Whaitua Te Whanganui-a-Tara
River and stream water quality and ecology

30th October 2018

Report Prepared for Greater Wellington Regional Council

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EXECUTIVE SUMMARY

Background

Greater Wellington Regional Council (GWRC) will be working with the Whaitua Te Whanganui-a-Tara Committee to develop a Whaitua Implementation Programme (WIP) that will include:

- Specific whaitua or catchment objectives and targets for water quality and quantity outcomes related to the management of ecosystem health and human health for recreation, including setting timeframes and priorities for achieving whaitua or catchment objectives and targets; and
- Water quality limits, including nutrient load and contaminant limits, that will ensure objectives and targets are met.

In this report the current state and trends of the waterways in the whaitua in terms of water quality and ecology are summarised and discussed. This report is not only intended to inform the Whaitua Committee of current state, but also of the key drivers of ecosystem health in the whaitua and any knowledge gaps, so that that these can be managed appropriately through the WIP.

Approach

Available water quality and ecology data for the Whaitua Te Whanganui-a-Tara were collated, and the results benchmarked against the proposed Natural Resources Plan outcomes, established guideline values from the literature and the National Policy Statement for Freshwater Management 2014 attribute states. Current state was assessed from data collected over the past five years and trend analyses were undertaken using 10 years of data.

Results and conclusions

Macroinvertebrate community health is degraded in rivers and streams draining catchments with a significant amount of urban or agricultural land-cover, but is generally good or excellent in catchments dominated by indigenous forest. In urban catchments, the major drivers of ecological degradation are modified flows (reduced base-flows, increased flood frequency), elevated concentrations of toxic metals, sedimentation and habitat degradation caused by channel modification. From the available data, nutrient enrichment and associated nuisance periphyton blooms appear to be the major drivers of degradation in agricultural catchments. However, it is likely that other unmeasured factors, including instream and riparian habitat degradation, stock access and river engineering activities, also contribute.

Significant faecal contamination is generally limited to urban streams, and the Mangaroa River and the Makara Stream are the only non-urban waterways that are not suitable for primary contact recreation due to elevated levels of the pathogen indicator bacteria *E. coli*. In contrast, all monitored urban waterways, except Speedy's Stream, are unsuitable for primary contact recreation. The main source of faecal contamination in urban streams is human wastewater, while in the Makara Stream and Mangaroa River the primary source is stock (sheep and beef cattle).

Benthic cyanobacteria also poses a significant health risk to recreational users in the Hutt River, but the causes for this are complex and not fully understood.

Improving the ecological and recreational state of urban streams in Whaitua Te Whanganui-a-Tara will require significant upgrades to the stormwater and wastewater infrastructure in the cities of Wellington, Lower Hutt and Upper Hutt, and the adoption of water sensitive urban design in new developments. Improving the state of agricultural catchments, specifically the Mangaroa River, will require a shift in land management practices. However, further information needs to be collected on nutrient sources, transport and dynamics to support future decision making.

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1. Introduction

1.1. Scope

The National Policy Statement for Freshwater Management 2014 (NPS-FM 2014) requires regional councils to establish objectives for a specified set of water quality measures (attributes), and set limits on resource use to ensure those objectives are met. To implement the NPS-FM 2014, Greater Wellington Regional Council (GWRC) will be working with the Whaitua Te Whanganui-a-Tara Committee to develop a Whaitua Implementation Programme (WIP) that will include:

- Specific whaitua or catchment objectives and targets for water quality and quantity outcomes related to ecosystem health and human health for recreation, including setting timeframes and priorities for achieving whaitua or catchment objectives and targets; and
- Water quality limits, including nutrient load and contaminant limits, that will ensure objectives and targets are met.

In this report, the current state and trends of water quality, ecology and habitat values in the rivers and streams in the whaitua are summarised and discussed. This report is not only intended to inform the Whaitua Committee of current state and trends, but also of the key drivers of ecosystem health in the whaitua, so that that they can be managed appropriately through the WIP.

1.2. Report approach

This report takes a top down approach in assessing the current state of the rivers and streams in the whaitua by first assessing macroinvertebrate communities as an indicator of ecosystem health, then considering how this is being influenced by various habitat and water quality parameters. The role of flow as a driver of ecosystem health cannot be explored in depth in this report, as the required hydrological data is yet to be compiled and reported on. However, it is accepted that flow is likely an important regulator of ecosystem function in Whaitua Te Whanganui-a-Tara, and how hydrology is currently impacting aquatic communities will need to be explored separately. The key habitat and water quality indicators assessed in this report are outlined in the following section.

Because of the size of the whaitua, and the diverse range of river types, land-uses and communities it contains, it has been split into four distinct sub-zones, which are reported on separately in this document (Figure 1). These sub-zones are:

- The Hutt River (Te Awakairangi) catchment sub-zone;
- The Southern and western coastal stream catchments sub-zone;
- The Wainuiomata and Orongorongo catchments sub-zone (including the Pencarrow lakes); and
- The Wellington Harbour stream catchments sub-zone (excluding the Hutt River) above the Waiwhetu Stream).

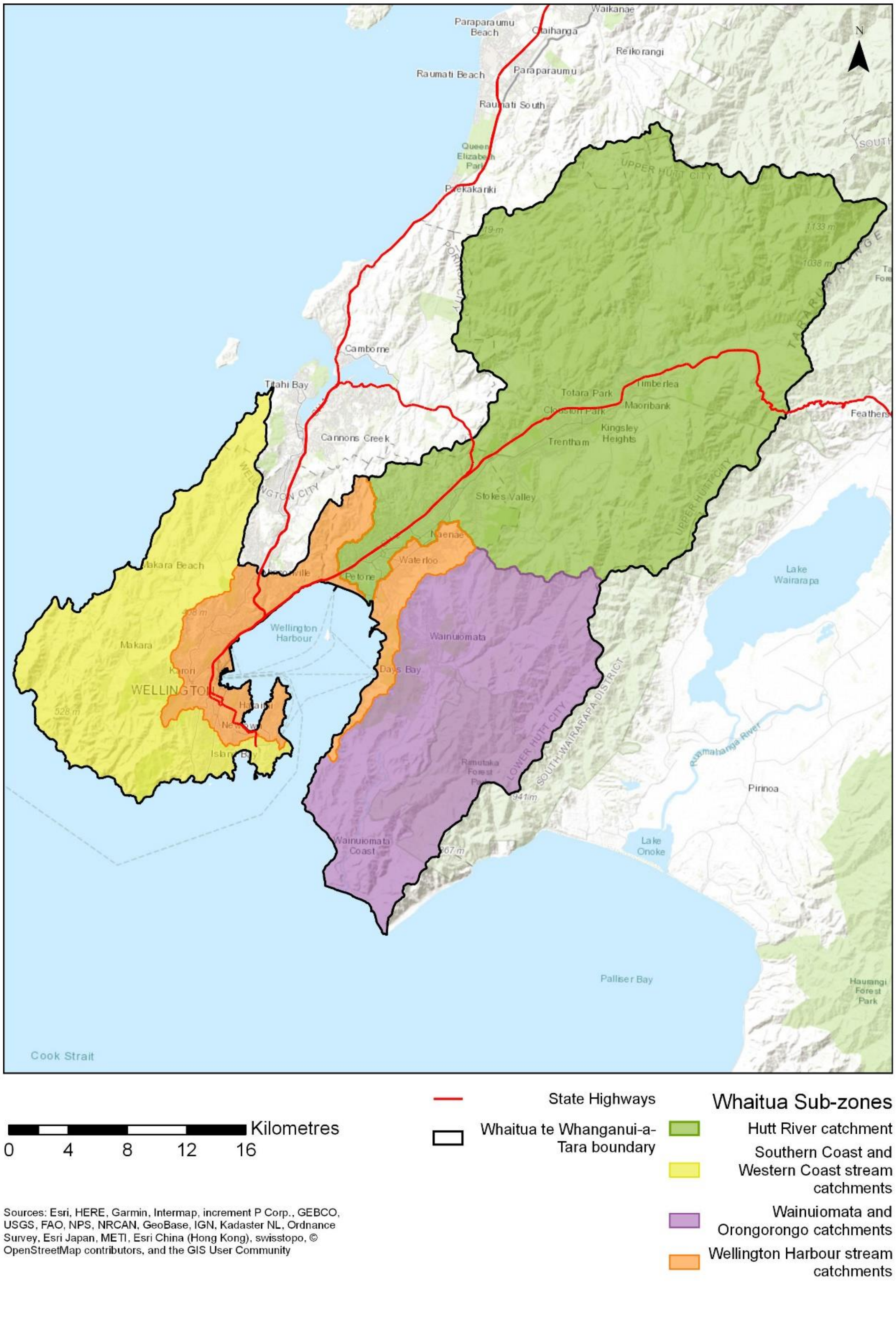

Figure 1: Map of Whaitua Te Whanganui-a-Tara with individual sub-zones identified.

1.3. Whaitua description

Whaitua Te Whanganui-a-Tara encompasses the area between the Rimutaka ranges and the west coast and extends from the Akatarawa Saddle in the north to Cook Strait in the south (Figure 1). While the northern boundary of the whaitua extends beyond Te Awarua-o-Porirua Harbour, it does not include those streams within the harbour catchment, or the coastal streams north of Porirua City. The main catchments in the whaitua are the Hutt, the Orongorongo and the Wainuiomata river catchments and the Makara Stream catchment. The whaitua also includes several smaller catchments that either discharge directly to Wellington Harbour (e.g. the Kaiwharawhara, Korokoro and Waiwhetu streams), or the coast (e.g. the Owhiro, Karori and Oteranga streams).

1.3.1. Wainuiomata and Orongorongo catchments sub-zone

The boundaries of the Wainuiomata and Orongorongo sub-zone encompasses the river catchments north, south and east of Wainuiomata township (Figure 1). The major waterways in the sub-zone are the Wainuiomata and Orongorongo rivers. The sub-zone also includes the Gollans Stream and Cameron's Creek catchments which drain in to Lakes Kohangatera and Kohangapiripiri respectively.

The Wainuiomata is a ~22 kilometre (km) long braided river that drains the south-western portion of the Rimutaka Ranges and discharges to the south coast at Baring Head. The Wainuiomata catchment is approximately 12,972 hectares (ha). In the upper catchment, Black Creek drains the township Wainuiomata, a large suburb of Lower Hutt with a population of 16,786 (2013 census), the Wainuiomata Stream drains the largely rural Moores Valley catchment and Skull Gully Stream and the east and west branches of the Wainuiomata River drain the heavily protected indigenous forest within the GWRC managed Wainuiomata-Orongorongo Water Collection Area (hardwood/indigenous forest = 65% of catchment area) (Table 1). Below the confluence of these waterways, the Wainuiomata River runs through the Wainuiomata Valley, the floor of which has been mostly converted to pasture (9% of catchment area) (Table 1).

The Orongorongo River is a ~32 km long braided river in the southern Rimutaka ranges, immediately to the east of the Wainuiomata catchment. It has a catchment area of 8,028 ha, the vast majority of which is covered in indigenous forest within the Rimutaka Forest Park or the GWRC managed Wainuiomata-Orongorongo Water Collection Area (hardwood/indigenous forest = 95% of catchment area) (Table 1). Only at the very bottom of the Orongorongo Valley does forest give way to gorse/broom and pasture.

1.3.2. Hutt River catchment sub-zone

The Hutt River catchment sub-zone encompasses the surface water catchment of the Hutt River (exc. the Waiwhetu Stream) (Figure 1). This is by far the largest sub-zone in Whaitua Te Whanganui-a-Tara, and covers the entire Hutt Valley as well as large areas of the Rimutaka and Tararua Ranges. The major rivers in the sub-zone are the Hutt River and its four major tributaries, the Pakuratahi, Mangaroa, Akatarawa and Whakatikei rivers.

The Hutt River is a ~56 km shallow, sometimes braided, river which drains the south-west portion of the Tararua Ranges, and runs through the Hutt Valley before discharging into Wellington Harbour. The catchment of the Hutt River is 57,419 ha, the majority of which is covered in hardwood and indigenous forest, including the Kaitoke Regional Park and the adjacent Hutt Water Collection Area (hardwood/indigenous forest = 66% of catchment area). In terms of productive land-use, there are large areas of plantation forestry in the hill country (13% of catchment area), and large areas of, primarily dry-stock, sheep and beef farming in the low altitude areas in the Pakuratahi and Mangaroa river catchments (11% of catchment area) (Table 1). In the middle and lower reaches of the Hutt River the catchment becomes increasingly urbanised (6% of catchment), and the river flows through the cities of Lower Hutt and Upper Hutt, which have a combined population of 138,417 (2013 census). Because of the Hutt River's proximity to major urban centres, it is popular for a range of recreational pursuits including swimming, boating, fishing, walking, running and cycling. The Hutt River also provides approximately 40% of the municipal water supply for the Wellington metropolitan area.

The Pakuratahi River is ~15 km long and flows in a north-west direction through the southern Rimutaka Ranges, before discharging to the Hutt River near Kaitoke. Its 7,954-ha catchment is primarily covered in hardwood and indigenous forest (71% of catchment area) (Table 1). However, the low gradient area near where the Pakuratahi meets the Hutt River has been extensively developed for pastoral land-use, and 11% of the catchment is covered in high productivity pasture (Table 1).

The Mangaroa River is a ~20 km river that drains the western foothills of the Rimutaka Ranges. Its headwaters lie at the top of Whiteman's Valley, to the west of Lower Hutt, and it discharges to the Hutt River just upstream of Upper Hutt. The 8,406-ha catchment has been extensively developed for agricultural and 37% is in pastoral land-use (Table 1). The remainder of the catchment is primarily covered in hardwood and indigenous forest (37% of catchment area) and planation forestry (20% of catchment area) (Table 1). There is also a large area of peatland to the south of Wallaceville Road, which is known as Waipango Swamp.

The Akatarawa River catchment is the largest sub-catchment of the Hutt River. Its headwaters arise in the Tararua Ranges, ~10 km south of Waikanae. The river runs southward for ~20 km through the Akatarawa Valley before discharging to the Hutt River near Birchville. The catchment of the Akatarawa River is 11,582 ha in area, and is primarily covered in hardwood and indigenous forest (79% of catchment area) (Table 1). However, there are areas of plantation forestry on the hills above the Akatarawa Valley (17% of catchment area) and on the hills above its major tributary the Akatarawa River West. The floor of the Akatarawa Valley is largely deforested and has been converted to pasture (3% of catchment area).

The headwaters of the Whakatikei River are also in the Tararua Ranges, five km south-east of Paekakariki. The river is ~15 km long, and discharges to the Hutt River opposite the suburb of Trentham. The 8,005-ha catchment is primarily covered in hardwood and indigenous forest (66% of catchment area) (Table 1). However, there is a concentrated area of pastoral land-use and plantation forestry in the lower half of the catchment (6% and 24% of catchment area respectively) (Table 1).

1.3.3. Wellington Harbour stream catchments sub-zone

There are two parts to the Wellington Harbour stream catchments sub-zone, separated from each other by the Hutt River. The western part includes all the streams draining into the harbour between the western end of Petone Beach and the Harbour mouth (Figure 1). It encompasses most of the residential suburbs of Wellington City south of Johnsonville (except Karori) and the whole of the Korokoro Valley. The eastern part of the sub-zone includes the streams draining into the harbour east of the Hutt River (Figure 1). It encompasses the suburbs of Naenae, Waterloo and Waiwhetu and the western faces of the hills behind the eastern bays. Although it discharges to the Hutt River, the Waiwhetu Stream catchment is also included in this sub-zone, as its influence on the Hutt River is limited to the tidal zone. The major waterways in the sub-zone are the Kaiwharawhara Stream, the Ngauranga Stream, the Korokoro Stream and the Waiwhetu Stream.

The Kaiwharawhara is a ~10 km long hill-fed stream that drains the suburbs between Karori and Khandallah and discharges to Wellington Harbour near the Interislander Ferry Terminal. The catchment of the Kaiwharawhara is approximately 1,618 ha. While land-use in the catchment is largely urban (38% of catchment area), there are also large areas of forest including Zealandia Eco-sanctuary and Trelissick Park (37% of catchment area) (Table 1).

The Ngauranga Stream drains parts of Khandallah, Johnsonville and Newlands. It is approximately five km long, but a significant proportion of this, and the wider catchment, is piped. Its most obvious feature is the Ngauranga Gorge, through which one of Wellington’s main arterial highways runs. Below the gorge, the Ngauranga Stream discharges to the sea at Ngauranga. It has an 879 ha catchment that is primarily residential, with some commercial and light industry areas in Johnsonville, Newlands and Ngauranga (urban land-cover = 63% of catchment area) (Table 1).

The Korokoro Stream is approximately eight km long, and drains the Korokoro Valley before discharging to Wellington Harbour to the west of Petone Beach. The Korokoro catchment is approximately 1,640 ha, and is predominately indigenous forest (54% catchment area), with a small amount of pastoral land-use and urban development (17% and 5% of catchment area respectively) (Table 1).

The Waiwhetu Stream is a ~10 km low gradient stream that drains the eastern Hutt hills and the suburbs of Naenae, Waterloo, Waiwhetu and Gracefield and discharges to the Hutt River estuary at Seaview. The Waiwhetu catchment is 1,806 ha and is predominately in residential and commercial land-use (urban land-cover = 54% of catchment area) (Table 1), and there is a significant industrial area in Gracefield.

1.3.4. Southern and western coastal stream catchments sub-zone

The southern and western coastal stream catchments sub-zone covers all the stream catchments west of the Hutt River that discharge to the open coast (i.e. not Wellington Harbour). It extends from Cook Strait in the south, to just below Titahi Bay in the north (Figure 1). West to east it encompasses the area between the sea and the suburbs of Tawa, Johnsonville, Crofton Downs and Brooklyn. The major waterways in the sub-zone are the Makara Stream and its main tributaries, the Ohariu Stream and Mill Creek, and the Karori Stream. The zone also includes several smaller waterways that discharge directly to the sea, including the Owhiro and the Oteranga streams

The Makara Stream drains most of the area west of Tawa, Johnsonville, Crofton Downs and Karori before discharging to the west coast through the Makara Estuary at Ohariu Bay. It is comprised of two major sub-catchments, the Makara Stream sub-catchment, and the Ohariu Stream sub-catchment. The Makara Stream itself is ~10 km long, and drains the portion of the catchment south of where Makara Road and Takarau Gorge Road meet. The Ohariu Stream is ~14km long and drains everything to the north. The catchment as a whole is 7,269 ha, and is predominately in pastoral land-use and scrub (64% and 20 % of catchment area respectively) (Table 1).

The Karori Stream is a 10 km long hill fed system, with a catchment of 3,043 ha. The stream arises in the hills around the suburb of Karori, and discharges directly to Cook Strait. The upper catchment is primarily urban, and much of the headwater streams have been modified into a piped stormwater system. However, below the suburb of Karori, land-use is predominantly gorse/broom (52% catchment area), and at the catchment scale, urban land-cover is proportionally small (11% of catchment area) (Table 1).

Table 1: Land-cover in each of the major catchments in Whaitua Te Whanganui-a-Tara

Sub-zone	Catchment	Land-cover class	Area (ha)	% of catchment
Wainuiomata & Orongorongo	Orongorongo River	Forestry	22.1	0.3%
		Gorse/broom	199.1	2.5%
		Pasture	154.1	1.9%
		Hardwood/indigenous forest	7,652.9	95.3%
		Total	8,028.1	
	Wainuiomata River	Urban	580.5	4.5%
		Forestry	394.1	3.0%
		Gorse/broom	2,364.8	18.2%
		Pasture	1,221.1	9.4%
		Hardwood/indigenous forest	8,411.7	64.8%
		Total	12,972.2	
Hutt River	Hutt River	Urban	3,426.3	6.0%
		Forestry	7,259.7	12.6%
		Gorse/broom	2,235.2	3.9%
		Pasture	6,406.9	11.2%
		Hardwood/indigenous forest	38,090.9	66.3%
		Total	57,419.0	
	Pakuratahi River	Urban	8.2	0.1%
		Forestry	638.7	8.0%
		Gorse/broom	788.6	9.9%
		Pasture	894.0	11.2%
		Hardwood/indigenous forest	5,624.3	70.7%
		Total	7,953.8	
	Mangaroa River	Urban	144.7	1.7%
		Forestry	1,642.5	19.5%
		Gorse/broom	372.1	4.4%
		Pasture	3,106.1	36.9%
		Hardwood/indigenous forest	3,141.5	37.4%
		Total	8,406.9	
	Akatarawa River	Urban	4.6	0.0%
		Forestry	1,980.3	17.1%
		Gorse/broom	89.6	0.8%
		Pasture	356.2	3.1%
		Hardwood/indigenous forest	9,151.7	79.0%
		Total	11582.3	
	Whakatikei River	Urban	20.7	0.3%
		Forestry	1,952.8	24.4%
		Gorse/broom	265.1	3.3%
		Pasture	505.0	6.3%

Sub-zone	Catchment	Land-cover class	Area (ha)	% of catchment
		Hardwood/indigenous forest	5,261.5	65.7%
		Total	8,005.1	
Wellington Harbour	Kaiwharawhara Stream	Urban	613.9	37.9%
		Forestry	65.4	4.0%
		Gorse/broom	248.7	15.4%
		Pasture	84.7	5.2%
		Hardwood/indigenous forest	606.1	37.4%
		Total	1,618.9	
	Ngauranga Stream	Urban	558.3	63.5%
		Forestry	9.5	1.1%
		Gorse/broom	88.8	10.1%
		Pasture	27.8	3.2%
		Hardwood/indigenous forest	195.1	22.2%
		Total	879.6	
	Korokoro Stream	Urban	77.3	4.7%
		Forestry	203.6	12.4%
		Gorse/broom	191.4	11.7%
		Pasture	280.5	17.1%
		Indigenous forest	887.6	54.1%
		Total	1,640.4	
	Waiwhetu Stream	Urban	968.8	53.6%
		Forestry	9.4	0.5%
		Gorse/broom	366.7	20.3%
		Hardwood/indigenous forest	461.3	25.5%
		Total	1,806.2	
South/west coastal	Makara Stream	Urban	21.2	0.3%
		Forestry	573.1	7.9%
		Gorse/broom	1,481.0	20.4%
		Pasture	4,681.2	64.4%
		Hardwood/indigenous forest	513.2	7.1%
		Total	7,269.7	
	Karori Stream	Urban	336.6	11.1%
		Forestry	124.5	4.1%
		Gorse/broom	1,570.3	51.6%
		Pasture	348.6	11.5%
		Hardwood/indigenous forest	663.1	21.8%
		Total	3,043.1	

1.4. Key indicators and drivers

1.4.1. Ecosystem health - Macroinvertebrates

The aquatic macroinvertebrate community is an important component of lotic ecosystems, and macroinvertebrate community health is a widely used indicator of ecosystem health. Sensitivity to habitat and water quality stressors differs between macroinvertebrate taxa, thus the composition of macroinvertebrate communities in a stream can provide valuable information about how the state and trends in water quality and habitat are influencing ecosystem health.

