{50}$, expressed as a percentage.

The compliance assessment results are summarised in Table 3-4 through Table 3-8, with shading used to indicate sites that failed to meet the relevant numeric limit over a rolling five-year period.

NNN

- In each five-year period, the water quality limit of 0.075 mg/L was exceeded at the Manuherikia at Larkhill site, and in six years of seven at the Chatto Cr u/s Manuherikia confluence site.
- Sub-catchments where NNN is potentially an emerging problem (indicated by several years comprising a large proportion of individual results above the numerical limit value) include the Thomsons Creek and Poolburn.

Ammoniacal-N

- As noted earlier, the bulk of results were at or below the analytical detection limit.
- The Poolburn was the only sub-catchment to regularly record ammoniacal-N concentrations above 0.01 mg/L.
- Data are not tabulate for ammoniacal-N.

Dissolved reactive phosphorus

- The DRP limit was exceeded during at least two five-year periods at 11 sites across the catchment.
- DRP concentrations in the Manuherikia mainstem exceeded the limit in most five-year period at sites downstream of Omakau.
- The bulk of the exceedances of the water quality limit occurred in the lower reaches of tributary streams, or along the main stem of the Manuherikia River downstream of the Ida Burn confluence.

E. coli

- The 260 cfu/100 mL limit was exceeded at the Thomsons Creek at SH 85 site in each five-year period.
- All other sites met the limit, although approximately one third of results in the Manuherikia River at Ophir site exceeded 260 cfu/100 mL in most five-year periods.

Turbidity

- The limit of 5 NTU was exceeded at the Thomsons Creek site in the 2009-2013 period.
- A relatively large number of turbidity measurements were above 5 NTU in Thomsons Creek in other five-year periods, as well as the Ida Burn and the Manuherikia River at Blackstone Hill site.

Table 3-4: Summary of compliance with the ORC RWP NNN limit. Where concentrations in more than 80% of water samples collected in a five-year period (when flows are less than median at an associated flow monitoring site) exceed 0.075 mg/L, the cell is shaded magenta. P1 to P7 indicate 'rolling' five-year periods where P1 is 2009-2013 and P7 is 2015 to 2019. Sites where data were not available are excluded.

Site	Non-compliant sample results per five-year period (percent)						
	P1	P2	P3	P4	P5	P6	P7
Chatto Cr u/s Manuherikia	94	100		100	100	100	100
Dunstan Cr at Beattie Rd	5	5					5
Lauder Cr at Rail trail	7	10					
Manuherikia at Galloway	4	4					
Manuherikia at Larkhill	100	100	100	100	100	100	100
Manuherikia at Ophir	9	10	11	8	8		5
Pool Burn at Auripo Rd	12	16	67	67	67		
Poolburn at Cob Cottage							17
Thomsons Cr at SH85	32	50	63	50	47	41	40

Table 3-5: Summary of compliance with the ORC RPW ammoniacal-N limit. Where concentrations in more than 80% of water samples collected in a five-year period (when flows are less than median at an associated flow monitoring site) exceed 0.1 mg/L, the cell is shaded pink. P1 to P7 indicate 'rolling' five-year periods where P1 is 2009-2013 and P7 is 2015 to 2019. Sites where data were not available are excluded.

Site	Proportion non-compliant per five-year period (percent)						
	P1	P2	P3	P4	P5	P6	P7
Pool Burn at Auripo Rd	6	8	34	34	34		

Table 3-6: Summary of compliance with the ORC RWP DRP limit. Where concentrations in more than 80% of water samples collected in a five-year period (when flows are less than median at an associated flow monitoring site) exceed 0.01 mg/L, the cell is shaded pink. P1 to P7 indicate 'rolling' five-year periods where P1 is 2009-2013 and P7 is 2015 to 2019. Sites where data were not available are excluded.

Site	Proportion non-compliant per five-year period (percent)						
	P1	P2	P3	P4	P5	P6	P7
Chatto Cr u/s Manuherikia	100	100		100	100	100	100
Ida Burn at Auripo Rd	100	100	100	100	100		
Ida Burn at Blackstone H	100	100					
Lauder Cr at Rail trail	74	90		100	100	100	100
Manuherikia at Galloway	80	86	80	83	84	75	66
Manuherikia at Larkhill	63	50	55	70	60	50	100
Manuherikia at Omakau	94	90		100	67	58	58
Manuherikia at Ophir	96	96	95	96	100	96	96
Manuherikia u/s Chatto C	88	91		100	84	63	63
Manuherikia u/s Ida Burn	14	10					
Pool Burn at Auripo Rd	100	100	100	100	100		
Poolburn at Cob Cottage				100	100	100	100
Thomsons Cr at SH85	100	100	100	100	100	97	97

Table 3-7: Summary of compliance with the ORC RPW *E. coli* limit. Where concentrations in more than 80% of water samples collected in a five-year period (when flows are less than median at an associated flow monitoring site) exceed260 cfu/100 mL, the cell is shaded pink. P1 to P7 indicate 'rolling' five-year periods where P1 is 2009-2013 and P7 is 2015 to 2019. Sites where data were not available are excluded.

Site	Proportion non-compliant per five-year period (percent)						
	P1	P2	P3	P4	P5	P6	P7
Chatto Cr u/s Manuherikia					50	50	50
Dunstan Cr at Beattie Rd					4	5	5
Hills Cr at SH85							50
Ida Burn at Auripo Rd	45	54	34	34	34		
Manuherikia at Blackstone Hill	6	7	9	6	9	5	15
Manuherikia at Galloway	12	18	17	16	19	19	14
Manuherikia at Ophir	35	50	37	28	36	30	24
Manuherikia u/s Chatto C					17	13	13
Pool Burn at Auripo Rd	23	24	34	34	34		
Poolburn at Cob Cottage							17
Thomsons Cr at SH85	85	85	88	82	84	82	80

Table 3-8: Summary of compliance with the ORC RPW turbidity limit. Where values in more than 80% of water samples collected in a five-year period (when flows are less than median at an associated flow monitoring site) exceed 5 NTU, the cell is shaded pink. P1 to P7 indicate 'rolling' five-year periods where P1 is 2009-2013 and P7 is 2015 to 2019. Sites where data were not available are excluded.

Site	Proportion non-compliant per five-year period (percent)						
	P1	P2	P3	P4	P5	P6	P7
Dunstan Cr at Beattie Rd					4	5	5
Ida Burn at Auripo Rd	29	40	67	67	67		
Lauder Cr at Rail trail					25	25	25
Manuherikia at Blackstone Hill			25	23	18	20	24
Manuherikia at Galloway	6	5					
Manuherikia at Ophir	17	15	11	8	8		
Thomsons Cr at SH85	100	78	50	37	27	22	18

3.5.2 NPS-FM NOF attribute assessment

The numeric attribute states for ammoniacal-N are based on thresholds defined using annual median and maximum concentration statistics. We omitted these data from this evaluation because the overwhelming majority of data were at or below the analytical limits of detection (which were lower than the NPS-FM thresholds), and for several sites and years too few data exist for calculation of meaningful statistics. The numbers of results per site is indicated in Table 3-9.

Table 3-9: Number of ammoniacal-N concentration results available for each site annually over 2008 to 2019.

Site	Annual number of results for ammoniacal-N												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Chatto Cr u/s Manuherikia	.	8	18	.	.	.	.	.	3	9	.	.	38
Dunstan Cr at Beattie Rd	.	9	18	4	6	9	12	12	12	12	12	2	108
Hills Cr at SH85	.	.	.	.	.	.	.	.	.	.	5	2	7
Ida Burn at Auripo Rd	.	9	17	.	3	3	.	.	.	.	.	.	32
Ida Burn at Blackstone H	.	8	18	.	.	.	.	.	.	.	.	.	26
Ida Burn at SH85	.	9	17	.	3	3	.	.	.	.	.	.	32
Lauder Cr at Cattle Yard	.	.	.	.	.	.	.	.	3	7	.	.	10
Lauder Cr at Rail trail	.	8	18	.	.	.	.	.	3	9	.	.	38
Manuherikia at Blackstone Hill	.	9	18	.	3	3	6	12	12	12	12	2	89
Manuherikia at Falls Dam	.	8	18	.	.	.	.	.	.	.	.	.	26
Manuherikia at Galloway	23	23	28	23	22	25	12	12	12	12	12	2	206
Manuherikia at Larkhill	.	.	.	6	16	2	5	2	1	.	.	.	32
Manuherikia at Loop Rd	.	8	18	.	.	.	.	.	3	12	5	.	46
Manuherikia at Omakau	.	8	18	.	.	.	.	.	3	12	5	.	46
Manuherikia at Ophir	6	11	18	6	6	9	12	12	12	12	12	2	118
Manuherikia d/s Forks	.	.	.	.	.	.	.	.	3	9	5	2	19
Manuherikia u/s Chatto C	.	8	18	.	.	.	.	.	3	12	5	.	46
Manuherikia u/s Ida Burn	.	8	18	.	.	.	.	.	.	.	.	.	26
Pool Burn at Auripo Rd	.	9	18	.	3	3	.	.	.	.	.	.	33
Poolburn at Cob Cottage	.	.	.	.	.	.	.	.	3	9	5	2	19
Thomsons Cr at Race	.	.	.	.	.	.	.	.	3	15	16	2	36
Thomsons Cr at SH85	.	8	17	.	.	7	12	12	12	14	21	4	107
Total	**29**	**151**	**295**	**39**	**62**	**64**	**59**	**62**	**88**	**156**	**115**	**20**	**1140**

NNN attribute states are based on thresholds defined using median and 95th percentile concentration statistics. Assessment of Manuherikia River catchment site data against these thresholds are summarised in Table 3-10, with the number of results for each site included as Table 3-11.

Table 3-10: Classification of sites according to NPS-FM NNN statistical thresholds, based on 95th percentile (Pt) and median concentrations recorded in each calendar year. Cells shaded blue = attribute state A and green = attribute state B (see Table 2-4).

Site	Conc. statistic	Annual NNN statistic concentration value (mg/L)											
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Chatto Cr u/s Manuherikia	95th Pt		0.217	0.376						0.077	0.16		
	Median		0.085	0.164						0.048	0.086		
Dunstan Cr at Beattie Rd	95th Pt		0.024	0.223	0.145	0.106	0.33	0.136	0.179	0.176	0.56	0.147	0.087
	Median		0.019	0.05	0.094	0.046	0.034	0.022	0.028	0.051	0.058	0.099	0.076
Hills Cr at SH85	95th Pt											0.162	0.038
	Median											0.022	0.028
Ida Burn at Auripo Rd	95th Pt		0.066	1.406		0.182	0.039						
	Median		0.016	0.023		0.076	0.007						
Ida Burn at Blackstone H	95th Pt		0.057	1.126									
	Median		0.034	0.023									
Ida Burn at SH85	95th Pt		0.028	0.022		0.004	0.008						
	Median		0.005	0.006		0.004	0.006						
Lauder Cr at Cattle Yard	95th Pt									0.002	0.014		
	Median									0.002	0.002		
Lauder Cr at Rail trail	95th Pt		0.01	0.239						0.009	0.106		
	Median		0.007	0.035						0.005	0.006		
Manuherikia at Blackstone Hill	95th Pt		0.005	0.26		0.014	0.003	0.025	0.09	0.042	0.196	0.074	0.005
	Median		0.005	0.005		0.003	0.002	0.002	0.004	0.004	0.004	0.006	0.003
Manuherikia at Falls Dam	95th Pt		0.005	0.1									
	Median		0.005	0.005									
Manuherikia at Galloway	95th Pt	0.081	0.113	0.349	0.16	0.101	0.504	0.172	0.248	0.115	0.414	0.281	0.021
	Median	0.045	0.018	0.018	0.037	0.045	0.035	0.027	0.006	0.01	0.03	0.09	0.018
Manuherikia at Larkhill	95th Pt				2.2	3.2	1.43	2.5	1.8				
	Median				1.91	1.37	1.085	1.94	1.65	2.5			
Manuherikia at Loop Rd	95th Pt		0.005	0.1						0.004	0.1	0.01	
	Median		0.005	0.005						0.002	0.002	0.001	
Manuherikia at Omakau	95th Pt		0.019	0.368						0.059	0.423	0.103	
	Median		0.014	0.02						0.02	0.034	0.023	
Manuherikia at Ophir	95th Pt	0.069	0.137	0.381	0.202	0.13	0.49	0.247	0.288	0.173	0.388	0.418	0.076
	Median	0.028	0.027	0.045	0.072	0.072	0.084	0.04	0.025	0.04	0.041	0.155	0.066
Manuherikia d/s Forks	95th Pt									0.005	0.004	0.007	0.001
	Median									0.002	0.003	0.001	0.001
Manuherikia u/s Chatto Cr	95th Pt		0.022	0.375						0.02	0.414	0.29	
	Median		0.014	0.03						0.015	0.033	0.032	
Manuherikia u/s Ida Burn	95th Pt		0.01	0.288									
	Median		0.007	0.021									
Pool Burn at Auripo Rd	95th Pt		0.053	0.334		0.065	0.28						
	Median		0.005	0.005		0.007	0.24						
Poolburn at Cob Cottage	95th Pt									0.032	0.62	0.104	0.082
	Median									0.017	0.006	0.062	0.056
Thomsons Cr at Race	95th Pt									0.005	0.041	0.323	
	Median									0.002	0.002	0.001	
Thomsons Cr at SH85	95th Pt						0.68	0.395	0.417	0.409	0.338	0.478	0.31
	Median						0.3	0.112	0.094	0.066	0.081	0.207	0.26

Table 3-11: Number of NNN concentration results available for each site annually, 2008 to 2019.

Sites	Annual number of results for NNN												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Chatto Cr u/s Manuherikia	.	8	18	.	.	.	.	.	3	9	.	.	38
Dunstan Cr at Beattie Rd	.	9	18	4	6	9	12	12	12	12	12	2	108
Hills Cr at SH85	.	.	.	.	.	.	.	.	.	.	5	2	7
Ida Burn at Auripo Rd	.	9	17	.	3	3	.	.	.	.	.	.	32
Ida Burn at Blackstone H	.	8	18	.	.	.	.	.	.	.	.	.	26
Ida Burn at SH85	.	9	17	.	3	3	.	.	.	.	.	.	32
Lauder Cr at Cattle Yard	.	.	.	.	.	.	.	.	3	7	.	.	10
Lauder Cr at Rail trail	.	8	18	.	.	.	.	.	3	9	.	.	38
Manuherikia at Blackstone Hill	.	9	18	.	3	3	6	12	12	12	12	2	89
Manuherikia at Falls Dam	.	8	18	.	.	.	.	.	.	.	.	.	26
Manuherikia at Galloway	23	23	28	23	22	25	12	12	12	12	12	2	206
Manuherikia at Larkhill	.	.	.	6	16	2	5	2	1	.	.	.	32
Manuherikia at Loop Rd	.	8	18	.	.	.	.	.	3	12	5	.	46
Manuherikia at Omakau	.	8	18	.	.	.	.	.	3	12	5	.	46
Manuherikia at Ophir	6	11	18	6	6	9	12	12	12	12	12	2	118
Manuherikia d/s Forks	.	.	.	.	.	.	.	.	3	9	5	2	19
Manuherikia u/s Chatto C	.	8	18	.	.	.	.	.	3	12	5	.	46
Manuherikia u/s Ida Burn	.	8	18	.	.	.	.	.	.	.	.	.	26
Pool Burn at Auripo Rd	.	9	18	.	3	3	.	.	.	.	.	.	33
Poolburn at Cob Cottage	.	.	.	.	.	.	.	.	3	9	5	2	19
Thomsons Cr at Race	.	.	.	.	.	.	.	.	3	15	16	2	36
Thomsons Cr at SH85	.	8	17	.	.	7	12	12	12	14	21	4	107
Total	**29**	**151**	**295**	**39**	**62**	**64**	**59**	**62**	**88**	**156**	**115**	**20**	**1140**

Ammoniacal-N:

Data are available for 22 sites, but not continuously over the 12-year period of assessment. These data indicate:

- All but eight sites were categorised as NOF band A waters, indicating that there will be no toxic effects on sensitive aquatic life.
- The eight sites were classified in band B as a consequence of exceeding the annual maximum threshold concentration of 0.05 mg/L.
- The “Thomsons Cr at SH85” site was the only site to be classified in B state multiple times (three times).
- The largest annual maximum concentration recorded at any site in the 11 years of record was at the “Pool Burn at Auripo Rd” site in 2013 (0.35 mg/L, the most recent record for this site).

- These classification results should be considered cautiously:
  - in several cases fewer than ten results are available in an annual period
  - many results are reported as less than the analytical limit of detection, and the detection limit changed in July 2014 (discussed in Section 3.2 and Section 3.3).

NNN:

- All sites but one were graded in the NOF A band, indicating that there are unlikely to be toxic effects on sensitive aquatic life.
- The Manuherikia at Larkhill site was graded in band B, although limited data were available for this site.

E. coli:

Robust assessment of *E. coli* data against the four NOF *E. coli* attribute states was only possible at a handful of sites where sufficient data (60 measurements over five years) were available. Data for the popular swimming sites on the Manuherikia River at Ophir and Galloway indicate the overall attribute classification varied from grade D ('orange') to C ('yellow'), indicating that the predicted average infection risk to swimmers varies from at least 3% to 7% (Table 3-12).

Table 3-12: Overall grading of selected Manuherikia River catchment sites following assessment of *E. coli* data against the four *E. coli* attribute states in the NPS-FM. Colour gradings are as defined in Table 2-5. Underlined gradings indicate fewer than 60 (but more than 50) results were available for the five-year period. The actual number of results in each period is given in Table F-1.

Site	Period and grade						
	2009/13	2010/14	2011/15	2012/16	2013/17	2014/18	2015/19
Dunstan Cr at Beattie Rd				Blue	Blue	Green	Orange
Manuherikia at Blackstone Hill						Blue	Green
Manuherikia at Galloway	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Orange
Manuherikia at Ophir	Yellow	Orange		Orange	Yellow	Orange	Orange
Thomsons Cr at SH85					Red	Red	Red

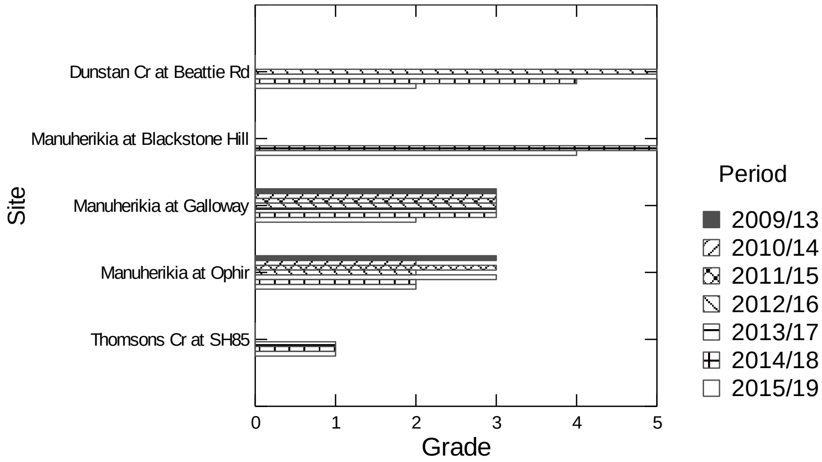

Figure 3-5: Overall grading of selected Manuherikia River catchment sites over successive five-year periods based on an assessment against the four *E. coli* attribute states in the NPS-FM. Grade of 5=Blue, 4=Green, 3=Yellow, 2=Orange, and 1=Red (described in Table 2-5).

3.6 Estimates of nutrient loads

Nutrient loads were calculated for NNN and DRP – these are summarised as annual values in Appendix I (Table I-1 and Table I-2), with summary statistics in Table I-3 to Table I-11. The latter provide estimates derived from grab samples as well, along with estimates of uncertainty. Here we summarise loads and estimates graphically. The generally low ammoniacal-N concentrations (with much of the data at most sites being at or near the analytical detection limit) limited our ability to identify a reliable flow-concentration relationship, which underpins the load estimation technique. Other load estimation techniques would also be limited by the relatively weak flow-concentration relationship.

A time-series of NNN and DRP loads are provided in a series of plots in Figure 3-6, where model predictions are provided together with instantaneous loads (the product of grab sample concentrations and daily average flows on the day of sampling, expressed in a suitable unit such as "kg/year").

Points to note:

- NNN and DRP loads are distinctly seasonal at all sites.
- The load estimates should be used with care:
  - Load estimation is limited by availability of concentration calibration data, and at some sites, flow measurements.
  - The models are relatively simple and do not capture the minima and maxima perfectly.
  - Despite these limitations, the results help identify river reaches where nutrient inputs occur, and to a limited extent the tributary sources.

- It was not possible to predict DRP loads with reasonable certainty at the Poolburn at Cobb Cottage site, and the DRP load estimates for the Chatto Creek u/s confluence are also limited, mainly because of the extent of calibration data.
- At several sites, flow data were not available for at least part of the period 2011-2016.

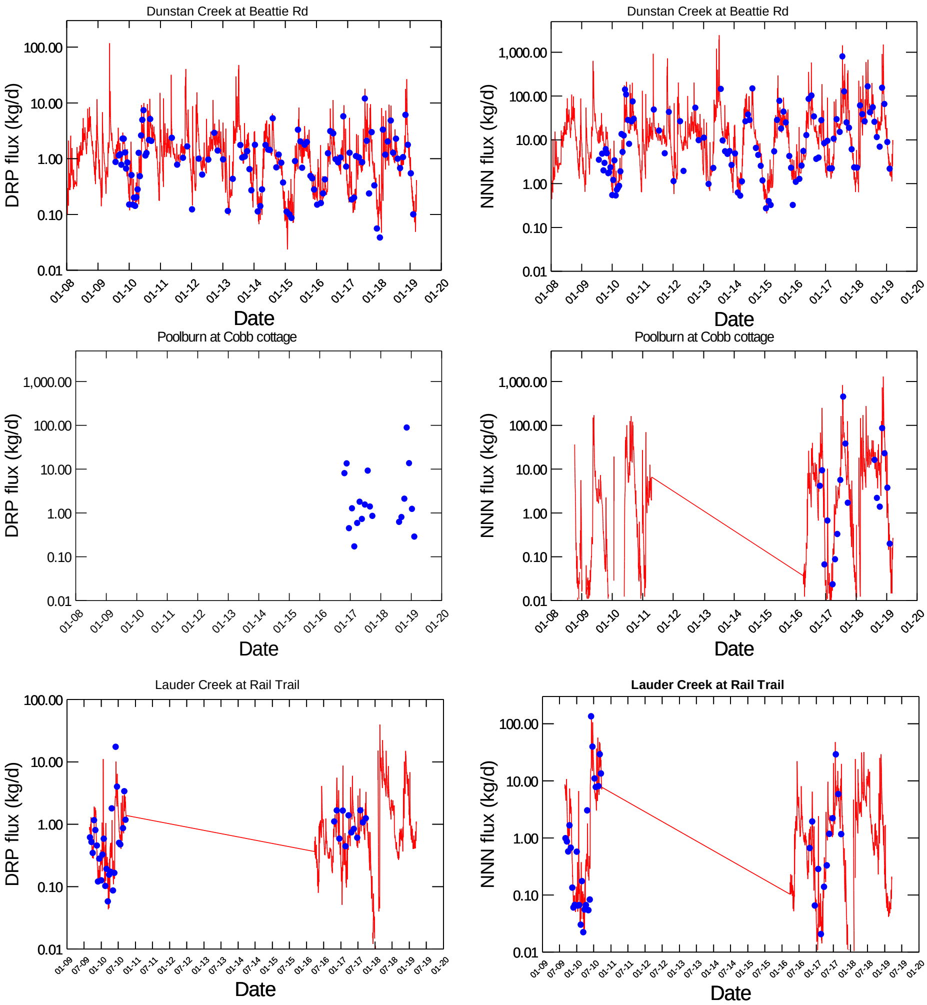

Figure 3-6: Time series of daily average DRP and NNN flux estimates for sites in the Manuherikia River catchment. The blue dots represent the instantaneous flux derived from the grab sample concentration value and the daily average flow estimated for the date of sample collection. The red line is daily average flux estimate. Note *y*-axis scales vary, and have a $\log_{10}$ scale. The line joining the two periods for which load estimates exist is an artefact of the graphical software.

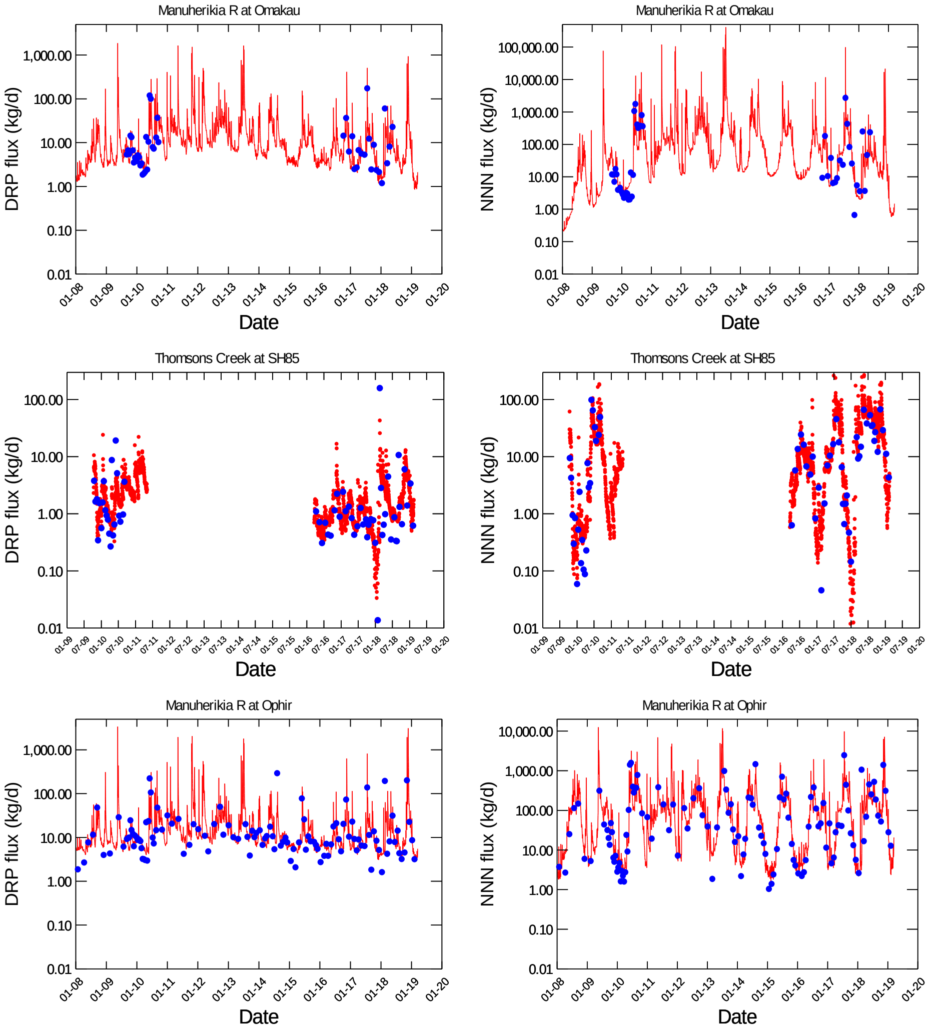

Figure 3-6 (Continued)

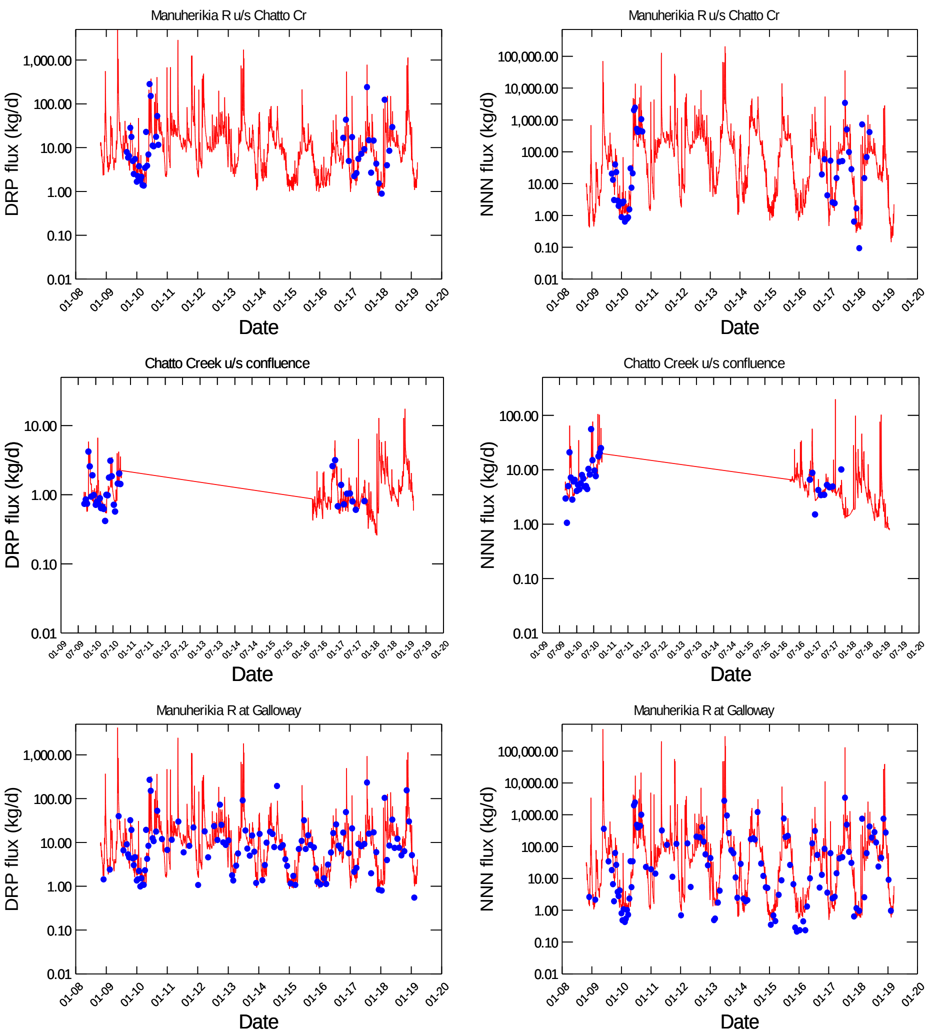

Figure 3-6 (Continued). The line joining the two periods for which load estimates exist is an artefact of the graphical software.

The seasonal magnitude of NNN and DRP loads is summarised in Figure 3-7. At most sites, NNN loads are largest in winter, followed by approximately equal magnitude loads in autumn and spring. Smallest loads occur in summer, which likely equates with higher periphyton growth (discussed later in Section 4.3). Seasonal variation appears less pronounced for DRP, with the exception of the Chatto Creek site.

It would be informative to relate estimated nutrient loads at those sites where such estimates are available to land use information. This may provide insights regarding the effect that land use change over time has had on water quality and stream condition.

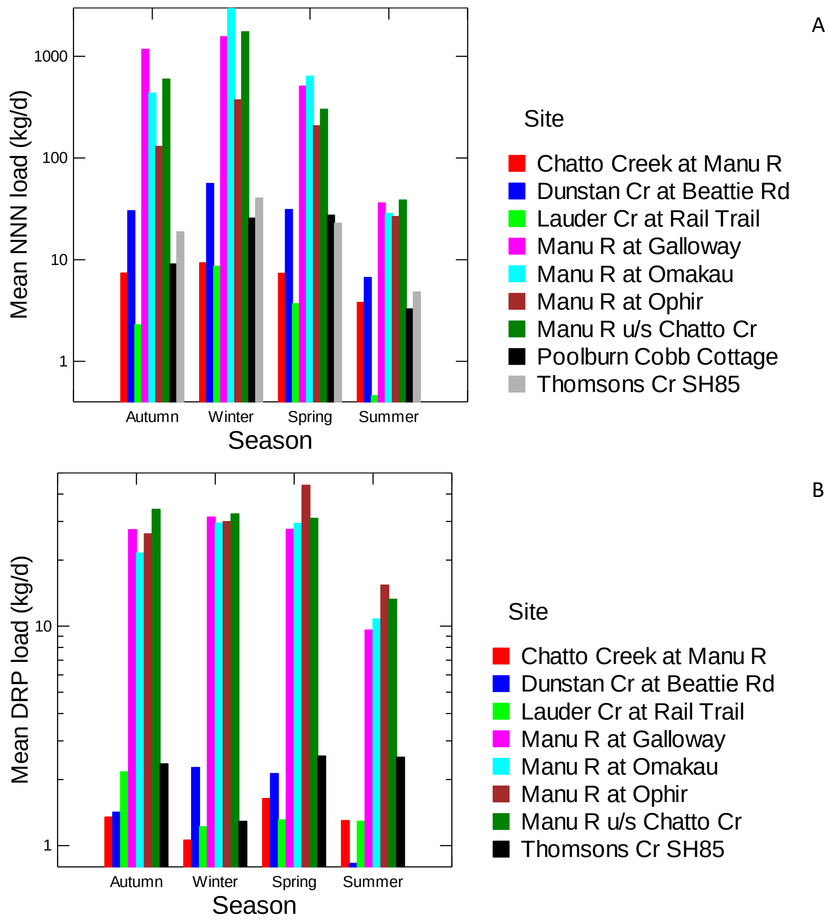

Figure 3-7: Seasonal DRP and NNN flux estimates for sites in the Manuherikia River catchment, based on data collected over 2009 to 2019. Note *y*-axes have a $\log_{10}$ scale.

4 Ecological data

It is important to consider the hydrological conditions that existed during the assessment periods. These were summarised in Section 3.1.

4.1 Habitat quality

Habitat assessment scores for each of six Manuherikia River sites surveyed (refer Table 2-6) in December 2017 are summarised in Table 4-1. The results for ten survey components are presented in tables and figures from the most upstream site (Downstream of Fork) to the most downstream site (Galloway).

4.1.1 Vegetation and riparian margins

Bank vegetation assessment scores ranged between three and six. Generally mature shrub and sparse tree cover was greater than cover of young exotic or long rank grass. Only at Ophir were regenerating native or flaxes/sedges/tussock more prevalent than dense exotic vegetation. The width of riparian vegetation was consistently high, ranging between scores of nine and ten. Riparian width at Downstream of Fork, Loop Road, Blackstone Hill and Ophir was ≥30 m in each case, while at Omakau and Galloway it was 15 m. Riparian shade was very low at all sites, ranging between scores of one and three. At Omakau and Galloway there was no stream shading, while at Downstream of Fork, Loop Road and Ophir 10% of the stream bed was shaded and at Blackstone Hill 15% was shaded.

4.1.2 Invertebrate and fish: habitat diversity and cover diversity

Invertebrate habitat diversity through different substrate types (such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes and periphyton) ranged between seven and ten across each of the sites. Blackstone Hill and Ophir scored the highest (10), followed by Omakau and Downstream of Fork (9), Loop Road (8), and Galloway (7).

Invertebrate habitat abundance (percentage of substrate favourable for sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) colonisation) ranged between seven and ten. Downstream of Fork, Ophir, Omakau and Galloway each received the highest score (10), followed by Loop Road (8) and Blackstone Hill (7).

Fish cover diversity provided through spatial complexity of different substrate types (such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders and cobbles) ranged between three and seven. Loop Road received the highest score (7), followed by Ophir (6), Blackstone Hill, Omakau and Galloway (5), and Downstream of Fork (3).

Fish cover abundance (the percentage of fish cover available) was moderate to high across the sites, ranging between five and nine. Downstream of Fork and Loop Road had the highest scores (9), followed by Blackstone Hill and Omakau (7), Ophir (6) and Galloway (5).

4.1.3 Hydraulic heterogeneity and bank erosion

Hydraulic heterogeneity (number of hydraulic components such as pool, riffle, fast run, slow run, rapid cascade, waterfalls) scores ranged from five to ten. Blackstone Hill (10), Omakau, Ophir and Galloway (9) each received high scores, while Downstream of Fork and Loop Road (5) received moderate scores. Bank erosion (percentage of the stream bank recently/actively eroding due to scouring at the waterline, slumping of the bank or stock pugging) was low across all sites, with Galloway (10), Downstream of Fork, Blackstone Hill and Omakau (9.5), Loop Road and Ophir (9) each exhibiting <5% erosion.

Table 4-1: Habitat condition scores (0–10) at six sites on the Manuherikia River surveyed on 20-21/12/17. Higher scores reflect more favourable conditions.

Site	Deposited sediment (%)	Invertebrate habitat diversity (N)	Invertebrate habitat abundance (%)	Fish cover diversity (N)	Fish cover abundance (%)	Hydraulic heterogeneity	Bank erosion (%)	Bank vegetation (N)	Riparian width (m)	Riparian shade (%)	Total Score
Downstream of Fork	10	9	10	3	9	5	9.5	5	10	2	72.5
Loop Road	10	8	8	7	9	5	9	5	10	2	73
Blackstone Hill	9	10	7	5	7	10	9.5	5	10	3	75.5
Omakau	8	9	10	5	7	9	9.5	3	9	1	70.5
Ophir	9	10	10	6	6	9	9	6	10	2	77
Galloway	9	7	10	5	5	9	10	4	9	1	69

4.1.4 Substrate composition

The percentage of stream bed covered by deposited fine sediment was low at all sites, with Downstream of Fork and Loop Road (10), Blackstone Hill, Ophir and Galloway (9), and Omakau (8) each recording <10% cover.

