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Nelson Freshwater Quality

An Analysis of State and Issues

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1 Executive Summary

Water quality and aquatic ecosystem health are generally good in the upper reaches of most catchments in Nelson and in areas with little resource pressure like the Whangamoa. However, the impacts of urban, pastoral and production forestry land uses are apparent in different waterways and declines in water quality and ecosystem health in mid and lower areas of some catchments are common. Poor water quality and ecosystem health require a response in the Nelson Plan in order to meet Objectives A1 and A2 of the National Policy Statement for Freshwater Management (2014) and section 30 of the Resource Management Act (1991).

Issues specific to each Freshwater Management Unit (FMU) are detailed within individual sections of this report, in addition to information on the potential causes of any water quality or ecosystem health issues where this information was available. A better understanding of cause and effect relationships between land and resource use and freshwater quality will come as more frequent data collection over a range of flow conditions continues. A comprehensive periphyton dataset, regular habitat assessment and ongoing native fish monitoring across the SOE network will also assist in comparing water quality with the National Objectives Framework and other relevant guidelines, limits and objectives proposed in the Nelson Plan.

Efforts to reduce sediment run-off from production forestry are recommended for tributaries of the Mahitahi/Maitai River, particularly in the Sharland and Groom but also in the Brook Stream catchments. Improved management of nutrient and sediment run-off from pastoral land use is recommended for the lower Sharland, Saxton, Lud, Hillwood and Todds catchments in particular to improve water quality outcomes. Investigation and management of contaminants arising from urban run-off, stormwater, sewage leakage and overflow or discharges of landfill leachate are recommended for the York, lower Mahitahi/Maitai River, Saltwater Creek and Stoke Streams.

An understanding of the current degree of urbanisation (e.g. impervious cover) and modification of habitat through piping, undergrounding or hard engineering of the flood channel is urgently needed to understand the scale of any effects on habitat and natural character. Understanding the current state and the effects this has had on the ecological health across the various urban catchments in Nelson can inform future land development and flood management practices. This information will also be relevant to assessments of natural character and impacts on waterbody values.

1.1 Stoke FMU

Saxton Creek has some of the worst water quality of all sites in Nelson. Elevated nitrogen, phosphorus, faecal contaminants and sediment are indicative of pastoral land use with unmanaged or unmitigated contaminant losses in the upper catchment. There has been some suggestion that there are also water quality issues associated with irrigation ponds in the upper and lower Saxton catchment. Further monitoring to assess the effects of these ponds is warranted. The SOE site in the lower Saxton is in the process of being moved. Damming in the headwaters, discharge of sediment from the resulting pond and removal of water in this area may also contribute to poor aquatic health. Contaminant management plans (e.g. farm plans) are recommended to assist in remedying or mitigating losses of contaminants to water from pastoral land.

Urban development of the Saxton Creek catchment and the proximity of the development to the stream and true left tributary catchment are underway. Significant flood channel controls have been included in the subdivisions already underway and more is planned. Habitat effects are likely and monitoring of these activities in relation to native fish values is recommended. Sediment impacts from continued sub-division and land development across the Stoke FMU are found in recent monitoring records and commonly observed by NCC staff.

Despite poor water quality and ongoing habitat modification, Saxton Creek contains a good diversity of native fish and supports īnanga spawning in its lower reaches. These values are at significant risk from further catchment urbanisation, water abstraction, pollution and flood channel modification. This is a common theme across the Stoke streams, all of which are home to diverse native fish communities, many of which are nationally threatened or at risk species. Streams with lesser degrees of contamination and modification have healthier fish communities. This is most apparent in the Poorman Valley and Orphanage streams when compared to the Orchard, Jenkins and Saxton catchments. However, the latter three waterways are still good when compared to national trends.

Urban impacts need strategic and long-term management in order to maintain and improve aquatic habitat, spawning habitat and access to habitat over the long term. Sources of poor water quality need further investigation and remedial action.

1.2 Roding FMU

Little water quality monitoring has been undertaken in the Roding as NCC do not have an SOE monitoring site in the catchment. However, some data is collected on behalf of the infrastructure group for the water take consent compliance and monitoring purposes. Biomonitoring of the water take consent shows significant increasing trends in ecosystem health downstream of the water take since 2002. Data collected by Tasman District Council for the Roding at Twin Bridges site, downstream of the NCC boundary shows faecal pathogens are very low and the Roding is almost always suitable for primary contact recreation, with water clarity and fine sediment also indicating good to excellent water quality. Although there is some periphyton growth, macroinvertebrates are usually in a good state with MCI greater than 100.

1.3 Mahitahi/Maitai FMU

Water quality in the South Branch of the Mahitahi/Maitai and the upper reaches of the Brook Stream is excellent. However, the Groom and Sharland tributaries contribute to elevated nutrient and sediment in the Mahitahi/Maitai, potentially contributing to cyanobacterial blooms in the lower river. Sources of fine sediment and nitrogen from forestry and pastoral land uses require careful management in the Mahitahi/Maitai and a programme is underway to better understand the relative contributions of sediment from various sources in the catchment.

York, Hillwood and Todds Streams have poor water quality. The impacts of urban land use and landfill leachate in the York Stream need to be addressed urgently and pastoral land use in the Todds and Hillwood Streams require farm contaminant management and riparian plans. A better understanding of the impacts of land use on water quality through site visits and investigation of the sampling sites is recommended for the Hillwood Stream catchment area. Connectivity between freshwater and marine environments is almost completely absent for all of the streams draining to the Wakapuaka flats due to a tidal flood gate. Ecosystem Health and the significant values of the Wakapuaka Reserve wetland are adversely affected by this structure.

1.4 Wakapuaka FMU

Water quality is generally good in the Wakapuaka catchment, with the exception of the Lud River. The key water quality issues are elevated faecal contaminants, nitrogen and sediment, primarily in the Lud sub-catchment. Sediment level increase between the upstream and downstream sites on the Lud indicates losses characteristic of pastoral land use, stock access, erosion and lack of riparian cover. Non-regulatory programmes have started to address this issue in some reaches of the Lud, extension of riparian planting and fencing into the upper reaches is needed to reduce farm run-off to streams. Production forest harvest in the upper Lud is also likely to have contributed to poor water quality at times within the period of record covered by SOE monitoring. On-farm contaminant and riparian management is recommended for the Lud catchment to improve water quality and reduce cumulative impacts on freshwater values in the Wakapuaka mainstem. Little is known about the ecosystem health or water quality of the Māori Pā Stream, further investigation is recommended.

1.5 Whangamoa FMU

Water quality and ecological health is very good throughout the Whangamoa FMU, most likely the result of a high proportion of indigenous forest and mature plantation forest cover in the catchment. Maintenance of water quality will be an important consideration, particularly if there is any risk of land use change or intensification, and to address changes in the location and scale of production forest harvesting and associated activities. Recent results suggest sediment run-off from production forest harvest are already on the increase.

2 Introduction

Nelson City Council (NCC) are reviewing their resource management plans and policies with a view to updating and integrating them into one plan known as the Whakamahere Whakatū Nelson Plan ("Nelson Plan"). The plan must give effect to the National Policy Statement for Freshwater Management (2014) or "NPS-FM". The NPS-FM requires Councils to take a number of steps in relation to the management of freshwater (Figure 1).

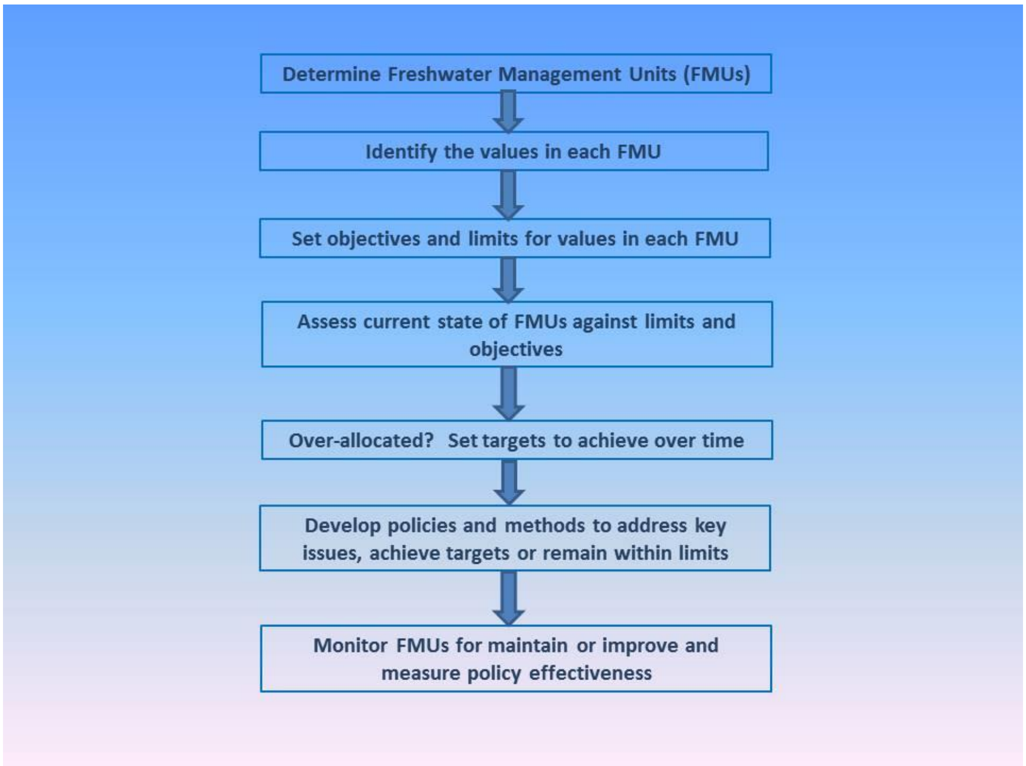


Figure 1. Summary of the National Policy Statement for Freshwater Management (2014) implementation for Councils.

Nelson City Council have proposed five Freshwater Management Units (FMUs), shown on Map 1. Ideally, a common management approach will be applied within each FMU. However, in some cases water quality, quantity, ecological and tāngata whenua resource management issues and values will vary within an FMU, particularly in those which contain multiple catchments. Understanding the variability in water quality and the multiple causes of degradation is important to determining the best scale and approach for managing Nelson's waterways, using the NPS-FM framework as a foundation.

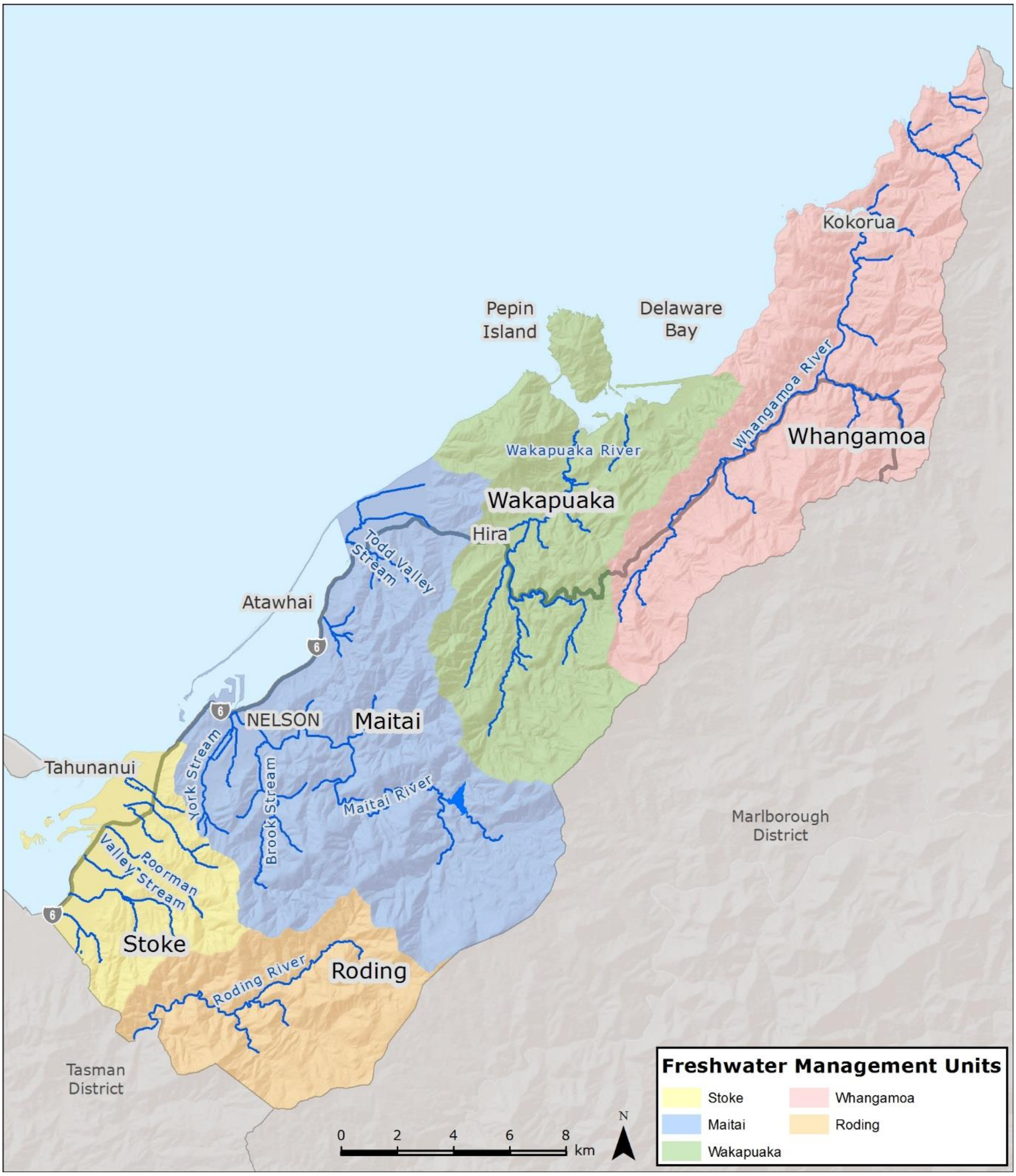
2.1 Format and context of report

This report explores the water quality issues for Whakatū Nelson firstly at the regional scale. Summaries of key findings are provided at the beginning of each section. The report then goes on to look in more detail at the monitoring, issues and the environmental context of each FMU in the following order:

I. Stoke FMU –Saxton Creek, Orchard, Poorman Valley, Orphanage, Jenkins and Arapiki Streams.
II. Roding FMU – Upper Roding River and tributaries.
III. Mahitahi/Maitai FMU – Mahitahi/Maitai River and tributaries; York and Saltwater Creek, Oldham, Todds Valley and Hillwood Streams.

IV. Wakapuaka FMU – Wakapuaka River and tributaries, including Māori Pā Stream and other small coastal streams flowing to Delaware Bay.

V. Whangamoa FMU – Whangamoa River and tributaries, including small coastal streams flowing to Delaware Bay to the north of Māori Pā Stream.



Map 1. Proposed Freshwater Management Units (FMUs) for Nelson.

3 Purpose and scope of report

This report aims to provide a summary of the key water quality issues for each proposed FMU and is part of the science foundation of the freshwater section of the Nelson Plan (Figures 2 and 3).

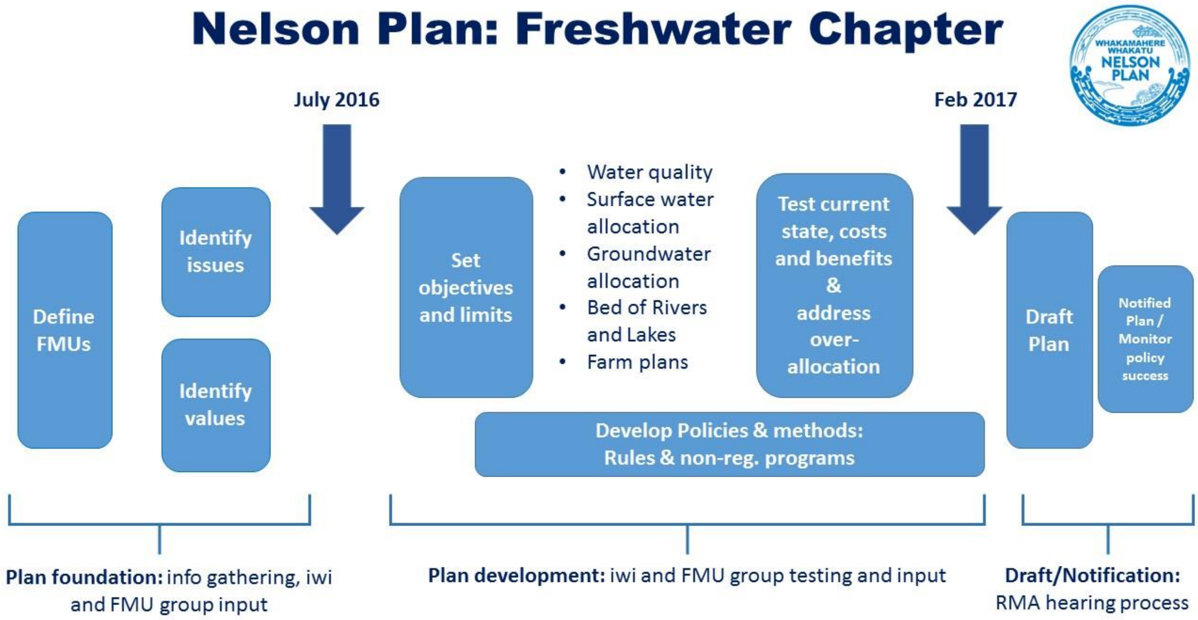


Figure 2. Whakamahere Whakatū - Nelson Plan water chapter development timeline.

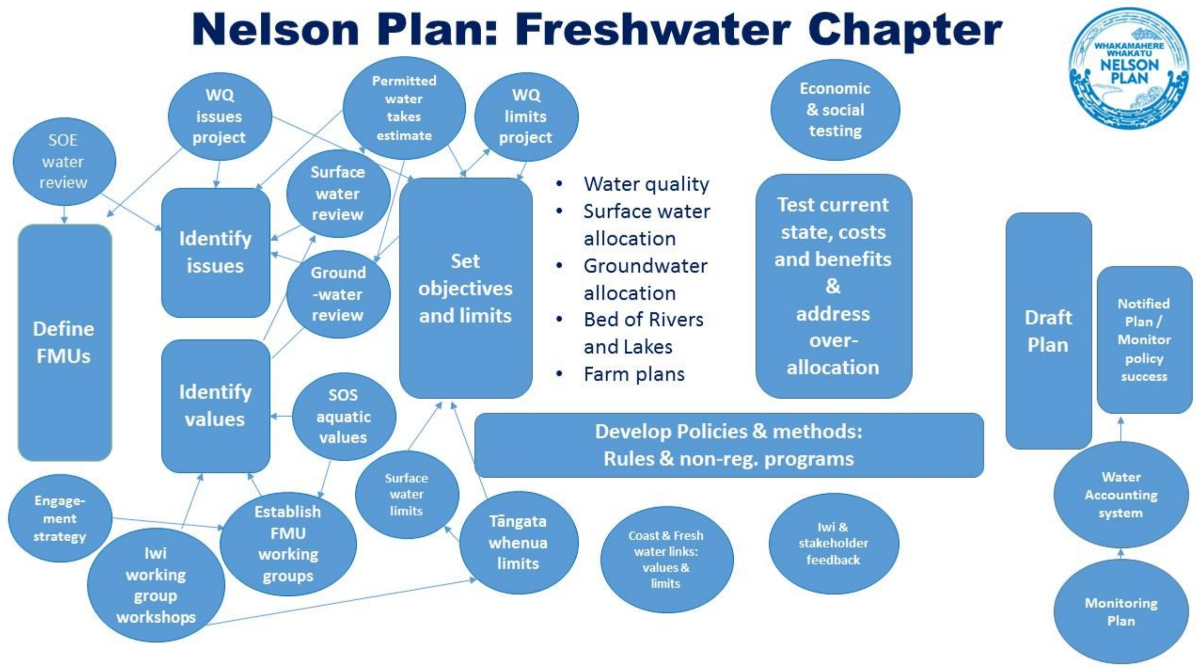


Figure 3. Whakamahere Whakatū - Nelson Plan water chapter proposed technical projects to support plan development.

3.1 Monitoring

The condition of rivers in Nelson is assessed every year using a scoring system that combines information on general habitat condition, water quality, sediment toxicity and biological (invertebrate and periphyton) community assessments. This method of classification provides a good long term record of state and trend but does not always assist in clearly identifying the cause and effect relationships between resource use and water quality or ecosystem health. The state of the environment (SOE) monitoring programme for freshwater was informed by a review by the Cawthron Institute in the late 1990's. The programme has excellent coverage of the Nelson area and spans a range of river types and resource intensity.

A review and summary of the water SOE programme can be found in McArthur (2015). McArthur identified some issues with the former SOE programme through the review that impact on the reliability of the data to definitively describe the causes of declines in water quality. The key limitations within the 2015 programme include:

I. quarterly SOE water quality monitoring
II. water quality sample collection during base-flow (i.e. avoidance of stormflows and peak contaminant loads),
III. infrequent (annual) periphyton monitoring,
IV. absence of linked water quality and flow observations, and
V. a need for a longer flow record to enable the calculation of reliable flow statistics for all SOE water quality sites.

Changes to the SOE programme to incorporate monthly sampling across the full range of river flows were made at the beginning of 2015. As a more frequently collected data records grows, impacts to water quality across the range of flows will be better understood.

The SOE record holds sufficient data to infer basic cause and effect relationships between the state of water quality, ecological health and activities in the surrounding catchment area. The information used in this report was gathered from the State of the Environment (SOE) programme between May 2002 and July 2016. Monitoring data was supplemented by a wealth of information in the form of external research reports, largely prepared by the Cawthron Institute in Nelson, often for Nelson City Council.

Objectives and limits from the National Objectives Framework (NOF) of the NPS-FM and any national guidelines or trigger values have been used in this report to compare with the state of water quality. This information will inform the objective and limit setting process, particularly with regard to the requirements in the NPS-FM to "maintain or improve" freshwater quality in order to provide for the national compulsory values of Ecosystem Health and Human Health. Identifying the state of water quality in each FMU will help to inform/provide the justification for the policy and rule framework and associated methods in the Nelson Plan.

Summary of Water Quality Issues for Nelson

Ecosystem health:

1. The upper reaches of the Mahitahi/Maitai, Wakapuaka and Whangamoa catchments have the healthiest macroinvertebrate communities. The upper reaches of the Roding River, Poorman, Groom and Brook Streams have good ecosystem health in relation to MCI and the remaining sites range from good to fair. Orphanage, Todds Valley, Hillman, York, Jenkins and Saxton Streams have the lowest MCI scores, ranging from fair to poor, indicating severe organic pollution. A number of sites had variable MCI scores over the 13-year monitoring period.

2. The middle reaches of the Brook, Orphanage and Jenkins exceeded periphyton cover guidelines for recreation and indicate poor ecological condition at times. Mahitahi/Maitai at Groom and Brook at Manuka indicated 'fair' ecological condition at least once since 2002. All other sites are within the good to excellent categories for ecological condition with respect to periphyton, showing only occasional exceedances of the nuisance guideline. However, potentially toxic cyanobacteria in the lower Mahitahi/Maitai is a regular problem. More frequent sampling is needed throughout Nelson sites to better understand the state of periphyton growth.

3. Native fish communities are generally diverse in most Nelson rivers and streams and many of the species found in Nelson are nationally at risk or threatened. There is potential for the Stoke streams draining into the Waimea Inlet to have high indigenous biodiversity values that require protection. Īnanga spawn in the lower reaches of many streams and rivers.

Faecal contaminants:

4. Very high levels of faecal contaminants were found in Saxton and York, with other Stoke Streams, Hillwood, Todds and Lud also having elevated levels. Saxton sits right on the NOF bottom line for *E. coli* and there are obvious problems in the Jenkins, York, Hillwood, Todds and Lud Streams. High *E. coli* under base flow conditions suggests point source discharges, sewer leakage or direct stock access issues are the causes, depending on the individual catchment land use.

5. With the exception of the above sites, most other freshwater bathing sites are within safe-swimming limits almost all of the time, with occasional exceedances.

6. Summer-only recreational monitoring of bathing sites shows issues with elevated faecal contaminants in the lower Mahitahi/Maitai and to a lesser degree the lower Wakapuaka.

Nutrients:

7. Saxton Creek has highly elevated nitrogen levels, well above all other sites for nitrate, soluble inorganic nitrogen and ammoniacal nitrogen.

8. With the exception of the Lud, the Wakapuaka and Whangamoa FMUs both have very low nitrogen concentrations. A number of small catchments including the Sharland and Groom (as they enter the Mahitahi/Maitai) and Jenkins and Orphanage Streams have elevated nitrogen concentrations above ANZECC lowland guidelines.

9. Phosphorus is elevated throughout the Stoke FMU and in the Brook, York, Hillwood, Todds and Lud Streams. Saxton and Todds Valley had considerably elevated concentrations when compared to other sites. Some sites may have naturally elevated phosphorus from soft-sedimentary and volcanic acidic geology.

Sediment:

10. Sediment data needs to be interpreted with adequate measurements across a range of flows. Sediment at base-flows can be caused by direct disturbance activities such as gravel extraction, instream works, stock access or production forest activities and harvesting. Resuspension of fine deposited sediment by flow or tidal influences can also increase turbidity and sediment readings.

11. Sediment and turbidity issues at base-flows are apparent in Saxton, Orphanage, Jenkins, Hillwood, York and Todds Valley Streams. Saxton again has the greatest sediment issue. When monthly observations across a range of flows were included in the dataset the Todds and Hillwood showed the most extreme increases in maximum values, indicating bank erosion, stock access, and lack of riparian margins may be causing sediment to enter water after rainfall.

12. Water clarity (measured by black disc) showed similar patterns to most other water quality attributes. Clarity was low in the Stoke streams, the Groom and Sharland sites and very poor in the York, Hillwood,Todds and Lud. Generally, the remaining Mahitahi/Maitai, Wakapuaka and Whangamoa sites had reasonable to good water clarity.

13. Smaller sites are more difficult to monitor for clarity, particularly when flows are low. Results in the Groom and Sharland support recent research undertaken as part of Project Maitai, suggesting they are significant contributors of fine sediment and nutrients to the Mahitahi/Maitai.

4 Ecological Health

Macroinvertebrates

Aquatic macroinvertebrates[1] and periphyton[2] are good indicators of ecological health, known as biological indicators. These organisms integrate water quality conditions within the river environment over time and often provide a better understanding of the effect of multiple stressors and sources of impacted water quality than physico-chemical 'grab' samples. However, physico-chemical results provide important cause and effect linkages between catchment scale impacts and in-stream ecological effects despite the snap-shot nature of spot sampling, as results accumulate over time robust statistical relationships can be determined. Biological indicators and physico-chemical measures of water quality are important components within any freshwater monitoring programme.

The aquatic macroinvertebrates found at a site can be scored according to their sensitivity or tolerance to organic pollution and other stressors. These scores can be calculated into an index (the MCI) and used to indicate differences in water quality and ecological health between sites and over time (Table 1) using standardised methods.

Table 1. Relationship between degradation categories and water quality classes for interpretation of the Macroinvertebrate Community Index (MCI) scores.

Degradation category (Boothroyd & Stark 2000)	Quality class (Stark & Maxted 2007)	MCI score
Clean water	Excellent	> 119
Doubtful quality or possible mild pollution	Good	100-119
Probable moderate pollution	Fair	80-99
Probable severe pollution	Poor	< 80

Figure 4 shows the distribution of MCI scores over the last thirteen years for all monitoring sites in Nelson. Generally, the upper Mahitahi/Maitai, Wakapuaka and Whangamoa Rivers have excellent ecological health according to their MCI scores. The upper reaches of the Poorman Valley, Groom and Brook Streams have good water quality. The Todds, Hillwood, York, Jenkins and Saxton streams have the lowest MCI scores, varying between fair and poor.

[1] Insect larvae and other stream animals such as worms, snails and crustaceans.
[2] Algae growing on the stream bed.

Periphyton

The amount of periphyton cover (algae) affects a number of in-stream water values. Levels of periphyton cover are directly associated with macroinvertebrate community health (Matheson et al. 2012) and recreational, aesthetic and cultural values for freshwater (Biggs 2000). The cover of the stream bed is usually assessed using visual observations of the proportion of cover of different types of periphyton across transects of the river bed. Nelson City Council have made annual visual observations alongside collection of benthic macroinvertebrates from 2002, usually during summer low flows. Ideally, the annual maximum periphyton growth is determined from monthly observations of cover throughout the year. Because periphyton was only assessed annually in Nelson, it is fair to assume that the *actual* maximum cover exceeds the levels reported below in many instances.

The periphyton cover data used for this report should be considered indicative only because of the annual nature of the samples. Recommendations have been implemented to include periphyton biomass sample collection and cover observations on a monthly basis within the SOE monitoring programme (McArthur 2015).

Filamentous periphyton[3] and mat periphyton[4] percentages (Appendix 1) can be combined into a weighted composite cover index to determine effects on ecological condition and aesthetic values (Figure 5). Using this index indicates the Orphanage, Jenkins and Brook at Burn sites have 'poor' ecological condition. The Mahitahi/Maitai at Groom and Brook at Manuka exceeded the threshold indicating 'fair' ecological condition on at least one sampling occasion since 2002. Generally, all other sites sit within the good to excellent categories for ecological condition with very occasional exceedances of the aesthetic and recreational nuisance guidelines of 30% cover. However, Wood et al. (2015) found higher levels of periphyton cover at different sites in the lower Mahitahi/Maitai River, supporting the assumption that the annual maximum cover may not be well represented amongst the current dataset.

Cyanobacteria

Benthic cyanobacteria are potentially toxic organisms that form part of the mat periphyton community in rivers. At times of stable flow, species of these cyanobacteria (commonly *Phormidium autumnale* in New Zealand) can dominate the periphyton mat and proliferate to nuisance levels (MfE/MoH 2009). This type of algal cover has the added risk of potential toxin production. The conditions or factors which trigger the production of toxins in cyanobacteria mats are not well understood at this time, but research focussed in this area is ongoing (Martin, 2016).

The toxins produced by benthic cyanobacteria are particularly harmful to dogs as they contain powerful neurotoxins known as anatoxins, which can cause rapid onset of severe illness and death when ingested. The time of greatest risk is when there are high levels of cyanobacterial cover and algae is sloughing off and/or flows are receding, leaving algal material stranded on river beaches.

[3] Usually strands >2cm in length (Biggs 2000).

[4] Diatom or cyanobacterial growth that cover the bed of the river as a low-growing periphyton 'mat'.

These circumstances make cyanobacteria easily accessible and desirable to dogs and are also a risk to stock and recreational river users, particularly small children.

The visual assessment methods previously used by NCC do not specifically account for mat growth attributable to potentially toxic cyanobacteria. More recent assessments of periphyton have separately noted cyanobacterial cover as part of the visual assessment method; analysis will be needed once more data is collected in this manner. This method of visual assessment assists with monitoring cyanobacteria growth against national guidelines and alert levels as well as looking at the effects of growth on values and against other limits and guidelines.

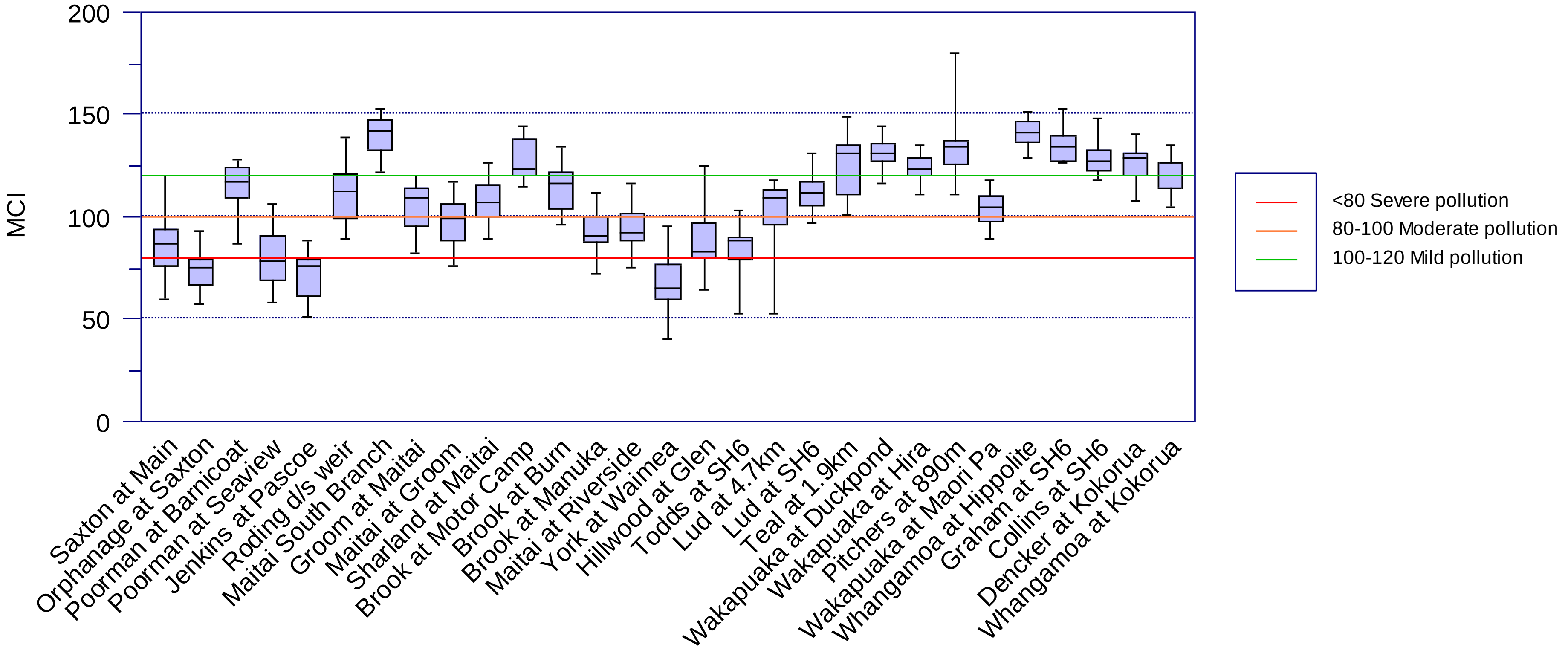


Figure 4. Macroinvertebrate community index (MCI) scores for all monitoring sites in Nelson between 2002 and 2014. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. MCI scores >120 indicate clean water. N = 13 (except for Roding d/s Weir site where N = 16).

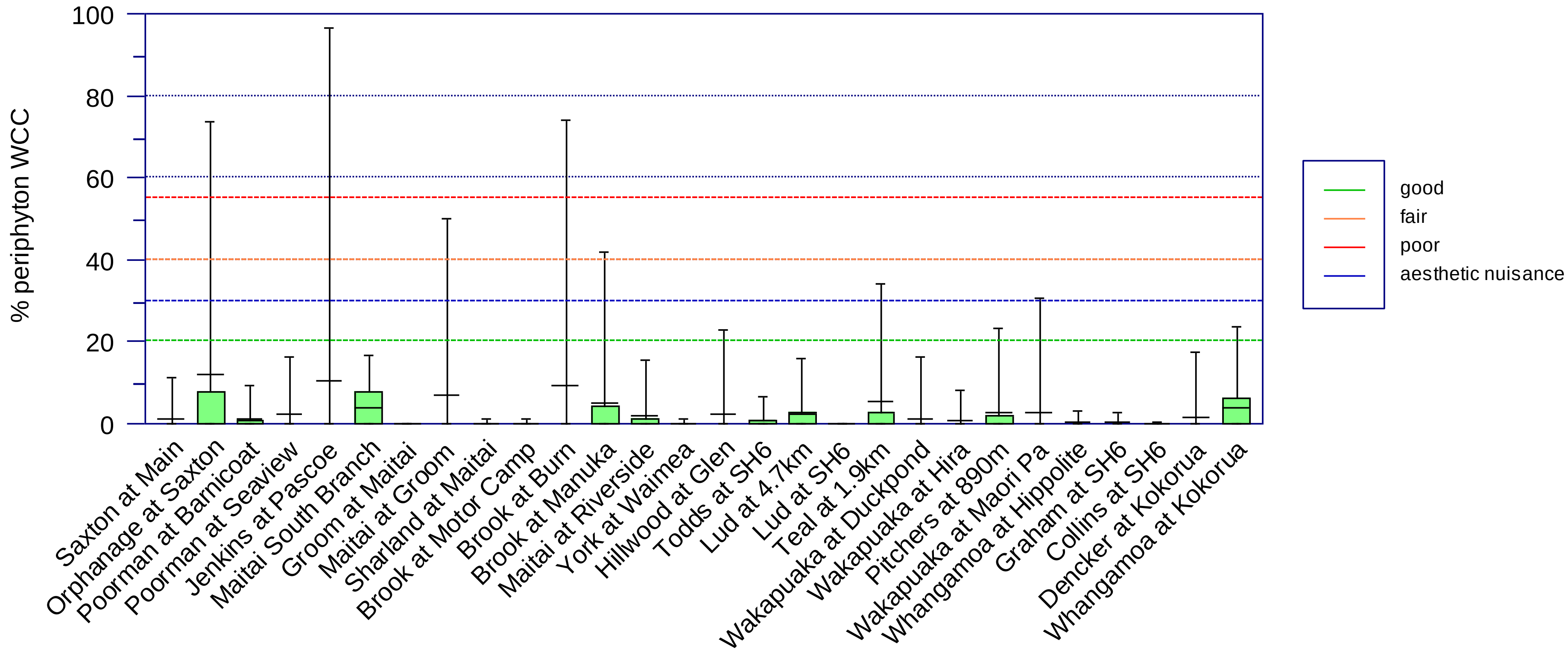


Figure 5. Percent cover by periphyton using a weighted composite cover (WCC) percentage for annual visual assessment observations between 2002 and 2014 at 28 monitoring sites in Nelson. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. 'Good', 'fair' and 'poor' are indicators of ecological condition and <20% cover = 'excellent' ecological condition. N = 13 (except Teal, Pitchers and Whangamoa sites where N = 12).

5 Faecal Contaminants

Faecal contaminants in water bodies pose a risk to food gathering, recreational and tāngata whenua values and uses and for stock and domestic drinking water supplies (depending on treatment). Faecal contaminants in water such as *Cryptosporidium, Salmonella, Giardia* or *Campylobacter*, if ingested, can cause gastro-intestinal illnesses. Many of these illnesses can be very serious and require notification to Public Health Services. Outbreaks or epidemics of these illnesses have historically been associated with water-borne contaminants in New Zealand.

Faecal contaminants originate in the gut of warm-blooded animals and reach freshwater by a variety of mechanisms, including:

1. Direct deposition of faecal matter into waterways by livestock (the impact of cattle directly defecating into waterways is particularly well understood in the New Zealand literature);
2. Over-land flow or run-off of faecal matter from faecal matter in paddocks during rainfall events;
3. Direct (point source) discharge of wastewater containing faecal matter (either human or other animals); and
4. Storage and resuspension of faecal bacteria within the bed of streams and drains, often those with thick layers of fine-grained bed sediment, typically following rainfall/high flow events.

Directly measuring the whole range of potential pathogens in water is difficult, expensive and time consuming, so faecal indicator bacteria are used as 'surrogate' measures to indicate the risk of pathogenic illness from contact with water. *Escherichia coli (E. coli)* have been the indicator of choice for freshwater since the release of the Ministry of Health recreational guidelines in 2002. Prior to this faecal coliforms and Enterococci were used as freshwater indicators.

Results from quarterly SOE monitoring of *E. coli* at all Nelson sites (Figures 6 - 9) shows that a number of sites[5] are within the primary contact limit of 260 E. coli/100ml under base-flow conditions throughout the year, with some sites occasionally sitting between the primary contact limit and the NOF bottom-line for secondary contact[6], including the lower Poorman, some of the Mahitahi/Maitai sites, the Teal, some Wakapuaka sites and the Dencker tributary of the Whangamoa.

Sites where high *E. coli* is a problem under base-flow conditions are: Saxton Creek, Orphanage, Jenkins, York, Hillwood, Todds Valley and Lud Streams. The relationship between flow and faecal load is critical to be able to understand whether a waterway is affected by direct faecal inputs (either through stock access or point-source discharges) or through run-off and overland flow; or both. The historic SOE dataset has made this type of assessment difficult in the past due to the collection of samples only under low flow conditions prior to 2015.