The macroinvertebrate community index (MCI) is an index of macroinvertebrate sensitivity to a wide range of environmental variables (Stark and Maxted, 2007), and is used to measure community health (Clapcott and Goodwin, 2014). The MCI responds to multiple stressors, including point source discharges, diffuse discharges, habitat degradation and water abstraction (Collier *et al.*, 2014); generally, the higher the MCI score the better the water and habitat quality. The MCI is used in the Greater Wellington Region Proposed Natural Resources Plan (pNRP) to measure ecosystem condition according to river classes defined by Greenfield *et al.* (2015b)[1]. The river class system uses a poor-fair-good-excellent grading system developed by Clapcott and Goodwin (2014) (adapted from the national grading system set out in Stark and Maxted (2007), more detail is provided in Section 2.2.2). The NPS-FM 2014 also stipulates that if an MCI score falls below 80, or shows a declining trend, regional councils must identify the causes and develop a response plan.

1.4.2. Habitat as a driver of ecosystem health

<u>Periphyton and macrophyte cover/biomass</u>

Periphyton are primary producers and an important foundation of many river and stream food webs, particularly in rivers with hard, cobbly substrate. Periphyton also stabilise substrata and serve as habitat for many other organisms. However, an over-abundance of periphyton can reduce ecological habitat quality (Matheson *et al.*, 2012). Large standing crops of periphyton can smother stream-bed substrate, thereby reducing the amount of suitable habitat available for fish and macroinvertebrates. High densities of periphyton can also cause large daily fluctuations in dissolved oxygen concentrations and pH, especially in slower flowing systems. Therefore, it is important to manage rivers and streams to reduce the risk of nuisance growths. Periphyton biomass covering the riverbed (measured in milligrams of chlorophyll *a* per metre squared of riverbed (Chl-*a* mg/m^2)) is a commonly used measure for assessing ecosystem health, and the NPS-FM 2014 defines numeric biomass attribute states which reflect poor, fair, good and excellent ecosystem health (Snelder, 2017). Matheson *et al.* (2012) also provides a similar grading system which is based on long filamentous and thick mat algal cover.

Macrophytes, which encompass macroalgae (Charophytes), mosses and liverworts (Bryophytes), ferns and angiosperms, are a common occurrence in waterbodies, and are found across a broad range of habitat types. These plants are a natural component of the biodiversity and functioning of stream and river systems – in particular those with stable, slow flows. However, excessive

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[1] See Appendix 1 for a description of the pNRP river classes

macrophyte growth, generally associated with introduced rather than indigenous species (Matheson *et al.*, 2012), is detrimental to ecosystem function. At high densities, macrophytes can reduce habitat availability for fish and macroinvertebrates. Large macrophyte stands also reduce stream hydraulic capacity, increase sediment deposition (Hearne and Armitage, 1993; Kaenel and Uehlinger, 1998) and alter daily oxygen patterns (Wilcock *et al.*, 1999; Wilcock and Nagels, 2001). Due to a lack of empirical data, robust macrophyte cover and volume thresholds for the onset of detrimental effects on ecological condition, hydrology and aesthetics do not currently exist (Matheson *et al.*, 2012). However, Matheson *et al.* (2012) recommended a provisional macrophyte volume guideline of less than 50% of the channel for the protection of instream ecological condition, flow conveyance and recreation.

<u>Sedimentation (deposited fine sediment)</u>

Deposited fine sediment has a range of negative effects on stream ecosystems. Excessive fine sediment deposition reduces food and benthic habitat availability to macroinvertebrates (Kemp *et al.*, 2011) by smothering periphyton and macrophytes (Brookes, 1986; Graham, 1990; Kemp *et al.*, 2011; Ryan, 1991; Yamada and Nakamura, 2002) and infilling interstitial spaces (Kemp *et al.*, 2011). In addition, sediment deposition can affect benthic macroinvertebrates by reducing dissolved oxygen near the substrate (Sear and DeVries, 2008). Consequently, benthic fine sediment cover is an important stressor on macroinvertebrate communities. Indeed, Greenwood *et al.* (2012) found that sedimentation was the single most important predictor of macroinvertebrate community composition in some Canterbury streams, and Burdon *et al.* (2013) determined that above 20% fine sediment cover macroinvertebrate community health declines markedly.

The effects of sediment deposition on macroinvertebrates can alter food availability to the fish species that prey upon them (Matthaei *et al.*, 2006; Wood and Armitage, 1999), which can affect growth rates and community structure (Henley *et al.*, 2000; Kemp *et al.*, 2011). Deposited sediment can also affect the reproductive performance of freshwater fish species. The availability of spawning habitat is a major determinant in the success or failure of fish populations, and large amounts of deposited sediment can have significant impacts on fish species that spawn in or on the bed substrate. Clapcott *et al.* (2011) recommended a guideline value of <20% fine sediment cover to protect stream biodiversity and fish (both native and exotic).

<u>Riparian habitat and stream morphology</u>

There are a number of physical habitat parameters that influence ecosystem health besides plant growth and sedimentation. Factors such as shading, riparian zone composition and stream morphology all affect the structure of aquatic communities. However, there is insufficient data available on the state of riparian habitat and stream morphology to include these parameters in this report.

1.4.3. Water quality as an indirect driver of ecosystem health

<u>Plant available nutrients</u>

Dissolved inorganic nitrogen (DIN) is composed of nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), and ammoniacal nitrogen (NH_4-N), and is the component of nitrogen that is readily available for plant uptake. As concentrations of DIN increase so too does the risk of nuisance periphyton growths in hill-fed systems and, to a lesser extent, nuisance macrophyte growths in spring-fed systems. Dissolved reactive phosphorus (DRP) is the readily available component of phosphorus for plant uptake, and, as with DIN, the higher the DRP concentration the greater the risk of nuisance periphyton and macrophyte growths. Biggs (2000) developed an empirical relationship between periphyton growth and DIN and DRP concentrations to establish thresholds for the protection of benthic biodiversity and trout habitat and angling values from nuisance periphyton growths. Similarly, for the purpose of developing a Bayesian Belief Network model, Matheson *et al.* (2012) defined the DIN and DRP concentrations at which there is a 90%, 70% and 30% probability of nuisance macrophyte growths in spring-fed streams. There is, however, a high level of uncertainty around these thresholds as nutrient availability is just one of a number of factors that influence macrophyte growth. Light availability, flow conditions and rooting substrate also have a strong influence over macrophyte densities and growth rates. Furthermore, some rooted macrophyte species extract nutrients from bed and bank sediments rather than the water column; these plants are unlikely to be affected by instream DIN and DRP concentrations.

The response of benthic cyanobacteria (blue-green algae), such as *Microcoleus* (formally known as *Phormidium*), to nutrient enrichment has been investigated recently in New Zealand. Sustained low flows and high water temperatures are thought to be key drivers in cyanobacteria blooms (Heath *et al.*, 2011; Heath and Greenfield, 2016; Quiblier *et al.*, 2013), and Wood and Young (2012) and Heath *et al.* (2011) found a positive relationship between cyanobacteria coverage and high ratios of total nitrogen to total phosphorus. Heath (2015) identified DIN concentrations >0.1 mg/L and DRP concentrations <0.01 mg/L) as being associated with potentially toxic cyanobacteria (such as *Microcoleus*) bloom formation. However, the drivers of cyanobacteria growth are likely to be complex and are not fully understood.

Suspended solids

At high concentrations, suspended sediments can have a range of direct and indirect negative ecological effects. Physical abrasion and reduced light penetration at high suspended sediment concentrations can reduce periphyton and macrophyte abundance (Bruton, 1985; Davies-Colley *et al.*, 1992; Graham, 1990; Van Nieuwenhuyse and LaPerriere, 1986), thereby limiting food availability to macroinvertebrates (Henley *et al.*, 2000; Kemp *et al.*, 2011). This, combined with increased drift as macroinvertebrates are dislodged by sediment, can reduce macroinvertebrate abundance (Kemp *et al.*, 2011; Quinn *et al.*, 1992; Wood and Armitage, 1999). Fish can also be impacted by high suspended sediment concentrations by reduced recruitment of migrating juveniles, clogged gills, reduced feeding performance, and reduced food availability (Boubée *et al.*, 1997; Greer *et al.*, 2015a; Kemp *et al.*, 2011; Lake and Hinch, 1999; Rowe and Dean, 1998; Sutherland and Meyer, 2007). Total suspended solids (TSS) is the measure of the mass concentration of sediments suspended in the water column used in this report.

1.4.4. Water quality as a direct driver of ecosystem health

Potentially toxic contaminants (including metals, ammonia and nitrate)

In addition to promoting plant growth, high concentrations of nitrate nitrogen and ammonia can be toxic to aquatic fauna. Nitrate is toxic to invertebrates and fish in high concentrations, as it interferes with oxygen transport in the blood, and consequently, metabolic function (Camargo and

Alonso, 2006). In humans this effect is known as methemoglobinemia, and is often referred to as blue baby syndrome, due to the cyanosis (blue skin colouration) commonly observed in affected children (Knobeloch *et al.*, 2000). Susceptibility to nitrate toxicity varies between species and even different life stages of a particular species (Camargo and Alonso, 2006). Ammonia toxicity occurs when accumulations inside the body interfere with metabolic processes and increase body pH (Camargo and Alonso, 2006; Randall and Tsui, 2002). When exposed to extreme concentrations of ammonia, fish go into convulsions followed by coma, and death. As with nitrate, susceptibility to ammonia toxicity is species and life stage dependent. The NPS-FM 2014 defines numeric attribute states for both ammonia and nitrate toxicity.

At elevated concentrations, metals (particularly in the dissolved phase) including copper (Cu), zinc (Zn) and lead (Pb) can also be toxic to aquatic fauna and flora. What is more, these contaminants may accumulate in bed sediments and the flesh of exposed animals, meaning that toxicity effects can build up over time (Stewart *et al.*, 2017). Metal toxicity is dependent on a number of factors, including water temperature, pH, dissolved organic matter and hardness (Stewart *et al.*, 2017). Species sensitivity to contaminants also depends on the life-stage of exposure (juvenile versus adult), the ability to regulate body-burdens, as well as the duration and frequency of exposure (e.g. pulse disturbance of first flush stormwater discharges).

Dissolved oxygen (DO) and temperature

Dissolved oxygen (DO) is a vital component of water quality and has a significant impact on aquatic fauna. The amount of oxygen fish and macroinvertebrates can absorb across the membranes of respiratory organs is heavily dependent on environmental oxygen conditions, so reductions in external DO limits the supply of oxygen to body tissues (Dean and Richardson, 1999). Long-term exposure to mild exposure can hinder reproductive success, reduce growth rates and decrease mobility (Alabaster and Lloyd, 1982). Hypoxia becomes lethal when oxygen supply is no longer adequate to meet the energy demands essential for life functions (Kramer, 1987).

Temperature has a significant effect on the physiological performance of biota, and, consequently ecosystem function. The physiological processes of periphyton, macroinvertebrates and fish have thermal optima, and changes in temperature regime can affect the metabolic function, reproductive performance, mobility and migration of exposed species (Alabaster and Lloyd, 1982; ANZECC, 2000; Davies-Colley *et al.*, 2013; USEPA, 1986).

1.4.5. Water quality and plants as a determinant of recreational value

Faecal contamination

Escherichia coli (*E. coli*) is a bacterium that naturally occurs in the lower intestines of humans and warm-blooded animals; for that reason, its presence in freshwater is indicative of faecal contamination (MfE/MoH, 2003). Water contaminated by faecal material contains a range of pathogenic bacteria, viruses and other micro-organisms (e.g. protozoa) that present a risk to the health of people conducting recreational activities where water is ingested, inhaled (as an aerosol), or comes into direct contact with sensitive areas (eyes, ears, open wounds) (MfE/MoH, 2003). *E. coli* does not generally pose a significant risk to human health in itself. However, it is used as a Faecal Indicator Bacteria (FIB), meaning the level at which it is present can be used to quantify the risk of infection from faecal pathogens such as *Campylobacter, Salmonella, Giardia, Cryptosporidium* and Norovirus which are difficult or impractical to routinely measure directly in water (MfE/MoH, 2003). Consequently, *E. coli* is the primary attribute used in New Zealand to assess the microbiological health risks associated with contact with recreational freshwaters.

Toxic cyanobacteria

Benthic cyanobacteria grow attached to the substrate of rivers and streams. In Wellington rivers the dominant bloom-forming benthic cyanobacteria genus is *Microcoleus* (Heath *et al.*, 2010; Heath and Greenfield, 2016; Wood *et al.*, 2007). *Microcoleus* blooms are primarily associated with river or stream environments where they form leathery dark brown or black mats (Figure 2), but they can also establish in lakes and ponds (Heath and Greenfield, 2016; Quiblier *et al.*, 2013). *Microcoleus* can produce four lethal neurotoxins, known collectively as anatoxins, which cause convulsions, coma, rigors, cyanosis, limb twitching, hyper salivation and/or death. The presence of anatoxins in *Microcoleus* mats is widespread. Heath and Greenfield (2016) found 59% *Microcoleus*-dominated mat samples collected from across the Wellington Region contained anatoxins. However, the concentration of all four variants is highly spatially and temporally variable (Heath *et al.*, 2011; Wood *et al.*, 2012, 2010). Dogs are particularly susceptible to the toxins produced, with death occurring in as little as 30 minutes in some cases (Wood *et al.*, 2007). Cyanobacteria can also produce odorous compounds that taint fish flesh, making it unpalatable.

Figure 2: Typical *Microcoleus* bloom on the surface of a cobble.

The human health risks associated with benthic cyanobacteria are not fully understood, and the MfE/MoH (2009) guidelines are the only existing numeric thresholds against which the potential health risks associated with benthic cyanobacteria can be assessed. The MfE/MoH (2009) guidelines recommend coverage thresholds for potentially toxigenic cyanobacteria as part of three-tier surveillance, alert and action sequence for managing the public health risk associated with benthic cyanobacteria. However, these thresholds are based on preliminary observations, and still require significant refinement.

The Ministry for the Environment, with the support of regional councils, has recently commissioned a team of researchers to review and update the guidelines. One of the possible updates to the guidelines is a shift from the coverage-based assessments currently used to assess the risk to human health, to toxicity-based assessments (Mark Heath pers. comm. 2018). The Ministry has also been working with a team of researchers to develop a benthic cyanobacteria attribute for inclusion in the NPS-FM 2014.

2. Methods

2.1. Data sources

2.1.1. Water quality.

Water quality data (i.e. temperature, dissolved oxygen concentrations, nutrient concentrations, faecal containment levels and total suspended solid concentrations) were sourced from GWRC's River Water Quality and Ecology (RWQE) monitoring programme[2]. For this programme, GWRC currently conducts, or has recently conducted, monthly monitoring water quality sampling at 14 sites in Whaitua Te Whanganui-a-Tara (Table 2 and Figure 3). Additional *E. coli* data were also sourced from GWRC's Recreational Water Quality monitoring programme, and Wellington and Hutt City Councils' (WCC and HCC) *E. coli* monitoring programmes (Table 3). GWRC conducts weekly *E. coli* monitoring at eight popular river bathing sites in Whaitua Te Whanganui-a-Tara (Table 2) over summer to determine their suitability for contact recreation. WCC and HCC monitor minor streams within their districts for *E. coli* on a monthly or fortnightly basis, year-round, and this monitoring is targeted to potentially problematic areas of stormwater discharges (which may contain wastewater).

2.1.2. Plants and sediment

Periphyton, cyanobacteria, macrophyte and fine sediment cover data were also sourced from GWRC's RWQE monitoring programme. As part of this programme, GWRC staff make monthly observations of periphyton cover (including cyanobacteria), by surveying five transects at each site using a stream viewer (five views per transect) to determine the percentage of the visible bed covered by the aforementioned plants (this method is adapted from RAM-1 in Biggs and Kilroy

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[2] Not all RWQE sites have had data collected for the same length of time. Table 2 provides a summary of where water quality data are available, how long sites have been monitored for, and how frequently monitoring has been conducted. Figure 3 depicts where sites are located in Whaitua Te Whanganui-a-Tara.

(2000)). These data are then converted into the periphyton Weighted Composite Cover (periWCC) for each sampling occasion using the following equation:

$$PeriWCC = Filamentous\ cover\ (\%) + \frac{Mat\ cover\ (\%)}{2}$$

GWRC also conduct, or have recently conducted, monthly periphyton biomass monitoring at four sites in Whaitua Te Whanganui-a-Tara using the QM1b and QM3 protocols in Biggs and Kilroy (2000); monitoring sites are listed in Table 2.

Between July 2012 and June 2016 GWRC monitored macrophytes and deposited sediment, by estimating from the stream bank, the percentage of the visible stream bed covered. This technique was stopped in 2016 after concerns were raised about the usefulness and repeatability of subjective bankside assessment methodologies. Consequently, fine sediment and macrophyte cover data do not exist after this point. It should be noted that a more quantitative method of assessing sediment cover was re-instated in July 2017. However, these data are outside of the assessment period considered in this report.

2.1.3. Macroinvertebrates

This assessment incorporates macroinvertebrate data also collected as part of GWRC's RWQE monitoring programme. GWRC staff monitor macroinvertebrate communities and habitat quality annually at RWQE monitoring sites. Each site is visited between spring and early summer and a composite kick net macroinvertebrate sample is collected. Macroinvertebrates are then identified and counted to calculate an MCI score for the site which can be graded using the poor-fair-good-excellent system set out in Clapcott and Goodwin (2014) and compared with the freshwater outcomes set out in the proposed Natural Resources Plan (pNRP).

2.1.4. Fish distribution and significant habitat types

Fish distribution

Current fish monitoring undertaken by GWRC is typically for targeted investigations (e.g., urban biodiversity) or undertaken at a regional scale and hence not necessarily applicable to Whaitua Te Whanganui-a-Tara. However, to provide some context of potential freshwater fish values, distributional data were accessed through the New Zealand Freshwater Fish Database (NZFFD). The NZFFD is maintained by NIWA and provides a repository in which researchers and members of the public can record data pertaining to fish sampling. The database provides information about the location of sampled sites and the fish species present and their abundance. The database does not provide definitive presence-absence data, and that a species is not recorded does not mean that it is not present. However, in well sampled areas, the NZFFD does provide an indicative range of the species present. For each subzone, the range of species recorded in the NZFFD for the period 2000 to 2017 is listed.

While fish are an extremely important biological indicator of river and stream health, it is difficult with the current data available to undertake a robust analysis of fish community condition at the whaitua sub-zone scale used in this report. Consequently, fish distributions are not treated as a key indicator of ecological health in this report (hence why they are not discussed in Section 1.4). This is acknowledged as a gap in our current understanding of ecological health in this whaitua.

Significant habitat types

Rivers and streams identified in the notified version of the pNRP as providing significant trout fishery, trout spawning and inanga spawning values are indicated for each subzone. In regards to inanga, one of the few indigenous freshwater fish where there is reasonable knowledge of spawning habitat requirements, additional information relating to inanga spawning habitat in Whaitua Te Whanganui-a-Tara subzones was sourced from past surveys (Marshall and Taylor, 2017; Taylor and Kelly, 2003, 2001; Taylor and Marshall, 2016) and a model of potential inanga spawning habitat in Wellington rivers which was generated using the same methodology outlined in Greer *et al.*(2015b).

The pNRP also identifies rivers and streams that provide significant migratory and threatened/at risk indigenous fish values. However, as this list contains almost all of the waterways in the Wellington Region, it is of limited use when assessing and comparing fish community health across individual rivers and streams, and is not in presented in this report.

2.1.5. Flow

Stream and river flow data used in this report were provided by the GWRC hydrology team. Simultaneous gauging data were used to derive relationships between flows at RWQE sites without long-term flow records and the GWRC flow recorders on Mill Creek, Porirua Stream and the Hutt, Pakuratahi, Whakatikei, Wainuiomata and Orongorongo rivers (a detailed description of how flows were derived can be found in (Thompson and Gordon, 2011) This provided a continuous record of daily mean flows for all RWQE monitoring sites.

2.1.6. Other

Past reports on the water quality and ecology of rivers and streams in Whaitua Te Whanganui-a-Tara are referenced in this report where appropriate.

Table 2: Greater Wellington Regional Council water quality and ecological monitoring sites in Whaitua Te Whanganui-a-Tara.