4.2 Sediment

Results from instream visual estimates of the proportion of stream embedded with fine sediment are summarised in Table 4-2. Stream embeddedness was generally low at all sites. Across all sampling events the highest average embeddedness was observed at Blackstone Hill (~7%), while the lowest was observed at Downstream of Fork (<1%). The highest percentage of embedded streambed of any sampling event was also observed at Blackstone Hill during December 2016 sampling (10%). Overall, little variability was observed between sampling events at any of the sites.

Table 4-2: Proportion (mean ± Standard Error) of stream embeddedness at six Manuherikia River sites surveyed on four separate occasions over 2016/17.

Date	Extent of stream embeddedness at each site (%)					
	Downstream of Fork	Loop Road	Blackstone Hill	Omakau	Ophir	Galloway
17/12/2016	0.7 ± 0.1	2.4 ± 0.5	10.0 ± 0.6	6.1 ± 1.1	1.6 ± 0.1	5.6 ± 0.2
21/02/2017	0.6 ±0.1	0.4 ± 0.1	3.2 ± 0.4	5.1 ± 0.6	5.5 ± 0.5	4.2 ± 0.4
31/03/2017	0.5 ± 0.1	2.6 ± 0.5	7.6 ±0.7	6.5 ± 0.7	6.7 ± 0.8	4.1 ± 0.6
26/04/2017	0.6 ± 0.1	0.7 ± 0.1	6.8 ±0.3	2.8 ± 0.2	4.6 ± 0.4	3.2 ± 0.4
Average	**0.6 ± 0.4**	**1.5 ± 1.7**	**6.9 ± 3.4**	**5.1 ± 3.3**	**4.6 ± 2.9**	**4.3 ± 1.9**

4.3 Periphyton

4.3.1 Cover and community composition

Periphyton communities in the Manuherikia River were surveyed at six sites on four occasions between December 2016 and April 2017. River flows during these surveys are summarised graphically in Figure 4-1 and listed in Table 4-3 along with the long term monthly median river flow.

Figure 4-1 indicates that all four surveys were carried out when flows were at (or mostly less) than median. However, based on monthly median flows for 2008-2019, only one of the four surveys – February 2017 – coincided with flows typical for the time of year (Table 4-3). The December 2016 surveys at all sites occurred while flows were in recession following several months of flow greater than median. The February 2017 survey followed an event on 23 January 2017 (28 days previously), when flows peaked at 38,000 L/s and 55,000 L/s at the Ophir and Campground sites, respectively. Flows of this magnitude were greater than and approximately equal to the 95th percentile flows for these sites, respectively. The March 2017 and April 2017 surveys also followed flood events, although these events were much smaller.

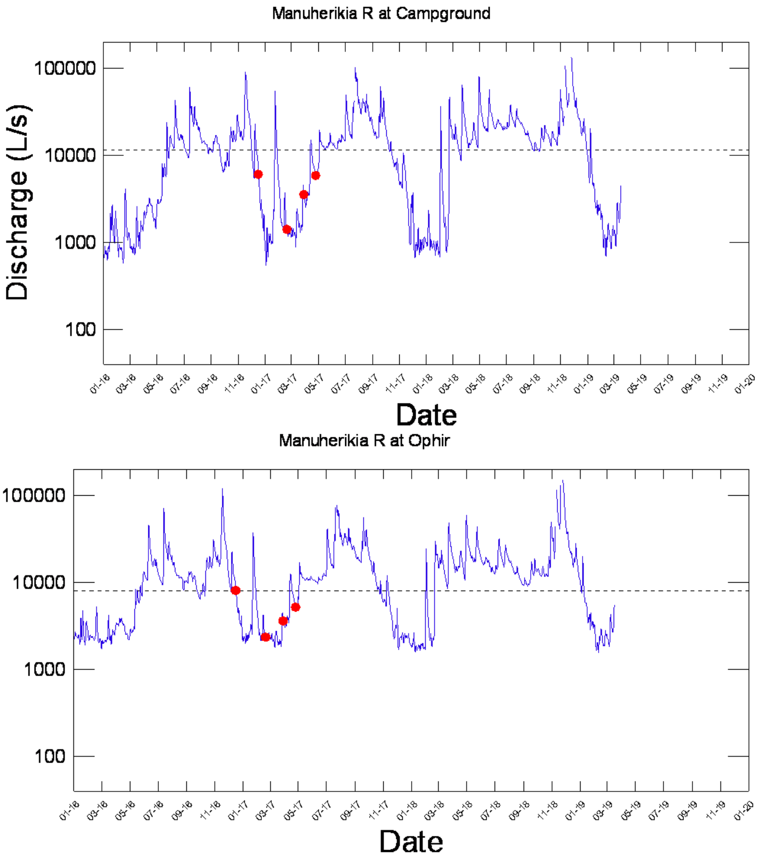

Figure 4-1: Time series of flows (discharge) since January 2016 for two flow reference sites in the Manuherikia River catchment; Campground (top) and Ophir (bottom). The red dots indicate flows at the times of each periphyton survey, and the broken horizontal lines are the defined median flow values for the two reference sites (11,600 and 8,010 L/s, respectively). Note *y*-axes have a $\log_{10}$ scale.

Table 4-3: Comparison of flow at time of survey with long term monthly median flow values for the period 2008 to2019. Flows at time of sampling exceeding long-term median values are in red.

Sample date	Flow in Manuherikia R at Campground (L/s)		Flow in Manuherikia R at Ophir (L/s)	
	At time of sampling	Monthly median (2008-2019)	At time of sampling	Monthly median (2008-2019)
16/12/2016	5,998	1,965	8,011	3,485
19/02/2017	1,399	1,485	2,322	2,534
29/03/2017	3,522	1,964	3,584	2,938
25/04/2017	5,802	4,486	5,137	3,814

Flow data were also available for the upper Manuherikia catchment (Figure 4-2), but the effect of the Falls Dam should be accounted for when considering the impact on periphyton and stream condition in the lower catchment. Unfortunately flow data were not available for the Manuherikia at Falls Dam site for the survey period.

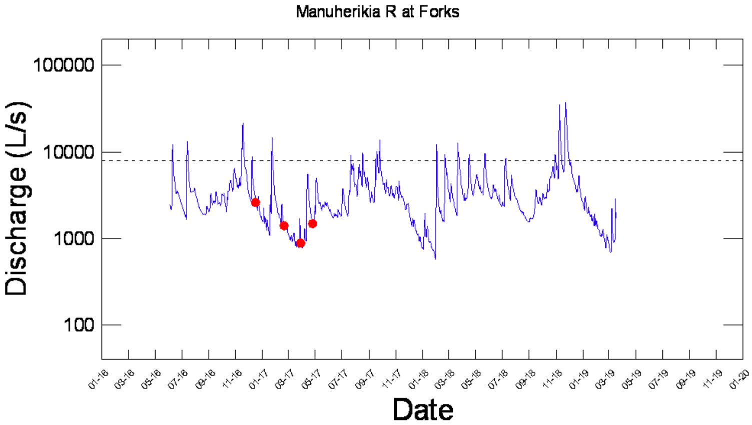

Figure 4-2: Time series of flows since January 2016 for the Manuherikia River at Forks site. The red dots indicate flows at the times of biological surveys, and the broken horizontal line is the defined median flow value for the Ophir reference sites (8,010 L/s). Note *y*-axis has a $\log_{10}$ scale.

Total periphyton cover at each site is presented in Figure 4-3, and the composition of the periphyton communities and Periphyton Index Scores (PIS) according to the methods of (Biggs and Kilroy 2002), are presented in Table 4-4. In general, periphyton communities dominated by thin mat algae are typical of clean streams with higher stream water flow and low concentrations of nutrients, while thicker mats of algae and long filamentous algae are typical of increasingly enriched conditions, low flows, increasing water temperatures and/or diffuse or point-source nutrient inputs. Scores of up to 1.9 are classified as 'very poor', those of 2–3.9 as 'poor to moderate', those of 4–5.9 as 'moderate', those of 6–7.9 as 'good', and those of 8–10 as 'very good' (Biggs and Kilroy 2002).

At the most upstream site, Downstream of Fork, median periphyton cover was 42% and thin light brown films dominated on each sampling occasion except April 2017 when thick green / light brown mat became the dominant type. The change in community reflected a slight change in the periphyton index ranking from 'very good' (9–9.9) to 'good' (6.6) in April 2017, based on categories in Biggs and Kilroy (2002).

Loop Road had the highest median periphyton cover (83%) of the six sites although, the results were also the most variable between sampling occasions. Thin light brown mats were dominant at this site in December 2016, however, thick green / light brown mat algae then became highly abundant, dominating the community during February, March and April 2017. The changes in the community reflect a decline in water quality from 'very good' (9.1) in December 2016 to 'moderate' (4.5–5.1), to 'poor to moderate' (3.7) in the following months.

At Blackstone Hill, median periphyton cover was equal lowest (42%), with the community dominated by thin light brown films in December 2016, long green filaments in February 2017, short green filaments in March 2017, and long brown / reddish filaments in April 2017. This reflected a change in water quality from 'very good' (10) in December 2016 to 'moderate' (4.7), to 'good' (6–6.5) in the following months.

Further downstream at Omakau, Ophir and Galloway the median periphyton cover ranged between 61–80% and was heavily dominated by thin light brown films on each sampling occasion, with other periphyton types being rare or absent. As such the periphyton index scores reflected 'very good' water quality at each of Omakau (average 9.7), Ophir (average 9.9) and Galloway (average 9.8) on each sampling occasion.

Benthic cyanobacteria (identified as thin, medium or thick, black/dark brown mats in Table 4-4), were observed at Downstream of Fork, Ophir and Galloway in low abundance (<10% cover). Cyanobacteria were absent from both the Omakau and Loop Road sites.

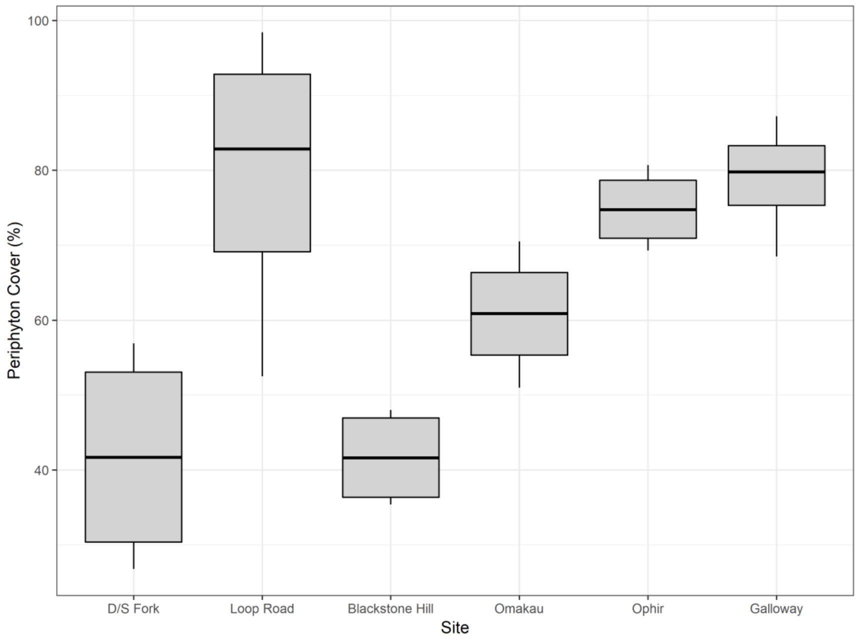

Figure 4-3: Summary of periphyton cover recorded at six sites on the Manuherikia River across four surveys between December 2016 and April 2017.

Table 4-4: Composition of the periphyton communities and Periphyton Index Scores at six sites on the Manuherekia River sampled on four occasions between December 2016-April 2017. The dominant periphyton type on each sampling occasion is in bold. G=Green, LBr = light brown, B/DBr = black/dark brown, Br/R = brown/reddish. Periphyton scores range from 0 to 10, with higher scores indicative of higher water quality.

Site	Date	Thin mat/film (<0.5 mm thick)			Medium mat (0.5–3 mm thick)			Thick mat (>3 mm thick)		Short filaments (1 - 2 cm)		Long filaments (>2 cm long)		Periphyton Score (0–10)
		G	LBr	B/DBr	G	LBr	B/DBr	G/LBr	B/DBr	G	Br/R	G	Br/R	
Downstream of Fork	17/12/2016	–	25.5	–	–	0.8	–	0.5	–	0.5	–	–	–	9.9
	20/02/2017	–	17.8	–	–	12.8	–	–	–	1	–	0.1	–	9
	30/03/2017	–	37.3	–	–	3	9.7	0.5	–	1.4	–	–	–	9.5
	26/04/2017	–	11.3	–	–	7.3	10	22.5	3.9	1.6	–	0.5	–	6.6
Loop Road	17/12/2016	9.8	39.5	–	–	1.5	–	0.5	–	1.2	–	0.1	–	9.1
	20/02/2017	–	8	–	–	16.3	–	39	–	1	–	10.5	–	5.1
	30/03/2017	–	–	–	–	18.5	–	69.8	–	0.1	–	2.6	–	4.5
	26/04/2017	–	–	–	–	1.8	–	89	–	–	–	12.4	–	3.7
Blackstone Hill	17/12/2016	–	48	–	–	–	–	–	–	–	–	–	–	10
	20/02/2017	–	9	–	–	1	–	–	–	7.3	–	18.1	–	4.7
	30/03/2017	–	10.3	–	–	3.1	–	1.3	–	14.6	–	7.5	–	6.5
	26/04/2017	–	6	–	–	3	0.8	1.5	0.8	1.2	3.7	3	26.8	6
Omakau	17/12/2016	–	56.8	–	–	–	–	–	–	–	–	–	–	9
	20/02/2017	–	51	–	–	–	–	–	–	–	–	–	–	10
	30/03/2017	–	65	–	–	–	–	–	–	–	–	–	–	10
	26/04/2017	2.3	68.3	–	–	–	–	–	–	–	–	–	–	9.9
Ophir	17/12/2016	–	71.3	–	–	8.5	0.3	–	–	0.7	–	–	–	9.6
	20/02/2017	–	69	–	–	–	0.3	–	–	–	–	–	–	10
	30/03/2017	–	78	–	–	–	–	–	–	–	–	–	–	10
	26/04/2017	–	71	–	–	–	–	–	–	0.5	–	–	–	10
Galloway	17/12/2016	–	56	–	–	9	–	–	–	3.5	–	–	–	9.4
	20/02/2017	–	82	–	–	–	–	–	–	–	–	–	–	10
	30/03/2017	–	86	–	–	–	–	–	–	0.4	–	0.8	–	9.9
	26/04/2017	–	75.8	1.5	–	–	–	–	–	0.3	–	–	–	10

4.3.2 Compliance with periphyton guidelines

The extent of long (>2 cm) filamentous periphyton cover at each of the six Manuherikia River sites are compared with the Schedule 15 and provisional national periphyton cover guideline for aesthetics/recreation and trout habitat and angling in Figure 4-4. Cover was very low at four of the five sites (Downstream of Fork, Galloway, Loop Road, Omakau and Ophir) and did not come close to exceeding the filamentous periphyton cover guideline of 30%. At Blackstone Hill long, filamentous periphyton cover was notably higher than at the other sites, and in April 2017 it exceeded the guideline (34%).

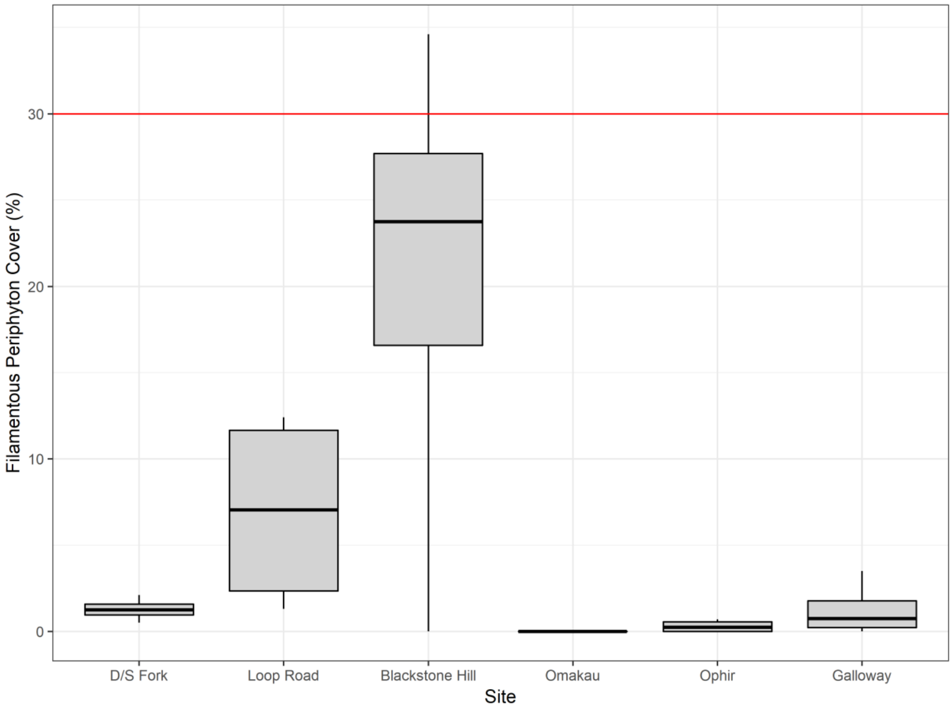

Figure 4-4: Extent of long filamentous periphyton cover at the six Manuherikia River sites surveyed on four occasions between December 2016 and April 2017. The red line represents the ORC RPW Schedule 15 guideline and the national periphyton cover guideline for long, filamentous algae (30% cover) (Biggs 2000).

The extent of thick mat periphyton cover at each of the sites is compared with the national periphyton cover guideline for aesthetics/recreation in Figure 4-5. Cover was very low at four of the five sites (Blackstone Hill, Downstream of Fork, Galloway, Omakau and Ophir) and did not come close to exceeding the mat cover guideline of 60%. At Loop Road, the cover of thick mat periphyton varied widely, was generally higher than at the other sites, and in March and April 2017 exceeded the guideline value (70% and 89%, respectively).

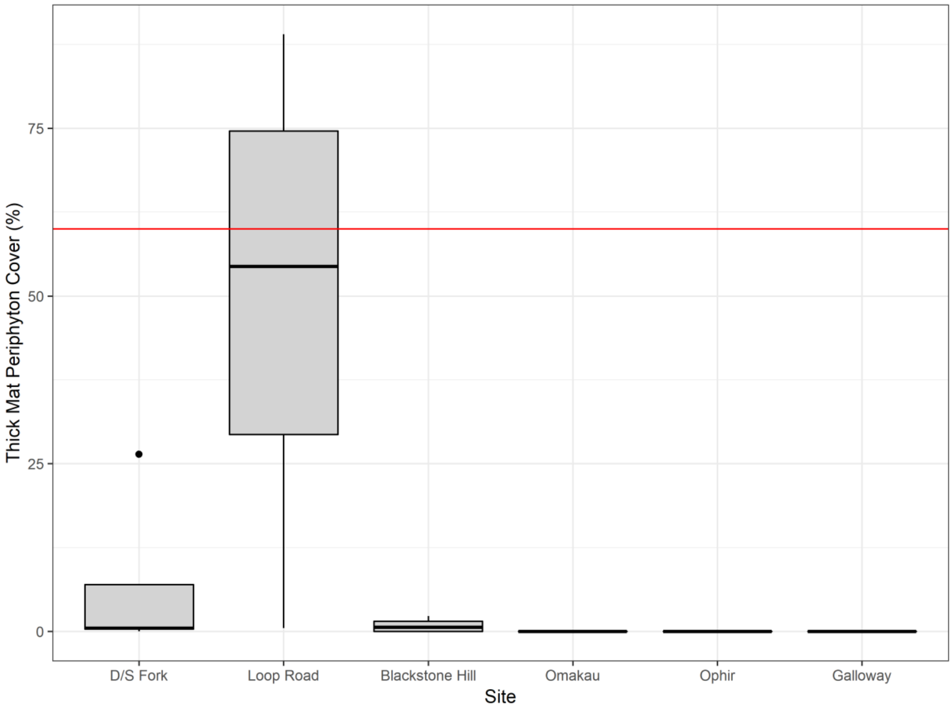

Figure 4-5: Extent of thick mat periphyton cover at the six study sites. The red line represents the national periphyton cover guideline for thick mat periphyton (60% cover) (Biggs 2000).

4.4 Macroinvertebrates

The results of macroinvertebrate surveys undertaken on three occasions over the 2016/17 summer at six Manuherikia River mainstem sites are summarised in Table 4-5 and the plots in Figure 4-6.

At the Downstream of Fork site, the number of taxa (median 25 taxa) was the second highest of the six sites and comprised predominantly Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) taxa (median 16 taxa, 62% of all taxa). The Macroinvertebrate Community Index (MCI) score was the highest of all the sites, and given the large proportion of EPT taxa, was classed as 'excellent' during each sampling event (median score 120). The Semi-Quantitative Macroinvertebrate Community Index (SQMCI) score was also the highest of all the sites and was classed as 'excellent' on each sampling occasion (median score 6.7), with this classification driven by the high abundance of EPT taxa. Larvae of the common mayfly *Deleatidium* sp. were the most abundant macroinvertebrate taxa during December 2016 and April 2017 sampling, classed as 'very, very abundant', although *Deleatidium* sp., riffle beetles (Elmidae), and the caddisfly larvae *Olinga* sp., were equally abundant during February 2017 sampling, being classed as 'very abundant'.

At Loop Road, the number of taxa (median 27 taxa) was the highest of the study sites, although EPT taxa did not make up a large proportion of the community (median 11 taxa, 40% of all taxa). The high taxa richness was largely derived from Crustacea, Diptera and Mullusca. Consequently, the MCI score was the equal lowest of the study sites, and was classed as 'fair' during each sampling event (median score 95). The SQMCI score was also the lowest of all the sites and was classed as 'poor' on each sampling occasion (median score 3.5), with this classification driven by the high abundance of relatively pollution-insensitive taxa. The mud snail, *Potamopyrgus antipodarum*, was the most abundant species in December 2016, being 'very abundant'. However, in February 2017 Elmidae, the crustacean Cladocera, the Chironomid midge larvae Tanytarsini, *Deleatidium* sp., *P. antipodarum*, worms (Oligochaeta), and the caddisfly larvae *Oxyethira albiceps* were the most common taxa, each being 'very abundant'. In April 2017 *P. antipodarum* and Oligochaeta were again the most abundant taxa and were 'very, very abundant'. Chironomid midge larvae, *Potamopyrgus antipodarum* and Oligochaeta are often associated with disturbed stream reaches, particularly where there is high periphyton biomass. They can become very abundant when periphyton is prolific, such as in enriched waterways or stream reaches that have experienced a prolonged period of stable flows. As a result, most of these taxa give rise to low MCI tolerance scores.

At Blackstone Hill, the number of taxa (median 18 taxa) was the equal lowest of the six sites, with half of the community richness comprising EPT taxa (median 9 taxa, 50% of all taxa). The MCI scores ranged between 'fair' (94) and 'good' (102) with the median score placing the site at the high end of the 'fair' category (97). The SQMCI score ranged between 'fair' (4.2) and 'excellent' (7.2) with the median score (6.5) being within the 'excellent' category. The higher scores were in part due to *Deleatidium* sp. that were 'very, very abundant' (it was the most abundant taxon during February and April 2017 sampling). The lower scores in December 2016 reflected a mixed community where Elmidae, the Chironomid midge larvae Orthocladiinae, the blackfly larvae *Austrosimulium* sp., *Deleatidium* sp., Oligochaeta and the caddisfly larvae *Pycnocentrodes* sp. were the most common species, present in 'abundant' numbers.

A median of 22 taxa were found at Omakau, with half of those being EPT taxa (median 10 taxa, 50% of all taxa). The MCI scores fell in the 'good' category on each sampling occasion (median score 107) as did the SQMCI scores (median score 5.5). *Pycnocentrodes* sp. was the most common taxa in December 2016, being 'very, very abundant'. In February 2017, *Deleatidium* sp. and *Pycnocentrodes* sp. were equally common and classed as 'very, very abundant' while in April 2017 *Deleatidium* sp. and *P. antipodarum* were the most common taxa ('very, very abundant').

At Ophir, the number of taxa (median 18 taxa) was the equal lowest of the study sites and EPT taxa represented less than half of that richness (median 18 taxa, 44% of all taxa). The MCI scores ranged between 'fair' (96) and 'good' (109) with the median score placing the site at the high end of the 'fair' category (99). In contrast, SQMCI scores ranged between 'good' (5.2) and 'excellent' (7), with the median score being firmly within the 'excellent' category (6.8). The lower December score was in part influenced by 'very, very abundant' numbers of *Pycnocentrodes* sp., , and because the sensitive *Deleatidium* sp. was the most common taxon recorded during February and April 2017 (classed as 'very, very abundant').

At Galloway, a median of 21 taxa were found, with less than half of those being EPT taxa (median 9 taxa, 43% of all taxa). The MCI score fell within the 'fair' category during each sampling event (median score 95). In contrast, SQMCI scores ranged between 'fair' (4.9) and 'excellent' (7), with the median score falling within the 'excellent' category (6.6). Large numbers of *Deleatidium* sp. were largely responsible for the high scores. In December 2016, *Deleatidium* sp., *P. antipodarum* and *Pycnocentrodes* sp. were the most common taxa, although they were only classed as 'abundant'. However, in February and April 2017, *Deleatidium* sp. was the most common taxon, classed as 'very, very abundant'.

Table 4-5: Macroinvertebrate community composition at six sites on the Manuherikia River catchment based on the results of three surveys between December 2016 and April 2017. Relative abundance scores are coded as: Rare = R, Common = C, Abundant = A, Very Abundant =VA, Very Abundant = VVA. Sampling event dates are coded as: mm/yy.

Taxon/species	MCI score	Relative abundance score by site and sampling event																	
		D/s of Fork			Loop Road			Blackstone Hill			Omakau			Ophir			Galloway		
		12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17
ACARINA	5				R	C		R											R
CNIDARIA							R												
Hydra sp.	3				R	C													
COLEOPTERA																			
Berosus sp.	5										R								
Dytiscidae	5										R								
Elmidae	6	A	VA	VA	A	VA	VA	A	A	A	C	R	C	C	C	A	R	C	A
CRUSTACEA																			
Cladocera	5				R	VA	C								C				
Ostrocoda	3														R				R
Paracalliope fluviatilis	5				R	R	C				C		R	R	C	R		C	R
Paraleptamphopus sp.	5				R														
DIPTERA																			
Aphrophila sp.	5	C	R	C															
Austrosimulium sp.	3	VA	C	R	A			A	R	C	A	VA	C	A	C	C	C	R	A
Ceratopogonidae	3							C	C	C				R					
Empididae	3	R	R	R	R	C	A												
Eriopterini	9	R	R	C			R		R	R	R		R			R			
Maoridiamesa sp.	3		R	R	R	R	C			R									
Muscidae	3			R			C			R									
Orthocladiinae	2	A	R	A	A	A	VA	A	A	C	C	C	C	C	C	R	C	R	R
Polypedilum sp.	3										R								
Tanypodinae	5					R	C	R	R		R								
Tanytarsini	3	R		R	A	VA	VA	R	C	R	A	C		C	R			R	R
EPHEMEROPTERA																			
Atalophlebioides cromwelli	9				R														
Austroclima sp.	9	R		C						A		R	C	C	C	A		R	
Coloburiscus humeralis	9	C	R	R															
Deleatidium sp.	8	VVA	VA	VVA	A	VA	VA	A	VVA	VVA	VA	VVA	VVA	VA	VVA	VVA	A	VVA	VVA
Nesameletus sp.	9			R								R			R			R	

Table 4-5 (continued): Macroinvertebrate community composition at six sites on the Manuherikia River catchment based on the results of three surveys between December 2016 and April 2017.

Taxon/species	MCI score	Relative abundance score by site and sampling event																	
		D/s of Fork			Loop Road			Blackstone Hill			Omakau			Ophir			Galloway		
		12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17
HIRUDINEA	3																	R	
MEGALOPTERA																			
Archichauliodes diversus	7	C	C	C		R	R			R	R	R	C	R	R	R		R	R
MOLLUSCA																			
Gyraulus sp.	3						R												R
Physa / Physella sp.	3					R						R	R			R		R	C
Potamopyrgus antipodarum	4				VA	VA	VVA	R		R	C	A	VVA	A	A	VA	A	A	VA
Sphaeriidae	3				R									R					
NEMATODA	3					C	A	R	R										
NEMERTEA	3						R			R	R	R	A		C	R		C	C
OLIGOCHAETA	1	C	C	VA	A	VA	VVA	A	VA	A	A	A	VA	A	A	A	C	A	A
PLATYHELMINTHES	3						C						C			C		R	C
PLECOPTERA																			
Stenoperla sp.	10	C	C	C															
Zelandobius sp.	5		R	A		R	VA		C	A			R			R		R	R
Zelandoperla sp.	10		C	R															
TRICHOPTERA																			
Aoteapsyche sp.	4	A	A	A	R	C	A	R	A	A	C	A	A	C	A	A	C	A	A
Beraeoptera roria	8	R	R	C								R				R			
Confluens sp.	5	R	R																
Costachorema sp.	7		R	R		R	R	R		R	R	R	R	C					R
Hudsonema amabile	6					R	C		R	C	R		R			C		R	
Hydrobiosis sp.	5	R	R	A	C	A	A	C	C	A	C	C	C	C	C	C	R	C	C
Neurochorema sp.	6			R	R		A	R		R									
Olinga sp.	9	VA	VA	VA		R	R	R		A	R		C	R		R			R
Oxyethira albiceps	2		R	R	A	VA	A		R	R	R			R					
Philorheithrus agilis	8			R															
Plectrocnemia maclachlani	8	R	R								R						R		
Psilochorema sp.	8	R	R	A	C	C	A	R	R	C		C	C			C		C	C
Pycnocentria sp.	7	C	R	C		C	A		A	VA		VA	A		A	VA			C
Pycnocentrodes sp.	5	A	R	A	R	C	A	A	C	A	VVA	VVA	VA	VVA	VA	VA	A	VA	VA

Table 4-5 (continued): Macroinvertebrate community composition at six sites on the Manuherikia River catchment based on the results of three surveys between December 2016 and April 2017.

Taxon/species	MCI score	Relative abundance score by site and sampling event																	
		D/s of Fork			Loop Road			Blackstone Hill			Omakau			Ophir			Galloway		
		12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17	12/16	2/17	4/17
Number of taxa		22	25	29	22	27	30	18	18	25	23	19	22	18	18	22	10	21	23
Number of EPT taxa		13	16	18	8	11	12	8	9	13	9	10	11	8	7	11	5	9	9
% EPT taxa		59	64	62	36	41	40	44	50	52	39	53	50	44	39	50	50	43	39
MCI score		122	119	120	89	96	95	97	94	102	100	107	108	96	99	109	92	97	95
SQMCI score		6.2	7.3	6.7	3.9	3.1	3.5	4.2	6.5	7.2	5.2	6.1	5.5	5.2	7.0	6.8	4.9	7.0	6.6

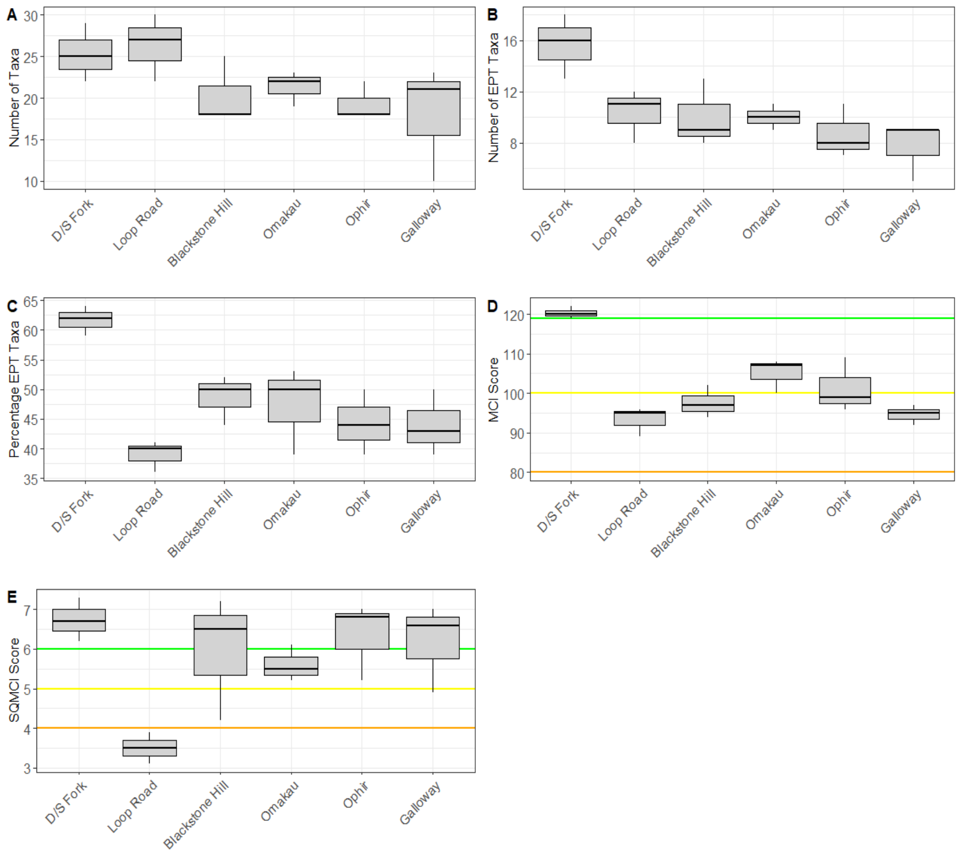

Figure 4-6: Comparison of (A) number of taxa, (B) number of EPT taxa, (C) percentage of EPT taxa, (D) MCI scores, (E) SQMCI scores between six sites on the Manuherikia River, based on three surveys between December 2016 and April 2017. Horizontal lines in plots 'D' and 'E' indicate boundaries for quality classes. Anything below the orange line is 'poor', between the orange and yellow lines is 'fair', between the yellow and green lines is 'good' and above the green line is 'excellent' (Stark and Maxted 2007).

4.5 Fish

4.5.1 New Zealand Freshwater Fish Database (NZFFD) records

Fish recorded in the Manuherikia catchment, and those that are known to occur in Dunstan and Thomson creeks are presented in Table 4-6 along with their respective conservation status. Nine native fish species occur in the Manuherikia catchment, including diadromous (1 species) and non-diadromous (3 species) galaxiids, bullies (2 species), lamprey (1 species) and eels (2 species). Six of these species are conservation listed. Koaro (*Galaxias brevipinnis*) and longfin eel (*Anguilla dieffenbachia*) are listed as 'declining', lamprey (*Geotria australis*) are listed as 'nationally vulnerable', and the three non-diadromous galaxiids are either 'nationally endangered' (round head galaxias (*Galaxias anomalus*) and alpine galaxias "Manuherikia" (*Galaxias* aff. *paucispondylus*)) or 'nationally critical' (Clutha flathead galaxias (*Galaxias* sp. D)) (Dunn et al. 2018). Three species of introduced sport fish are also present, including brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*) and brook char (*Salvelinus fontinalis*). Of the conservation listed species, a population of roundhead galaxias occurs in Dunstan Creek, while longfin eel occur in both Thomson and Dunstan creeks.

Table 4-6: Fishes that have been recorded in the Manuherikia catchment (NZFFD) and their conservation status. Conservation status according to Dunn et al. (2018). Fishes marked with an asterisk are typically diadromous. Fishes recorded in the Dunstan and Thomson creek tributaries are also noted. Note that the alpine galaxias "Manuherikia" is a genetically determined candidate species that is currently classified as taxonomically indeterminate (it is not yet a described species). It has previously been identified as an alpine galaxias.

	Species	Conservation value	Occurrence	
			Dunstan Creek	Thomson Creek
Native	koaro* (*Galaxias brevipinnis*)	Declining		
	roundhead galaxias (*Galaxias anomalus*)	Nationally endangered	Yes	
	alpine galaxias "Manuherikia" (*Galaxias* aff. *paucispondylus*)	Nationally endangered		
	Clutha flathead galaxias (*Galaxias* sp. D)	Nationally critical		
	lamprey* (*Geotria australis*)	Nationally vulnerable		
	common bully* (*Gobiomorphus cotidianus*)	Not threatened		
	upland bully (*Gobiomorphus breviceps*)	Not threatened	Yes	Yes
	shortfin eel* (*Anguilla australis*)	Not threatened	Yes	Yes
	longfin eel* (*Anguilla dieffenbachii*)	Declining	Yes	Yes
Introduced	brook char (*Salvelinus fontinalis*)		Yes	
	brown trout (*Salmo trutta*)		Yes	Yes
	rainbow trout (*Oncorhynchus mykiss*)		Yes	Yes

4.5.2 Fish surveys

The results of annual electric fishing surveys carried out in Dunstan Creek and Thomson Creek between 2015 and 2018 inclusive are summarised in Table 4-7 and Table 4-8, respectively, in terms of fish catch per unit effort (presented as the number of fish per 100 m^2). Catch number and size ranges for the two survey sites are summarised in Table 4-9.