A one-off Microbial Source Tracking (MST) survey was undertaken at identified 'problem' catchments to better understand sources of faecal contaminants in 2011 and analysed by the Cawthron Institute for molecular markers associated with ruminant (cows, sheep, goats etc.), wildfowl, gull and human faecal bacteria (Table 2). Ruminant markers were present at all sites with the exception of the York.

[5] Poorman at Barnicoat, Maitai South Branch, Maitai at Groom, Brook at Motor Camp, Brook at Burn, Wakapuaka at Duckpond, Pitchers at 890m and all sites in the Whangamoa FMU with the exception of the Dencker at Kokorua.

[6] Moderate risk of illness when wading or boating.

Wildfowl markers were also common to all sites except the York and the Frost confluence with the Lud. Gull markers were found only at the Collingwood Street Bridge site on the Mahitahi/Maitai River. All three human markers were present in the York Stream and two were present at Collingwood Street Bridge. These results indicated an urgent need for attention to address the sources of faecal contaminants, particularly in the Mahitahi/Maitai. Despite some suggestion that septic tanks were a potential source of faecal contamination in the Lud, no human markers were found there. It is more likely, given the catchment land use, that the key causes are direct stock access and diffuse run off of ruminant faecal matter, with some wildfowl contribution in places.

Table 2. Microbial Source Tracking (MST) results for selected sites sampled once on 1 March 2011. Results courtesy of Cawthron Institute.

Description	**MST Markers**						
	General	Ruminant	Wildfowl (duck, geese)	Gull	Human		
	GBAC	RBAC	DE2	GCMA	HBAC	HMBS	HPYV
Macs confluence w Lud	+	+	+	-	-	-	-
Frost confluence w Lud	+	+	-	-	-	-	-
Lud at SH6	+	+	+	-	-	-	-
Paremata Flats Reserve	+	+	+	-	-	-	-
Collingwood Bridge	+	+	+	+	+	-	+
Orphanage at Saxton	+	(+)	+	-	-	-	-
York at Waimea	+	-	-	-	+	+	+

N.B. presence [+] or absence [-] of a molecular marker. Results within brackets (…) indicate a weak molecular signal.[7]

The MST results support the association between stream catchments with pastoral land use and elevated *E. coli* levels. The levels of *E. coli* contamination in Saxton Creek are extremely high and require targeted investigation and action. Initial analysis of *E. coli* under high flow conditions is included below, based on recent changes to SOE sampling protocols.

[7] *Temporal and spatial variability in the presence of markers can occur in natural systems. Some cross-reactivity can also occur, where contamination from an organism that the marker is not targeting results in a false-positive (eg the ruminant bacteroides marker has been shown to cross-react with faecal material from brushtail possums). For these reasons, replicate sampling, the use of multiple markers, and an understanding of the surrounding land uses and hydrology of the area can aid in confirming contamination sources.*

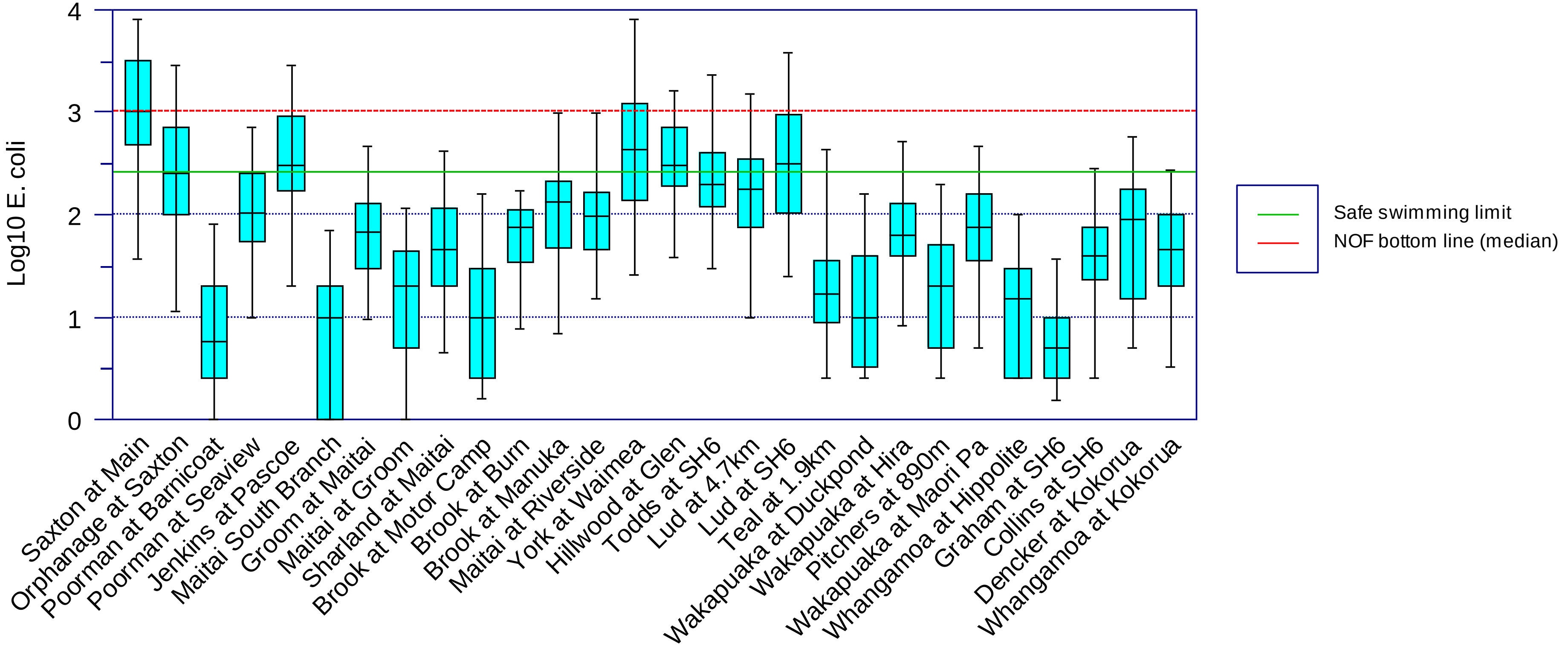


Figure 6. Log$_{10}$ *Escherichia coli (E. coli)* CFU/100ml at all SOE monitoring sites in Nelson, data collected quarterly under base flows between May 2002 and December 2014. Box = 75th and 25th quartiles, mid-point line = median, bars = 5th and 95th data percentiles.

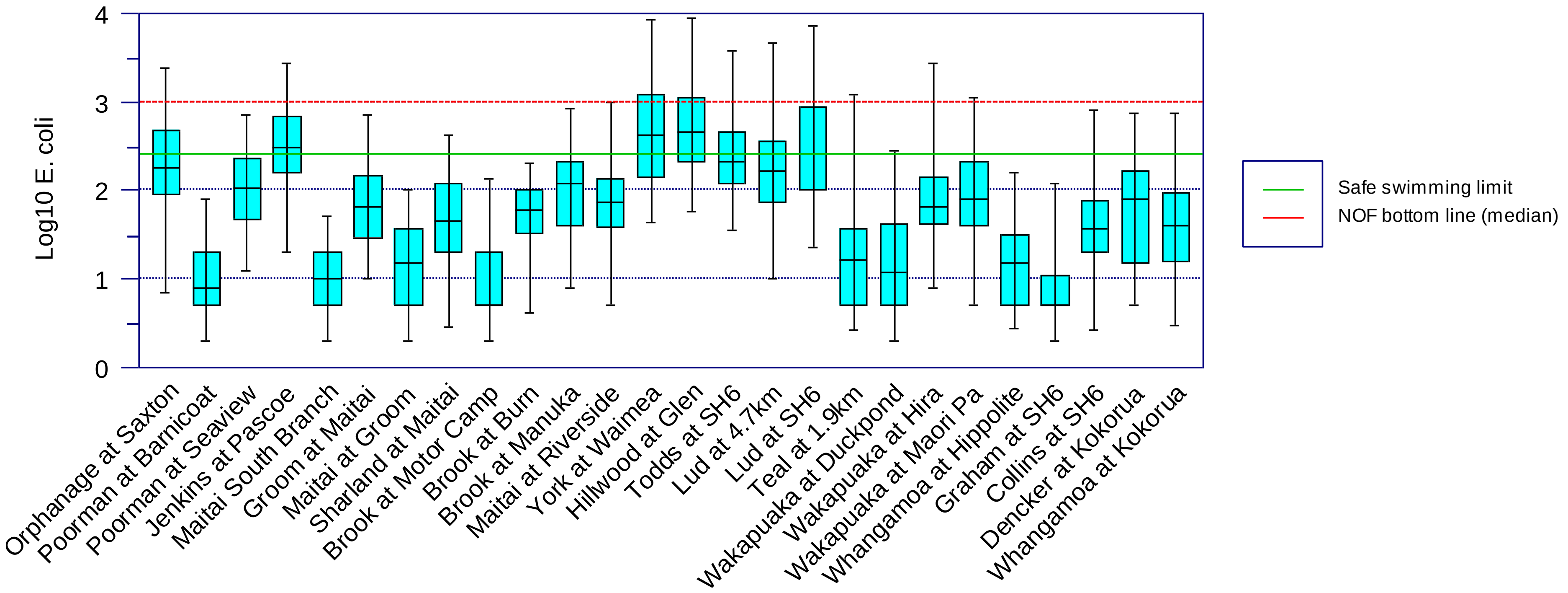


Figure 7. Log_{10} *Escherichia coli (E. coli)* CFU/100ml at SOE monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th and 25th quartiles, mid-point line = median, bars = 5th and 95th data percentiles.

6 *E. coli* with flow

Using the first 18 months of 'all-flows' *E. coli* data has enabled a closer examination of potential causes of contamination at sites where the long-term *E. coli* profile changes with the inclusion of some higher flow samples[8]. Figure 7, when compared with data prior to 2015 (Figure 6), shows some changes in the distribution of *E. coli* data at certain sites when samples were collected under a wider range of flow conditions monthly. Robust statistical analysis is not warranted until a greater number of samples have been collected under these conditions. However, indicative results are apparent from visual inspection of the change in data range.

It is expected that the inclusion of *E. coli* samples collected under higher flow conditions will result in an increase in the upper distribution of the data (e.g. the 95th percentile), given that rainfall and higher flow events provide increased transport mechanisms for faecal contaminants from the land to waterways. Sites where the increase in *E. coli* was significant or where increases resulted in limits/objectives being exceeded by the 95th percentile or the median (where this did not previously occur) are detailed below.

Sites with elevated *E. coli* when high flow data were included were:

- Hillwood at Glen - significant increase in the 95th percentile and median for *E. coli*, highest 95th percentile of all sites in Nelson, although still within the NOF bottom line for secondary contact with respect to the median.
- Lud (both sites) - notable increases in 95th percentile and increase in the median at the State Highway 6 site. Both sites still within the NOF bottom line for secondary contact.
- Teal - notable increase in 95th percentile, although NOF bottom line for secondary contact still met by median.
- Wakapuaka at Hira - notable increase in 95th percentile, although NOF bottom line for secondary contact still met by median.
- Wakapuaka at Māori Pā - notable increase in 95th percentile, although NOF bottom line for secondary contact still met by median.
- Collins at SH6 - 95th percentile now exceeds safe to swim guideline.
- Whangamoa at Kokorua - 95th percentile now exceeds safe to swim guideline.

Sites with significant increases in *E. coli* are examined more closely across three flow categories below.

6.1 Flow category method

The method for determining the flow categories was to:

I. Calculate or estimate flow percentiles for each SOE site from available flow information or correlations (Appendix 2; flow sites for calculation or estimation of percentiles);
II. Paired flow was recorded or estimated at the time of water quality sampling;
III. Flow observations were assigned site-specific percentiles and low, moderate and high flow categories were assigned to each water quality observation based on percentile ranges as

[8] Saxton Creek and Pitchers monitoring sites are not included as monitoring was discontinued by NCC in 2015.

follows: Low = 70-100th flow percentiles, Moderate = 30th-70th flow percentiles and High = 0-30th flow percentiles.

Flow categories were used to assess the more recently collected SOE data against river flow across faecal and nutrient parameters. The purpose of assessing water quality data in this way is to be able to discern any changes in concentrations of faecal contaminants of nutrients at either low or high flows. Elevated concentrations at high flows can indicate over-land run-off of sediment, nutrients or faecal matter into rivers and streams, from diffuse sources. Concentrations that are elevated at low flows usually indicates direct or point source inputs. Direct inputs of faecal contaminants at low flows can occur from stock access to water and direct defecation, as opposed to point sources, which usually enter rivers and streams via pipes or infrastructure networks.

7 Human Health for Recreation

Figure 8 shows results of the bathing beaches monitoring programme which collects samples for *E. coli* from six popular swimming sites, weekly throughout the summer bathing period (1 December – 31 March). This more regular monitoring shows that even in the Mahitahi/Maitai sites there are occasionally very high faecal bacteria results during summer; the Collingwood Bridge site is significantly elevated above the others.

Targeted investigations as part of NCC's Project Mahitahi/Maitai have looked into the causes of alert level *E. coli* results at the Collingwood Street site. The investigations over the 2015/2016 year have yielded evidence that although faecal contamination at this site is not always from human sources[9], there is contamination via the stormwater and sewage network as a result of aging earthenware and brick and mortar infrastructure. Identification of 'hot spot' areas within the network and remedial work are ongoing with the objective of Project Maitai/Mahitahi in this area being "The Collingwood St Bridge swimming hole reliably meets recreational bathing guidelines, and the community can safely swim there."

Coastal bathing beach monitoring uses enterococci as the faecal indicator bacteria. Results for the summer monitoring programme collected since 2002 show coastal faecal contaminants are highest at the Haven at Atawhai site and lowest at Tahunanui Beach (Figure 9). More work looking at water quality and ecological issues in the coastal environment forms part of a separate project to support the Nelson Plan development.

[9] Ruminant (excluding sheep), wildfowl, dog, possum and human molecular markers were identified although human markers associated with high concentrations of human faecal matter were absent.

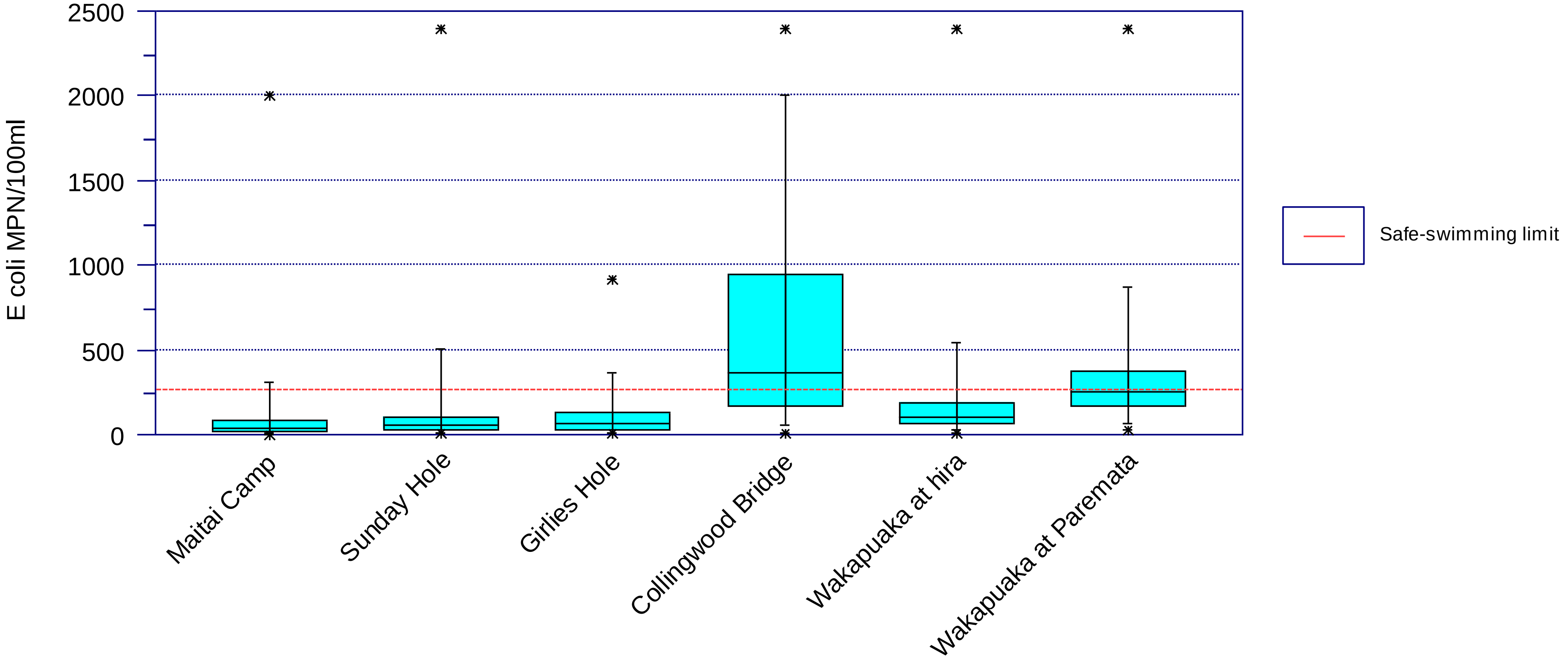


Figure 8. *Escherichia coli (E. coli)* (MPN)/100ml for freshwater recreational bathing sites in Nelson, collected weekly from December until April between 1998 and 2015. Box = 75th and 25th quartiles, mid-point line = median, bars = 5th and 95th data percentiles, asterisks = min and max.

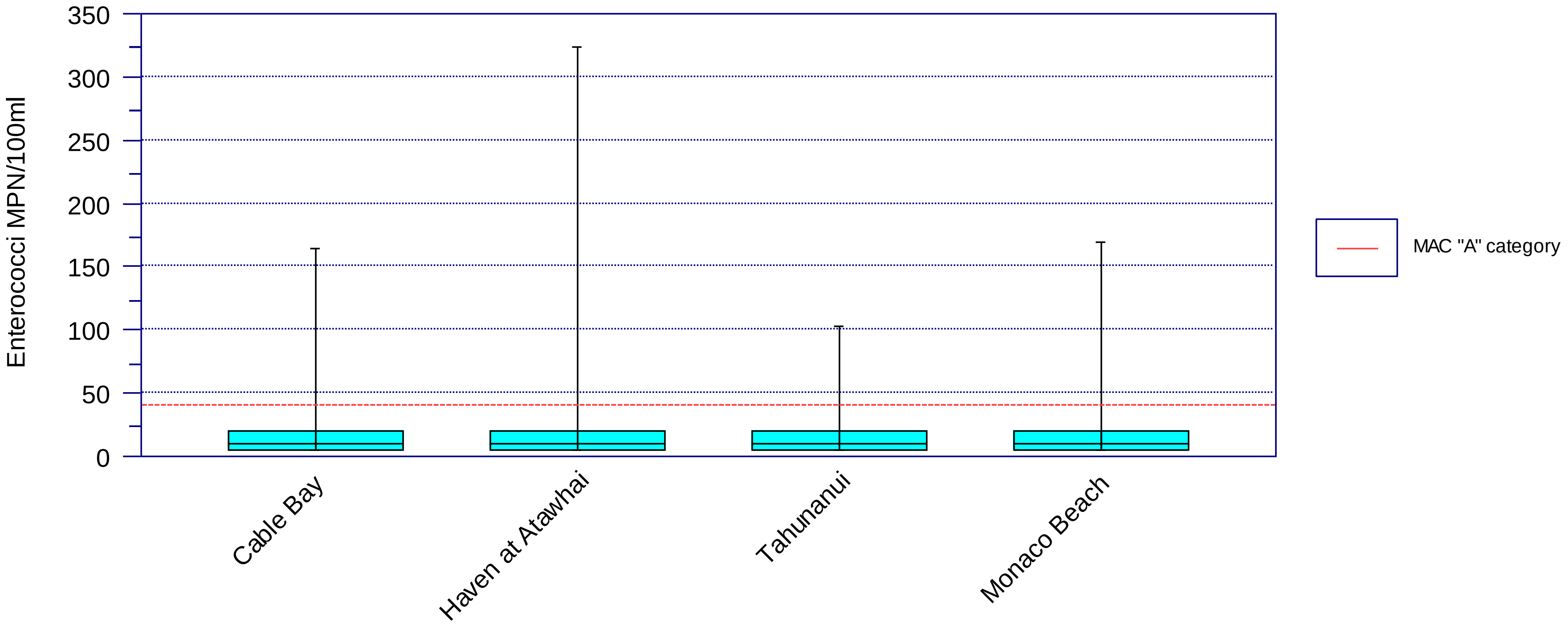


Figure 9. Enterococci (MPN)/100ml for marine recreational bathing sites in Nelson, collected weekly from December until April between 1998 and 2015. Box = 75th and 25th quartiles, mid-point line = median, bars = 5th and 95th data percentiles. MAC "A" category = Microbiological Assessment Category for 95th percentile.

8 Nutrients

The key nutrients of concern in freshwater systems are nitrogen and phosphorus. These nutrients stimulate plant growth and in aquatic systems they also have a 'fertilising' effect on aquatic weeds and periphyton (algae). Contaminants to water are often discussed as 'diffuse' (or non-point sourced) or point sourced. Diffuse nutrients enter waterways cumulatively via landscape scale inputs either through run-off/overland flow or via leaching through the soil profile into subsurface and groundwater flows. Diffuse nutrients emanate from the varying land use within a catchment and generally require a 'whole of catchment' approach to manage the effects. Diffuse nutrients are not just associated with pastoral or forested landscapes and can be sourced from urban areas, entering waterways via run-off. Urban stormwater can be both a diffuse and point-source impact from stormwater network discharge points.

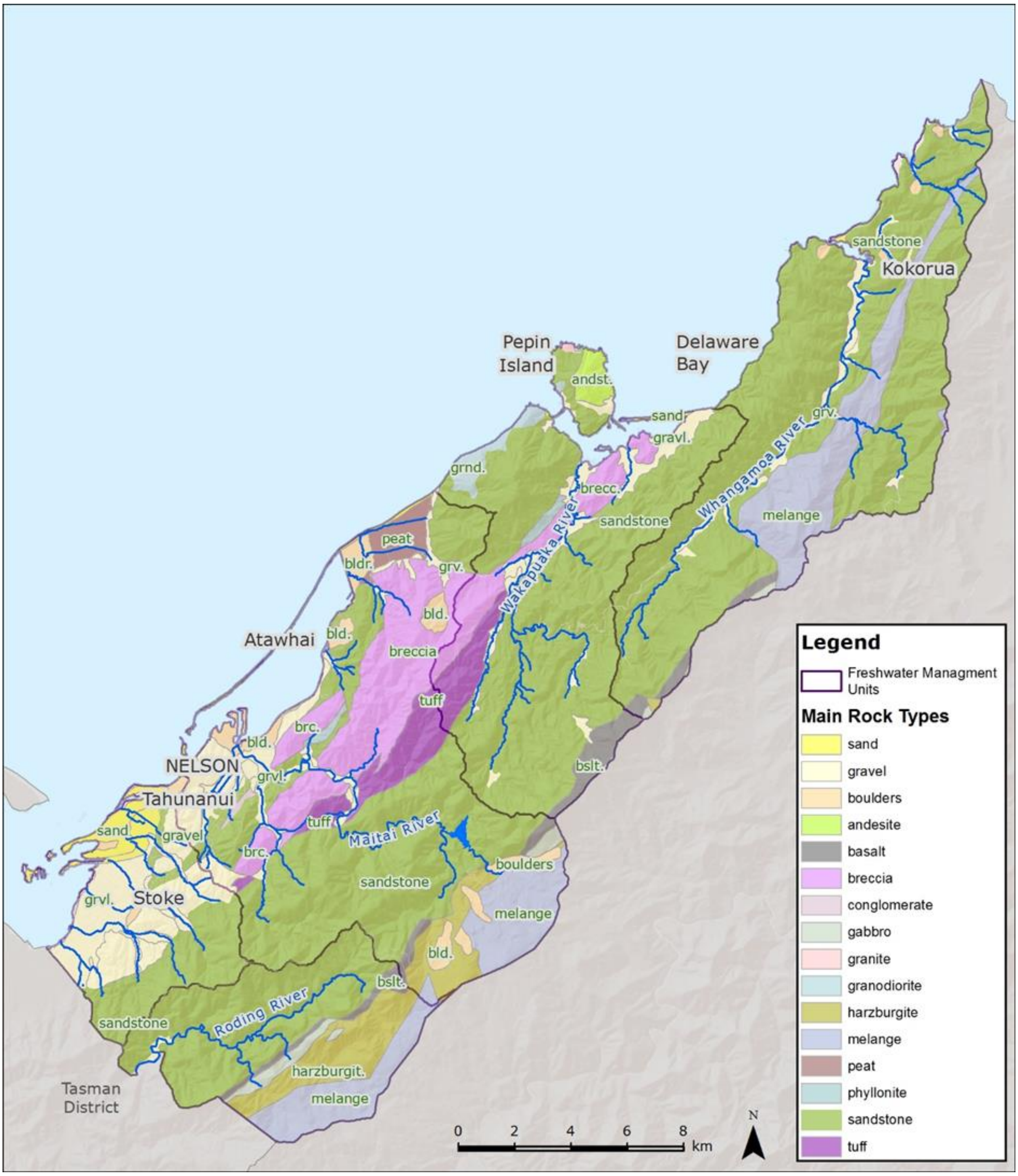
Point sources are direct discharges of waste to water, often via pipes. The discharge point is known and loads and concentrations of contaminants and their sources are easier to identify and theoretically simpler to manage through resource consents and discharge permits. Despite this, point-sources still comprise a measurable proportion of contaminants discharged to many rivers and streams throughout New Zealand and continue to contribute to the degradation of the quality of freshwater.

There are six main sources of nutrients entering freshwater, including:

I. Natural sources from catchment soil and rock type/geology (i.e. elevated phosphorus concentrations are common in many catchments with volcanic or soft-sedimentary deposits and through rock weathering processes; Map 2) phosphorus enrichment of water is exacerbated by accelerated erosion (see below);
II. Erosion or bank instability causing high sediment and phosphorus loads following rainfall;
III. Break-down of organic matter from indigenous or exotic forest (breakdown rates and loads of nutrients differ between natural indigenous forests and exotic systems, where some enrichment of waterways can occur from deposition of slash or root breakdown following production forest harvest);
IV. Catchment run-off and leaching from horticultural fertiliser or pastoral land use from animal excrement and/or fertiliser – these are diffuse sources;
V. Direct inputs to streams from animal dung (high in phosphorus) and urine (high in nitrogen); and
VI. Point source discharges of stormwater, sewage, dairyshed effluent, or industrial wastewater discharges (e.g. food processing, brewing, milk powder production, tanneries, pulp-mills or meatworks).

Phosphorus is often present in sediment in a number of different chemical forms. Those different forms are often loosely bound to sediment and are readily bioavailable for aquatic weed and periphyton growth. Management of fine sediment is critical to managing the pathways for phosphorus input to rivers and streams.

Pathways for diffuse inputs of nitrogen are more difficult to manage. Nitrogen is highly soluble and travels easily with water through the soil if it is not taken up by plants in the root zone. Moderate to high concentrations of nitrogen contribute (along with phosphorus) to the growth of aquatic weeds and periphyton that can degrade ecosystem health. Bioavailable nitrogen, along with fine sediments



Map 2. Main rock types in Nelson river and stream catchments.

are thought to be contributing factors to cyanobacteria blooms in the lower Mahitahi/Maitai River. At very high concentrations nitrogen can be directly toxic to aquatic life and can cause human health concerns if highly elevated in domestic drinking water supplies.

Nitrogen has two potential mechanisms of effect on aquatic communities: 1) a direct effect through nitrate toxicity and 2) an indirect effect through the stimulation of periphyton growth. The figures below show concentrations of two soluble forms of nitrogen that are assessed for each of these effects (Figures 10-15). The concentration of nitrate-nitrogen (Figures 10 and 11) is used to determine the potential for toxic effects on aquatic life[10]. The waterways of Nelson City have a large diversity of sensitive native fish species, many of which are at-risk or threatened nationally (Appendix 3). Given the two pathways of effect and the NPS-FM requirement to maintain or improve, this reports interprets measured nitrate values against the A-band for median toxicity[11] from the National Objectives Framework (NOF), consistent with the conservation value of the fish community[12].

All sites in Nelson are within the 'A' band median for nitrate toxicity. Most sites also meet the 95th percentile threshold of the nitrate-nitrogen 'A' band, although Saxton Creek, Orphanage, Jenkins, Groom, Sharland and York streams all exceed this level. In comparing the quarterly base-flow monitoring with the data including the last 18 months of monthly 'all-flows' data collection there are only minor changes in the distribution of nitrate-nitrogen:

- Groom at Maitai - reduction in the upper distribution of data;
- Sharland at Maitai - slight reduction in upper and middle of distribution;
- York at Waimea - reduction in upper distribution of data; and
- Lud at 4.7km - slight reduction in upper distribution.

These changes may indicate nitrate dilution effects are occurring at higher flows, meaning nitrate sources are more connected to water under to base-flow conditions. However, more data is needed to test this statistically.

Ammoniacal nitrogen is also toxic to aquatic life and included in the NOF. Results presented here are not pH or temperature adjusted[13] however, they are indicative of the potential for a site to exceed the 'A' band attribute states (median and maximum). Figures 12 and 13 show very little change in the distribution of ammonia data with increased sampling frequency and flow variability. The Maitai at South Branch, Brook at Burn and Teal sites all show slight increases in the upper ammonia distribution. Only the Saxton Creek site exceeds both the median and maximum ammonia-N attribute states in the NOF 'A' band. Jenkins, York, Hillwood, Todds Valley, Teal, Whangamoa at Hippolite and Kokorua exceed the maximum for the 'A' band, with the York, Hillwood, Todds and Lud exceeding the maximum significantly. When the removed outliers are considered the York and Lud are also likely to exceed the national bottom line in 2008 and the 'B' band in 2007 respectively.

[10] The NOF bottom line for nitrate toxicity is considered by many to be extremely 'permissive' as it allows for "growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects."

[11] "High conservation value system. Unlikely to be effects even on sensitive species."

[12] The NOF 'A' band attribute state is to support "High conservation value systems. Unlikely to be effects even on sensitive species."

[13] The NOF ammonia toxicity attribute requires a pH and temperature adjustment to assess potential for toxicity.

Nitrate and ammonia toxicity are only one effect of elevated nitrogen concentrations. Indirect effects on ecosystem health also occur as a result of nitrogen stimulation of nuisance aquatic weed and periphyton growth. Figures 14 and 15 show the soluble inorganic nitrogen (SIN) concentrations for all sites. Soluble inorganic nitrogen is the combined bioavailable nitrate, nitrite and ammoniacal forms of nitrogen that can all be utilised by plants or periphyton to increase growth. The 'lowland' ANZECC guideline (0.444 mg/l when ammonia and nitrate-nitrite nitrogen are considered together) is used here as a benchmark, against which measured SIN concentrations are compared. This default trigger has been applied in the Horizons and Otago Regions as the most permissive limit/target for SIN in rivers and streams. The annual average (midpoint or mean line on the boxes) is compared with the ANZECC default trigger guideline. Using the 2002 to December 2014 dataset the Saxton, Orphanage, Groom, Sharland, York and the lower Lud sites exceed this guideline and may be at risk of nuisance periphyton growth if the substrate, phosphorus and flow conditions are also suitable.

For upper catchment sites a tighter guideline should be considered. Once the more recent data are added the lower Lud sits right on the guideline. When flow is considered there are reductions in the upper distribution of the data in the York, and to a lesser extent the Jenkins. This indicates that higher concentrations may be occurring at low to moderate flows and thus inputs may be more direct or point sourced rather than via diffuse run-off. The upper distribution of SIN at the Groom at Maitai site increases with the addition of higher flow data, this indicates an increase in the proportion of diffuse inputs leached through the soil profile and into water that are driven by rainfall. However, it is important to keep in mind that there are few data points collected at higher flows and these results are indicative only.

Stable isotope analysis of nitrate and water was undertaken for eight sites in the Poorman, Sharland and Lud catchments in 2011. The findings of that analysis were typical of nitrogen sourced from forestry and pastoral inputs in most cases, with the exception of the lower Poorman Stream, which indicated leaking sewage or marine inputs as the most likely sources of nitrate at that site. It is unclear whether any network testing has been undertaken to confirm this. The Sharland Stream samples were sourced solely from forestry inputs, although it is unclear from the report whether these are exotic or indigenous inputs or whether these sources can even be separated by isotope analysis.

The form of phosphorus most readily available for the growth of plants and periphyton in rivers and streams is dissolved reactive phosphorus (DRP). The 'lowland' ANZECC guideline for DRP is generally considered fit for purpose to manage the risk of nuisance growth in rivers and streams. This trigger value has been used as a limit/target in the Horizons, Hawkes Bay, and Otago Regional Plans. Like the SIN guideline, it is the annual average of the data that is compared with the guideline as the average nutrient concentration has been more closely correlated to periphyton growth (Biggs 2000).

All the Stoke FMU sites are well above the ANZECC DRP guideline (Figure 16), including the upper catchment Poorman site, which suggests inputs there are either natural from the catchment geology or diffuse inputs entering water with erosion and sediment inputs. The Mahitahi/Maitai mainstem sites are generally lower in DRP apart from the Brook Stream, which is highly elevated, particularly in the upper catchment. York, Hillwood, Todds and Lud are also elevated in DRP with the Todds showing the highest levels in Nelson. The Pitchers at 890m site on the Wakapuaka is also elevated, although generally the Wakapuaka and Whangamoa catchments have low DRP concentrations and geology may be a relevant consideration here too. This reference site was discontinued in 2015.

A comparison of the entire dataset with the 2002 to December 2014 data (which only covers baseflow conditions) (Figure 17) shows that the mean value for the Groom at Maitai site decreased to within the guideline and the upper distributions of the DRP data have increased slightly in the Sharland, Hillwood, Wakapuaka at Hira and Wakapuaka at Māori Pā Road sites. The changes in DRP concentration by flow category have not been assessed as no sites show any significant change from 2002 to 2014 data. Further assessment of flow and phosphorus concentrations are recommended once a further two years' worth of monthly samples have been collected.

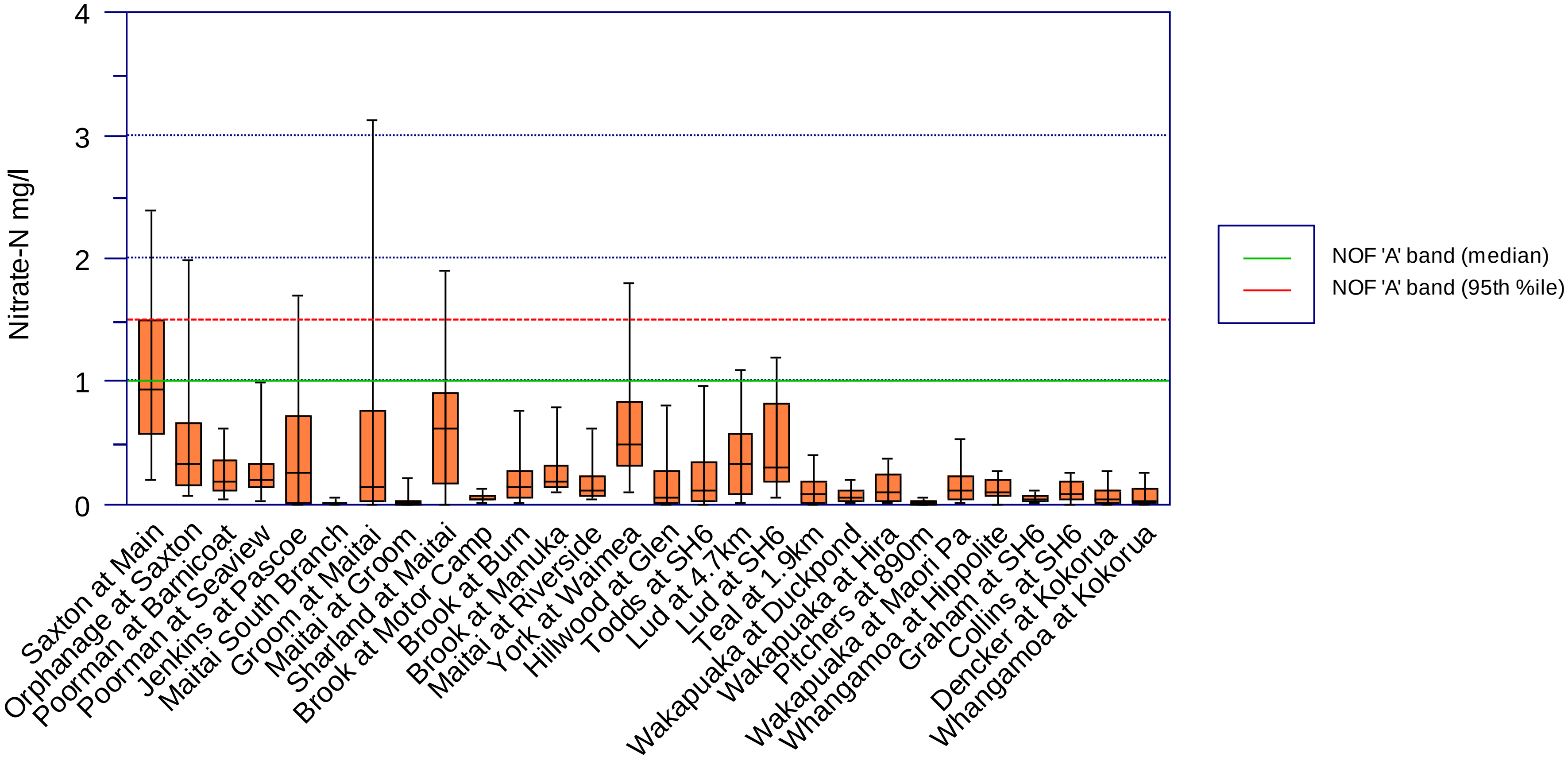


Figure 10. Nitrate-nitrogen concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and Dec 2014. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = median.

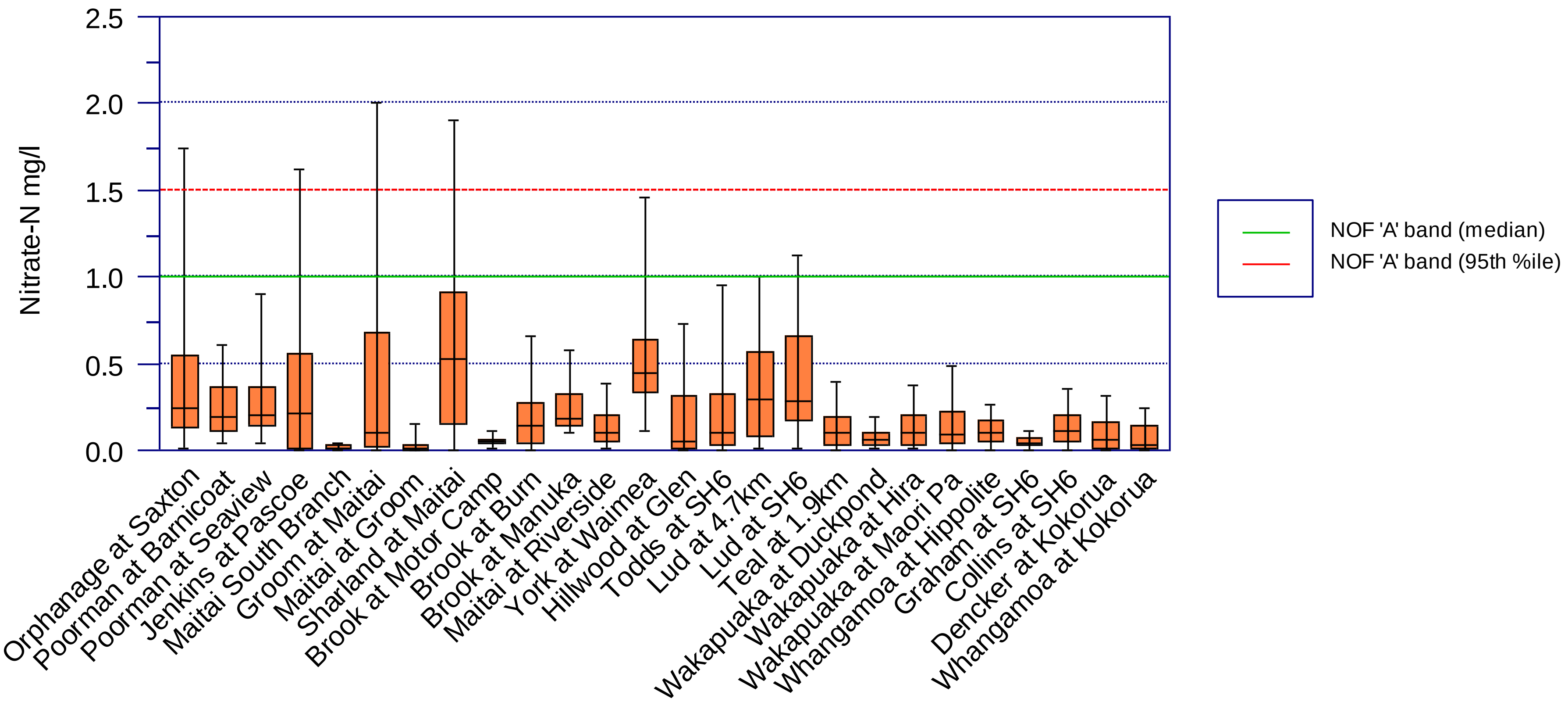


Figure 11. Nitrate-nitrogen concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = median.