Site	Site ID	East	North	Programme	Sub-zone	River class[1]	Macroinvertebrate	Periphyton biomass	Period
Orongorongo R. @ Orongorongo St.	RS30	1758930	5413094	RWQE	Wainuiomata & Orongorongo	1	Yes	No	01/07/12 – 30/06/16
Wainuiomata R. @ Manuka Tr.	RS28	1768301	5430792	RWQE	Wainuiomata & Orongorongo	1	Yes	No	01/07/12 – 30/06/17
Wainuiomata R. d/s of White Br.	RS29	1757315	5415739	RWQE	Wainuiomata & Orongorongo	4	Yes	Yes	01/07/12 – 30/06/17
Wainuiomata R. @ RP Pk.		1764536	5429141	Rec.	Wainuiomata & Orongorongo	1	No	No	01/07/12 – 30/06/17
Akatarawa R. @ Hutt Conf.	RS25	1776183	5449184	RWQE/Rec.	Hutt River	1	Yes	No	01/07/12 – 30/06/17
Hutt R. @ Te Marua	RS20	1780071	5450158	RWQE	Hutt River	1	Yes	Yes	01/07/12 – 30/06/17
Mangaroa R. @ Te Marua	RS24	1778726	5448590	RWQE	Hutt River	1	Yes	Yes	01/07/12 – 30/06/17
Pakuratahi R. below Farm Cr.	RS23	1784607	5451677	RWQE	Hutt River	1	Yes	No	01/07/12 – 30/06/17
Hutt R. @ Boulcott	RS22	1761038	5437628	RWQE	Hutt River	4	Yes	Yes	01/07/12 – 30/06/17
Hutt R. @ Manor Park	RS21	1766679	5442285	RWQE	Hutt River	4	Yes	No	01/07/12 – 30/06/17
Whakatikei R. @ Riverstone	RS26	1772256	5446748	RWQE	Hutt River	4	Yes	No	01/07/12 – 30/06/17
Hutt R. @ Birchville		1776196	5449091	Rec.	Hutt River	4	No	No	01/07/12 – 30/06/17
Hutt R. @ Maoribank Corner		1775882	5446696	Rec.	Hutt River	4	No	No	01/07/12 – 30/06/17
Hutt R. @ Melling Bridge		1759906	5436831	Rec.	Hutt River	4	No	No	01/07/12 – 30/06/17
Hutt R. @ Poets Park		1771461	5446092	Rec.	Hutt River	4	No	No	01/07/12 – 30/06/17
Hutt R. @ Silverstream Br.		1767598	5443172	Rec.	Hutt River	4	No	No	01/07/12 – 30/06/17
Pakuratahi R. @ Hutt Forks		1784288	5452620	Rec.	Hutt River	1	No	No	01/07/12 – 30/06/17
Kaiwharawhara S. @ Ngaio G.	RS19	1749069	5431077	RWQE	Wellington Harbour	2	Yes	Yes	01/07/12 – 30/06/17
Waiwhetu S. @ Whites Line East	RS57	1760977	5434510	RWQE	Wellington Harbour	6	Yes	No	01/07/12 – 30/06/17
Karori S. @ Makara Peak	RS18	1744222	5427016	RWQE	South/west coastal	2	Yes	No	01/07/12 – 30/06/17
Makara S. @ Kennels	RS17	1743530	5433635	RWQE	South/west coastal	2	Yes	No	01/07/12 – 30/06/17

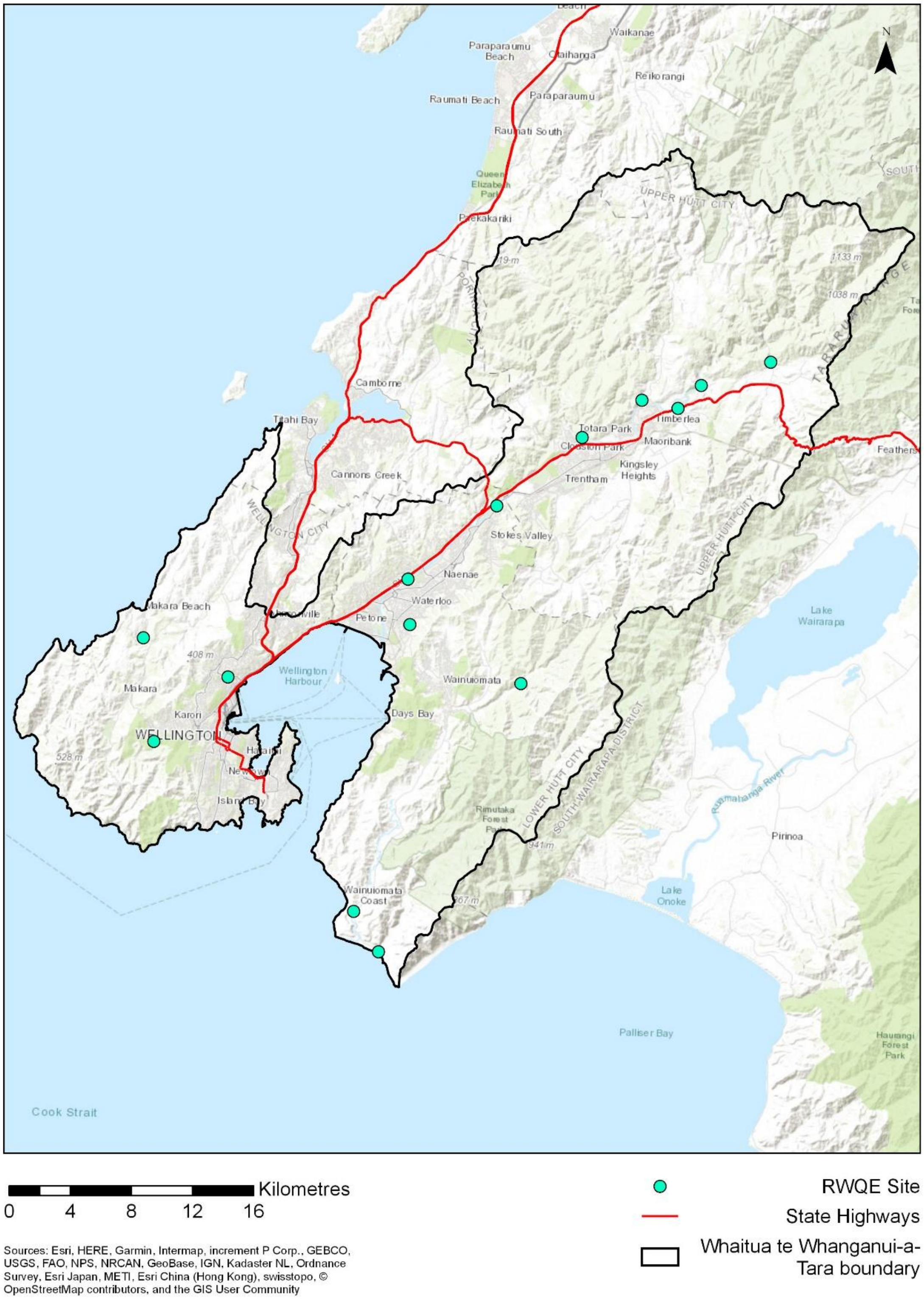

Figure 3: Location of the GWRC RWQE monitoring sites in Whaitua Te Whanganui-a-Tara.

Table 3: Hutt City Council and Wellington City Council *E. coli* monitoring sites within each sub-zone.

Sub-zone	Council	Site	Easting	Northing
Wainuiomata & Orongorongo	HCC	Black Creek at Moohan St.	1763582	5429484
		Wainuiomata Stream at Reservoir Road	1764725	5429199
Hutt River		Speedy's S. @ Western Hutt Rd.	1761754	5438279
		Opahu S. @ Penrose St.	1760225	5435703
		Opahu S. @ Whites Line West	1759417	5434970
		Te Mome S. @ Bracken St.	1758791	5434795
		Te Mome S. @ The Esplanade	1759056	5433704
		Awamutu S. @ Hutt Park	1759621	5433500
Wellington Harbour		Waiwhetu S. @ Rishworth St.	1760565	5434141
		Waiwhetu S. @ Tilbury St.	1762345	5436401
	WCC	Kaiwharawhara S. near harbour	1749965	5430731
		Ngauranga S. near harbour	1751933	5432400
		Otari Park S.	1747640	5430512
		Tyers St. @Gorge	1751827	5432776
South/west coastal		Karori S. @South Karori Rd.	1744222	5427015
		Karori S. @ WTP- 100m u/s.	1742255	5425520
		Karori S. @ WTP- 100m d/s.	1747046	5422951
		Owhiro S. @ Kingston	1747090	5423394
		Lower Careys Gully S.	1747046	5422951
		Owhiro S. @ Happy Valley Tip Br.	1747076	5422706
		Owhiro S. d/s Happy Valley Tip	1747284	5422341
		Owhiro Bay S. Outlet	1747106	5421522

2.2. Analysis

2.2.1. Data criteria

The current state of ecosystem health, habitat and water quality at each monitoring site was assessed using data from the past five **water years**[3] (hereafter referred to as years) (July to June 2012-2017)[4]. Five years is the minimum length of time to assess normal state in sites that are sampled on a quarterly basis (McBride, 2016, 2005). For some sites there are fewer than five years of data available, and the decision to include these sites in this assessment was made based on the high sampling frequency at these sites (monthly).

2.2.2. Current state of macroinvertebrate communities

The pNRP sets river-class specific numeric outcomes for MCI (Table 5). A description of how these outcomes were set can be found in Clapcott and Goodwin (2014) and Greer (2018a). These outcomes were developed to ensure a good level of ecosystem health in all rivers and an excellent level of ecosystem health in rivers with high macroinvertebrate community health.

Annual MCI values have been graded on river class specific poor-fair-good-excellent scales developed by Clapcott and Goodwin (2014) (Table 4). Rolling 3-year median MCI results have also been compared to the river class specific MCI outcomes in Table 3.4 of Objective O25 of the pNRP (Table 5). The rationale for the selection of these outcomes is covered in Greenfield *et al.* (2015b), Clapcott and Goodwin (2014) and Greer (2018a).

Table 4: Wellington specific MCI quality classes developed by Clapcott and Goodwin (2014).

River Class	Excellent	Good	Fair	Poor
1	≥130	≥120	≥110	<110
2	≥130	≥105	≥80	<80
3	≥130	≥105	≥80	<80
4	≥130	≥110	≥90	<90
5	≥120	≥100	≥80	<80
6	≥120	≥100	≥80	<80

[3] July 1 to June 30.
[4] Summary statistics for key parameters are presented in Appendix 2

Table 5: Summary of relevant pNRP outcomes for the assessed river types.

River Class	MCI outcome (sig. rivers)	Periphyton biomass outcome (sig. rivers)	periWCC outcome (sig. rivers)
	Unitless	mg chl-a/m2	(% cover)
1	≥120 (≥130)	≤50 (≤50)	<20 (<20)
2	≥105 (≥130)	≤120 (≤50)	<40 (<20)
3	≥105 (≥130)	≤120 (≤50)	<40 (<20)
4	≥110 (≥130)	≤120 (≤50)	<40 (<20)
5	≥100 (≥120)	≤120 (≤50)	<40 (<20)
6	≥100 (≥120)	≤120 (≤50)	<40 (<20)

2.2.3. Current state of cyanobacteria, periphyton and macrophytes

The pNRP sets river-class specific outcomes for numeric outcomes for periphyton biomass and cover[5] (Table 5). A description of how these outcomes were set can be found in Greenfield *et al.* (2015b) and Greer (2018b). As with MCI, these outcomes were developed to ensure a good level of ecosystem health in all rivers and an excellent level of ecosystem health in rivers with high macroinvertebrate community health.

In this assessment, annual maximum periWCC values for each site have been graded on the poor-fair-good-excellent scale developed by Matheson *et al.* (2012) (Table 6), and compared against the relevant pNRP outcomes. Similarly, periphyton biomass data from each site have been graded on the poor-fair-good-excellent scale presented in Snelder *et al.* (2013)[6][7] (Table 6) and assessed against the pNRP outcomes. The biomass grading methodology set out in Snelder *et al.* (2013) and the pNRP stipulate that for a threshold to be met it must not be exceeded by more than 8% of samples from non-productive rivers and 17% of samples from productive rivers. However, this assessment is meant to be based on three years of monthly data, and, at the time of writing, less than two years' worth of data has been collected at all sites. Consequently, the highest possible grade (i.e. what the site would be graded if all remaining samples were below the excellent threshold) and the predicted grade (i.e. what the site would be graded if the observed patterns in

[5] The notified version of the pNRP does not include outcomes for periWCC. However, it is likely that the final version of the plan will, as both submitters and GWRC officers have recommended that they be included.

[6]See Section 2.1.2 for description of the periWCC

[7] Recommends an A-B-C-D grading scale, in line with the NPS-FM 2014 attribute state framework. However, the letter based grading system used in the NPS-FM 2014 is based on a poor-fair-good-excellent scale, with A representing excellent ecological condition and D representing poor ecological condition (NOF Reference Group, 2012)

the existing data continue for the remainder of the sampling period) were both calculated for each site.

Table 6: Ecosystem health thresholds for periphyton biomass and cover (as periWCC) (Matheson *et al.*, 2012; Snelder *et al.*, 2013) and the NPS-FM 2014 attribute states for periphyton biomass. The boundary between attribute states C and D represents the national bottom line.

Grade	Attribute state (periphyton biomass only)	Periphyton biomass (mg chl-*a*/m²)	periWCC (% cover)	Narrative (biomass only)
Excellent	A	≤50	<20	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat
Good	B	≤120	<40	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat
Fair	C	≤200	<55	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat
Poor	D	>200	>55	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat

The pNRP only sets narrative outcomes for benthic cyanobacteria and macrophyte growth. Greenfield *et al.* (2015b), which provides suggested guidance on how to assess rivers against these outcomes, recommends a guideline value of <20% be used when assessing cyanobacteria cover against the narrative outcome and a cross sectional area/volume guideline value of < 50% be used when assessing macrophytes against the outcome. The cyanobacteria guideline recommended in Greenfield *et al.* (2015b) is aligned with the 'alert' threshold in the MfE/MoH (2009) interim guidelines and the macrophyte guideline aligns with the threshold recommended by Matheson *et al.* (2012) to protect instream ecological condition, flow conveyance and recreation values. In this assessment, annual maximums of recorded observations of cyanobacteria cover were compared against the guideline suggested by Greenfield *et al.* (2015b).

However, GWRC has never monitored macrophyte cross sectional area/volume, and it is not possible to assess macrophytes against the guideline suggested by Greenfield *et al.* (2015b). Instead annual maximum macrophyte surface cover was compared with the guideline recommended by Matheson *et al.* (2012) for the protection of instream aesthetic and recreational values (<50% cover). The use of this guideline to assess sites against the pNRP macrophyte outcome is consistent with the approach taken in Greenfield *et al.* (2015a).

2.2.4. Current state of sedimentation

Box and whisker plots were used to present the distribution of fine sediment cover values recorded at each site over the past five years. The box and whisker plots depict the median, the 5th, 25th, 75th and 95th percentiles of recorded values. Appendix 3 describes how these box and whisker plots should be interpreted. The distribution of fine sediment cover values recorded at each site were compared to the guideline value of 20% cover designed to protect stream biodiversity and fish (Clapcott *et al.*, 2011).

2.2.5. Current state of dissolved oxygen (DO) and temperature

Annual maximums of recorded temperatures[8] and annual minimums of recorded DO saturations[9] at each site were graded on the poor-fair-good-excellent scales developed by Davies-Colley *et al.* (2013) (Table 7 and Table 8). Temperature and dissolved oxygen can fluctuate dramatically between and within days. Therefore, the single monthly measurements of temperature and DO saturation presented in this report are not representative of the full diurnal range of conditions and can only be used to identify where issues definitely exist. When recorded observations of DO and temperature meet a given threshold does not mean that this threshold is not regularly being breached at a site.

Table 7: Ecosystem health thresholds for temperature (Davies-Colley *et al.*, 2013). Maximum temperature used instead of Cox-Rutherford Index.

Grade	Annual max. temp. (°C)	Narrative
Excellent	≤18	No thermal stress on any aquatic organisms that are present at matched reference (near-pristine) sites
Good	≤20	Minor thermal stress on occasion (clear days in summer) on particularly sensitive organisms such as certain insects and fish
Fair	≤24	Some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish
Poor	>24	Significant thermal stress on a range of aquatic organisms. Risk of local elimination of keystone species with loss of ecological integrity

[8] The grading system for temperature set out in Davies-Colley *et al.* (2013) uses a statistical measure that cannot be calculated without continuous data. However, Davies-Colley *et al.* (2013) states maximum temperature measurements can be used in small streams with large diel temperature variations or at sites with minimal monitoring data, as is the case here.

[9] The grading system for DO set out in Davies-Colley *et al.* (2013) uses three statistical measures, the 7-day mean, the 7-day mean minimum and the 1-day minimum. As DO data is not collected continuously, sites can only be graded based on the 1-day minimum

Table 8: Ecosystem health thresholds for dissolved oxygen (Davies-Colley *et al.*, 2013).

Grade	Annual min. DO conc. (mg/L)	Narrative
Excellent	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.
Good	≥5.0	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
Fair	≥4.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
Poor	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

2.2.6. Current state of nutrient concentrations and loads

State

Box and whisker plots were used to present the distribution of DIN and DRP concentrations recorded at each site since July 2012. Comparisons of the median values of those nutrients with established thresholds for periphyton and macrophyte growth allowed for a relative assessment of risk of nuisance plant growths. For hard-bottomed rivers, the results have been compared to guidelines set to protect benthic biodiversity and trout habitat and angling values from nuisance periphyton growths in rivers with 20 or 30-day accrual periods (Biggs, 2000). Accrual period was decided for each site based on the information presented in Ausseil (2011). DIN and DRP concentrations in spring-fed streams were compared to the thresholds at which there is a 90%, 70% and 30% probability of nuisance macrophyte growths (Matheson *et al.*, 2012). As previously stated there is a high level of uncertainty around these thresholds.

Box and whisker plots were used to present the distributions of nitrate nitrogen (NO_3-N) and ammoniacal (NH_4-N) nitrogen concentrations. NO_3-N and NH_4-N concentrations at at each site were also assessed against guidelines designed to prevent chronic nitrate and ammonia toxicity (Hickey, 2014, 2013) (Table 9 and Table 10). Un-ionised ammonia (NH_3-N) is the most toxic form of ammoniacal nitrogen, and the NH_4-N guidelines developed by Hickey (2014) are based on the ratio between NH_3-N and NH_4-N when pH is 8 and temperature is 20^{o}C. Under different pH and temperature conditions the NH_3- N:NH_4-N ratio changes. Accordingly, before compliance with the guidelines can be assessed the measured NH_4-N data, needs to be adjusted for pH and temperature. The adjustment methodology employed in this report involved converting all NH_4-N concentrations to NH_3-N concentrations[10], and assessing those against NH_3-N thresholds that correspond to the guidelines[11].

Table 9: Thresholds for species protection from nitrate toxicity (Hickey, 2013) and the NPS-FM 2014 attribute states for nitrate toxicity. The boundary between attribute states C and D represents the national bottom line.

Species protection level	Attribute state	Annual NO_3-N median (mg/L)	Annual NO_3-N 95th %ile (mg/L)	Narrative
99%	A	≤1	≤1.5	High conservation value system. Unlikely to be effects even on sensitive species.
95%	B	≤2.4	≤3.5	Some growth effect on up to 5% of species
90%		≤3.8	≤5.6	
80%	C	≤6.9	≤9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
<80%	D	>6.9	>9.8	Impacts on growth of multiple species and starts approaching acute impact level (i.e. risk of death) for sensitive species at higher concentrations (>20 mg/L).

[10] Based on the measured water pH and temperature measured on the day of sampling.
[11] Calculated from percentage of total ammoniacal nitrogen composed of unionised ammonia nitrogen at pH of 8 and 20ºC (3.8%).

Table 10: Thresholds for species protection from ammonia toxicity (Hickey, 2014) and the NPS-FM 2014 attribute states for ammonia toxicity. The boundary between attribute states C and D represents the national bottom line.

Species protection level	Attribute state	Annual NH_3-N median (mg/L)	Annual NH_3-N maximum (mg/L)	Narrative
99%	A	≤0.001	≤0.002	99% species protection level: No observed effect on any species tested
95%	B	≤0.009	≤0.015	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
80%	C	≤0.05	≤0.084	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
<80%	D	>0.05	>9.8	Starts approaching acute impact level (i.e. risk of death) for sensitive species

Loads

For sites in the Wellington Harbour stream catchments sub-zone and the Hutt River catchment sub-zone, annual DIN, TN, DRP and TP loads were calculated each year from daily mean flow data, and discrete water sampling data using the averaging method and the Beale's ratio estimator method.

2.2.7. Current state of metal concentrations

Box and whisker plots were used to present the distribution of copper (Cu) and zinc (Zn) concentrations recorded at each monitored site since July 2012. The median values of these contaminants were compared with the alternate levels of protection (protection of 99%, 95%, 90% and 80% of species) set out in the draft updated Australian and New Zealand guidelines for fresh and marine water quality guidelines (formerly the ANZECC guidelines)[12] to determine the risk they pose to ecosystem health (Table 11). It is important to note that the ANZECC (2000) guidelines specify that assessment against the trigger values be based on the 95th percentile of sample concentrations to account for the fact that a single exposure at this level represents a risk to sensitive organisms. However, where the guidelines are generally considered a management response tool to inform mitigation decisions, the purpose this report is to describe current state. Accordingly, the median sample concentration has been compared against the trigger values as this statistic best reflects the 'normal' state of a river or stream.

[12] The draft guidelines are still subject to change. Dissolved organic carbon (DOC) concentration, water hardness and pH are supposed to be used to adjust the guidelines for site specific applications. GWRC does not monitor DOC, and it was not possible to adjust the guidelines for this assessment.

Table 11: Draft Australian and New Zealand guidelines for fresh and marine water quality guidelines for species protection from metal toxicity.

Species protection level	Cu (mg/L)	Zn (mg/L)	Narrative
99%	≤0.00035	≤0.0006	High conservation value systems.
95%	≤0.0012	≤0.003	Slightly to moderately disturbed systems
90%	≤0.0021	≤0.006	Highly disturbed systems
80%	≤0.004	≤0.012	Highly disturbed systems
<80%	>0.004	>0.012	Highly disturbed systems

2.2.8. Current state of total suspended solids concentrations

Box and whisker plots were used to present the distribution of total suspended solids (TSS) concentrations recorded at each site. The median TSS concentrations were compared with the commonly cited threshold of 25 mg/L for the onset of detrimental effects to fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001). TSS can change significantly with flow, and the available data does not necessarily describe the entire range of sediment concentrations that occur at the monitoring sites. Therefore, these data do not allow for definitive conclusions regarding the effects of suspended sediment in Whaitua Te Whanganui-a-Tara.