In Dunstan Creek, upland bully was by far the most abundant species in each survey (3.98–23.32 fish/100 m^2). Individuals ranged in length from 11–90 mm, indicating the presence of both juveniles and adults. Rainbow trout (0.80–3.04 fish/100 m^2) and brown trout (0.35–2.68 fish/100 m^2) were also present in each year and were the next most abundant, although they were only present in modest numbers. Numbers of brown trout (mean length 72–97.5 mm) and rainbow trout (mean length 72–97.5 mm) were dominated by juvenile fish, and no trout greater than 200 mm in length was caught. Roundhead galaxiids were caught in low abundance (0.08–0.09 fish/100 m^2) in 2016 and 2017, and were likely the unidentified galaxiids observed, but not caught in 2015 (0.63 fish/100 m^2). Furthermore, two longfin eel were caught in 2015 (0.18 fish/100m^2) and a single shortfin eel was caught in 2017 (0.09 fish/100 m^2).

In Thomson Creek, brown trout were the most abundant species in three of the four survey years (2.59–10.38 fish/100 m^2). Upland bullies were most abundant during the 2018 survey (17.69 fish/100 m^2) and were the second most abundant in all other surveys (1.89–4.38 fish/100 m^2). Longfin eel were present in three of the four surveys in very low abundance (0.22–0.46 fish/100 m^2). A single juvenile rainbow trout was caught during the 2017 survey (0.24 fish/100 m^2).

Table 4-7: Fish densities observed in Dunstan Creek during annual electric fish surveys between 2015 and 2018 inclusive.

Species	2015	2016	2017	2018
Roundhead galaxiid	–	0.08	0.09	–
Unidentified galaxiid	0.63	–	–	–
Upland bully	23.32	3.98	12.95	14.17
Longfin eel	0.18	–	–	–
Shortfin eel	–	–	0.09	–
Brown trout	2.68	0.88	0.35	0.81
Rainbow trout	3.04	0.80	1.29	0.97
TOTAL	29.85	5.73	14.67	15.94

Table 4-8: Fish densities observed in Thomson Creek during annual electric fish surveys between 2015 and 2018 inclusive.

Species	2015	2016	2017	2018
Longfin eel	0.46	0.23	–	0.22
Unidentified eel	–	–	–	0.22
Upland bully	3.65	4.38	1.89	17.69
Brown trout	7.76	10.38	5.91	2.59
Rainbow trout	–	–	0.24	–
TOTAL	11.87	15.00	8.04	20.71

Table 4-9: Catch number (N) and size ranges (mm) for fish captured in Dunston Creek and Thomson Creek during annual electric-fishing surveys between 2015 and 2018 inclusive. Min = minimum, max = maximum and med = median length.

Site	Year	Species, catch number (N) and size range (mm)																							
		Upland bully				Longfin eel				Shortfin eel				Roundhead galaxiid				Brown trout				Rainbow trout			
		N	min	max	med	N	min	max	med	N	min	max	med	N	min	max	med	N	min	max	med	N	min	max	med
Dunston Creek	2018	130	27	85	63	–	–	–	–	–	–	–	–	1	53	53	53	10	52	110	97.5	11	55	86	70.5
	2017	111	38	90	57	–	–	–	–	1	500	500	500	1	74	74	74	4	78	80	80	15	60	80	68
	2016	50	41	83	60.5	–	–	–	–	–	–	–	–	1	73	73	73	11	41	200	75	10	34	61	44.5
	2015	125	11	83	71	2	1020	1125	1073	–	–	–	–	–	–	–	–	27	78	112	88	34	37	88	71
Thomson Creek	2018	81	28	73	32	1	700	700	700	–	–	–	–	–	–	–	–	12	61	90	72	–	–	–	–
	2017	8	44	64	53	–	–	–	–	–	–	–	–	–	–	–	–	25	37	250	87	1	70	70	70
	2016	19	23	84	54	1	400	400	400	–	–	–	–	–	–	–	–	45	55	250	79	–	–	–	–
	2015	16	46	81	59.5	2	700	1100	900	–	–	–	–	–	–	–	–	34	57	121	100	–	–	–	–

5 Discussion

5.1 Nutrient and other physico chemical variables

Ammoniacal-N concentrations are generally very low (often below analytical detection), which is a favourable water quality state. Temporal trend analysis was not undertaken owing to the large number of non-detect values and, in particular, a change in the way detection limit was managed in July 2014. DRP concentrations increase in downstream direction along the Manuherikia mainstem. Concentrations are generally elevated in the Chatto Creek and Poolburn, with these tributaries contributing approximately 10% of the DRP load to the lower Manuherikia River (with the proportion of load seasonally variable).

Tributaries of the Manuherikia River generally contribute less than 10% of the NNN load present in the mainstem of the Manuherikia River. Of the tributaries, Dunstan Creek is the largest contributor, followed by Thomsons Creek. Surveys over 2016/17 indicate that periphyton cover is greatest in the upper third of the catchment, presumably as a consequence of good water clarity, longer accrual periods as a consequence of regulation of flow by the Falls Dam, adequate nutrient availability and suitable substrate.

5.2 Human health risk

Analysis of *E. coli* concentrations indicates that all sites comply with the ORC's Regional Plan Water (RPW) limit; fewer than 80% of water sample results collected during flows lower than median exceeded 260 cfu/100 mL. The greatest proportion of results exceeding 260 cfu/100 mL during flows less than median occurred in the Thomsons Creek and Chatto Creek subcatchments.

Application of the NPS-FM 2014 *E. coli* attribute states indicates that undertaking contact recreation along the mainstem of the Manuherikia River, as well as in the Thomsons Creek and Dunstan Creek, is likely to present a measurable risk of infection to recreational water users.

- In the 2014-2018 five-year period (the most recent period during which more than 60 data exist for most sites), one site was graded 'blue', one 'green', one 'yellow', one 'orange' and one 'red'.
- In the following five-year period, it appears that three of five sites are likely to be graded 'orange, one 'green' and one 'red' (provisional grading only because fewer than 60 data are available for all sites.).

Review of the individual components that drive overall site grades indicates that exceedance of the proportion of values exceeding 540 cfu/100 mL and 95th percentile concentration-base attribute states are the most likely reason for poor grading. 'Orange' and 'red' grading indicates a >3% and greater than 7% risk of infection, respectively.

5.3 Habitat quality

The quantity and quality of habitat are important factors that can affect many instream values, among which the composition of the streambed is particularly important because it provides the substrate for periphyton attachment and the habitat for macroinvertebrates and fish.

Riparian vegetation at most sites surveyed on the main stem of Manuherikia River over 2016/17 was characterised by mature shrubs and sparse tree cover with some young exotic vegetation, although regenerating native plant cover and established exotic vegetation was present at Ophir. The riparian strip was intact at each site, ranging from 15 m in width to greater than 30 m. However, riparian shading was quite low. This is likely due in part to the sparse cover of tall trees and also because the river is typically quite wide.

The substrate at each site was varied, with different substrate types providing a high abundance of ideal habitat for invertebrates (i.e., a mixture of boulders, cobbles, gravels). Of the two sites that received less than the maximum score for invertebrate habitat abundance, one site – Loop Road – was dominated by thick mat algae (in excess of the 60% cover guideline on three occasions). The other site – Blackstone Hill – supported moderate growth of long filamentous algae on two occasions, although cover never exceeded the national guideline. There is indication of increasing NNN concentration downstream of the Manuherikia at Forks site, particularly at Blackstone Hill (over the 2014-2018 period). In contrast, NNN concentrations at the two upstream sites showed deceasing trend over this period. Median summer nutrient concentrations are lower than the annual median concentrations in the upper catchment sites (Figure J-1 and Figure J-2).

The diversity of fish cover (i.e., woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes) was moderate to low at most sites, with Loop Road receiving the highest score.

There was little fine sediment deposition at any site, with the mean cover not exceeding 10% (Blackstone Hill). Further, as the annual median values in Appendix J indicate, turbidity is lowest in the headwaters of the Manuherikia mainstem, and increases in a downstream direction, particularly downstream of Omakau. Sediment cover is likely to follow a similar trend. Burdon et al. (2013) identified a sediment threshold response at 20% sediment cover (estimated by instream visual assessment) in a regression with % EPT relative abundance. While little research has been done into the relationship between New Zealand fish communities and percent fine sediment cover, a limit of 20% has been proposed for the maintenance of trout spawning habitats based on international literature. Thus, sediment deposition likely has little influence on invertebrate or fish community health at the main stem sites.

5.4 Periphyton

The periphyton community forms the slimy coating on the surface of stones and other substrates in freshwaters. This community can include green (Chlorophyta), yellow-green (Xanthophyta), golden brown (Chrysophyta) and red (Rhodophyta) algae, blue-greens (Cyanobacteria), diatoms (Bacillariophyta), bacteria and fungi. Periphyton is an integral part of stream food webs; it captures energy from the sun and converts it, via photosynthesis, to energy sources available to macroinvertebrates, which feed on it. These, in turn, are fed on by other invertebrates and fish. Periphyton can also form nuisance blooms that can detrimentally affect other instream values, such as aesthetics, biodiversity, recreation (swimming and angling), water takes (irrigation, stock/drinking water and industrial) and water quality. The most extreme case of periphyton affecting instream values is toxin-producing benthic cyanobacteria. Some cyanobacteria may produce toxins that pose a health risk to humans and animals.

Periphyton monitoring at the six main stem Manuherikia River sites on four occasions over 2016/17 indicated that assorted diatoms and cyanobacteria dominated the periphyton community at most sites, indicative of relatively unenriched (i.e., oligotrophic) habitats (Biggs 2000). However, Blackstone Hill went from being dominated by diatoms and cyanobacteria at the start of summer

(December 2016) to being dominated by filamentous periphyton typical of moderately enriched (i.e., mesotrophic) to enriched (i.e., eutrophic) habitats. Similarly, Loop Road was dominated by diatoms and cyanobacteria at the start of summer before becoming dominated by thick mat algae, typical of moderately enriched habitats, in subsequent months. This may reflect a build-up of periphyton that utilise the nutrients as flows recede over the dry summer period. Although the data are sparse, median monthly nutrient concentrations in the upper Manuherikia River decrease over the summer, most probably reflecting uptake by periphyton. This is most noticeable for DRP. NNN concentrations are particularly low at the Loop Road site, providing further evidence of algal uptake.

The combined total cover of long filamentous and thick mat species at Blackstone Hill and Loop Road was variable. The guideline for cover of long filamentous algae (30%) was only exceeded once in late summer (April 2017) at Blackstone Hill, while the guideline for cover of thick mat algae (60%) was exceeded twice towards the end of summer (March and April 2017) at Loop Road. Overall, the results indicate that although nutrient concentrations are generally quite low in the upper Manuherikia River, they are adequate to support periphyton growth if other conditions are favourable. Nutrient concentrations increase downstream of the Blackstone Hill site but periphyton growths are probably inhibited by factors such as substrate and possibly light penetration (e.g., Figure J-7 indicates an increase in turbidity over the period of periphyton sampling).

5.5 Macroinvertebrates

Macroinvertebrates are a diverse group of animals and include insects, crustaceans, worms, molluscs and mites. They are an important part of stream-food webs, linking primary producers (periphyton and terrestrial leaf litter) to higher trophic levels (fish and birds). Because of the length of the aquatic part of their life-cycles, which generally range from a few months up to two years, macroinvertebrates provide a good indication of the medium- to long-term water quality of a waterway. For this reason, they are used as a biomonitoring tool around the world. In New Zealand, the MCI (Stark 1985) and its derivatives, such as the SQMCI (Stark 1998), are commonly used as a measure of organic enrichment and sedimentation in gravel-bed streams.

The MCI and SQMCI scores generated from the four macroinvertebrate community surveys conducted at the six main-stem Manuherikia River sites indicated that stream health was 'excellent' at Downstream of Fork, above Falls Dam sites. However, immediately downstream of the dam at Loop Road, stream health was classed as 'fair' (MCI) to 'poor' (SQMCI) given the communities were dominated in terms of richness and abundance by taxa tolerant of poor water quality. Most prominent amongst these were the mud snail *Potamopyrgus antipodarum*, the crustacean Cladocera, the Chironomid midge larvae Tanytarsini, worms (Oligochaeta), and the purse-cased caddisfly larvae *Oxyethira albiceps*. These findings support those of the periphyton surveys that showed high riverbed coverage of filamentous algae at the site, indicative of enriched conditions that would be unsuitable for taxa sensitive to organic pollution. These findings are also consistent with the decrease in nutrient concentration at the Loop Road site in response to periphyton growth.

Further downstream the two macroinvertebrate community indices indicated that water quality was 'good' at Omakau, but gave notably different assessments of water quality at the Blackstone Hill, Ophir and Galloway. The communities at these sites were dominated, in terms of abundance, by EPT taxa such as mayfly larvae *Deleatidium* sp. and stony-cased caddisfly larvae *Pycnocentrodes* sp. and as a result SQMCI scores indicated that water quality – and stream health – was generally 'excellent'. However, the number of pollution sensitive taxa mostly made up a low proportion of the overall communities. For example, the median % EPT taxa at these sites was less than 50% (Figure 4-6).

Consequently, MCI scores indicated that water quality was ‘fair’, although the scores were in the upper end of this category. Overall, the notably lower diversity of taxa sensitive to poor water quality at these sites compared to that observed above Falls Dam (at Downstream of Fork) suggests that water quality may be having a low to moderate impact on macroinvertebrate communities at the downstream sites. As Figure J-7 indicates, turbidity appears locally elevated in the reach including the Blackstone Hill site, which may reflect sediment input, the effect of sloughed-off periphyton from the upstream site, or other factors, such as increased water temperature.

5.6 Fish

Six fish species were recorded at the Dunstan Creek survey site over the course of four annual sampling events between 2015 and 2018 inclusive: the introduced brown and rainbow trout and the native upland bully, roundhead galaxias, longfin eel and shortfin eel. The high density of upland bully caught, both juveniles and adults, suggests that the site offers highly productive habitat for this species. Only juvenile brown and rainbow trout were observed and were in similarly low abundance. Adult trout are not effectively captured by backpack electrofishing due to their size and speed, so they still may have been present at the site. From the survey data, Dunstan Creek appears to represent a trout fishery, so adult trout are certainly present in the catchment. Adult roundhead galaxiids were present in very low abundance, although likely juveniles of the species were observed in larger numbers in backwaters by field personnel. Juvenile roundhead galaxiids are too small to be effectively fished by backpack electrofishing and numbers would likely be underestimated using that survey method alone. The presence of both adults and juveniles suggests that the population is self-sustaining, rather than juveniles having been washed down from upstream reaches. Longfin and short fin eels were detected, but they appear to be rare at the site.

Four fix species were captured at the Thomson Creek survey site over the four surveys: brown and rainbow trout as well as upland bully and longfin eel. Brown trout were the most abundant species and were present in moderate densities. Again, although adult trout were not observed, they are not easily detected using backpack electrofishing and are likely present, at least on occasion. Adult and juvenile upland bullies were also present in moderate densities indicating they are a resident population. Longfin eel were present in most years, but in very low abundance. No species of conservation significance were observed during the four surveys and New Zealand Freshwater Fish Database (NZFFD) records indicate that none have been recorded in the past.

Non-migratory galaxiids are highly vulnerable to trout predation as their larvae form pelagic schools in still backwaters where they are easily detected and consumed. As such, stream reaches where brown trout and non-migratory galaxiids co-exist are uncommon (Townsend and Crowl 1991; Leprieur et al. 2006; Woodford and McIntosh 2010). In the Manuherikia catchment, the roundhead galaxiid is thought to have been displaced from the main-stem by trout and now persists in residual pockets in several tributaries within the catchment. There are only 35 known sub-populations. In a study of the Manuherikia catchment, Leprieur et al. (2006) found that increased water abstraction was a major factor excluding brown trout from stream reaches as the lower flows (or cessation of flow) created unfavourable conditions (i.e., high water temperatures, low dissolved oxygen) for the cool-water adapted species. Consequently, roundhead galaxiids were found to persist where trout numbers were reduced or absent. The low numbers of trout and the presence of adult and juvenile roundhead galaxiids at the Dunstan Creek survey site suggest it provides a critical refuge for the roundhead galaxiid.

Four further fish species of conservation concern occur in the Manuherikia catchment, and although most were not detected in surveys undertaken between 2015-2018, NZFFD records provide evidence of their distributions. The Clutha flathead galaxias and alpine galaxias (Manuherikia) have fragmented distribution in the catchment, as does the roundhead galaxiid, which is likely driven by trout predation. These species are confined to several isolated tributaries in the upper Manor Burn–Poolburn area. The alpine galaxias "Manuherikia" on the other hand is largely confined to the Manuherikia River mainstream above Falls Dam. While previously identified as the alpine galaxias, genetic analysis of the Manuherikia River population suggests that it may represent a separate, new species. However, until morphological analysis of the candidate species is complete, its classification remains as 'taxonomically indeterminate' (Dunn et al. 2018).

Lamprey appear to be uncommon in the Manuherikia catchment and have only been detected in the lower mainstem river reaches near the confluence with the Clutha River/Mata-au. Lamprey are generally found close to the coast at low altitudes and the Manuherikia River appears to be close to the upstream extent of their distribution. On the other hand, the longfin eel is found throughout the catchment.

5.7 Synthesis

In general, based on the data made available to prepare this report, water quality and ecosystem health in the Manuherikia River mainstem are fair to good, evidenced by MCI values ranging from 90 to 120. The SQMCI scores were greater than 4 (fair), with most macroinvertebrate samples collected in 2016/17 (10 of 18) indicating good to excellent condition. The exception appears to be the Loop Road site, where lower MCI and SQMCI scores in 2016/17 were consistent with greater periphyton growth. The Falls Dam regulates flows in the upper Manuherikia River, and to some extent reduces the discharge of sediment to the lower catchment – this is evident from the relatively low turbidity values at the Loop Road site.

Both trout and various native fish species inhabit that Manuherikia River catchment, where Dunstan Creek may provide a critical refuge for the roundhead galaxiid.

Lastly, we note that flows in the Manuherikia River during the 2016/17 ecological survey period were generally above what might be considered 'low flow' conditions, reflecting the high flows that extended into summer 2016/17, as well as several rainfall events. These 'atypical' flow conditions mean caution is required when evaluating the periphyton data (which may be more extensive in a period of lower flows), which in turn will also impact macroinvertebrate communities.

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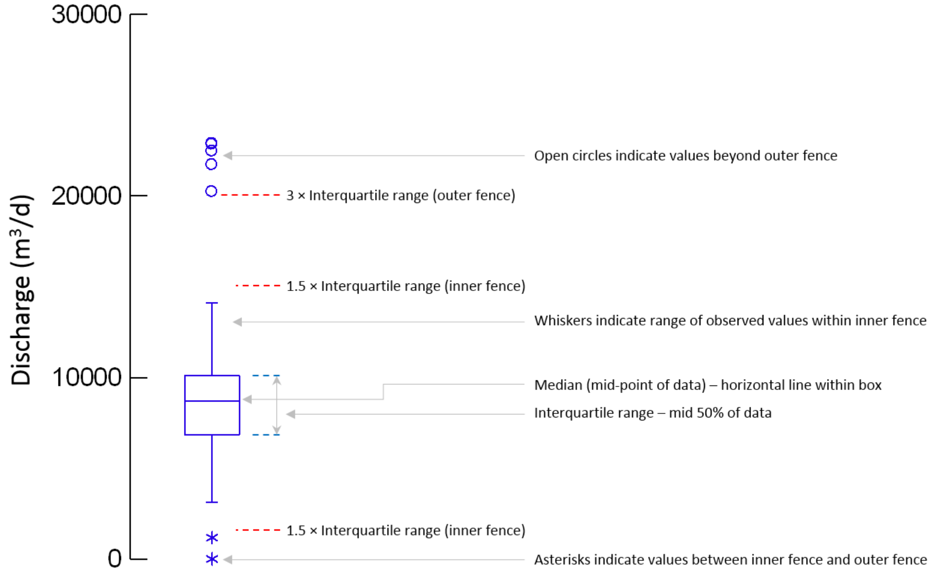
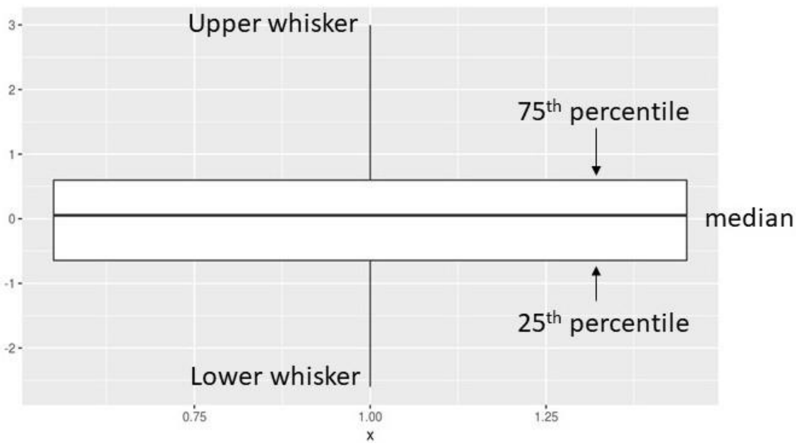
Appendix A Explanation of box and whisker plots

Box and whisker plot derived from Systat v 13.2

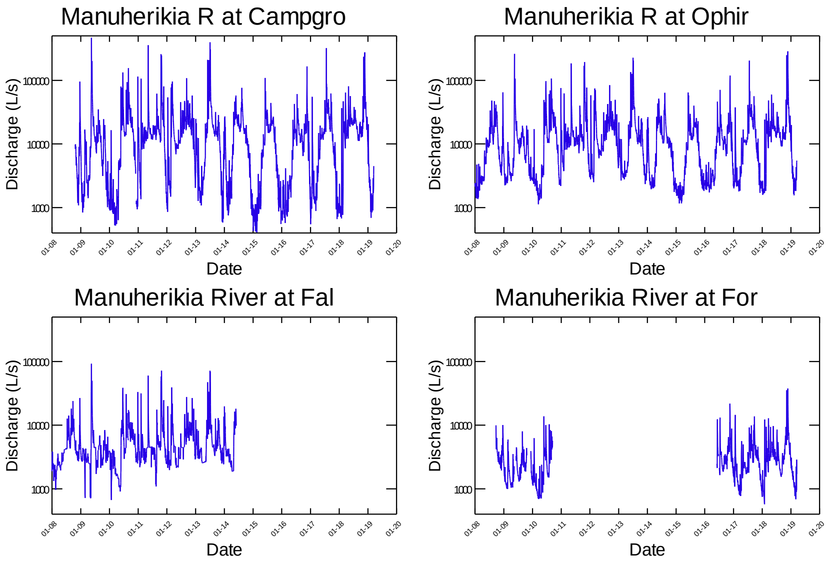


Box and whisker plot derived from *R*

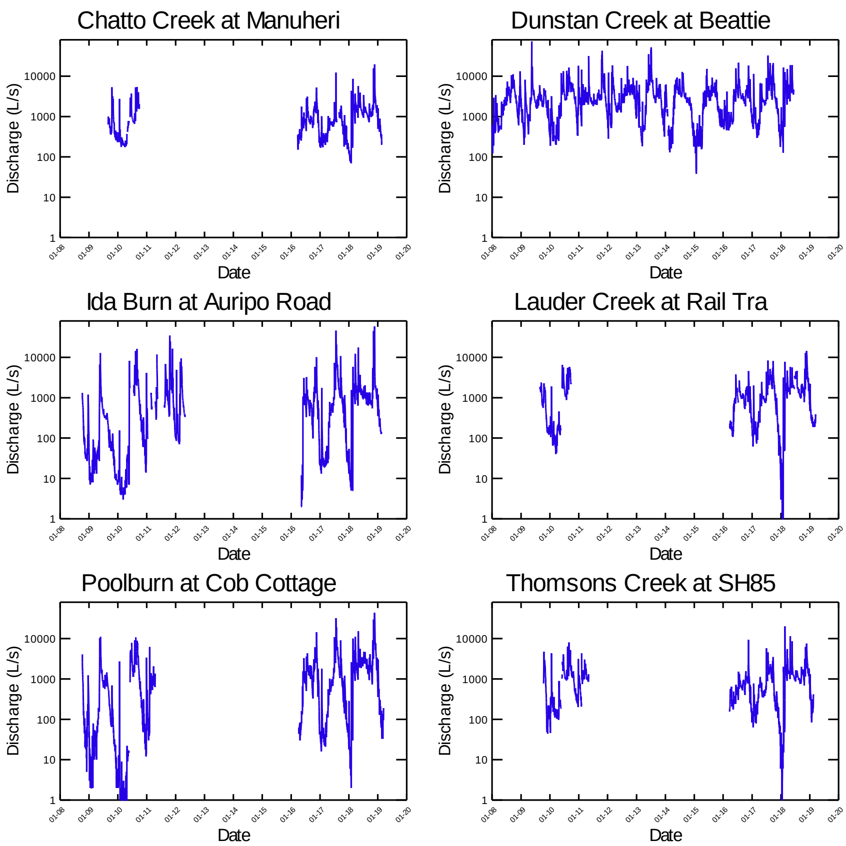


The median of the data is plotted, while the lower and upper hinges correspond to the 25th and 75th percentiles. The upper whisker extends from the hinge to the largest value no further than 1.5 * inter-quartile range (distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * inter-quartile range of the hinge. Data beyond the end of the whiskers (outliers) are plotted individually.

Appendix B Summary of available flow data



Statistic	Discharge (L/s)			
	Campground	Ophir	Falls Dam	Forks
N of Cases	3787	4095	2337	1640
Minimum	406	1131	666	573
Maximum	465457	285884	92227	37711
Median	11783	10084	4220	2494
Arithmetic Mean	16325	13976	5722	3085
Standard Deviation	26240	19250	6189	2724
Cleveland percentile				
1%	621	1440	1063	717
5%	892	1927	1725	856
10%	1130	2275	2222	1058
20%	1881	2951	2647	1369
25%	2645	3380	2824	1552
30%	3913	4176	3087	1710
40%	7853	7092	3682	2064
50%	11783	10084	4220	2494
60%	14653	12034	4532	2893
70%	17719	15117	5536	3408
75%	19863	17238	6524	3697
80%	22259	19519	7366	4094
90%	32390	27631	9944	5514
95%	45106	38198	13581	7240
99%	126129	96265	33280	12854


Chatto Creek at Manuheri
Dunstan Creek at Beattie
Ida Burn at Auripo Road
Lauder Creek at Rail Tra
Poolburn at Cob Cottage
Thomsons Creek at SH85
Discharge (L/s)
10000
1000
100
10
1
Date

Statistic	Discharge (L/s)		
	Dunstan Creek at Beattie	Ida Burn at Auripo Road	Poolburn at Cob Cottage
N of Cases	3784	2101	1971
Minimum	38	2	1
Maximum	73015	58576	43893
Median	2512	438	586
Arithmetic Mean	3271	1273	1488
Standard Deviation	3733	3394	3027
Method = CLEVELAND			
1%	185	4	1
5%	313	7	3
10%	460	11	11
20%	769	32	40
25%	1036	48	54
30%	1344	74	75
40%	1997	215	191
50%	2512	438	586
60%	3019	685	923
70%	3705	970	1467
75%	4155	1183	1852
80%	4660	1473	2218
90%	6422	2736	3414
95%	8902	4957	5521
99%	17421	15727	14138

Statistic	Discharge (L/s)		
	Thomsons Creek at SH85	Chatto Creek	Lauder
N of Cases	1613	1417	1462
Minimum	1	69	1
Maximum	20129	19726	14430
Median	748	734	980
Arithmetic Mean	989	1016	1324
Standard Deviation	1189	1235	1507
Method = CLEVELAND			
1%	10	88	3
5%	79	188	66
10%	129	216	117
20%	214	286	176
25%	263	340	211
30%	325	417	270
40%	483	612	689
50%	748	734	980
60%	982	881	1263
70%	1174	1148	1589
75%	1301	1303	1785
80%	1427	1457	2004
90%	1997	1978	3133
95%	2706	2577	3929
99%	5630	5285	6527

Appendix C Graphical comparison of concentrations of physico-chemical and water quality variables and *E. coli*

These box and whisker plots summarise all data provided for the Manuherikia River catchment. Site are generally arranged in downstream order from top to bottom. Numeric threshold limits are indicated; these are discussed in Section 3.3 in more detail.

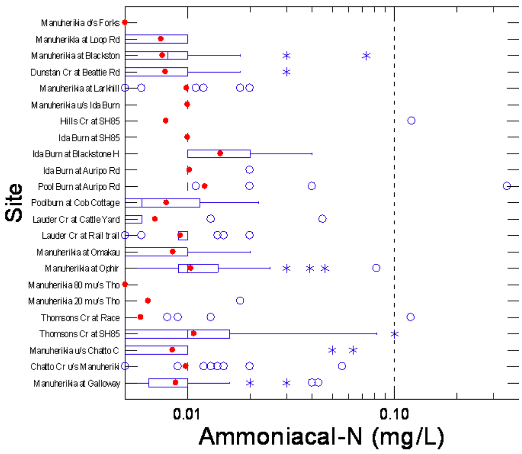


Figure C-1: Ammoniacal-N concentrations. The broken black line indicates the ORC Water Plan limit of 0.1 mg/L. The red dot indicates the average value for the data period.

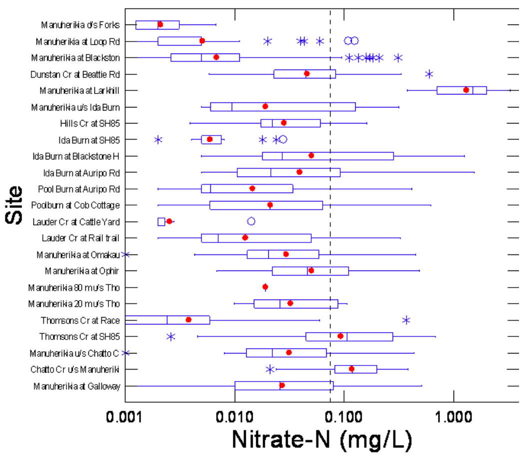


Figure C-2: NNN concentrations. The broken black line indicates the ORC Water Plan limit of 0.075 mg/L. The red dot indicates the average value for the data period.

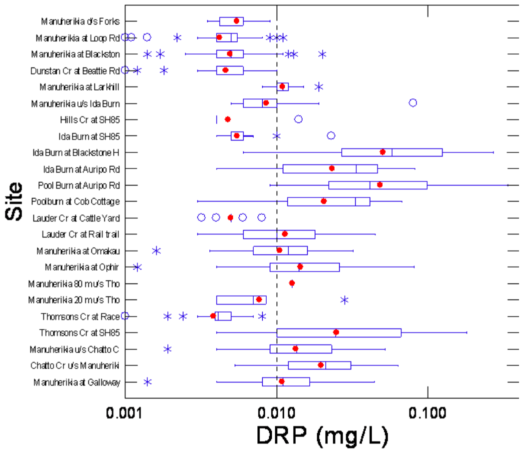


Figure C-3: DRP concentrations. The broken black line indicates the ORC Water Plan limit of 0.01 mg/L. The red dot indicates the average value for the data period.

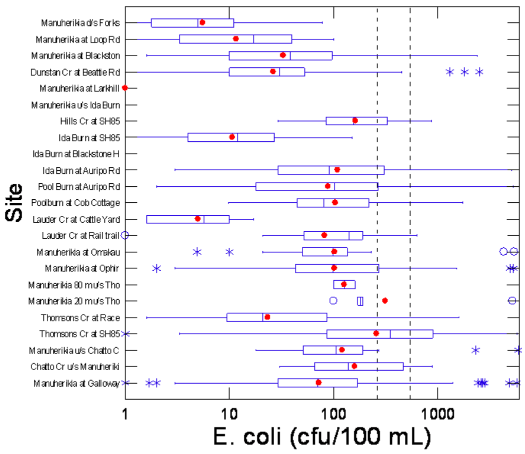


Figure C-4: ***E. coli*** **concentrations.** The lower value broken black line indicates the ORC Water Plan limit of 260 cfu/ 100 mL and one of the NPS-FM attribute values, and the higher value broken black line indicates another NPS-FM attribute value. See Section 3.3 for details. The red dot indicates the average value for the data period.

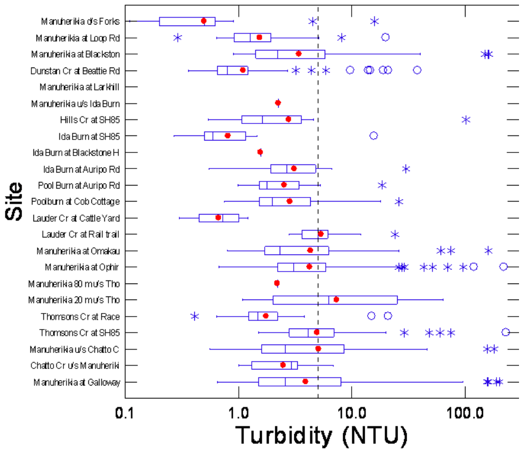


Figure C-5: Turbidity values. The broken black line indicates the ORC Water Plan limit of 5 NTU. The red dot indicates the average value for the data period.