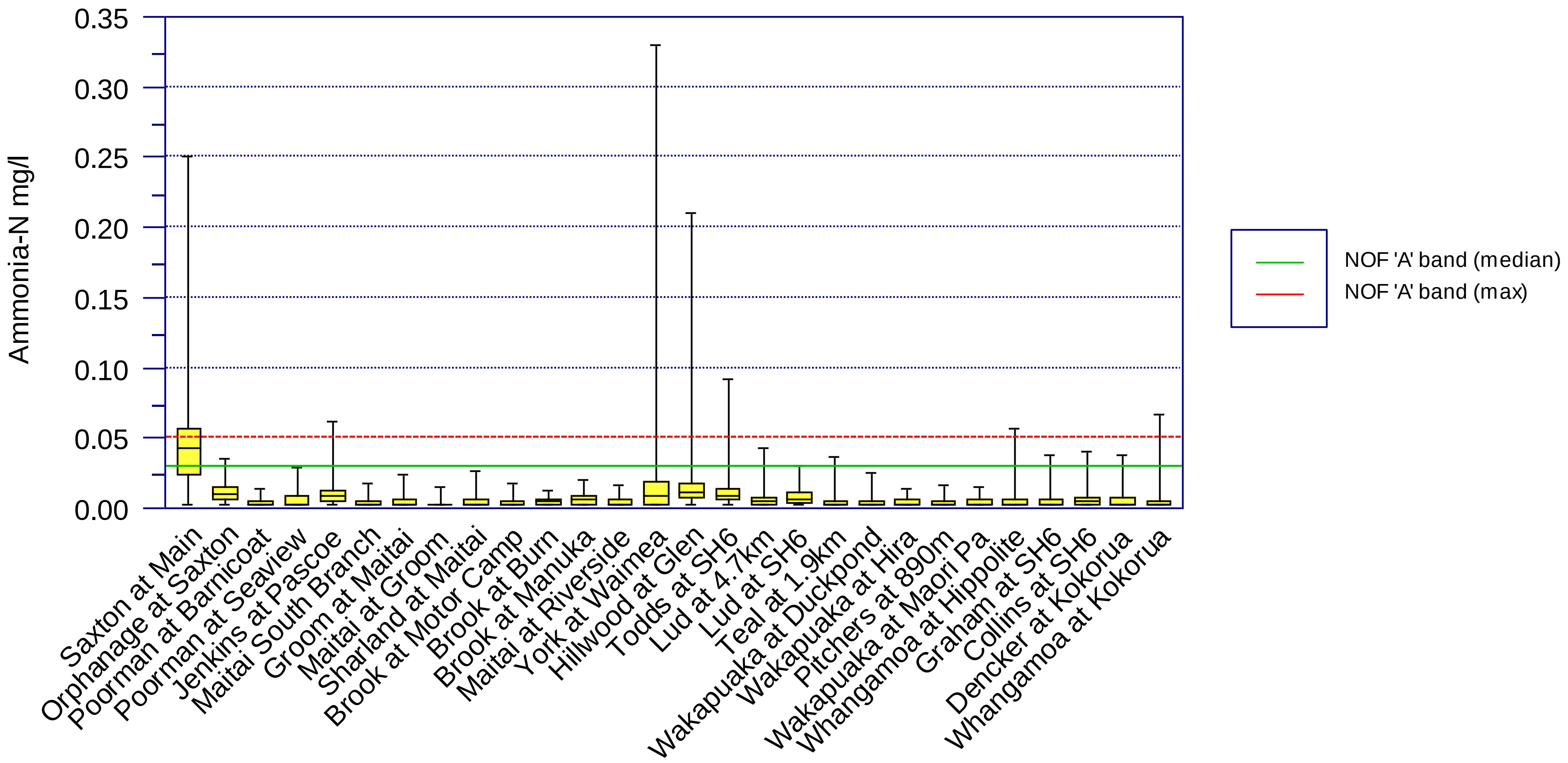


Figure 12. Ammoniacal-nitrogen (NH4) concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and December 2014. Box = 75th - 25th quartiles, bars = min and max, mid-point line = median. Outliers removed: York at Waimea 11mg/l, 28/05/2008; Lud at 4.7km 0.76mg/l, 18/09/2007.

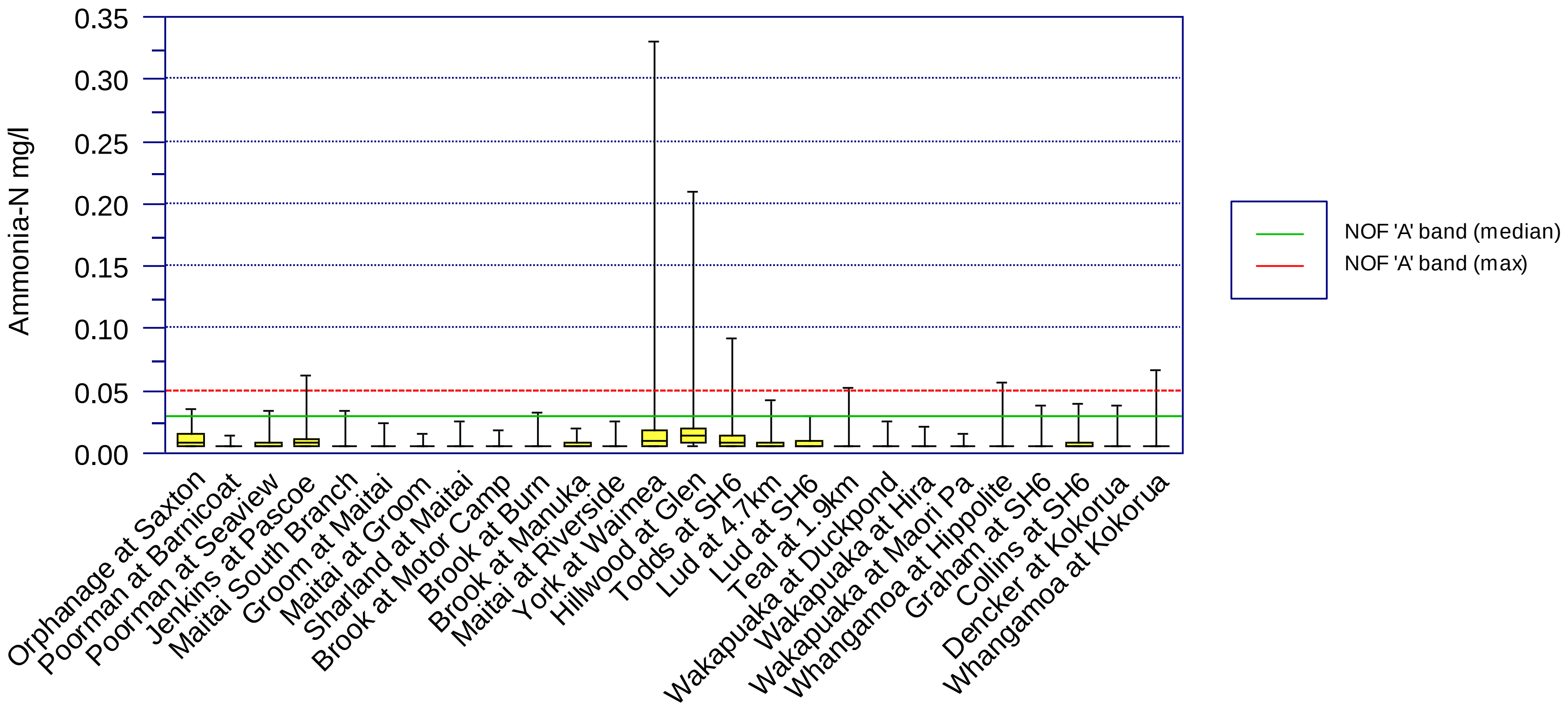


Figure 13. Ammoniacal-nitrogen (NH4) concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th - 25th quartiles, bars = min and max, mid-point line = median. Outliers removed: York at Waimea 11mg/l, 28/05/2008; Lud at 4.7km 0.76mg/l, 18/09/2007.

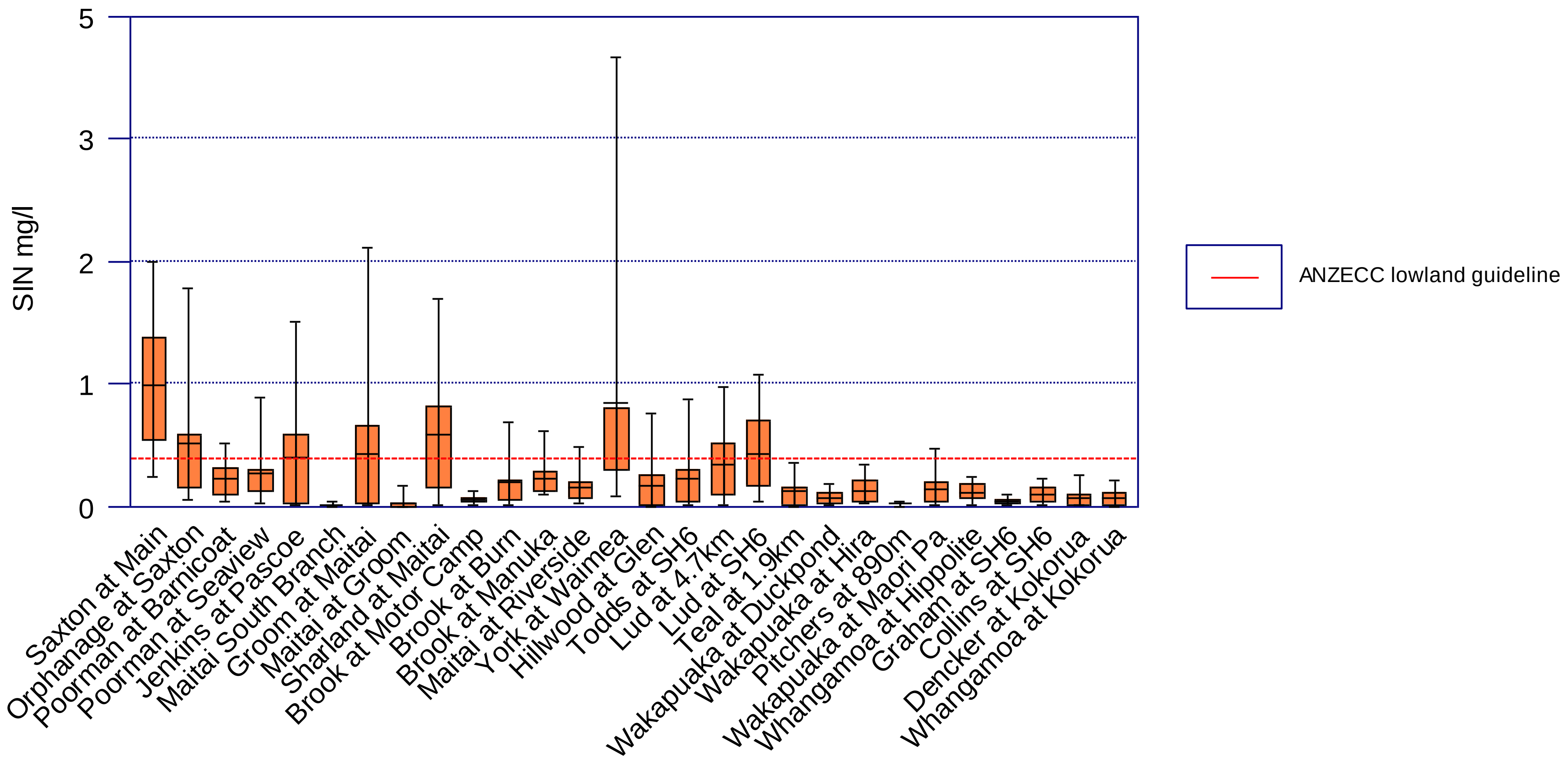


Figure 14. Soluble inorganic nitrogen (SIN) concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and December 2014. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = mean.

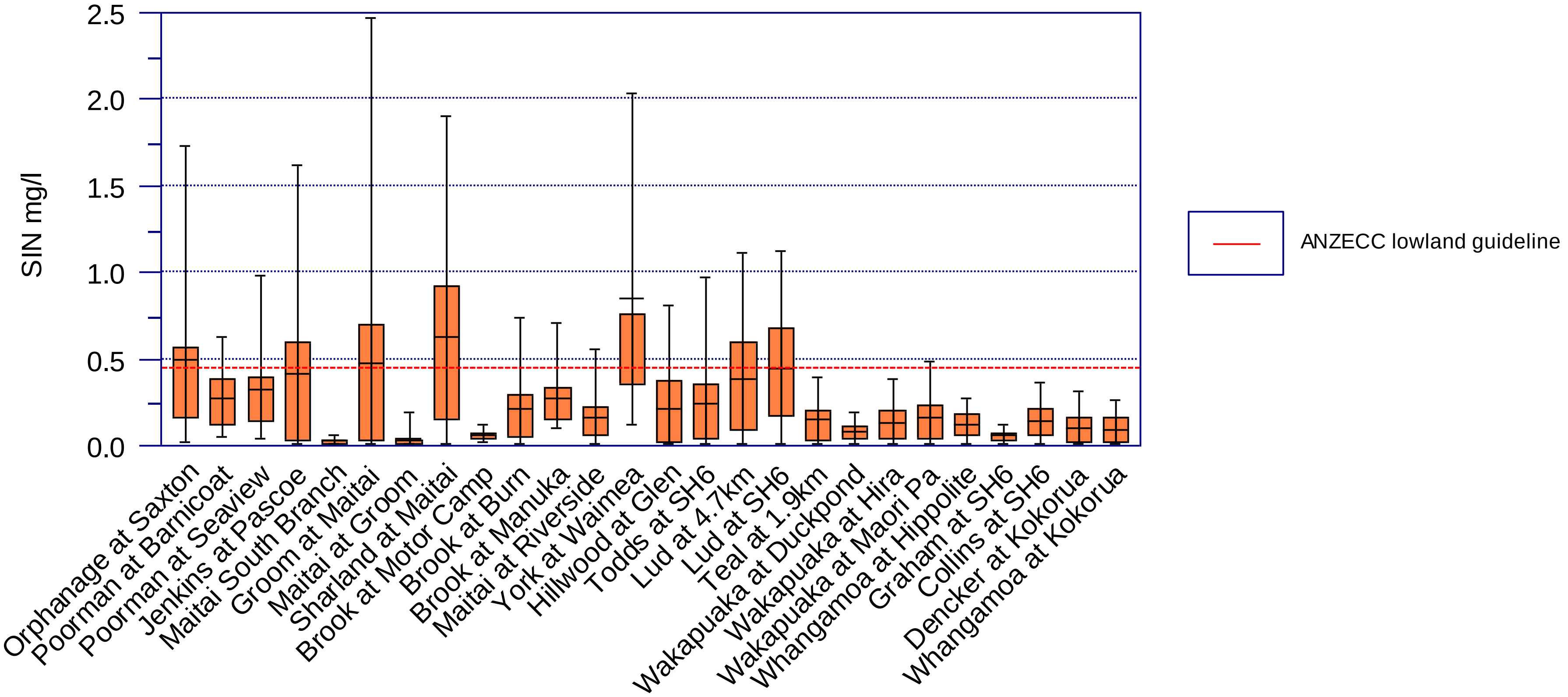


Figure 15. Soluble inorganic nitrogen (SIN) concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = mean.

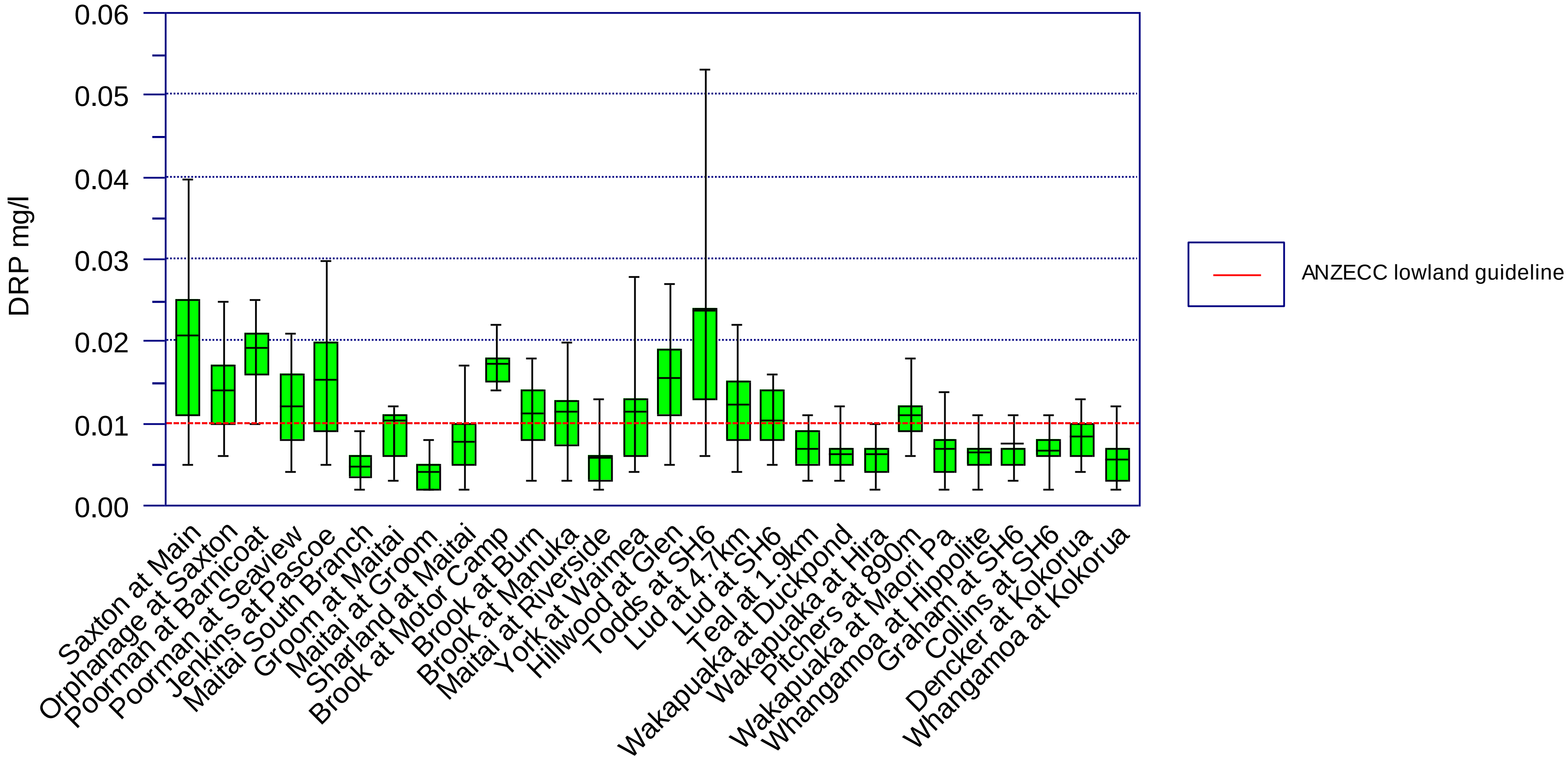


Figure 16. Dissolved reactive phosphorus (DRP) concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and December 2014. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = mean.

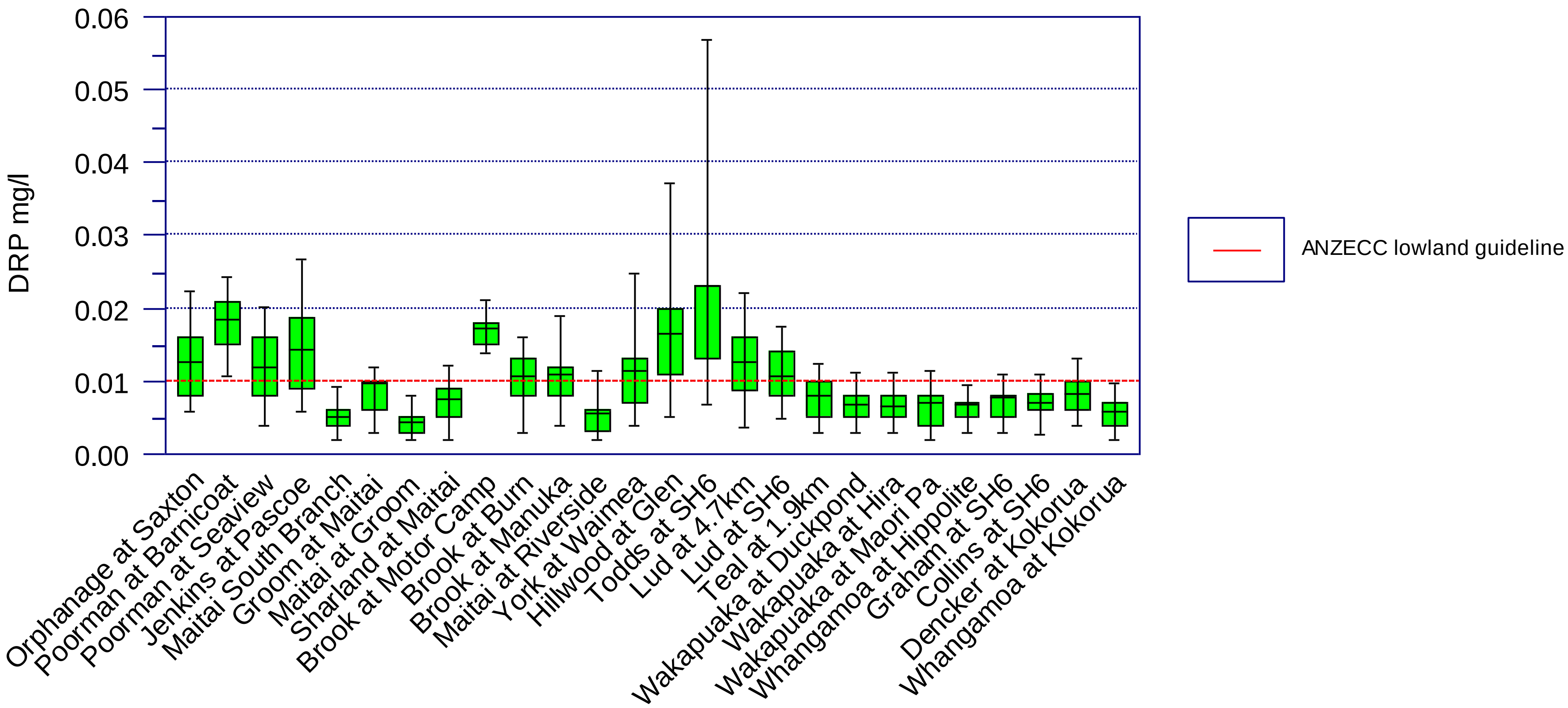


Figure 17. Dissolved reactive phosphorus (DRP) concentration for all monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = mean.

9 Sediment

Sediment is most often a diffuse sourced contaminant of freshwater, often carrying with it other contaminants such as phosphorus and faecal bacteria. Where fine sediment levels are high, other parameters are often elevated too and may in combination contribute to poor recreational water quality and increased aquatic weed growth.

Land disturbance activities can accelerate the delivery of sediment to waterways and cumulatively reduce the particle size of bed sediment over time (Clapcott et al. 2011). Discharges of sediment from construction, erosion and flood control works and horticultural cultivation can also contribute to elevated suspended and deposited sediment, depending on the scale, intensity and duration of the activities. Soft sedimentary catchment geology can mean some catchments are more susceptible than others to from the effects of soil erosion. Sediment can affect aquatic ecosystems, streams and estuaries/harbours.

Sedimentation generally worsens downstream as tributary inflows contribute sediment loads and it is often associated with high relative proportions of pastoral development, cultivation, earthworks or production forestry activities in a catchment. Suspended and deposited sediments are known to cause significant habitat change. In combination with vegetation encroachment, deposited sediment can cause loss of stream width in rural streams (Davies-Colley 1997) resulting in a shift from a gravel bed to a soft-bottomed stream. This type of habitat change will have highly detrimental effects on aquatic macroinvertebrates and fish, and reduce water quality, i.e. through lowered dissolved oxygen and/or increased water temperature.

Suspended sediment can directly smother the feeding and gill structures of invertebrates and gills of fish and is known to reduce fish diversity (Richardson and Jowett 2002), cause avoidance behaviour in a number of native species, including juvenile banded kōkopu (Rowe et al. 2000; Richardson et al. 2001), reduce the ability of fish to feed (Rowe and Dean 1998), and disrupt the natural primary productivity base of the food chain in both freshwater and estuarine ecosystems (Rafaelli et al. 1998).

Deposited sediment directly affects aquatic life by increasing invertebrate drift out of affected habitat (Suren and Jowett 2001); reduces interstitial space, spawning habitat and refugia for aquatic invertebrates and fish (Clapcott et al. 2011); enables the establishment of aquatic weeds, alters bed habitat and can create anoxic conditions. In severe cases, estuarine sedimentation contributes to anoxia and mortality of estuarine fauna (Robertson and Stevens 2007, 2011).

Total suspended sediment and turbidity results shown in Figures 18 and 20 were collected under base-flow conditions and relationships between the catchment land use, rainfall, flow and sediment can be obscured by the lack of observations over a range of flows. Saxton Creek, Orphanage, Jenkins, Groom, Sharland, York, Hillwood, Todds and Lud Streams are all significantly elevated in suspended sediment when compared with other sites in Nelson. The median value for the Saxton Creek is substantially higher than all other sites. Data on deposited sediment has begun to be collected recently, alongside other changes to the SOE programme. In future, the management of sedimentation can be informed by this data.

The inclusion of samples collected monthly over all flows was expected to cause generally elevated total suspended sediment (TSS) and turbidity values. This is apparent in the difference in the distribution of TSS and turbidity data (Figures 19 and 21) at the upper Poorman, Teal, Collins, Wakapuaka, Graham and Whangamoa sites which all showed small increases with the inclusion of data collected at elevated flows. Hillwood, Todds and to a lesser degree the Lud had significant increases in maximum turbidity measures. A similar pattern was seen for TSS results, the most substantial increase in maximum TSS occurring in Todds Valley Stream, indicating diffuse sediment issues under high rainfall.

Water clarity is commonly measured through horizontal sighting of a black disc through the water. Clarity can also be affected by sedimentation and is a useful measure of the effect in the water column. Reduced clarity can be an issue for recreational safety (not being able to see through the water when swimming, boating or fishing), aesthetic and amenity values and as a direct measure of the ability of fish to be able to sight feed on drifting invertebrates and other fish in the water column. Black disc results, using the most recent data, are presented in Figure 22.

The Stoke streams show low water clarity (but may also be affected by the difficulties of sampling in small streams, particularly in low flows. The Mahitahi/Maitai at South Branch has the highest measured water clarity; it is likely the Roding is also high but this cannot be confirmed without measured data. The Sharland and Groom are both low, which corresponds to the increase in fine sediment from forestry and other activities in these catchments. The Brook has good clarity in upstream sites but declines at lower catchment sites. York, Todds, and Lud are low with the Hillwood showing the lowest water clarity in Nelson. The Teal, Wakapuaka and Whangamoa are generally high with the Collins, Dencker and Kokorua sites slightly lower.

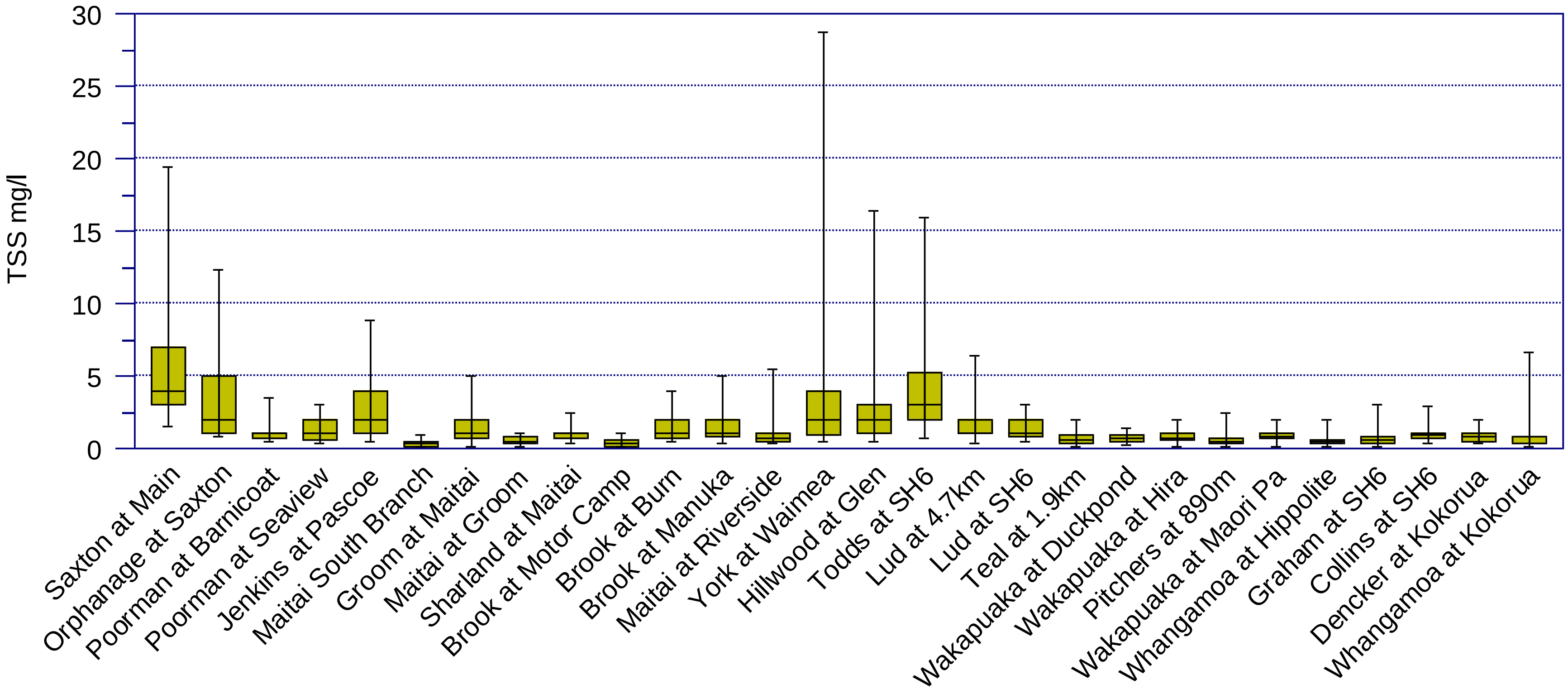


Figure 18. Total suspended sediment (TSS) concentrations for all monitoring sites in Nelson collected quarterly under base-flow conditions between 2002 and December 2014. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = median.

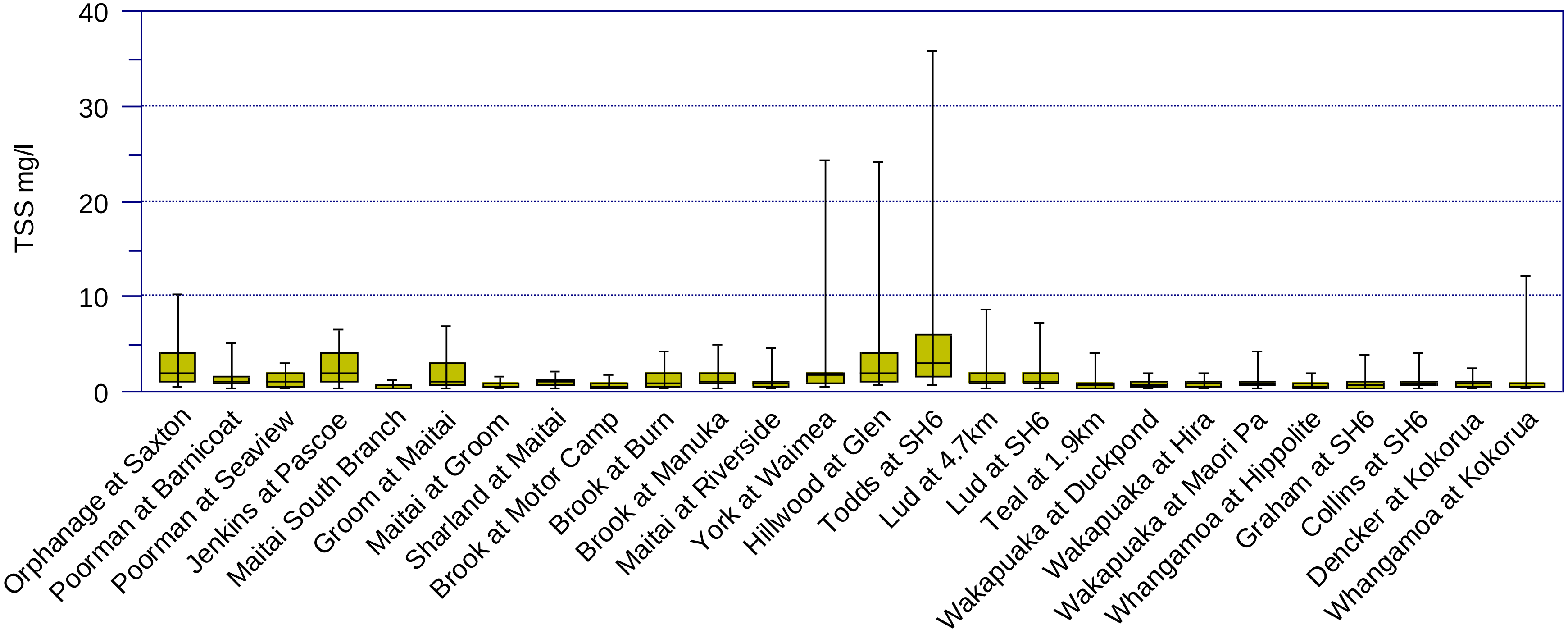


Figure 19. Total suspended sediment (TSS) concentrations for all monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows from 2015 to July 2016. Box = 75th - 25th quartiles, bars = 5th and 95th data percentiles, mid-point line = median.

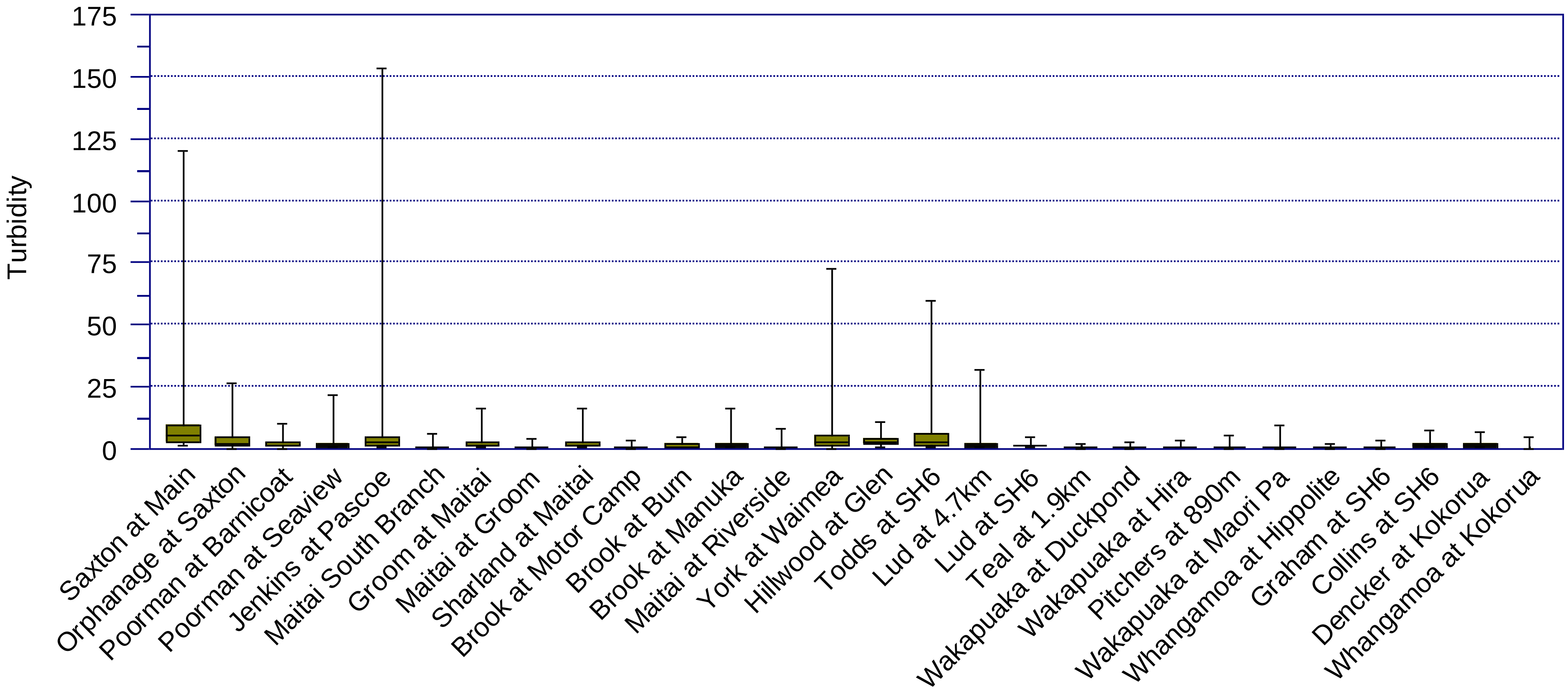


Figure 20. Turbidity (NTU) for all monitoring sites in Nelson collected quarterly under base-flow conditions between 2002 and December 2014. Box = 75th - 25th quartiles, bars = min and max, mid-point line = median.

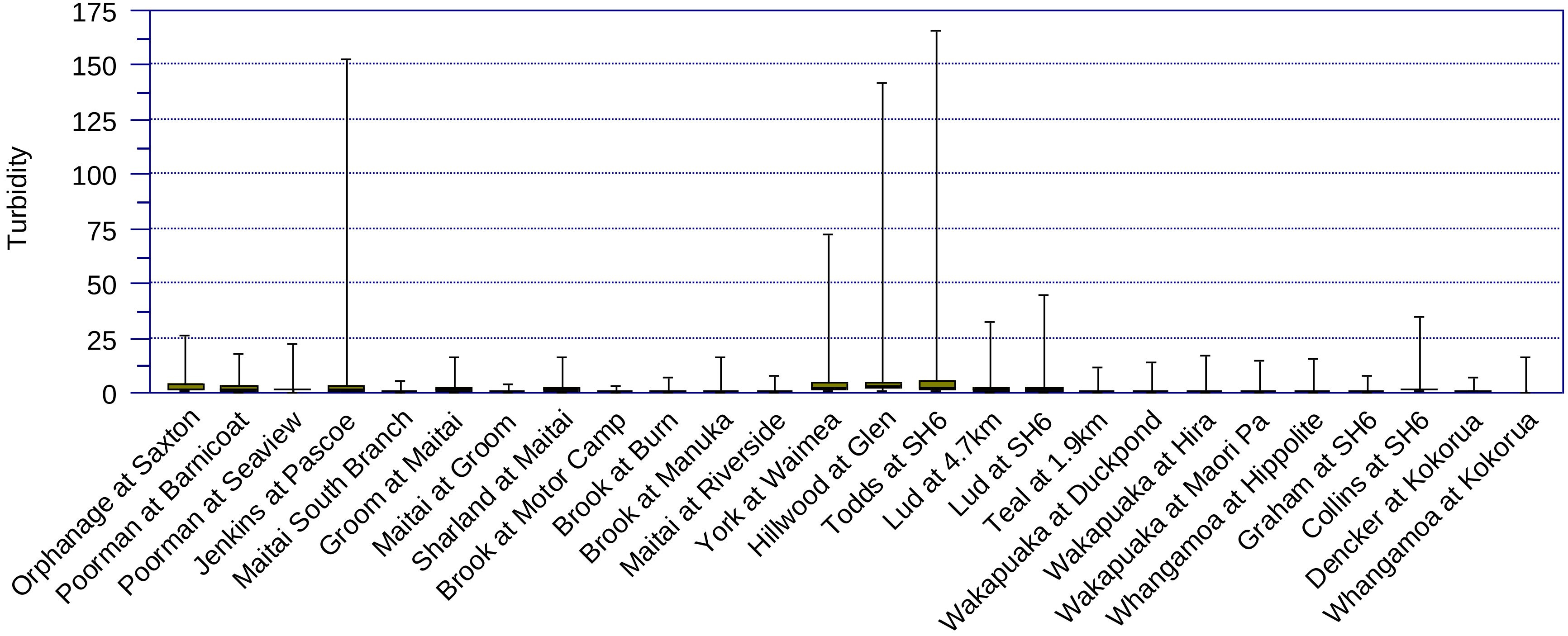


Figure 21. Turbidity (NTU) for all monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75^{th} - 25^{th} quartiles, bars = min and max, mid-point line = median.