2.2.9. Current state of faecal contamination

All *E. coli* data are summarised using the NPS-FM 2014 *E. coli* attribute states (Table 12). The NPS-FM 2014 describes five "Attribute states" (A-E) which provide different levels of protection for primary contact recreation (Table 12). The attribute states set thresholds for the percentage of exceedances over 540 CFU/100ml, the percentage of exceedances over 260 CFU/100ml, the median concentration and the 95th percentile of *CFU*/100ml based on a minimum of 60 samples collected over a five-year period. Rivers and lakes with *E. coli* concentrations that fall into attribute states A, B and C are considered suitable for primary contact recreation, those with *E. coli* concentrations in attribute states D and E are not (see Appendix 4 for the NPS-FM 2014 narrative attribute states)

For sites monitored as part of GWRC's RWQE and Recreational Water Quality monitoring programmes and WCC's and HCC's *E. coli* monitoring programmes, *E. coli* attribute states have been calculated using the most recent five years of monthly monitoring data from each site. It is important to note that these three programmes have different objectives, and the RWQE is the only one focused on NPS-FM 2014 attribute state monitoring. Attribute states calculated from data collected under the Recreational programme and the WCC/HCC *E. coli* monitoring programmes should be considered preliminary.

Table 12: Description of NPS-FM 2014 *E. coli* attribute states.

Attribute state	% of *E. coli* measurements below 540 cfu/100mL	% of *E. coli* measurements below 260 cfu/100mL	Median *E. coli* concentration (cfu/100mL)	95th percentile *E. coli* concentration (cfu/100mL)	Narrative
A	<5%	<20%	≤130	≤540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 1%
B	5-10%	20-30%	≤130	≤1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 2%
C	10-20%	20-34%	≤130	≤1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 3%
D	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >3%
E	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >7%

2.3. Comparison with National Policy Statement (2014) attribute states

GWRC RWQE sites in Whaitua Te Whanganui-a-Tara were compared against the NPS-FM 2014 attribute states for periphyton biomass (Table 6), NO_3-N (Table 9), NH_3-N[13] (Table 10) and *E. coli* (Table 12). For NO_3-N, NH_3-N[13] and *E. coli*, attribute states were calculated annually (*E. coli* annual grades based on the previous five years of data), and an overall average grade was

[13] NH_4-N concentrations and attribute states thresholds have been converted to un-ionised ammonia (NH_3-N) concentrations (see Section 2.2.6 for more details)

calculated. For periphyton biomass, the highest possible attribute state and the predicted attribute state were both calculated for each site using all available data[14].

2.4. Trends

Trends analyses were conducted for the following parameters by Snelder (2017):

- MCI;
- Mat algal cover;
- Filamentous algal cover;
- Periphyton biomass;
- DIN;
- DRP;
- *E. coli* (note trends were only calculated for the RWQE sites);
- NO_3-N;
- NH_4-N; and
- TSS.

A detailed description of the assessment methodology can be found in Snelder (2017). Trends are reported as uncertain, improving or degraded, and are considered environmentally meaningful when the Relativised Seasonal Kendall Slope Estimator [RSSE (median annual Sen slope divided by median result)] indicates an annual change of more than 1% per year. While arbitrary, this approach has been used extensively when analysing trends in water quality data e.g. (Ballantine and Davies-Colley, 2009).

[14] Because only a proportion of the data required by the NPS-FM 2014 (12 months instead of at least 36 months) were used to calculate periphyton biomass attribute states, the results of this assessment should be considered as preliminary only (see Section 2.2.3. for further information on how highest possible and predicted attribute states were calculated)

3. Results

3.1. Wainuiomata and Orongorongo catchments sub-zone

3.1.1. Ecology and habitat

<u>*Macroinvertebrates*</u>

Long-term macroinvertebrate monitoring data exists for three sites in the Wainuiomata and Orongorongo catchments sub-zone; the Orongorongo River at Orongorongo Station, the Wainuiomata River at Manuka Track and the Wainuiomata River downstream of White Bridge.

The MCI outcomes in the pNRP were not met in the Orongorongo River at Orongorongo Station in any of the years that monitoring was conducted between 2012 and 2016. While rolling three-year rolling median MCI scores at the site in 2012 and 2013 were indicative of good ecological condition (based on Wellington specific MCI thresholds set out in Clapcott and Goodwin (2014)), the score in 2014 was indicative of only fair ecological condition (Table 13).

The pNRP MCI outcomes were met in the Wainuiomata River at Manuka Track in every year between 2012 and 2016, and MCI scores were indicative of excellent ecological condition during this period (Table 13). Further downstream, below White Bridge, MCI scores in the Wainuiomata River only met the pNRP outcomes in 2015 and 2016, when ecological condition was good. In 2012, 2013 and 2014, ecological condition at this site was only fair (Table 13).

Table 13: Rolling 3-year median MCI scores (and annual MCI scores) recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not.

Site	pNRP outcome	2012	2013	2014	2015	2016
Orongorongo R. @ Orongorongo St.	130	125 (125)	125 (107)	119 (119)	-	-
Wainuiomata R. @ Manuka Tr.	130	137 (138)	138 (144)	138 (138)	138 (130)	131 (131)
Wainuiomata R. d/s of White Br.	110	105 (107)	107 (109)	109 (114)	111 (111)	111 (104)

<u>*Fish*</u>

Six native species were found in the Wainuiomata and Orongorongo catchments between 2000 and 2017: longfin eel, shortfin eel, koaro, redfin bully, dwarf galaxias, lamprey. Giant kokopu and banded kokopu were also found in the Gollans Stream catchment. All of these species, except shortfin eel and banded kokopu are classified as either at risk or threatened (Goodman *et al.*, 2014).

Brown trout was the only introduced sports fish found in the Wainuiomata and Orongorongo catchments sub-zone between 2000 and 2017. The Wainuiomata and Orongorongo rivers are both identified as important trout fishery rivers in Schedule I of the pNRP, and the Wainuiomata is identified as an important spawning water.

Suitable inanga spawning habitat has been found in the Wainuiomata (Taylor and Kelly, 2001), and spawning has been confirmed in the lower reaches (Taylor and Marshall, 2016). However, the mouth of the Wainuiomata River is often closed to the sea, and the inanga spawning habitat model suggests that, when this occurs, the river is unlikely to provide suitable conditions for successful inanga spawning (i.e. eggs laid and hatched) due to a lack of tidal inundation. The Orongorongo River is unlikely to support inanga spawning, as the short reach that is tidally inundated does not support spawning vegetation and is not hydrologically suited for spawning (Taylor and Kelly, 2001).

Periphyton

Periphyton growth is likely to be driving the slight degradation in the macroinvertebrate community health in the Orongorongo River at Orongorongo Station and the moderate degradation in the Wainuiomata River downstream of White Bridge.

Annual maximum periWCC in the Orongorongo River at Orongorongo Station exceeded the pNRP outcomes in all years monitored between 2012 and 2016 (Table 14). In 2014, the maximum periWCC at the site was indicative of poor ecological condition and in 2012, 2013, and 2015 was indicative of only fair ecological condition (Table 14). It is important to note that the GWRC monitoring site on the Orongorongo River is located near the bottom of the river, in the only deforested part of the entire catchment. Therefore, periphyton cover at this site is likely to be worse than in the rest of the Orongorongo River, and is probably not representative of conditions in the wider catchment.

Annual maximum periWCC in the Wainuiomata at White Bridge consistently exceeded the pNRP outcome between 2012 and 2016 (Table 14). Similar to the Orongorongo monitoring site, maximum periWCC in 2015 was indicative of poor ecological condition; in all other years maximum periWCC was indicative of only fair ecological condition (Table 14). Periphyton biomass data also indicates that periphyton growth is a potential source of ecological degradation in the Wainuiomata River below White Bridge. Periphyton biomass data collected up until June 2017 indicates that the site is unlikely to meet the periphyton biomass outcome in the pNRP (Table 15), and it is predicted that the site will be graded as poor once three years of monitoring has been completed (based on the grading system set out in Snelder *et al.* (2013)). This assessment should be considered as preliminary only, as the requisite data (36 months) for a full assessment is yet to be collected.

Periphyton cover in the Wainuiomata River at Manuka Track was low between 2012 and 2016, and the lack of nuisance algae at this site is reflected in the excellent condition of its macroinvertebrate communities. Annual maximum periWCC at this site was indicative of excellent ecological condition in all years sampled and was consistently below the pNRP outcome (Table 14).

Table 14: Annual maximum periWCC scores recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not.

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Orongorongo R. @ Orongorongo St.	20	49	50	70.5	48	-
Wainuiomata R. @ Manuka Tr.	20	1	4	1	6	6
Wainuiomata R. d/s of White Br.	40	50	39	44	58	42

Table 15: Grading of periphyton biomass samples from rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016 (Snelder *et al.*, 2013). The highest possible grade (if all remaining samples were below the excellent threshold) and the predicted grade (if the observed patterns in the existing data continue for the remainder of the sampling period) have been calculated for each site. Whether the pNRP outcome is likely to be met has been assessed from the predicted grade.

Site	pNRP outcome	≤ 50 (Exc.)	> 50 - ≤ 120 (Good)	> 120 - ≤ 200 (Fair)	> 200 (Poor)	Curr. Grade	Pred. grade	Likely to meet outcome
	mg chl-*a*/m²							
Wainuiomata R. d/s of White Br.	120	8	0	1	1	Exc.	Poor	×

Cyanobacteria

GWRC's regular RWQE monitoring data shows that cyanobacteria is not normally a health risk in the Orongorongo River at Orongorongo Station or the Wainuiomata River at Manuka Track. The MfE and MoH (2009) alert guideline (20% cover), which is the guideline Greenfield *et al.* (2015b) recommends be used to assess rivers against the cyanobacteria outcome in the pNRP, was not breached at either site between 2012 and 2016 (Table 16).

At times, benthic cyanobacteria has posed a potential health risk to recreational users in the lower Wainuiomata River. Annual maximum cover exceeded 20% downstream of White Bridge in 2013 and 2015, therefore not meeting the pNRP cyanobacteria outcome in these years (Table 16). It is worth noting that the MfE and MoH (2009) action guideline (50% cover) was not breached at this site.

Table 16: Annual maximum benthic cyanobacteria cover recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not (based on the suggested guidance in Greenfield *et al.* (2015b)).

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Orongorongo R. @ Orongorongo St.	20	-	0	18.5	6.5	-
Wainuiomata R. @ Manuka Tr.	20	-	2	0.5	1	1
Wainuiomata R. d/s of White Br.	20	-	33.75	9	33	14

Fine sediment cover

Fine sediment cover is unlikely to be a main driver of the slight degradation in macroinvertebrate community health in the Orongorongo River but may contribute to the moderate degradation in the Wainuiomata River downstream of White Bridge.

Annual maximum fine sediment cover in the Orongorongo River at Orongorongo Station exceeded the guideline value for the protection of biodiversity (<20% cover (Clapcott *et al.*, 2011)) in all years that monitoring was conducted (Table 17). However, this is the result of occasional spikes in sediment cover, rather than persistently elevated levels of sedimentation; indeed 75% of recorded observations of fine sediment cover were below the guideline (Figure 4). Sporadically elevated levels of deposited fine sediment in the lower Orongorongo River may be having a slight impact on ecosystem health, but the generally healthy macroinvertebrate community at the Orongorongo Station site indicates the effects are not significant.

Annual maximum fine sediment cover in the Wainuiomata at White Bridge exceeded the 20% cover guideline in all years that monitoring was conducted (Table 17). Furthermore, sediment cover was persistently elevated at the site, with over 50% of recorded observations exceeding the guideline level of 20% cover (Figure 4). Accordingly, it is likely that the deposited sediment in the Wainuiomata at Whites Bridge is a driver of the moderately degraded state of macroinvertebrate community at this site.

Fine sediment cover in the Wainuiomata River at Manuka Track was consistently low between 2012 and 2016, and all recorded observations of stream bed cover taken at this site were well below the 20% guideline (Table 17 and Figure 4). That sedimentation does not pose a threat to ecosystem health in the upper Wainuiomata River is supported by the excellent health of the resident macroinvertebrate community.

Table 17: Annual maximum fine sediment cover recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016. Values highlighted in green meet the guideline set out in Clapcott *et al.* (2011) for the protection of benthic biodiversity, values highlighted in red do not.

Site	Clapcott *et al.* (2011) guideline (%cover)	2012	2013	2014	2015	2016
Orongorongo R. @ Orongorongo St.	20	-	50	40	20	-
Wainuiomata R. @ Manuka Tr.	20	-	10	0	10	-
Wainuiomata R. d/s of White Br.	20	-	65	60	40	-

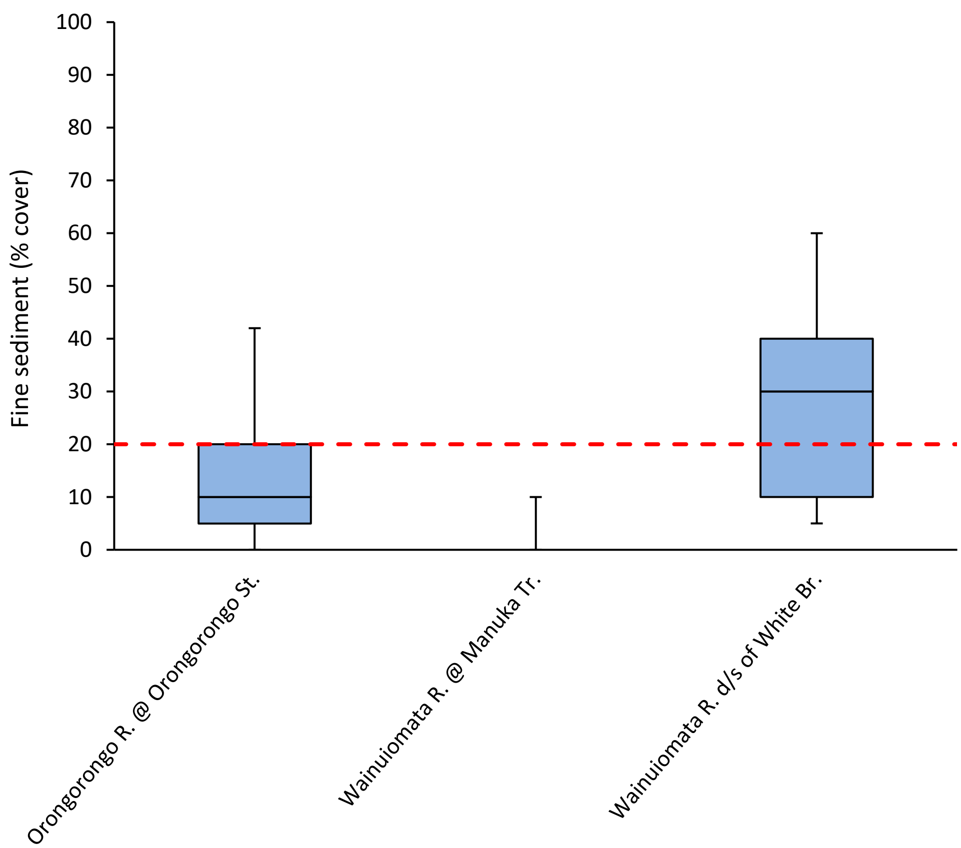

Figure 4: Distribution of fine sediment cover data recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone. The red line indicates the Clapcott *et al.* (2011) guideline for the protection of biodiversity

Water temperature and dissolved oxygen

The single monthly measurements of temperature collected for GWRC's RWQE programme are not representative of the full diurnal range of temperatures and can only be used to identify where guidelines have definitely been breached. Based on the guidelines presented in Davies-Colley *et al.* (2013), annual maximum temperatures recorded in the Orongorongo River at Orongorongo Station and the Wainuiomata River downstream of White Bridge were graded as fair (20°C- 24°C) in three years, and were good (18°C- 20°C) in the remaining years that monitoring was conducted (Table 18). That maximum temperatures were above 20°C at these sites indicates that there may be some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish (Davies-Colley *et al.*, 2013). However, continuous monitoring would be needed to confirm this.

Annual maximum temperatures in the Wainuiomata River at Manuka Track were consistently graded as excellent (≤20 °C) (Table 18). That recorded temperatures did not exceed any of the thresholds presented in Davies-Colley *et al.* (2013), does not necessarily mean that the thresholds were not breached at any point during this period. However, given that this site is in a heavily forested area it is likely that thermal stress does not pose a threat to ecosystem health.

Table 18: Annual maximum temperature recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the guidelines set out in Davies-Colley *et al.* (2013) for rivers with a maritime climate).

Site	Davies-Colley *et al.* (2013) guidelines (°C)	2012	2013	2014	2015	2016
Orongorongo R. @ Orongorongo St.	≤18 (Exc.) ≤20 (Good) ≤24 (Fair) >24 (Poor)	19.7	20.1	23.6	22.5	
Wainuiomata R. @ Manuka Tr.		14.8	13.8	15.8	14.6	13.9
Wainuiomata R. d/s of White Br.		20.7	18.2	20.6	21.9	18.3

As with temperature, the measurements of DO saturation made by GWRC are not representative of the full diurnal range and can only be used to identify where guidelines have definitely been breached. Based on the guidelines presented in Davies-Colley *et al.* (2013), annual 1-day minimum DO concentrations in the Orongorongo River at Orongorongo Station and the Wainuiomata River at Manuka Track and downstream of White Bridge were consistently graded as excellent (Table 19). That DO concentrations did not breach any of the thresholds presented in Davies-Colley *et al.* (2013), does not necessarily mean that the thresholds were not breached at any point during this period, and it is possible, though unlikely, that low DO is a stressor in this sub-zone.

Table 19: Annual minimum DO concentrations recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the 1-day minimum concentration guidelines set out in Davies-Colley *et al.* (2013)).

Site	Davies-Colley *et al.* (2013) guidelines (mg/L)	2012	2013	2014	2015	2016
Orongorongo R. @ Orongorongo St.	≥7.5 (Exc.) ≥5.0 (Good)	9.08	9.23	8.61	8.68	
Wainuiomata R. @ Manuka Tr.	≥4.0 (Fair)	9.58	10.2	9.62	9.73	9.67
Wainuiomata R. d/s of White Br.	<4.0 (Poor)	9.65	9.71	9.2	7.85	8.95

3.1.2. Current state of water quality

Nutrients as a driver of plant growth

Median DIN and DRP concentrations at all sites in the Wainuiomata and Orongorongo catchments sub-zone exceeded the Biggs *et al.* (2000) guidelines for the protection of biodiversity from nuisance periphyton growths. Median DIN and DRP concentrations in Wainuiomata River downstream of White Bridge also exceeded the threshold for the protection of trout habitat and angling values, as did median DRP concentrations at the Manuka Track site (DRP concentrations in the Wainuiomata River are naturally high due to the underlying geology (Ausseil, 2011)) (Figure 5 and Figure 6).These data suggest that nutrient concentrations are likely contributing to nuisance algal growth in the Orongorongo River at Orongorongo Station, and the Wainuiomata River downstream of White Bridge. As nuisance periphyton growths have not been observed at the Manuka Track site (max periWCC = 6% cover), despite sufficient nutrient concentrations it is likely that some other factor is limiting growth at this site, most likely shade.

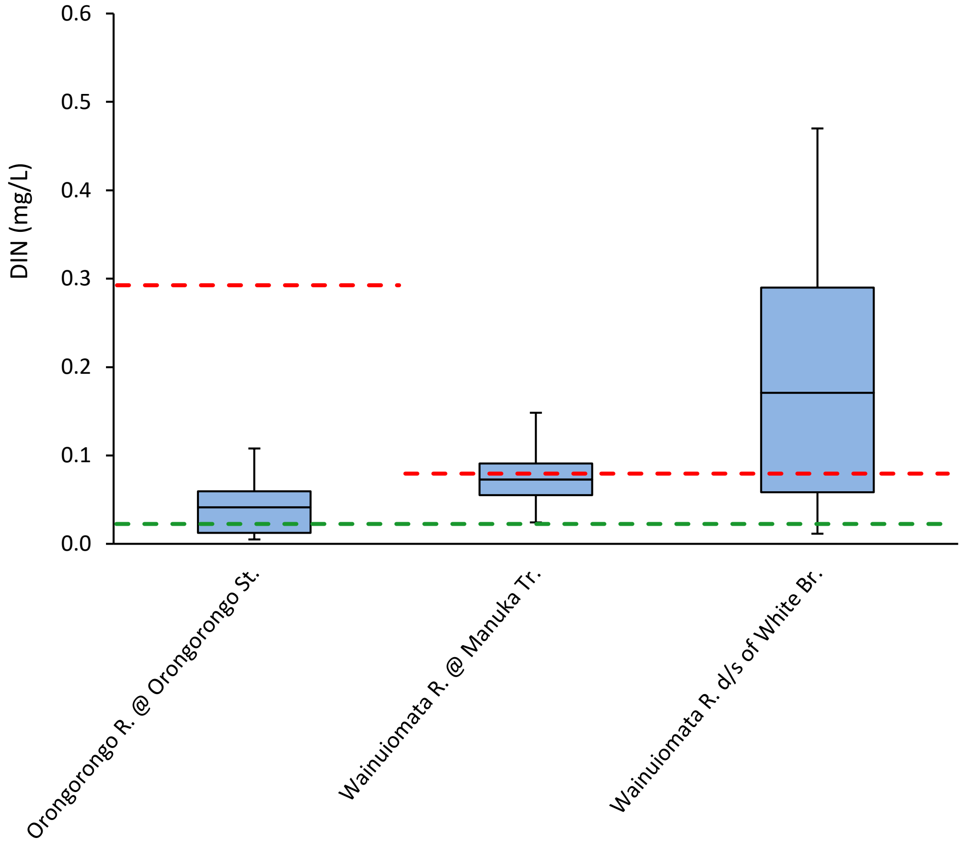

Figure 5: Distribution of DIN concentrations recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone. The red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively.