Appendix D Summary statistics, water quality variables

Manu R d/s Fork

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	19	19	19	19	19
Minimum	0.005	0.001	0.004	1.000	0.110
Maximum	0.005	0.007	0.009	78.000	15.800
Median	0.005	0.002	0.006	5.000	0.500
Mean	0.005	0.002	0.006	12.447	1.449
Standard Error of Mean	0.000	0.000	0.000	4.342	0.827
95.0% LCL of Mean	0.005	0.002	0.005	3.326	-0.289
95.0% UCL of Mean	0.005	0.003	0.006	21.569	3.187
Standard Deviation	0.000	0.002	0.002	18.925	3.605
Coefficient of Variation	0.000	0.620	0.275	1.520	2.488
Cleveland percentiles					
1%	0.005	0.001	0.004	1.000	0.110
5%	0.005	0.001	0.004	1.000	0.128
10%	0.005	0.001	0.004	1.240	0.170
20%	0.005	0.001	0.004	1.600	0.200
25%	0.005	0.001	0.004	1.700	0.200
30%	0.005	0.002	0.004	2.000	0.200
40%	0.005	0.002	0.005	3.190	0.432
50%	0.005	0.002	0.006	5.000	0.500
60%	0.005	0.002	0.006	9.420	0.550
70%	0.005	0.003	0.006	10.800	0.586
75%	0.005	0.003	0.006	11.000	0.635
80%	0.005	0.004	0.007	17.300	0.741
90%	0.005	0.005	0.008	35.000	3.060
95%	0.005	0.006	0.009	61.350	10.715
99%	0.005	0.007	0.009	78.000	15.800

Manu R at Loop Road

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	46	46	46	20	21
Minimum	0.005	0.001	0.001	1.000	0.290
Maximum	0.010	0.126	0.011	100.000	20.000
Median	0.010	0.005	0.005	17.000	1.270
Mean	0.008	0.013	0.005	27.695	2.708
Standard Error of Mean	0.000	0.004	0.000	7.283	0.952
95.0% LCL of Mean	0.007	0.005	0.004	12.451	0.722
95.0% UCL of Mean	0.009	0.021	0.005	42.939	4.694
Standard Deviation	0.002	0.026	0.002	32.572	4.363
Coefficient of Variation	0.314	1.977	0.445	1.176	1.611
Cleveland percentiles					
1%	0.005	0.001	0.001	1.000	0.290
5%	0.005	0.001	0.001	1.300	0.483
10%	0.005	0.001	0.001	1.600	0.736
20%	0.005	0.002	0.003	2.450	0.900
25%	0.005	0.002	0.004	3.300	0.907
30%	0.005	0.002	0.004	4.150	0.966
40%	0.005	0.005	0.005	5.750	1.092
50%	0.010	0.005	0.005	17.000	1.270
60%	0.010	0.005	0.005	22.000	1.304
70%	0.010	0.005	0.005	30.500	1.504
75%	0.010	0.005	0.005	40.000	1.990
80%	0.010	0.011	0.006	57.000	2.800
90%	0.010	0.043	0.007	86.000	6.300
95%	0.010	0.070	0.009	100.000	13.455
99%	0.010	0.126	0.011	100.000	20.000

Manu R at Blackstone

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	89	89	89	88	69
Minimum	0.005	0.001	0.001	1.600	0.900
Maximum	0.073	0.311	0.020	2400.000	161.000
Median	0.008	0.005	0.005	38.000	2.200
Mean	0.009	0.024	0.005	118.242	11.425
Standard Error of Mean	0.001	0.006	0.000	32.983	3.856
95.0% LCL of Mean	0.007	0.013	0.005	52.686	3.731
95.0% UCL of Mean	0.010	0.035	0.006	183.798	19.120
Standard Deviation	0.008	0.053	0.003	309.404	32.030
Coefficient of Variation	0.897	2.180	0.494	2.617	2.803
Cleveland percentiles					
1%	0.005	0.001	0.002	1.600	0.900
5%	0.005	0.001	0.003	1.970	0.996
10%	0.005	0.002	0.003	4.000	1.100
20%	0.005	0.002	0.004	8.210	1.315
25%	0.005	0.003	0.004	9.900	1.415
30%	0.005	0.003	0.004	12.900	1.606
40%	0.005	0.005	0.004	20.700	2.000
50%	0.008	0.005	0.005	38.000	2.200
60%	0.010	0.005	0.005	54.300	3.260
70%	0.010	0.007	0.006	90.000	4.980
75%	0.010	0.012	0.006	96.500	5.825
80%	0.010	0.017	0.007	129.000	7.210
90%	0.011	0.087	0.008	207.000	14.920
95%	0.015	0.160	0.011	326.000	45.500
99%	0.056	0.272	0.017	2020.000	160.810

Dunstan Cr at Beattie Rd

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	108	107	107	107	88
Minimum	0.005	0.006	0.001	1.000	0.360
Maximum	0.030	0.600	0.010	2500.000	38.000
Median	0.010	0.045	0.004	30.000	0.800
Mean	0.008	0.068	0.005	96.488	2.502
Standard Error of Mean	0.000	0.007	0.000	30.837	0.603
95.0% LCL of Mean	0.008	0.053	0.005	35.350	1.304
95.0% UCL of Mean	0.009	0.082	0.005	157.626	3.699
Standard Deviation	0.003	0.076	0.002	318.985	5.653
Coefficient of Variation	0.408	1.125	0.357	3.306	2.260
Cleveland percentiles					
1%	0.005	0.008	0.001	1.000	0.390
5%	0.005	0.015	0.003	2.000	0.458
10%	0.005	0.016	0.003	4.180	0.540
20%	0.005	0.021	0.004	8.200	0.600
25%	0.005	0.022	0.004	10.000	0.650
30%	0.005	0.026	0.004	12.600	0.669
40%	0.008	0.034	0.004	22.000	0.727
50%	0.010	0.045	0.004	30.000	0.800
60%	0.010	0.055	0.005	37.700	0.930
70%	0.010	0.073	0.005	48.800	1.101
75%	0.010	0.085	0.006	52.750	1.200
80%	0.010	0.103	0.006	68.200	1.400
90%	0.010	0.139	0.008	135.600	4.033
95%	0.010	0.181	0.008	219.100	15.040
99%	0.023	0.446	0.009	2101.000	31.540

Poolburn at Cob

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	19	19	19	19	19
Minimum	0.005	0.002	0.003	9.800	0.750
Maximum	0.022	0.620	0.067	1733.000	26.000
Median	0.006	0.021	0.033	80.000	1.990
Mean	0.009	0.070	0.029	271.989	5.063
Standard Error of Mean	0.001	0.033	0.004	100.243	1.545
95.0% LCL of Mean	0.007	0.001	0.019	61.387	1.817
95.0% UCL of Mean	0.011	0.139	0.038	482.592	8.308
Standard Deviation	0.005	0.142	0.019	436.950	6.734
Coefficient of Variation	0.540	2.034	0.679	1.606	1.330
Cleveland percentiles					
1%	0.005	0.002	0.003	9.800	0.750
5%	0.005	0.002	0.003	12.140	0.773
10%	0.005	0.002	0.005	19.000	0.960
20%	0.005	0.005	0.009	36.500	1.430
25%	0.005	0.006	0.011	42.500	1.515
30%	0.005	0.007	0.013	50.800	1.588
40%	0.006	0.016	0.015	68.200	1.819
50%	0.006	0.021	0.033	80.000	1.990
60%	0.009	0.032	0.037	108.100	2.590
70%	0.011	0.058	0.041	201.200	2.680
75%	0.012	0.064	0.042	219.000	5.850
80%	0.012	0.077	0.045	527.700	8.370
90%	0.016	0.168	0.054	802.800	15.260
95%	0.019	0.435	0.062	1349.150	22.355
99%	0.022	0.620	0.067	1733.000	26.000

Lauder Cr at yards

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	10	10	10	10	10
Minimum	0.005	0.002	0.003	1.600	0.300
Maximum	0.045	0.014	0.008	17.000	1.200
Median	0.005	0.002	0.005	5.700	0.725
Mean	0.010	0.003	0.005	7.070	0.725
Standard Error of Mean	0.004	0.001	0.000	1.817	0.093
95.0% LCL of Mean	0.001	0.001	0.004	2.959	0.514
95.0% UCL of Mean	0.019	0.006	0.006	11.181	0.936
Standard Deviation	0.013	0.004	0.001	5.747	0.295
Coefficient of Variation	1.271	1.156	0.244	0.813	0.406
Cleveland percentiles					
1%	0.005	0.002	0.003	1.600	0.300
5%	0.005	0.002	0.003	1.600	0.300
10%	0.005	0.002	0.004	1.600	0.350
20%	0.005	0.002	0.005	1.600	0.425
25%	0.005	0.002	0.005	1.600	0.450
30%	0.005	0.002	0.005	2.450	0.525
40%	0.005	0.002	0.005	4.100	0.625
50%	0.005	0.002	0.005	5.700	0.725
60%	0.005	0.002	0.005	7.350	0.825
70%	0.005	0.002	0.005	9.100	0.925
75%	0.006	0.002	0.005	10.000	1.000
80%	0.010	0.003	0.006	13.000	1.000
90%	0.029	0.009	0.007	16.500	1.100
95%	0.045	0.014	0.008	17.000	1.200
99%	0.045	0.014	0.008	17.000	1.200

Lauder Cr at Rail Trail

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	38	38	38	12	13
Minimum	0.005	0.002	0.003	1.000	2.800
Maximum	0.020	0.325	0.045	630.000	24.000
Median	0.010	0.007	0.010	140.000	5.000
Mean	0.010	0.033	0.015	158.750	6.624
Standard Error of Mean	0.000	0.010	0.002	47.403	1.599
95.0% LCL of Mean	0.009	0.014	0.011	54.416	3.139
95.0% UCL of Mean	0.011	0.052	0.019	263.084	10.108
Standard Deviation	0.003	0.059	0.013	164.209	5.766
Coefficient of Variation	0.285	1.780	0.835	1.034	0.871
Cleveland percentiles					
1%	0.005	0.002	0.003	1.000	2.800
5%	0.005	0.002	0.004	3.000	2.800
10%	0.006	0.004	0.005	15.000	2.800
20%	0.009	0.005	0.006	31.800	3.159
25%	0.009	0.005	0.006	56.500	3.478
30%	0.010	0.005	0.007	83.000	3.720
40%	0.010	0.005	0.008	116.000	4.180
50%	0.010	0.007	0.010	140.000	5.000
60%	0.010	0.010	0.013	157.000	5.520
70%	0.010	0.021	0.017	169.000	5.980
75%	0.010	0.050	0.018	190.000	6.425
80%	0.010	0.057	0.022	210.000	7.270
90%	0.010	0.099	0.041	336.000	14.320
95%	0.015	0.109	0.044	588.000	22.185
99%	0.020	0.325	0.045	630.000	24.000

Manu R at Omakau

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	46	46	46	20	21
Minimum	0.005	0.001	0.002	4.900	0.800
Maximum	0.020	0.450	0.032	5400.000	160.000
Median	0.010	0.021	0.012	98.000	2.300
Mean	0.009	0.074	0.012	568.445	17.610
Standard Error of Mean	0.001	0.016	0.001	330.082	8.355
95.0% LCL of Mean	0.008	0.040	0.010	-122.425	0.182
95.0% UCL of Mean	0.010	0.107	0.014	1259.315	35.038
Standard Deviation	0.004	0.112	0.007	1476.173	38.287
Coefficient of Variation	0.392	1.519	0.569	2.597	2.174
Cleveland percentiles					
1%	0.005	0.001	0.002	4.900	0.800
5%	0.005	0.007	0.004	7.450	0.965
10%	0.005	0.009	0.005	15.500	1.160
20%	0.005	0.013	0.006	37.000	1.496
25%	0.005	0.013	0.007	50.500	1.670
30%	0.008	0.014	0.008	69.500	1.788
40%	0.010	0.016	0.010	87.000	1.926
50%	0.010	0.021	0.012	98.000	2.300
60%	0.010	0.025	0.013	120.000	3.230
70%	0.010	0.039	0.015	130.000	5.400
75%	0.010	0.059	0.016	135.000	6.900
80%	0.010	0.124	0.016	160.000	14.100
90%	0.010	0.262	0.022	2265.000	66.600
95%	0.018	0.327	0.029	4850.000	113.250
99%	0.020	0.450	0.032	5400.000	160.000

Manu R at Ophir

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	118	118	118	117	101
Minimum	0.005	0.007	0.001	2.000	0.670
Maximum	0.082	0.490	0.081	5300.000	220.000
Median	0.010	0.046	0.014	98.000	3.080
Mean	0.012	0.086	0.019	303.332	11.152
Standard Error of Mean	0.001	0.009	0.001	65.206	2.795
95.0% LCL of Mean	0.010	0.068	0.016	174.184	5.607
95.0% UCL of Mean	0.014	0.104	0.022	432.481	16.697
Standard Deviation	0.009	0.098	0.015	705.309	28.089
Coefficient of Variation	0.761	1.138	0.774	2.325	2.519
Cleveland percentiles					
1%	0.005	0.007	0.003	2.670	0.808
5%	0.005	0.012	0.004	6.210	1.255
10%	0.005	0.015	0.005	15.000	1.418
20%	0.005	0.020	0.008	31.800	2.100
25%	0.009	0.022	0.009	42.000	2.175
30%	0.010	0.024	0.009	51.200	2.200
40%	0.010	0.034	0.011	74.300	2.600
50%	0.010	0.046	0.014	98.000	3.080
60%	0.010	0.066	0.017	157.000	3.574
70%	0.011	0.090	0.023	223.400	5.500
75%	0.014	0.110	0.026	270.000	5.950
80%	0.016	0.134	0.031	311.000	7.260
90%	0.020	0.217	0.040	712.000	25.400
95%	0.024	0.289	0.050	1230.000	59.880
99%	0.058	0.456	0.067	5032.000	169.000

Thomsons Cr at Race

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	31	0	31	36	0
Minimum	0.005	.	0.001	1.600	.
Maximum	0.120	.	0.008	1600.000	.
Median	0.005	.	0.004	21.000	.
Mean	0.009	.	0.004	99.500	.
Standard Error of Mean	0.004	.	0.000	45.549	.
95.0% LCL of Mean	0.002	.	0.004	7.030	.
95.0% UCL of Mean	0.017	.	0.005	191.970	.
Standard Deviation	0.021	.	0.002	273.296	.
Coefficient of Variation	2.244	.	0.385	2.747	.
Cleveland percentiles					
1%	0.005	.	0.001	1.600	.
5%	0.005	.	0.001	1.600	.
10%	0.005	.	0.002	1.600	.
20%	0.005	.	0.003	5.700	.
25%	0.005	.	0.004	8.000	.
30%	0.005	.	0.004	10.300	.
40%	0.005	.	0.004	12.900	.
50%	0.005	.	0.004	21.000	.
60%	0.005	.	0.005	33.100	.
70%	0.005	.	0.005	48.100	.
75%	0.005	.	0.005	86.000	.
80%	0.005	.	0.005	109.000	.
90%	0.008	.	0.006	159.000	.
95%	0.013	.	0.007	407.600	.
99%	0.120	.	0.008	1600.000	.

Manu R u/s Thomsons Cr

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	5	5	5	5	5
Minimum	0.005	0.010	0.004	100.000	1.080
Maximum	0.018	0.107	0.028	5200.000	64.000
Median	0.005	0.026	0.007	180.000	6.200
Mean	0.008	0.049	0.010	1168.000	19.656
Standard Error of Mean	0.003	0.020	0.005	1008.124	11.901
95.0% LCL of Mean	0.000	-0.007	-0.002	-1631.001	-13.387
95.0% UCL of Mean	0.015	0.105	0.023	3967.001	52.699
Standard Deviation	0.006	0.045	0.010	2254.234	26.612
Coefficient of Variation	0.765	0.914	0.979	1.930	1.354
Cleveland percentiles					
1%	0.005	0.010	0.004	100.000	1.080
5%	0.005	0.010	0.004	100.000	1.080
10%	0.005	0.010	0.004	100.000	1.080
20%	0.005	0.013	0.004	135.000	1.540
25%	0.005	0.014	0.004	152.500	1.770
30%	0.005	0.015	0.004	170.000	2.000
40%	0.005	0.021	0.006	175.000	4.100
50%	0.005	0.026	0.007	180.000	6.200
60%	0.005	0.057	0.008	185.000	15.600
70%	0.005	0.088	0.009	190.000	25.000
75%	0.008	0.093	0.013	1442.500	34.750
80%	0.012	0.098	0.018	2695.000	44.500
90%	0.018	0.107	0.028	5200.000	64.000
95%	0.018	0.107	0.028	5200.000	64.000
99%	0.018	0.107	0.028	5200.000	64.000

Thomsons Cr at SH85

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	102	102	102	106	78
Minimum	0.005	0.003	0.004	1.000	1.500
Maximum	0.100	0.680	0.180	5700.000	230.000
Median	0.010	0.107	0.025	347.000	4.100
Mean	0.014	0.166	0.042	732.325	10.151
Standard Error of Mean	0.002	0.015	0.004	95.407	3.149
95.0% LCL of Mean	0.011	0.136	0.034	543.152	3.881
95.0% UCL of Mean	0.018	0.195	0.050	921.499	16.421
Standard Deviation	0.016	0.150	0.042	982.272	27.809
Coefficient of Variation	1.084	0.906	0.993	1.341	2.740
Cleveland percentiles					
1%	0.005	0.004	0.004	2.288	1.556
5%	0.005	0.008	0.004	9.800	1.782
10%	0.005	0.013	0.006	26.200	2.130
20%	0.005	0.039	0.009	51.400	2.600
25%	0.005	0.045	0.010	86.000	2.800
30%	0.008	0.058	0.011	113.000	3.090
40%	0.010	0.079	0.016	209.100	3.580
50%	0.010	0.107	0.025	347.000	4.100
60%	0.010	0.168	0.042	517.300	5.330
70%	0.013	0.230	0.059	760.000	5.820
75%	0.016	0.280	0.066	890.000	6.900
80%	0.020	0.310	0.073	1204.000	7.590
90%	0.024	0.403	0.097	2100.000	10.040
95%	0.042	0.430	0.134	2900.000	40.400
99%	0.091	0.597	0.175	4580.000	186.600

Manu R u/s Chatto Cr

Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	46	46	46	20	21
Minimum	0.005	0.001	0.002	18.000	0.560
Maximum	0.063	0.440	0.052	5900.000	180.000
Median	0.010	0.022	0.014	105.000	2.600
Mean	0.010	0.081	0.017	507.450	23.530
Standard Error of Mean	0.002	0.017	0.002	304.581	10.887
95.0% LCL of Mean	0.007	0.046	0.013	-130.046	0.822
95.0% UCL of Mean	0.013	0.116	0.020	1144.946	46.239
Standard Deviation	0.010	0.117	0.011	1362.128	49.888
Coefficient of Variation	1.007	1.448	0.682	2.684	2.120
Cleveland percentiles					
1%	0.005	0.001	0.002	18.000	0.560
5%	0.005	0.007	0.005	19.000	0.665
10%	0.005	0.009	0.005	25.000	1.074
20%	0.005	0.012	0.008	37.500	1.500
25%	0.005	0.013	0.009	52.000	1.567
30%	0.005	0.014	0.010	71.000	1.598
40%	0.010	0.020	0.011	87.000	1.895
50%	0.010	0.022	0.014	105.000	2.600
60%	0.010	0.030	0.017	125.000	5.420
70%	0.010	0.046	0.020	170.000	8.500
75%	0.010	0.069	0.023	190.000	10.275
80%	0.010	0.184	0.024	210.000	24.420
90%	0.010	0.288	0.031	1285.000	90.000
95%	0.018	0.332	0.044	4100.000	166.800
99%	0.063	0.440	0.052	5900.000	180.000

Chatto Cr at Manu R

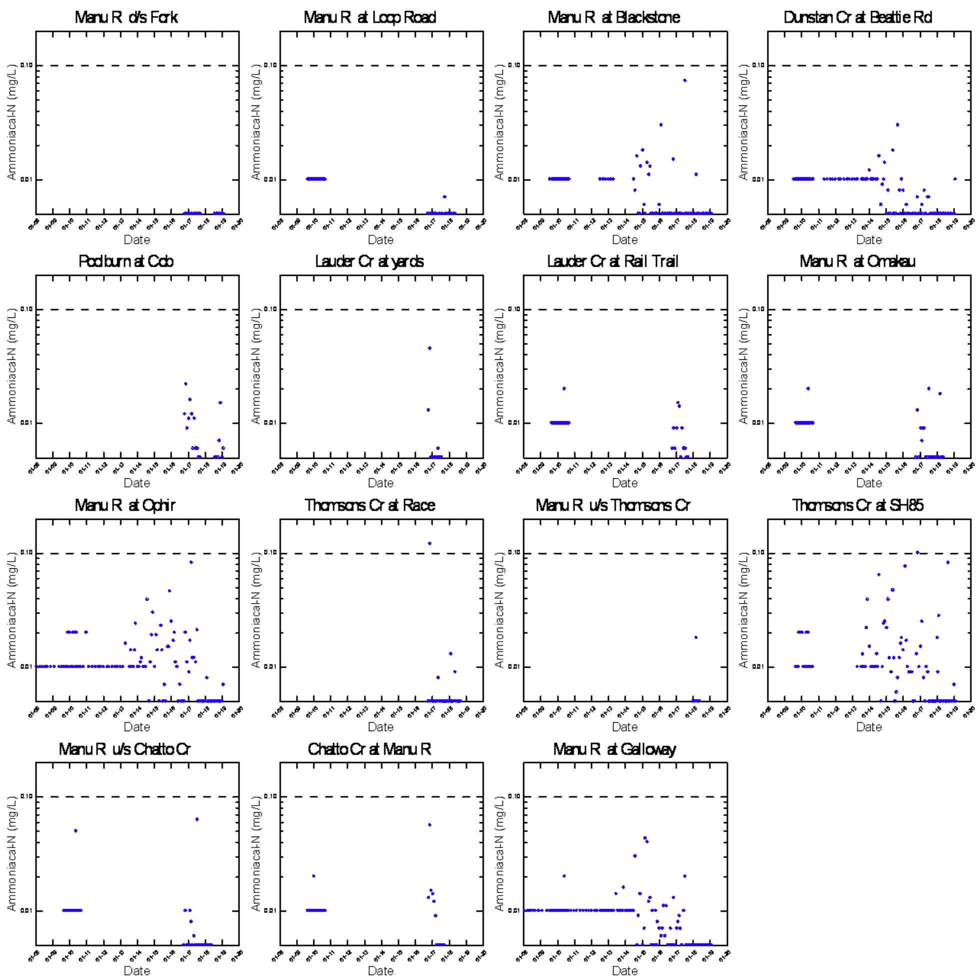
Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	38	38	38	12	13
Minimum	0.005	0.021	0.005	30.000	1.000
Maximum	0.056	0.386	0.063	880.000	6.800
Median	0.010	0.120	0.021	140.000	2.900
Mean	0.011	0.147	0.023	280.500	2.982
Standard Error of Mean	0.001	0.015	0.002	84.418	0.510
95.0% LCL of Mean	0.008	0.116	0.019	94.698	1.870
95.0% UCL of Mean	0.014	0.179	0.027	466.302	4.094
Standard Deviation	0.008	0.095	0.013	292.431	1.840
Coefficient of Variation	0.728	0.643	0.546	1.043	0.617
Cleveland percentiles					
1%	0.005	0.021	0.005	30.000	1.000
5%	0.005	0.030	0.007	30.300	1.015
10%	0.005	0.047	0.009	32.100	1.080
20%	0.010	0.077	0.011	42.000	1.264
25%	0.010	0.083	0.012	71.500	1.290
30%	0.010	0.086	0.014	102.000	1.460
40%	0.010	0.111	0.017	120.000	2.260
50%	0.010	0.120	0.021	140.000	2.900
60%	0.010	0.146	0.025	188.000	3.130
70%	0.010	0.163	0.030	371.000	3.260
75%	0.010	0.200	0.031	470.000	3.800
80%	0.010	0.216	0.034	569.000	5.100
90%	0.014	0.302	0.038	782.000	5.600
95%	0.018	0.338	0.043	866.000	6.575
99%	0.056	0.386	0.063	880.000	6.800

Manu R at Galloway

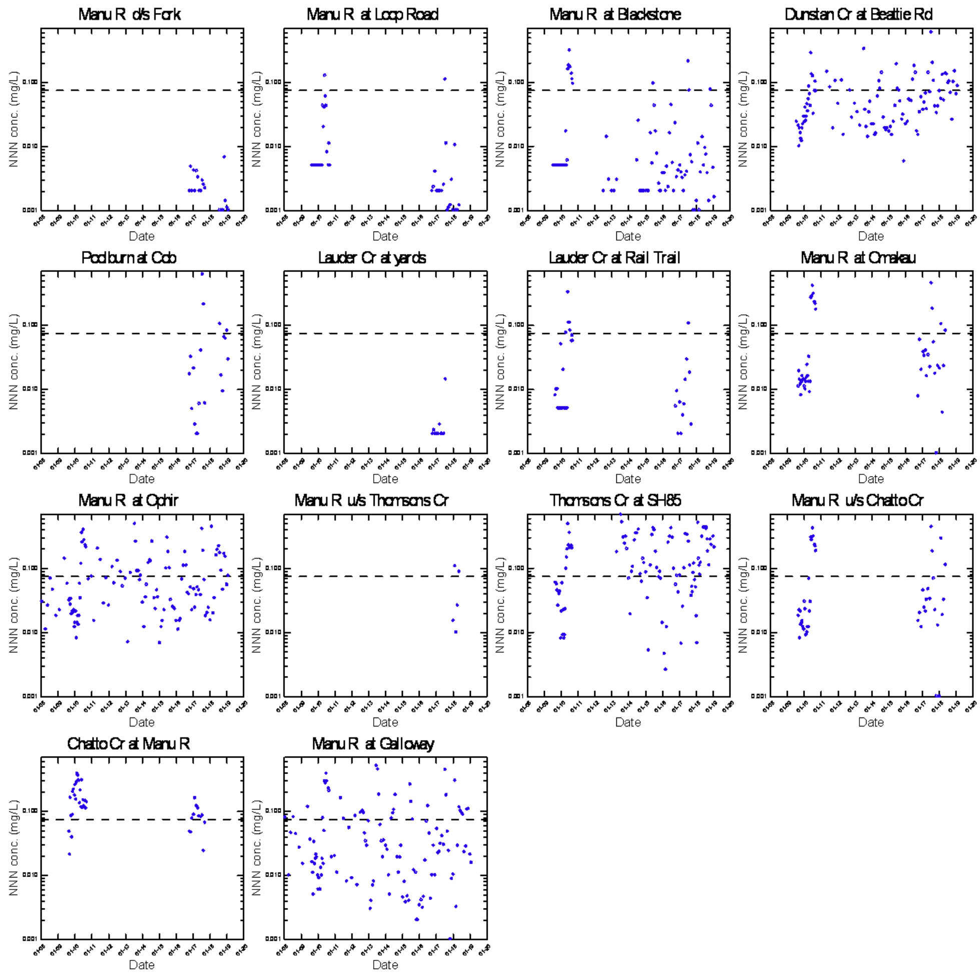
Statistic	Ammoniacal-N (mg/L)	NNN conc. (mg/L)	DRP conc. (mg/L)	*E. coli* conc. (MPN/100 mL)	Turbidity (NTU)
N of Cases	124	124	124	205	107
Minimum	0.005	0.001	0.001	1.000	0.650
Maximum	0.043	0.510	0.044	5700.000	200.000
Median	0.010	0.026	0.011	70.000	2.600
Mean	0.010	0.065	0.013	254.548	13.508
Standard Error of Mean	0.000	0.009	0.001	45.563	3.392
95.0% LCL of Mean	0.009	0.048	0.011	164.713	6.783
95.0% UCL of Mean	0.011	0.083	0.014	344.383	20.232
Standard Deviation	0.005	0.097	0.007	652.365	35.084
Coefficient of Variation	0.554	1.481	0.575	2.563	2.597
Cleveland percentiles					
1%	0.005	0.002	0.003	1.385	0.678
5%	0.005	0.003	0.004	4.675	0.938
10%	0.005	0.004	0.005	12.000	1.100
20%	0.005	0.008	0.007	24.500	1.369
25%	0.006	0.010	0.008	28.750	1.485
30%	0.008	0.011	0.008	34.000	1.640
40%	0.010	0.019	0.010	47.500	2.330
50%	0.010	0.026	0.011	70.000	2.600
60%	0.010	0.035	0.013	99.000	3.940
70%	0.010	0.069	0.015	133.000	5.180
75%	0.010	0.080	0.017	171.000	8.038
80%	0.010	0.095	0.017	227.500	10.110
90%	0.011	0.180	0.020	580.000	20.540
95%	0.015	0.292	0.023	1105.000	72.305
99%	0.041	0.466	0.043	3700.000	194.300

Appendix E Time series plots, all sites

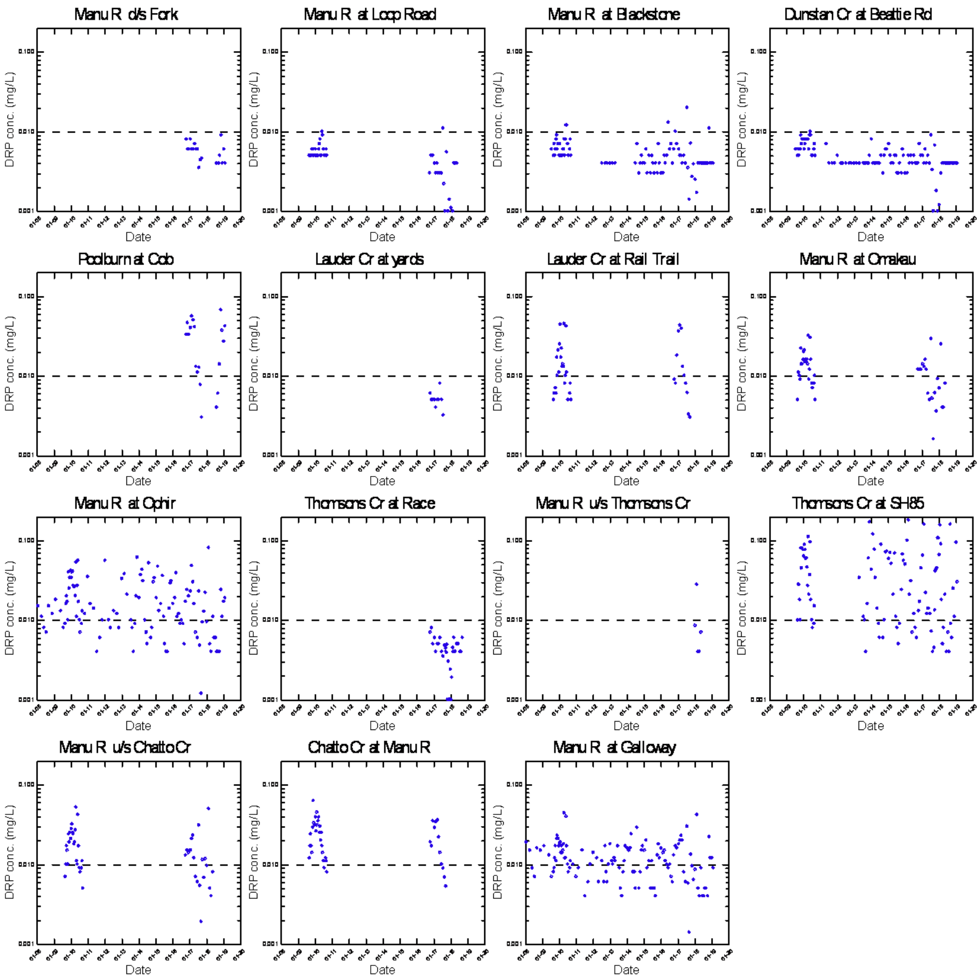
Ammoniacal-N concentrations



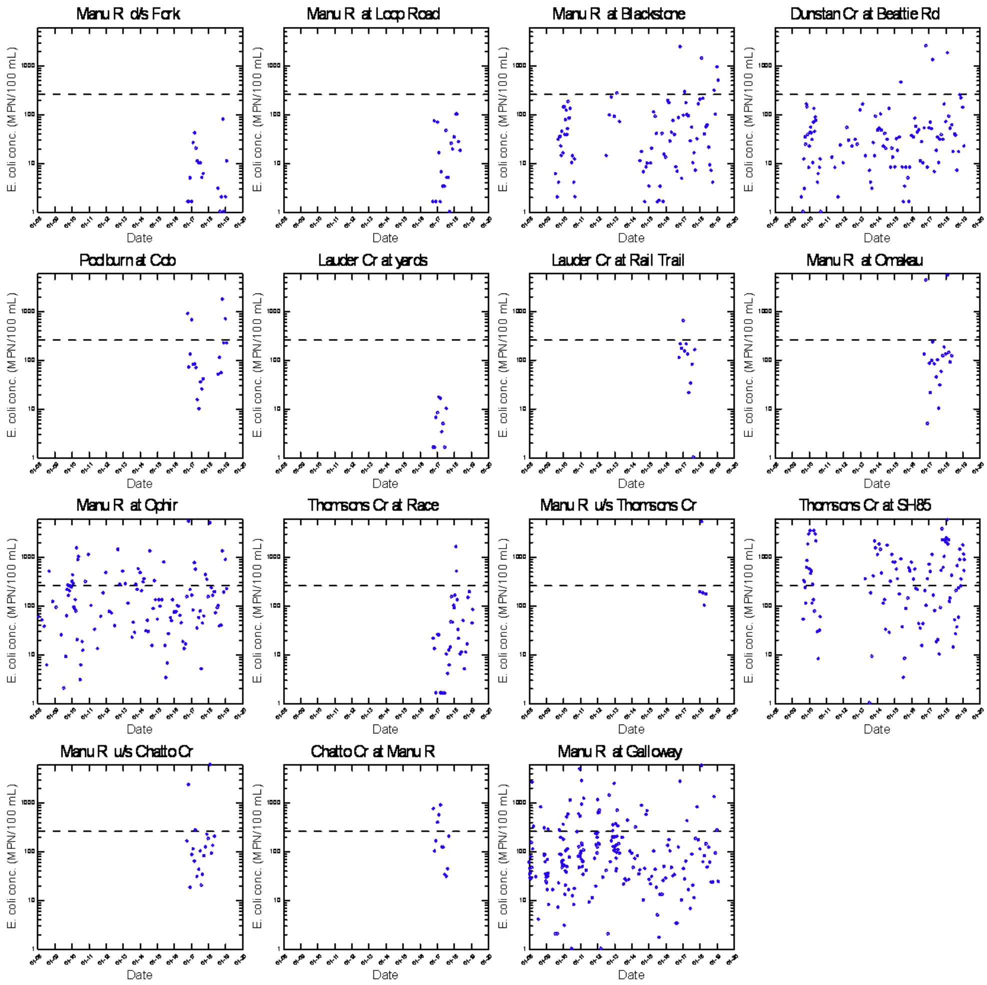
NNN concentrations



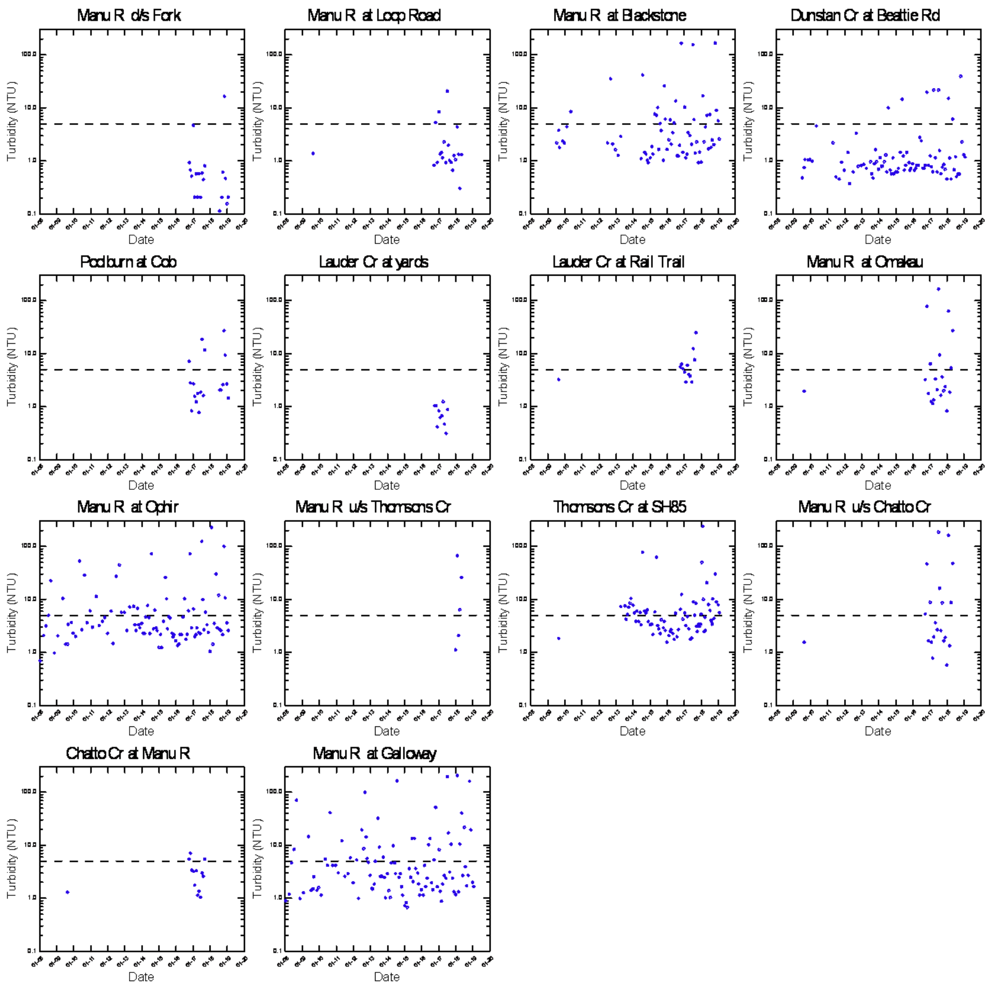
DRP concentrations



E. coli concentrations



Turbidity values



Appendix F NPS-FM NOF *E. coli* grades

Table F-1: Grading of *E. coli* concentrations according to the MfE NPS-FM attribute values and schema. Where sufficient data exist (~60 per five-year period), the row is shaded. Where at least 10 values exist for the five-year period (insufficient for NPS-FM grading), an approximate "grading" is indicated in the column Overall Grade (indicative only).