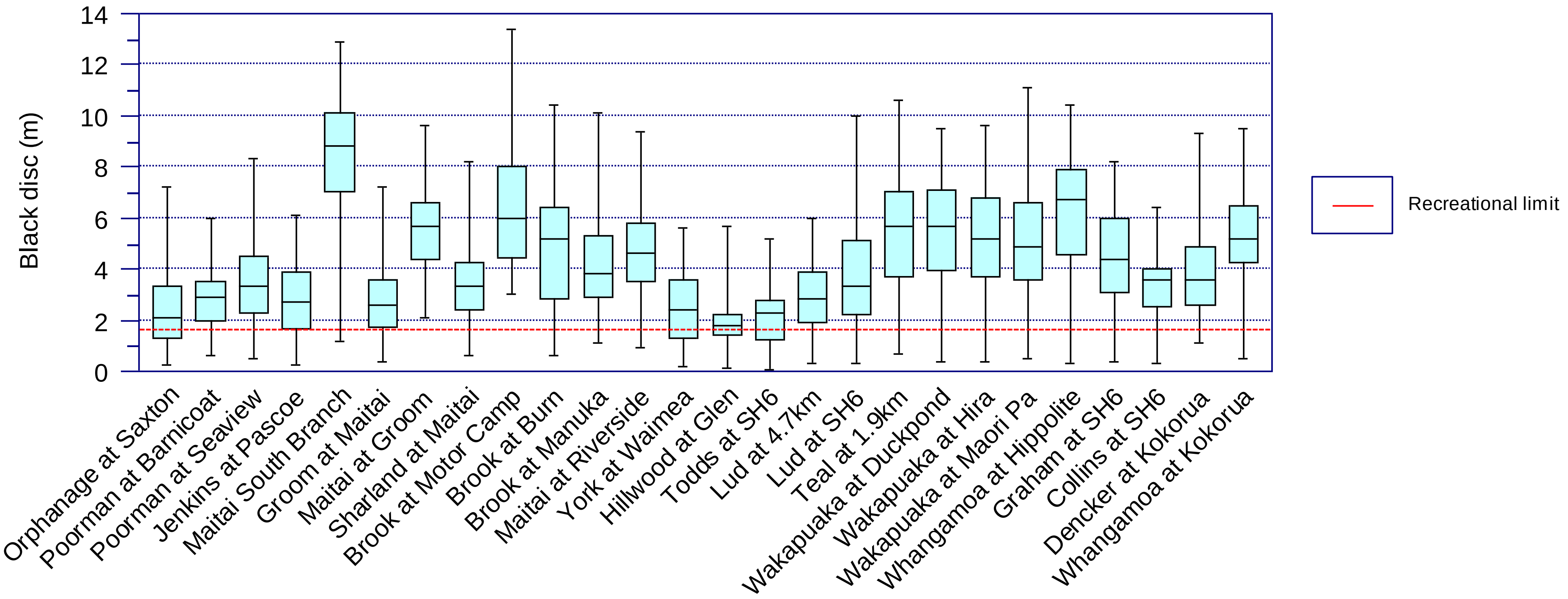


Figure 22. Clarity (black disc measurement in metres) for monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th - 25th quartiles, bars = min and max, mid-point line = median.

10 Other Contaminants and Stressors

Metals, metalloids and organic compounds can have toxic effects on the ecological health of rivers and streams. Physical stressors are also an issue affecting water quality and aquatic life. These stressors include aspects such as water temperature, pH and dissolved oxygen. Changes in pH can also affect the availability of toxicants and heavy metals in some cases. These toxicants and stressors are often key water quality issues in catchments with large proportions of urban and industrial land use. These contaminants accumulate in stream bed sediments and sediment testing against ANZECC guidelines can be undertaken[14]. In relation to sediment contamination the guidelines state:

> *"Many urban and harbour sediments fall into the first category, usually being contaminated by heavy metals and hydrophobic organic compounds resulting from both diffuse and point-source inputs. They are not easily remediated. At present, ex situ treatment or dredging and disposal are the most cost-effective options. If a site is known to have highly contaminated sediments with potential for biological uptake, it may be possible to control the collection of benthic organisms for human consumption. For the most part, because of the enormous costs involved, there is unlikely to be large-scale sediment remediation, unless it is driven by human health risk assessments.*
>
> *Contaminated sediments can be remediated naturally when fresh sediments, able to support viable biological populations, settle on top of them. This can occur through water column inputs and can be managed through controls on inputs via water quality guidelines. Management conflicts can arise when natural sediment accumulation restricts navigation."*

In a recent study of Saltwater Creek, which is a small, brackish 'stream' that comprises an arm of the Mahitahi/Maitai Estuary within Nelson City, a number of contaminants were found in stream sediments that exceeded the low and high thresholds for sediment. The Nelson mineral belt provides some natural background nickel, chromium and to a lesser extent copper. However, nickel and zinc both significantly exceeded the ISQG threshold indicating a high probability of adverse effects on sensitive organisms from human sourced contaminants (Berthelsen 2016).

Chromium, copper, lead and mercury all exceeded the 10% probability of effect threshold. A number of semi-volatile organic chemicals (SVOCs) and polycyclic aromatic hydrocarbons (PAHs) were present above the high threshold, along with phthalates (synthetic compounds from plastics which bio-accumulate). Macroinvertebrate communities had poor diversity and a high dominance of pollution tolerant species, indicating the ecosystem health of the estuarine environment is affected by contaminants from human sources. These findings are similar to earlier studies and are supported by a lack of native fish diversity and abundance (Olley and Kroos 2014).

[14] The Interim Sediment Quality Guidelines (ISQG) within the ANZECC 2000 guidelines can be used to compare contaminant concentrations in stream sediment. The low and high threshold levels relate to the probability of adverse effects, based on international studies using amphipods (Crustacea) and are the 10% and 50% probabilities of effects respectively.

Other streams with high levels of urbanisation have similar results. Preliminary results from the York Stream (also undertaken in 2016) show that in addition to the toxicants, contaminants and poor ecosystem health described above, York Stream at Waimea Road is also subject to elevated copper, lead, zinc, PAHs, manganese, chromate and arsenic; with significant fluctuations in dissolved oxygen. All of these stressors and contaminants are potentially causing the loss of sensitive stream taxa, although a focus on the York Stream water quality and enhancement of the aquatic habitat is underway through NCC's non-regulatory programmes under Project Maitai/Mahitahi and Nelson Nature. Given the significant water quality issues in the York Stream and other urban waterways in Nelson it is likely that objectives for Ecosystem Health under the NPS-FM will not be met and a stronger regulatory response to managing the inputs of stressors needed. These contaminant effects extend into the Port of Nelson area and therefore are also a concern in relation to coastal water quality policy development for the Nelson Plan.

Streams in the highly urbanised Stoke catchments are also subject to significant contamination – see the Stoke FMU section below.

Figures 23 and 24 show the distribution of two physical stressors: pH and conductivity. pH results are largely within safe ranges for aquatic life (6.5-8.5). Some sites are more variable than others and this variability corresponds directly to the sites with poorer water quality i.e. Orphanage, Jenkins, York and Hillwood but also includes the Brook at Motor Camp and Maitai at Riverside sites. Variability in pH range through the day can be caused by the photosynthesis and respiration cycles of algal cells, as well as discharges of waste which directly alter the pH or the water. Further periphyton monitoring may confirm which sites are variable due to biological growths on stream beds.

Conductivity indicates the concentration of dissolved electrolyte ions in freshwater. Significant increases in conductivity can indicate the presence of polluting discharges in water. Natural levels of conductivity are affected by geology and soil type. Ideal freshwater conductivity levels range between 50 and 500 µS/cm. Figure 24 shows the conductivity ranges for all sites. The York at Waimea Road and Todds sites both exceed ideal conductivity levels, indicating the presence of high concentrations of dissolved ions at these sites.

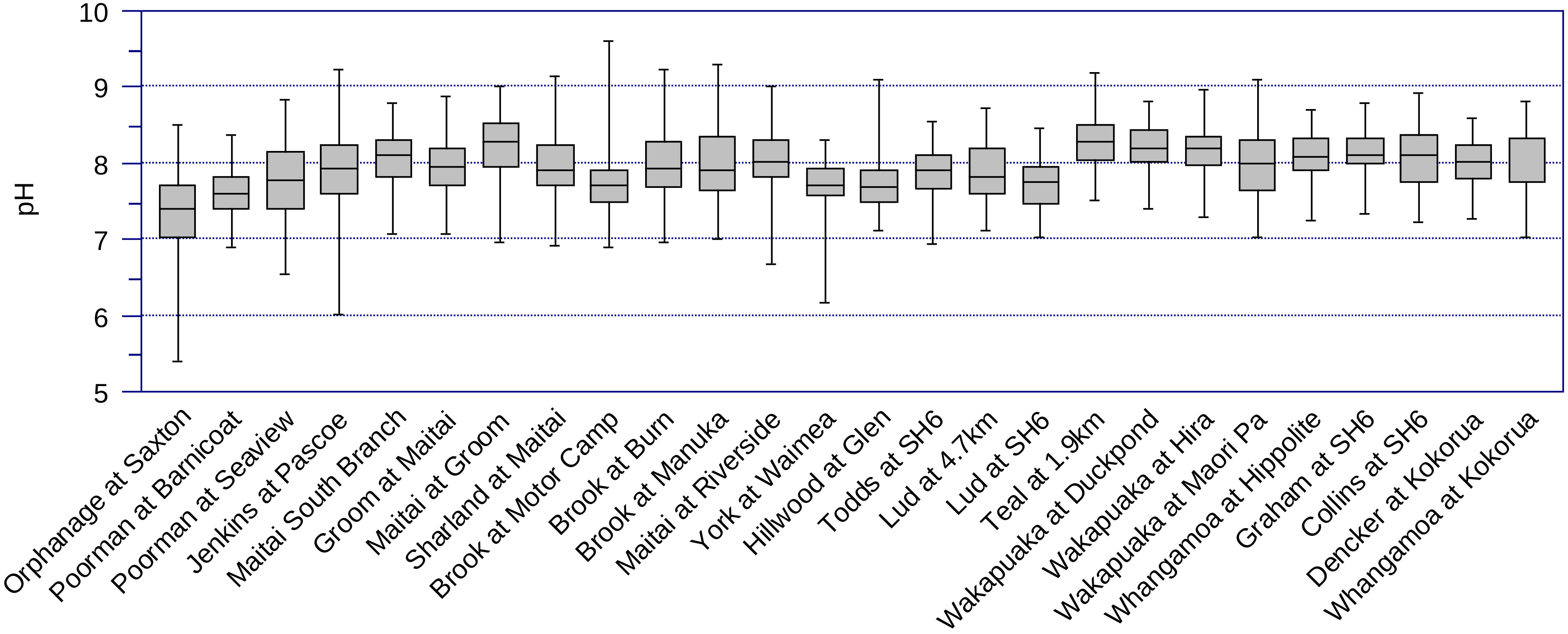


Figure 23. pH range for monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th - 25th quartiles, bars = min and max, mid-point line = median.

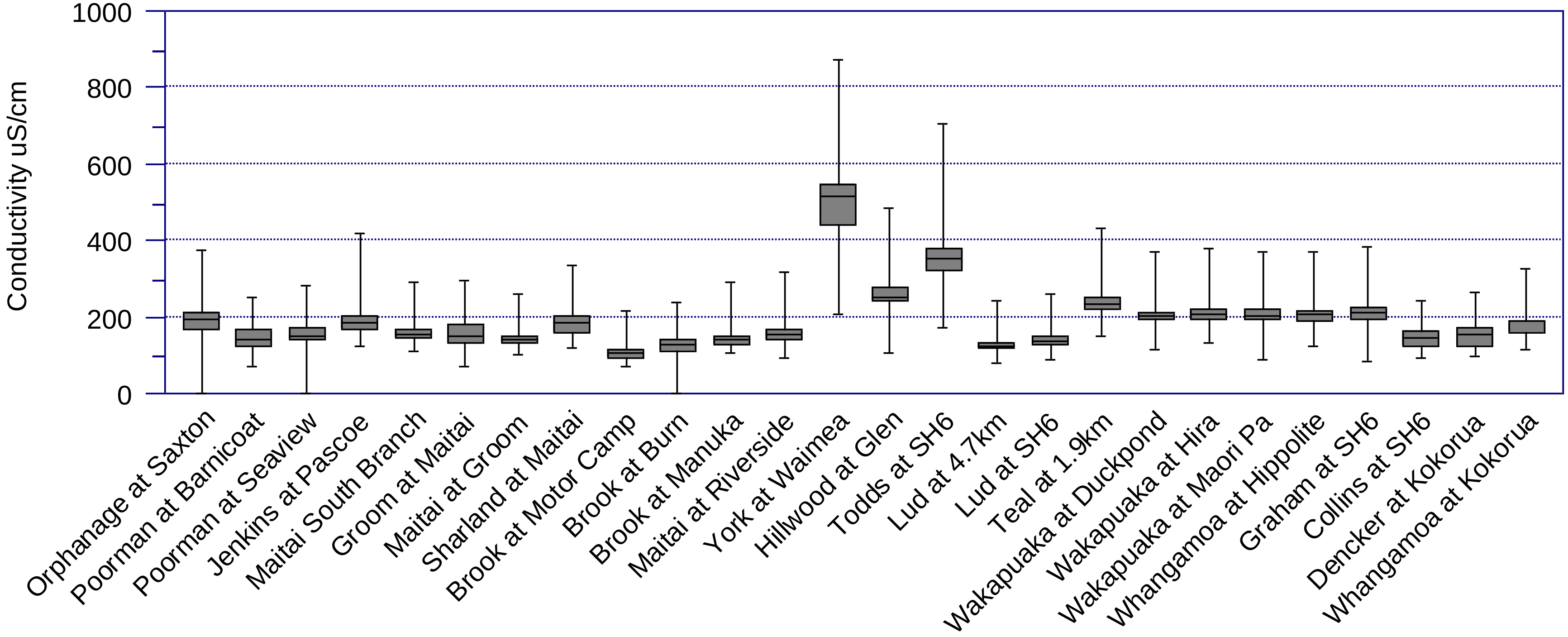


Figure 24. Conductivity range for monitoring sites in Nelson collected quarterly under base flows between 2002 and 2014 and monthly under all flows in 2015 to July 2016. Box = 75th - 25th quartiles, bars = min and max, mid-point line = median.

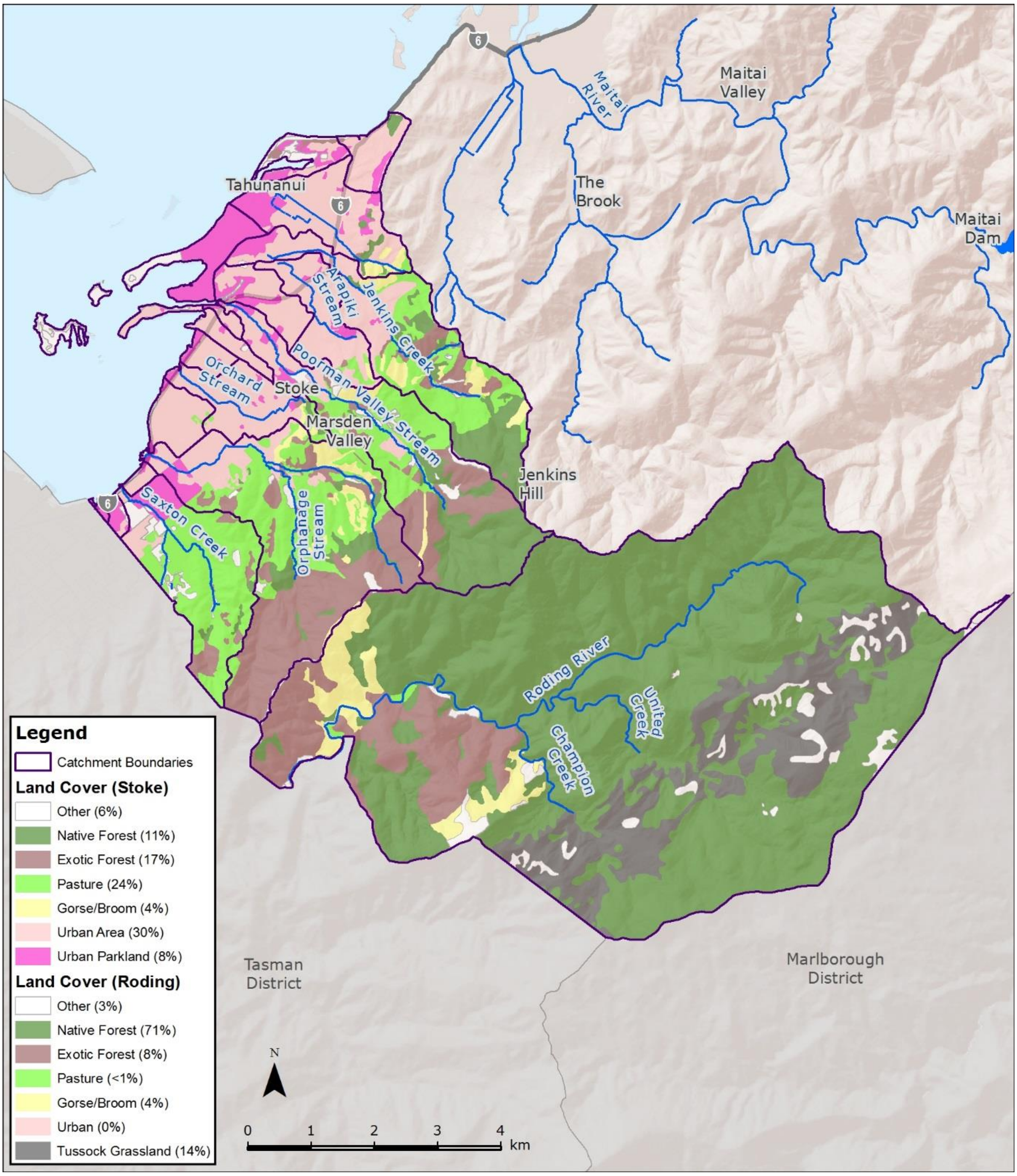
11 Stoke Freshwater Management Unit

The Stoke FMU comprises the small coastal streams to the south-west of Nelson City that flow into the Waimea Inlet. The total land area of the FMU is 3,757ha.

Landuse in the Stoke area is predominantly urban and industrial in the lower reaches, with pastoral land use dominating the upper reaches (including one dairy farm in the Saxton catchment) (Table 3). Production forestry and native forest are also present in the upper catchment areas with native forest concentrated in the upper Poorman Stream catchment (Map 3). The true left tributary of the Saxton Creek crosses the boundary between NCC and Tasman District Council (TDC) near Champion Road.

Table 3. Approximate land use proportions in the Stoke FMU.

Land use type	Proportion of FMU area
Pasture	28%
Urban	27%
Production (exotic) forest	19%
Native forest	13%
Other	9%
Gorse/broom	4%



Map 3. Land use and land cover in the Stoke and Roding FMUs, Nelson.

As a response to consistently poor water quality results in Stoke, the Stoke Streams Rescue Project, a partnership between NCC, Waimāori Streamcare and the Cawthron Institute, supported with funding from the Ministry for the Environment (MFE) was initiated. Undertaken between 2011 and 2013, the purpose of the project was to improve the water quality of the four Stoke streams. All of the streams were identified as being highly degraded in 2010, which was the key impetus for the project.

The recommendations of the Stoke Streams Rescue project included:

I. Better urban planning and design to allow for wider flood and riparian setbacks;
II. Planning for better flood control to ensure that ecological needs of the stream are also met;
III. Education, assessment and enforcement of industrial discharges and consents;
IV. Promote the Poorman Stream as a flagship urban stream in Nelson;
V. Identification of the need for more staff and resourcing in the water quality and urban stream areas of Council; and
VI. Signage and fish motifs to improve stormwater awareness.

To date it is unclear how many of these recommendations have been implemented, and of those implemented how many have been successful in terms of positive outcomes for water quality and aquatic habitat in Stoke. The value of this work and the recommendations need to be furthered through the Nelson Plan provisions for urban streams, particularly in the Stoke FMU.

Table 4. Summary of water quality and ecosystem health monitoring for all SOE sites in the Stoke FMU.

Monitoring site	Human Health[15]	Ecosystem Health				
	E. coli	MCI	Peri-phyton[16]	Nitrate toxicity	N trophic risk[17]	P trophic risk
Saxton at Main	Bottom line	Fair	Good	Band B[18]	High	High
Orphanage at Saxton	Band C	Poor	Poor	Band A	High	High
Poorman at Barnicoat	Band A	Good	Good	Band A	Low	High
Poorman at Seaview	Band C	Fair/Poor	Good	Band A	Low	High
Jenkins at Pascoe	Band C	Poor	Poor	Band B[18]	High	High

[15] Compared with NOF *E. coli* attribute states. The threshold between Bands B and C is the minimum acceptable state for swimming/primary contact.
[16] Based on annual PeriWCC % cover observations in relation to Ecosystem Health (Matheson et al. 2012) not NOF periphyton biomass objectives.
[17] A coarse measure using the ANZECC lowland guidelines trigger values as a threshold between low and high trophic risk for nitrogen and phosphorus.
[18] Based on the 95th percentile attribute state.

Water quality is poor across a number of attributes in the Stoke FMU (Table 4). Saxton Creek in particular has some of the worst water quality of all sites in Nelson. Elevated nitrogen, phosphorus, faecal contaminants and sediment (see Appendix 4) are indicative of intensive pastoral land use with unmanaged or unmitigated contaminant losses to the stream. Downstream areas are affected by run-off from urban expansion. The Saxton monitoring site was discontinued in 2015 due to flood control management to support urban development encroaching onto the site. A new monitoring site is needed.

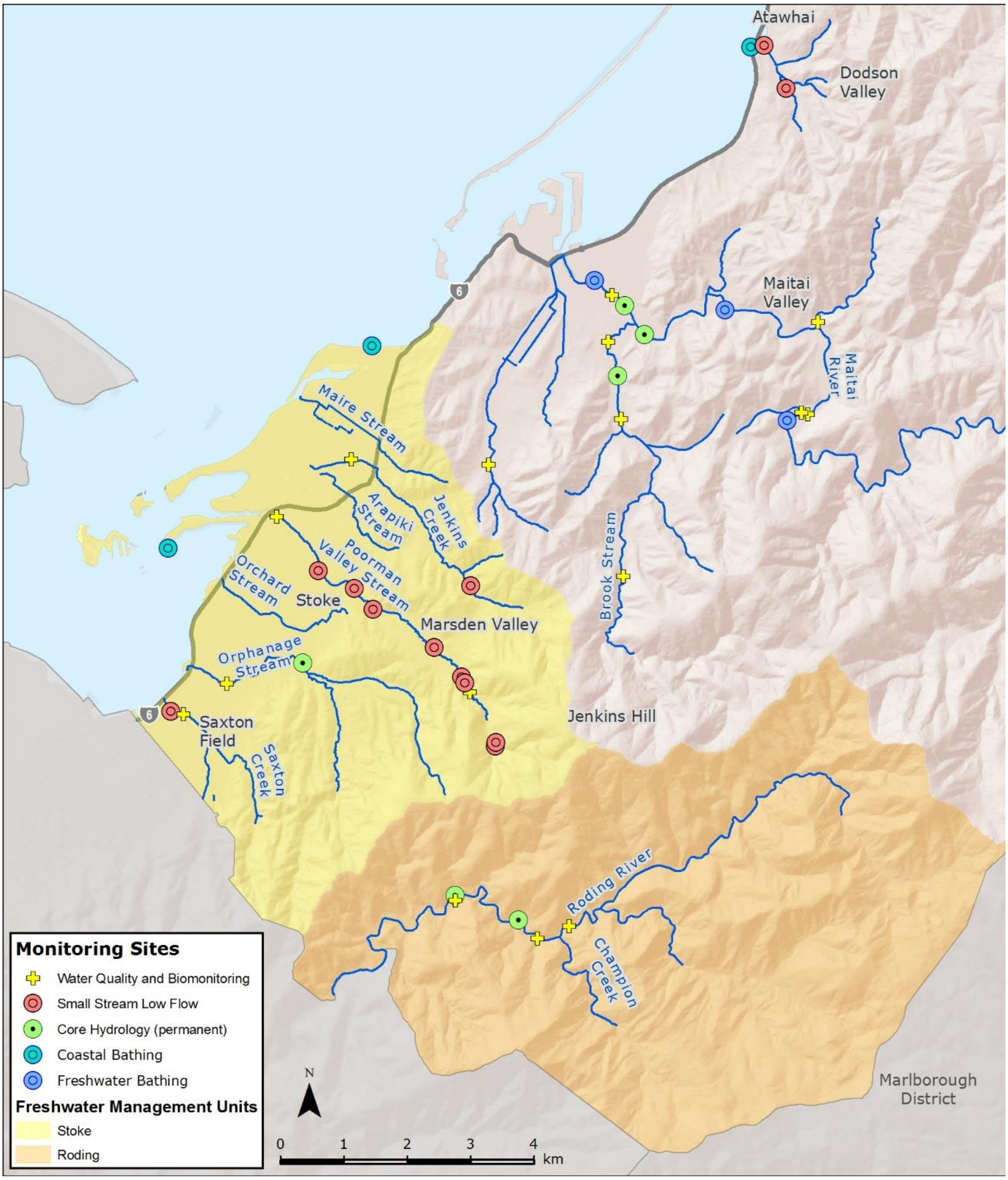
The Orphanage and Jenkins Streams are highly affected by urban modification and run-off, and to a lesser extent so is the lower Poorman Valley Stream. The intensive nature of land use within these catchments is a significant limiting factor for realising high levels of aquatic ecosystem health, despite the streams having high potential for native fish.

The Land Air Water Aotearoa web site[19] shows meaningful improving trends in *E.coli* at most sites (excluding Poorman at Seaview) and improving black disc at three out of five sites (Table 5). Phosphorus concentrations have also reduced over the last five years of monitoring at the Saxton site (Map 4).

Table 5. Summary of trend information from LAWA (2015 data) for monitoring sites in the Stoke FMU. Downward arrows indicate improvement, upward arrows indicate degradation.

Monitoring site	Human Health	Clarity		Nitrogen		Phosphorus
	E. coli	Black disc	Turb.	Total oxidised nitrogen	Ammonia-N	DRP
Saxton at Main	↓	-	-		-	↓
Orphanage at Saxton	↓	↓	-		-	-
Poorman at Barnicoat	↓	-	-		-	-
Poorman at Seaview	-	↓	↓		-	-
Jenkins at Pascoe	↓	↓	-		-	-

[19] www.lawa.org.nz



Map 4. Monitoring sites in the Stoke and Roding Freshwater Management Units, Nelson.

Summary of water quality issues for the Stoke FMU

Ecosystem health:

1. The upper reaches of the Poorman Stream have macroinvertebrate communities indicative of good ecosystem health. Orphanage, Jenkins and Saxton Streams had the lowest MCI scores in Nelson, varying between fair and poor ecosystem health and indicative of moderate to severe water pollution. The degree of urban development, pastoral and production forestry land use in the upper catchment areas of these streams limits ecosystem health near the coast, where biodiversity values would usually be highest.
2. Orphanage and Jenkins Streams occasionally had annual periphyton cover that exceeded ecological, aesthetic and recreational guidelines. Lower reaches of the streams in the Stoke FMU may be affected by nuisance aquatic weed growth, due to sedimentation of stream beds.

Faecal contaminants:

3. Saxton Creek had very high levels of faecal contaminants and along with Orphanage, Jenkins and lower Poorman are not currently suitable for any primary contact. Because results are from low flow conditions there is likely to be some direct faecal contamination of the Stoke Streams that requires investigation and remedial action.

Nutrients:

4. Saxton Creek has extremely elevated nitrogen levels, well above all other sites for nitrate, soluble inorganic nitrogen and ammoniacal nitrogen.
5. Phosphorus concentrations were elevated throughout the Stoke Streams FMU, including in the upper reaches of the Poorman Stream, indicating potential for an upper catchment land use or geological source, possibly exacerbated by sediment transport.

Sediment:

6. Sediment and turbidity issues at base flows are apparent in Saxton, Orphanage, and Jenkins Streams. Saxton has the greatest sediment issue at low flow.

Summary of issues and potential causes:

7. The Saxton Stream has some of the worst water quality of all sites in Nelson. Elevated nitrogen, phosphorus, faecal contaminants and sediment are indicative of pastoral land use with poorly managed contaminant losses. Poor water quality and habitat affect MCI.
8. Given their proximity to the Waimea inlet the Stoke streams have high potential as habitats for indigenous biodiversity, particularly native fish.
9. The implications of these issues are that without management intervention the ecosystem health and biodiversity potential of these streams is at risk.

12 Roding Freshwater Management Unit

The Roding River is a tributary of the Lee River in the Waimea/Wairoa catchment, flowing through the Tasman District to the sea at the Waimea Inlet. The upper catchment of the Roding is within the NCC boundary and the majority of the FMU catchment area is within native forest, tussock grassland and production forestry (Table 6). The upper Roding catchment is managed largely for Nelson and Richmond's municipal water supply, contributing roughly one third of Nelson City's water, and for production forestry. There is a large water intake structure downstream of the inflows from the Champion and United Creek tributaries (Photo 1). The intake structure is a potential barrier to any native fish that are not strong climbers and venture as far inland as the weir. However, the amount of water taken at the weir reduces the habitat available for a number of native fish, particularly torrentfish at low flows and may have resulted in lower fish diversity than expected both upstream and downstream of the weir (Holmes et al. 2015).

There are no state of the environment monitoring sites in the Roding Freshwater Management Unit. As part of consent conditions for the Roding water supply take, macroinvertebrates are collected at one site downstream of the weir near the confluence with Stratford creek and flow and water temperature data are collected upstream and downstream of the intake weir. A small amount of physico-chemical water quality data is also collected with the macroinvertebrate samples twice yearly (i.e. pH, dissolved oxygen and conductivity). All physico-chemical data suggest good water quality in the Roding River in the vicinity of the intake weir. Data collected by Tasman District Council for the Roding at Twin Bridges site, downstream of the NCC boundary shows faecal pathogens are very low and the Roding is almost always suitable for primary contact recreation, with water clarity and fine sediment also indicating good to excellent water quality. Although there is some periphyton growth, macroinvertebrates are usually in a good state with MCI>100.

Macroinvertebrate results are shown in Figure 25 below. The long-term average over sixteen years of monitoring suggests a good water quality classification, but it is clear from the data and through statistical testing[20] that there has been a significant improving trend in MCI over the 2002-2012 monitoring period. Reasons for this improving trend are not clear but changes were made to increase minimum flows in 2008 (Holmes et al. 2015).

Table 6. Approximate land use proportions in the Roding FMU.

Land use type	Proportion of FMU area
Native forest	71%
Production (exotic) forest	8%
Pasture	<1%
Gorse/broom	4%
Other	3%
Tussock grassland	14%

[20] Using TimeTrends seasonal Kendall trend analysis – this analysis was used in place of the Mann Kendall test due to the collection of seasonal samples for macroinvertebrates twice-yearly.

Photo 1. Nelson/Richmond water supply weir, Roding River, Nelson

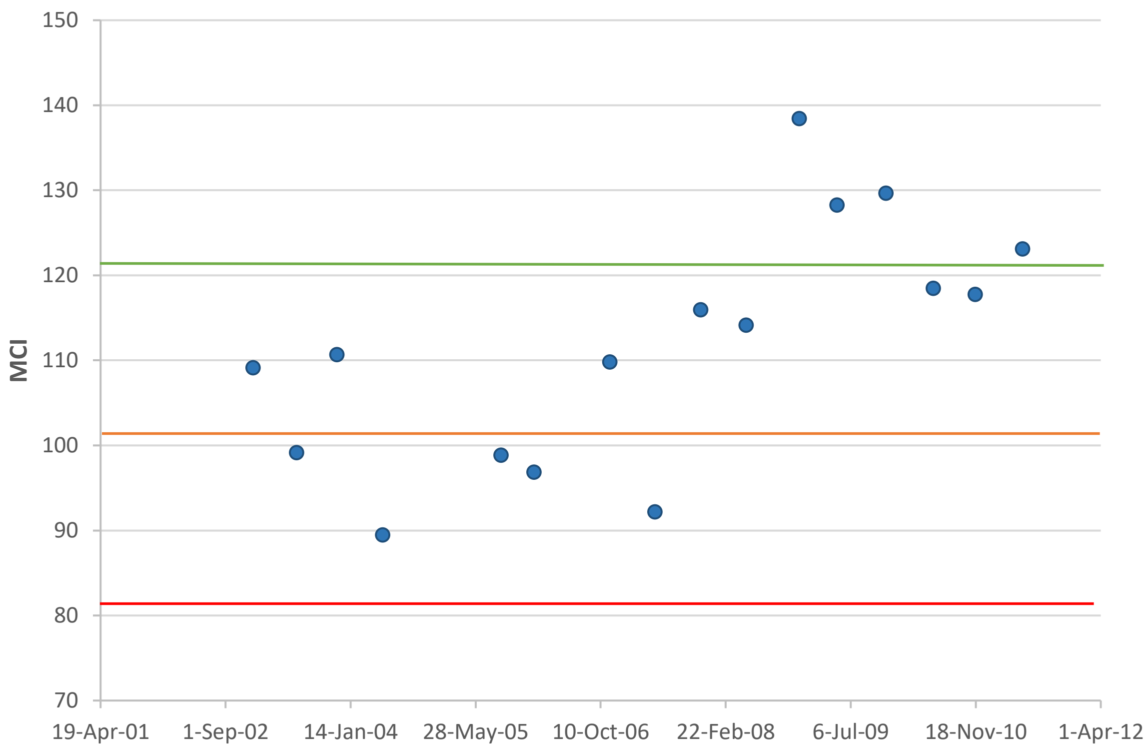


Figure 25. Macroinvertebrate community index (MCI) for the Roding River (downstream of water supply weir) collected December 2002 to May 2011. Coloured horizontal lines delineate MCI water quality classes: MCI <80 = poor, MCI 80-100 = fair, MCI 100-120 = good, MCI >120 = excellent.

Summary of water quality issues for Roding FMU

Ecosystem health:

1. Ecosystem health is generally good to excellent in recent years, as indicated by the MCI. However, native fish habitat in the upper reaches is affected by the water supply weir, which is a potential barrier to high quality upland habitat for fish species that penetrate this far inland. Data indicate the water take may be having long-term adverse impacts on fish diversity and the occurrence of species such as torrentfish.

Faecal contaminants:

2. NCC does not monitor faecal contaminants in the Roding, although given the catchment land use and management for water supply there are unlikely to be any significant sources. The Roding is highly used for recreation, including swimming and boating.

Nutrients:

3. No data available, but elevated nutrient concentrations are unlikely to be an issue.

Sediment:

4. Sediment and turbidity are potential issues from production forestry activities and harvest, most of which is in NCC ownership. Careful management is needed to maintain water quality for water supply and other purposes if harvest is initiated.

Summary of issues and potential causes:

5. The Roding water quality is likely to be good, some limited monitoring may be needed in future to meet NPS-FM requirements. Management of production forestry activities, particularly during any harvesting, will be needed to ensure water supply values are maintained over time.

13 Mahitahi/Maitai Freshwater Management Unit

The Mahitahi/Maitai FMU comprises the largest catchment area of Nelson. Nelson City sits within the lower Mahitahi/Maitai River and the river is a central focus of the City. The Mahitahi/Maitai flows to the sea at Port Nelson, at the southern end of the Nelson Haven. The FMU contains the York Stream catchment, which also flows into Port Nelson with the lower Mahitahi/Maitai and the Oldham Creek, Todds Valley and Hillwood Streams to the north. These streams enter the Nelson Haven at the northern end near Atawhai. The total land area of the FMU is 13,038 ha.

Despite the position of Nelson City as a primary feature in the landscape of the Mahitahi/Maitai River, urban landuse makes up the smallest proportion of the land uses within the FMU (Table 7; Map 5). Landuse is predominantly native and exotic forest and the upper catchment is a drinking water capture area for the municipal supply to the city. The Hillwood Stream catchment has the highest proportion of pastoral land use while the York Stream is dominated by urban land cover in Nelson South. According to Allen et al. (2013) land use in the Mahitahi/Maitai catchment has changed little over the last twenty years.

Table 7. Approximate land use proportions in the Mahitahi/Maitai FMU.

Land use type	Proportion of FMU area
Native forest	45%
Production (exotic) forest	22%
Pasture	10%
Gorse/broom	8%
Other	8%
Urban	7%

Water quality in the upper Mahitahi/Maitai catchment is good but declines downstream as the river is affected by tributary contaminant loads, particularly nitrogen (Table 8) and sediment (Appendix 5). Water quality in the York and Todds Valley catchments is also relatively poor as a result of urban and pastoral impacts, including the two landfills in the York.

The Mahitahi/Maitai FMU is affected by multiple impacts. However, the key impacts are:

1) Changes to the hydrological regime and water quality resulting from the reservoir dam and back-feed discharge to the South Branch;
2) Tributary contaminant loads affected primarily by production forestry in the Sharland and Groom catchments, with pastoral influences in the lower end of these tributaries;
3) The degree of urbanisation in the lower Mahitahi/Maitai and York and associated contaminants from stormwater discharges, landfill leachate, sewer leakage and impervious run-off; and
4) Pastoral impacts on the Todds Valley stream.

Significant increasing trends in nitrogen were seen in the 2015 LAWA data, affecting the lower Mahitahi/Maitai and tributaries and the York Stream catchment (Table 9). These trends indicate land use impacts have worsened over recent years. Cyanobacteria blooms that affect amenity and recreational values are associated with land use impacts.

Table 8. Summary of water quality and ecosystem health monitoring for all SOE sites in the Mahitahi/Maitai FMU.

Monitoring site	Human Health[21]	Ecosystem Health				
	E. coli	MCI	Peri-phyton[22]	Nitrate toxicity	N trophic risk[23]	P trophic risk
Maitai at South Branch	Band A	Excellent	Good	Band A	Low	Low
Groom at Maitai	Band B	Good	Good	Band B	High	Moderate
Maitai at Groom	Band A	Fair	Fair	Band A	Low	Low
Sharland at Maitai	Band B	Good	Good	Band B	High	Low
Brook at Motor Camp	Band A	Excellent	Good	Band A	Low	High
Brook at Burn	Band A	Good	Poor	Band A	Low	High
Brook at Manuka	Band C	Fair	Fair	Band A	Low	High
Maitai at Riverside	Band C	Fair	Good	Band A	Low	Low
York at Waimea	Band C	Poor	Good	Band B	High	High
Hillwood at Glen	Band C	Fair	Good	Band A	Low	High
Todds at SH6	Band C	Fair	Good	Band A	Low	High

[21] Compared with NOF *E. coli* attribute states. The threshold between Bands B and C is the minimum acceptable state for swimming.
[22] Based on annual PeriWCC % cover observations in relation to Ecosystem Health (Matheson et al. 2012) NOT NOF periphyton biomass objectives.
[23] A coarse measure using the ANZECC lowland guidelines trigger values as a threshold between low and high trophic risk for nitrogen and phosphorus.

Table 9. Summary of trend information from LAWA (2015 data) for monitoring sites in the Mahitahi/Maitai FMU. Downward arrows indicate improvement, upward arrows indicate degradation.