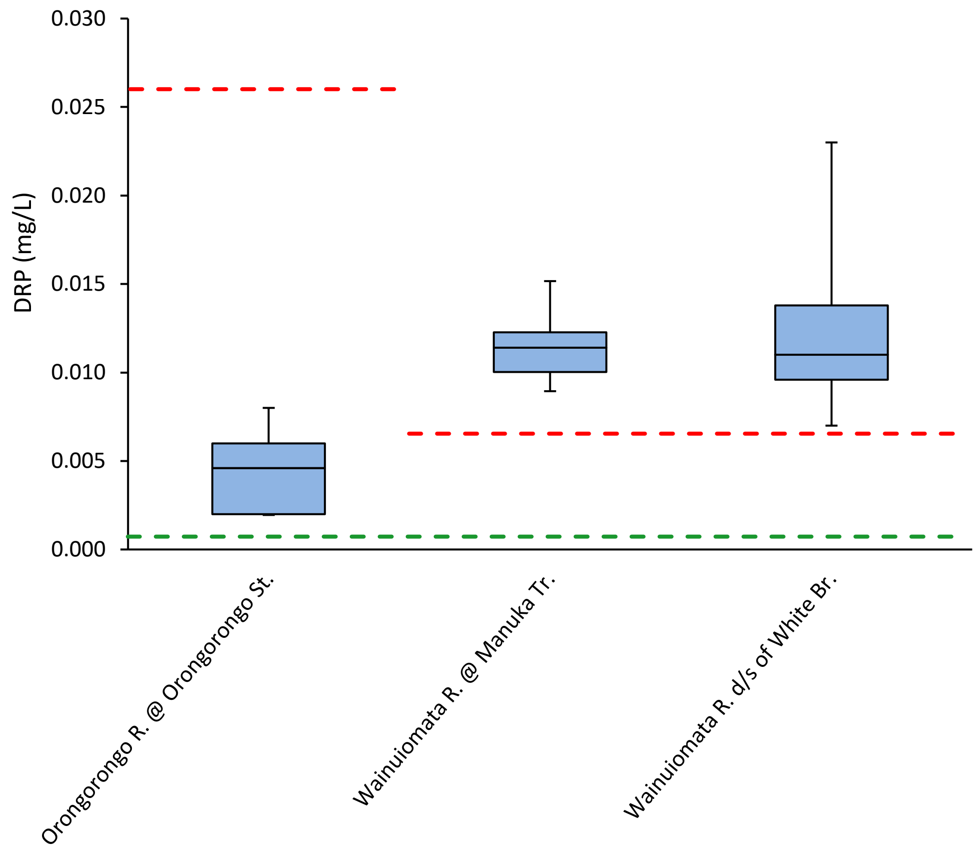

Figure 6: Distribution of DRP concentrations recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone. The red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively.

Nutrients as toxicants

Nitrate toxicity is unlikely to be impacting aquatic ecosystem health at any of the monitoring sites in the Wainuiomata and Orongorongo catchments sub-zone. Overall (Figure 7) median and 95th percentile (thresholds not plotted on Figure 7) NO_3-N concentrations at all sites were below the threshold for the protection of 99% of species from nitrate toxicity (Hickey, 2013) (Figure 7). These data suggest that nitrate levels in this sub-zone are sufficiently low to protect even pristine environments with high biodiversity and conservation values (Hickey, 2013).

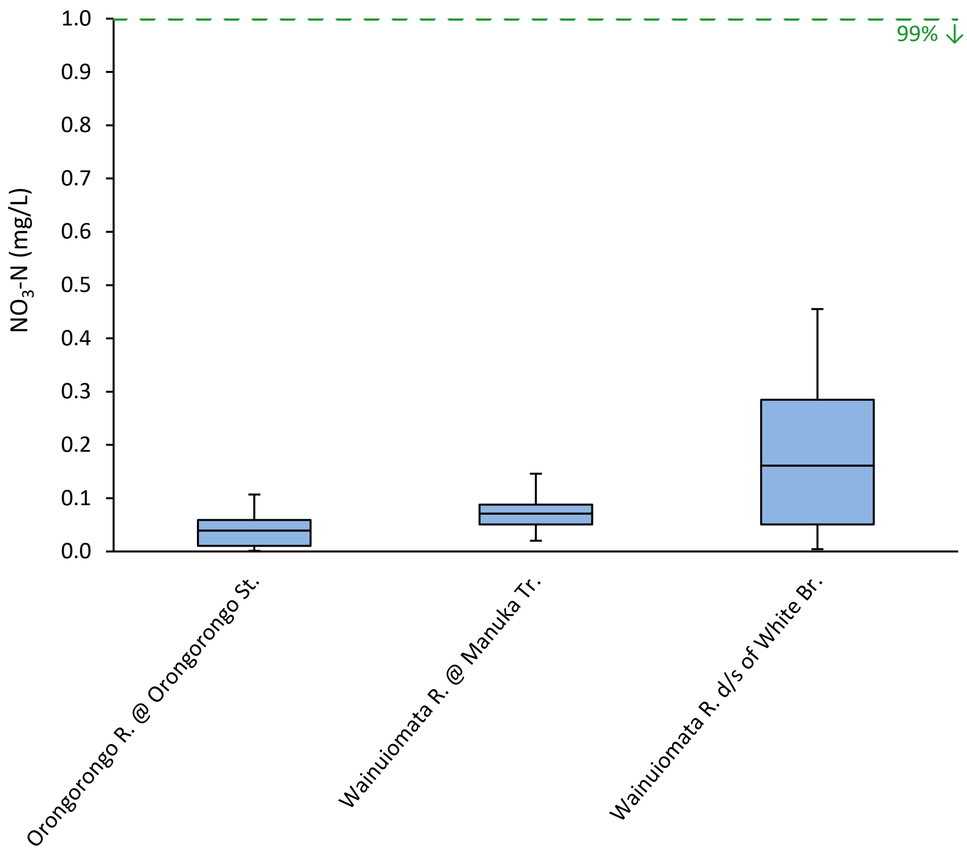

Figure 7: Distribution of NO_3-N concentrations recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone. The green line represents the 99% species protection guideline (Hickey, 2013).

Ammonia toxicity is also unlikely to be impacting aquatic ecosystem health at any of the monitoring sites in the Wainuiomata and Orongorongo catchments sub-zone. Overall median and maximum NH_3-N concentrations in the Orongorongo River at Orongorongo Station and the Wainuiomata River at Manuka Track were below the threshold for the protection of 99% of species from ammonia toxicity (Hickey, 2014) (Figure 8). The median NH_3-N concentration in the Wainuiomata River downstream of White Bridge site was also below the threshold for the protection of 99% of species (Figure 8) (Hickey, 2014), and while the maximum (not plotted on Figure 8) was above the 99% protection threshold, it was well below the 95% protection threshold (Hickey, 2014).

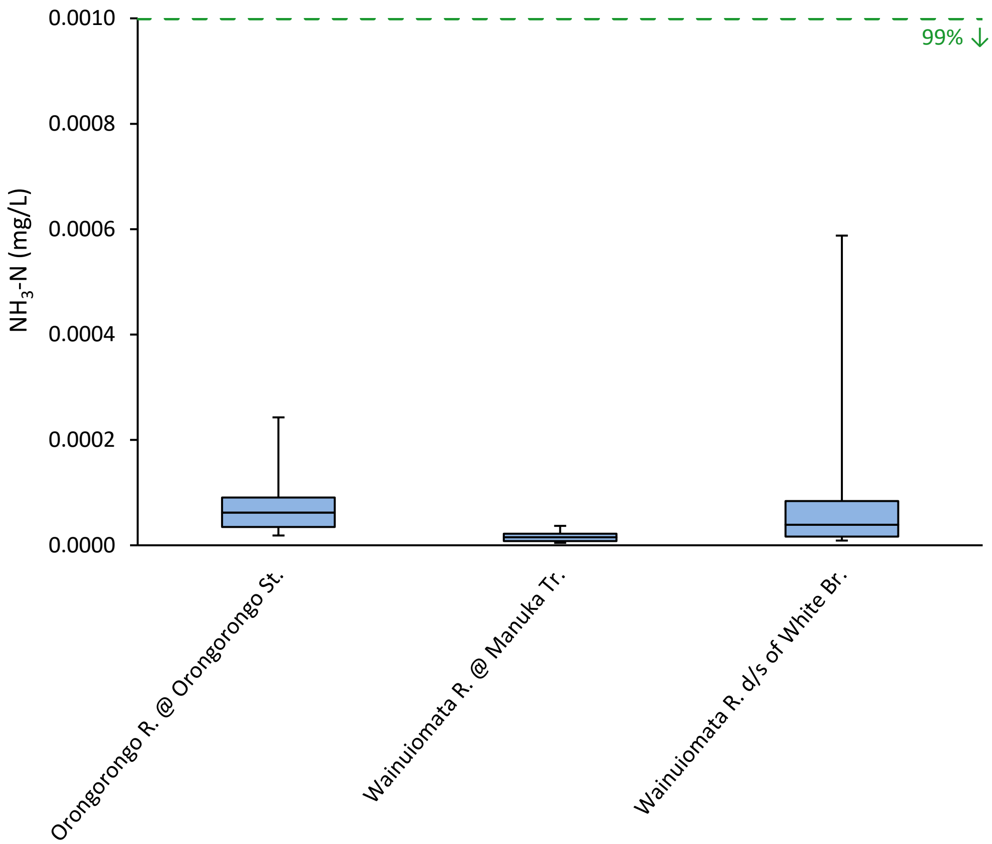

Figure 8: Distribution of NH_3-N concentrations recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone. The green line represents the 99% species protection guideline (Hickey, 2014).

TSS

It does not appear that TSS is affecting aquatic ecosystem health at any of the monitoring sites in the Wainuiomata and Orongorongo catchments sub-zone. TSS concentrations recorded at all sites were generally well below the commonly cited threshold of 25 mg/L for the onset of detrimental effects for fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001) (Figure 9). However, TSS concentration can change significantly with flow, and the available data does not allow for definitive conclusions regarding the effects of suspended sediment in the Wainuiomata and Orongorongo catchments sub-zone.

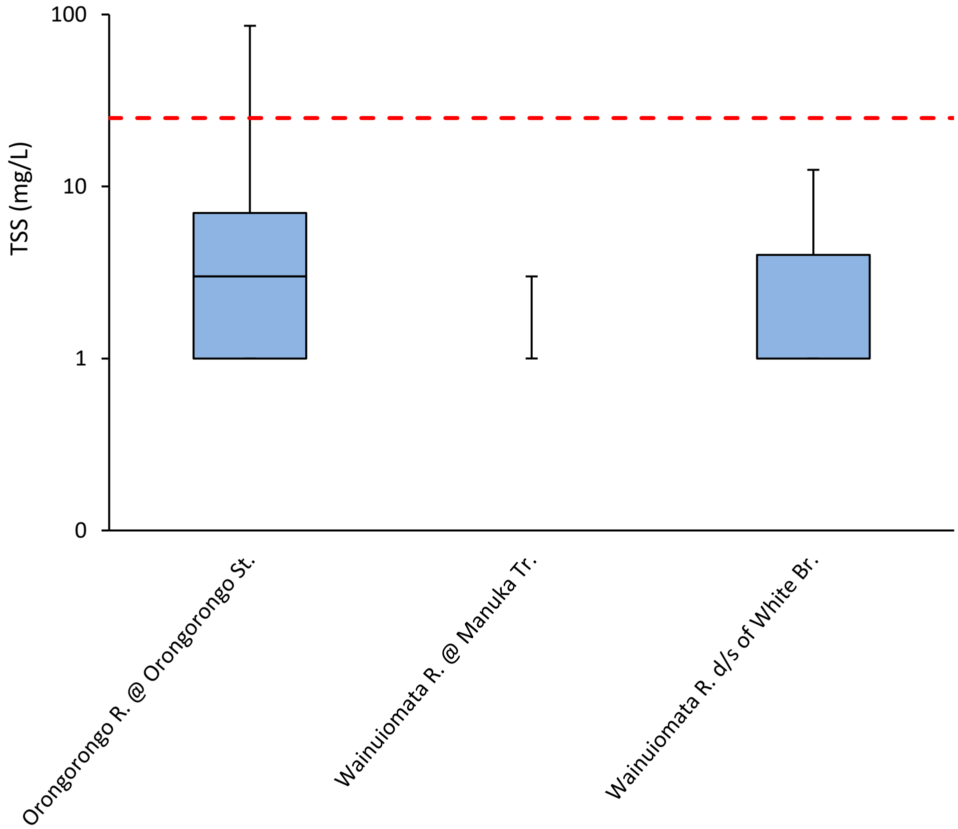

Figure 9: Distribution of TSS concentrations recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone. The red line represents the commonly cited threshold of 25 mg/L for the onset of detrimental effects on fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001). Note the box is not visible for the Wainuiomata River at Manuka Track as the 25th percentile, median, and 75th percentile were all the same at this site (1 mg/L).

E. coli

An assessment of *E. coli* concentrations measured at each GWRC and HCC monitoring site against the different attribute states of the NPS-FM is provided in Table 20. Statistics have been calculated once for each site using data from the period between 01/07/2012 and 30/06/2017 inclusive.

E. coli concentrations at all GWRC monitoring sites in the Wainuiomata River and the Orongorongo River were considered suitable for primary contact recreation. *E. coli* concentrations in the Wainuiomata River at Manuka Track, and the Orongorongo River at Orongorongo Station were within the NPS-FM attribute state A, the highest possible grading (Table 20). *E. coli* concentrations in the Wainuiomata River downstream of White Bridge and at Richard Prouse Park, were higher, but still in the suitable for primary contact recreation range; these sites were assigned to the attribute state B and C respectively (Table 20).

HCC monitoring data suggests that the urban streams in the Wainuiomata and Orongorongo catchments sub-zone are not suitable for contact recreation due to faecal contamination, and *E.*

coli concentrations at both Black Creek at Moohan Street and the Wainuiomata Stream at Reservoir Road were within attribute state E (Table 20). This means that for more than 30% of the time the estimated risk of *Campylobacter* infection at both sites was greater than 50 in 1000 (>5% risk).

Table 20: Summary of *E. coli* data recorded in rivers in the Wainuiomata and Orongorongo catchments sub-zone from 2012 to 2016 graded against the NPS-FM 2014 attribute state thresholds. Shaded cells represent the following attribute states; blue = A, green = B, yellow = C, Orange = D and red = D.

Data source	Site	% above 540 cfu/100ml	% above 260 cfu/100ml	Median (cfu/100ml)	95th %ile (cfu/100ml)	NPS-FM attribute state	Suitable for prim. contact rec.
GWRC RWQE	Orongorongo R. @ Orongorongo St.	3	11	14	440	A	✓
	Wainuiomata R. @ Manuka Tr.	0	0	4	100	A	✓
	Wainuiomata R. d/s of White Br.	7	18	100	1000	B	✓
GWRC Rec	Wainuiomata R. @ Richard Prouse P.	13	23	110	950	C	✓
HCC *E. coli*	Black C. @ Moohan St.	38	77	418	4190	E	×
	Wainuiomata S. @ Reservoir Rd	17	65	327	1530	E	×

3.1.3. Trends in water quality and ecology

Environmentally meaningful water quality trends in both directions were observed in the Wainuiomata and Orongorongo catchments sub-zone. Between 2006 and 2016 a meaningful degrading trend in DRP was observed in the Wainuiomata River at Manuka Track (Table 21); as the entire upstream catchment is indigenous forest, this was likely caused by climatic patterns. Meaningful improving trends in DIN and NO_3-N were observed in the Orongorongo River at Orongorongo Station, and the Wainuiomata River downstream of White Bridge (Table 21). A meaningful improving trend in NH_4-N was also observed at the White Bridge site. Despite improvements in DIN at the White Bridge site, meaningful degrading trends in periphyton biomass[15] filamentous algae, and mat algae cover were also observed (Table 21).

[15] This trend is based on annual data only and should be considered preliminary

Table 21: Temporal trends (10yr) in various physico-chemical and ecological parameters in rivers in the Wainuiomata and Orongorongo catchments sub-zone. Adapted from Snelder (2017).

Parameter	Orongorongo R. @ Orongorongo St.		Wainuiomata R. @ Manuka Tr.		Wainuiomata R. d/s of White Br.	
	Trend direction	Ann. Δ	Trend direction	Ann. Δ	Trend direction	Ann. Δ
MCI	Uncertain		Uncertain		Improving	2%
Mat algal cover	Uncertain		N/A		Degrading	13%
Fil. algal cover	Uncertain		N/A		Degrading	23%
Peri. biomass	Uncertain		Uncertain		Degrading	18%
DIN	Improving	8.5%	Uncertain		Improving	4.5%
DRP	Uncertain		Degrading	3.4%	Uncertain	
E. coli	Uncertain		Uncertain		Uncertain	
NO_3-N	Improving	8.6%	Uncertain		Improving	4.6%
NH_4-N	Uncertain		Uncertain		Improving	29%
TSS	Uncertain		Uncertain		Uncertain	

Uncertain
Improving. Not environmentally meaningful
Improving. Environmentally meaningful
Degrading. Not environmentally meaningful
Degrading. Environmentally meaningful

3.1.4. NPS-FM 2014 attribute state grading

Periphyton biomass

Periphyton biomass data collected up until June 2017 indicates that Wainuiomata River downstream of White Bridge is likely to be assigned to attribute state D under the in the NPS-FM 2014, and will not meet the national bottom line (Table 22).

Ammonia toxicity

When corrected for temperature and pH, unionised ammonia (NH_3-N) concentrations at all sites were assigned to attribute state A for ammonia toxicity under the NPS-FM 2014 (based on the overall average of annual median and maximum concentration) (Table 22). NH_3-N concentrations fell within the A attribute state in all years between 2012 and 2016 in the Orongorongo River at Orongorongo Station and the Wainuiomata River at Manuka Track, and only slipped into attribute state B in one year at the Wainuiomata River downstream of White Bridge site (Table 22).

Nitrate toxicity

NO_3-N concentrations in all years at all sites were assigned to attribute state A for nitrate toxicity under the NPS-FM 2014 (Table 22).

E. coli

The *E. coli* attribute state assessment statistics at all GWRC RWQE sites were consistently assigned to attribute state A, B or C, meaning all sites are considered suitable for contact recreation under the NPS-FM 2014 (Table 22).

Table 22: Water quality and ecology results from GWRC RWQE monitoring sites in the Wainuiomata and Orongorongo catchments sub-zone collected since 2012 compared to numeric attributes as specified in the NPS-FM 2014. Cells shaded in red indicate a national bottom line has been breached.

Parameter	Site	Lowest attribute state	Overall average attribute state
Periphyton biomass	Wainuiomata R. d/s of White Br.	A	D*
NO_3-N	Orongorongo R. @ Orongorongo St.	A	A
	Wainuiomata R. @ Manuka Tr.	A	A
	Wainuiomata R. d/s of White Br.	A	A
NH_3-N	Orongorongo R. @ Orongorongo St.	A	A
	Wainuiomata R. @ Manuka Tr.	A	A
	Wainuiomata R. d/s of White Br.	B	A
E. coli	Orongorongo R. @ Orongorongo St.	B	A
	Wainuiomata R. @ Manuka Tr.	A	A
	Wainuiomata R. d/s of White Br.	C	B

*Predicted attribute state based on current patterns in biomass

3.1.5. Human drivers of any degradation

The key human causes of the slight degradation of ecosystem health in the lower Orongorongo River is pastoral land-use immediately upstream and adjacent to the GWRC monitoring site. The vast majority of the Orongorongo river catchment is in indigenous forest (95%), and sediment and nutrient loads coming from this land-cover likely reflect natural state. At the very bottom of the catchment there is a small amount of sheep and beef farming on the valley floor. While the impact of this land-use on nutrient concentrations are low, the deforestation of the forest floor has likely contributed to the elevated temperatures and periphyton growth at the site, which has in turn led to a slight degradation in macroinvertebrate community health.

Degraded water quality and ecosystem health in the lower Wainuiomata River (at the GWRC Monitoring site below White Bridge) is likely the result of agricultural land-use in the catchment. While 580 ha of the upper catchment is in urban land-use, this represents a small fraction (4.5%) of the total catchment. In contrast there is 1,221 ha of sheep and beef farming (9.4% of the catchment) (Table 1). Consequently, the majority of elevated nutrient concentrations and sedimentation in the lower catchment is likely caused by farming on the valley floor.

3.1.6. Knowledge gaps

Monitoring data for the Orongorongo River catchment comes from just one, now retired, GWRC site, which did not adequately represent the catchment as a whole, as it was located in the only section of the river that is not surrounded by indigenous forest. Despite the limited available data from this catchment, additional monitoring is not needed to assess the impact of human activity, as there is no urban or rural development in the majority of the catchment. However, additional monitoring in the catchment could provide valuable reference data for minimally impacted locations.

Additional monitoring aimed at confirming the relative impact of urban and agricultural land-use on water quality and ecology in the Wainuiomata River could be useful. The locations of the current monitoring sites, one upstream of all urban and rural development, and one downstream, means the effects of the different land-use types cannot be distinguished from each other. Even a small number of synoptic water quality and flow surveys downstream of the Wainuiomata Township would provide valuable insight into the major contaminant sources in the catchment.

Another major knowledge gap for the Wainuiomata and Orongorongo catchments sub-zone is the lack of water quality and ecological data for the Gollans Stream and Cameron's Creek catchments which drain in to Lakes Kohangatera and Kohangapriripiri respectively. It does not appear that there is any monitoring data from these streams and filling this gap should be part of the technical work conducted for the Whaitua Te Whanganui-a-Tara process.