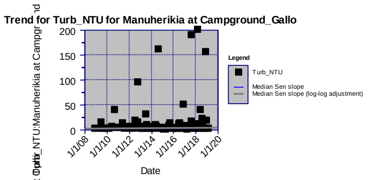
Period	Site	N of Cases	Numeric attributes state				Grading according to individual attribute state				Indicative "Overall grade"
			Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	
2009/13	Dunstan Cr at Beattie Rd	45	0	0	23	145	Blue	Blue	Blue	Blue	Blue
2009/13	Ida Burn at Auripo Rd	31	13	30	90	3745	Yellow	Yellow	Blue	Orange	Orange
2009/13	Ida Burn at SH85	31	0	0	12	109	Blue	Blue	Blue	Blue	Blue
2009/13	Manuherikia at Blackston	32	0	4	38	216	Blue	Blue	Blue	Blue	Blue
2009/13	Manuherikia at Galloway	143	12	19	81	1107	Yellow	Blue	Blue	Yellow	Yellow
2009/13	Manuherikia at Ophir	55	11	30	110	1075	Yellow	Yellow	Blue	Yellow	Yellow
2009/13	Pool Burn at Auripo Rd	32	13	25	102	2400	Yellow	Green	Blue	Orange	Orange
2009/13	Thomsons Cr at SH85	31	36	59	320	3375	Red	Orange	Orange	Orange	Red
2010/14	Dunstan Cr at Beattie Rd	48	0	0	24	130	Blue	Blue	Blue	Blue	Blue
2010/14	Ida Burn at Auripo Rd	22	14	37	135	3140	Yellow	Orange	Orange	Orange	Orange
2010/14	Ida Burn at SH85	22	0	0	12	126	Blue	Blue	Blue	Blue	Blue
2010/14	Manuherikia at Blackston	29	0	4	38	223	Blue	Blue	Blue	Blue	Blue
2010/14	Manuherikia at Galloway	109	16	23	101	1124	Yellow	Green	Blue	Yellow	Yellow
2010/14	Manuherikia at Ophir	50	14	40	130	1300	Yellow	Orange	Blue	Orange	Orange
2010/14	Pool Burn at Auripo Rd	23	14	27	130	3415	Yellow	Green	Blue	Orange	Orange
2010/14	Thomsons Cr at SH85	35	40	60	400	3275	Red	Orange	Orange	Orange	Red
2011/15	Dunstan Cr at Beattie Rd	43	0	3	20	141	Blue	Blue	Blue	Blue	Blue
2011/15	Manuherikia at Blackston	24	0	5	15	235	Blue	Blue	Blue	Blue	Blue
2011/15	Manuherikia at Galloway	94	14	21	99	1080	Yellow	Green	Blue	Yellow	Yellow

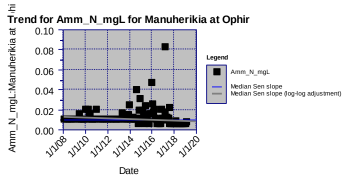
Period	Site	N of Cases	Numeric attributes state				Grading according to individual attribute state				Indicative "Overall grade"
			Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	
2011/15	Manuherikia at Ophir	45	12	32	99	1150	Yellow	Yellow	Blue	Yellow	Yellow
2011/15	Thomsons Cr at SH85	31	39	59	350	1795	Red	Orange	Orange	Orange	Orange
2012/16	Dunstan Cr at Beattie Rd	51	2	4	26	159	Blue	Blue	Blue	Blue	Blue
2012/16	Manuherikia at Blackston	36	3	6	19	255	Blue	Blue	Blue	Blue	Blue
2012/16	Manuherikia at Galloway	83	14	20	100	958	Yellow	Green	Blue	Green	Yellow
2012/16	Manuherikia at Ophir	51	10	28	96	1274	Yellow	Green	Blue	Orange	Orange
2012/16	Thomsons Cr at SH85	43	33	52	310	1735	Red	Orange	Orange	Orange	Red
2013/17	Chatto Cr u/s Manuheriki	12	25	34	140	866	Orange	Orange	Orange	Green	Orange
2013/17	Dunstan Cr at Beattie Rd	57	4	6	30	349	Blue	Blue	Blue	Blue	Blue
2013/17	Lauder Cr at Cattle Yard	10	0	0	6	17	Blue	Blue	Blue	Blue	Blue
2013/17	Lauder Cr at Rail trail	12	9	9	140	588	Green	Blue	Orange	Green	Orange
2013/17	Manuherikia at Blackston	45	3	7	28	275	Blue	Blue	Blue	Blue	Blue
2013/17	Manuherikia at Galloway	73	10	17	70	784	Yellow	Blue	Blue	Green	Yellow
2013/17	Manuherikia at Loop Rd	15	0	0	5	71	Blue	Blue	Blue	Blue	Blue
2013/17	Manuherikia at Omakau	15	7	7	84	3283	Green	Blue	Blue	Orange	Orange
2013/17	Manuherikia at Ophir	57	11	27	86	763	Yellow	Green	Blue	Green	Yellow
2013/17	Manuherikia d/s Forks	12	0	0	8	40	Blue	Blue	Blue	Blue	Blue
2013/17	Manuherikia u/s Chatto C	15	7	14	84	1793	Green	Blue	Blue	Orange	Orange
2013/17	Poolburn at Cob Cottage	12	17	17	69	858	Yellow	Blue	Blue	Green	Yellow
2013/17	Thomsons Cr at Race	18	0	0	11	109	Blue	Blue	Blue	Blue	Blue
2013/17	Thomsons Cr at SH85	57	36	53	340	1995	Red	Orange	Orange	Orange	Red
2014/18	Chatto Cr u/s Manuheriki	12	25	34	140	866	Orange	Orange	Orange	Green	Orange

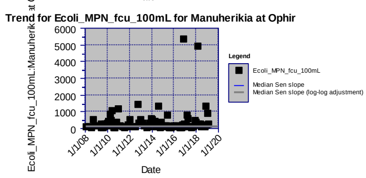
Period	Site	N of Cases	Numeric attributes state				Grading according to individual attribute state				Indicative "Overall grade"
			Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	
2014/18	Dunstan Cr at Beattie Rd	60	5	7	34	875	Green	Blue	Blue	Green	Green
2014/18	Lauder Cr at Cattle Yard	10	0	0	6	17	Blue	Blue	Blue	Blue	Blue
2014/18	Lauder Cr at Rail trail	12	9	9	140	588	Green	Blue	Orange	Green	Orange
2014/18	Manuherikia at Blackston	54	4	8	30	305	Blue	Blue	Blue	Blue	Blue
2014/18	Manuherikia at Galloway	60	12	15	47	1085	Yellow	Blue	Blue	Yellow	Yellow
2014/18	Manuherikia at Loop Rd	20	0	0	17	100	Blue	Blue	Blue	Blue	Blue
2014/18	Manuherikia at Omakau	20	10	10	98	4850	Yellow	Blue	Blue	Orange	Orange
2014/18	Manuherikia at Ophir	60	12	22	93	1300	Yellow	Green	Blue	Orange	Orange
2014/18	Manuherikia d/s Forks	17	0	0	5	66	Blue	Blue	Blue	Blue	Blue
2014/18	Manuherikia u/s Chatto C	20	10	15	105	4100	Yellow	Blue	Blue	Orange	Orange
2014/18	Poolburn at Cob Cottage	17	18	18	70	1435	Yellow	Blue	Blue	Orange	Orange
2014/18	Thomsons Cr at Race	34	3	6	19	439	Blue	Blue	Blue	Blue	Blue
2014/18	Thomsons Cr at SH85	71	39	53	340	2200	Red	Orange	Orange	Orange	Red
2015/19	Chatto Cr u/s Manuheriki	12	25	34	140	866	Orange	Orange	Orange	Green	Orange
2015/19	Dunstan Cr at Beattie Rd	50	6	8	34	1300	Green	Blue	Blue	Orange	Orange
2015/19	Lauder Cr at Cattle Yard	10	0	0	6	17	Blue	Blue	Blue	Blue	Blue
2015/19	Lauder Cr at Rail trail	12	9	9	140	588	Green	Blue	Orange	Green	Orange
2015/19	Manuherikia at Blackston	50	6	12	40	921	Green	Blue	Blue	Green	Green
2015/19	Manuherikia at Galloway	50	8	12	45	1300	Green	Blue	Blue	Orange	Orange
2015/19	Manuherikia at Loop Rd	20	0	0	17	100	Blue	Blue	Blue	Blue	Blue
2015/19	Manuherikia at Omakau	20	10	10	98	4850	Yellow	Blue	Blue	Orange	Orange
2015/19	Manuherikia at Ophir	50	14	18	93	1300	Yellow	Blue	Blue	Orange	Orange

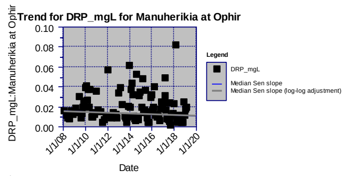
Period	Site	N of Cases	Numeric attributes state				Grading according to individual attribute state				Indicative "Overall grade"
			Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	Proportion of values >540 cfu/100 mL (%)	Proportion of values >260 cfu/100 mL (%)	Median	Pct95	
2015/19	Manuherikia d/s Forks	19	0	0	5	62	Blue	Blue	Blue	Blue	Blue
2015/19	Manuherikia u/s Chatto C	20	10	15	105	4100	Yellow	Blue	Blue	Orange	Orange
2015/19	Poolburn at Cob Cottage	19	22	22	80	1350	Orange	Green	Blue	Orange	Orange
2015/19	Thomsons Cr at Race	36	3	6	21	408	Blue	Blue	Blue	Blue	Blue
2015/19	Thomsons Cr at SH85	63	39	53	344	2270	Red	Orange	Orange	Orange	Red

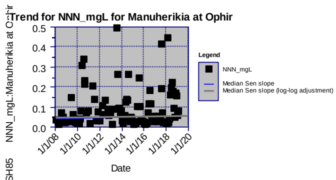
Appendix G Trend assessment results

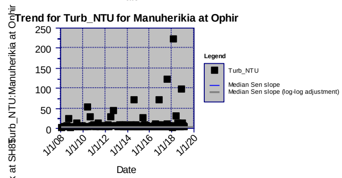


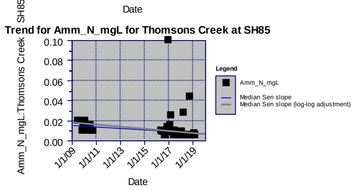


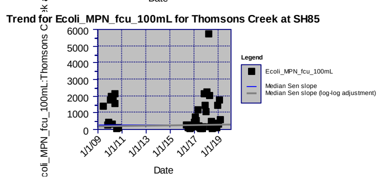


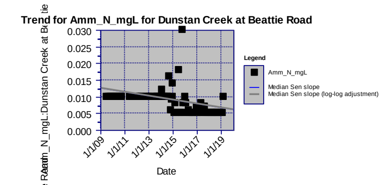
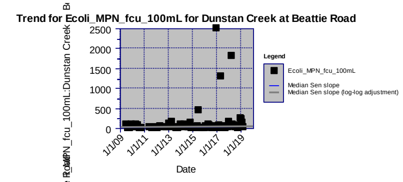
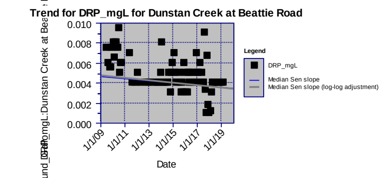











Trend for Amm_N_mgL for Dunstan Creek at Beattie Road

Trend for Ecoli_MPN_fcu_100mL for Dunstan Creek at Beattie Road

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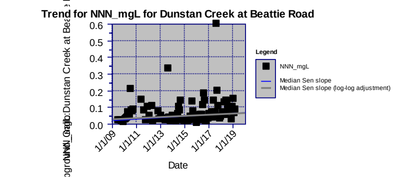
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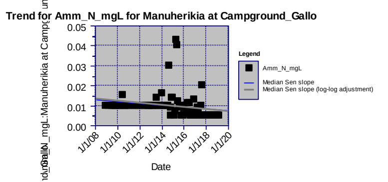
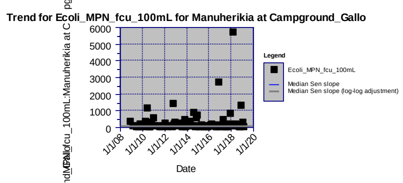

Trend for Amm_N_mgL for Manuherikia at Campground_Gallo

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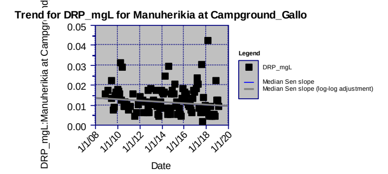
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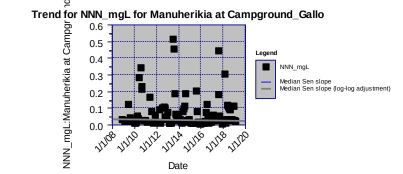
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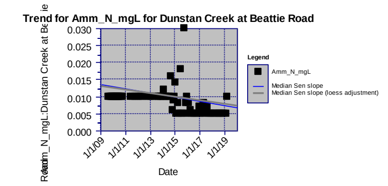
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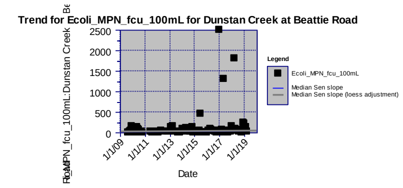
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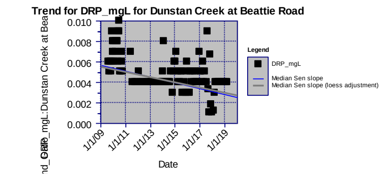
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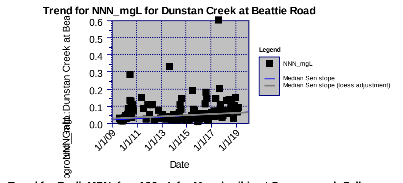
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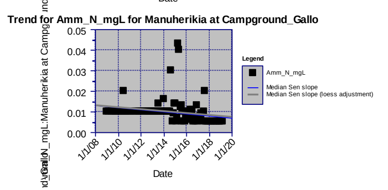
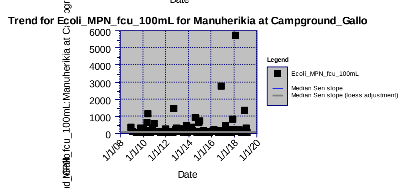
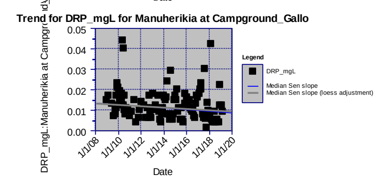

Trend for Amm_N_mgL for Manuherikia at Campground_Gallo

Trend for Ecoli_MPN_fcu_100mL for Manuherikia at Campground_Gallo

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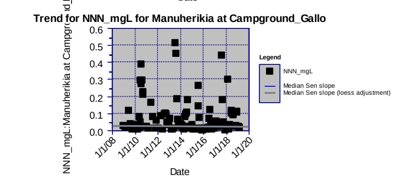
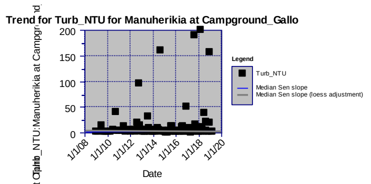

Trend for NNN_mgL for Manuherikia at Campground_Gallo


Trend for Turb_NTU for Manuherikia at Campground_Gallo
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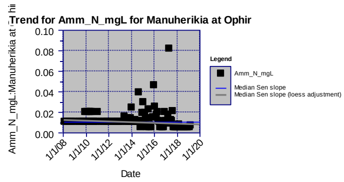
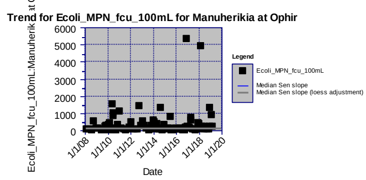
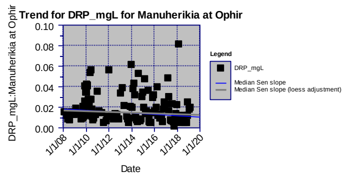
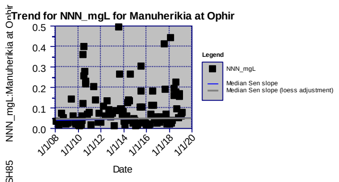
Legend
Turb_NTU
Median Sen slope
Median Sen slope (loess adjustment)


Trend for Amm_N_mgL for Manuherikia at Ophir
Date
Legend
Amm_N_mgL
Median Sen slope
Median Sen slope (loess adjustment)


Trend for Ecoli_MPN_fcu_100mL for Manuherikia at Ophir
Date
Legend
Ecoli_MPN_fcu_100mL
Median Sen slope
Median Sen slope (loess adjustment)


Trend for DRP_mgL for Manuherikia at Ophir
Date
Legend
DRP_mgL
Median Sen slope
Median Sen slope (loess adjustment)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Legend
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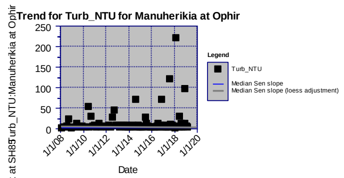
Median Sen slope (loess adjustment)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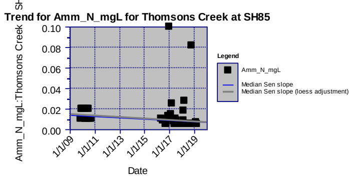
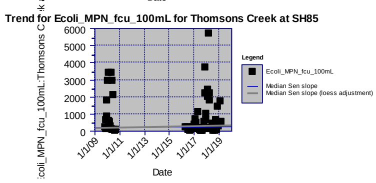
Legend
Turb_NTU
Median Sen slope
Median Sen slope (loess adjustment)


Trend for Amm_N_mgL for Thomsons Creek at SH85
Date
Legend
Amm_N_mgL
Median Sen slope
Median Sen slope (loess adjustment)


Trend for Ecoli_MPN_fcu_100mL for Thomsons Creek at SH85
Date
Legend
Ecoli_MPN_fcu_100mL
Median Sen slope
Median Sen slope (loess adjustment)

Assessment of trend using Mann-Kendall test and slope analysis with median values in each time period of one month

Time periods used in analysis are: January February March April May June July August September October November December
If the sample size is less than 10 small sample size probabilities are used otherwise a normal approximation is used to determine P value
Slope assessment excludes any censored values. Data for ammoniacal-N are struck-through, to cautioning against use of this information because of the impact of change in detection limit over time.

Site	Variable	Samples used	Sampling period	Median value	Kendall statistic	Variance	Z	P	Median Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
~~Dunstan Creek at Beattie Road~~	~~Amm_N_mgL~~	~~93~~	~~17/6/09-11/2/19~~	~~0.01~~	~~-2038~~	~~77456.00~~	~~-7.32~~	~~0.00~~	~~0.00~~	~~-6.45~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
~~Dunstan Creek at Beattie Road~~	~~Flow_L_s adjusted~~	~~93~~	~~17/6/09-11/2/19~~	~~0.01~~	~~-2057~~	~~90777.67~~	~~-6.82~~	~~0.00~~	~~0.00~~	~~-6.60~~	~~0.00 to 0.00~~	~~1.00~~	~~Increasing trend virtually certain~~
Dunstan Creek at Beattie Road	Ecoli_MPN_fcu_100mL	93	17/6/09-11/2/19	30.00	673	90732.00	2.23	0.03	2.23	7.43	0.19 to 4.71	0.99	Increasing trend very likely
Dunstan Creek at Beattie Road	Flow_L_s adjusted	93	17/6/09-11/2/19	30.00	496	90788.67	1.64	0.10	1.81	6.04	-0.45 to 4.24	0.95	Increasing trend possible
Dunstan Creek at Beattie Road	DRP_mgL	93	17/6/09-11/2/19	0.00	-1199	79914.33	-4.24	0.00	0.00	-2.61	0.00 to 0.00	1.00	Decreasing trend virtually certain
Dunstan Creek at Beattie Road	Flow_L_s adjusted	93	17/6/09-11/2/19	0.00	-1085	90783.00	-3.60	0.00	0.00	-4.43	0.00 to 0.00	1.00	Increasing trend virtually certain
Dunstan Creek at Beattie Road	NNN_mgL	93	17/6/09-11/2/19	0.05	915	90749.67	3.03	0.00	0.00	9.03	0.00 to 0.01	1.00	Increasing trend virtually certain
Dunstan Creek at Beattie Road	Flow_L_s adjusted	93	17/6/09-11/2/19	0.05	600	90788.67	1.99	0.05	0.00	5.42	0.00 to 0.01	0.98	Increasing trend very likely
~~Manuherikia at Campground_Gallo~~	~~Amm_N_mgL~~	~~106~~	~~4/12/08-11/2/19~~	~~0.01~~	~~-2201~~	~~115517.64~~	~~-6.47~~	~~0.00~~	~~0.00~~	~~-4.60~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
~~Manuherikia at Campground_Gallo~~	~~Flow_L_s adjusted~~	~~106~~	~~4/12/08-11/2/19~~	~~0.01~~	~~-2253~~	~~130424.33~~	~~-6.24~~	~~0.00~~	~~0.00~~	~~-5.28~~	~~0.00 to 0.00~~	~~1.00~~	~~Increasing trend virtually certain~~
Manuherikia at Campground_Gallo	Ecoli_MPN_fcu_100mL	106	4/12/08-11/2/19	47.50	245	134143.67	0.67	0.51	1.18	2.48	-2.78 to 5.02	0.75	Increasing trend about as likely as not

Site	Variable	Samples used	Sampling period	Median value	Kendall statistic	Variance	Z	P	Median Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
Manuherikia at Campground_Gallo	Flow_L_s adjusted	106	4/12/08-11/2/19	47.00	126	130433.33	0.35	0.73	0.82	1.72	-3.85 to 5.11	0.64	Trend unlikely
Manuherikia at Campground_Gallo	DRP_mgL	106	4/12/08-11/2/19	0.01	-686	133743.71	-1.87	0.06	0.00	-3.12	0.00 to 0.00	0.97	Decreasing trend likely
Manuherikia at Campground_Gallo	Flow_L_s adjusted	106	4/12/08-11/2/19	0.01	-916	130433.33	-2.53	0.01	0.00	-2.88	0.00 to 0.00	0.99	Increasing trend very likely
Manuherikia at Campground_Gallo	NNN_mgL	106	4/12/08-11/2/19	0.03	-192	134118.01	-0.52	0.60	0.00	-1.70	0.00 to 0.00	0.70	Decreasing trend about as likely as not
Manuherikia at Campground_Gallo	Flow_L_s adjusted	106	4/12/08-11/2/19	0.03	-324	130433.33	-0.89	0.37	0.00	-2.68	0.00 to 0.00	0.82	Increasing trend about as likely as not
Manuherikia at Campground_Gallo	Turb_NTU	100	4/12/08-11/2/19	2.70	142	112701.33	0.42	0.67	0.02	0.92	-0.13 to 0.20	0.66	Trend unlikely
Manuherikia at Campground_Gallo	Flow_L_s adjusted	100	4/12/08-11/2/19	2.70	-114	112750.00	-0.34	0.74	-0.02	-0.63	-0.12 to 0.09	0.63	Trend unlikely
~~Manuherikia at Ophir~~	~~Amm_N_mgL~~	~~105~~	~~30/1/08-11/2/19~~	~~0.01~~	~~-1106~~	~~120817.54~~	~~-3.18~~	~~0.00~~	~~0.00~~	~~0.00~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
~~Manuherikia at Ophir~~	~~Flow_L_s adjusted~~	~~105~~	~~30/1/08-11/2/19~~	~~0.01~~	~~-1045~~	~~126757.67~~	~~-2.93~~	~~0.00~~	~~0.00~~	~~-3.49~~	~~0.00 to 0.00~~	~~1.00~~	~~Increasing trend virtually certain~~
Manuherikia at Ophir	Ecoli_MPN_fcu_100mL	105	30/1/08-11/2/19	98.00	254	130408.67	0.70	0.48	2.10	2.14	-4.73 to 8.83	0.76	Increasing trend about as likely as not
Manuherikia at Ophir	Flow_L_s adjusted	105	30/1/08-11/2/19	98.50	46	126758.67	0.13	0.90	0.43	0.44	-7.37 to 6.98	0.55	Trend unlikely
Manuherikia at Ophir	DRP_mgL	105	30/1/08-11/2/19	0.01	-630	130214.02	-1.74	0.08	0.00	-3.97	0.00 to 0.00	0.96	Decreasing trend likely
Manuherikia at Ophir	Flow_L_s adjusted	105	30/1/08-11/2/19	0.01	-808	126758.67	-2.27	0.02	0.00	-4.14	0.00 to 0.00	0.99	Increasing trend very likely

Site	Variable	Samples used	Sampling period	Median value	Kendall statistic	Variance	Z	P	Median Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
Manuherikia at Ophir	NNN_mgL	105	30/1/08-11/2/19	0.05	367	130396.34	1.01	0.31	0.00	2.62	0.00 to 0.00	0.84	Increasing trend possible
Manuherikia at Ophir	Flow_L_s adjusted	105	30/1/08-11/2/19	0.05	182	126758.67	0.51	0.61	0.00	1.05	0.00 to 0.00	0.70	Increasing trend about as likely as not
Manuherikia at Ophir	Turb_NTU	99	30/1/08-11/2/19	3.08	-4	109294.67	-0.01	0.99	0.00	0.00	-0.13 to 0.14	0.51	Trend exceptionally unlikely
Manuherikia at Ophir	Flow_L_s adjusted	99	30/1/08-11/2/19	3.08	-197	109417.00	-0.59	0.55	-0.03	-1.04	-0.14 to 0.07	0.73	Increasing trend about as likely as not
~~Thomsons Creek at SH85~~	~~Amm_N_mgL~~	~~46~~	~~17/6/09-11/2/19~~	~~0.01~~	~~-450~~	~~10346.67~~	-4.41	~~0.00~~	~~0.00~~	~~-7.88~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
~~Thomsons Creek at SH85~~	~~Flow_L_s adjusted~~	~~46~~	~~17/6/09-11/2/19~~	~~0.01~~	~~-453~~	~~11155.00~~	-4.28	~~0.00~~	~~0.00~~	~~-8.63~~	~~0.00 to 0.00~~	~~1.00~~	~~Increasing trend virtually certain~~
Thomsons Creek at SH85	Ecoli_MPN_fcu_100mL	46	17/6/09-11/2/19	259.50	11	11153.00	0.09	0.92	1.89	0.73	-37.10 to 49.04	0.54	Trend extremely unlikely
Thomsons Creek at SH85	Flow_L_s adjusted	46	17/6/09-11/2/19	259.50	51	11155.00	0.47	0.64	11.92	4.59	-36.26 to 71.09	0.68	Increasing trend about as likely as not
Thomsons Creek at SH85	DRP_mgL	46	17/6/09-11/2/19	0.02	-157	11145.33	-1.48	0.14	0.00	-6.45	0.00 to 0.00	0.93	Decreasing trend possible
Thomsons Creek at SH85	Flow_L_s adjusted	46	17/6/09-11/2/19	0.02	-57	11155.00	-0.53	0.60	0.00	-1.84	0.00 to 0.00	0.71	Increasing trend about as likely as not
Thomsons Creek at SH85	NNN_mgL	46	17/6/09-11/2/19	0.12	281	11148.33	2.65	0.01	0.01	12.26	0.00 to 0.03	1.00	Increasing trend virtually certain
Thomsons Creek at SH85	Flow_L_s adjusted	46	17/6/09-11/2/19	0.12	279	11155.00	2.63	0.01	0.02	13.39	0.00 to 0.03	1.00	Increasing trend virtually certain
Thomsons Creek at SH85	Turb_NTU	34	13/4/16-11/2/19	4.85	207	4546.33	3.06	0.00	1.51	31.03	0.61 to 2.50	1.00	Increasing trend virtually certain

Site	Variable	Samples used	Sampling period	Median value	Kendall statistic	Variance	Z	P	Median Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
Thomsons Creek at SH85	Flow_L_s adjusted	34	13/4/16-11/2/19	4.85	51	4550.33	0.74	0.46	0.32	6.56	-0.46 to 1.08	0.77	Increasing trend about as likely as not

Assessment of trend using seasonal Kendall test and slope analysis and all values in each season of 1 month

Loess smooth
Seasons used in analysis are: January February March April May June July August September October November December
If the sample size is less than 10 small sample size probabilities are used otherwise a normal approximation is used to determine P value
Slope assessment excludes any censored values.

Site	Variable	Samples used	Sampling period	Kendall statistic	Variance	Z	P	Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
~~Dunstan Creek at Beattie Road~~	~~Amm_N_mgL~~	~~107~~	~~30/7/09-11/2/19~~	~~-221~~	~~913.90~~	~~-7.28~~	~~0.00~~	~~0.00~~	~~-6.23~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
~~Dunstan Creek at Beattie Road~~	~~Adjusted for Flow_L_s~~	~~107~~	~~6/1/10-10/12/18~~	~~-200~~	~~1155.13~~	~~-5.86~~	~~0.00~~	~~0.00~~	~~-5.19~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
Dunstan Creek at Beattie Road	Ecoli_MPN_fcu_100mL	106	30/7/09-11/2/19	90	1138.15	2.64	0.01	1.61	5.37	0.50 to 3.67	1.00	Increasing trend virtually certain
Dunstan Creek at Beattie Road	Adjusted for Flow_L_s	106	6/1/10-10/12/18	55	1143.00	1.60	0.11	1.26	4.20	-0.43 to 3.15	0.95	Increasing trend possible
Dunstan Creek at Beattie Road	DRP_mgL	106	30/7/09-11/2/19	-168	994.45	-5.30	0.00	0.00	-7.11	0.00 to 0.00	1.00	Decreasing trend virtually certain
Dunstan Creek at Beattie Road	Adjusted for Flow_L_s	106	6/1/10-10/12/18	-160	1126.00	-4.74	0.00	0.00	-6.37	0.00 to 0.00	1.00	Decreasing trend virtually certain
Dunstan Creek at Beattie Road	NNN_mgL	107	30/7/09-11/2/19	118	1148.32	3.45	0.00	0.00	8.86	0.00 to 0.01	1.00	Increasing trend virtually certain
Dunstan Creek at Beattie Road	Adjusted for Flow_L_s	107	6/1/10-10/12/18	88	1158.00	2.56	0.01	0.00	6.75	0.00 to 0.00	0.99	Increasing trend very likely
Manuherikia at Campground_Gallo	Amm_N_mgL	119	4/12/08-11/2/19	-219	1215.70	-6.25	0.00	0.00	-4.98	0.00 to 0.00	1.00	Decreasing trend virtually certain

Site	Variable	Samples used	Sampling period	Kendall statistic	Variance	Z	P	Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
Manuherikia at Campground_Gallo	Adjusted for Flow_L_s	119	6/1/10-10/12/18	-237	1513.68	-6.07	0.00	0.00	-4.69	0.00 to 0.00	1.00	Decreasing trend virtually certain
Manuherikia at Campground_Gallo	Ecoli_MPN_fcu_100mL	118	4/12/08-11/2/19	73	1485.14	1.87	0.06	2.05	4.31	-0.03 to 4.85	0.97	Increasing trend likely
Manuherikia at Campground_Gallo	Adjusted for Flow_L_s	118	6/1/10-10/12/18	83	1489.00	2.13	0.03	2.42	5.09	0.41 to 5.36	0.98	Increasing trend very likely
Manuherikia at Campground_Gallo	DRP_mgL	119	4/12/08-11/2/19	-103	1483.38	-2.65	0.01	0.00	-3.60	0.00 to 0.00	1.00	Decreasing trend virtually certain
Manuherikia at Campground_Gallo	Adjusted for Flow_L_s	119	6/1/10-10/12/18	-100	1514.67	-2.54	0.01	0.00	-2.80	0.00 to 0.00	0.99	Decreasing trend very likely
Manuherikia at Campground_Gallo	NNN_mgL	119	4/12/08-11/2/19	-22	1508.16	-0.54	0.59	0.00	-1.24	0.00 to 0.00	0.72	Decreasing trend about as likely as not
Manuherikia at Campground_Gallo	Adjusted for Flow_L_s	119	6/1/10-10/12/18	-30	1514.67	-0.75	0.46	0.00	-2.91	0.00 to 0.00	0.79	Decreasing trend about as likely as not
Manuherikia at Campground_Gallo	Turb_NTU	102	4/12/08-11/2/19	21	1019.02	0.63	0.53	0.02	0.92	-0.09 to 0.18	0.73	Increasing trend about as likely as not
Manuherikia at Campground_Gallo	Adjusted for Flow_L_s	102	6/1/10-10/12/18	-27	1021.00	-0.81	0.42	-0.03	-1.12	-0.12 to 0.05	0.80	Decreasing trend about as likely as not
~~Manuherikia at Ophir~~	~~Amm_N_mgL~~	~~118~~	~~30/1/08-11/2/19~~	~~-105~~	~~1319.64~~	~~-2.86~~	~~0.00~~	~~0.00~~	~~0.00~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
~~Manuherikia at Ophir~~	~~Adjusted for Flow_L_s~~	~~118~~	~~30/1/08-10/12/18~~	~~-76~~	~~1551.35~~	~~-1.90~~	~~0.06~~	~~0.00~~	~~-3.07~~	~~0.00 to 0.00~~	~~0.97~~	~~Decreasing trend likely~~
Manuherikia at Ophir	Ecoli_MPN_fcu_100mL	117	30/1/08-11/2/19	89	1523.74	2.25	0.02	2.91	2.97	0.51 to 6.80	0.99	Increasing trend very likely
Manuherikia at Ophir	Adjusted for Flow_L_s	117	30/1/08-10/12/18	50	1526.67	1.25	0.21	3.00	3.06	-0.91 to 7.44	0.90	Increasing trend possible
Manuherikia at Ophir	DRP_mgL	118	30/1/08-11/2/19	-110	1529.51	-2.79	0.01	0.00	-4.48	0.00 to 0.00	1.00	Decreasing trend virtually certain

Site	Variable	Samples used	Sampling period	Kendall statistic	Variance	Z	P	Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
Manuherikia at Ophir	Adjusted for Flow_L_s	118	30/1/08-10/12/18	-99	1552.33	-2.49	0.01	0.00	-2.67	0.00 to 0.00	0.99	Decreasing trend very likely
Manuherikia at Ophir	NNN_mgL	118	30/1/08-11/2/19	86	1544.92	2.16	0.03	0.00	2.17	0.00 to 0.00	0.98	Increasing trend very likely
Manuherikia at Ophir	Adjusted for Flow_L_s	118	30/1/08-10/12/18	33	1552.33	0.81	0.42	0.00	1.06	0.00 to 0.00	0.79	Increasing trend about as likely as not
Manuherikia at Ophir	Turb_NTU	101	30/1/08-11/2/19	-7	1073.68	-0.18	0.85	-0.01	-0.33	-0.15 to 0.15	0.60	Trend unlikely
Manuherikia at Ophir	Adjusted for Flow_L_s	101	30/1/08-10/12/18	-22	1076.67	-0.64	0.52	-0.06	-1.89	-0.16 to 0.08	0.76	Decreasing trend about as likely as not
~~Thomsons Creek at SH85~~	~~Amm_N_mgL~~	~~65~~	~~20/10/09-11/2/19~~	~~-77~~	~~205.72~~	~~-5.30~~	~~0.00~~	~~0.00~~	~~-6.97~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
~~Thomsons Creek at SH85~~	~~Adjusted for Flow_L_s~~	~~65~~	~~6/1/10-10/12/18~~	~~-60~~	~~243.13~~	~~-3.78~~	~~0.00~~	~~0.00~~	~~-7.79~~	~~0.00 to 0.00~~	~~1.00~~	~~Decreasing trend virtually certain~~
Thomsons Creek at SH85	Ecoli_MPN_fcu_100mL	64	20/10/09-11/2/19	12	236.13	0.72	0.47	4.35	1.67	-3.61 to 21.81	0.76	Increasing trend about as likely as not
Thomsons Creek at SH85	Adjusted for Flow_L_s	64	6/1/10-10/12/18	19	237.00	1.17	0.24	13.13	5.06	-7.63 to 58.93	0.87	Increasing trend possible
Thomsons Creek at SH85	DRP_mgL	65	20/10/09-11/2/19	-42	238.93	-2.65	0.01	0.00	-7.09	0.00 to 0.00	1.00	Decreasing trend virtually certain
Thomsons Creek at SH85	Adjusted for Flow_L_s	65	6/1/10-10/12/18	-8	244.00	-0.45	0.65	0.00	-1.32	0.00 to 0.00	0.71	Decreasing trend about as likely as not
Thomsons Creek at SH85	NNN_mgL	65	20/10/09-11/2/19	70	244.00	4.42	0.00	0.01	11.69	0.01 to 0.02	1.00	Increasing trend virtually certain
Thomsons Creek at SH85	Adjusted for Flow_L_s	65	6/1/10-10/12/18	68	244.00	4.29	0.00	0.01	13.66	0.01 to 0.02	1.00	Increasing trend virtually certain
Thomsons Creek at SH85	Turb_NTU	43	13/4/16-11/2/19	12	76.67	1.26	0.21	0.98	23.27	-0.42 to 2.44	0.90	Increasing trend possible

Site	Variable	Samples used	Sampling period	Kendall statistic	Variance	Z	P	Sen slope (annual)	Percent annual change	95% confidence limits for slope	Probability	Trend direction and confidence
Thomsons Creek at SH85	Adjusted for Flow_L_s	43	25/1/17-10/12/18	4	76.67	0.34	0.73	0.28	6.58	-1.30 to 1.14	0.65	Trend unlikely

Appendix H Comparison of data between periods

Table H-1: Comparison of median ammoniacal-N concentration (mg/L) for two time periods by site. For ammoniacal-N, no difference is indicated because of the effect of analytical detection limit on reported results.

Site	Median concentration		No. of samples	
	pre-2013	post-2015	pre-2013	post-2015
Chatto Cr at Manuherikia	0.01	0.007	26	12
Dunstan Cr at Beattie Rd	0.01	0.005	31	38
Hills Cr at SH85	.	0.005	.	7
Ida Burn at Auripo Rd	0.01	.	26	.
Ida Burn at Blackstone H	0.01	.	26	.
Ida Burn at SH85	0.01	.	26	.
Lauder Cr at Cattle Yard	.	0.005	.	10
Lauder Cr at Rail Trail	0.01	0.006	26	12
Manuherikia 20m u/s Thom	.	0.005	.	5
Manuherikia 80m u/s Thom	.	0.005	.	1
Manuherikia at Blackston	0.01	0.005	27	38
Manuherikia at Galloway	0.01	0.005	41	38
Manuherikia at Larkhill	0.01	0.006	6	1
Manuherikia at Loop Rd	0.01	0.005	26	20
Manuherikia at Omakau	0.01	0.005	26	20
Manuherikia at Ophir	0.01	0.005	41	38
Manuherikia d/s Fork	.	0.005	.	19
Manuherikia u/s Chatto C	0.01	0.005	26	20
Manuherikia u/s Ida Burn	0.01	.	26	.
Pool Burn at Auripo Rd	0.01	.	27	.
Poolburn at Cob Cottage	.	0.006	.	19
Thomsons Cr at Race	.	0.005	.	31
Thomsons Cr at SH85	0.01	0.005	25	46

Table H-2: Comparison of median NNN concentration (mg/L) for two time periods by site. Where sample number between periods are approximately equal, increase in median concentration from pre-2012 to post-2015 is shaded red, decrease is shaded blue. No change is shaded green. Formal significance tests follow further in this section.