Monitoring site	Human Health	Clarity		Nitrogen		Phosphorus
	E. coli	Black disc	Turb.	Total oxidised nitrogen	Ammonia-N	DRP
Maitai at South Branch	-	-	-	-	-	-
Groom at Maitai	-	-	-	↑	-	-
Maitai at Groom	-	-	-	↑	-	-
Sharland at Maitai	-	-	-	↑	-	-
Brook at Motor Camp	-	-	-	↑	-	-
Brook at Burn	-	-	-	-	-	-
Brook at Manuka	-	-	-	↑	-	-
Maitai at Riverside	-	-	-	↑	-	-
York at Waimea	-	↓	-	↑	-	-
Hillwood at Glen	-	-	-	-	-	-
Todds at SH6	-	↓	↓	-	-	-

13.1 Summary of research findings for the Mahitahi/Maitai River catchment

A large body of research has been undertaken in the Mahitahi/Maitai catchment, largely by the Cawthron Institute. Some of the findings from this research are summarised here. Research continues as part of Project Mahitahi/Maitai.

Production forestry and urbanisation appear to be the dominant pressures facing the Mahitahi/Maitai catchment. Forestry is the main land use in the mid-catchment, dominating the Sharland Creek tributary area. Macroinvertebrate community health indicators are sensitive to changes in nutrient and deposited fine-sediment levels. High levels of both of these contaminants are found in tributary catchments dominated by production forestry. The declines in the macroinvertebrate community health throughout the mid-catchment suggest forestry works are negatively impacting stream life downstream through increased fine sediment and/or nutrient levels in addition to impacts from the operation of the reservoir. Significant declining trends have been seen in the South Branch of the Mahitahi/Maitai below the backfeed discharge (Allen et al. 2013).

Blooms of the potentially toxic benthic mat-forming cyanobacteria *Phormidium* have been a problem in the lower Mahitahi/Maitai River in recent years, causing closure of popular recreational areas due to high cover. Specific studies to look at the occurrence of *Phormidium* in the Mahitahi/Maitai have been undertaken and are planned to continue (Wood et al. 2015). Key findings from this research have associated fine sediment loads and elevated nitrogen with *Phormidium* blooms in the lower Mahitahi/Maitai River. Land use practices (particularly production forestry management) are the most likely causes of elevated contaminants which are contributing to *Phormidium* growth in this catchment. Wood et al. (2015) concluded *Phormidium* blooms were likely to be an ongoing issue, particularly in spring and autumn unless fine sediment and nutrient levels were reduced. In the Mahitahi/Maitai River, unlike the findings in other areas of New Zealand, prolonged periods of low flows, at least over the summer months, do not necessarily favour Phormidium blooms. Elevated nitrogen during the early stages of mat formation, may be one of the key factors associated with promoting growth.

Phormidium can capture suspended fine sediment particles from river water and incorporate them into their mat structure. Research suggests that the geochemical conditions within *Phormidium* mats enable the release of phosphorus bound to these sediments. This may provide a source of phosphorus for *Phormidium* growth. Sediment from different sources can have varying amounts of phosphorus. Analysis of fine sediment from different parts of the Mahitahi/Maitai River showed concentrations of phosphorus available for *Phormidium* growth was highest in sediment collected downstream of Sharland Creek. Erosion is usually the key cause of phosphorus entering streams where there are no direct discharges of waste. In addition to production forestry, stock access to rivers can also cause elevated levels of sediment, phosphorus and faecal contaminants through bank erosion and direct deposition of faeces into water.

The Maitai Dam, municipal water take and reservoir are also key catchment influences in the Mahitahi/Maitai and the subject of considerable study. Cawthron studies suggest the impact of the Mahitahi/Maitai Reservoir on the mid and lower Mahitahi/Maitai River is comparatively minor when considered in the context of the magnitude and extent of other land use pressures facing the catchment. Degradation of ecosystem health in the lower catchment is largely attributable to forestry, urbanisation and the high level of hydrological alteration from the reservoir and water take. Sediment and nutrient loading from Sharland and Groom Creeks, and nutrient and contaminant loading from various stormwater drains and sewer leakage in combination with habitat loss and modification are key contributors. Nutrients from the back-feed discharge from the reservoir may contribute to cumulative impacts within the catchment, although these appear to be secondary to other land-use pressures.

There are three specific ecological issues that arise as a result of the Reservoir that may contribute to reductions in ecosystem health in the wider catchment:

1. Concentrations of naturally occurring heavy metals (manganese, iron, nickel and chromium) are higher in the upper Mahitahi/Maitai River than in the mid-catchment. There is a risk that this issue may be exacerbated by the discharge of anoxic water from the Mahitahi/Maitai Reservoir.

2. The Reservoir spillway is a significant fish passage obstacle within the Mahitahi/Maitai River, restricting access for native fish (particularly longfin eel and kōaro which tend to penetrate further upstream than other migratory species) to habitat in the Mahitahi/Maitai Reservoir and North Branch. Mussel spat ropes have been fitted to the spillway and a pumped flow alongside the ropes to keep them wet. Elvers have been observed climbing the spat ropes to access the reservoir, however because the journey for small fish can take some time they are vulnerable to predation while attempting the climb.

3. Water chemistry is altered below the Reservoir's back-feed discharge, especially during periods when anoxic reservoir water is discharged. Subtle changes in water chemistry can alter algal communities, potentially providing favourable conditions for undesirable species

(e.g. toxic cyanobacteria). Large amounts of algal mat growth are obvious in the reaches below the reservoir and extend right through middle river downstream of the golf course, although cyanobacteria does not dominate algal mats throughout these reaches and is most often concentrated below the backfeed discharge to the South Branch and downstream of Sharland Creek.

Recent analyses carried out to assess long-term changes in macroinvertebrate communities below the Reservoir found there have been significant declining trends between 1989 and 2012, indicating that ecosystem health has decreased below the Mahitahi/Maitai Reservoir (Holmes 2012). This may be associated with elevated water temperature, exacerbated by the abstraction of water from the river. Cover by periphyton mats increases over the same reach, for up to 2.6km downstream (Allen et al. 2013).

13.2 Faecal contaminants and stream flow in the Mahitahi/Maitai FMU

The Hillwood at Glen site has the most significant faecal contamination in the Mahitahi/Maitai FMU. Figure 26 shows elevated *E. coli* occurring mostly at low and moderate flows, although this variability is affected by the larger number of samples in these flow categories. More high flow observations are needed to better understand the relationship of *E.coli* with flow.

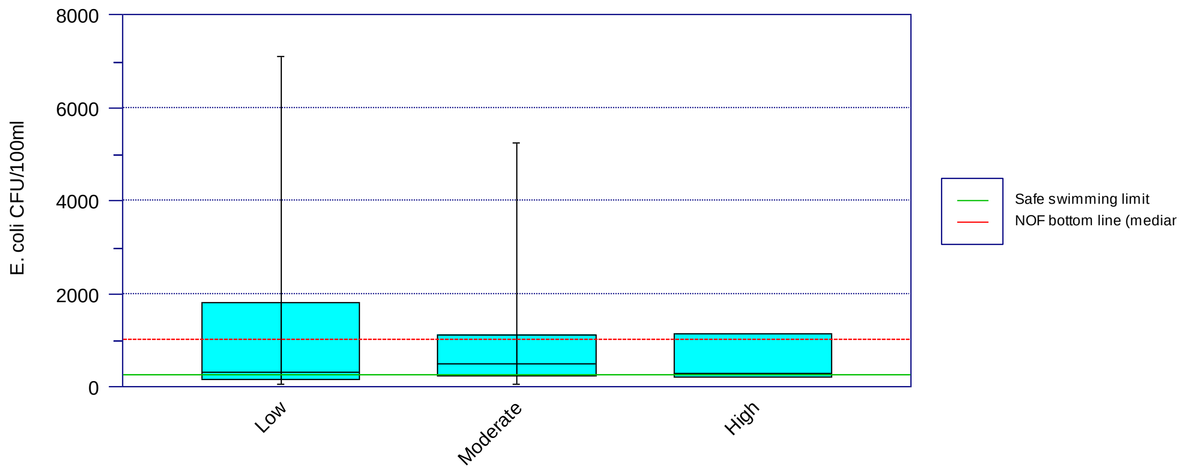


Figure 26. *Escherichia coli (E. coli)* for the Hillwood at Glen Road SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016. Boxes = 25th – 75th data percentiles, whiskers = 5th and 95th percentiles and mid-point line = median.

York Stream also has high faecal contaminant concentrations that may be associated with run-off from landfills in the head of the catchment, storage of animals on Council land between the NCC landfill and the residential area, or from sewage/stormwater infrastructure leakage and/or cross contamination. There are a number of locations where sewage mains cross the stream (Map 6). A single round of microbial source tracking (Table 2) identified human faecal contaminants as the key source in the York Stream, supporting the hypothesis that sewage leakage may be an issue. Further investigation is warranted.

13.3 Nutrients

Nitrate concentrations are consistently higher in the Mahitahi/Maitai mainstem below the Sharland Creek confluence, which also has high nitrogen concentrations just upstream of the Mahitahi/Maitai confluence (Map 7). Contaminants coming from the Sharland are attributable to the high proportion of production forestry in the sub-catchment and exacerbated by pastoral inputs from cattle grazing and stock access to the lower Sharland. The Brook and Sharland (including the Packer tributary) are key contributors of nutrient and fine sediment into the lower Mahitahi/Maitai River[24].

Groom Creek has also been identified as a source of contaminants. Figures 27 and 28 indicate that soluble nitrogen inputs in the Groom are elevated during high flow events and soluble phosphorus is elevated under more moderate flows. A wetland construction is planned for the lower end of Groom Creek under Project Mahitahi/Maitai. Construction of the wetland will need to take into account changes in nutrient flux with stream flow (Figure 29) and the lag time for a wetland to effectively remove sediment or nutrients.

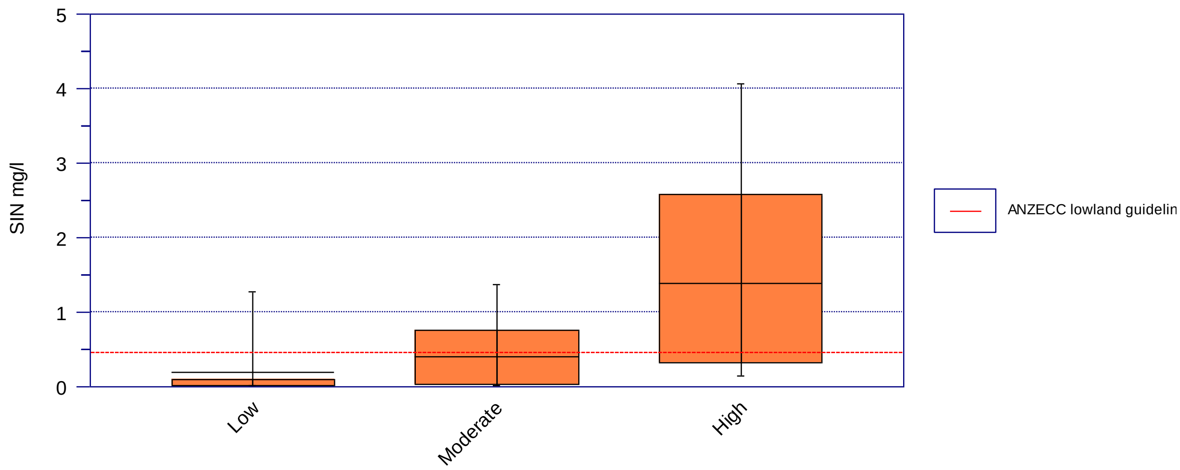


Figure 27. Soluble inorganic nitrogen (SIN) for the Groom at Maitai SOE monitoring site by flow category (low, moderate, high). SIN sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016. Boxes = 25th – 75th data percentiles, whiskers = 5th and 95th percentiles and mid-point line = mean.

[24] See Wood et al. (2015) section 3.4 pages 21 and 22.

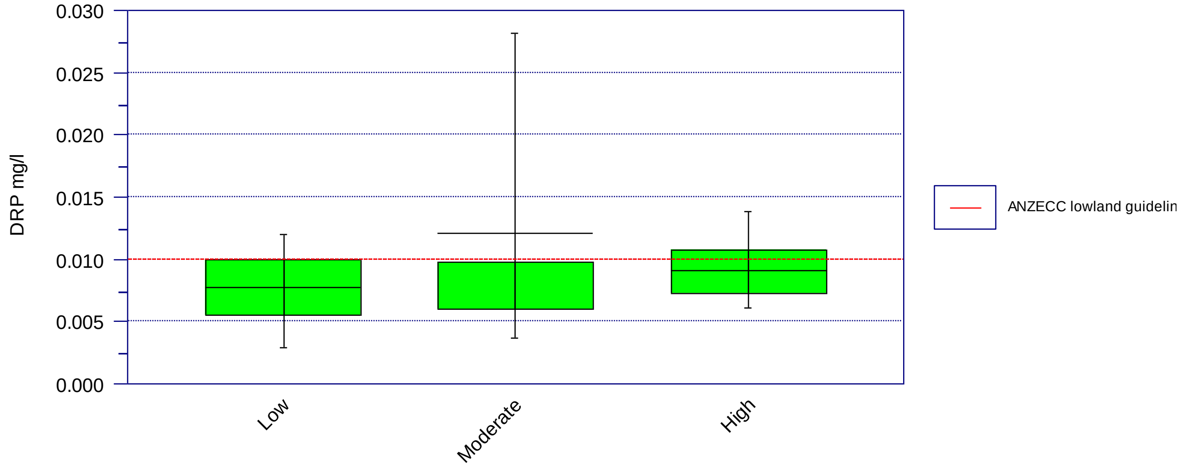
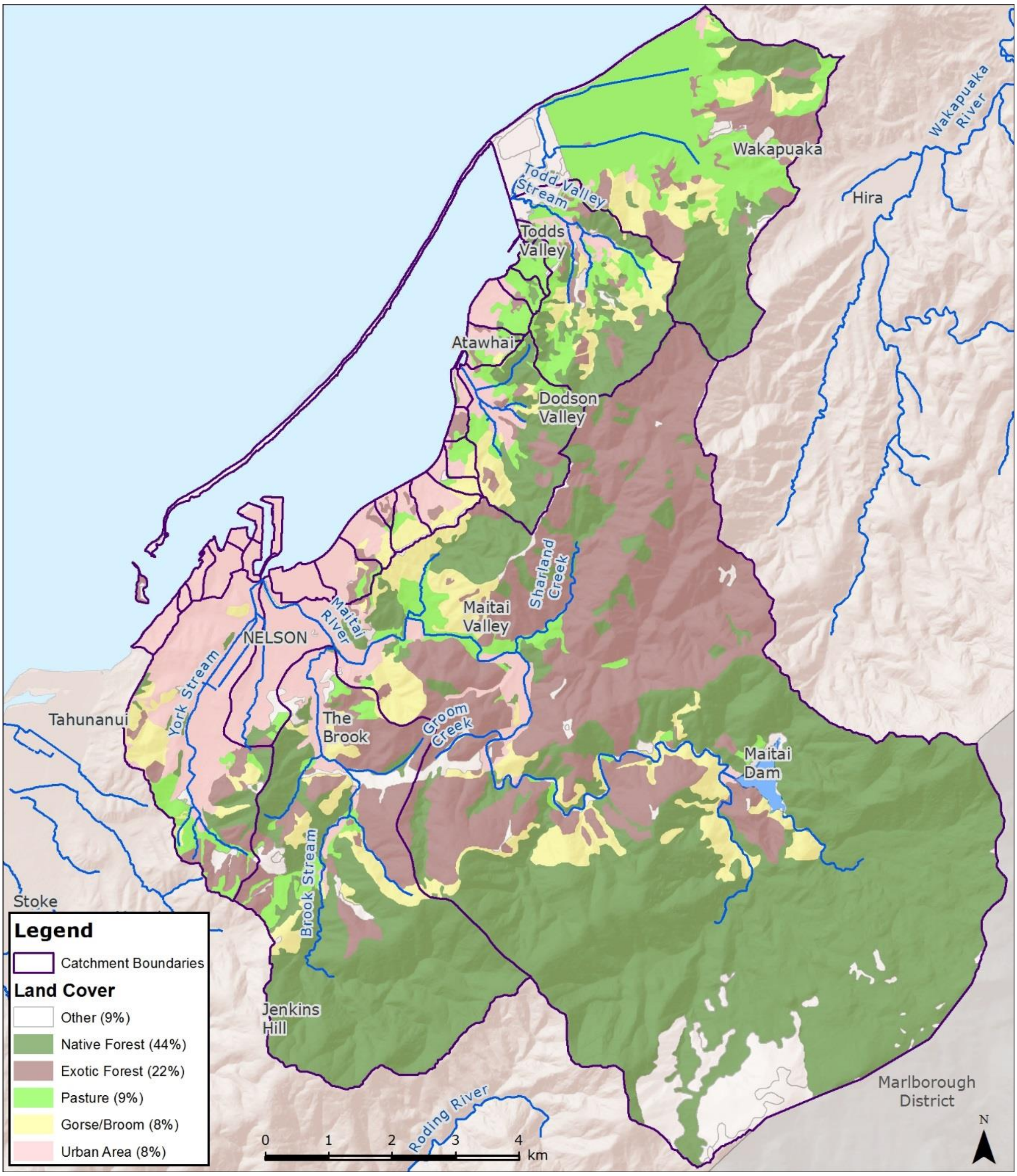
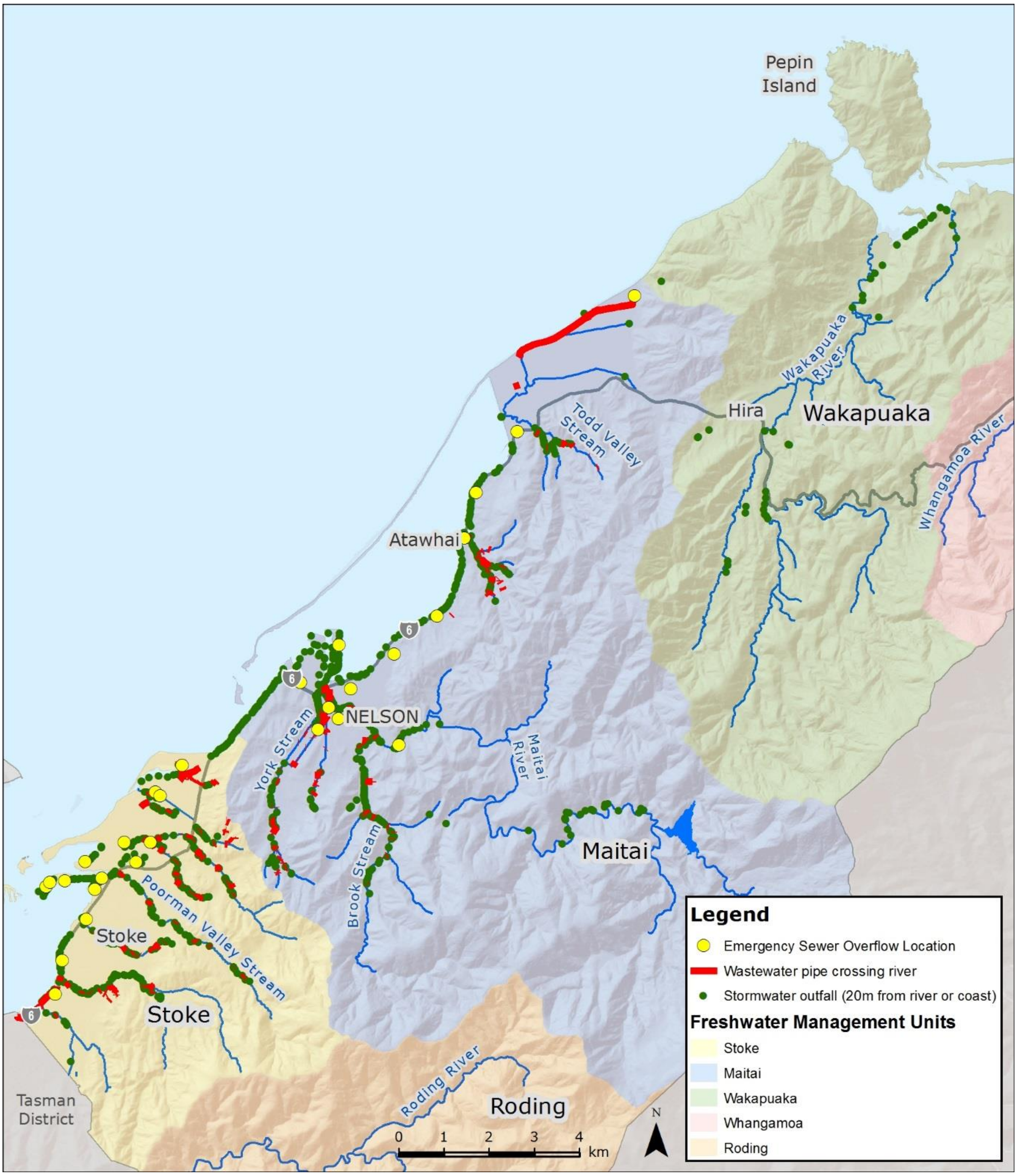


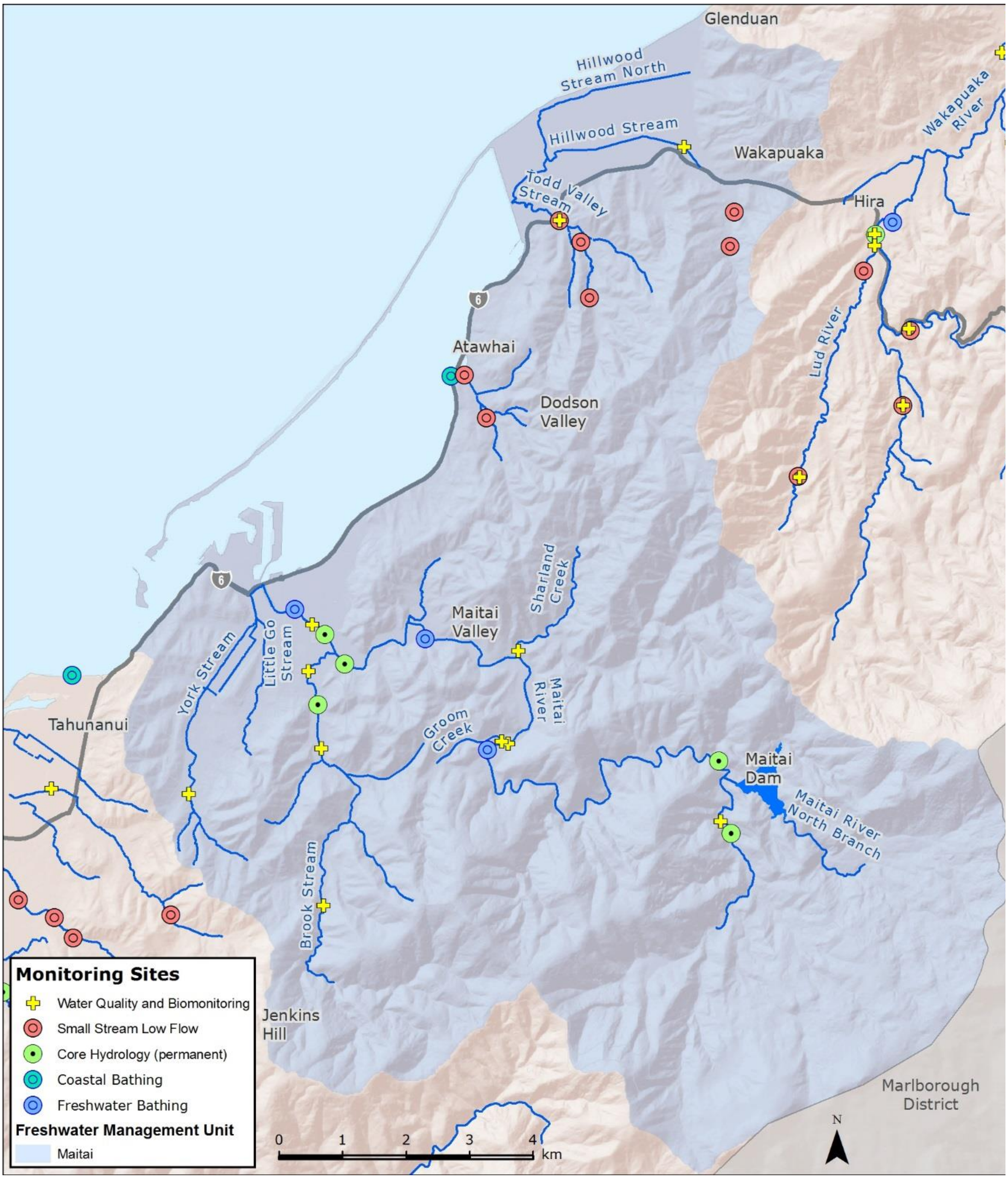
Figure 28. Dissolved reactive phosphorus (DRP) for the Groom at Maitai SOE monitoring site by flow category (low, moderate, high). DRP sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016. Boxes = 25th – 75th data percentiles, whiskers = 5th and 95th percentiles and mid-point line = mean.



Map 5. Land cover and land use in the Mahitahi/Maitai FMU, Nelson.



Map 6. Locations of sewerage and storm water infrastructure associated with waterbodies in Nelson.



Map 7. Monitoring sites in the Mahitahi/Maitai Freshwater Management Unit, Nelson.

Summary of water quality issues for the Mahitahi/Maitai

Ecosystem health:

1. The upper reaches of the Mahitahi/Maitai have the healthiest macroinvertebrate communities in the FMU, although ecosystem health downstream of the backfeed into the South Branch has significantly declined. The Brook at Motor Camp site consistently indicates excellent ecosystem health. The York has the worst ecological health in the FMU. The lower Brook, Mahitahi/Maitai, Hillwood and Todds all have fair ecological health, despite differences in catchment land use (urban vs. pastoral).

2. The middle and lower Brook and the Mahitahi/Maitai at Groom all exceed periphyton cover thresholds on occasion. This is consistent with the decline in macroinvertebrate health seen in The Brook and Mahitahi/Maitai at downstream sites. Periphyton is often dominated by *Phormidium* cyanobacteria in spring and summer, which adversely affects ecological, amenity, cultural and recreational values.

Faecal contaminants:

3. Very high levels of faecal contaminants found in the York, Hillwood and Todds Valley Streams. High *E. coli* under base flow conditions indicates point source discharges, sewer leakage or direct stock access issues as potential causes.

4. Swimming safety is affected by *E. coli* concentrations in the lower Brook, Mahitahi/Maitai and in the streams catchments mentioned above. The Collingwood Bridge site on the Mahitahi/Maitai regularly exceeds the safe swimming guideline.

Nutrient contaminants:

5. The Sharland and Groom have elevated nitrogen concentrations and increasing trends in nitrogen. All other sites have concentrations well below guidelines to manage nuisance periphyton growth. Nitrogen from the Sharland and Groom contributes significantly to loads in the Mahitahi/Maitai, possibly contributing to cyanobacteria blooms there.

6. Phosphorus is elevated throughout the Brook (even in the upper catchment), York and Todds Valley Streams. The Hillwood and Todds DRP concentrations are very high.

Sediment:

7. There are sediment and turbidity issues at base flows in Hillwood, York and Todds Valley Streams.

Summary of issues and potential causes:

8. York, Hillwood and Todds Valley Streams have poor water quality. The impacts of urban land use and landfills in the York are likely causes. Groom and Sharland tributaries contribute significantly to water quality decline in the lower Mahitahi/Maitai and potentially contribute to cyanobacterial blooms there. Sources of fine sediment and nitrogen are likely to arise from forestry and pastoral land use.

14 Wakapuaka Freshwater Management Unit

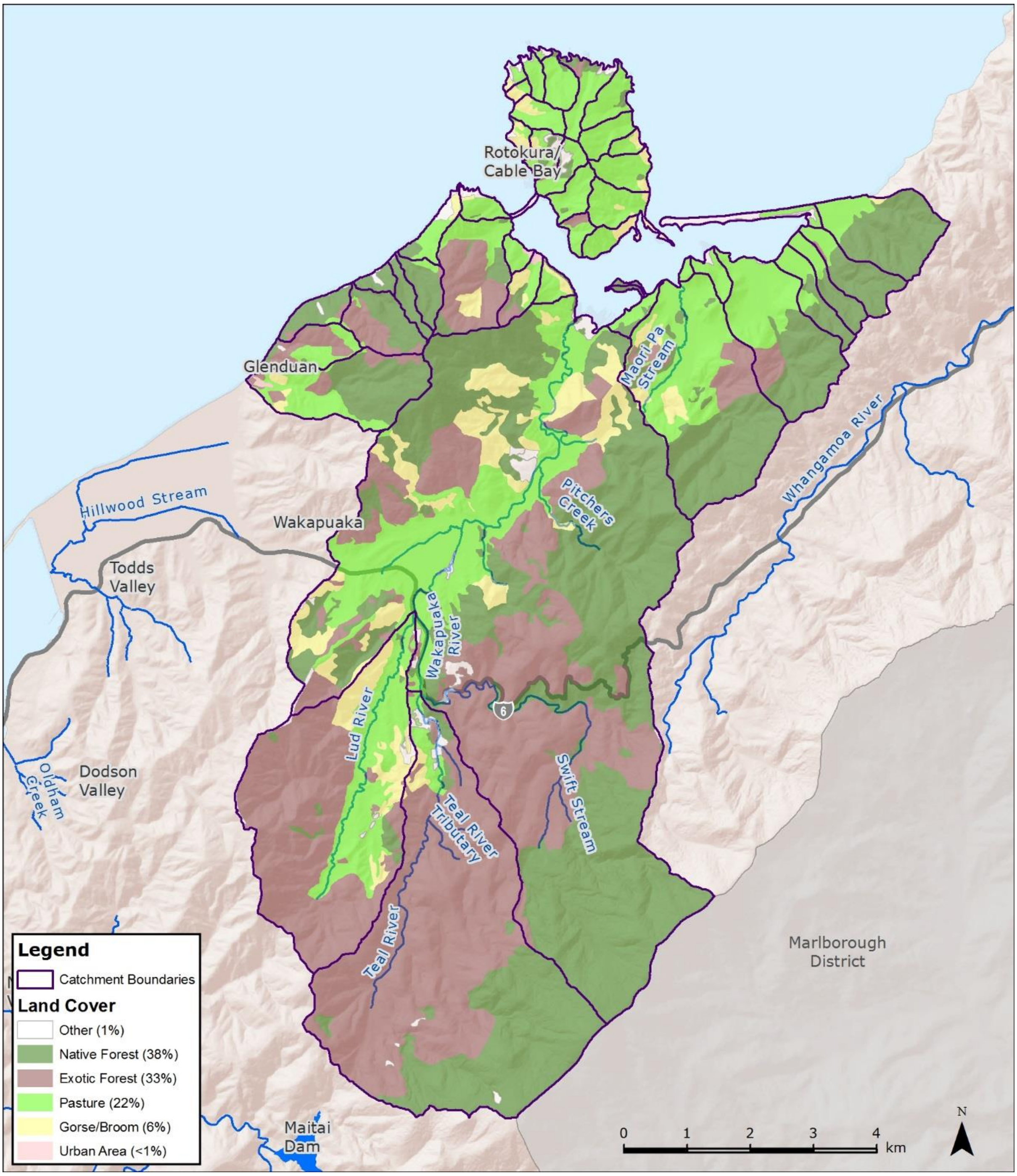
The Wakapuaka FMU sits to the North of the Mahitahi/Maitai FMU area and flows to the sea East of Pepin Island at Delaware Bay. The main tributaries of the Wakapuaka River are the Lud and Teal Rivers and the Swift Stream in the upper catchment. The Wakapuaka FMU is bisected by State Highway 6. Despite the FMU name, the Wakapuaka Flats are not included within the FMU area[25]. The total land area of the Wakapuaka FMU is 9,276ha.

The Lud and Teal Rivers drain most of the production forestry in the Wakapuaka FMU (Map 8). The catchment also has a large proportion of native forest. Pastoral land use, including a large number of small lifestyle blocks are the predominant land uses in the lower Lud and Wakapuaka (Table 10).

Table 10. Approximate land use proportions in the Wakapuaka FMU.

Land use type	Proportion of FMU area
Production (exotic) forest	40%
Native forest	37%
Pasture	15%
Gorse/broom	6%
Other	1%
Urban	<1%

[25] The Wakapuaka Flats are drained by the Hillwood Stream which forms the Northern area of the Mahitahi/Maitai FMU.



Map 8. Land cover and land use in the Wakapuaka FMU, Nelson.

Table 11. Summary of water quality and ecosystem health monitoring for all SOE sites in the Wakapuaka FMU.

Monitoring site	Human Health[26]	Ecosystem Health				
	E. coli	MCI	Peri-phyton[27]	Nitrate toxicity	N trophic risk[28]	P trophic risk[9]
Lud at 4.7km	Band C	Fair/Good	Good	Band A	Moderate	High
Lud at SH6	Band C	Good	Good	Band A	High	High
Teal at 1.9km	Band B	Excellent	Good	Band A	Low	Low
Wakapuaka at Duckpond	Band A	Excellent	Good	Band A	Low	Low
Wakapuaka at Hira	Band B	Excellent	Good	Band A	Low	Low
Pitchers at 890m	Band A	Excellent	Good	Band A	Low	High
Wakapuaka at Māori Pa	Band B	Good	Good	Band A	Low	Low

Table 12. Summary of trend information from LAWA (2015 data) for monitoring sites in the Wakapuaka FMU. Downward arrows indicate improvement, upward arrows indicate degradation.

Monitoring site	Human Health	Clarity		Nitrogen		Phosphorus
	E. coli	Black disc	Turb.	Total oxidised nitrogen	Ammonia-N	DRP
Lud at 4.7km	-	-	-	⇧	-	-
Lud at SH6	-	⇩	-	-	-	-
Teal at 1.9km	-	-	-	⇧	-	⇧
Wakapuaka at Duckpond	-	⇩	⇩	-	-	-
Wakapuaka at Hira	-	⇩	⇩	-	-	-
Pitchers at 890m	-	⇩	⇩	⇩	-	-
Wakapuaka at Māori Pā	-	⇩	⇩	-	-	-

26 Compared with NOF *E. coli* attribute states. The threshold between Bands B and C is the minimum acceptable state for primary contact recreation, e.g. swimming.
27 Based on annual PeriWCC % cover observations in relation to Ecosystem Health (Matheson et al. 2012) NOT NOF periphyton biomass objectives.
28 A coarse measure using the ANZECC lowland guidelines trigger values as a threshold between low and high trophic risk.

The key area of water quality problems is in the Lud catchment. Elevated faecal contaminants, soluble nitrogen and sediment in the Lud indicate contaminant effects characteristic of pastoral land use, unimpeded stock access (causing bank erosion) and a lack of riparian management (Table 11; Appendix 6). Elevated trophic state and adverse effects on contact recreation values are found in the Lud. Increasing nutrient trends in the Lud and Teal are also of concern (Table 12).

14.1 Faecal contaminants and flow in the Lud River

The upper Lud site at 4.7km shows elevated faecal contaminants at low *and* high flow categories (Figure 29), indicating inputs from direct and diffuse sources in the upper catchment area. At the State Highway 6 site on the Lud the highest concentrations of *E. coli* tend to be under high flows (Figure 30), with the exception of one very high reading in 2010 of 180,000 *E. coli*/100mls which was collected under low flow conditions. This indicates that direct sources may be more concentrated in the upper catchment and that diffuse run-off under rainfall events is the predominant source affecting the lower Lud site (Map 9). Elevated faecal contaminants in the Lud are likely to be the reason for the increases under high flows in the Wakapuaka at Hira (Figure 32) as contaminants are cumulatively washed down the catchment following rainfall. The Teal (Figure 31) also shows elevated faecal contaminants under high flows, riparian management may assist with improving this issue. Cumulatively the increases at high flows from all sites also affect the Wakapuaka at Māori Pā Road (Figure 33).

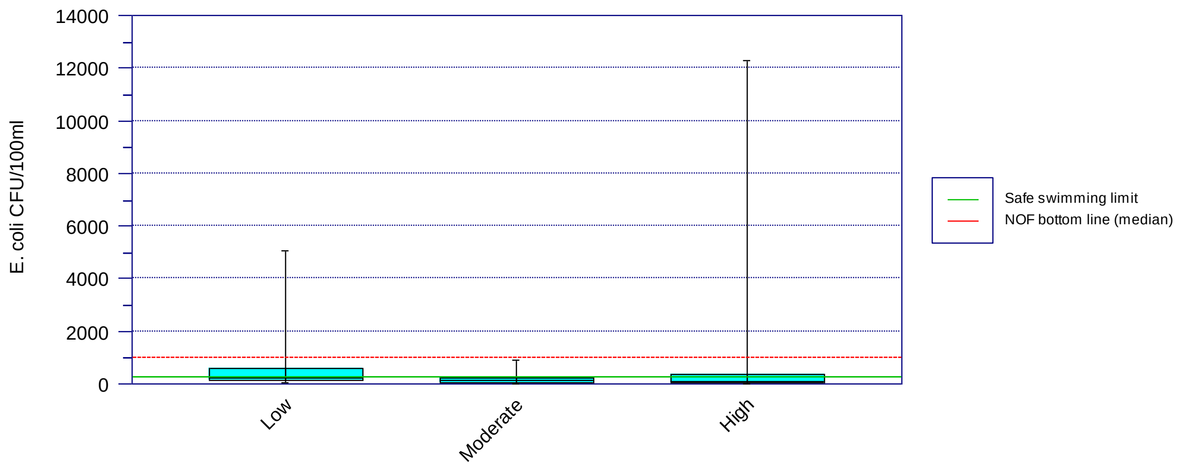


Figure 29. Escherichia coli (E. coli) for the Lud at 4.7km SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016.

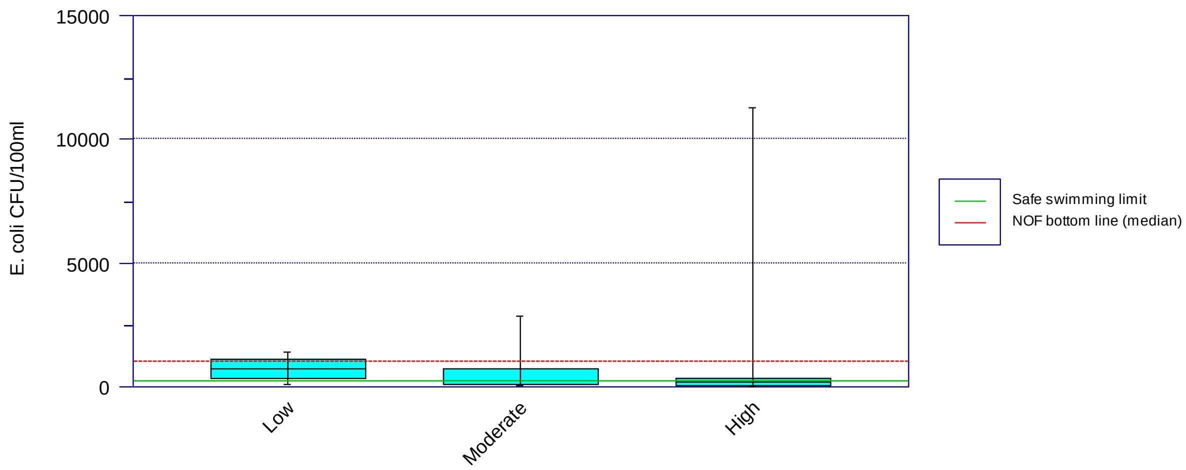


Figure 30. Escherichia coli (E. coli) for the Lud at State Highway 6 SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016. One observation excluded from 'Low' flow category (2/03/2010, E. coli = 180,000).

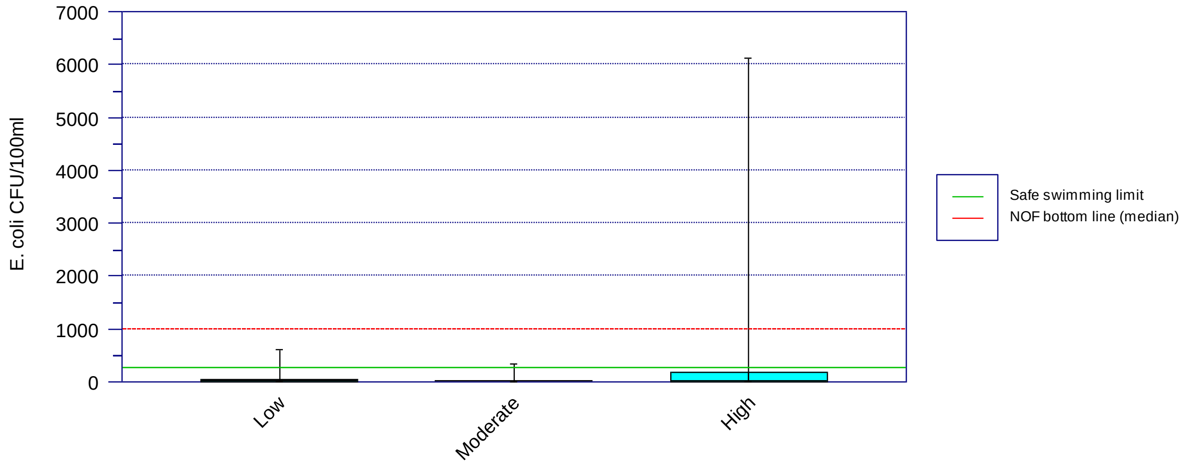


Figure 31. Escherichia coli (E. coli) for the Teal at 1.9km SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016.