3.1.7. Summary

Macroinvertebrate communities are in a slightly degraded state in the Orongorongo River at Orongorongo Station, and a moderately degraded state in the Wainuiomata River downstream of White Bridge; both sites fail to meet the pNRP outcome for MCI. A number of factors are likely responsible for this degradation. Periphyton growth is not limited by nutrient availability at either site, and pNRP outcomes for periphyton biomass and cover are regularly breached. Accordingly, nuisance periphyton growth is likely a key driver of degraded stream health in the lower reaches of the Orongorongo River and Wainuiomata Rivers. High levels of deposited fine sediment have also been recorded at both sites; while the impact this is having on ecosystem health in the Orongorongo river is likely low, the effects in the lower Wainuiomata River are potentially significant. It is important to note that GWRC monitoring site on the Orongorongo River was located near the bottom of the river, in the only deforested part of the entire catchment. Therefore, ecosystem health and water quality at this site is unlikely to be representative of condition of the wider Orongorongo catchment, which is probably similar to that observed in the Wainuiomata river at Manuka Track.

Not surprisingly, given that the upstream catchment is entirely forested, macroinvertebrate and plant communities and habitat are in excellent condition in the Wainuiomata river at Manuka Track.

In terms of recreational value, the rivers and streams in the Wainuiomata and Orongorongo catchments sub-zone are in a good state. Benthic cyanobacteria does not generally pose a health risk to recreational users, and faecal contamination in the main stems of the Orongorongo and Wainuiomata Rivers is generally low. All GWRC monitoring sites are considered suitable for primary contact recreation.

Improving trends in nitrogen species were observed in the Wainuiomata River at White Bridge and the Orongorongo River at Orongorongo Station, but DRP was degrading in the Wainuiomata River at Manuka Track. As there is no urban or rural development upstream of this site, increasing DRP concentrations are unlikely to be driven by human activity.

3.2. Hutt River catchment sub-zone

3.2.1. Ecology and habitat

Macroinvertebrates

Macroinvertebrate monitoring data exists for three sites on the Hutt River, and at one site on each of its four major tributaries, the Pakuratahi River, the Mangaroa River, the Akatarawa River and the Whakatikei River.

The pNRP MCI outcomes were met in the Hutt River at Te Marua and opposite Manor Park Golf Course (hereafter referred to as at Manor Park) in every year between 2012 and 2016, and rolling three-year median and annual MCI scores were indicative of excellent ecological condition at Te Marua (the most upstream site), and good ecological condition at Manor Park (Table 23).

In 2012, 2014 and 2016, both the rolling three-year median and annual MCI scores at the most downstream site on the Hutt River, Hutt River at Boulcott, were indicative of only fair ecological condition, and while the annual score in 2013 was graded as ‘good’, the three-year median at this time was still only in the fair category (Table 23). Accordingly, the site only met the pNRP MCI outcome in 2015 when both the rolling three-year median score and the annual score were indicative of good ecological condition.

Of the major tributaries of the Hutt River monitored by GWRC, only the Whakatikei at Riverstone consistently met the pNRP MCI outcome. Rolling three-year median MCI scores at this site were indicative of excellent ecological condition in all years, except 2015, when it was indicative of good ecological condition (Table 23). Annual minimum MCI scores in the Whakatikei were in the excellent category in 2012, 2013 and 2015, and in the good category in 2014 and 2016 (Table 23).

While the Pakuratahi and Akatarawa Rivers failed to meet the pNRP MCI outcomes in five and four years respectively, it cannot be said that the GWRC monitoring sites on these rivers are in a degraded state. Both the rolling three-year median and annual MCI scores at these sites were generally at or near 130, which is the excellent threshold for these water bodies. Accordingly, these rivers can be considered to be in near excellent ecological condition.

Macroinvertebrate communities in the Mangaroa River at Te Marua are in a moderately degraded state. Rolling three-year median MCI scores at this site were generally indicative of only fair ecological condition and were only above the ‘good’ threshold in 2012 and 2013, which were the only years when the site met the pNRP outcome. Annual scores in the Mangaroa were also indicative of only fair ecological condition in three out of the five years, and were only graded as good 2013 and 2016

Table 23: Rolling 3-year median MCI scores (and annual MCI scores) recorded in rivers in the Hutt River catchment sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not.

Site	pNRP outcome	2012	2013	2014	2015	2016
Hutt R. @ Te Marua	130	135 (140)	135 (128)	138 (138)	138 (138)	138 (138)
Hutt R. @ Manor Park	110	110 (127)	127 (128)	127 (126)	126 (122)	122 (120)
Hutt R. @ Boulcott	110	103 (107)	107 (111)	109 (109)	111 (113)	109 (105)
Pakuratahi R. below Farm Cr.	130	129 (131)	128 (125)	125 (121)	121 (114)	121 (121)
Mangaroa R. @ Te Marua	120	121 (118)	127 (128)	118 (106)	115 (115)	115 (122)
Akatarawa R. @ Hutt Conf.	130	129 (128)	129 (135)	128 (124)	130 (130)	128 (128)
Whakatikei R. @ Riverstone	110	132 (130)	132 (138)	130 (120)	131 (131)	123 (123)

Fish

Thirteen native species were found in the Hutt River catchment sub-zone between 2000 and 2017: longfin eel, shortfin eel, koaro, inanga, dwarf galaxias, giant kokopu, banded kokopu, Cran's bully, bluegill bully, redfin bully, common bully, common smelt and lamprey. All of these species, except shortfin eel, banded kokopu, common smelt, common bully and Cran's bully, are classified as either at risk or threatened (Goodman *et al.*, 2014).

Brown trout was the only introduced sports fish found in the Hutt River catchment sub-zone between 2000 and 2017. The Akatarawa, Hutt, Mangaroa, Pakuratahi and Whakatikei rivers are all identified as important trout fishery rivers and spawning waters in Schedule I of the pNRP.

Suitable inanga spawning habitat has been found in the Hutt River, and spawning has been confirmed in the lower reaches around the Sladden Park Boat Ramp (Taylor and Marshall, 2016). Based on modelled tidal inundation data, spawning could potentially occur as far as 200 m upstream of the Railway Avenue Bridge.

Periphyton

Periphyton growth is unlikely to be having a detrimental effect in most of the monitored rivers and streams in the Hutt River catchment sub-zone, but may be driving the moderate degradation in macroinvertebrate community health in the Mangaroa River.

Periphyton cover in the Hutt, Pakuratahi, Akatarawa and the Whakatikei rivers was generally low, and the lack of nuisance algae at monitoring sites in these rivers is reflected in the generally unimpacted condition of their macroinvertebrate communities. Annual maximum periWCC in the

Hutt River at Te Marua and Manor Park, the Pakuratahi River, the Akatarawa River and the Whakatikei River were consistently indicative of excellent ecological condition, although the Pakuratahi River was graded as ‘good’ in 2015 (Table 24). Annual maximum periWCC in the Hutt River at Boulcott was indicative of excellent ecological condition in three years and good ecological condition in one other (Table 24). However, in 2012 maximum periWCC was indicative of poor ecological condition (Table 24). Periphyton biomass data from the Hutt River is generally consistent with the cover data, and indicates that sites at Te Marua and Boulcott are likely to meet the periphyton biomass outcome in the pNRP (Table 25), and that these sites will be graded as excellent and good respectively once three years of monitoring has been completed (based on the grading system set out in Snelder *et al.* (2013)).

Annual maximum periWCC in the Mangaroa River at Te Marua consistently exceeded the pNRP outcome in the years between 2012 and 2016. While the maximum periWCC in 2015 was indicative of good ecological condition, in all other years it was within the ‘poor’ category (Table 24). Periphyton biomass data also indicates that periphyton growth is a potential source of ecological degradation in the Mangaroa River. Periphyton biomass data collected up until June 2017 indicates that the site is unlikely to meet the pNRP outcome (Table 25), and it is predicted that the site will be graded as ‘poor’ once three years of monitoring has been completed (based on the grading system set out in Snelder *et al.* (2013)).

Table 24: Annual maximum periWCC scores recorded in rivers in the Hutt River catchment sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not.

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Hutt R. @ Te Marua	20	2	0	3	3	5
Hutt R. @ Manor Park	40	14	1	6	13	2
Hutt R. @ Boulcott	40	66	30	7	13	16
Pakuratahi R. below Farm Cr.	20	17	0	10	24	6
Mangaroa R. @ Te Marua	20	51	12	47	77	58
Akatarawa R. @ Hutt Conf.	20	9	12	3	2	0
Whakatikei R. @ Riverstone	40	18	9	22	15	17

Table 25: Grading of periphyton biomass samples from rivers in the Hutt River catchment sub-zone from 2012 to 2016 (Snelder *et al.*, 2013). The highest possible grade (if all remaining samples were below the excellent threshold) and the predicted grade (if the observed patterns in the existing data continue for the remainder of the sampling period) have been calculated for each site. Whether the pNRP outcome is likely to be met has been assessed from the predicted grade.

Site	pNRP outcome	≤ 50 (Exc.)	> 50 - ≤ 120 (Good)	> 120 - ≤ 200 (Fair)	> 200 (Poor)	Curr. Grade	Pred. grade	Likely to meet outcome
	mg chl-*a*/m²							
Hutt R. @ Te Marua	50	11	0	0	0	Exc.	Exc.	✓
Hutt R. @ Boulcott	120	20	1	1	0	Exc.	Good	✓
Mangaroa R. @ Te Marua	50	9	7	2	2	Fair	Poor	×

Cyanobacteria

Potentially toxic cyanobacteria is a very well publicised issue in the Hutt River catchment, has caused at least 11 dog deaths in the past, and regularly limits recreational use. GWRC's regular RWQE monitoring data does not show that cyanobacteria is a health risk at the sites where this type of monitoring is conducted, and somewhat hides the full extent of the problem, because the monitoring programme is not designed around bloom occurrences. Between 2012 and 2016, the MfE and MoH (2009) alert guideline (20% cover) was breached at least once in the Hutt River at Manor Park, the Hutt River at Boulcott, the Pakuratahi River below Farm Creek and the Akatarawa River at the Hutt River confluence, and it is unlikely that these sites will meet the pNRP outcome (Table 26). However, only the Akatarawa River at the Hutt River confluence was found to have breached the MfE and MoH (2009) alert guideline (50% cover) (Table 26). In reality significant blooms (>50% cover) also occurred at popular swimming sites in the Hutt River in the summer of 2011/12, and 2017/18; the latter received significant media attention and even lead to discussions about closing the river for use.

Table 26: Annual maximum benthic cyanobacteria cover recorded in rivers in the Hutt River catchment sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not (based on the suggested guidance in Greenfield *et al.* (2015b)).

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Hutt R. @ Te Marua	20	-	1	3	8	4
Hutt R. @ Manor Park		-	2	15	28	5
Hutt R. @ Boulcott		-	23	19	25	0
Pakuratahi R. below Farm Cr.		-	1	7	53	21
Mangaroa R. @ Te Marua		-	2	3	19	3
Akatarawa R. @ Hutt Conf.		-	20	9	15	3
Whakatikei R. @ Riverstone		-	3	11	9	15

Fine sediment cover

Fine sediment cover does not appear to be having a significant impact on ecosystem health in the monitored rivers and streams in the Hutt River catchment sub-zone.

Fine sediment cover in Hutt River at Te Marua and the Mangaroa River at Te Marua was consistently low between 2012 and 2016, and all recorded observations of stream bed cover taken at these sites were below the guideline for the protection of biodiversity (<20% cover (Clapcott *et al.*, 2011)) (Table 27 and Figure 10). While annual maximum fine sediment cover in the Hutt River at Boulcott, the Akatarawa River and the Pakuratahi River exceeded the 20% cover guideline in at least one year (Table 27), this was the result of occasional spikes in sediment cover, rather than persistently elevated levels of sedimentation. Indeed 75% of recorded observations of fine sediment cover in these rivers were below guideline level (Figure 10). The generally healthy state of macroinvertebrate communities in the Akatarawa River and the Pakuratahi Rivers suggest that sporadically elevated levels of deposited fine sediment are not impacting ecosystem health in these rivers. However, it may be contributing to the degradation observed in the Hutt River at Boulcott.

Deposited fine sediment cover was frequently high in the Hutt River at Manor Park and the Whakatikei River at Riverstone. Annual maximum fine sediment cover exceeded the 20% cover guideline in all years (Table 27). Furthermore, sediment cover was persistently elevated in both rivers; exceeding the guideline more than half the time (Figure 10). Despite this, high deposited fine sediment cover does not appear to be significantly impacting macroinvertebrate communities in these rivers, as MCI in both the Hutt River at Manor Park, and the Whakatikei River at Riverstone are consistently indicative of excellent or near excellent ecological condition.

Table 27: Annual maximum fine sediment cover recorded in rivers in the Hutt River catchment sub-zone from 2012 to 2016. Values highlighted in green meet the guideline set out in Clapcott *et al.* (2011) for the protection of benthic biodiversity, values highlighted in red do not.

Site	Clapcott *et al.* (2011) guideline (%cover)	2012	2013	2014	2015	2016
Hutt R. @ Te Marua	20	-	0	0	10	-
Hutt R. @ Manor Park		-	40	30	40	-
Hutt R. @ Boulcott		-	0	15	30	-
Pakuratahi R. below Farm Cr.		-	30	10	5	-
Mangaroa R. @ Te Marua		-	5	5	10	-
Akatarawa R. @ Hutt Conf.		-	20	30	40	-
Whakatikei R. @ Riverstone		-	70	50	60	-

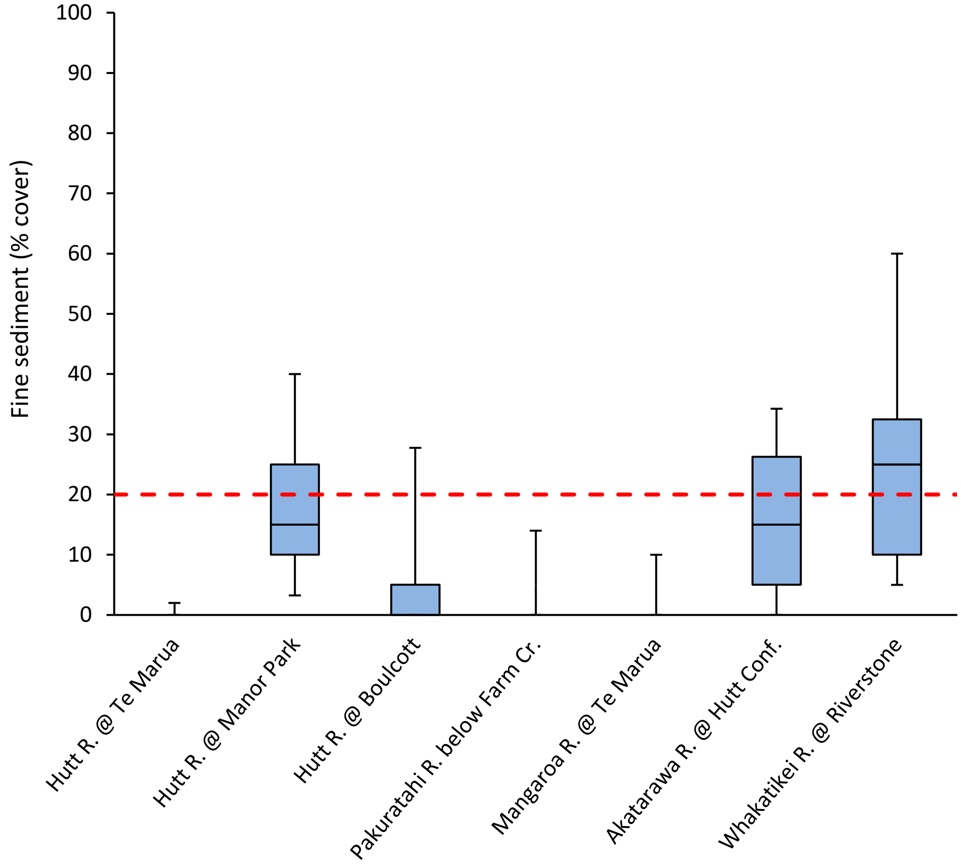

Figure 10: Distribution of fine sediment cover data recorded in rivers in the Hutt River catchment sub-zone. The red line indicates the Clapcott *et al.* (2011) guideline for the protection of biodiversity.

Water temperature and dissolved oxygen

Based on the guidelines presented in Davies-Colley *et al.* (2013), annual maximum temperatures recorded in the Hutt River at Te Marua and the Pakuratahi, Akatarawa and Whakatikei Rivers were graded as either good (18°C- 20°C) or excellent (<18°C) in all years between 2012 and 2016 (Table 28) (Note: that recorded temperatures did not exceed fair or poor thresholds presented in Davies-Colley *et al.* (2013), does not necessarily mean that they were not breached).

Annual maximum temperatures in the Hutt River at Manor Park and Boulcott were graded as good between 2012 and 2014, and as excellent in 2016. However, in 2015, the annual maximum temperature at both sites was in the fair category (20°C- 24°C) (Table 28). That the maximum temperature recorded in 2015 was above 20°C indicates that there may be some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish at this site. However, continuous monitoring would be needed to confirm this (Davies-Colley *et al.*, 2013).

Table 28: Annual maximum temperature recorded in rivers in the Hutt River catchment sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the guidelines set out in Davies-Colley *et al.* (2013) for rivers with a maritime climate).

Site	Davies-Colley *et al.* (2013) guidelines (°C)	2012	2013	2014	2015	2016
Hutt R. @ Te Marua	≤18 (Exc.) ≤20 (Good) ≤24 (Fair) >24 (Poor)	16	15	17	19	16
Hutt R. @ Manor Park		20	19	19	22	17
Hutt R. @ Boulcott		20	19	20	23	18
Pakuratahi R. below Farm Cr.		16	17	16	19	15
Mangaroa R. @ Te Marua		17	17	16	18	17
Akatarawa R. @ Hutt Conf.		16	17	17	19	16
Whakatikei R. @ Riverstone		16	17	16	19	15

Based on the guidelines presented in Davies-Colley *et al.* (2013), annual 1-day minimum DO concentrations in all monitored rivers in the Hutt River catchment sub-zone were consistently graded as excellent (>7.5 mg/L) (Table 29). Again, that DO concentrations did not breach any of the thresholds presented in Davies-Colley *et al.* (2013), does not necessarily mean that the thresholds were not breached at any point during this period.

Table 29: Annual minimum DO concentrations recorded in rivers in the Hutt River catchment sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the 1-day minimum concentration guidelines set out in Davies-Colley *et al.* (2013)).

Site	Davies-Colley *et al.* (2013) guidelines (mg/L)	2012	2013	2014	2015	2016
Hutt R. @ Te Marua	≥7.5 (Exc.) ≥5.0 (Good) ≥4.0 (Fair) <4.0 (Poor)	10	10	10	10	10
Hutt R. @ Manor Park		10	10	10	10	10
Hutt R. @ Boulcott		9	9	10	9	9
Pakuratahi R. below Farm Cr.		9	10	9	9	10
Mangaroa R. @ Te Marua		10	10	10	11	10
Akatarawa R. @ Hutt Conf.		10	10	10	10	10
Whakatikei R. @ Riverstone		10	10	10	10	10

3.2.2. Current state of water quality

Nutrients as a driver of plant growth

Median DIN and DRP concentrations at all sites in the Hutt River catchment sub-zone exceeded the Biggs *et al.* (2000) guidelines for the protection of biodiversity from nuisance periphyton growths (Figure 11 and Figure 12). However, only the Mangaroa River at Te Marua and the Whakatikei River at Riverstone had median DIN concentrations above the Biggs *et al.* (2000) guidelines for the protection of trout habitat and angling values (Figure 11), and the corresponding DRP guideline was only breached in the Whakatikei River (Figure 12). It is important to note that although the Whakatikei River was the least compliant with the nutrient guidelines for periphyton growth, this was not because nutrient concentrations were higher at this site than at others in the sub-zone, rather it was because accrual times are longer (i.e. as periphyton have longer to grow less nutrients are required to cause nuisance blooms). Indeed, nutrient concentrations in the Whakatikei River are consistent with those found in pristine rivers in the Wellington Region (Ausseil, 2011).

The risk of nuisance periphyton growths from nutrient enrichment is low through most of the Hutt River catchment sub-zone. Although DIN and DRP concentrations exceeded the periphyton guidelines in the Hutt, Pakuratahi, Akatarawa and Whakatikei Rivers, it is likely nutrient concentrations, particularly DRP (exc. the Whakatikei River) are still sufficiently low to be limiting periphyton growth (Ausseil, 2011), as nuisance periphyton growths are not regularly observed in these rivers. It is also possible that other factors, such as shading, flow velocity, temperatures and substrate suitability are also limiting periphyton growth at these sites. In contrast, nuisance periphyton growths are common in the Mangaroa River at Te Marua, where DIN and DRP concentrations are the highest in the sub-zone, and it is clear that nutrient concentrations are likely contributing to, or at least are not limiting, elevated periphyton growth at this site.

While low nutrient concentrations in the Hutt River may be limiting periphyton growth, they may also be contributing the cyanobacterial blooms in this river. In New Zealand there is a positive relationship between cyanobacteria coverage and high ratios of total nitrogen to total phosphorus (Heath *et al.*, 2011; Quiblier *et al.*, 2013; Wood and Young, 2012), and Heath (2015) identified DIN concentrations >0.1 mg/L and DRP concentrations <0.01 mg/L) as being associated with potentially toxic cyanobacteria (such as *Microcoleus*) bloom formation. These nutrient conditions are consistent with those observed at the GWRC monitoring sites on the Hutt River, where DIN concentrations are sufficiently high to facilitate *Microcoleus* growth, and DRP concentrations are sufficiently low to provide *Microcoleus* a competitive advantage over other types of periphyton that require higher levels of phosphorus. However, while nutrients are an important driver of *Microcoleus* growth, their influence is not always predictable, and varies spatially and temporally. Other factors, such as temperature and hydrology also exert a significant influence over bloom formation, and how these factors interact with nutrients and each other to control *Microcoleus* growth is likely complex and is not fully understood. Thus, while it is safe to say that nutrient concentrations in the Hutt River are suitable for cyanobacteria growth, it is unclear how nutrient management could be used to minimise the risk of blooms, or if this is even possible. A full assessment of the role of nutrients in the formation of cyanobacteria blooms in the Hutt River is provided in Heath and Greenfield (2016).