Site	Median concentration		No. of samples	
	pre-2013	post-2015	pre-2013	post-2015
Chatto Cr at Manuherikia	0.15	0.082	26	12
Dunstan Cr at Beattie Rd	0.035	0.066	31	38
Hills Cr at SH85	.	0.022	.	7
Ida Burn at Auripo Rd	0.02	.	26	.
Ida Burn at Blackstone H	0.028	.	26	.
Ida Burn at SH85	0.005	.	26	.
Lauder Cr at Cattle Yard	.	0.002	.	10
Lauder Cr at Rail Trail	0.009	0.006	26	12
Manuherikia 20m u/s Thom	.	0.026	.	5
Manuherikia 80m u/s Thom	.	0.019	.	1
Manuherikia at Blackston	0.005	0.004	27	38
Manuherikia at Galloway	0.02	0.029	41	38
Manuherikia at Larkhill	1.91	2.5	5	1
Manuherikia at Loop Rd	0.005	0.002	26	20
Manuherikia at Omakau	0.014	0.028	26	20
Manuherikia at Ophir	0.031	0.049	41	38
Manuherikia d/s Fork	.	0.002	.	19
Manuherikia u/s Chatto C	0.021	0.028	26	20
Manuherikia u/s Ida Burn	0.009	.	26	.
Pool Burn at Auripo Rd	0.005	.	27	.
Poolburn at Cob Cottage	.	0.021	.	19
Thomsons Cr at Race	.	0.002	.	31
Thomsons Cr at SH85	0.056	0.111	25	46

Table H-3: Comparison of median DRP concentration (mg/L) for two time periods by site. Where sample number between periods are approximately equal, increase in median concentration from pre-2012 to post-2015 is shaded red, decrease is shaded blue. No change is shaded green. Formal significance tests follow further in this section.

Site	Median concentration		No. of samples	
	pre-2013	post-2015	pre-2013	post-2015
Chatto Cr at Manuherikia	0.025	0.018	26	12
Dunstan Cr at Beattie Rd	0.007	0.004	30	38
Hills Cr at SH85	.	0.004	.	7
Ida Burn at Auripo Rd	0.035	.	26	.
Ida Burn at Blackstone H	0.058	.	26	.
Ida Burn at SH85	0.005	.	26	.
Lauder Cr at Cattle Yard	.	0.005	.	10
Lauder Cr at Rail Trail	0.01	0.009	26	12
Manuherikia 20m u/s Thom	.	0.007	.	5
Manuherikia 80m u/s Thom	.	0.013	.	1
Manuherikia at Blackston	0.006	0.004	27	38
Manuherikia at Galloway	0.014	0.01	41	38
Manuherikia at Larkhill	0.009	0.019	6	1
Manuherikia at Loop Rd	0.005	0.003	26	20
Manuherikia at Omakau	0.014	0.009	26	20
Manuherikia at Ophir	0.016	0.011	41	38
Manuherikia d/s Fork	.	0.006	.	19
Manuherikia u/s Chatto C	0.018	0.012	26	20
Manuherikia u/s Ida Burn	0.008	.	26	.
Pool Burn at Auripo Rd	0.041	.	27	.
Poolburn at Cob Cottage	.	0.033	.	19
Thomsons Cr at Race	.	0.004	.	31
Thomsons Cr at SH85	0.037	0.018	25	46

Table H-4: Comparison of median *E. coli* concentration (cfu/100 mL) for two time periods by site. Where sample number between periods are approximately equal, increase in median concentration from pre-2012 to post-2015 is shaded red, decrease is shaded blue. No change is shaded green. Formal significance tests follow further in this section.

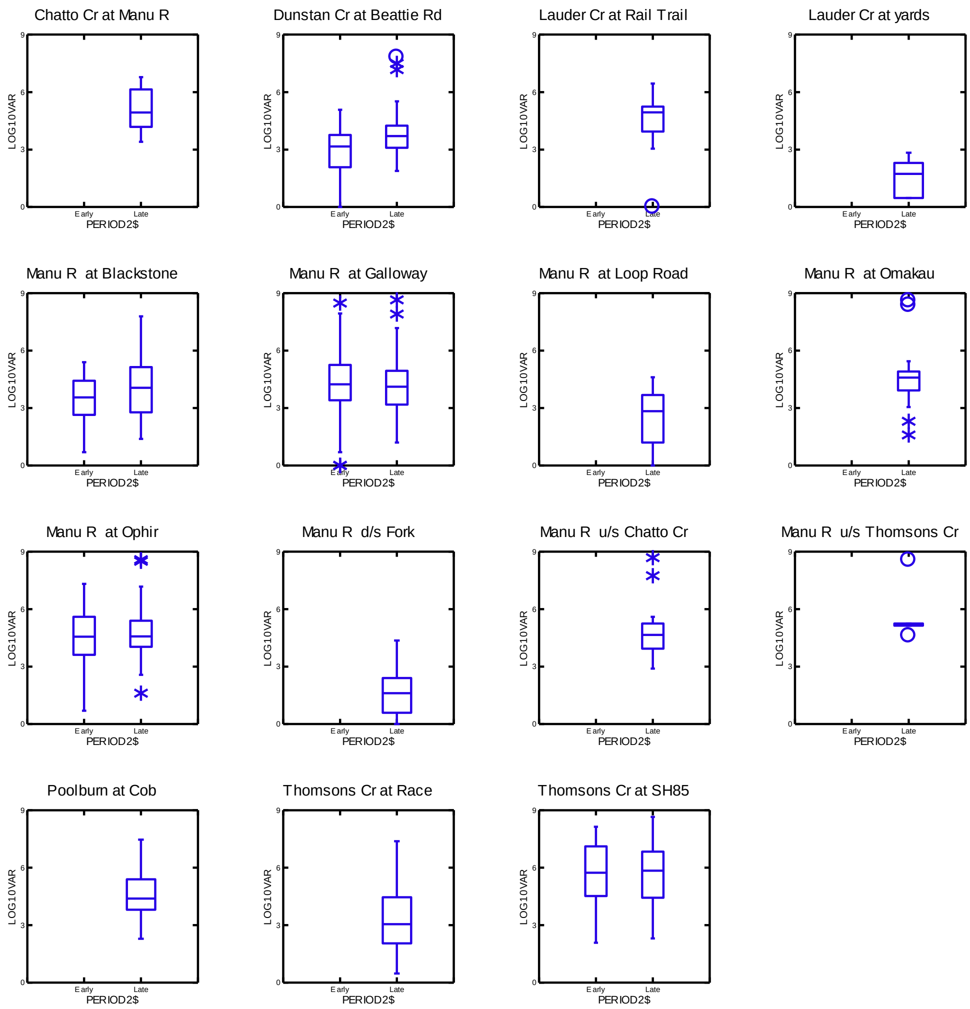
Site	Median concentration		No. of samples	
	pre-2013	post-2015	pre-2013	post-2015
Chatto Cr at Manuherikia	.	140	0	12
Dunstan Cr at Beattie Rd	22.5	40.5	30	38
Hills Cr at SH85	.	155	.	7
Ida Burn at Auripo Rd	84	.	25	.
Ida Burn at Blackstone H	.	.	0	.
Ida Burn at SH85	8	.	25	.
Lauder Cr at Cattle Yard	.	5.7	.	10
Lauder Cr at Rail Trail	.	140	0	12
Manuherikia 20m u/s Thom	.	180	.	5
Manuherikia 80m u/s Thom	.	130	.	2
Manuherikia at Blackston	34.5	57.5	26	38
Manuherikia at Galloway	60.5	61	96	38
Manuherikia at Larkhill	1	.	1	0
Manuherikia at Loop Rd	.	17	0	20
Manuherikia at Omakau	.	98	0	20
Manuherikia at Ophir	95.5	97	40	38
Manuherikia d/s Fork	.	5	.	19
Manuherikia u/s Chatto C	.	105	0	20
Manuherikia u/s Ida Burn	.	.	0	.
Pool Burn at Auripo Rd	76	.	26	.
Poolburn at Cob Cottage	.	80	.	19
Thomsons Cr at Race	.	21	.	36
Thomsons Cr at SH85	310	344	24	51

Table H-5: Comparison of median turbidity (NTU) for two time periods by site. Where sample number between periods are approximately equal, increase in median concentration from pre-2012 to post-2015 is shaded red, decrease is shaded blue. No change is shaded green. Formal significance tests follow further in this section.

Site	Median concentration		No. of samples	
	pre-2013	post-2015	pre-2013	post-2015
Chatto Cr at Manuherikia	1.26	3	1	12
Dunstan Cr at Beattie Rd	0.95	0.8	11	38
Hills Cr at SH85	.	1.61	.	7
Ida Burn at Auripo Rd	1.93	.	7	.
Ida Burn at Blackstone H	1.56	.	1	.
Ida Burn at SH85	0.71	.	7	.
Lauder Cr at Cattle Yard	.	0.725	.	10
Lauder Cr at Rail Trail	3.11	5.2	1	12
Manuherikia 20m u/s Thom	.	6.2	.	5
Manuherikia 80m u/s Thom	.	2.2	.	1
Manuherikia at Blackston	2.29	2.4	7	38
Manuherikia at Galloway	2.86	2.6	24	38
Manuherikia at Larkhill	.	.	0	0
Manuherikia at Loop Rd	1.34	1.245	1	20
Manuherikia at Omakau	1.89	2.7	1	20
Manuherikia at Ophir	3.19	2.7	24	38
Manuherikia d/s Fork	.	0.5	.	19
Manuherikia u/s Chatto C	1.5	3.05	1	20
Manuherikia u/s Ida Burn	2.25	.	1	.
Pool Burn at Auripo Rd	1.62	.	7	.
Poolburn at Cob Cottage	.	1.99	.	19
Thomsons Cr at Race	.	1.57	.	31
Thomsons Cr at SH85	1.77	4	1	46

ANOVA results – yellow highlighted values indicate statistically meaningful differences

Data were $\log_{10}$ transformed to better approximate normal distribution (preferred condition for meaningful application of an ANOVA test).



Results for Site = Manu R at Blackstone

Data for the following results were selected according to
SELECT GROUP$ ="ECOLI_MPN_FCU_100ML" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	**Levels**	
PERIOD2$ (2 levels)	Early	Late

1 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	67
Multiple R	0.23
Squared Multiple R	0.05

Estimates of Effects B = (X'X)⁻¹X'Y

Factor	Level	LOG10VAR
CONSTANT		3.72
PERIOD2$	Early	-0.35

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	7.98	1	7.98	3.57	0.06
Error	145.26	65	2.23		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	3.37	0.28	29.00
PERIOD2$	Late	4.07	0.24	38.00

Results for Site = Manu R at Galloway

Data for the following results were selected according to
SELECT GROUP$ ="ECOLI_MPN_FCU_100ML" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

1 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	156
Multiple R	0.01
Squared Multiple R	1.62E-004

Estimates of Effects B = (X'X)⁻¹X'Y

Factor	Level	LOG10VAR
CONSTANT		4.26
PERIOD2$	Early	0.02

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.06	1	0.06	0.02	0.87
Error	397.93	154	2.58		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	4.29	0.15	118.00
PERIOD2$	Late	4.24	0.26	38.00

Results for Site = Manu R at Ophir

Data for the following results were selected according to
SELECT GROUP$ ="ECOLI_MPN_FCU_100ML" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

1 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	84
Multiple R	0.09
Squared Multiple R	0.01

Estimates of Effects B = (X'X)[-1]X'Y

Factor	Level	LOG10VAR
CONSTANT		4.67
PERIOD2$	Early	-0.14

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	1.63	1	1.63	0.68	0.41
Error	196.20	82	2.39		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	4.53	0.23	46.00
PERIOD2$	Late	4.81	0.25	38.00

Results for Site = Dunstan Cr at Beattie Rd
Data for the following results were selected according to
SELECT GROUP$ ="ECOLI_MPN_FCU_100ML" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

1 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	74
Multiple R	0.35
Squared Multiple R	0.13

Estimates of Effects B = (X'X)[-1]X'Y

Factor	Level	LOG10VAR
CONSTANT		3.40
PERIOD2$	Early	-0.51

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	19.02	1	19.02	10.31	1.98E-003
Error	132.84	72	1.85		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	2.89	0.23	36.00
PERIOD2$	Late	3.91	0.22	38.00

Results for Site = Thomsons Cr at SH85

Data for the following results were selected according to
SELECT GROUP$ ="ECOLI_MPN_FCU_100ML" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

1 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	75
Multiple R	0.03
Squared Multiple R	7.58E-004

Estimates of Effects B = $(X'X)^{-1}X'Y$

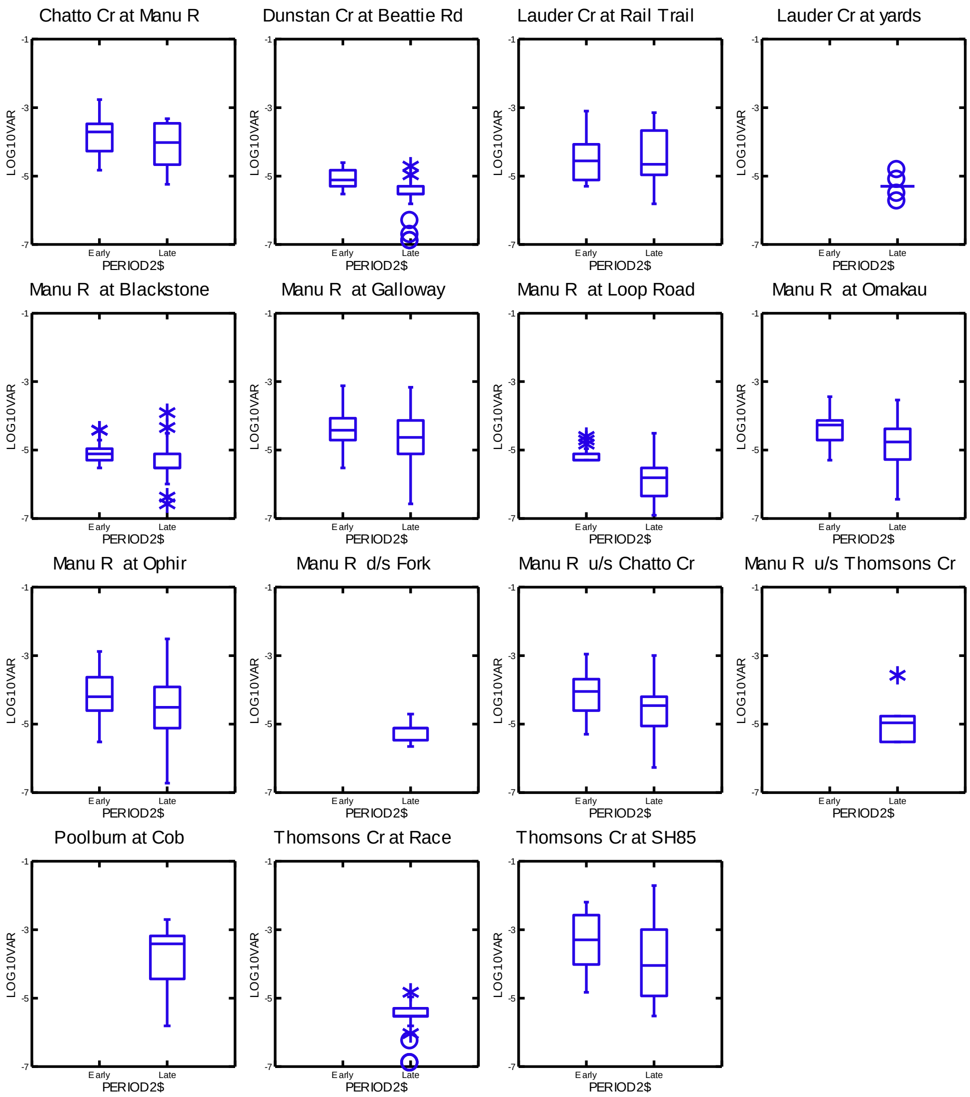
Factor	Level	LOG10VAR
CONSTANT		5.67
PERIOD2$	Early	0.05

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.15	1	0.15	0.06	0.81
Error	200.94	73	2.75		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	5.71	0.34	24.00
PERIOD2$	Late	5.62	0.23	51.00



Results for Site = Manu R at Blackstone

Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	68
Multiple R	0.32
Squared Multiple R	0.11

Estimates of Effects B = (X'X)⁻1X'Y		
Factor	Level	LOG10VAR
CONSTANT		-5.24
PERIOD2$	Early	0.14

Analysis of Variance					
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	1.36	1	1.36	7.76	0.01
Error	11.58	66	0.18		

Least Squares Means				
Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-5.10	0.08	30.00
PERIOD2$	Late	-5.38	0.07	38.00

Results for Site = Manu R u/s Chatto Cr
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	46
Multiple R	0.32
Squared Multiple R	0.11

Estimates of Effects B = (X'X)⁻1X'Y		
Factor	Level	LOG10VAR
CONSTANT		-4.34
PERIOD2$	Early	0.22

Analysis of Variance					
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	2.25	1	2.25	5.19	0.03
Error	19.10	44	0.43		

Least Squares Means				
Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-4.12	0.13	26.00
PERIOD2$	Late	-4.57	0.15	20.00

Results for Site = Manu R at Galloway
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

69 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	88
Multiple R	0.21

Dependent Variable	LOG10VAR
Squared Multiple R	0.04

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		-4.52
PERIOD2$	Early	0.12

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	1.25	1	1.25	3.84	0.05
Error	27.96	86	0.33		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-4.40	0.08	50.00
PERIOD2$	Late	-4.64	0.09	38.00

Results for Site = Manu R at Ophir
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	85
Multiple R	0.23
Squared Multiple R	0.05

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		-4.30
PERIOD2$	Early	0.18

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	2.62	1	2.62	4.82	0.03
Error	45.08	83	0.54		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-4.12	0.11	47.00
PERIOD2$	Late	-4.48	0.12	38.00

Results for Site = Manu R at Omakau
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	46
Multiple R	0.35
Squared Multiple R	0.12

Estimates of Effects B = (X'X)^-1X'Y

Factor	Level	LOG10VAR
CONSTANT		-4.59
PERIOD2$	Early	0.22

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	2.13	1	2.13	6.24	0.02
Error	14.98	44	0.34		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-4.37	0.11	26.00
PERIOD2$	Late	-4.80	0.13	20.00

Results for Site = Dunstan Cr at Beattie Rd
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

1 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	74
Multiple R	0.52
Squared Multiple R	0.27

Estimates of Effects B = (X'X)^-1X'Y

Factor	Level	LOG10VAR
CONSTANT		-5.35
PERIOD2$	Early	0.23

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	3.98	1	3.98	26.69	2.05E-006
Error	10.73	72	0.15		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-5.12	0.06	36.00
PERIOD2$	Late	-5.58	0.06	38.00

Results for Site = Manu R at Loop Road
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	46
Multiple R	0.60
Squared Multiple R	0.36

Estimates of Effects B = (X'X)⁻¹X'Y

Factor	Level	LOG10VAR
CONSTANT		-5.52
PERIOD2$	Early	0.34

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	5.28	1	5.28	25.21	8.99E-006
Error	9.22	44	0.21		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-5.18	0.09	26.00
PERIOD2$	Late	-5.86	0.10	20.00

Results for Site = Thomsons Cr at SH85
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

5 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	71
Multiple R	0.20
Squared Multiple R	0.04

Estimates of Effects B = (X'X)⁻¹X'Y

Factor	Level	LOG10VAR
CONSTANT		-3.64
PERIOD2$	Early	0.23

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	3.51	1	3.51	2.99	0.09
Error	81.00	69	1.17		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-3.41	0.22	25.00
PERIOD2$	Late	-3.88	0.16	46.00

Results for Site = Lauder Cr at Rail Trail
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"

Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	38
Multiple R	2.11E-003
Squared Multiple R	4.47E-006

Estimates of Effects B = (X'X)-1X'Y

Factor	Level	LOG10VAR
CONSTANT		-4.47
PERIOD2$	Early	-1.69E-003

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	9.38E-005	1	9.38E-005	1.61E-004	0.99
Error	20.98	36	0.58		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-4.48	0.15	26.00
PERIOD2$	Late	-4.47	0.22	12.00

Results for Site = Chatto Cr at Manu R
Data for the following results were selected according to
SELECT GROUP$ ="DRP_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	38
Multiple R	0.21
Squared Multiple R	0.04

Estimates of Effects B = (X'X)-1X'Y

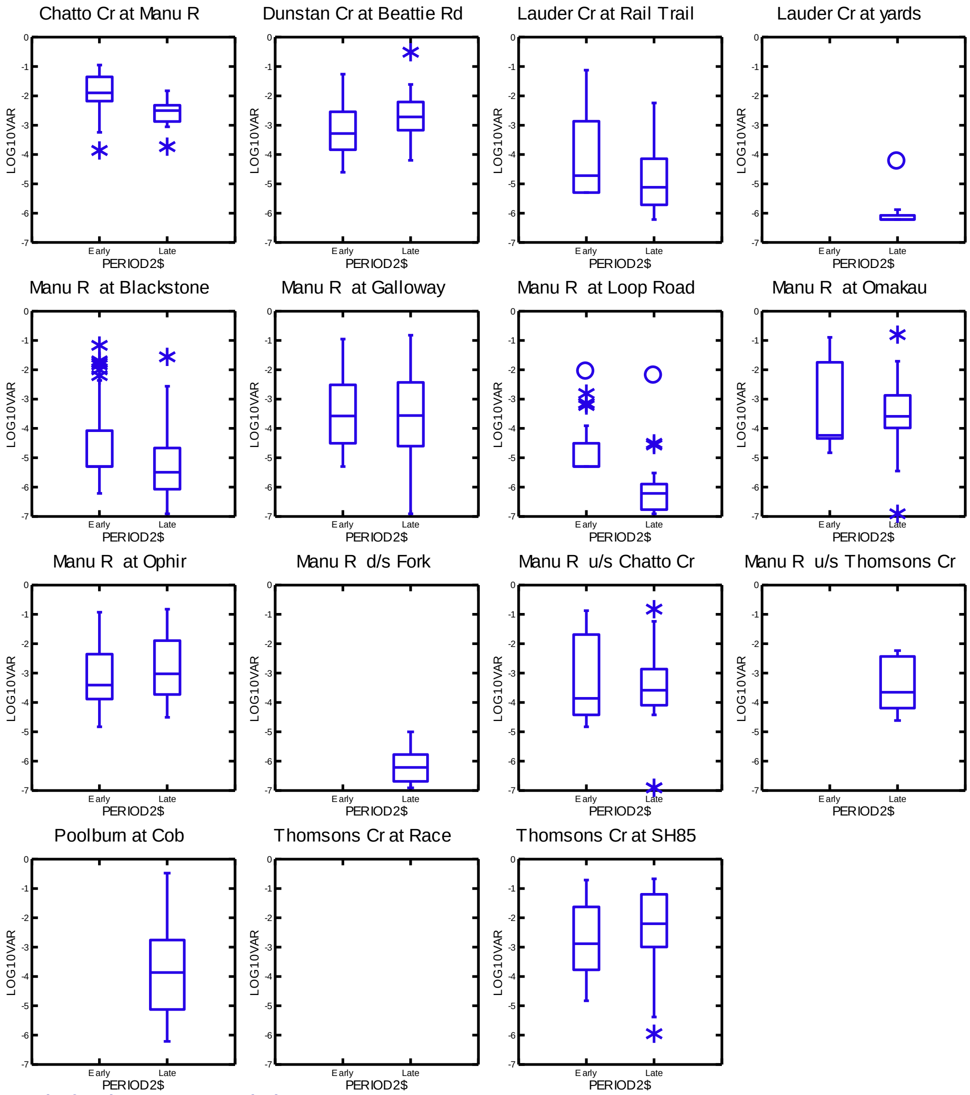
Factor	Level	LOG10VAR
CONSTANT		-3.97
PERIOD2$	Early	0.13

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.56	1	0.56	1.67	0.20
Error	12.07	36	0.34		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-3.84	0.11	26.00
PERIOD2$	Late	-4.11	0.17	12.00



Results for Site = Manu R at Blackstone

Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	68
Multiple R	0.25
Squared Multiple R	0.06

Estimates of Effects $B = (X'X)^{-1}X'Y$		
Factor	**Level**	**LOG10VAR**
CONSTANT		-4.82
PERIOD2$	Early	0.36

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-Ratio**	**p-Value**
PERIOD2$	8.62	1	8.62	4.51	0.04
Error	126.26	66	1.91		

Least Squares Means				
Factor	**Level**	**LS Mean**	**Standard Error**	**N**
PERIOD2$	Early	-4.46	0.25	30.00
PERIOD2$	Late	-5.18	0.22	38.00

Results for Site = Manu R u/s Chatto Cr
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	**Levels**	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	46
Multiple R	0.07
Squared Multiple R	4.33E-003

Estimates of Effects $B = (X'X)^{-1}X'Y$		
Factor	**Level**	**LOG10VAR**
CONSTANT		-3.47
PERIOD2$	Early	0.09

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-Ratio**	**p-Value**
PERIOD2$	0.39	1	0.39	0.19	0.66
Error	90.29	44	2.05		

Least Squares Means				
Factor	**Level**	**LS Mean**	**Standard Error**	**N**
PERIOD2$	Early	-3.37	0.28	26.00
PERIOD2$	Late	-3.56	0.32	20.00

Results for Site = Manu R at Galloway
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	**Levels**	
PERIOD2$ (2 levels)	Early	Late

69 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	88
Multiple R	0.08

Dependent Variable	LOG10VAR
Squared Multiple R	0.01

Estimates of Effects B = $(X'X)^{-1}X'Y$		
Factor	**Level**	**LOG10VAR**
CONSTANT		-3.53
PERIOD2$	Early	0.11

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-Ratio**	**p-Value**
PERIOD2$	0.97	1	0.97	0.59	0.45
Error	142.45	86	1.66		

Least Squares Means				
Factor	**Level**	**LS Mean**	**Standard Error**	**N**
PERIOD2$	Early	-3.43	0.18	50.00
PERIOD2$	Late	-3.64	0.21	38.00

Results for Site = Manu R at Ophir
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	85
Multiple R	0.11
Squared Multiple R	0.01

Estimates of Effects B = $(X'X)^{-1}X'Y$		
Factor	**Level**	**LOG10VAR**
CONSTANT		-2.98
PERIOD2$	Early	-0.11

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-Ratio**	**p-Value**
PERIOD2$	0.97	1	0.97	0.94	0.33
Error	85.35	83	1.03		

Least Squares Means				
Factor	**Level**	**LS Mean**	**Standard Error**	**N**
PERIOD2$	Early	-3.09	0.15	47.00
PERIOD2$	Late	-2.87	0.16	38.00

Results for Site = Manu R at Omakau
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	46
Multiple R	0.02
Squared Multiple R	3.62E-004

Estimates of Effects B = (X'X)[-1]X'Y

Factor	Level	LOG10VAR
CONSTANT		-3.52
PERIOD2$	Early	0.03

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.03	1	0.03	0.02	0.90
Error	78.77	44	1.79		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-3.49	0.26	26.00
PERIOD2$	Late	-3.54	0.30	20.00

Results for Site = Dunstan Cr at Beattie Rd
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

1 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	74
Multiple R	0.30
Squared Multiple R	0.09

Estimates of Effects B = (X'X)[-1]X'Y

Factor	Level	LOG10VAR
CONSTANT		-2.95
PERIOD2$	Early	-0.25

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	4.46	1	4.46	7.23	0.01
Error	44.41	72	0.62		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-3.19	0.13	36.00
PERIOD2$	Late	-2.70	0.13	38.00

Results for Site = Manu R at Loop Road
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	46
Multiple R	0.52
Squared Multiple R	0.27

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		-5.36
PERIOD2$	Early	0.63

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	17.99	1	17.99	16.23	2.19E-004
Error	48.80	44	1.11		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-4.73	0.21	26.00
PERIOD2$	Late	-5.99	0.24	20.00

Results for Site = Thomsons Cr at SH85
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

5 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	71
Multiple R	0.19
Squared Multiple R	0.04

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		-2.62
PERIOD2$	Early	-0.26

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	4.42	1	4.42	2.60	0.11
Error	117.44	69	1.70		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-2.88	0.26	25.00
PERIOD2$	Late	-2.36	0.19	46.00

Results for Site = Lauder Cr at Rail Trail
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"

Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	38
Multiple R	0.24
Squared Multiple R	0.06

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		-4.50
PERIOD2$	Early	0.34

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	3.76	1	3.76	2.23	0.14
Error	60.67	36	1.69		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-4.16	0.25	26.00
PERIOD2$	Late	-4.84	0.37	12.00

Results for Site = Chatto Cr at Manu R
Data for the following results were selected according to
SELECT GROUP$ ="NNN_MGL" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

Dependent Variable	LOG10VAR
N	38
Multiple R	0.45
Squared Multiple R	0.20

Estimates of Effects $B = (X'X)^{-1}X'Y$

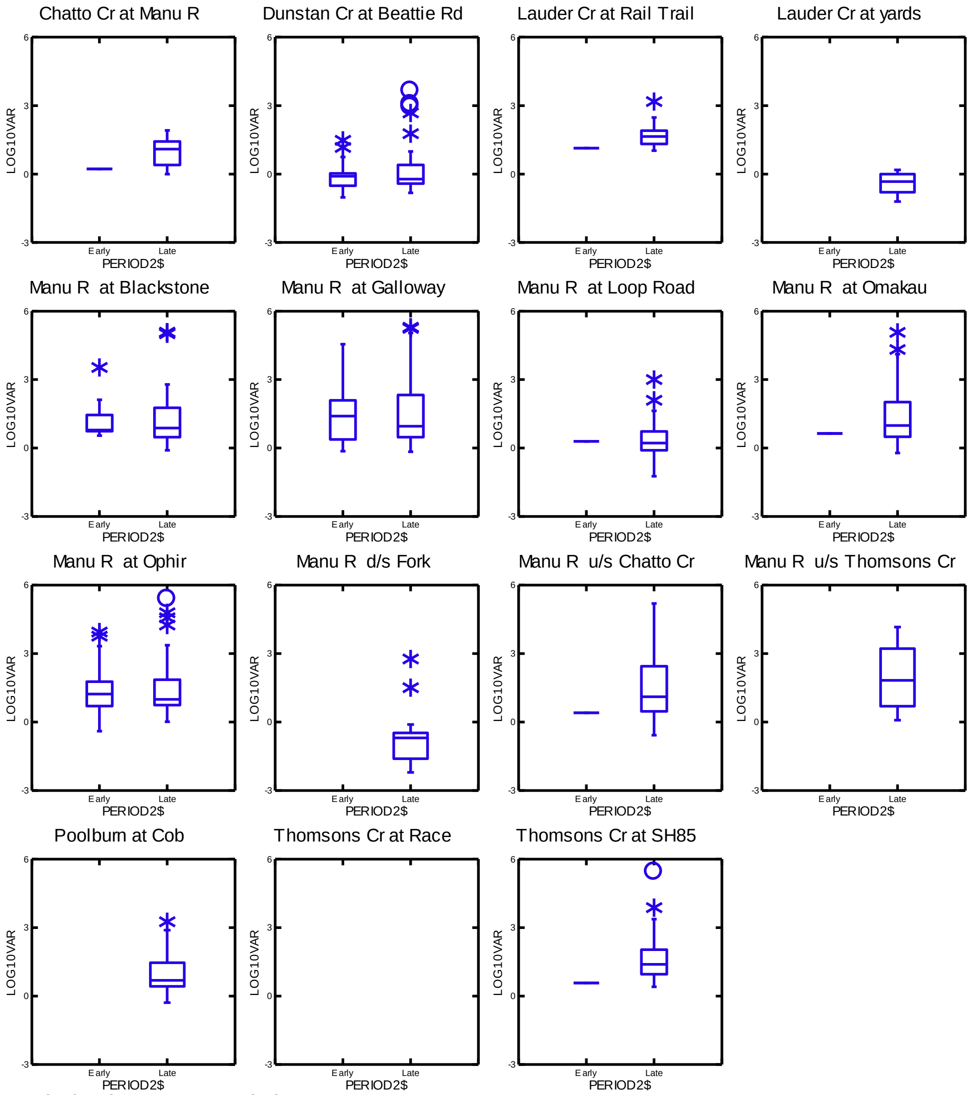
Factor	Level	LOG10VAR
CONSTANT		-2.26
PERIOD2$	Early	0.34

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	3.77	1	3.77	9.14	4.59E-003
Error	14.85	36	0.41		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-1.92	0.13	26.00
PERIOD2$	Late	-2.60	0.19	12.00



Results for Site = Manu R at Blackstone

Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

20 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	48
Multiple R	0.02
Squared Multiple R	4.52E-004

Estimates of Effects B = (X'X)⁻¹X'Y		
Factor	**Level**	**LOG10VAR**
CONSTANT		1.30
PERIOD2$	Early	-0.03

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-Ratio**	**p-Value**
PERIOD2$	0.03	1	0.03	0.02	0.89
Error	73.46	46	1.60		

Least Squares Means				
Factor	**Level**	**LS Mean**	**Standard Error**	**N**
PERIOD2$	Early	1.27	0.40	10.00
PERIOD2$	Late	1.33	0.21	38.00

Results for Site = Manu R u/s Chatto Cr
Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	**Levels**	
PERIOD2$ (2 levels)	Early	Late

25 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	21
Multiple R	0.17
Squared Multiple R	0.03

Estimates of Effects B = (X'X)⁻¹X'Y		
Factor	**Level**	**LOG10VAR**
CONSTANT		1.05
PERIOD2$	Early	-0.64

Analysis of Variance					
Source	**Type III SS**	**df**	**Mean Squares**	**F-Ratio**	**p-Value**
PERIOD2$	1.57	1	1.57	0.55	0.47
Error	53.67	19	2.82		

Least Squares Means				
Factor	**Level**	**LS Mean**	**Standard Error**	**N**
PERIOD2$	Early	0.41	1.68	1.00
PERIOD2$	Late	1.69	0.38	20.00

Results for Site = Manu R at Galloway
Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	**Levels**	
PERIOD2$ (2 levels)	Early	Late

86 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	71
Multiple R	0.05
Squared Multiple R	2.31E-003

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		1.50
PERIOD2$	Early	-0.07

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.31	1	0.31	0.16	0.69
Error	131.70	69	1.91		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	1.44	0.24	33.00
PERIOD2$	Late	1.57	0.22	38.00

Results for Site = Manu R at Ophir
Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

17 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	68
Multiple R	0.02
Squared Multiple R	5.73E-004

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		1.49
PERIOD2$	Early	-0.03

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.06	1	0.06	0.04	0.85
Error	100.87	66	1.53		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	1.46	0.23	30.00
PERIOD2$	Late	1.52	0.20	38.00

Results for Site = Manu R at Omakau
Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

25 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	21
Multiple R	0.13
Squared Multiple R	0.02

Estimates of Effects B = (X'X)⁻¹X'Y

Factor	Level	LOG10VAR
CONSTANT		1.07
PERIOD2$	Early	-0.43

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.72	1	0.72	0.31	0.59
Error	44.42	19	2.34		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	0.64	1.53	1.00
PERIOD2$	Late	1.50	0.34	20.00

Results for Site = Dunstan Cr at Beattie Rd
Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

20 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	55
Multiple R	0.16
Squared Multiple R	0.03

Estimates of Effects B = (X'X)⁻¹X'Y

Factor	Level	LOG10VAR
CONSTANT		0.12
PERIOD2$	Early	-0.19

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	1.70	1	1.70	1.45	0.23
Error	62.29	53	1.18		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	-0.07	0.26	17.00
PERIOD2$	Late	0.31	0.18	38.00

Results for Site = Manu R at Loop Road

Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

25 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	21
Multiple R	0.03
Squared Multiple R	1.15E-003

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		0.37
PERIOD2$	Early	-0.07

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.02	1	0.02	0.02	0.88
Error	17.44	19	0.92		

Least Squares Means

Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	0.29	0.96	1.00
PERIOD2$	Late	0.44	0.21	20.00

Results for Site = Thomsons Cr at SH85

Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

29 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	47
Multiple R	0.15
Squared Multiple R	0.02

Estimates of Effects $B = (X'X)^{-1}X'Y$

Factor	Level	LOG10VAR
CONSTANT		1.07
PERIOD2$	Early	-0.50

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.98	1	0.98	1.10	0.30
Error	40.08	45	0.89		

Least Squares Means				
Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	0.57	0.94	1.00
PERIOD2$	Late	1.57	0.14	46.00

Results for Site = Lauder Cr at Rail Trail
Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

25 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	13
Multiple R	0.27
Squared Multiple R	0.07

Estimates of Effects B = (X'X)-1X'Y		
Factor	Level	LOG10VAR
CONSTANT		1.43
PERIOD2$	Early	-0.29

Analysis of Variance					
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.32	1	0.32	0.85	0.38
Error	4.14	11	0.38		

Least Squares Means				
Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	1.13	0.61	1.00
PERIOD2$	Late	1.72	0.18	12.00

Results for Site = Chatto Cr at Manu R
Data for the following results were selected according to
SELECT GROUP$ ="TURB_NTU" AND PERIOD2$ <>"Middle"
Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
PERIOD2$ (2 levels)	Early	Late

25 case(s) are deleted due to missing data.