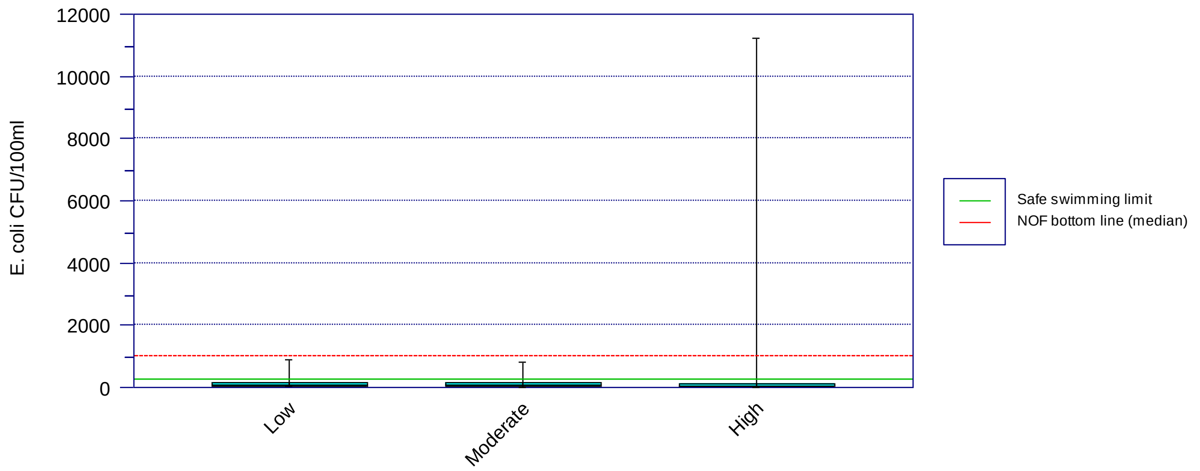


Figure 32. Escherichia coli (E. coli) for the Wakapuaka at Hira SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016.

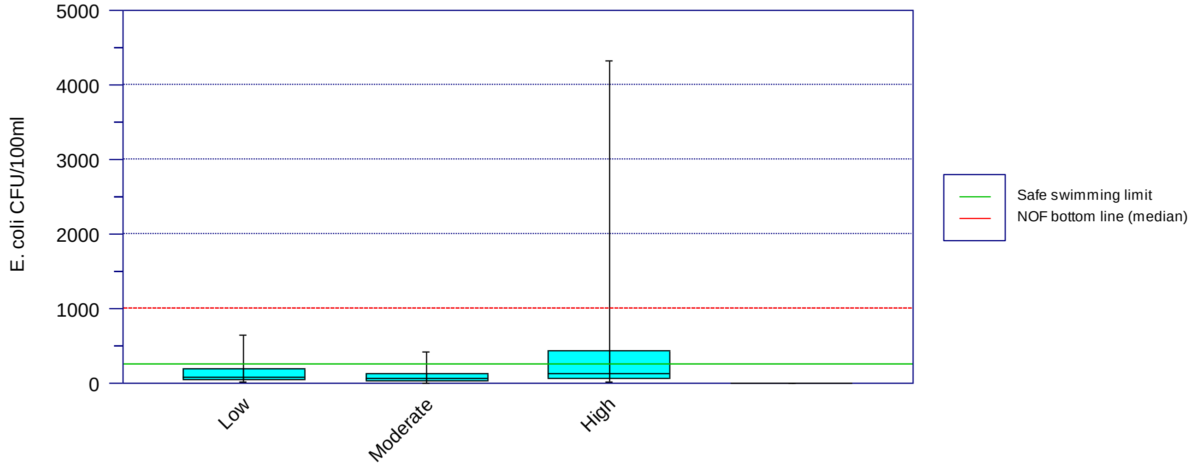
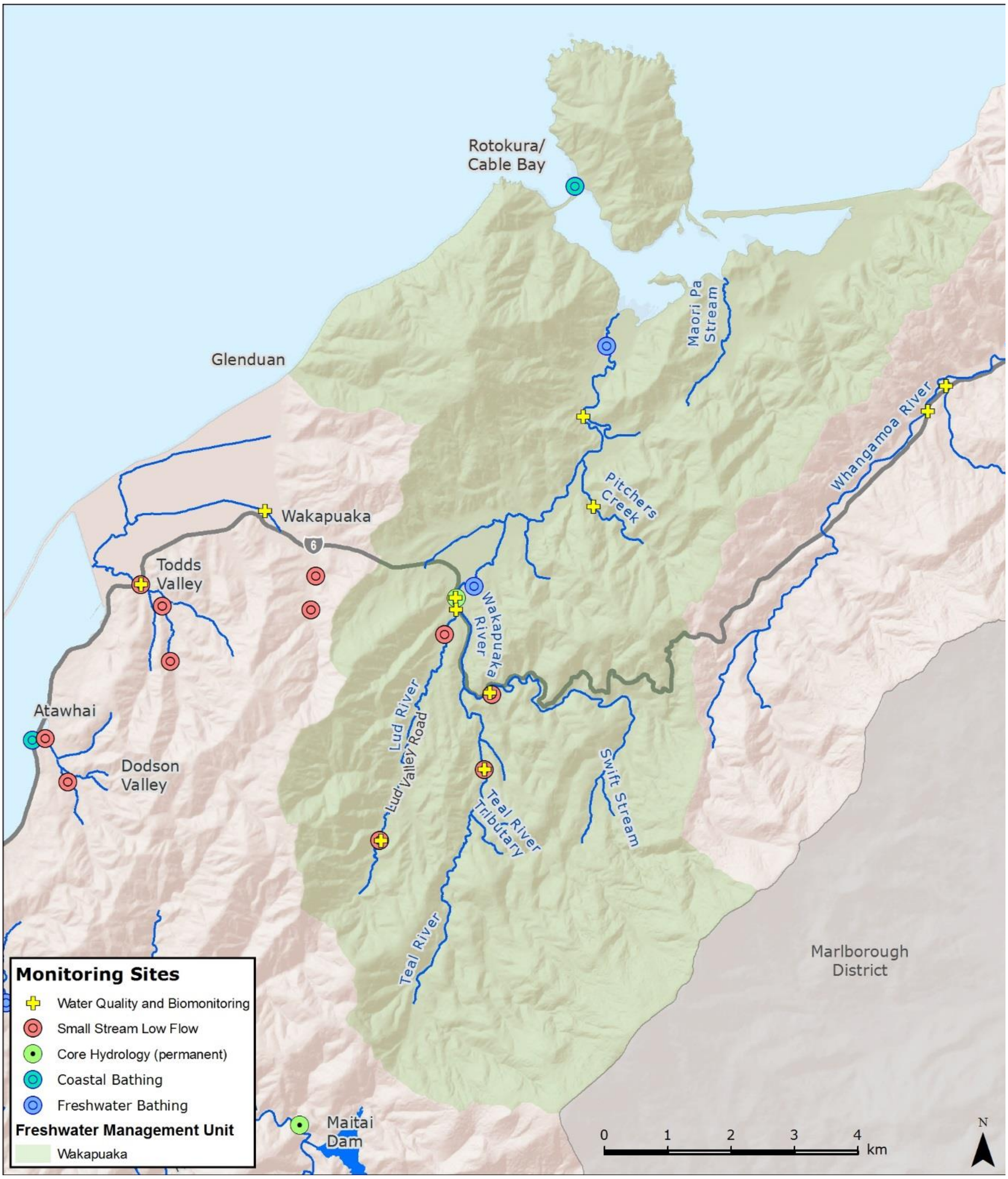


Figure 33. *Escherichia coli (E. coli)* for the Wakapuaka at Māori Pā Road SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016.



Map 9. Monitoring sites in the Wakapuaka Freshwater Management Unit, Nelson.

Summary of water quality issues for the Wakapuaka FMU

Ecosystem health:

1. The upper Wakapuaka has some of the healthiest macroinvertebrate communities in Nelson, indicating excellent water quality. The exception is the Lud tributary and the Māori Pa site at the bottom of the catchment which indicate good to fair ecological health, with occasional poor quality measured in the Lud.

2. Periphyton cover is generally low at all sites in the Wakapuaka FMU, based on annual observations. However, the Teal and Māori Pa sites have exceeded ecological and recreational guidelines for cover on at least one occasion. Increasing nutrient trends in the Teal may cause periphyton issues in future.

Faecal contaminants:

3. High levels of faecal contaminants were found in the Lud which effect safety for swimming and primary contact. Elevated *E. coli* under base flow and high flow conditions in combination with, the proportion of pastoral land use in the Lud catchment suggests direct stock access and a lack of riparian buffer to intercept contaminants during rainfall are the most likely combination of causes.

Nutrients:

4. Nitrogen is elevated in the Lud catchment and increases downstream. Concentrations exceed guidelines for ecosystem health. Nitrogen concentrations in the Lud and Teal are increasing over time. With the exception of the Lud the Wakapuaka has very low nitrogen concentrations.

5. Phosphorus is elevated throughout the Lud and Pitchers Streams. Analysis of DRP concentrations against flow and catchment geology is needed to understand whether this is driven solely by natural processes or exacerbated by land use practices. Elevated phosphorus and sediment in the Lud at low flows indicates pastoral contaminant losses and stock access.

Sediment:

6. Sediment and turbidity are much higher in the Lud catchment than at other sites in the Wakapuaka FMU. The causes of elevated sediment during baseflow sampling need to be investigated and are likely to be also associated with stock access to streams and streambank trampling and erosion.

Summary of issues and potential causes:

1. Water quality issues in the Lud, including elevated faecal contaminants, soluble nitrogen and sediment, that increases downstream indicate poor riparian management and contaminant losses characteristic of poorly managed pastoral land use. Further investigation and farm management plans are recommended for the Lud catchment to improve water quality there and reduce cumulative impacts on the Wakapuaka mainstem.

2. Increasing nutrient trends in the Teal catchment need to be monitored.

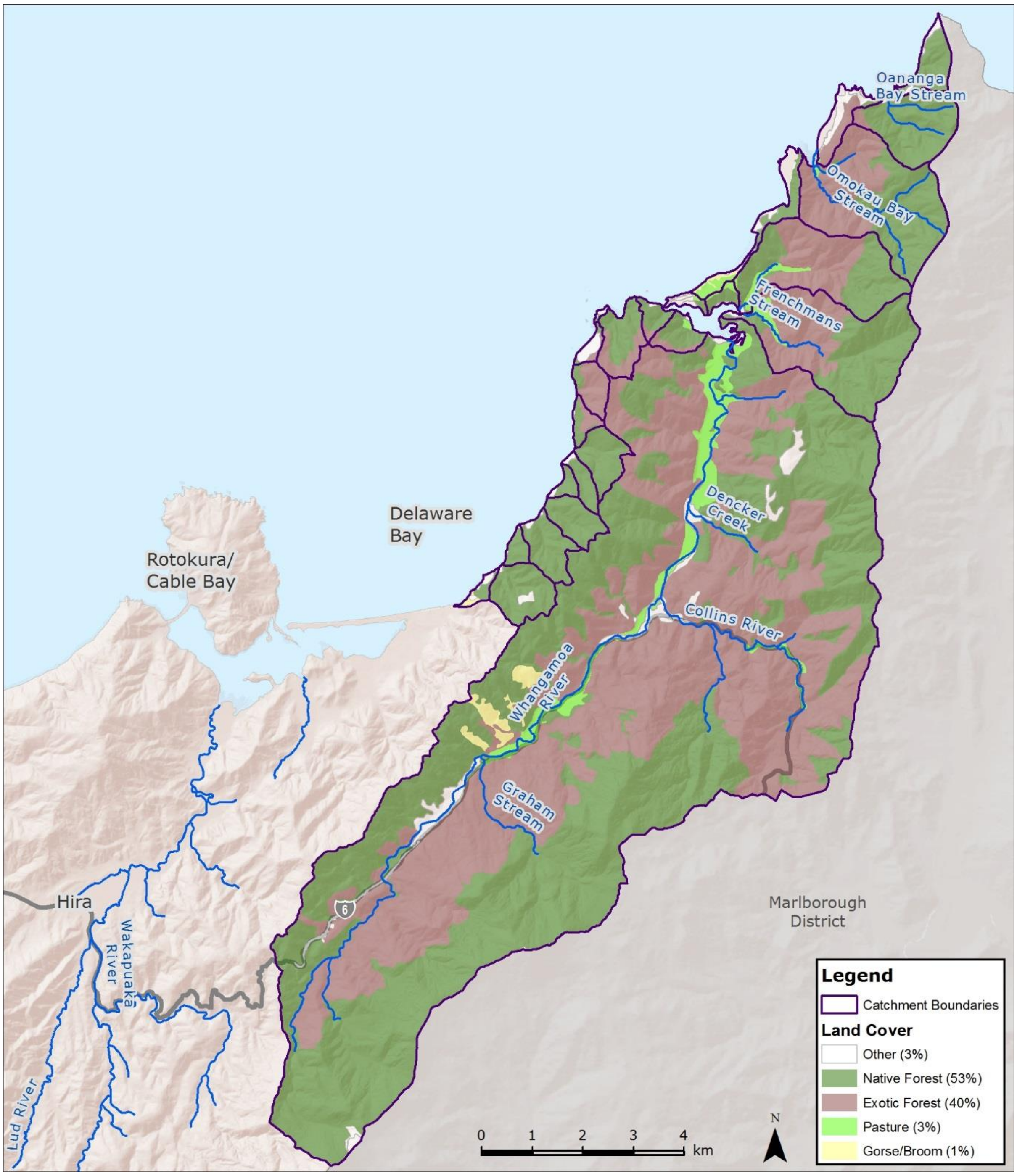
15 Whangamoa Freshwater Management Unit

The Whangamoa FMU is the most northerly of Nelson's FMUs and the Whangamoa is the second largest river catchment in Nelson. The Whangamoa flows into Tasman Bay at Kokorua Estuary. The main tributaries of the Whangamoa River are the Collins River in the mid catchment and Dencker and Graham streams are tributaries to the mid and upper catchment, respectively. State Highway 6 runs alongside the Whangamoa River through its middle reaches. A number of small coastal catchments to the north of the Whangamoa River are also within the FMU, including Frenchman's Stream and Omokau and Oananga Bay Streams. The total land area of the FMU is 11,224ha.

The large proportion of native forest in the Whangamoa FMU (Table 13) contributes to high water quality and the ecological health of the catchment (Table 14; Appendix 7). The Rai Forest is the main area of production forestry in the FMU (Map 10). Native forest is managed by the Department of Conservation and some areas in NCC Reserves. Improving trends in *E. coli* and clarity measures are evident at some sites (Table 15). Maintenance of water quality and ecosystem health is important.

Table 13. Approximate land use proportions in the Whangamoa FMU

Land use type	Proportion of FMU area
Native forest	52%
Production (exotic) forest	37%
Pasture	7%
Other	2%
Gorse/broom	1%
Urban	0%



Map 10. Land cover and land use in the Whangamoa FMU, Nelson.

Table 14. Summary of water quality and ecosystem health monitoring for all SOE sites in the Whangamoa FMU.

Monitoring site	Human Health[29]	Ecosystem Health				
	E. coli	MCI	Peri-phyton[30]	Nitrate toxicity	N trophic risk[31]	P trophic risk[31]
Whangamoa at Hippolite	Band A	Excellent	Good	Band A	Low	Low
Graham at SH6	Band A	Excellent	Good	Band A	Low	Low
Collins at SH6	Band B	Excellent	Good	Band A	Low	Low
Dencker at Kokorua	Band B	Excellent	Good	Band A	Low	Low
Whangamoa at Kokorua	Band B	Excellent/Good	Good	Band A	Low	Low

Table 15. Summary of trend information from LAWA (2015 data) for monitoring sites in the Whangamoa FMU. Downward facing arrows indicate improvement, upward arrows indicate degradation.

Monitoring site	Human Health	Clarity		Nitrogen		Phosphorus
	E. coli	Black disc	Turb.	Total oxidised nitrogen	Ammonia-N	DRP
Whangamoa at Hippolite	-	↓	↓	-	-	-
Graham at SH6	-	↓	-	-	-	-
Collins at SH6	-	↓	-	-	-	-
Dencker at Kokorua	↓	-	-	-	-	-
Whangamoa at Kokorua	↓	-	-	-	-	-

[29] Compared with NOF *E. coli* attribute states. The threshold between Bands B and C is the minimum acceptable state for swimming.
[30] Based on annual PeriWCC % cover observations in relation to Ecosystem Health (Matheson et al. 2012) NOT NOF periphyton biomass objectives.
[31] A coarse measure using the ANZECC lowland guidelines trigger values as a threshold between low and high trophic risk.

15.1 Faecal contaminants and flow in the Whangamoa FMU

Generally, faecal levels are safe for swimming and primary contact recreation in the Whangamoa FMU. However, contaminants increase with flow particularly in the Collins (Figure 34) and at the bottom of the catchment at the Kokorua monitoring site (Figure 35; Map 11). 'Freedom camping' and use of the roadside stopping area as a toilet has been anecdotally noted as a potential issue for the Graham Stream. Feral animals also contribute faecal contaminants to rivers and at high flows faeces are washed into the stream by rainfall. Faecal source tracking under these conditions is recommended to determine the key contaminant source.

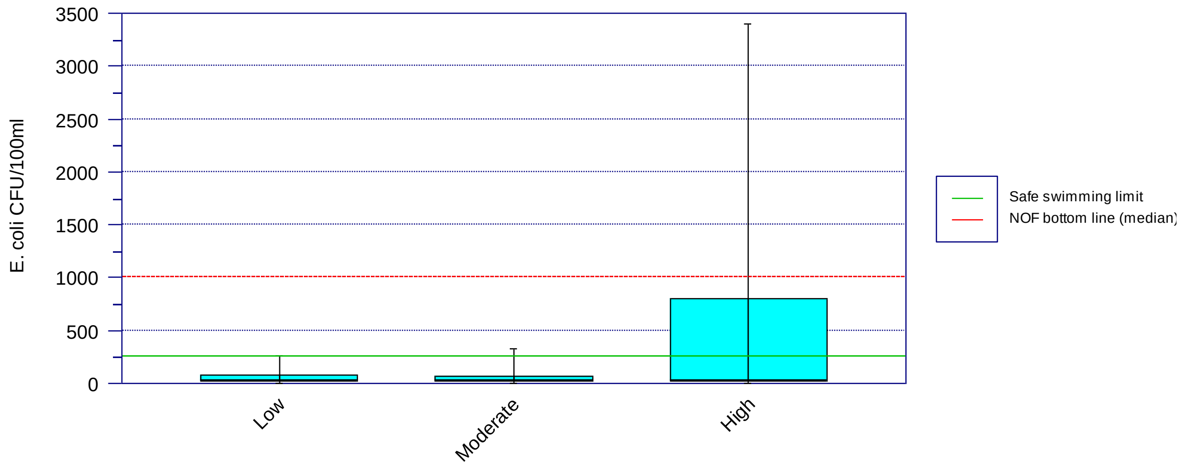


Figure 34. Escherichia coli (E. coli) for the Collins at State Highway 6 SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016.

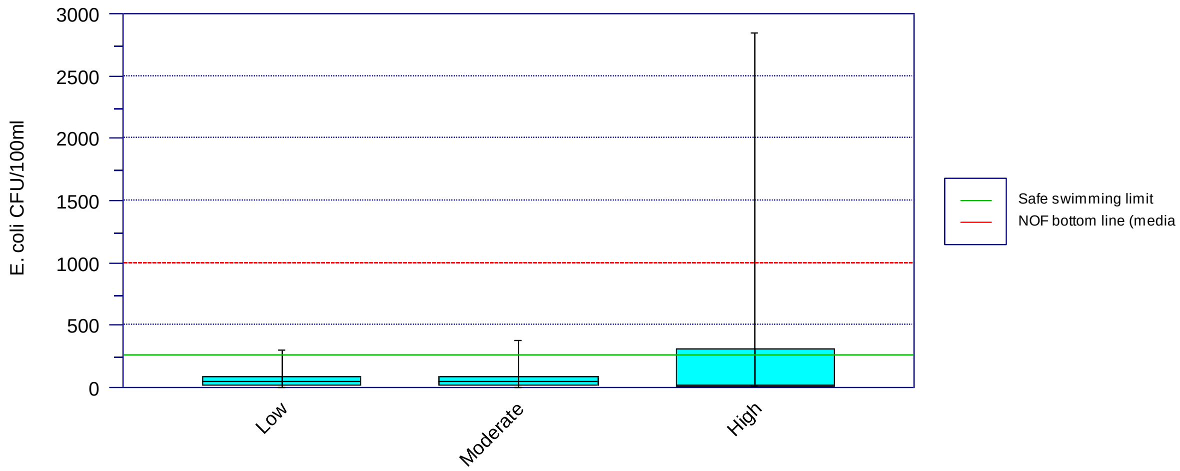
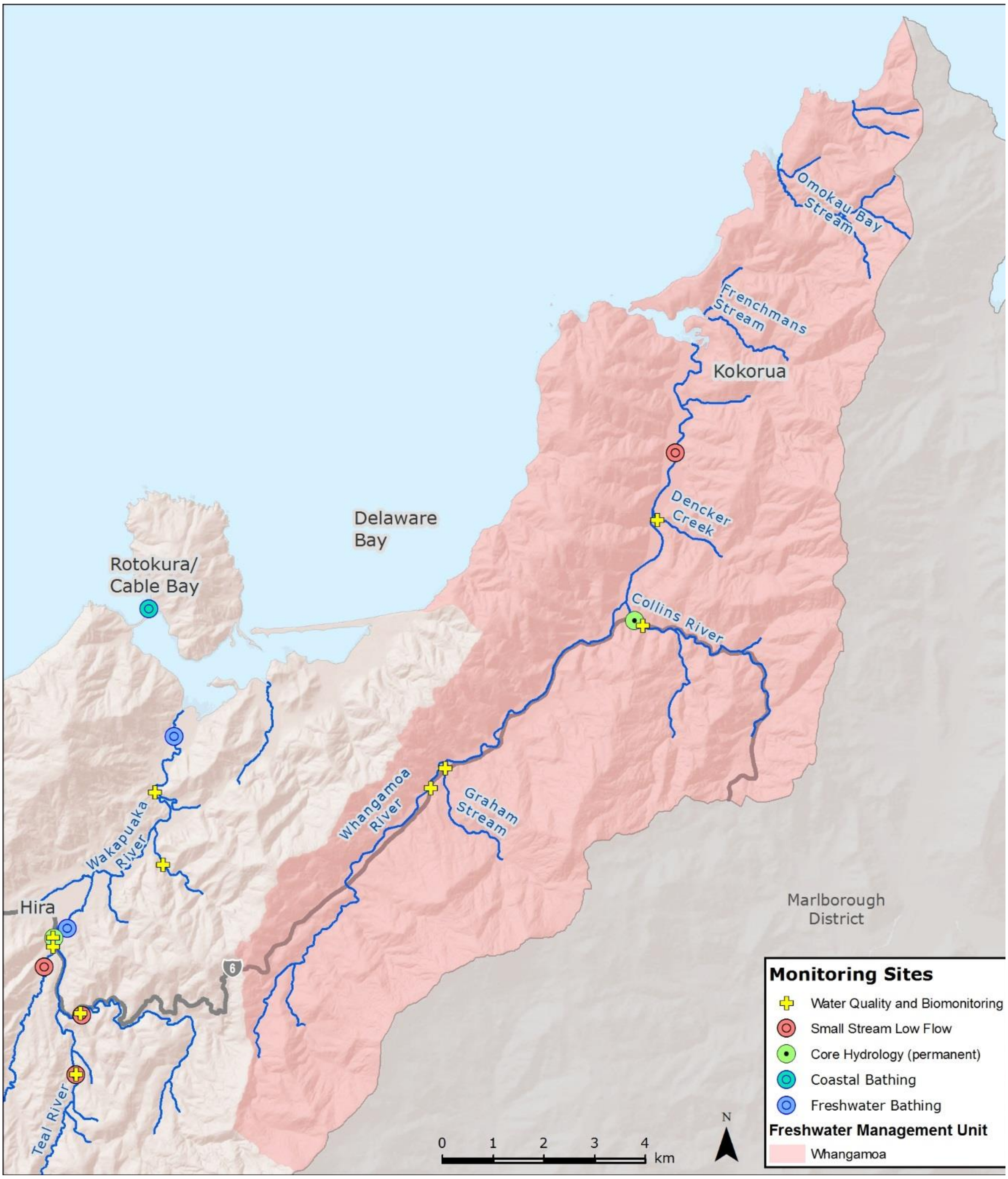


Figure 35. Escherichia coli (E. coli) for the Whangamoa at Kokorua SOE monitoring site by flow category (low, moderate, high). *E. coli* sampled quarterly at base flows between 2002 and 2014 and monthly under all flows between 2015 and July 2016.



Map 11. Monitoring sites in the Whangamoa Freshwater Management Unit, Nelson.

Summary of water quality issues for Whangamoa FMU

Ecosystem health:

1. The upper reaches of the Whangamoa have some of the healthiest macroinvertebrate communities in Nelson with all sites averaging at or above the threshold for excellent ecological health and clean water quality.

2. Annual periphyton cover is very low, only once exceeding the threshold for ecological condition at the bottom of the catchment. No samples exceeding the recreational threshold have been observed.

Faecal contaminants:

3. All sites are within primary contact limits almost all of the time. Dencker Creek is slightly elevated compared to the other sites and the Collins Stream is elevated under high flow conditions.

Nutrient contaminants:

4. The Whangamoa FMU has very low nitrogen and phosphorus concentrations throughout the catchment.

Sediment:

5. Turbidity and suspended sediment is relatively low at all sites. The Collins and Dencker tributaries have the highest observations within the Whangamoa FMU.

Summary of issues and potential causes:

6. Water quality and ecological health is very good in the Whangamoa FMU due to the high proportion of native forest in the catchment. Maintaining water quality is an important management consideration, particularly in relation to production forestry activities and current harvesting programme that has just begun.

16 Recommendations

Water quality and ecosystem health are generally good in the upper reaches of most catchments in Nelson and in areas with low resource pressure like the Whangamoa. However, the impacts of urban, pastoral and production forestry land uses are apparent in different waterways and declines in water quality at lower catchment sites are common. Declining water quality and ecosystem health require consideration within the 'maintain and improve' framework for water quality under the National Policy Statement for Freshwater Management and as a requirement of section 30 of the RMA.

Issues specific to each FMU and catchment are detailed below along with potential causes, based on data held by NCC and a review of current research reports. Better resolution of cause and effect relationships between land and resource use and water quality require more data collected over a range of flow conditions and on a more frequent basis. A comprehensive periphyton dataset and regular habitat assessment across the SOE network will also assist in measuring water quality against the National Objectives Framework and other relevant values, guidelines, limits and thresholds.

Management of fine sediment from production forestry is recommended for tributaries of the Mahitahi/Maitai, particularly the Sharland and Groom. Pastoral contaminant management is recommended for the lower Sharland, Saxton, Lud, Hillwood and Todds catchment areas in particular. Investigation and management of contaminants arising from urban stormwater, sewage overflow or discharges of landfill leachate are recommended for the York Stream, lower Mahitahi/Maitai River and Stoke streams.

16.1 Stoke FMU

Saxton Creek has some of the worst water quality in Nelson. Elevated nutrients, faecal contaminants and sediment are indicative of pastoral land use with unmanaged or unmitigated contaminant losses. Investigation associated with changes in land use is required. Urbanisation in the catchment and changes to the habitat to control flood risk are also major issues in the Saxton Creek and other Stoke streams.

Given their proximity to the Waimea inlet the Stoke Streams have high potential as habitats for indigenous biodiversity, particularly native fish. Urban impacts need strategic management in order to improve habitat over the long term. Sources of poor water quality need further investigation and remedial management.

16.2 Roding FMU

Little water quality monitoring has been undertaken in the Roding as NCC do not have an SOE monitoring site in the catchment. However, some data is collected on behalf of the infrastructure group for the water take consent compliance and monitoring purposes. Biomonitoring of the water take consent shows significant increasing trends in ecosystem health downstream of the water take since 2002. Data collected by Tasman District Council for the Roding at Twin Bridges site, downstream of the NCC boundary shows faecal pathogens are very low and the Roding is almost always suitable for primary contact recreation, with water clarity and fine sediment also indicating good to excellent water quality. Although there is some periphyton growth, macroinvertebrates are usually in a good state with MCI greater than 100.

16.3 Mahitahi/Maitai FMU

The Groom and Sharland tributaries contribute significantly to water quality decline in the lower Mahitahi/Maitai and potentially increase cyanobacteria blooms there. Fine sediment and nitrogen are sourced from forestry and pastoral land use. Safe contact recreation in the lower Mahitahi/Maitai also requires continued management intervention to improve the stormwater and sewage network function. The York, Hillwood and Todds Streams have poor water quality. The impacts of urban land use and landfills in the York needs addressing and pastoral land use in the Todds and Hillwood Streams requires management intervention.

16.4 Wakapuaka FMU

Water quality issues in the Lud including elevated faecal contaminants, soluble nitrogen and sediment indicates contaminant losses characteristic of pastoral land use and poor riparian management. Increasing nutrient trends in the Teal need to be watched. Little is known about the ecosystem health or water quality of the Māori Pa Stream, investigation is recommended.

16.5 Whangamoa FMU

Water quality and ecological health is very good in the Whangamoa FMU due to the high proportion of native forest in the catchment. Maintenance of water quality is the key consideration for management. Collins Stream shows some issues associated with faecal contamination at high flows.

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Appendix 1. Periphyton filamentous and mat cover data – all Nelson sites

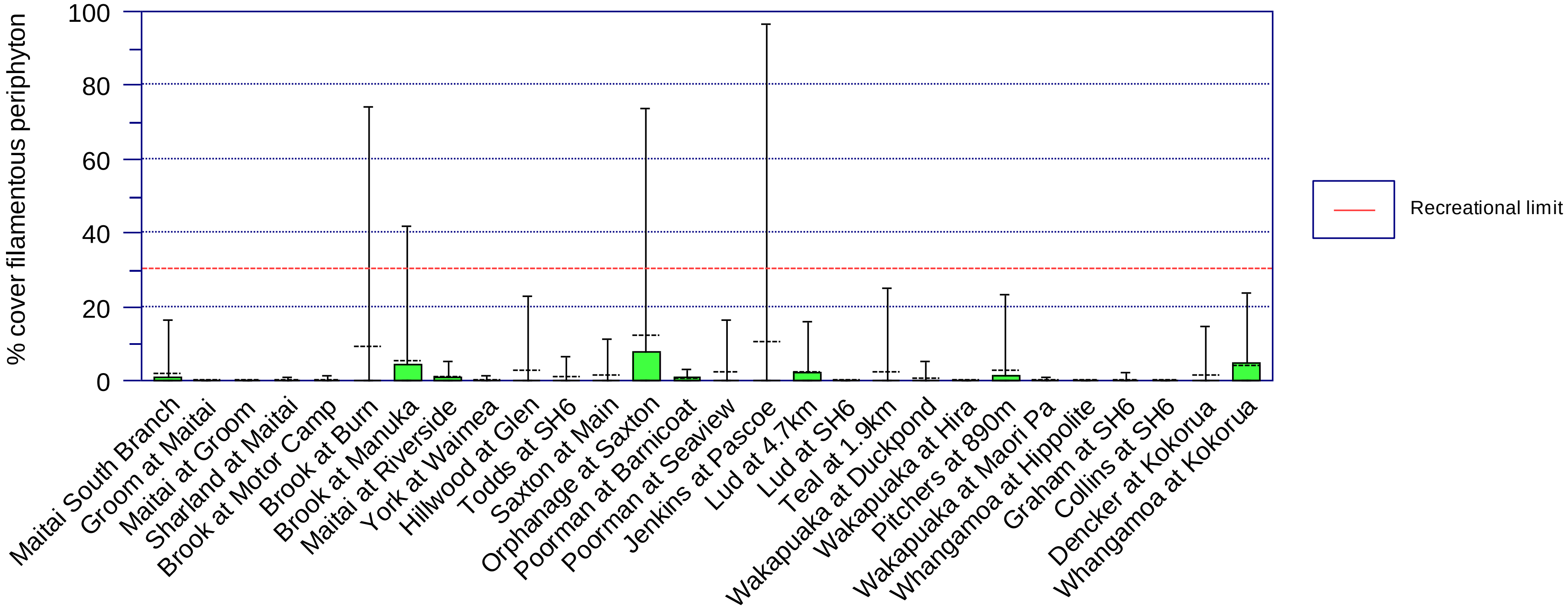

Figure 1. Percent cover by filamentous periphyton for all monitoring sites in Nelson. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. N = 13 (except Teal, Pitchers and Whangamoa sites where N = 12).

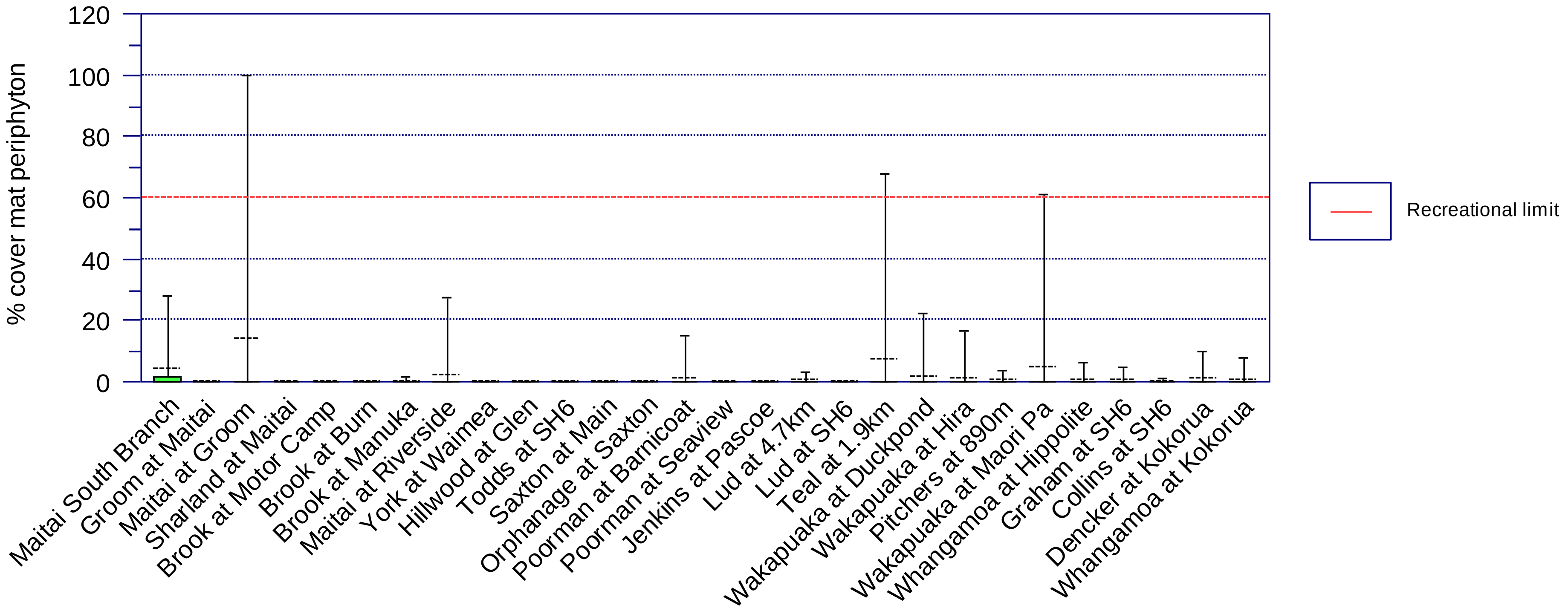

Figure 2. Percent cover by mat periphyton for all monitoring sites in Nelson. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. N = 13 (except Teal, Pitchers and Whangamoa sites where N = 12).

Appendix 2. Flow percentile estimates

Table 1. Estimates and flow sites used to determine flow durations percentiles for water quality SOE water quality sites in Nelson rivers and streams.

SOE site	Method used for flow percentile estimation
Orphanage at Saxton Rd East	Direct from Nearby Orphanage Flow Recorder
Poorman at Seaview Rd	Flow Gauging
Jenkins at Pascoe St	Flow Gauging
Poorman at Barnicoat	Flow Gauging
York at Waimea Rd	Flow Gauging
Brook at Manuka St	Direct from Nearby Seymour Ave Recorder
Brook at Burn Pl	Direct from Nearby Seymour Ave Recorder
Brook at Motor Camp	Flow Gauging
Maitai at Riverside	Direct from Nearby Maitai at Avon Tce Recorder
Maitai at Groom Rd	Flow Gauging
Maitai South Branch at Intake	Direct from Maitai South Recorder
Sharland at Maitai Confluence	Flow Gauging
Groom at Maitai Confluence	Flow Gauging
Todds at SH6	Flow Gauging
Hillwood at Glen Rd	Poor Relationship with Wakapuaka at Hira
Wakapuaka at Maori Pa Rd	Flow Gauging
Wakapuaka at Hira	Direct from Wakapuaka at Hira Recorder
Wakapuaka at Duckpond Rd	Flow Gauging
Lud at SH6	Flow Gauging
Lud at 4.7km	Flow Gauging
Teal at 1.9km	Flow Gauging
Whangamoa at Kokorua Bridge	Flow Gauging
Whangamoa at Hippolite Rd	Flow Gauging
Graham at SH6	Flow Gauging
Collins at SH6	Direct from Nearby Collins Recorder
Dencker at Kokorua Rd	Flow Gauging

Appendix 3. Native fish species-distribution across Nelson waterways. ***Source: The Catalyst Group (2015[32]).***

FMU	Waterways	Reaches	Shortfin eel	Longfin eel	Torrentfish	Giant kōkopu	Kōaro	Banded kōkopu	Īnanga	Shortjaw kōkopu	Lamprey	Upland bully	Common bully	Giant bully	Bluegill bully	Redfin bully	Black flounder
1	Roding River			✓	✓		✓					✓				✓	
2	Saxton Creek		✓	✓			✓	✓	✓				✓			✓	
	Orchard Stream		✓	✓			✓	✓	✓				✓	✓			
	Orphanage Stream		✓	✓	✓	✓	✓	✓	✓				✓	✓		✓	✓
	Poorman Valley Stream		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Jenkins Creek		✓	✓			✓	✓	✓			✓	✓			✓	
3	Mahitahi/Maitai River	Mainstem	✓	✓	✓		✓	✓	✓			✓	✓	✓		✓	✓
		North branch		✓			✓					✓				✓	
		South branch		✓			✓					✓	✓			✓	
		The Brook	✓	✓	✓		✓	✓	✓			✓	✓			✓	
		Sharland/Packer		✓	✓							✓				✓	

[32] The Catalyst Group 2015. Aquatic Site of Significance: Document in support of the Nelson Plan water management framework. The Catalyst Group Report No. 2015/031. Prepared for Nelson City Council.