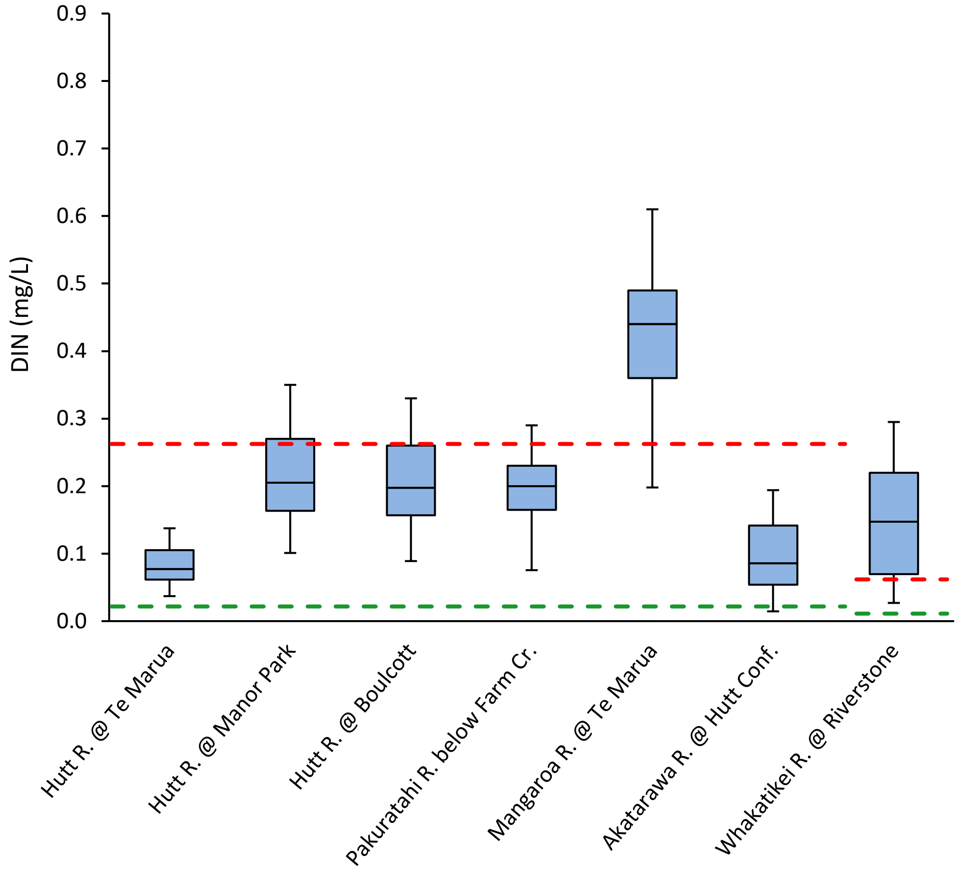

Figure 11: Distribution of DIN concentrations recorded in rivers in the Hutt River catchment sub-zone. The red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively.

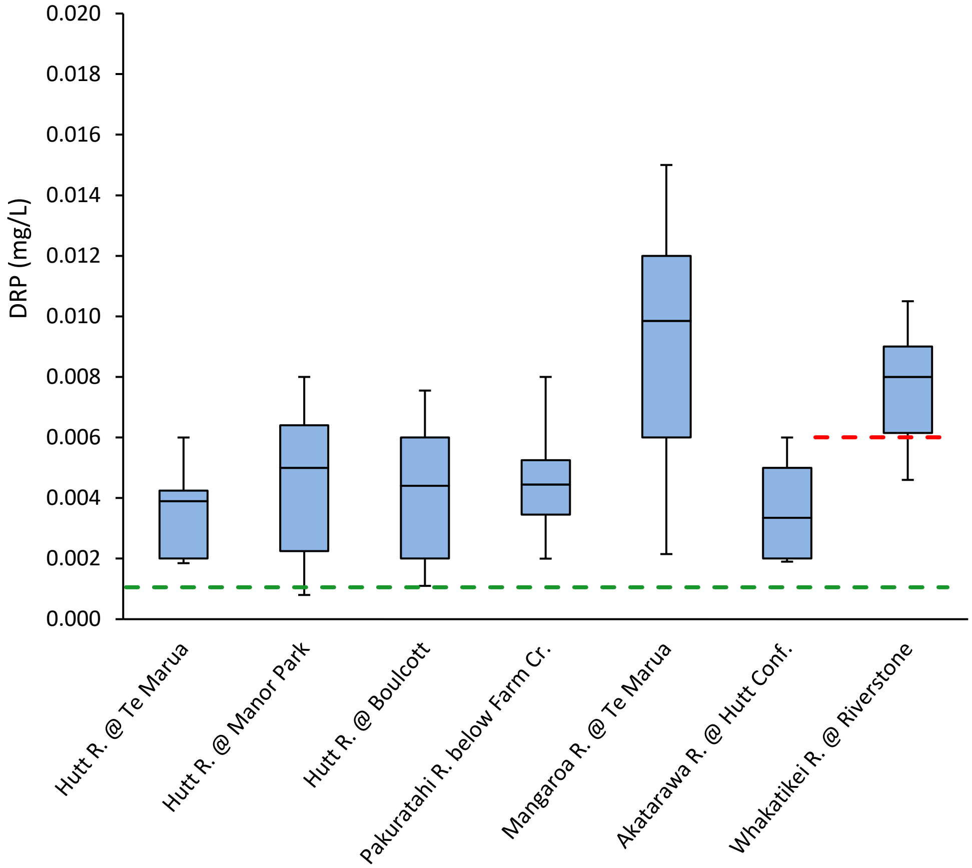

Figure 12: Distribution of DRP concentrations recorded in rivers in the Hutt River catchment sub-zone. The red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively.

Nutrients as toxicants

Nitrate toxicity is unlikely to be impacting aquatic ecosystem health at any of the monitoring sites in the Hutt River catchment sub-zone. Overall median and 95th percentile (thresholds not plotted on Figure 13) NO_3-N concentrations at all sites were below the threshold for the protection of 99% of species from nitrate toxicity (Hickey, 2013) (Figure 13). These data suggest that nitrate levels in this sub-zone are sufficiently low to protect even pristine environments with high biodiversity and conservation values (Hickey, 2013).

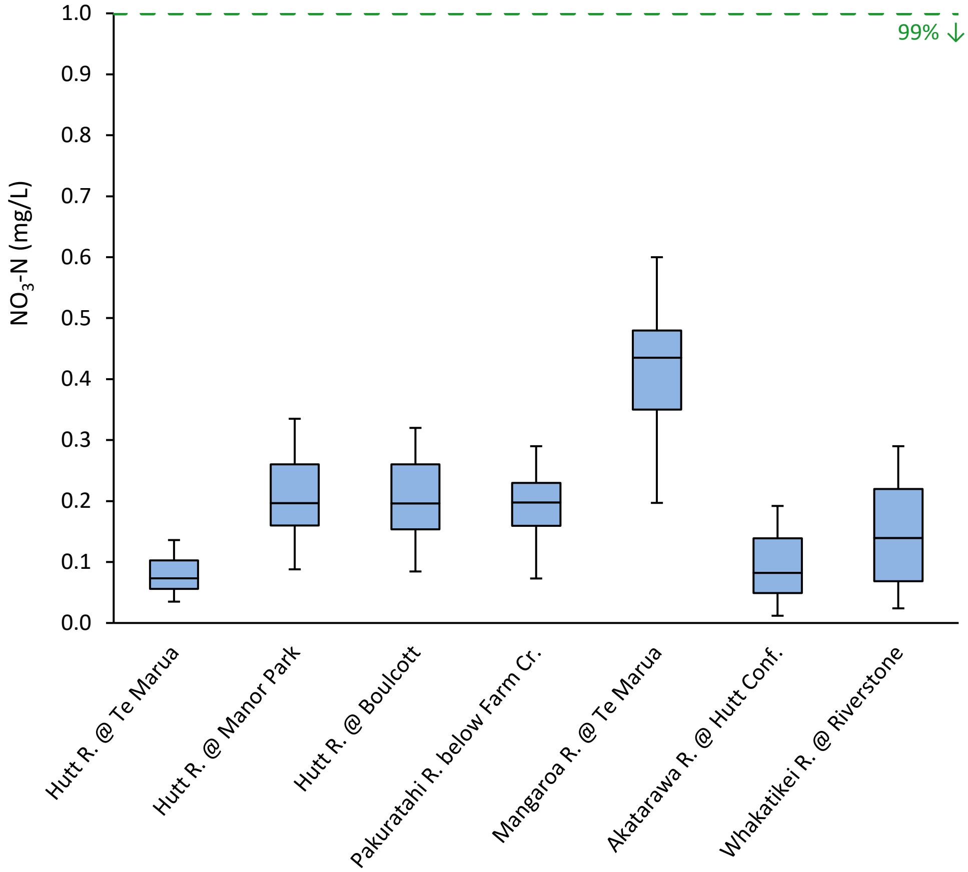

Figure 13: Distribution of NO_3-N concentrations recorded in rivers in the Hutt River catchment sub-zone. The green line represents the 99% species protection guideline (Hickey, 2013).

Ammonia toxicity is also unlikely to be impacting aquatic ecosystem health at any of the monitoring sites in the Hutt River catchment sub-zone. Overall median and maximum NH_3-N concentrations in all sites were below the threshold for the protection of 99% of species from ammonia toxicity (Hickey, 2014) (Figure 14). This suggests that there are unlikely to be ammonia toxicity effects on any species at sites in the Hutt River catchment sub-zone.

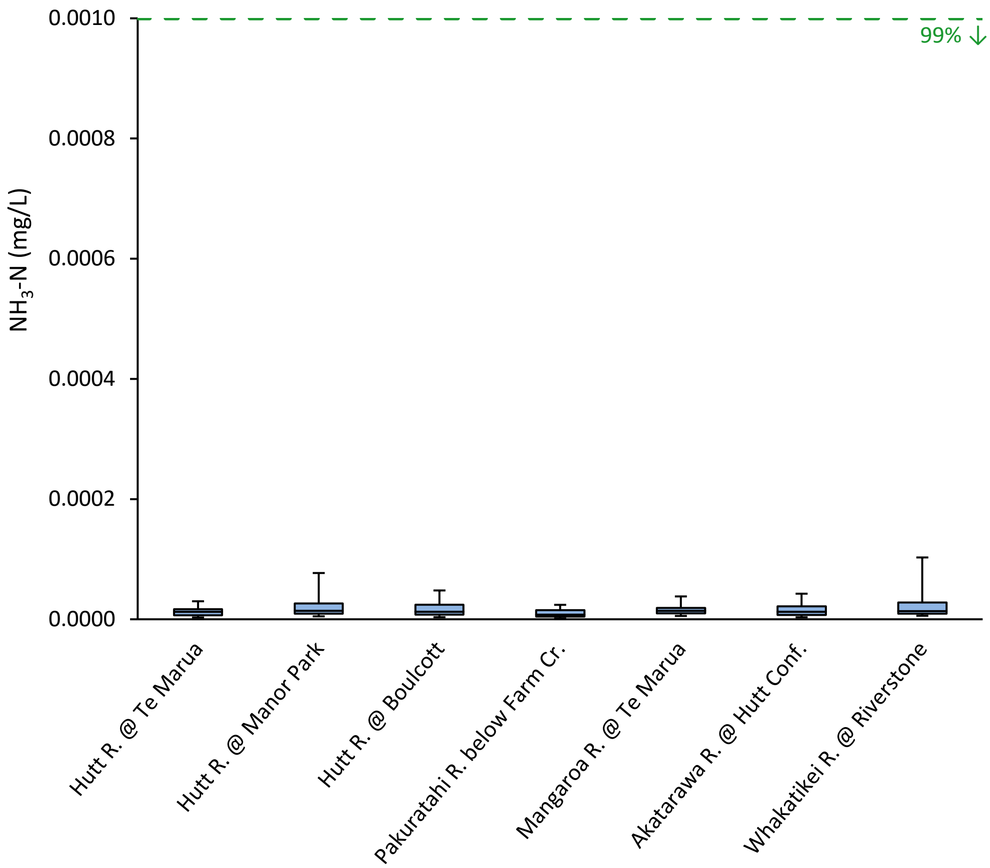

Figure 14: Distribution of NH_3-N concentrations recorded in rivers in the Hutt River catchment sub-zone. The green line represents the 99% species protection guideline (Hickey, 2014).

Metals as toxicants

Chronic toxicity effects from high concentrations of dissolved metals are also unlikely to be impacting ecosystem health in the Hutt River catchment sub-zone. Between 2012 and 2016, median dissolved copper and zinc concentrations in the Hutt River at Manor Park and at Boulcott were below the guideline level for the protection of 99% of species from toxicity effects (Figure 15 and Figure 16).

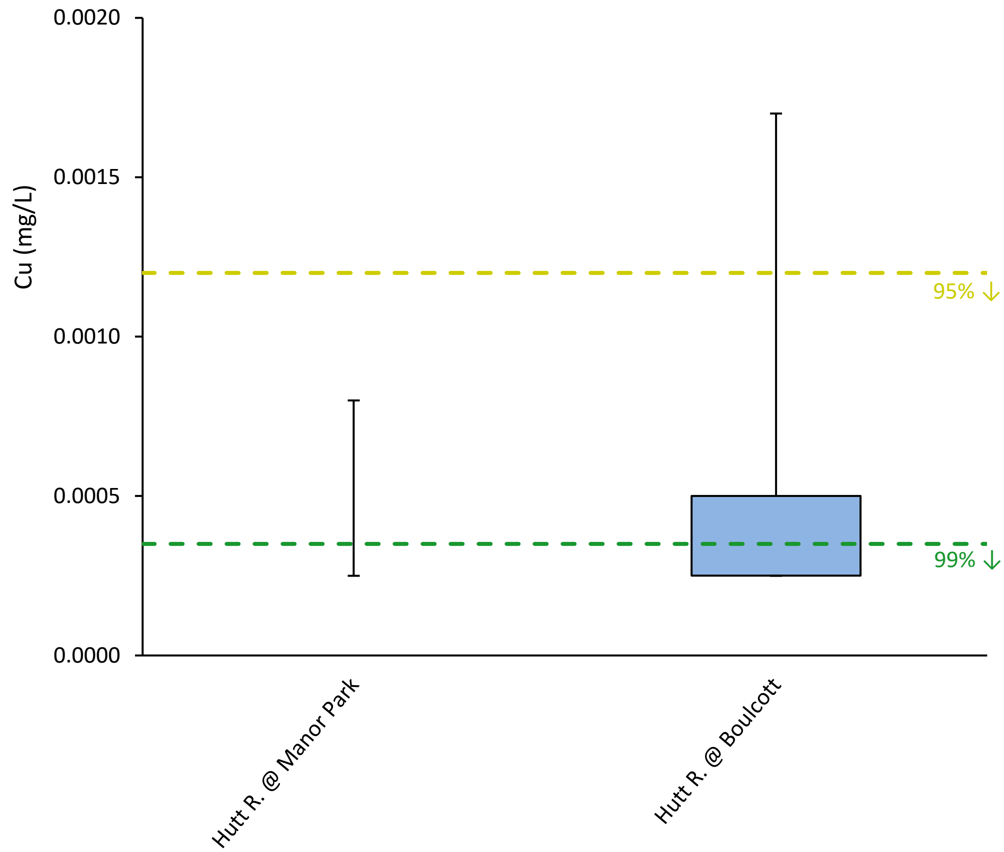

Figure 15: Distribution of Cu concentrations recorded in rivers in the Hutt River catchment sub-zone. The coloured lines represent species protection thresholds (Australian and New Zealand guidelines for fresh and marine water quality). Note the box is not visible for the Hutt River at Manor Park as the 25th percentile, median, and 75th percentile were all the same at this site (1 mg/L)

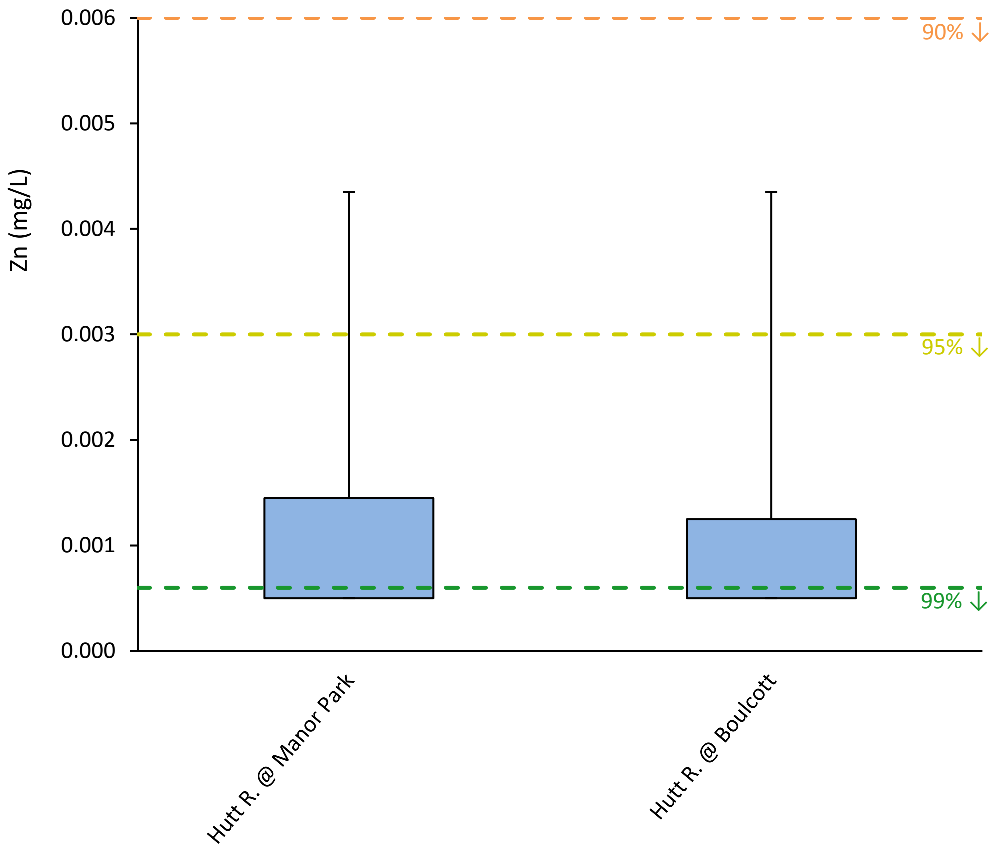

Figure 16: Distribution of Zn concentrations recorded in rivers in the Hutt River catchment sub-zone. The coloured lines represent species protection thresholds (Australian and New Zealand guidelines for fresh and marine water quality)

TSS

It does not appear that TSS is affecting aquatic ecosystem health at any of the monitoring sites in the Hutt River catchment sub-zone. TSS concentrations recorded at all sites were generally well below the commonly cited threshold of 25 mg/L for the onset of detrimental effects for fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001) (Figure 17).

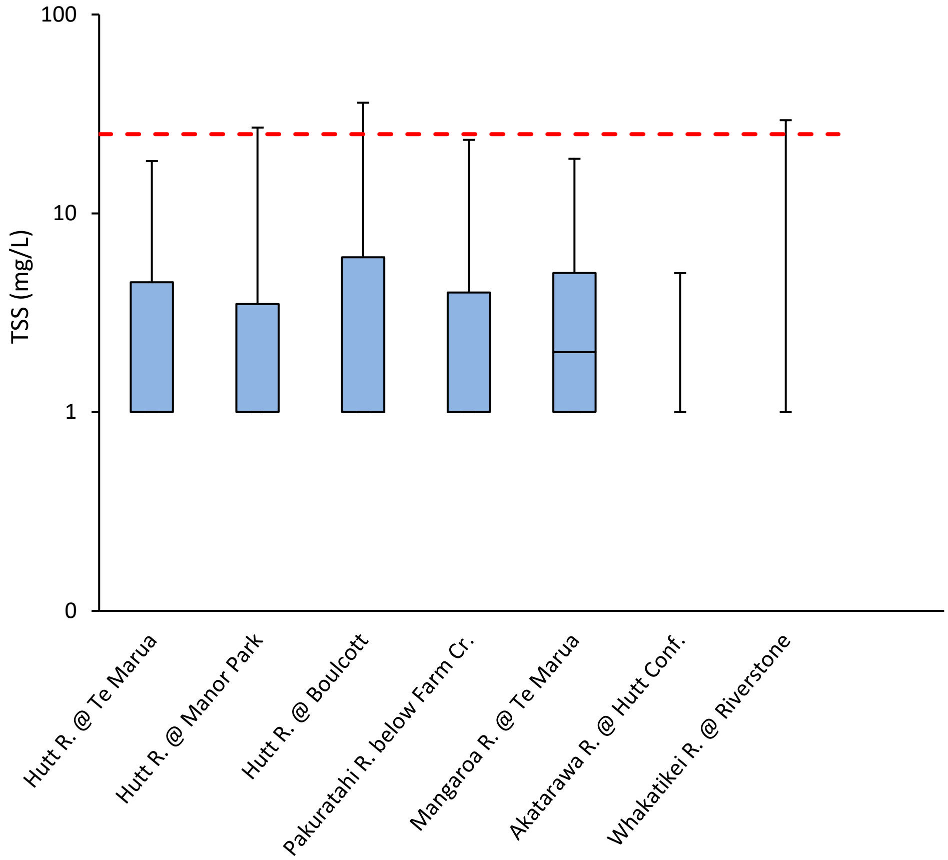

Figure 17: Distribution of TSS concentrations recorded in rivers in the Hutt River catchment sub-zone. The red line represents the commonly cited threshold of 25 mg/L for the onset of detrimental effects on fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001). Note the boxes are not visible for some sites as the 25th percentile, median, and 75th percentile were all the same.

E. coli

An assessment of *E. coli* concentrations measured at each GWRC and HCC monitoring site against the different attribute states of the NPS-FM 2014 is provided in Table 30. Statistics have been calculated once for each site using data from the period between 01/07/2012 and 30/06/2017 inclusive.