Dependent Variable	LOG10VAR
N	13
Multiple R	0.32
Squared Multiple R	0.10

Estimates of Effects B = (X'X)-1X'Y		
Factor	Level	LOG10VAR
CONSTANT		0.60
PERIOD2$	Early	-0.37

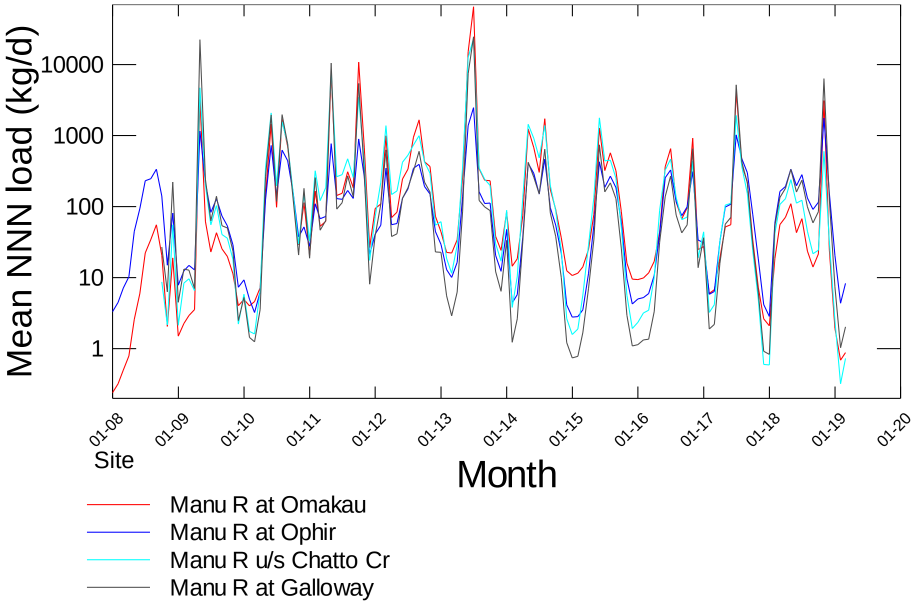
Analysis of Variance

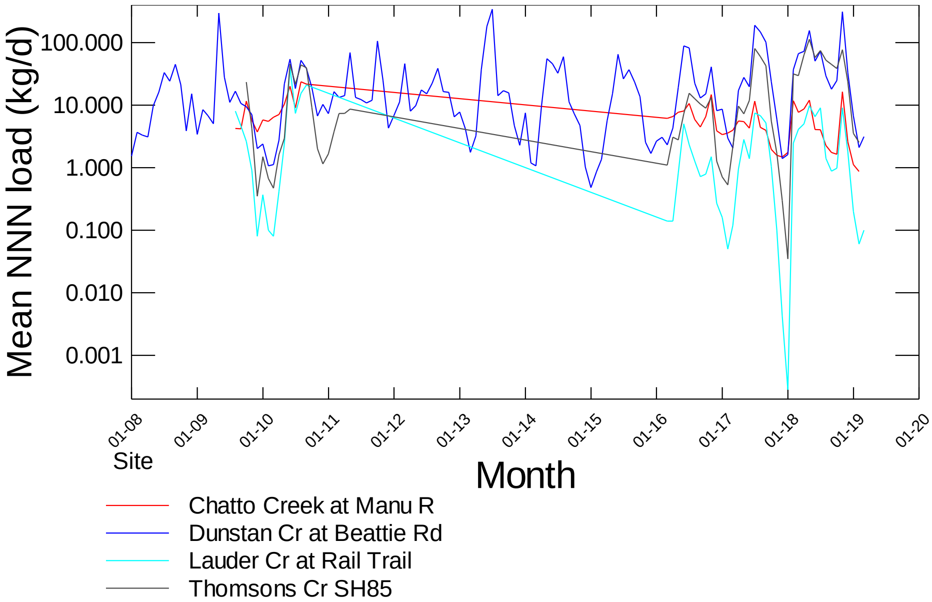
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
PERIOD2$	0.50	1	0.50	1.25	0.29
Error	4.40	11	0.40		

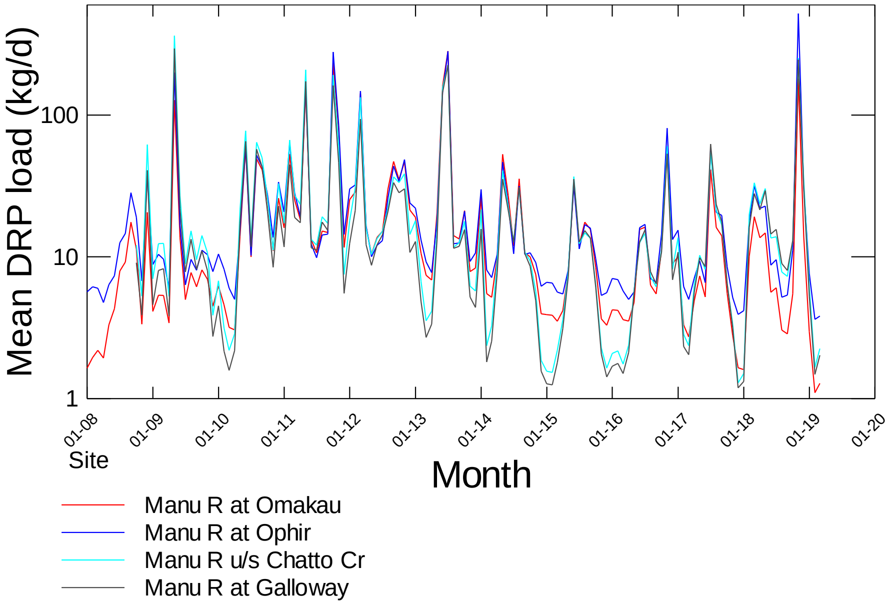
Least Squares Means

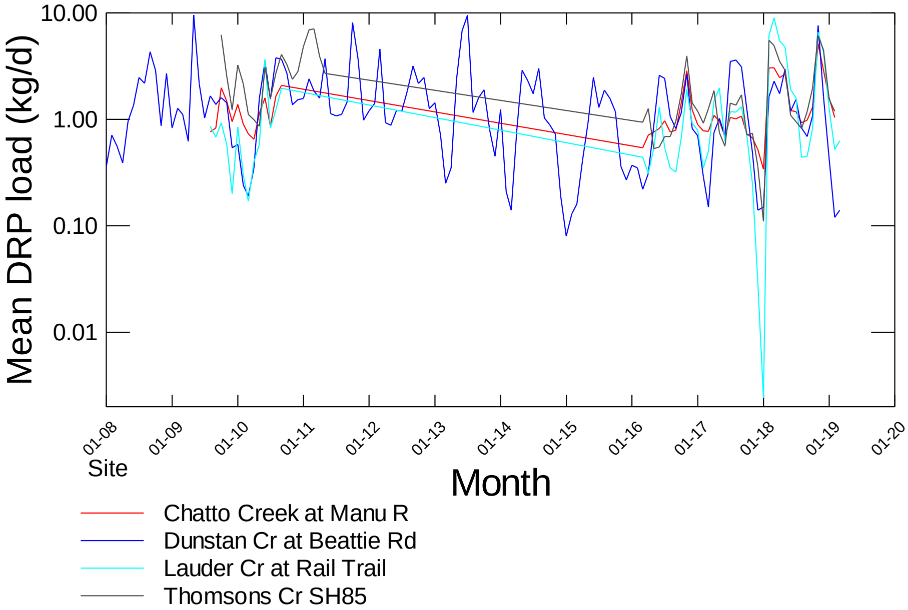
Factor	Level	LS Mean	Standard Error	N
PERIOD2$	Early	0.23	0.63	1.00
PERIOD2$	Late	0.97	0.18	12.00

Appendix I DRP and NNN flux estimates






Mean DRP load (kg/d)
100
10
1
01-08
01-09
01-10
01-11
01-12
01-13
01-14
01-15
01-16
01-17
01-18
01-19
01-20
Site
Month
Manu R at Omakau
Manu R at Ophir
Manu R u/s Chatto Cr
Manu R at Galloway


Mean DRP load (kg/d)
10.00
1.00
0.10
0.01
01-08
01-09
01-10
01-11
01-12
01-13
01-14
01-15
01-16
01-17
01-18
01-19
01-20
Site
Month
Chatto Creek at Manu R
Dunstan Cr at Beattie Rd
Lauder Cr at Rail Trail
Thomsons Cr SH85

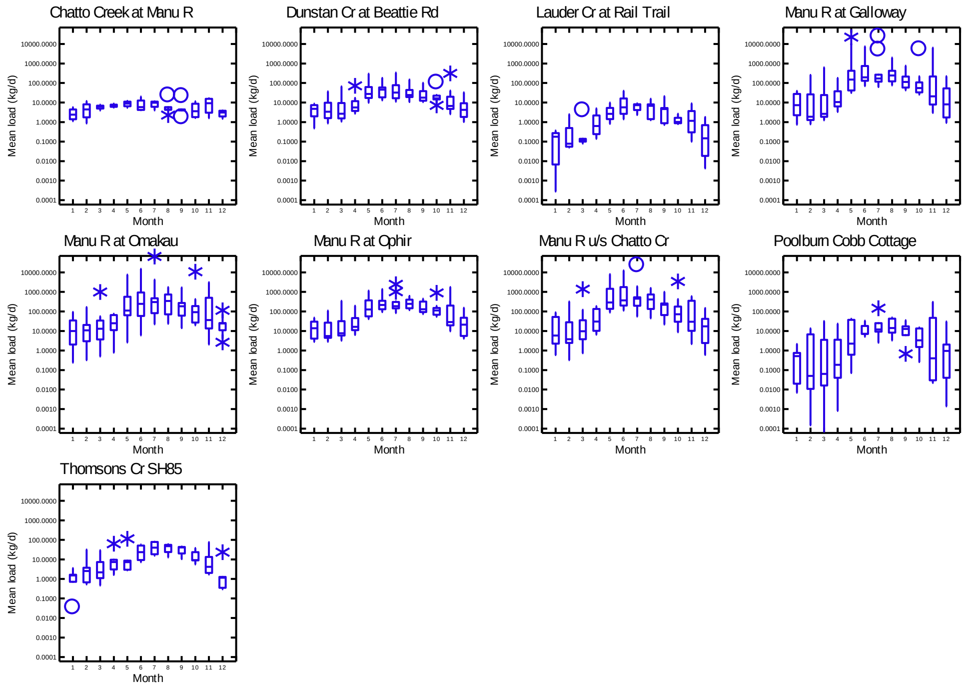


Figure I-1: Monthly NNN flux estimates. Values derived from the LOADEST modelling suite.

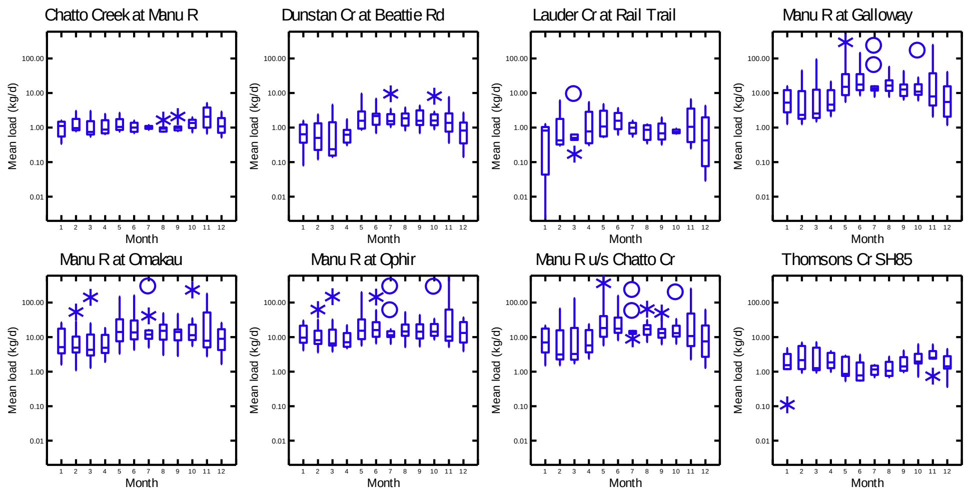


Figure I-2: Monthly DRP flux estimates. Values derived from the LOADEST modelling suite.

Table I-1: Mean annual NNN load expressed in kg/d. Estimate derived from AMLE model in LOADEST suite. [A] Note loads for 2019 based on incomplete data.

Site	Mean NNN load (kg/d)											
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019[A]
Chatto Creek at Manu R	.	5.9	12.2	.	.	.	.	.	7.5	4.3	6.2	1.0
Dunstan Cr at Beattie Rd	15.0	33.7	19.1	25.3	17.9	52.5	19.7	16.1	25.1	45.7	72.8	4.0
Lauder Cr at Rail Trail	.	3.3	9.7	.	.	.	.	.	1.3	2.2	4.3	0.1
Manu R at Galloway	85.1	1920.2	452.2	1435.0	207.9	2709.2	139.7	110.0	107.6	503.6	651.9	3.5
Manu R at Omakau	13.7	284.4	366.2	1689.7	451.5	6795.7	371.5	228.5	194.9	421.7	296.9	1.2
Manu R at Ophir	101.3	149.5	194.7	232.4	166.2	374.0	132.8	101.4	107.4	181.6	291.1	11.1
Manu R u/s Chatto Cr	22.1	432.1	444.1	1161.8	454.5	3105.8	398.3	262.7	135.6	231.1	123.1	1.2
Poolburn Cobb Cottage	1.7	4.6	10.9	3.6	.	.	.	.	10.8	18.1	44.0	0.8
Thomsons Cr SH85	.	9.3	14.2	5.8	.	.	.	.	7.6	18.6	50.5	3.0

Table I-2: Mean annual DRP load expressed in kg/d. Estimate derived from AMLE model in LOADEST suite. [A]Note loads for 2019 based on incomplete data.

Site	Mean DRP load (kg/d)											
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019[A]
Chatto Creek at Manu R	.	1.2	1.2	.	.	.	.	.	1.1	0.9	2.1	1.3
Dunstan Cr at Beattie Rd	1.6	1.9	1.8	2.4	1.9	2.3	1.3	0.9	1.1	1.3	1.9	0.2
Lauder Cr at Rail Trail	.	0.6	1.1	.	.	.	.	.	0.7	0.9	3.4	0.8
Manu R at Galloway	17.9	32.7	21.4	44.6	24.9	38.0	12.8	8.4	10.5	12.8	36.1	2.9
Manu R at Omakau	7.1	16.5	21.0	53.1	36.0	47.7	17.2	9.9	11.8	9.6	23.1	1.8
Manu R at Ophir	12.9	25.4	23.8	60.3	36.5	46.9	17.0	10.7	15.5	13.8	57.6	5.0
Manu R u/s Chatto Cr	26.4	40.8	25.9	55.4	31.8	40.1	14.2	8.7	11.2	12.3	37.6	3.4
Thomsons Cr SH85	.	3.3	2.4	5.1	.	.	.	.	1.3	1.1	2.8	1.4

Table I-3: Mean annual NNN and DRP load for Dunstan Creek at Beattie Rd expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	4094	107	4094	107
Minimum	0.02	0.04	0.21	0.27
Maximum	117.8	11.8	5749.3	789.0
Median	1.0	1.0	11.2	6.4
Mean	1.7	1.4	30.8	30.9
Standard Error of Mean	0.0	0.2	2.0	8.0
95.0% LCL of Mean	1.6	1.1	26.9	15.1
95.0% UCL of Mean	1.7	1.8	34.8	46.8
Standard Deviation	3.1	1.7	128.4	82.7
Cleveland percentiles				
1.00%	0.1	0.0	0.6	0.3
5.00%	0.1	0.1	0.9	0.5
10.00%	0.2	0.1	1.3	0.9
20.00%	0.3	0.3	2.3	1.9
25.00%	0.5	0.4	3.1	2.3
30.00%	0.6	0.5	4.3	2.5
40.00%	0.8	0.8	7.9	4.8
50.00%	1.0	1.0	11.2	6.4
60.00%	1.3	1.2	15.2	12.0
70.00%	1.6	1.4	20.7	26.0
75.00%	1.9	1.7	24.7	27.9
80.00%	2.2	2.1	30.5	37.4
90.00%	3.2	3.1	55.9	75.9
95.00%	4.7	5.1	97.8	139.1
99.00%	11.7	9.2	368.2	432.4

Table I-4: Mean annual DRP load for Pool Burn at Cobb Cottage expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	0	19	1997	19
Minimum	.	0.17	0.00	0.01
Maximum	.	87.4	1296.0	443.1
Median	.	1.3	1.8	2.2
Mean	.	7.6	16.0	33.3
Standard Error of Mean	.	4.5	1.5	23.2
95.0% LCL of Mean		-1.9	13.1	-15.5
95.0% UCL of Mean		17.2	18.8	82.2
Standard Deviation	.	19.8	65.1	101.3
Cleveland percentiles				
1.00%	.	0.2	0.0	0.0
5.00%	.	0.2	0.0	0.0
10.00%	.	0.3	0.0	0.0
20.00%	.	0.6	0.0	0.1
25.00%	.	0.6	0.0	0.2
30.00%	.	0.7	0.1	0.4
40.00%	.	0.9	0.3	1.4
50.00%	.	1.3	1.8	2.2
60.00%	.	1.5	3.6	4.0
70.00%	.	2.0	7.8	8.5
75.00%	.	6.5	11.0	14.3
80.00%	.	8.7	15.0	20.6
90.00%	.	13.4	29.4	65.9
95.00%	.	54.1	61.5	281.9
99.00%	.	87.4	232.9	443.1

Table I-5: Mean annual NNN and DRP load for Lauder Creek at Rail Trail expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	1484	38	1484	38
Minimum	0.00	0.06	0.00	0.02
Maximum	39.7	17.2	144.9	133.0
Median	0.6	0.6	1.0	0.6
Mean	1.5	1.3	3.8	7.7
Standard Error of Mean	0.1	0.5	0.2	3.7
95.0% LCL of Mean	1.4	0.4	3.3	0.2
95.0% UCL of Mean	1.6	2.2	4.2	15.2
Standard Deviation	2.6	2.8	8.8	22.7
Cleveland percentiles				
1.00%	0.0	0.1	0.0	0.0
5.00%	0.1	0.1	0.0	0.0
10.00%	0.1	0.1	0.0	0.1
20.00%	0.3	0.2	0.1	0.1
25.00%	0.3	0.3	0.1	0.1
30.00%	0.4	0.3	0.2	0.1
40.00%	0.5	0.5	0.5	0.2
50.00%	0.6	0.6	1.0	0.6
60.00%	0.8	0.8	1.6	1.0
70.00%	1.2	1.1	2.8	1.9
75.00%	1.5	1.2	3.9	3.0
80.00%	1.9	1.4	5.2	7.5
90.00%	3.7	1.7	9.5	24.1
95.00%	5.8	3.7	16.4	35.0
99.00%	13.3	17.2	37.7	133.0

Table I-6: Mean annual NNN and DRP load for Manuherikia River at Omakau expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	4094	46	4094	46
Minimum	0.8	1.2	0.2	0.6
Maximum	1866.5	170.8	554440.0	2650.7
Median	7.9	6.3	34.2	11.2
Mean	22.7	17.1	1002.7	197.6
Standard Error of Mean	1.3	4.8	214.6	71.9
95.0% LCL of Mean	20.1	7.4	581.9	52.9
95.0% UCL of Mean	25.3	26.8	1423.5	342.3
Standard Deviation	84.6	32.7	13733.7	487.3
Cleveland percentiles				
1.00%	1.3	1.2	0.3	0.6
5.00%	1.9	1.9	1.4	1.9
10.00%	2.8	2.1	3.0	2.4
20.00%	3.7	2.6	7.5	3.2
25.00%	4.0	3.3	10.4	3.6
30.00%	4.5	3.5	12.6	4.1
40.00%	5.9	5.2	19.3	6.8
50.00%	7.9	6.3	34.2	11.2
60.00%	10.1	7.8	62.2	17.6
70.00%	13.5	11.6	108.7	43.2
75.00%	16.6	13.1	149.0	176.7
80.00%	20.0	13.8	205.1	264.0
90.00%	34.8	36.2	495.4	417.1
95.00%	60.4	102.2	1129.6	1174.2
99.00%	313.9	170.8	9730.9	2650.7

Table I-7: Mean annual NNN and DRP load for Thomson Creek expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	1632	65	1632	65
Minimum	0.01	0.01	0.00	0.00
Maximum	42.4	156.5	553.7	887.0
Median	1.5	0.8	7.4	6.9
Mean	2.2	4.2	20.9	28.4
Standard Error of Mean	0.1	2.4	0.9	13.6
95.0% LCL of Mean	2.1	-0.7	19.1	1.1
95.0% UCL of Mean	2.3	9.0	22.8	55.7
Standard Deviation	2.5	19.4	38.0	110.0
Cleveland percentiles				
1.00%	0.1	0.0	0.0	0.0
5.00%	0.4	0.3	0.2	0.1
10.00%	0.5	0.3	0.4	0.1
20.00%	0.7	0.4	0.8	0.6
25.00%	0.8	0.5	1.4	0.8
30.00%	0.9	0.6	1.9	1.5
40.00%	1.1	0.7	4.1	3.8
50.00%	1.5	0.8	7.4	6.9
60.00%	1.9	1.0	11.4	10.6
70.00%	2.3	1.3	19.7	17.6
75.00%	2.7	1.6	27.1	22.2
80.00%	3.2	2.3	35.4	27.6
90.00%	5.1	4.4	57.6	48.7
95.00%	6.6	9.1	74.6	65.5
99.00%	11.6	135.9	173.5	768.5

Table I-8: Mean annual NNN and DRP load for Manuherikia River at Ophir expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	4094	118	4094	118
Minimum	3.0	1.6	1.5	1.0
Maximum	3382.3	287.0	12538.0	2415.1
Median	9.6	9.1	66.6	36.2
Mean	28.7	21.3	182.4	178.2
Standard Error of Mean	2.0	4.0	9.1	33.8
95.0% LCL of Mean	24.8	13.5	164.6	111.2
95.0% UCL of Mean	32.7	29.2	200.3	245.3
Standard Deviation	128.6	42.9	584.0	367.7
Cleveland percentiles				
1.00%	3.6	1.7	2.3	1.3
5.00%	4.5	2.7	3.5	2.2
10.00%	5.2	3.2	4.3	2.7
20.00%	6.1	4.8	7.0	5.4
25.00%	6.5	5.4	9.4	7.0
30.00%	7.0	6.4	12.8	11.2
40.00%	8.1	7.8	31.8	22.2
50.00%	9.6	9.1	66.6	36.2
60.00%	11.7	10.4	97.7	64.6
70.00%	15.8	14.1	131.9	136.6
75.00%	18.8	17.3	163.9	184.1
80.00%	23.1	20.0	203.0	213.4
90.00%	37.8	31.2	355.7	419.1
95.00%	65.5	93.2	584.2	1010.6
99.00%	394.1	240.7	2165.0	1827.5

Table I-9: Mean annual NNN and DRP load for Manuherikia River upstream Chatto Creek confluence expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

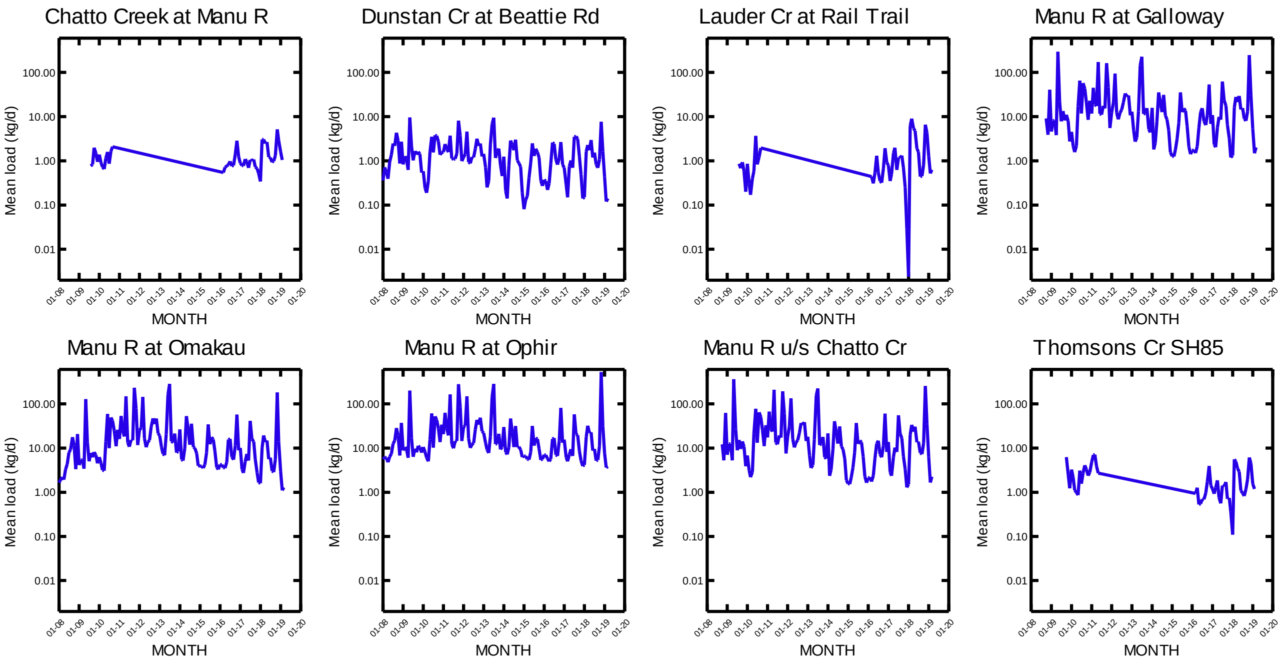
Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	3798	46	3798	46
Minimum	0.8	0.9	0.1	0.1
Maximum	4893.1	277.2	205260.0	3354.3
Median	9.8	6.6	64.3	19.5
Mean	27.5	26.1	654.7	277.3
Standard Error of Mean	2.1	8.4	95.5	98.5
95.0% LCL of Mean	23.4	9.1	467.4	78.9
95.0% UCL of Mean	31.5	43.1	842.1	475.8
Standard Deviation	127.4	57.2	5888.4	668.3
Cleveland percentiles				
1.00%	1.2	0.9	0.4	0.1
5.00%	1.5	1.4	1.0	0.6
10.00%	2.0	1.6	1.6	0.8
20.00%	3.0	2.4	3.9	1.8
25.00%	3.9	2.6	6.4	2.4
30.00%	4.9	3.7	10.0	2.6
40.00%	7.4	4.9	26.4	6.9
50.00%	9.8	6.6	64.3	19.5
60.00%	12.3	9.2	113.1	30.3
70.00%	16.5	14.4	183.1	55.2
75.00%	19.7	17.1	235.7	95.7
80.00%	23.7	18.9	299.0	412.3
90.00%	39.8	50.8	679.9	685.3
95.00%	70.2	165.9	1340.4	2060.3
99.00%	396.1	277.2	7724.9	3354.3

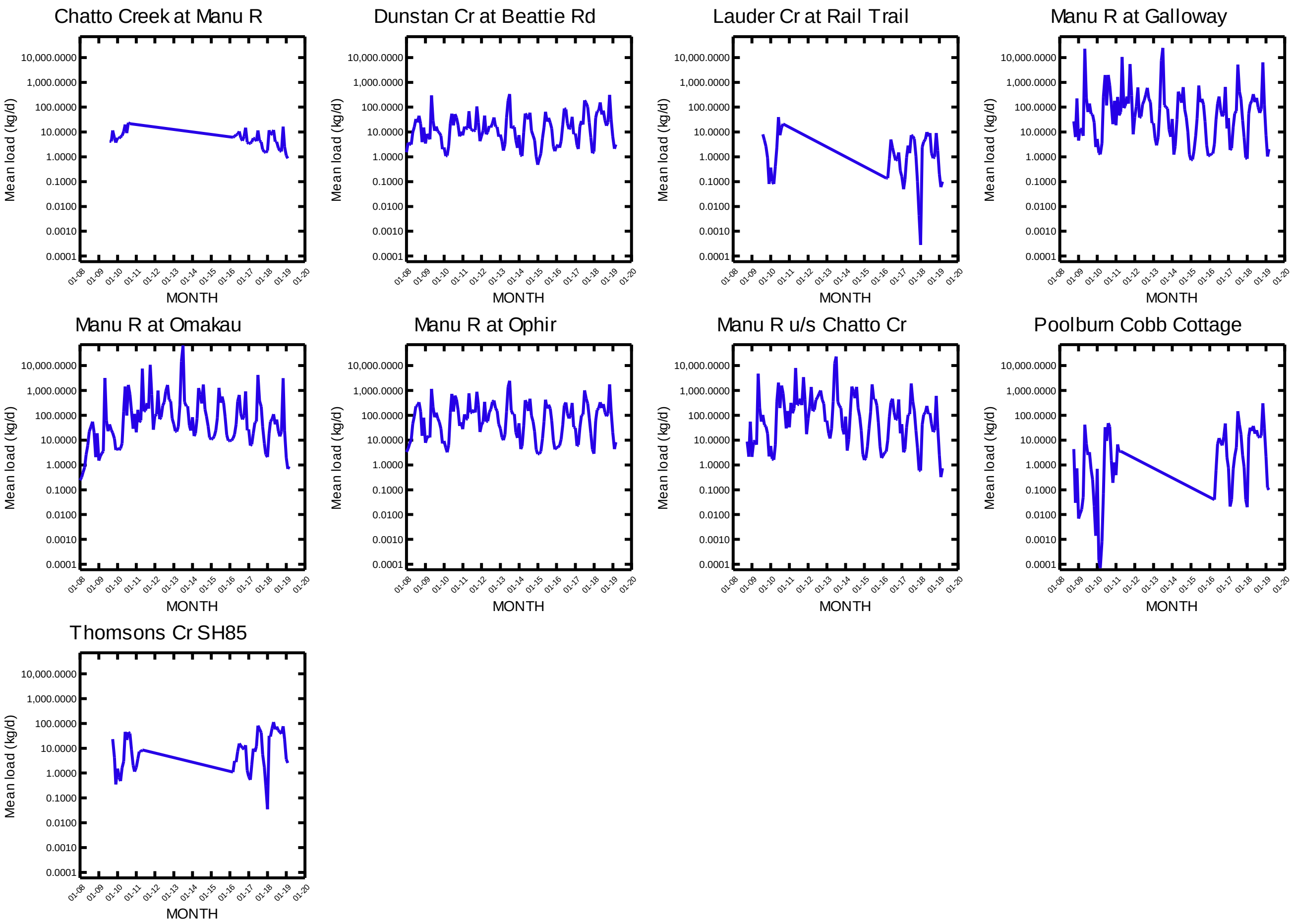
Table I-10: Mean annual NNN and DRP load for Chatto Creek expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	1432	36	1432	36
Minimum	0.3	0.4	0.8	1.0
Maximum	17.5	4.2	198.0	54.9
Median	0.9	0.9	4.6	5.8
Mean	1.3	1.3	7.0	8.9
Standard Error of Mean	0.0	0.1	0.3	1.6
95.0% LCL of Mean	1.3	1.0	6.4	5.6
95.0% UCL of Mean	1.4	1.6	7.5	12.1
Standard Deviation	1.3	0.9	10.3	9.6
Cleveland percentiles				
1.00%	0.3	0.4	0.9	1.0
5.00%	0.5	0.6	1.4	1.9
10.00%	0.6	0.6	1.6	3.0
20.00%	0.7	0.7	2.4	4.1
25.00%	0.7	0.7	3.0	4.3
30.00%	0.8	0.7	3.4	4.7
40.00%	0.9	0.8	4.0	4.9
50.00%	0.9	0.9	4.6	5.8
60.00%	1.1	1.0	5.7	6.8
70.00%	1.3	1.4	6.7	8.0
75.00%	1.5	1.6	7.2	9.1
80.00%	1.8	1.8	8.2	10.0
90.00%	2.6	2.6	12.9	20.0
95.00%	3.3	3.1	19.2	23.4
99.00%	6.2	4.2	52.7	54.9

Table I-11: Mean annual NNN and DRP load for Manuherikia River at Galloway expressed in kg/d. Estimates derived from grab samples and AMLE model in LOADEST suite.

Statistic	Load estimate (kg/d)			
	DRP load [AMLE]	DRP load [Grab]	NNN load [AMLE]	NNN load [Grab]
N of Cases	3798	119	3798	119
Minimum	0.8	0.5	0.5	0.2
Maximum	4177.7	264.0	490510.0	3354.3
Median	9.1	7.4	43.1	22.2
Mean	23.8	19.5	802.9	197.3
Standard Error of Mean	1.8	3.8	180.0	46.2
95.0% LCL of Mean	20.3	11.9	450.0	105.8
95.0% UCL of Mean	27.4	27.0	1155.8	288.7
Standard Deviation	112.0	41.5	11092.4	504.0
Cleveland percentiles				
1.00%	1.0	0.7	0.6	0.2
5.00%	1.3	1.1	0.9	0.4
10.00%	1.6	1.2	1.2	0.6
20.00%	2.4	2.1	2.2	1.7
25.00%	3.0	2.9	3.4	2.3
30.00%	3.9	4.1	5.5	2.8
40.00%	6.7	5.8	18.0	6.6
50.00%	9.1	7.4	43.1	22.2
60.00%	11.4	8.9	68.0	42.3
70.00%	14.7	12.1	102.6	105.1
75.00%	17.1	15.9	130.5	156.1
80.00%	20.2	18.1	163.0	198.3
90.00%	33.2	32.1	368.0	456.9
95.00%	59.3	96.3	771.1	951.8
99.00%	334.2	239.6	9614.7	2888.6


Chatto Creek at Manu R
Dunstan Cr at Beattie Rd
Lauder Cr at Rail Trail
Manu R at Galloway
Manu R at Omakau
Manu R at Ophir
Manu R u/s Chatto Cr
Thomsons Cr SH85
Mean load (kg/d)
100.00
10.00
1.00
0.10
0.01
01-08
01-09
01-10
01-11
01-12
01-13
01-14
01-15
01-16
01-17
01-18
01-19
01-20
MONTH


Chatto Creek at Manu R
Dunstan Cr at Beattie Rd
Lauder Cr at Rail Trail
Manu R at Galloway
Manu R at Omakau
Manu R at Ophir
Manu R u/s Chatto Cr
Poolburn Cobb Cottage
Thomsons Cr SH85
Mean load (kg/d)
10,000.0000
1,000.0000
100.0000
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
01-08
01-09
01-10
01-11
01-12
01-13
01-14
01-15
01-16
01-17
01-18
01-19
01-20
MONTH

Appendix J Comparison of annual median and summer median water quality variable concentrations

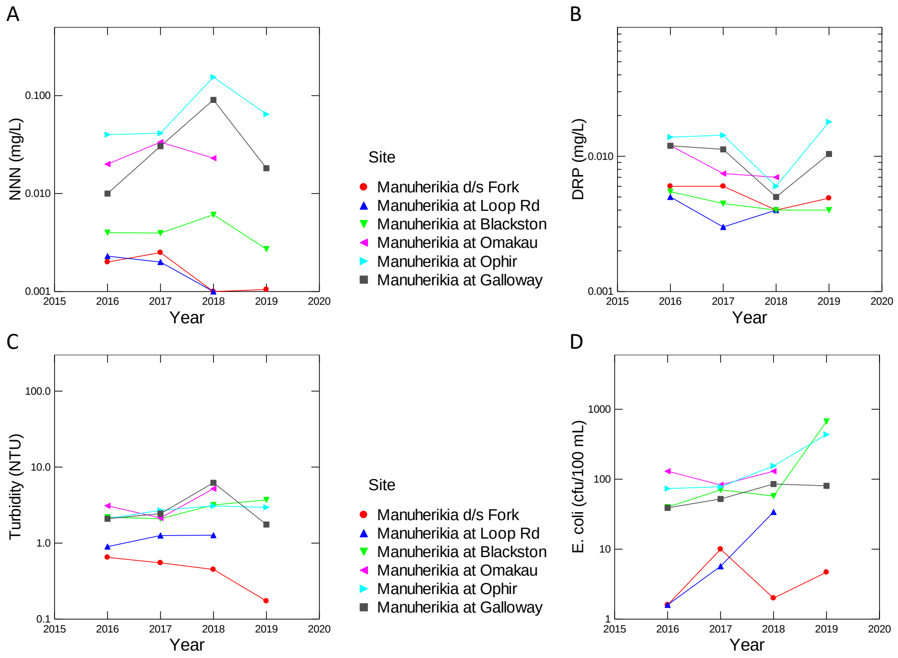


Figure J-1: Annual median values for sites used for biological monitoring purposes.