FMU	Waterways	Reaches	Shortfin eel	Longfin eel	Torrentfish	Giant kōkopu	Kōaro	Banded kōkopu	Īnanga	Shortjaw kōkopu	Lamprey	Upland bully	Common bully	Giant bully	Bluegill bully	Redfin bully	Black flounder
		York		✓	✓			✓									
	Oldham Creek		✓	✓			✓		✓			✓					
	Todds Valley Stream		✓	✓			✓	✓	✓				✓			✓	
	Hillwood Stream 2																
4	Wakapuaka River	Mainstem		✓	✓		✓		✓			✓	✓	✓		✓	
		Lud		✓								✓	✓	✓		✓	
		Teal		✓			✓					✓					
5	Whangamoa River	Mainstem		✓												✓	
		Collins		✓				✓	✓		✓				✓	✓	
		Graham		✓			✓										
	Frenchmans streams			✓					✓							✓	

Appendix 4. Stoke FMU water quality data

Ecological Health

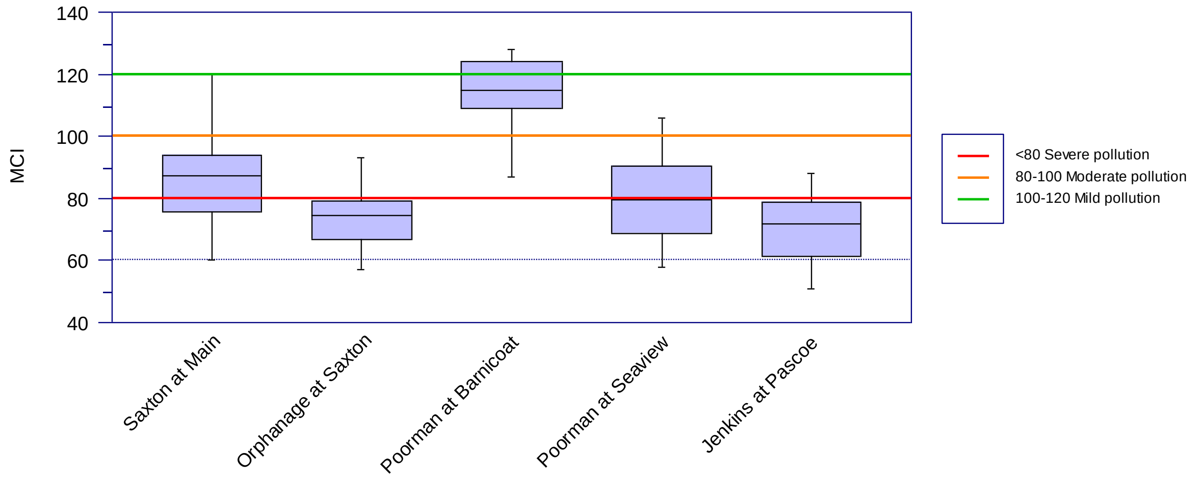

Figure 1. Macroinvertebrate community index (MCI) for monitoring sites in the Stoke FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. MCI scores >120 indicate clean water. N = 13.

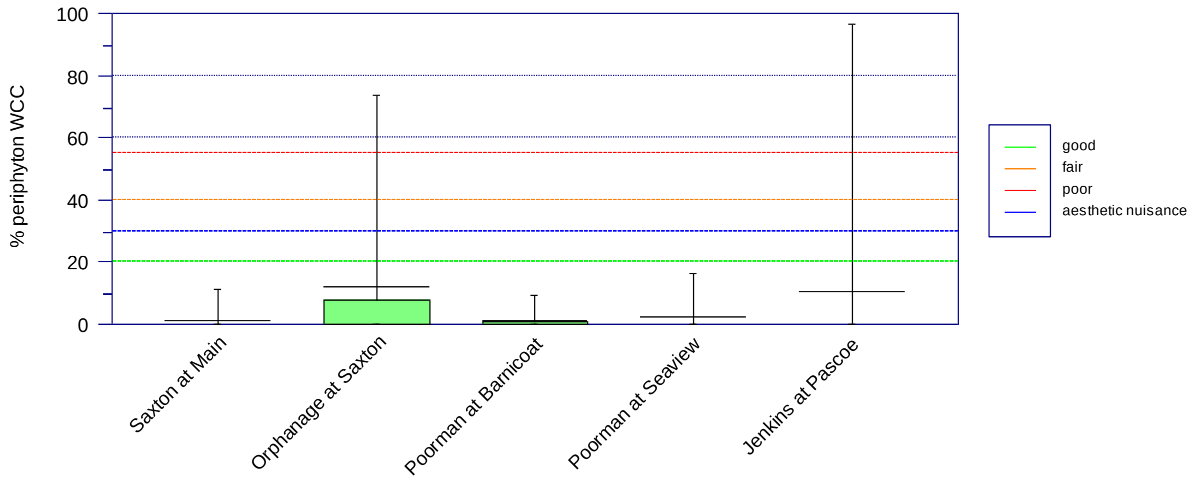

Figure 2. Percent cover by periphyton using weighted composite cover (WCC) method for annual visual assessment observations between 2002 and 2014 for the Stoke FMU, Nelson. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. 'Good', 'fair' and 'poor' are indicators of ecological condition and <20% cover = 'excellent' ecological condition. N=13.

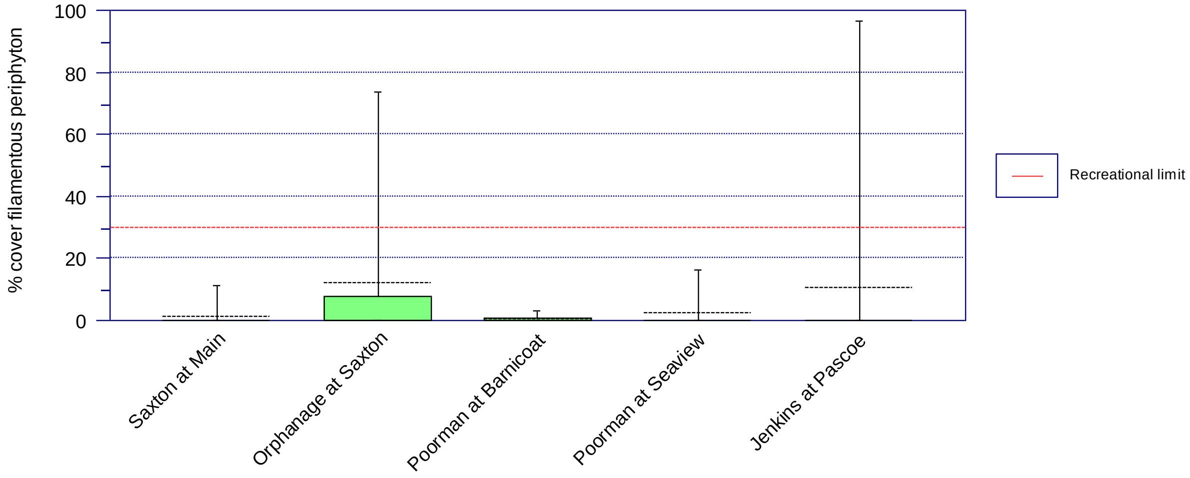

Figure 3. Percent cover by filamentous periphyton for monitoring sites in the Stoke FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. N = 13.

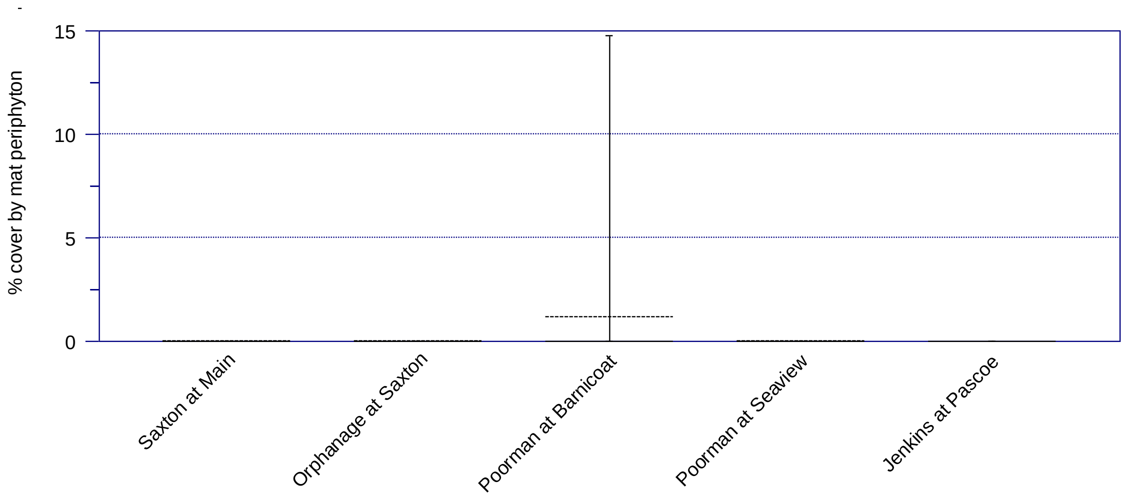

Figure 4. Percent cover by mat periphyton for monitoring sites in the Stoke FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. N = 13. Recreational limit = 60%.

Faecal contaminants

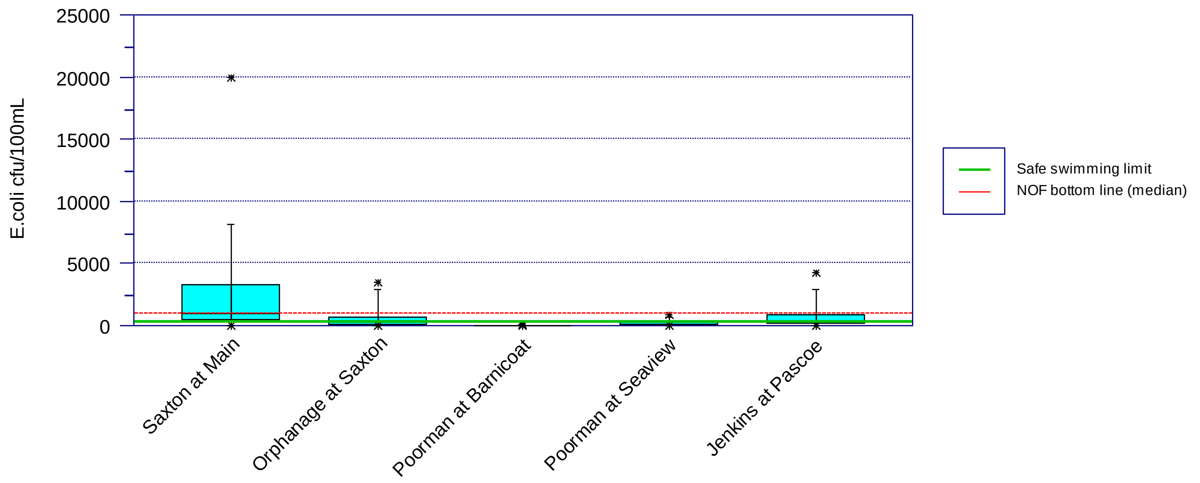

Figure 5. Escherichia coli (E.coli) cfu/100ml for SOE monitoring sites in the Stoke FMU, Nelson.

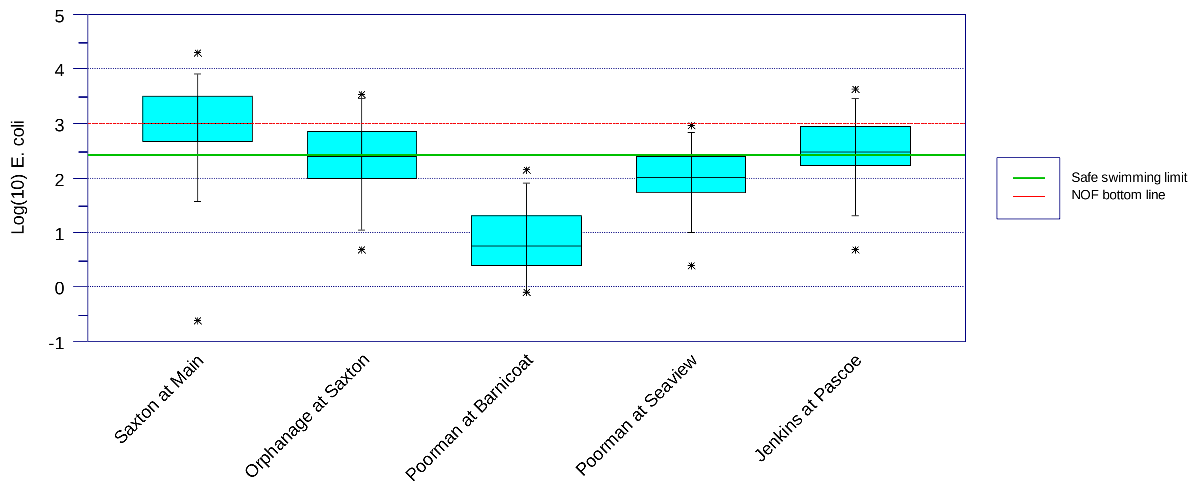

Figure 6. Log_{10} Escherichia coli (E.coli) cfu/100ml for SOE monitoring sites in the Stoke FMU, Nelson.

Nutrients

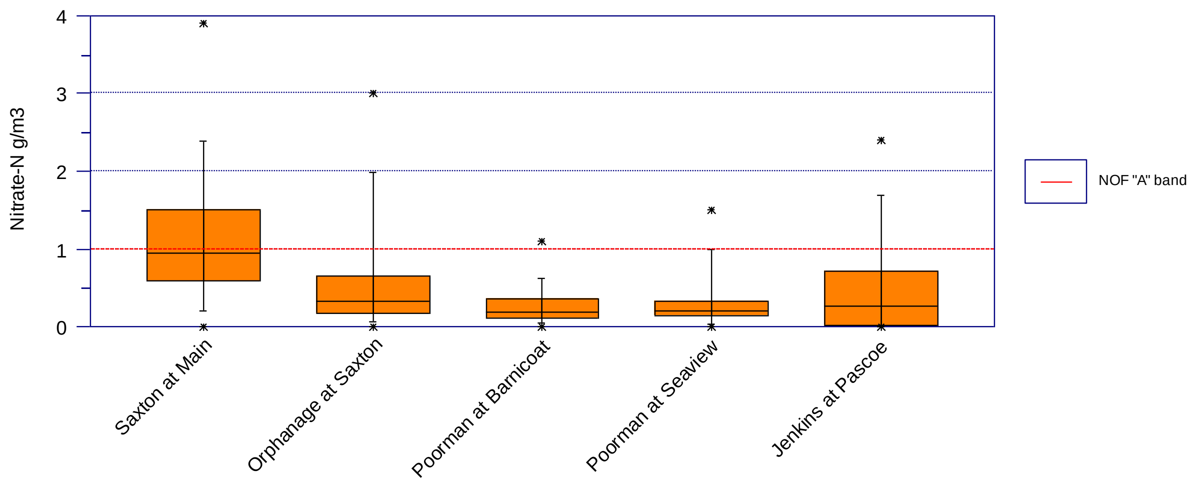

Figure 7. Nitrate nitrogen concentration (g/m^3) for monitoring sites in the Stoke FMU, Nelson.

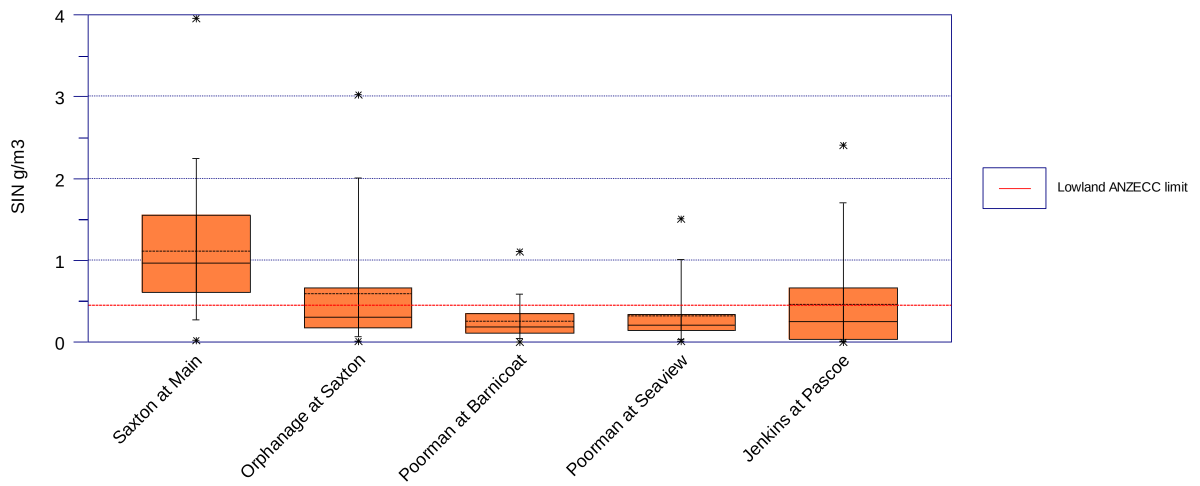

Figure 8. Soluble inorganic nitrogen (SIN) concentration g/m^3 for monitoring sites in the Stoke FMU, Nelson.

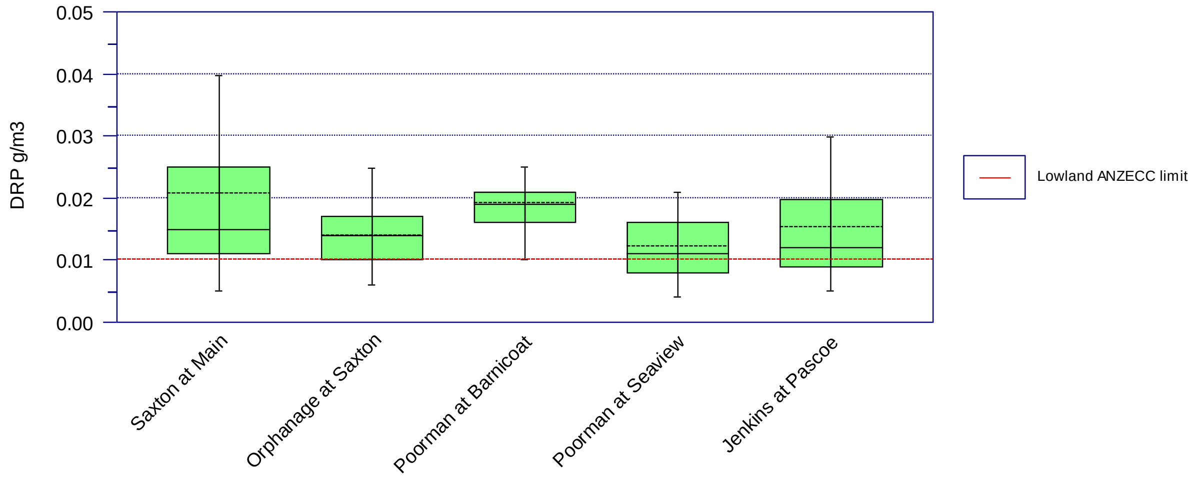

Figure 9. Dissolved reactive phosphorus (DRP) concentration g/m^3 for monitoring sites in the Stoke FMU, Nelson.

Sediment

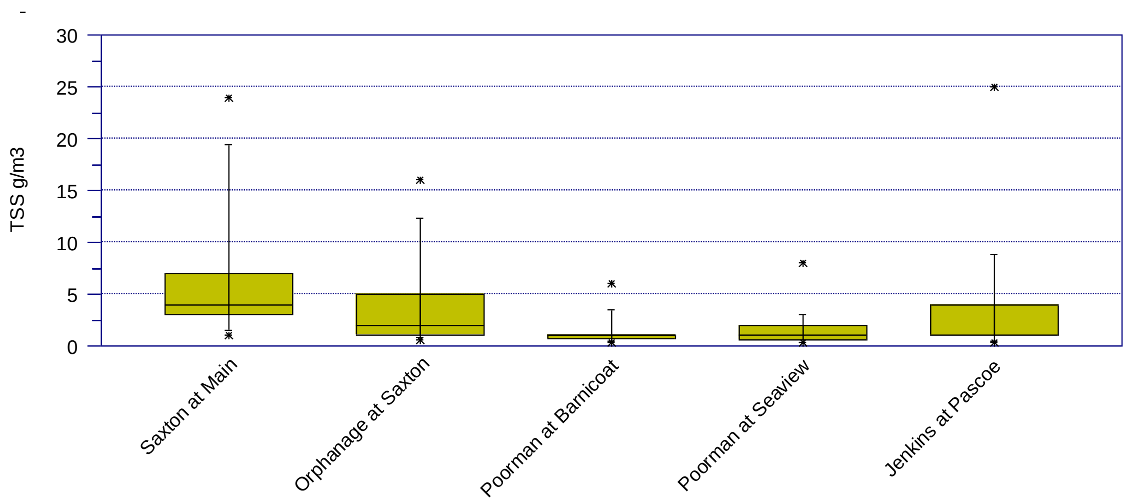

Figure 10. Total suspended sediment (TSS) concentration in g/m^3 for monitoring sites in the Stoke FMU, Nelson.

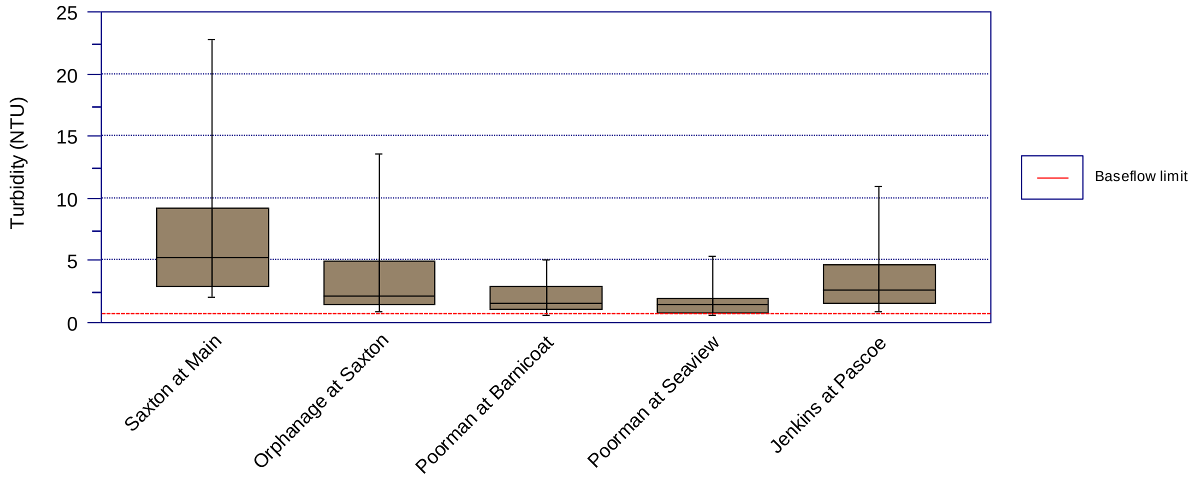

Figure 11. Turbidity (NTU) for monitoring sites in the Stoke FMU, Nelson. The baseflow turbidity limit is sourced from Hay et al. (2006)[33].

[33] Hay J, Hayes, JW and Young R. 2006. Water quality guidelines to protect trout fishery values. Cawthron Report No. 1205. Prepared for Horizons Regional Council.

Appendix 5. Mahitahi/Maitai FMU water quality data

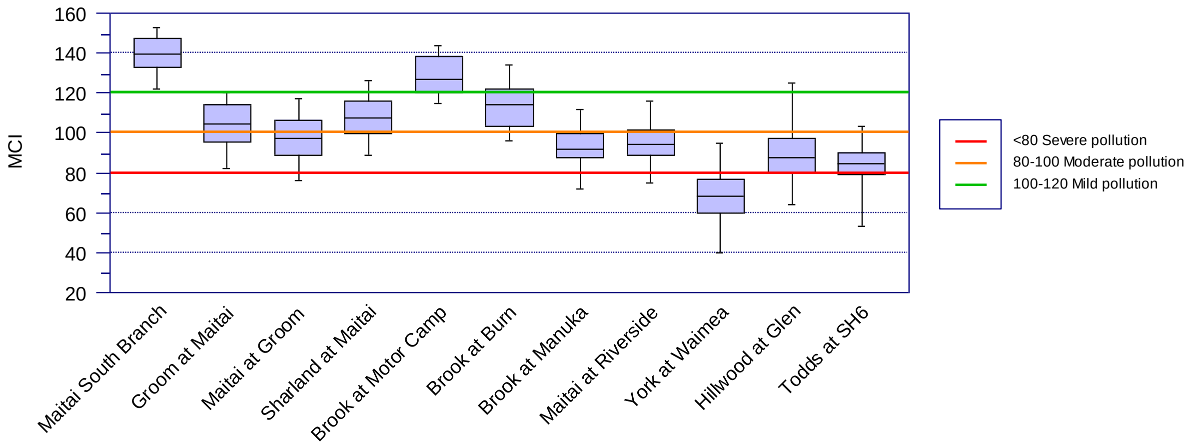

Figure 1. Macroinvertebrate community index (MCI) for monitoring sites in the Mahitahi/Maitai FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. MCI scores >120 indicate clean water. N = 13.

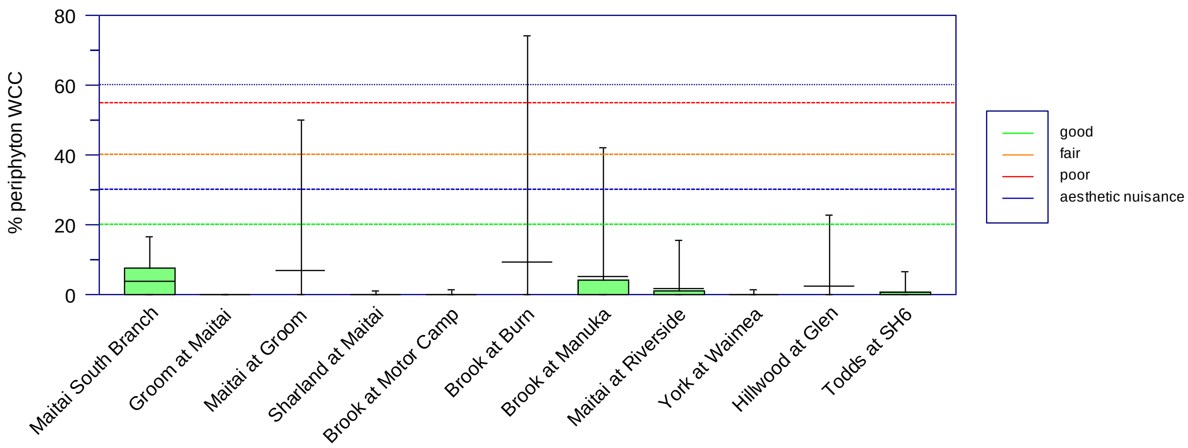

Figure 2. Percent cover by periphyton using weighted composite cover (WCC) method for annual visual assessment observations between 2002 and 2014 for the Mahitahi/Maitai FMU, Nelson. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. 'Good', 'fair' and 'poor' are indicators of ecological condition and <20% cover = 'excellent' ecological condition. N=13.

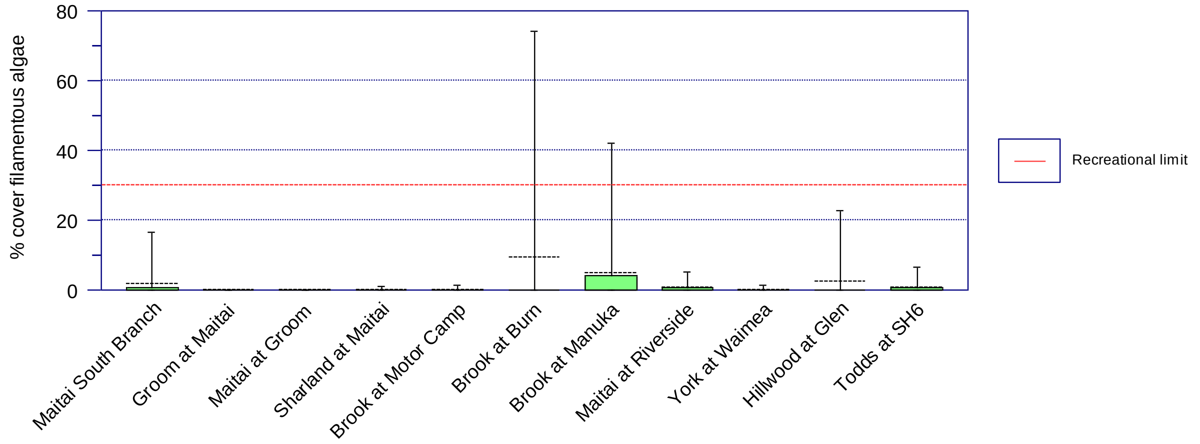

Figure 3. Per cent cover by filamentous periphyton for monitoring sites in the Mahitahi/Maitai FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = median, dashed midpoint line = mean. N = 13.

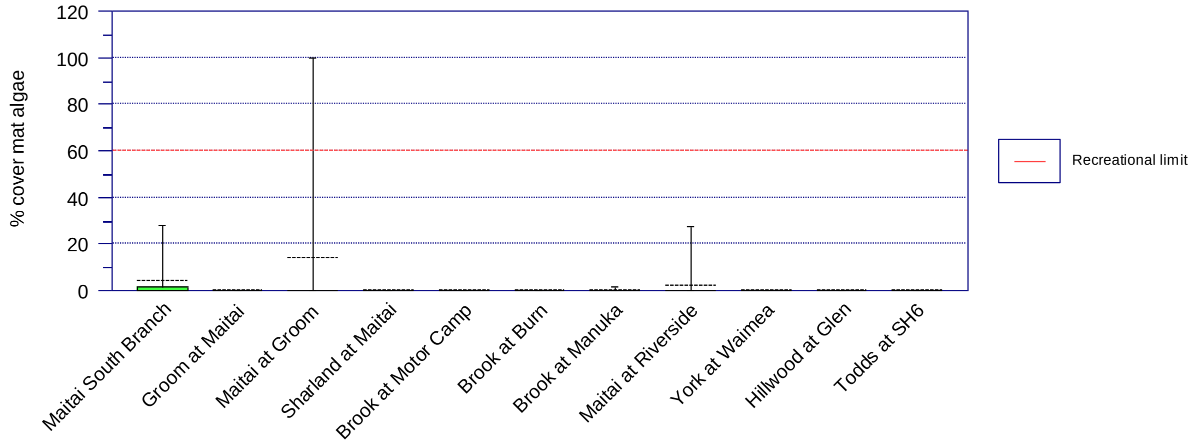

Figure 4. Per cent cover by mat periphyton for monitoring sites in the Mahitahi/Maitai FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = median, dashed midpoint line = mean. N = 13.

Faecal contaminants

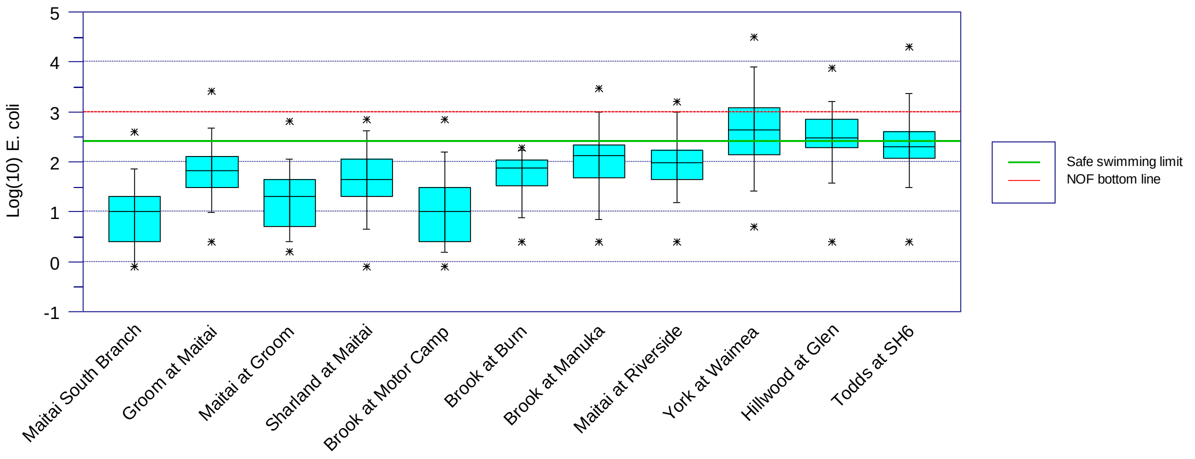

Figure 5. *Log$_{10}$ Escherichia coli (E. coli)* CFU/100ml for SOE monitoring sites in the Mahitahi/Maitai FMU, Nelson.

Nutrient contaminants

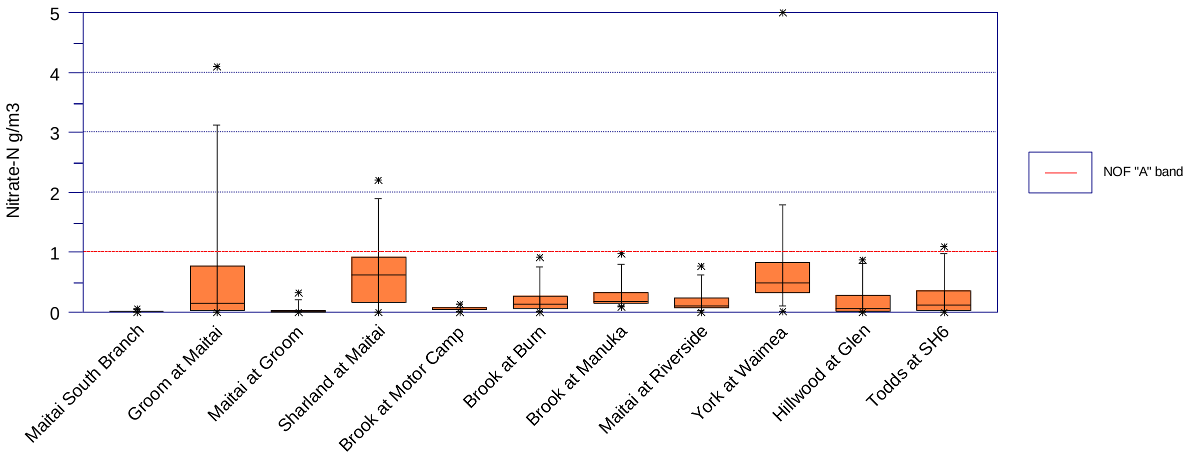

Figure 6. Nitrate-nitrogen concentration (g/m^3) for monitoring sites in the Mahitahi/Maitai FMU, Nelson.

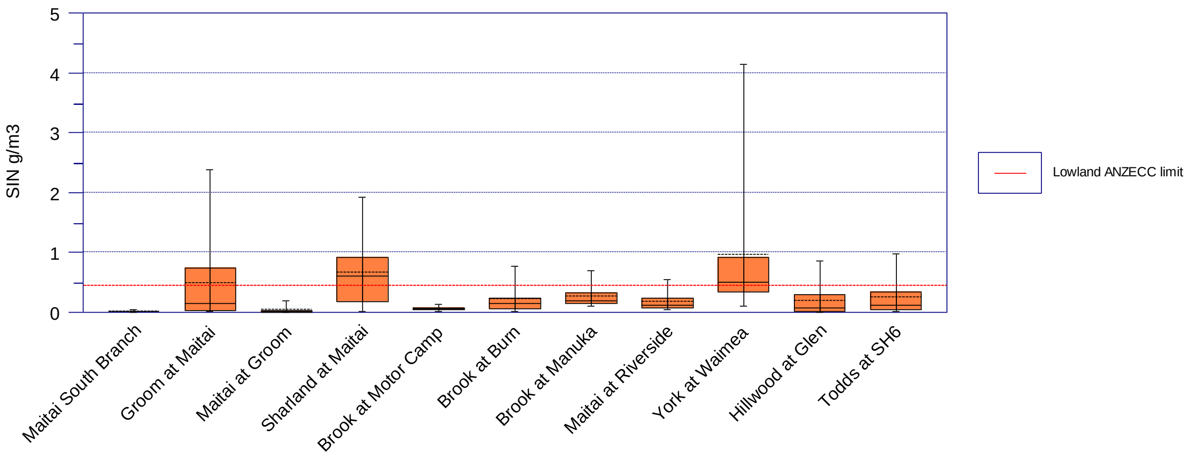

Figure 7. Soluble inorganic nitrogen (SIN) concentration g/m^3 for monitoring sites in the Mahitahi/Maitai FMU, Nelson.

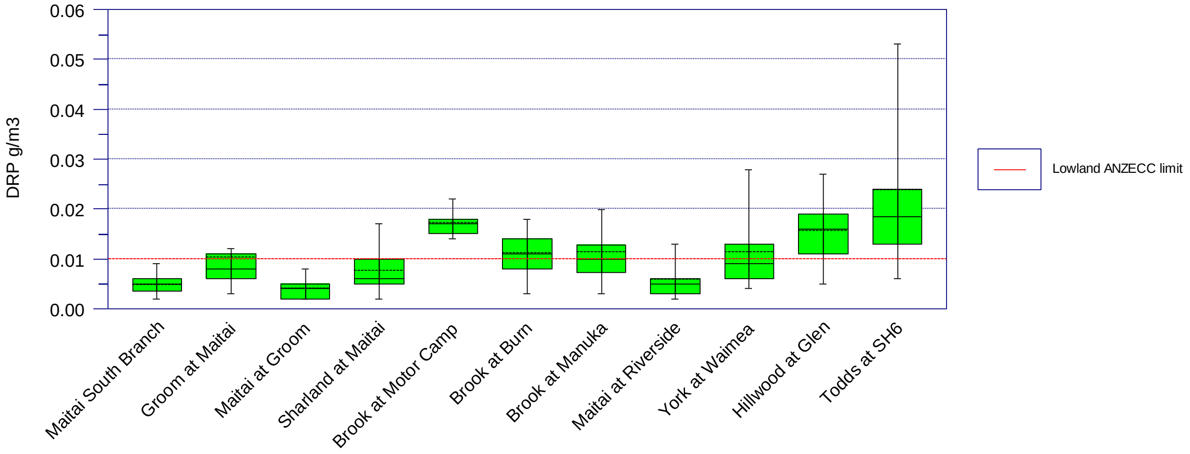

Figure 8. Dissolved reactive phosphorus (DRP) concentration g/m^3 for monitoring sites in the Mahitahi/Maitai FMU, Nelson.

Sediment

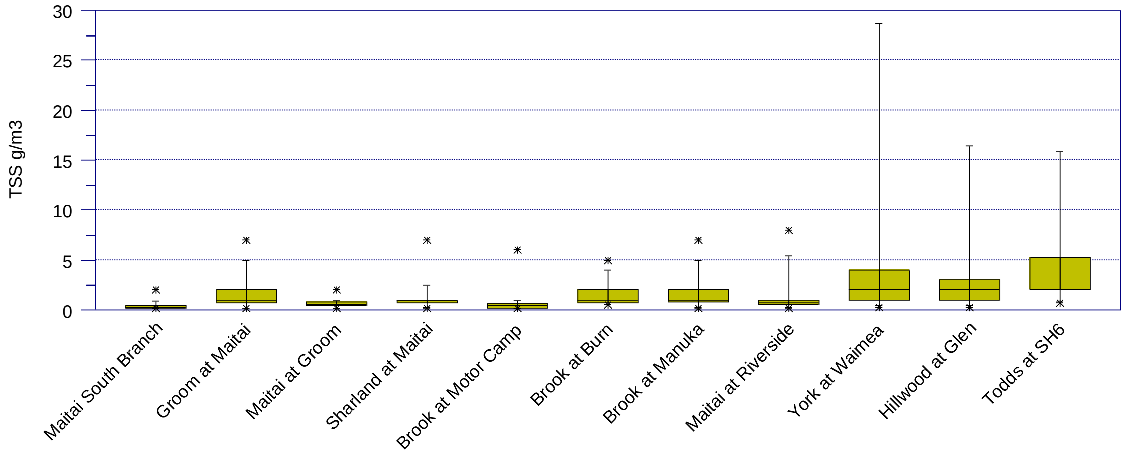

Figure 9. Total suspended sediment (TSS) in g/m^3 for monitoring sites in the Mahitahi/Maitai FMU, Nelson.

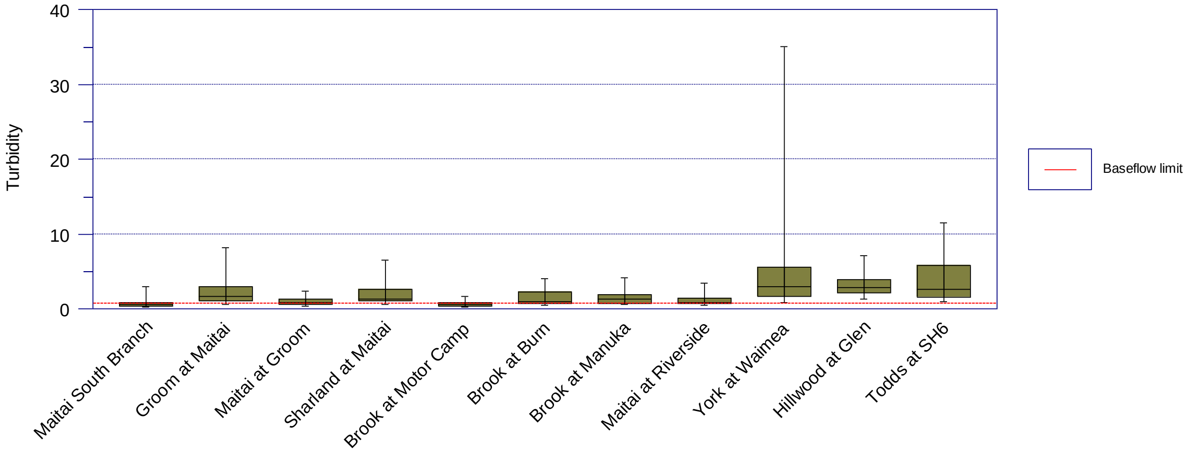

Figure 10. Turbidity (NTU) for monitoring sites in the Mahitahi/Maitai FMU, Nelson.

Appendix 6. Wakapuaka FMU water quality data

Ecosystem Health

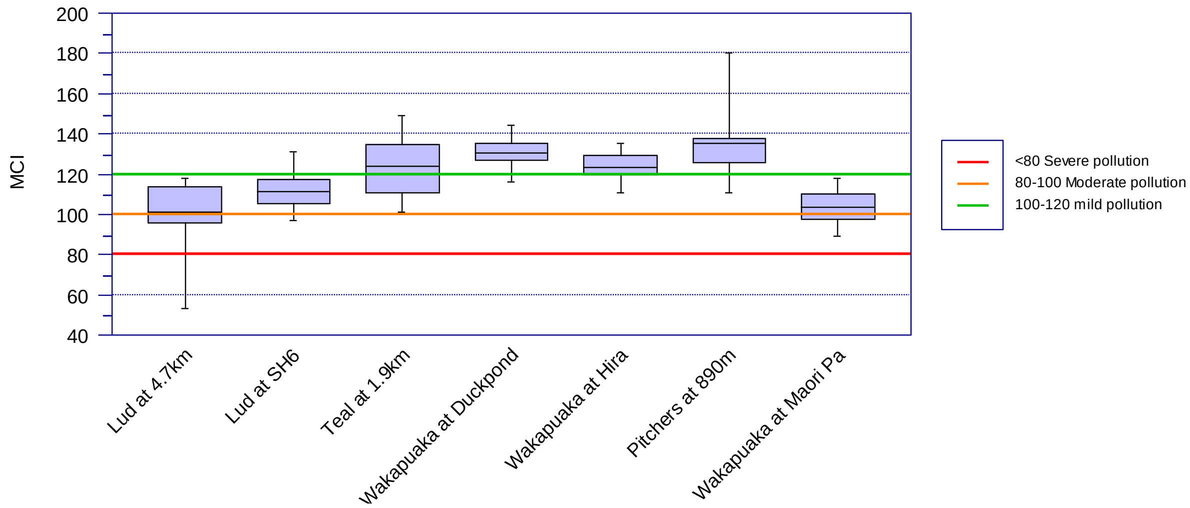

Figure 1. Macroinvertebrate community index (MCI) for monitoring sites in the Wakapuaka FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. N = 13.

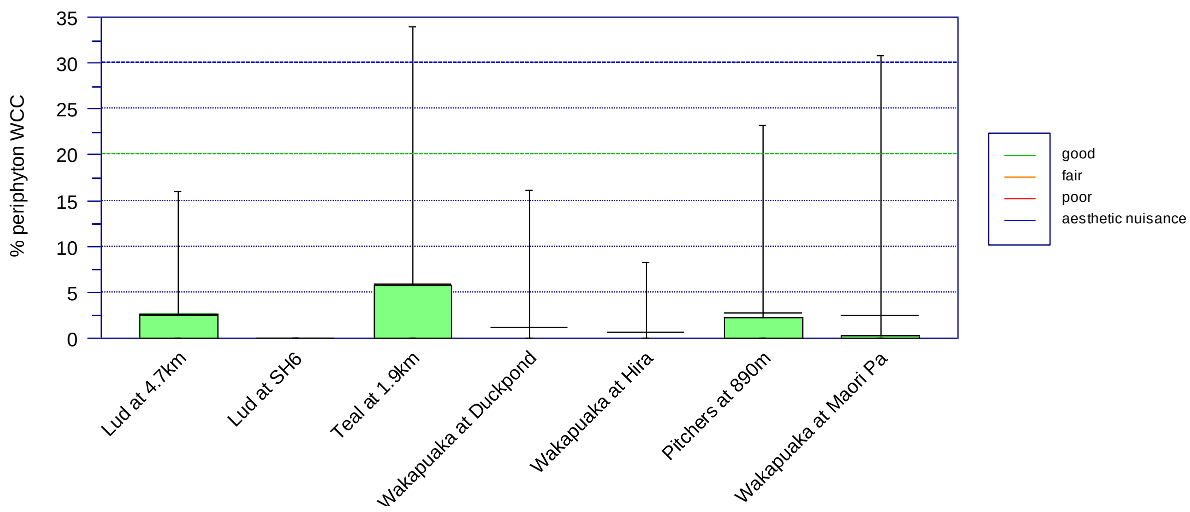

Figure 2. Percent cover by periphyton using weighted composite cover (WCC) method for annual visual assessment observations between 2002 and 2014 for the Wakapuaka FMU, Nelson. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. 'Good', 'fair' and 'poor' are indicators of ecological condition and <20% cover = 'excellent' ecological condition. N=13 (except Teal and Pitchers sites where N=12).

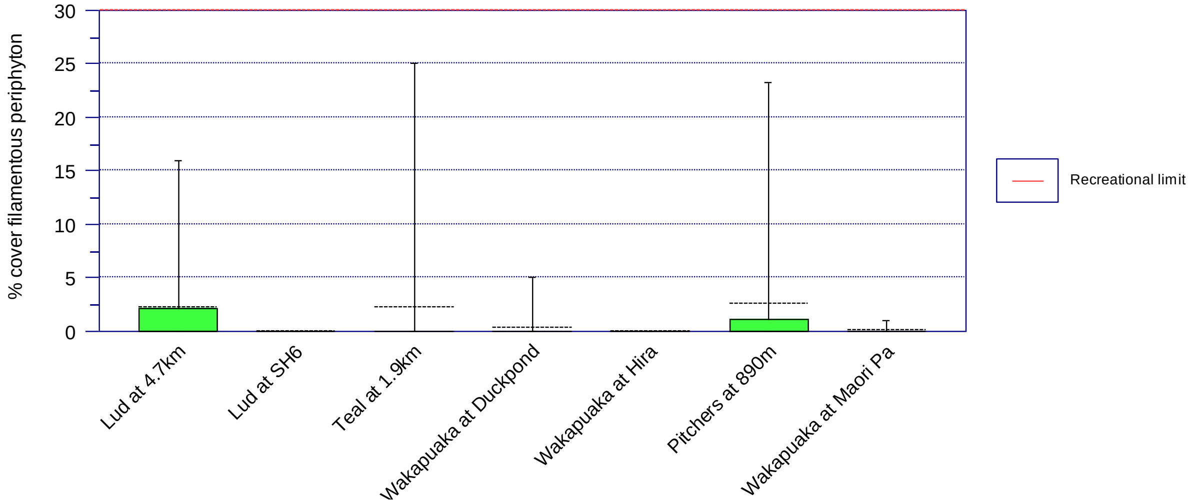

Figure 3. Percent filamentous periphyton cover for monitoring sites in the Wakapuaka FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. N = 13 (12 for Pitchers and Teal sites).

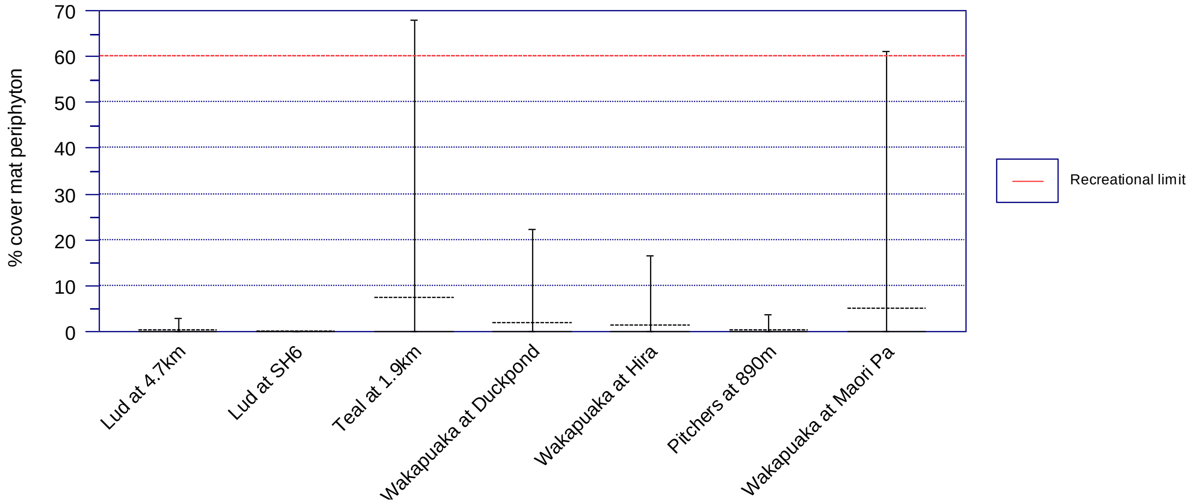

Figure 4. Percent mat periphyton cover for monitoring sites in the Wakapuaka FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. N = 13 (12 for Pitchers and Teal sites).

Faecal contaminants

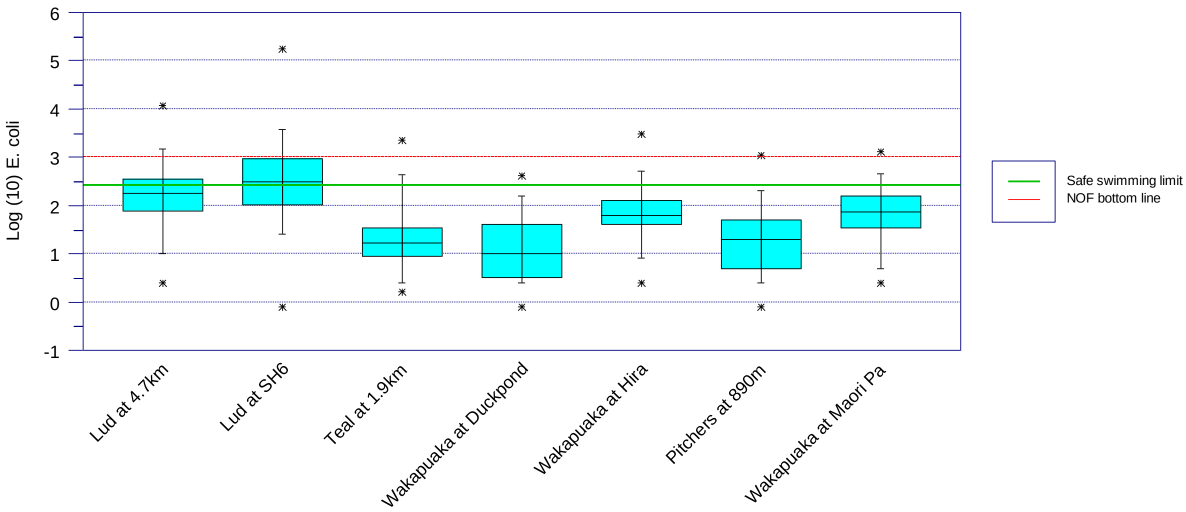

Figure 5. Log_{10} Escherichia coli (E.coli) cfu/100ml for SOE monitoring sites in the Wakapuaka FMU, Nelson.

Nutrient contaminants

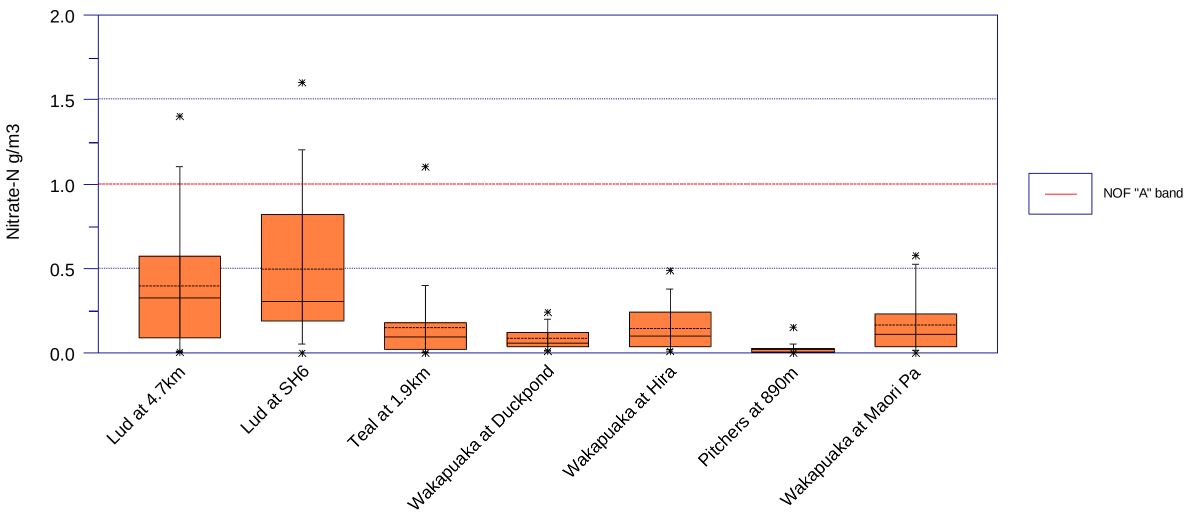

Figure 6. Nitrate nitrogen concentration (g/m^3) for monitoring sites in the Wakapuaka FMU, Nelson.

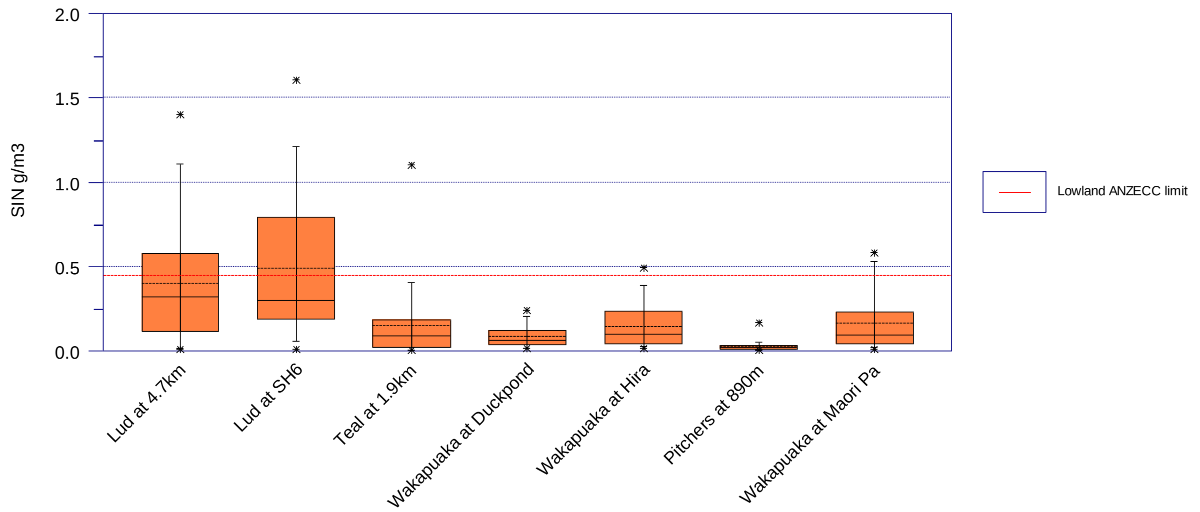

Figure 7. Soluble inorganic nitrogen (SIN) concentration (g/m^3) for monitoring sites in the Wakapuaka FMU, Nelson.

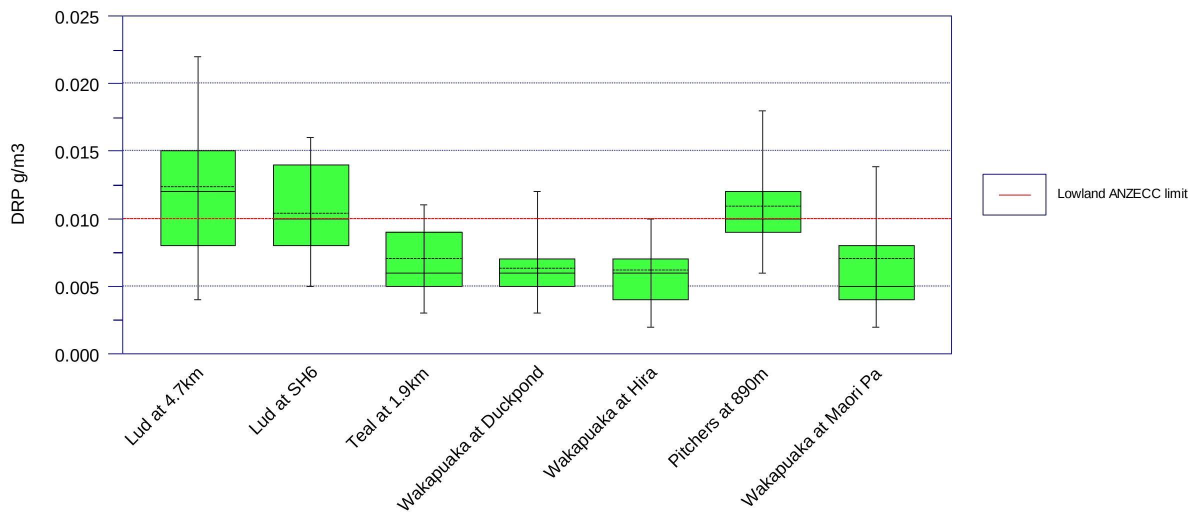

Figure 8. Dissolved reactive phosphorus (DRP) concentrations (g/m^3) for monitoring sites in the Wakapuaka FMU, Nelson.

Sediment

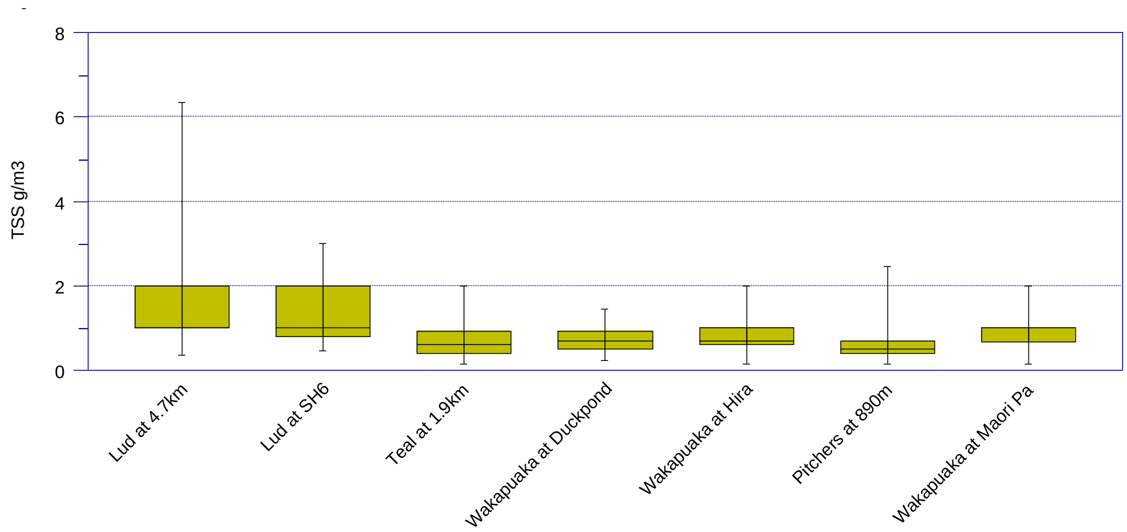

Figure 9. Total suspended sediment (TSS) concentrations (g/m^3) for monitoring sites in the Wakapuaka FMU, Nelson.

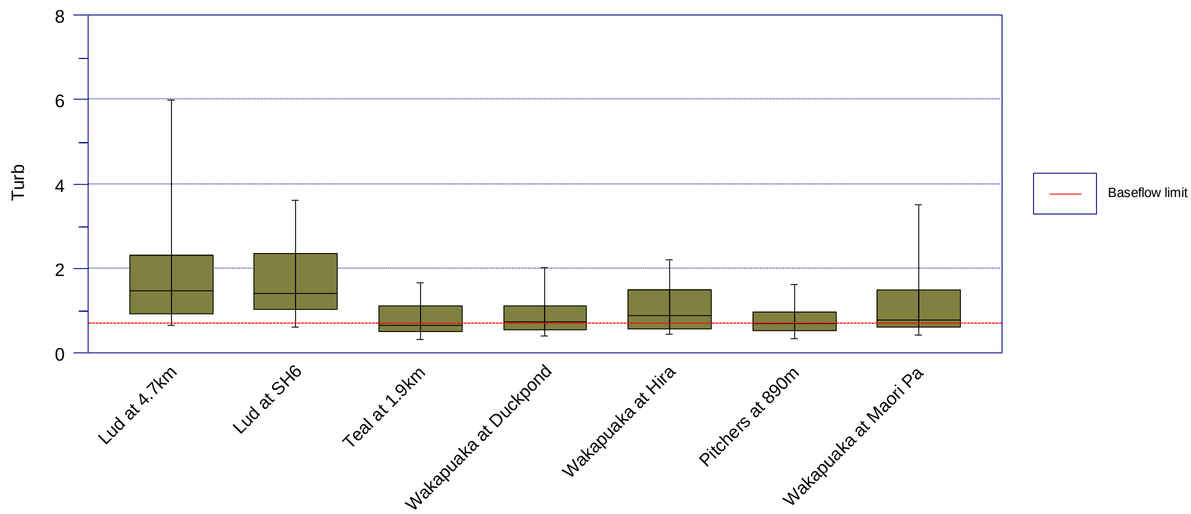

Figure 10. Turbidity (NTU) for monitoring sites in the Wakapuaka FMU, Nelson.

Appendix 7. Whangamoa FMU water quality data

Ecological health

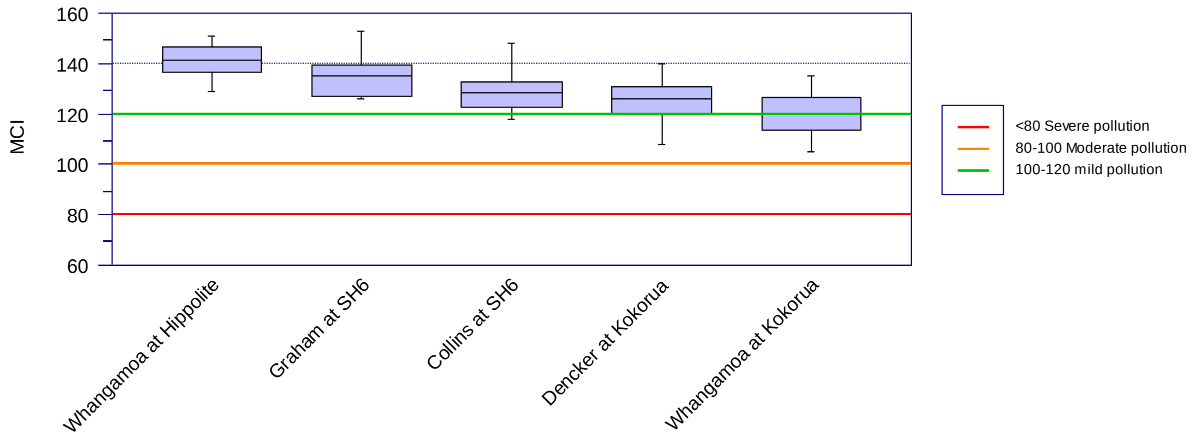

Figure 1. Macroinvertebrate community index (MCI) for monitoring sites in the Whangamoa FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. MCI scores >120 indicate clean water. N = 13.

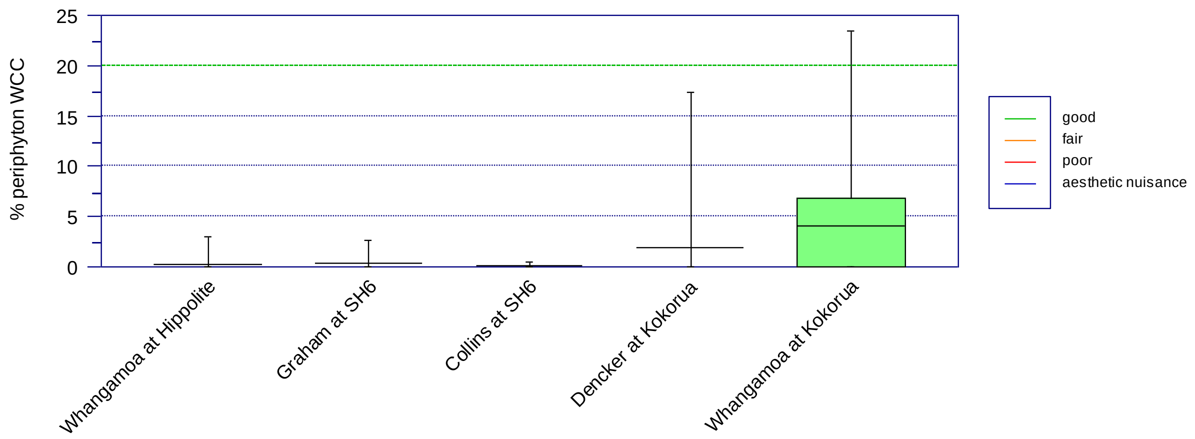

Figure 2. Percent cover by periphyton using weighted composite cover (WCC) method for annual visual assessment observations between 2002 and 2014 for the Whangamoa FMU, Nelson. Box = 75th and 25th quartiles, mid-point line = mean, bars = min and max. 'Good', 'fair' and 'poor' are indicators of ecological condition and <20% cover = 'excellent' ecological condition. N=12.

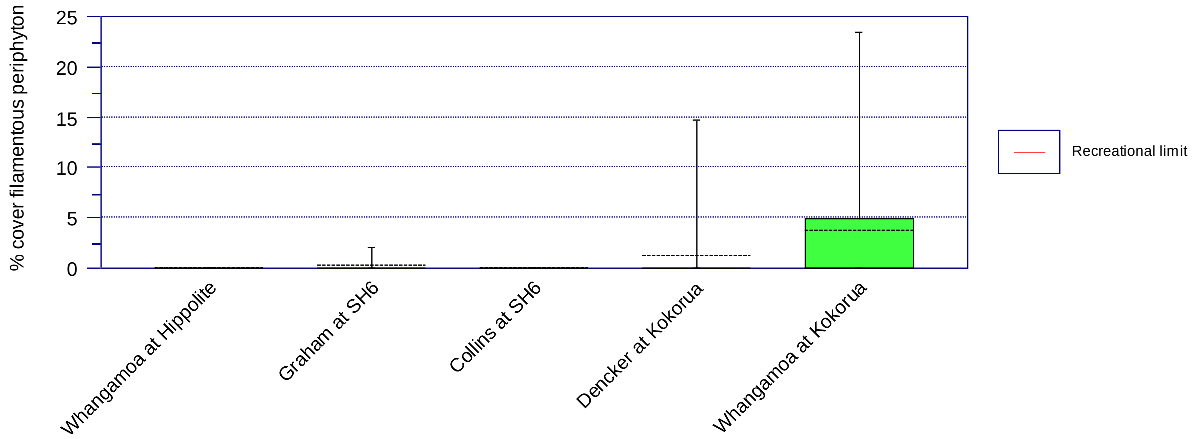

Figure 3. Percent filamentous periphyton cover for monitoring sites in the Whangamoa FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. Recreational limit = 30%. N = 12.

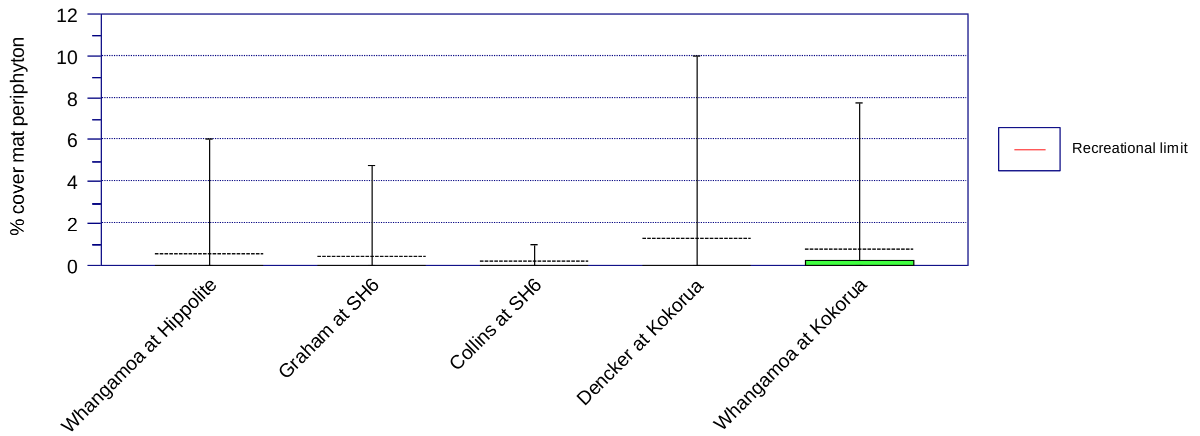

Figure 4. Percent mat periphyton cover for monitoring sites in the Whangamoa FMU, Nelson. Box = 75th – 25th data percentiles, bars = min and max, mid-box line = mean. Recreational limit = 60%. N = 12.

Faecal contaminants

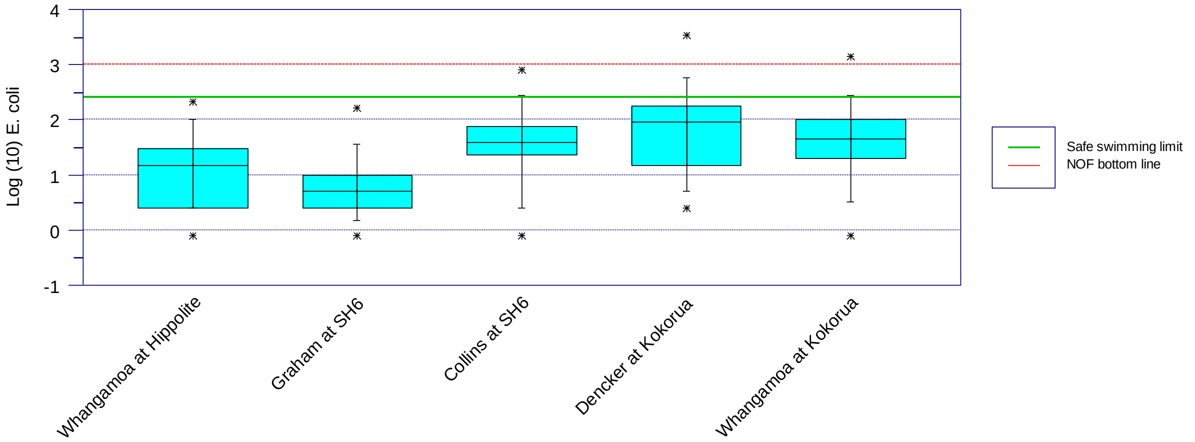

Figure 5. Log$_{10}$ *Escherichia coli (E.coli)* CFU/100ml for SOE monitoring sites in the Whangamoa FMU, Nelson.

Nutrients

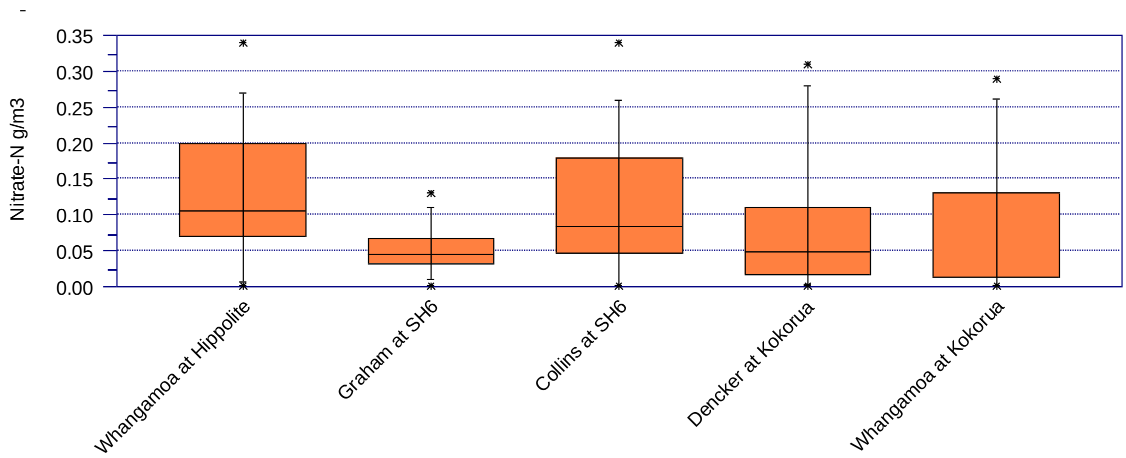

Figure 6. Nitrate concentration (g/m^3) for monitoring sites in the Whangamoa FMU, Nelson. N.B. NOF "A" band = 1g/m^3.

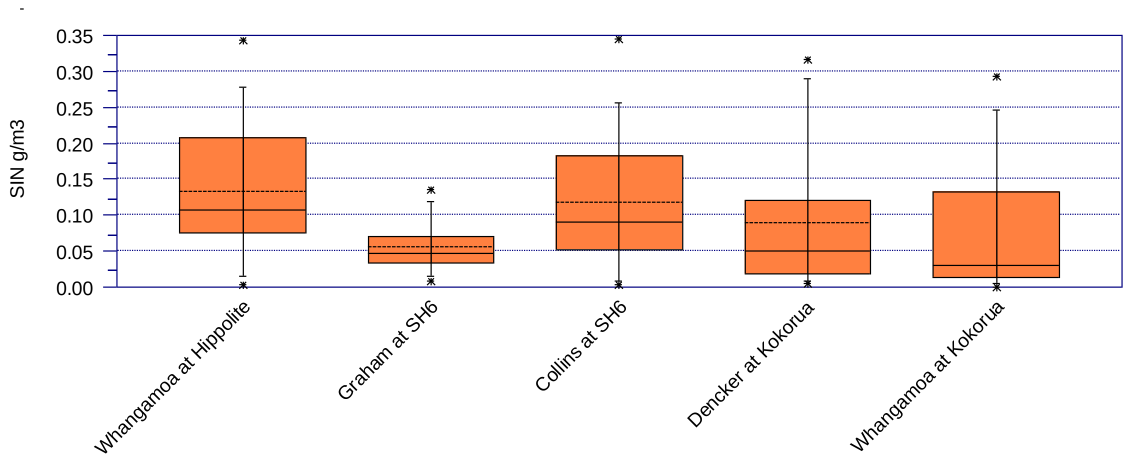

Figure 7. Soluble inorganic nitrogen (SIN) g/m^3 for monitoring sites in the Whangamoa FMU, Nelson. N.B. Lowland ANZECC limit = 0.444g/m^3.

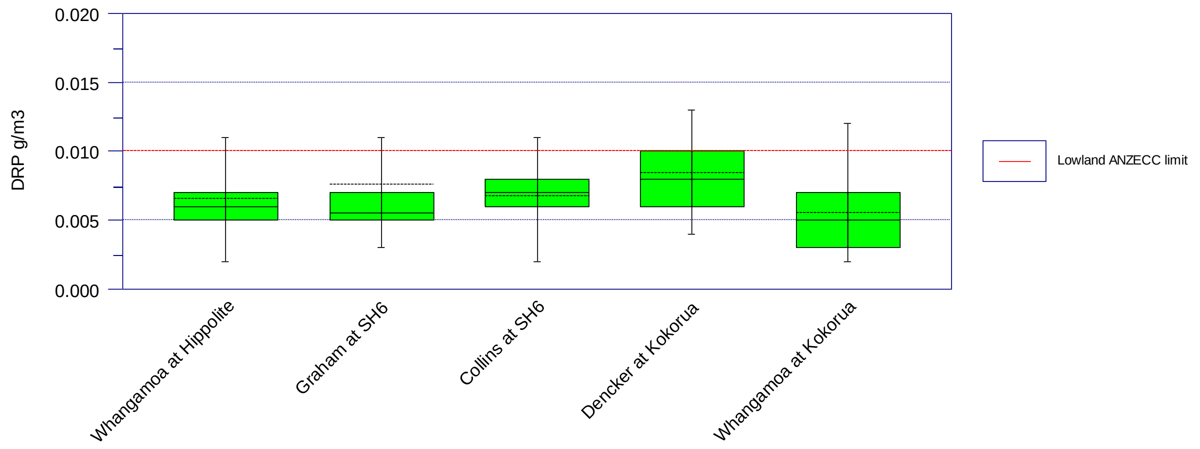

Figure 8. Dissolved reactive phosphorus (DRP) g/m^3 for monitoring sites in the Whangamoa FMU, Nelson.

Sediment

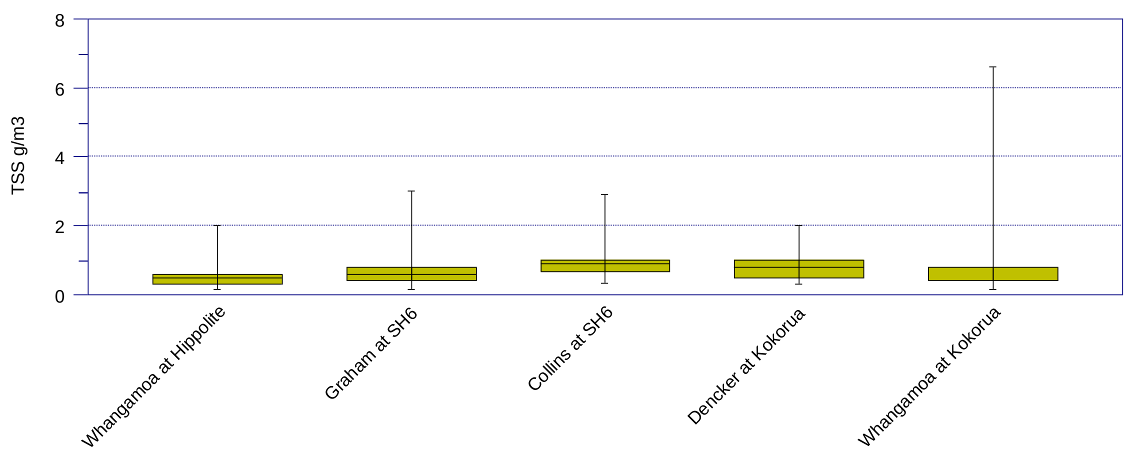

Figure 9. Total suspended sediment (TSS) g/m^3 for monitoring sites in the Whangamoa FMU, Nelson.

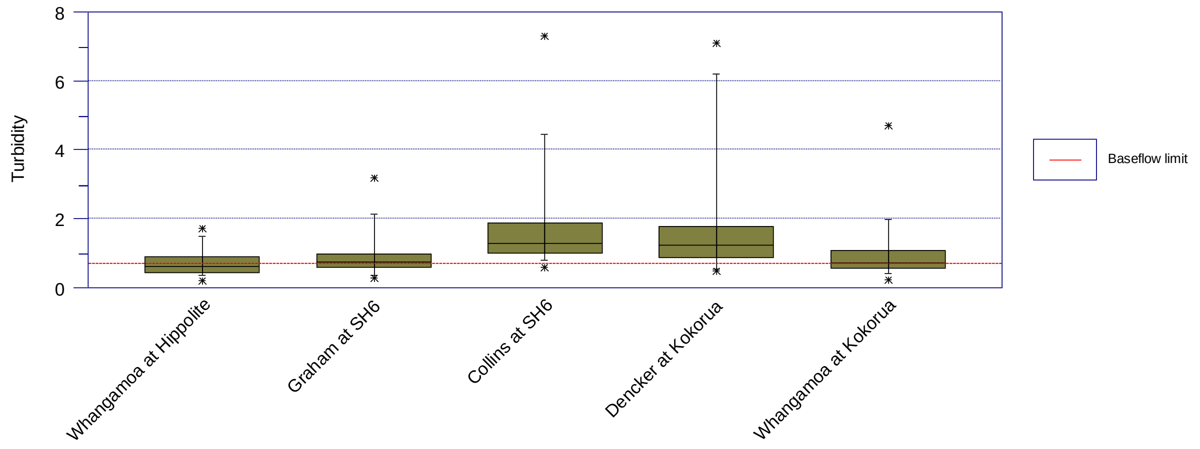

Figure 10. Turbidity (NTU) for monitoring sites in the Whangamoa FMU, Nelson.