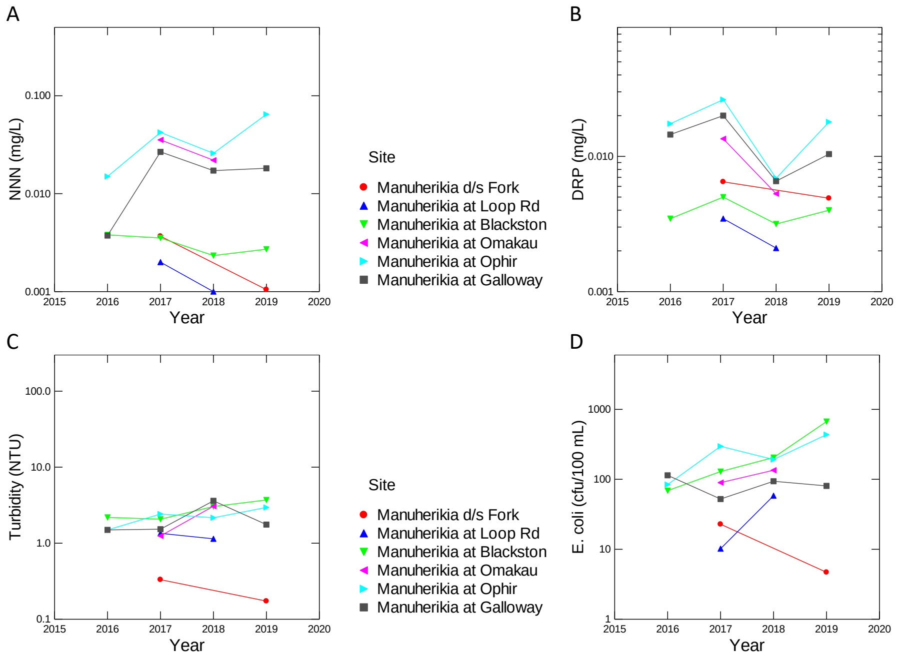


Figure J-2: **Annual summer median values for sites used for biological monitoring purposes.**

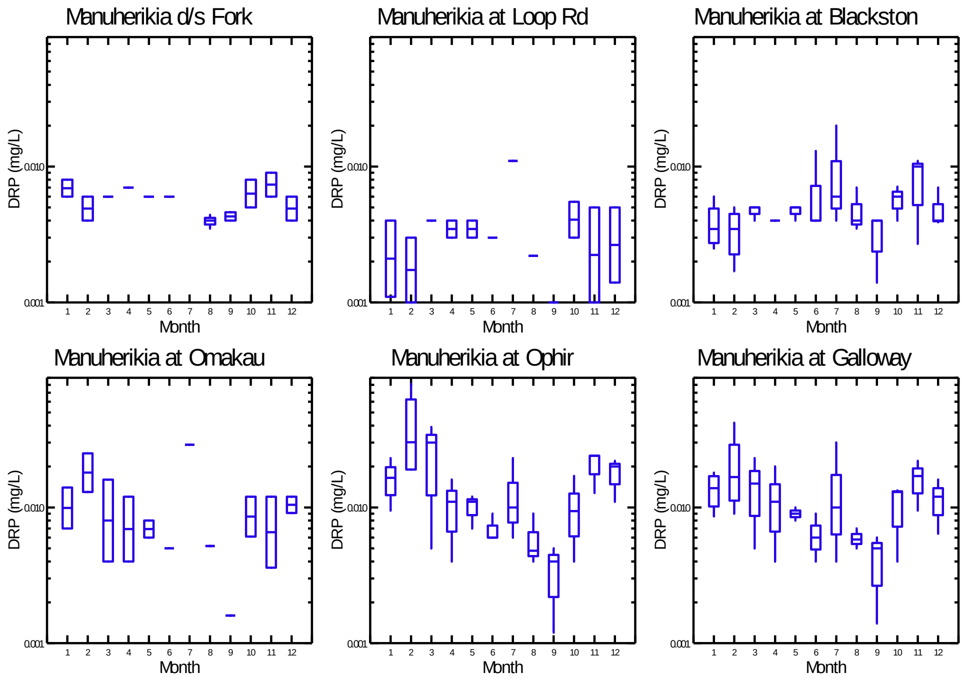


Figure J-3: Monthly DRP concentrations for the period 2016-2019 at sites used for biological monitoring purposes.

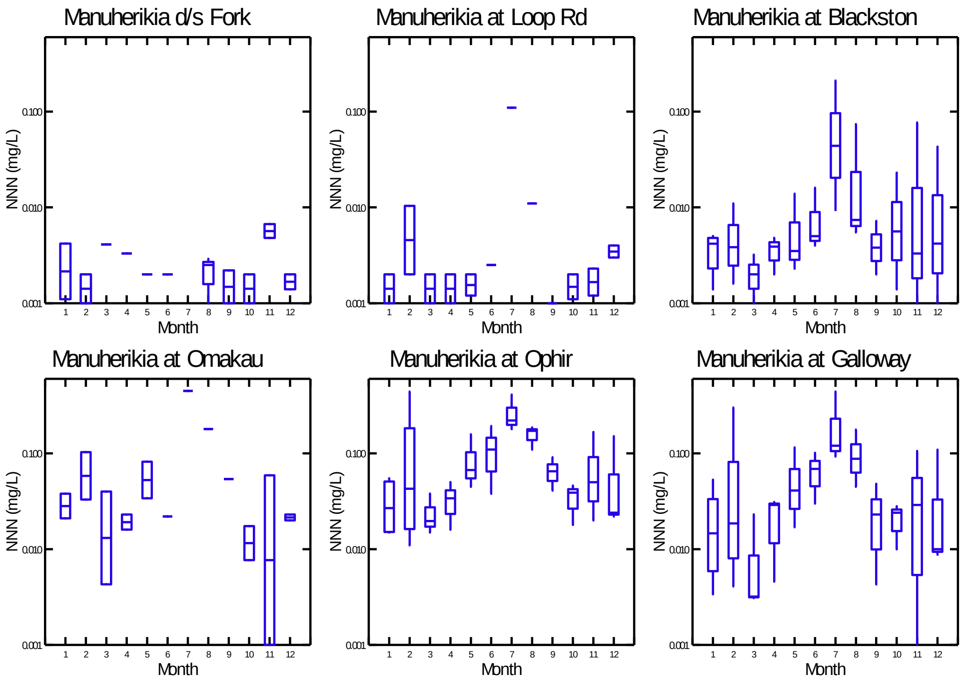


Figure J-4: Monthly NNN concentrations for the period 2016-2019 at sites used for biological monitoring purposes.

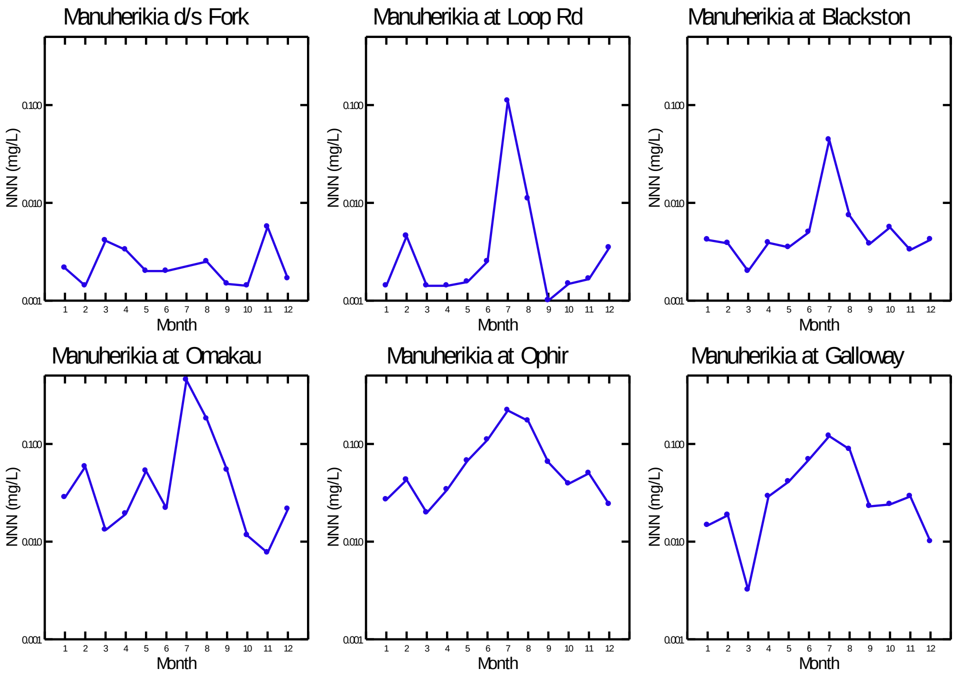


Figure J-5: Monthly median NNN concentrations for period 2016-2019 at sites used for biological monitoring purposes.

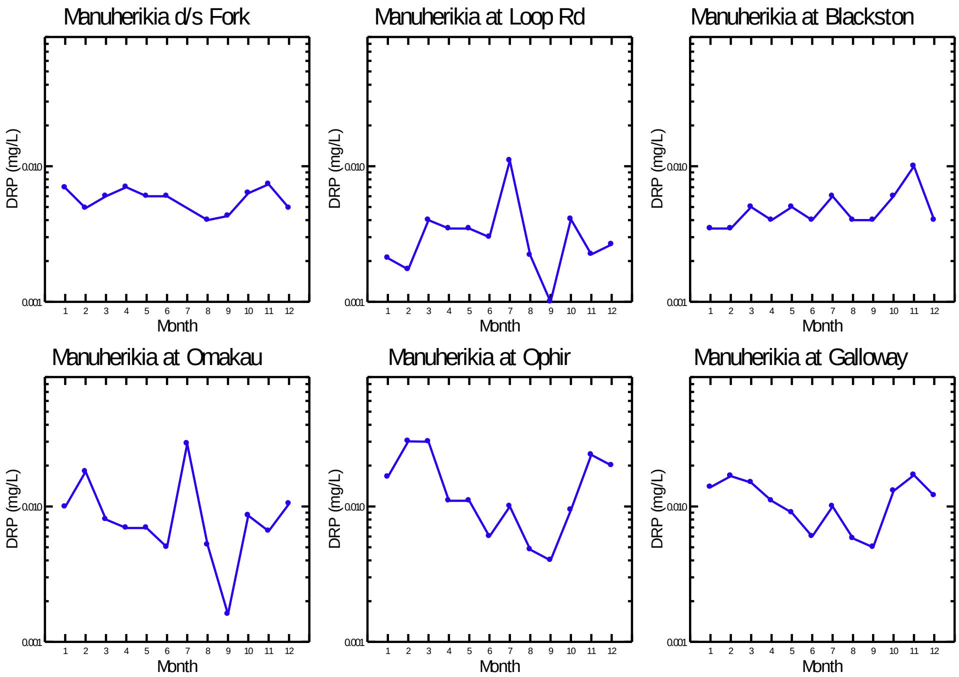


Figure J-6: Monthly median DRP concentrations for period 2016-2019 at sites used for biological monitoring purposes.

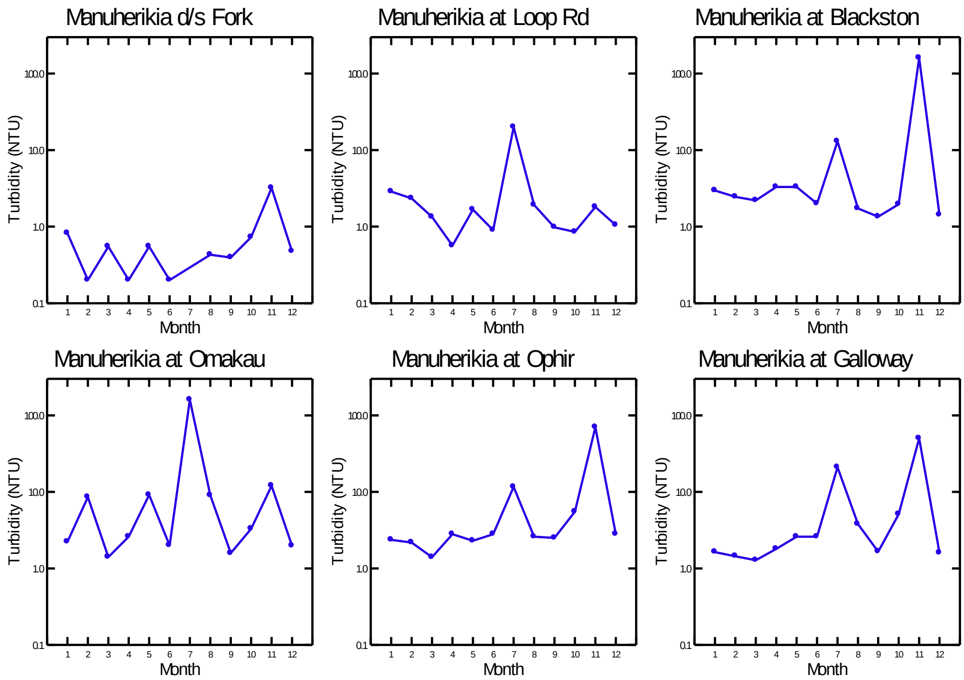


Figure J-7: Monthly median turbidity for the period 2016-2019 at sites used for biological monitoring purposes.

8.2. Regional Policy Statement Review - Programme for 2020

Prepared for:	Strategy and Planning Committee
Report No.	P&S1811
Activity:	Regulatory: Policy Development
Author:	Lisa Hawkins, Team Leader RPS, Air and Coast
Endorsed by:	Gwyneth Elsum, General Manager Strategy, Policy and Science
Date:	22 January 2020

PURPOSE

[1] To note the proposed programme for the Regional Policy Statement (RPS) Review, including a Communications and Engagement Plan for Community and Key Stakeholders.

EXECUTIVE SUMMARY

[2] In his letter of 18 November 2019, the Minister for the Environment, the Hon David Parker, made a recommendation to Council to undertake a complete review of its RPS. This is to ensure the ORC has a fit for purpose planning framework, in time for, and to include, an updated Water Plan for Otago by 2023. To achieve an updated planning framework by this date, the Minister recommended the review of the RPS be completed, and notified by, November 2020.

[3] Staff have already begun the process of the RPS Review, with the formation of an internal working group and some key stakeholder meetings. The work programme to achieve the November 2020 notification timeframe is attached to this report, along with a Communications and Engagement Plan.

RECOMMENDATION

That the Council:

1) ***Receives*** *this report.*

2) ***Notes*** *the attached work programme for 2020.*

3) ***Notes*** *the attached Communications and Engagement Plan.*

BACKGROUND

[4] Minister Parker wrote to the Council on 18 November 2019, setting out his recommendations made under section 24A of the Resource Management Act 1991. At the Council Meeting on 11 December, Council approved a letter in response to Minister Parker, which confirmed ORC will be undertaking a complete review of its RPS, to be notified by November 2020.

[5] The RPS is a critical document in the policy framework for ORC under the Resource Management Act 1991(the Act). Its purpose, set out in section 59 of the Act, is to provide an overview of the resource management issues of the region and to provide policies and methods to achieve the integrated management of these resources. The

preparation of Council's Regional Plans (i.e., Water Plan, Air Plan and Coast Plan) and territorial authority plans must give effect to the RPS. The RPS is therefore the principal resource management document for Otago, and it drives the management of resources across Otago.

[6] ORC currently has two Policy Statements, being the partially operative 2019 RPS and the partially operative 1998 RPS. The 2019 RPS has three outstanding topics under appeal – being mining and indigenous biodiversity, ports and the overall vires of the RPS.

[7] Whilst the preparation of the partially operative RPS 2019 has involved considerable input and resources both internally and externally, it has been criticised by the Environment Court as potentially not giving effect to the RMA. The Skelton Report, on which the Ministers' recommendations were based, noted that freshwater management within the 2019 RPS was not as prominent a topic as could be reasonably expected.

[8] The Minister has outlined that based on known information he considers the RPS 'not fit for purpose'.

[9] The RPS Review sets the scene for ORC to overhaul its policy framework and provide appropriate direction for the region. The review also meets the requirement to implement the National Planning Standards by 2022 and will give effect to the suite of new and proposed National Policy Statements (NPS). The recent work on the RPS 2019 will provide a valuable starting point for the review, and will be incorporated, where practical, into the RPS 2020.

ISSUE

[10] ORC is to undertake a complete review of the RPS and notify by November 2020.

DISCUSSION

[11] To meet the deadline of notification by November 2020, a condensed work programme has been put together. This programme, showing key milestones, is attached as Appendix One, and detailed in the tables below:

[12] Table 1: Council involvement in RPS Review 2020

Council / Committee Meeting	Purpose
22 January 2020 Strategy and Policy Committee	Workshop: seek input from Council regarding the Significant Resource Management Issues for the region and overall direction for the RPS Review Paper for noting: RPS Programme and Comms Plan
February 2020 Council Meeting	Paper for noting: Update on the Key Issues and Directions for consultation with the community
March 2020 Council	Paper for approval: Appointment of Hearing Panel. *Note: this appointment might be superseded by the RMA Amendment Bill, which currently proposes to set up a Freshwater Hearings Panel. The RPS may be referred to this Panel. There may also be other options resulting from the RMA Amendment Bill that are available.*
April 2020 Council	Paper for noting: Overview of consultation feedback
July 2020 Strategy and Policy	Workshop: Overview of the draft RPS Review

Committee	
October Council Meeting	Paper for approval: Seek Council approval to notify.

[13] Table 2: RPS Team work programme for RPS Review 2020

Task / Milestone	Detail
Internal working group	Commenced December 2019 and running through to March 2020, an internal working group has been set up with key personnel across Council. This group will inform and guide the early stages of the RPS Review. Tasks include reviewing the existing RPS, identifying significant resource management issues and defining the approach to topic areas. This internal working group also includes, in partnership, Aukaha.
Key stakeholder discussion	Commenced December 2019 and running through until April 2020, discussions with key stakeholders will focus on identifying significant resource management issues and solutions. This is further outlined in the Communication and Engagement plan, which also includes the list of Stakeholders.
Consultation with the community	In accordance with the Communication and Engagement Plan, community consultation will commence in March 2020. The details of targeted consultation options will be workshopped with Council on 22 January 2020.
Drafting of RPS	Following the consultation on issues and directions, drafting of the RPS Review will commence in April, culminating in a new draft RPS in July 2020.
Consultation with Sch 1 (3) parties	Prior to consulting with Iwi, consulting with Sch1(3) parties is required, this includes Ministers, Government Departments and Territorial Authorities. This consultation will seek feedback on the draft RPS. This will occur in July 2020.
Consultation with Iwi (Sch1 4A)	Prior to notifying the RPS Review, Council are required to consult with Iwi on the final draft of the RPS. This will occur in August 2020.
Finalise RPS for Council consideration to notify	Considering the input from Iwi, the RPS will be finalised in preparation for consideration by Council to notify.

OPTIONS

[14] A programme of the RPS and a Communication and Engagement Plan is attached for noting.

CONSIDERATIONS

Policy Considerations

[15] The RPS will set the scene and framework for the review of our Regional Plans, including Regional Plan Water, Regional Plan Coast and Regional Plan Air.

Financial Considerations

[16] The RPS Review is unbudgeted for the 2019/20 financial year. This includes staff time as well as any consultant and specialist advice needed. A Request for Proposal has already been released to seek appropriate consultant planning assistance, and additional workstreams are underway to support the specialist mapping and input work required.

Significance and Engagement

[17] Formal notification of the RPS will ensure consistency with the Significance and Engagement Policy. The work plan is considered significant and the communications and engagement plan covers a range of stakeholders to ensure a wide range of perspectives is obtained.

Legislative Considerations

[18] The Act requires that, at all times, regional councils must have an RPS in place; Sections 59-62 of the Act set out the requirements for and process by which Regional Councils must prepare an RPS, and the First Schedule of the Act sets out the process for the preparation, change and review of policy statements and plans. The RPS review will be consistent with all legislative requirements under the 1st Schedule of the Act.

Risk Considerations

[19] The Minister's expectations, informed by the Skelton Review and Report, direct that before a new Water Plan can be developed, Council must have in place an updated operative RPS. This properly reflects the hierarchy in the RMA. Therefore, if the timeframe for notifying the RPS by November 2020 is not achieved there is a potential consequence to upset the programme for the Water Plan Review. The approach set out in the following dot points aims to address this risk.

[20] Given the compressed timeframes, a more typical consultation programme, offering multiple opportunities for input prior to notification is not available. The consultation approach may be a challenge for the community for reasons relating to consultation fatigue, fast turn around and low-level awareness of the process.

[21] Budget and resources constraints, including having to divert resources, is a risk for the RPS. We are currently recruiting for an existing vacancy within the team and have a Request for Proposal (RFP) out for consultant support. The appointment of these two resources early in the new year will assist in managing the risks associated with time frames.

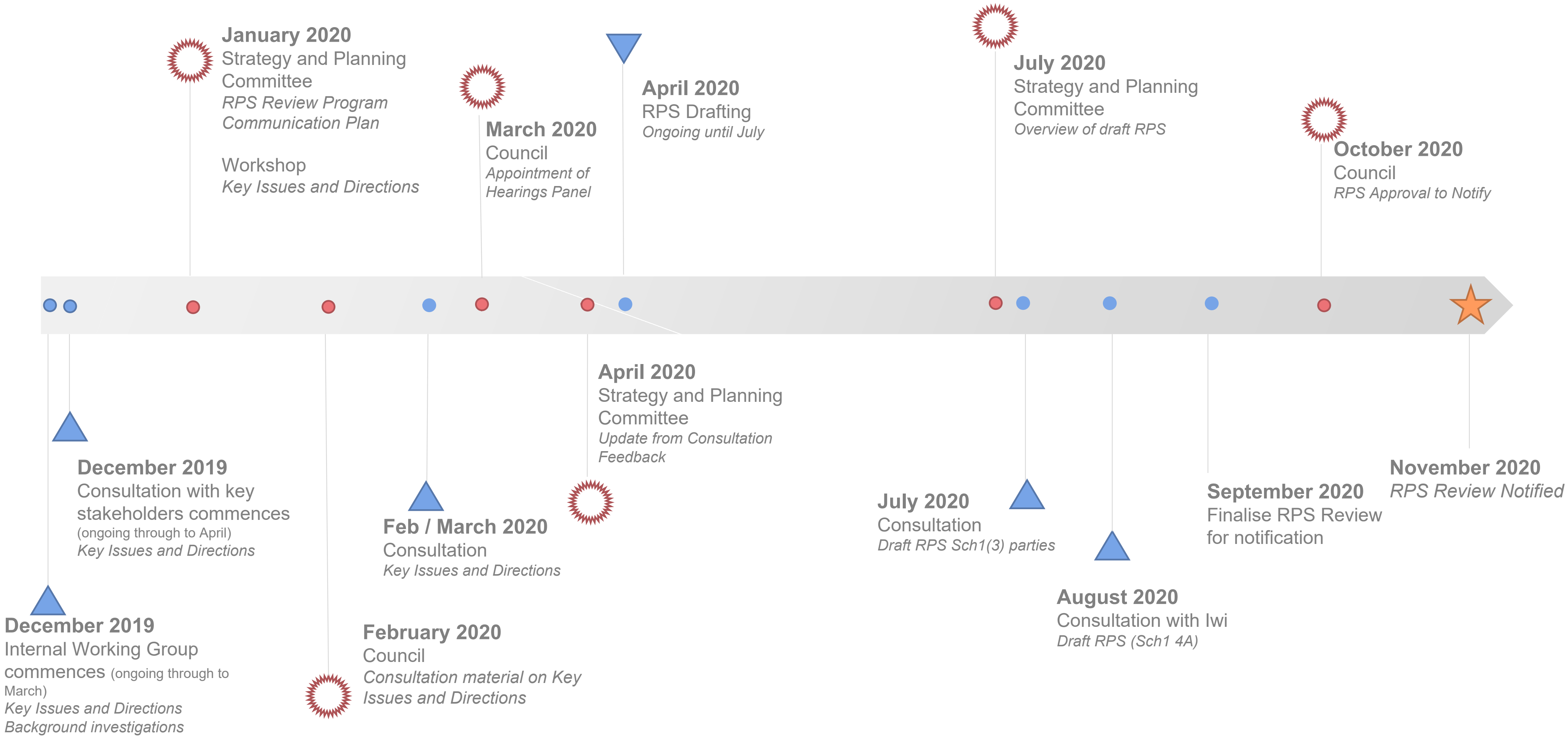
NEXT STEPS

[22] The team will continue to work on Issues and Directions identification for the RPS, to inform consultation in March 2020. Prior to commencing consultation, a paper will be brought to Council detailing the consultation material.

ATTACHMENTS

1. RPS Project Milestones Timeline [**8.2.1** - 1 page]
2. Communications plan - Regional Policy Statement final [**8.2.2** - 9 pages]

RPS Programme Milestones



Otago Regional Council

COMMUNICATIONS AND ENGAGEMENT PLAN

Regional Policy Statement

Created on: *17 December 2019*

Updated on: *17 January 2020*

Background

Minister for the Environment David Parker has set Otago Regional Council (ORC) a clear timeframe for addressing our planning framework, which has been deemed as not fit-for-purpose and needing an overhaul. We also need to implement the National Planning Standards by 2022.

ORC is to notify a new Regional Policy Statement (RPS) by November 2020, to be operative by 1 April 2022.

The key principles of the new RPS are:

- Clear direction on outcomes sought
- Vertically and horizontally integrated
- Consistent approach
- Regime that addresses increasingly complex issues and is flexible to changes in the statutory environment
- Focusses on key issues
- Plain language and ease of use for all
- Policies direct resource management outcomes
- All the answers are to be in the Plan

Objective

- To inform key stakeholders and the wider community about our work programme to achieve this timeframe for the new RPS
- To ensure our iwi partners, key stakeholders and the community understand the significance of this document in that it sets our overall planning framework.

Audience

The Schedule 1 process for plan making under the RMA requires consultation with the Minister for the Environment, other relevant ministers of the Crown, local authorities in the region and tangata whenua through iwi authorities. ORC may then determine anyone else to be consulted.

Across the RPS Review Programme engagement with the following stakeholders will occur at various times.

- Iwi partner (Kai Tahu)

- Minister Parker and Ministry for the Environment
- Central Government
- Statutory stakeholders, including Fish & Game and Department of Conservation
- Territorial authorities
- Primary industry groups
- Energy companies
- Developers
- ORC staff and councillors
- NGOs/community groups
- The wider Otago community

The policy team will manage the consultation with iwi partners and key stakeholders, and the communications and engagement team will manage the broader community consultation (please refer to the Tactics and Public Consultation Approach sections and Appendix 1 for more detail).

Purpose

- To provide our iwi partner, key stakeholders and the community with the opportunity to have input on the scope and content of the new RPS, through both formal engagement required by the Resource Management Act and through other options, such as face-to-face meetings and feedback online.
- To undertake good engagement early in the process to reduce the number of submissions made at notification stage, and therefore streamline the process.
- To write a new RPS that is in line with new national direction, National Planning Standards and proposed national policy statements for Highly Productive Land, Urban Development, Freshwater Management and Indigenous Biodiversity.

Key messages

- The outcomes of an investigation initiated by Minister for the Environment David Parker were received by ORC on 18 November 2019, and the key finding was that the Otago region does not have a fit-for-purpose planning framework in place.
- There were three recommendations for creating this planning framework:
    1. That ORC develops a fit-for-purpose freshwater planning framework to assess all water consent applications, including those to replace deemed permits before they expire.
    2. Develop a work programme to achieve the following:
        - For ORC to notify a new Regional Policy Statement (RPS) by November 2020, to be operative by 1 April 2022.
        - For ORC to notify a new Land and Water Regional Plan (LWRP) by 31 December 2023, to be operative by 31 December 2025.
    3. For ORC to prepare a plan change by 31 March 2020 that provides an interim framework to manage freshwater until new discharge and allocation limits are set in line with the National Policy Statement for Freshwater Management.

What is an RPS?

- The RPS sets the direction for future management of Otago's natural and physical resources. It identifies the Significant Resource Management Issues for the region and provides the foundation for the development of regional plans and district plans (similar to a blueprint).

- It sets out what we want for Otago, what's stopping us achieving this, and how we will solve those problems.
- The RPS doesn't contain rules; it establishes the framework for Otago's regional and district plans in which resource management policies, objectives and rules will sit.
- It includes how resources will be managed, including:
    - Air
    - Coastal
    - Land and freshwater (will include waste)
    - Topics
        - Ecosystems and biodiversity
        - Energy and infrastructure
        - Hazards and risks
        - Historical and cultural values
        - Heritage
        - Natural character
        - Natural features and landscapes
        - Urban form and development

Why does ORC need a new RPS?

- We have been instructed by Minister Parker to notify a new RPS by November 2020, to be operative by 1 April 2022.
- New national planning standards have been implemented since we wrote our current, partially-operative RPS.
- ORC needs an RPS that reflects the new national direction and is in line with the proposed National Policy Statement for Highly Productive Land, the proposed National Policy Statement for Urban Development, the proposed National Policy Statement for Freshwater Management and the proposed National Policy Statement for Indigenous Biodiversity.

How does the RPS affect you?

- District and regional councils need to give effect to the RPS when making district or regional plans or making decisions about resource consents.
- The RPS sets direction for what people and communities can and cannot do when using natural resources, subdividing or developing land, or undertaking a land use activity.
- Well-managed resources provide for Otago's social, economic, cultural and environmental wellbeing; community health and safety; and for future generations.
- The existing partially operative (2019) RPS is still undergoing an appeal process. This process will continue to run course separately to the programme for the RPS Review 2020.

Tactics

On online consultation with the community and stakeholders will be undertaken for two weeks in February 2020 to seek feedback from the public on what they consider to be the matters of value and concern for the natural or physical resources significant or specific to Otago. This consultation will build on the work of Council in the RPS workshop to be held on 22 January 2020, and the monitoring and investigations undertaken by staff.

A targeted approach to consultation with the public will be set up in February and March 2020. It will be a staged approach (as set out below) and will include an online survey, advertising, newsletters, social media, news stories as outline below, as well as face-to-face meetings, for example with localised target focus groups, which will bring together a diverse group of people to discuss the Significant Resource Management issues. This will result in the issues and any policy tensions created being explored and considered. The feedback sought will specifically focus on providing a policy direction for the RPS for staff and council to consider.

Discussions with key stakeholders (managed by the policy team) began in December 2019 and will be ongoing (please refer to Appendix 1 and 2).

To avoid consultation fatigue for the community, combining the RPS and Annual Plan consultation was investigated. Consultation on the Annual Plan is proposed for 26 March – 24 April 2020, however given the condensed timeframe to complete the RPS review, and to ensure consultation with the community is meaningful, it was decided this approach would delay the RPS process too much. This is why a separate consultation approach will be undertaken.

As mentioned above, the policy team will manage consultation with our iwi partners, those who we are statutorily required to consult with and key stakeholders, and the communications team will manage community consultation.

Public Consultation Approach

Stage One [February 2020]: Identify and define Otago's features

Channel
YourSay - Online consultation to identify and define Otago's features (based on 22 January workshop with councillors)
Social media - Boosted Facebook campaign to encourage people to take part in the online consultation.
Media Release - Media release to promote the consultation and encourage people to take part in the online consultation
Advertising - Advertising for RPS consultation to encourage people to take part in the online consultation
On-Stream newsletter (Feb edition) - Link to online consultation and encourage people to take part in the online consultation

Stage Two [March 2020]: Input into policy direction for identified features

Channel
Targeted Consultation Groups - Set up to be run across March 2020 - Options to be discussed at 22 January Council workshop - News story with one of the focus groups talking about what they hope to achieve.

Direct emails/meetings - Direct contact with key stakeholders as required under the Resource Management Act (see Appendix 1).
Waterlines newsletter (Autumn edition) - Article with update about RPS

Stage Three: [Ongoing from April to November]: Keep community informed of the process and the outcomes of stage one and two

Channel
ORC website - Information will be kept up to date, with links to web pages with online promotion - Information about making a submission will be added after the proposed RPS is notified. - Diagram showing RPS process and when the public can have input - Ongoing media releases and news stories about RPS progress.
On-Stream - Regular updates throughout 2020 on RPS progress, including interview with the focus group.
Internal comms (staff, exec, councillors) - Information shared internally and with councillors

Stage Three [November 2020]: Notification

Channel
Social media - Boosted Facebook campaign to summarise what the RPS is and encourage people to make submissions
Media Release - Media release to say the RPS is notified and to encourage submissions
Advertising - Advertising to encourage people to make submissions
On-Stream newsletter (Nov edition) - Link to news story and encourage to make submissions
Waterlines newsletter (Spring edition) - Article with update about RPS and how to make a submission

What will we be asking iwi partners/stakeholders/the community during the consultation?
We're not starting from a blank slate because of the work and consultation that went into the current RPS. Significant Resource Management Issues will be workshopped with Council and will be summarised for people to comment on and set the foundation for the new RPS.

Consultation questions are still being formulated, however they will be high-level and are likely to centre on:

- What's missing from the issue list?
- Is the RPS focussing on the right things?
- Please let us know your thoughts

Timeline/activity calendar

December 2019 – July 2020	Ongoing conversations with key stakeholders to inform RPS review and drafting.
January 2020	Councillor workshop – Significant Resource Management Issues
February / March 2020	Online community consultation and targeted local consultation groups approach – feedback on Significant Resource Management Issues
July 2020	Councillor workshop – draft RPS
July 2020	Clause 3 First Schedule Consultation: • Ministry for the Environment, Ministry for Conservation, Ministry for MPI, Ministry for Economic Development, • CODC, CDC, QLDC, DCC, WDC • Tangata whenua through Iwi authorities: Nga Runanga: Te Runanga o Otakou, Kati Huirapa ki Puketeraki, Te Runanga o Moeraki and Hokonui Runanga), Te Runaga o Ngai Tahu
August 2020	Clause 4A First Schedule Consultation: Tangata whenua through Iwi authorities: Nga Runanga: Te Runanga o Otakou, Kati Huirapa ki Puketeraki, Te Runanga o Moeraki and Hokonui Runanga), Te Runaga o Ngai Tahu
October 2020	Council approval to notify RPS
November 2020	RPS notified and submissions invited
Approx. early February 2021	Submissions close
Approx. mid March 2021	Further submissions close
Approx. mid April 2021	Hearing
Approx. mid June 2021	Decision
	Appeals
	RPS is made operative

Risks

- Consultation fatigue
- Frustration that ORC is consulting on the RPS again, when the current version is not fully operative
- The community potentially feeling overwhelmed and confused at the number of consultations we will be doing in the early part of 2020, and also the speed we are progressing work

- Greater involvement from the public than anticipated resulting in possible delays which poses a risk to meeting the notification of November 2020 deadline.

Budget

TBC

Measurement/review

- Clicks on the ORC website
- Uptake of the media release by newspapers/radio
- Shares and comments on Facebook posts
- Clicks on On-Stream articles
- Number of people taking part in the online consultation (YourSay)
- Attendance at local focus groups
- Stakeholder log (to be managed by the policy team)

APPENDIX 1: Stakeholder list

This list is based on parties to appeals on the now partially-operative Otago RPS 2019.

Councils:
- Dunedin City Council
- Queenstown Lakes District Council
- Clutha District Council
- Central Otago District Council
- Waitaki District Council

Central Govt:
- Director General of Conservation
- Minister of Energy and Resources

Crown entities and research institutes:
- Radio New Zealand Ltd
- Heritage New Zealand
- Agresearch Limited

Fish and Game
- Central South Island Fish and Game Council
- Otago Fish and Game Council

NGOs/community groups:
- Environmental Defence Society
- Royal Forest and Bird Protection Society
- Wise Response Incorporated

Industry
- Rayonier New Zealand
- Federated Farmers of New Zealand
- Horticulture New Zealand
- Alliance Group Ltd
- Ballance Agrinutrients
- Otago Water Resource Users Group
- Oceana Gold New Zealand
- Queenstown Airport Corporation
- Irrigator groups across Otago
- Port Otago Ltd

Energy
- Pioneer Energy
- Transpower New Zealand
- Aurora Energy limited
- Trustpower Ltd
- Contact Energy

Takata whenua:
- Hokonui Runanga

- Kati Huirapa Runaka ki Puketeraki
- Te Runanga O Moeraki
- Te Runanga O Ngai Tahu
- Te Runanga O Otakou
- Tumuaki for Waitaha Tai Whenua O Waitaki Trust Board

APPENDIX 2: Stakeholder engagement log

ORC Stakeholder Engagement

Stakeholder	Method of contact	Who
Port of Otago	Meeting 18 December 2019	Kevin Winders