E. coli concentrations at all GWRC monitoring sites in the Hutt, Pakuratahi, Akatarawa and Whakatikei over the past five years were considered suitable for primary contact recreation and were in the A, B or C attribute states under the NPS-FM 2014 (Table 30). The Mangaroa River was the only main river in the Hutt River catchment sub-zone considered unsuitable for contact recreation due to faecal contamination, and *E. coli* concentrations were with attribute state D at the site at Te Marua (Table 30).

HCC monitoring data indicates that some of the urban streams in the Hutt River catchment sub-zone are not suitable for contact recreation due to faecal contamination, and *E. coli* concentrations at sites on the Opahu and Te Mome streams were within attribute state D or E (Table 30). However, *E. coli* concentrations at Speedy's Stream at Western Hutt Road were within attribute state C, and this site is suitable for primary contact recreation.

Table 30: *E. coli* data recorded in rivers in the Hutt River catchment sub-zone from 2012 to 2016 graded against the NPS-FM 2014 attribute state thresholds. Shaded cells represent the following attribute states; blue = A, green = B, yellow = C, orange = D and red = E.

Data source	Site	% above 540 cfu/100ml	% above 260 cfu/100ml	Median (cfu/100ml)	95th %ile (cfu/100ml)	NPS-FM attribute state	Suitable for prim. contact rec.
GWRC RWQE	Hutt R. @ Te Marua	0	0	17	135	A	✓
	Hutt R. @ Manor Park	5	13	65	900	B	✓
	Hutt R. @ Boulcott	7	17	53	750	B	✓
	Pakuratahi R. below Farm Cr.	7	12	80	1000	B	✓
	Mangaroa R. @ Te Marua	17	33	170	2450	D	×
	Akatarawa R. @ Hutt Conf.	2	8	39	420	A	✓
	Whakatikei R. @ Riverstone	3	5	22	290	A	✓
GWRC Rec	Akatarawa R. at Hutt Confluence	5	11	68	1191	C	✓
	Hutt R. @ Birchville	4	5	54	290	A	✓
	Hutt R. @ Maoribank Cnr.	5	6	38	522	A	✓
	Hutt R. @ Melling Br.	8	12	58	900	B	✓
	Hutt R. @ Poets Park	3	4	37	161	A	✓
	Hutt R. @ Silverstream Br.	4	7	54	432	A	✓
HCC *E. coli*	Speedy's S. @ Western Hutt Rd.	13	25	75	1180	C	✓
	Opahu S. @ Penrose St.	56	81	566	56	E	×
	Opahu S. @ Whites Line West	31	53	292	31	E	×
	Te Mome S. @ Bracken St.	35	63	391	35	E	×
	Te Mome S. @ The Esplanade	17	38	224	17	D	×

3.2.3. Trends in water quality and ecology

Environmentally meaningful trends in both directions were observed in the Hutt River catchment sub-zone. Between 2006 and 2016 meaningful improving trends in DIN and NO_3-N were observed in the Pakuratahi River below Farm Creek, while a meaningful degrading trend in MCI was also observed at that site (Table 31). The drivers of changing nitrogen concentrations and MCI in the Pakuratahi River are unclear. However, as the entire upstream catchment is indigenous forest, it was likely caused by climatic patterns. Meaningful improving trends in DIN and NO_3-N were also observed in the Mangaroa River at Te Marua (Table 31), and *E. coli* concentrations were also observed to be decreasing at all sites except the Whakatikei River at Riverstone (Table 31).

Table 31: Temporal trends (10yr) in various physico-chemical and ecological parameters in rivers in the Hutt River catchment sub-zone. Adapted from Snelder (2017).

Parameter	Hutt R. @ Te Marua		Hutt R. @ Manor Park		Hutt R. @ Boulcott		Pakuratahi R. below Farm Cr.		Mangaroa R. @ Te Marua		Akatarawa R. @ Hutt Conf.		Whakatikei R. @ Riverstone
	Trend direction	Ann. Δ	Trend direction	Ann. Δ	Trend direction	Ann. Δ	Trend direction	Ann. Δ	Trend direction	Ann. Δ	Trend direction	Ann. Δ	Trend direction
MCI	Uncertain		Uncertain		Uncertain		Degrading	1%	Uncertain		Uncertain		Uncertain
Mat algal cover	N/A		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain
Fil. algal cover	N/A		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain
Peri. biomass	Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain
DIN	Uncertain		Uncertain		Uncertain		Improving	3%	Improving	3%	Uncertain		Uncertain
DRP	Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain
E coli	Improving	5%	Improving	8%	Improving	8%	Uncertain		Uncertain		Improving	4%	Uncertain
NO_3-N	Uncertain		Uncertain		Uncertain		Improving	3%	Improving	3%	Uncertain		Uncertain
NH_4-N	Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain
TSS	Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain		Uncertain

Uncertain
Improving. Not environmentally meaningful
Improving. Environmentally meaningful
Degrading. Not environmentally meaningful
Degrading. Environmentally meaningful

3.2.4. NPS-FM 2014 attribute state grading

Periphyton

Periphyton biomass data collected up until June 2017 indicates that the Hutt River at Te Marua is likely to be assigned to attribute state A under the in the NPS-FM 2014, the Hutt River at Boulcott is likely to be assigned to attribute state B, and the Mangaroa River at Te Marua is likely to be assigned to attribute state D, and will not meet the national bottom line (Table 32).

Ammonia toxicity

When corrected for temperature and pH, unionised ammonia (NH_3-N) concentrations at all sites were assigned an overall attribute state of A for ammonia toxicity under the NPS-FM 2014 (based on the overall average of annual median and maximum concentration) (Table 32). Furthermore, NH_3-N concentrations in all sites fell within the A attribute state in all years between 2012 and 2016.

Nitrate toxicity

NO_3-N concentrations in all years at all sites were assigned to attribute state A for nitrate toxicity under the NPS-FM 2014 (Table 32).

E. coli

E. coli concentrations in the Hutt River at Te Marua, the Pakuratahi River, the Akatarawa River and the Whakatikei River were assigned to either attribute state A, B or C in all years, meaning these sites are considered suitable for contact recreation under the NPS-FM 2014 (Table 32). *E. coli* concentrations in the Hutt River at Boulcott were assigned an overall average attribute state of C, indicating it to is generally suitable for primary contact recreation (Table 32). However, in 2014 the site was assigned to attribute state D, and during this period it was not suitable.

E. coli concentrations in the Hutt River at Manor Park, and the Mangaroa River at Te Marua, were both assigned an overall attribute state of D indicating they are generally unsuitable for primary contact recreation (Table 32). It is, however, important to note that the Manor Park site was assigned to attribute state B in 2016 (Table 30), indicating that for the last five years, faecal contamination has not been a major problem at this site. Over the past 10 years there has also been an improving trend in *E. coli* concentrations at this site (Section 3.2.3).

Table 32: Water quality and ecology results from GWRC RWQE monitoring sites in the Hutt River catchment sub-zone collected since 2012 compared to numeric attributes as specified in the NPS-FM 2014. Cells shaded in red indicate a national bottom line has been breached.

Parameter	Site	Lowest attribute state	Overall average attribute state
Periphyton biomass	Hutt R. @ Te Marua	A	A*
	Hutt R. @ Boulcott	A	B*
	Mangaroa R. @ Te Marua	C	D*
NO_3-N	Hutt R. @ Te Marua	A	A
	Hutt R. @ Manor Park	A	A
	Hutt R. @ Boulcott	A	A
	Pakuratahi R. below Farm Cr.	A	A
	Mangaroa R. @ Te Marua	A	A
	Akatarawa R. @ Hutt Conf.	A	A
	Whakatikei R. @ Riverstone	A	A
NH_3-N	Hutt R. @ Te Marua	A	A
	Hutt R. @ Manor Park	A	A
	Hutt R. @ Boulcott	A	A
	Pakuratahi R. below Farm Cr.	A	A
	Mangaroa R. @ Te Marua	A	A
	Akatarawa R. @ Hutt Conf.	A	A
	Whakatikei R. @ Riverstone	A	A
E. coli	Hutt R. @ Te Marua	A	A
	Hutt R. @ Manor Park	D	D
	Hutt R. @ Boulcott	D	C
	Pakuratahi R. below Farm Cr.	C	B
	Mangaroa R. @ Te Marua	D	D
	Akatarawa R. @ Hutt Conf.	A	A
	Whakatikei R. @ Riverstone	A	A

*Predicted attribute state based on current patterns in biomass

3.2.5. Nutrient loads

Between 2012 and 2016 the annual DIN load from the Hutt River to the Wellington Harbour[16] ranged from 166 to 278 tonnes (μ = 190.61 t/yr), the annual TN load ranged from 276 to 514 tonnes (μ = 354.73 t/yr), the annual DRP load ranged from 4.04 to 5.95 tonnes (μ = 4.5 t/yr) and the annual TP ranged from 20 to 72 tonnes (μ = 25.61 t/yr) (Table 33).

By far the biggest surface water contributor of DIN above the Manor Park monitoring site is the Mangaroa River. The average annual DIN load in the Hutt River at Manor Park was 196.85 t/yr, of which the Mangaroa contributed an average of 46.57 tonnes, or approximately 23% (Table 33). In contrast the Pakuratahi only contributed 25.64 t/yr (13%), the Akatarawa contributed 23.36 t/yr (12%) and the Whakatikei contributed 17.36 t/yr (9%) (Table 33).

Groundwater inputs are also significant contributors of DIN load in the Hutt River above Manor Park. Between 2012 and 2016, the Pakuratahi, Akatarawa, Mangaroa and Whakatikei rivers only contributed a combined average of 112.94 t/yr, to the 196.85 t/yr in the Hutt River at Manor Park (57%) (Table 33); at least 84 t/yr was from other sources. An investigation by Heath and Greenfield (2016), revealed that upwelling of nitrogen-rich groundwater in the Hutt River between its confluence with the Whakatikei River and Taita is responsible for this unaccounted load. However, the sources of nutrients in this groundwater are still not fully understood.

The Mangaroa River is also the largest contributor of DRP in the Hutt River above the Manor Park monitoring site. The average annual DRP load in the Hutt River at Manor Park was 4.6 t/yr, of which the Mangaroa contributed an average of 1.17 tonnes, or approximately 25% (Table 33). In contrast the Pakuratahi only contributed 0.66 t/yr (14%), the Akatarawa contributed 0.74 t/yr (16%) and the Whakatikei contributed 0.77 t/yr (17%) (Table 33). Unaccounted sources make up 1.2 t/yr of the average DRP load at the Manor Park monitoring site. It is important to note that DRP concentrations are low throughout the Hutt River catchment, and none of the surface water catchments can be considered to be sources of phosphorus enrichment.

Between 2012 and 2016 annual nutrient loads generally decreased downstream of the Manor Park monitoring site. Average DIN and DRP loads at the Boulcott monitoring sites were 6.24 t/yr and 0.1 t/yr lower than at the Manor Park monitoring site respectively (Table 33). Heath and Greenfield (2016) contributed this reduction in nutrient load to groundwater loss.

[16] Based on loads at the GWRC Boulcott monitoring site.

Table 33: Annual nutrient loads at monitoring sites in the Hutt River catchment sub-zone. Loads were calculated using the averaging method and the Beale's ratio estimator method. The results presented here are averages of the results of these two methods.

Site	Year	DIN	TN	DRP	TP
		t/yr			
Hutt R. @ Te Marua	2012	28.46	69.34	1.15	2.81
	2013	27.21	91.58	1.32	6.72
	2014	27.67	41.26	1.31	2.33
	2015	29.16	50.27	1.20	1.74
	2016	41.15	79.01	1.74	2.91
	Average	**30.73**	**66.29**	**1.34**	**3.30**
Hutt R. @ Manor Park	2012	189.35	310.23	4.02	12.27
	2013	162.80	330.14	5.14	17.72
	2014	166.97	516.27	4.63	66.63
	2015	195.58	256.72	3.61	6.71
	2016	269.57	385.44	5.61	10.04
	Average	**196.85**	**359.76**	**4.60**	**22.67**
Hutt R. @ Boulcott	2012	168.59	290.92	4.04	20.09
	2013	148.05	286.69	4.68	17.48
	2014	166.40	514.00	4.29	72.48
	2015	191.88	276.70	3.55	6.89
	2016	278.13	405.33	5.95	11.09
	Average	**190.61**	**354.73**	**4.50**	**25.61**
Pakuratahi R. below Farm Cr.	2012	26.44	40.51	0.71	1.50
	2013	23.35	57.59	1.04	3.29
	2014	18.82	26.03	0.40	0.86
	2015	24.01	32.77	0.46	0.72
	2016	35.58	56.87	0.70	1.21

Site	Year	DIN	TN	DRP	TP
		t/yr			
	Average	**25.64**	**42.75**	**0.66**	**1.51**
Mangaroa R. @ Te Marua	2012	46.64	67.45	1.24	2.60
	2013	40.81	72.13	1.51	3.63
	2014	38.48	53.24	0.94	1.63
	2015	43.93	61.38	0.84	1.52
	2016	63.00	86.47	1.30	2.36
	Average	**46.57**	**68.13**	**1.17**	**2.35**
Akatarawa R. @ Hutt Conf.	2012	37.10	51.00	0.53	1.33
	2013	18.80	46.34	0.73	2.30
	2014	19.72	98.62	0.74	17.02
	2015	18.59	26.48	0.70	0.96
	2016	22.57	44.55	0.99	1.50
	Average	**23.36**	**53.40**	**0.74**	**4.62**
Whakatikei R. @ Riverstone	2012	21.53	29.65	0.77	1.35
	2013	12.33	19.16	0.63	0.95
	2014	15.42	196.38	0.79	34.20
	2015	11.56	15.83	0.51	0.60
	2016	25.96	37.07	1.12	1.47
	Average	**17.36**	**59.62**	**0.77**	**7.71**

3.2.6. Human drivers of degradation

Ecosystem health in the Pakuratahi, Akatarawa River and Whakatikei Rivers, as well as the upper reaches of the Hutt River is excellent or near excellent, and human activities do not appear to be having a significant ecological impact in these systems. However, macroinvertebrate community monitoring data suggests that ecosystem health in the lower reaches of the Mangaroa and Hutt Rivers is moderately degraded by human activities.

Agricultural land-use is likely the main source of degradation in the Mangaroa River, and the mechanism through which this activity is impacting ecosystem health appears to be eutrophication, primarily nitrogen enrichment. Nitrogen and phosphorus concentrations in the Mangaroa are the highest in the Hutt River catchment sub-zone, and this has led to nuisance periphyton blooms, which in turn are having a negative influence on macroinvertebrate community health. Indeed, periphyton growth is so prolific in the Mangaroa River that it is likely that it does not meet the national bottom line for this attribute in the NPS-FM 2014. While it is clear that agricultural land-use is the driver of elevated nitrogen concentrations in the Mangaroa, the exact nutrient sources are not known. An investigation by Heath and Greenfield (2016) could not determine where the majority of the nitrogen load (i.e. location) enters the Mangaroa River and recommended that nitrogen inputs from groundwater be quantified to help elucidate the key sources. The Waipango Swamp/Peatland is one possible source of nitrogen in this catchment, contributing to DIN loads in surface water, and groundwater nitrogen concentrations (Health and Greenfield, 2016).

The drivers of ecological degradation in the lower reaches of the Hutt River are not as clear as those in the Mangaroa. Periphyton biomass data indicates that the site is not overly impacted by nuisance periphyton blooms, fine sediment cover is generally low, and there is no evidence of chronic risk of ammonia, nitrate and metal toxicity. As such, it is likely that the moderately degraded state of ecological communities is the cumulative effects of a number of different activities and land-uses, including:

- Pastoral land-use;
- Urban land-use;
- Water abstraction for municipal supply; and
- River engineering works for flood protection.

The impacts of flood protection works on the Hutt River will be investigated under new resource consents, and this work may well help develop a better understanding of the drivers of ecological degradation in the lower reaches of the Hutt River.

Of the sites monitored by GWRC in the Hutt River catchment sub-zone, only the Mangaroa River has consistently had *E. coli* concentrations that are considered unsuitable for primary contact recreation under the NPS-FM 2014. As there is no significant urban development in the Mangaroa catchment, the primary source of faecal contamination in this river is likely livestock. While the Hutt River at Manor Park has been assigned an overall attribute state of D for *E. coli* under the NPS-FM 2014 (Table 32), in 2016 it was assigned to attribute state B (Table 30), indicating that for the past five years faecal contamination has not posed a significant health risk at this site. Faecal contamination in small urban streams monitored by HCC is most likely from wastewater contamination.

The drivers of cyanobacteria blooms in the Hutt River are not fully understood. However, blooms are most common in the middle reaches of the river where DIN concentrations are highest (Heath and Greenfield, 2016). Therefore, activities that drive high nutrient concentrations may be increasing the incidence and magnitude of blooms (Heath and Greenfield, 2016). In the Hutt River catchment, the primary sources of DIN are pastoral land-use in the Mangaroa River, and the upwelling of nitrogen rich groundwater between the Whakatikei River confluence and Taita. While the sources of groundwater nitrogen entering the Hutt River are not known, it is likely that nutrient leaching from intensively managed areas such as parks, golf courses and racecourses, combined with leaking and/or cross connected wastewater and stormwater infrastructure are contributors (Heath and Greenfield, 2016).

3.2.7. Knowledge gaps

The key knowledge gaps in the Hutt River catchments sub-zone have already been pointed out in Heath and Greenfield (2016). The main issues in the sub-zone are eutrophication/periphyton blooms in the Mangaroa River and cyanobacteria blooms in the mid and lower reaches of the Hutt River. To fully understand and manage the drivers of both these issues a better understanding of nutrient sources, pathways and dynamics is needed. Specifically, investigations are needed to identify the major surface water and groundwater sources of nitrogen in the Mangaroa catchment, so they can be traced back to specific areas, and research is needed to determine where nitrogen entering the Hutt River through groundwater is leached from. There is also a need to develop a better understanding of the factors that drive cyanobacteria growth in the Hutt River. Research is ongoing in this still developing field.

3.2.8. Summary

Through most of the Hutt River catchment sub-zone, macroinvertebrate communities are indicative of excellent or near excellent ecological condition, and only two GWRC monitoring sites had significantly degraded ecosystem health during the assessment period, the Hutt River at Boulcott, and Mangaroa River at Te Marua. Eutrophication driven periphyton growth, caused by pastoral land-use, is responsible for the degraded ecosystem health in the Mangaroa River. However, the drivers of degraded macroinvertebrate community health in the Hutt River at Boulcott are less clear, and it is likely driven by a mixture of pastoral land-use, urban land-use, water abstraction and river engineering works.

In terms of recreational value, the main rivers in the Hutt River catchment sub-zone are in a good state. However, benthic cyanobacteria blooms frequently pose a health risk to recreational users in the mid and lower reaches of the Hutt River and the Mangaroa River is not suitable for primary contact recreation due to faecal contamination. HCC monitoring data suggests that small urban streams in the Hutt River catchment sub-zone, such as the Opahu and Te Mome Streams, are also unsuitable for primary contact recreation due to faecal contamination

Improving trends in nitrogen species were observed in the Pakuratahi and Mangaroa Rivers, and *E. coli* levels were found to be improving at all sites except the Whakatikei River at Riverstone. Interestingly a degrading trend in MCI was also observed in the Pakuratahi River, and the drivers of this change are unclear as almost the entire upstream catchment is indigenous forest.

3.3. Wellington Harbour stream catchments sub-zone

3.3.1. Ecology and habitat

Macroinvertebrates

Long-term macroinvertebrate monitoring data exists for two sites in the Wellington Harbour stream catchments sub-zone; the Kaiwharawhara Stream at Ngaio Gorge, and the Waiwhetu Stream at Whites Line East.

The MCI outcomes in the pNRP were not met at monitoring sites in the Kaiwharawhara and Waiwhetu Streams in any of the years that monitoring was conducted between 2012 and 2016 (Table 34). In all years rolling three-year median and annual MCI scores in the Kaiwharawhara Stream were generally below 90, indicating poor ecological condition (based on Wellington specific MCI thresholds set out in Clapcott and Goodwin (2014)) (Table 34). MCI scores in the Waiwhetu Stream at White Lines East, were lower still, and in all years the three-year median and annual MCI scores were below 80, again indicating poor ecological condition (Table 34). As MCI scores in the Waiwhetu Stream were below 80, GWRC are required to identify the causes of degraded macroinvertebrate community health and develop a response plan (NPS-FM, 2014).

Table 34: Rolling 3-year median MCI scores (and annual MCI scores) recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016. Values highlighted in red fail to meet pNRP outcomes.

Site	pNRP outcome	2012	2013	2014	2015	2016
Kaiwharawhara S. @ Ngaio G.	105	87 (81)	87 (96)	82 (82)	82 (71)	82 (99)
Waiwhetu S. @ Whites Line East	100	66 (60)	68 (68)	68 (76)	68 (60)	74 (74)

Fish

Ten native species were found in the Wellington Harbour stream catchments sub-zone between 2000 and 2017: longfin eel, shortfin eel, bluegill bully, redfin bully, common bully, koaro, inanga, giant kokopu, banded kokopu and shortjaw kokopu (single record from the Kaiwharawhara Stream). All of these species, except shortfin eel, banded kokopu and common bully are classified as either at risk or threatened (Goodman *et al.*, 2014).

Brown trout was the only introduced sports fish found in the Wellington Harbour stream catchments sub-zone between 2000 and 2017.

Inanga spawning has been confirmed in the lower reaches of the Kaiwharawhara and Waiwhetu Streams (Marshall and Taylor, 2017; Taylor and Marshall, 2016). The Korokoro Stream is unlikely to support inanga spawning, as the short reach that is tidally inundated (based on modelling data) does not support appropriate vegetation (Marshall and Taylor, 2017).

Periphyton

Periphyton growth is likely to be partially driving the moderate degradation in macroinvertebrate community health in the Kaiwharawhara River at Ngaio Gorge. Annual maximum periWCC at this site exceeded the pNRP outcome in all years between 2012 and 2016 (Table 35). In 2012, 2013, 2014 and 2016 annual maximum periWCC at the site was indicative of poor ecological condition (Table 35). The maximum periWCC in 2015 was much lower than in previous years, but was still only indicative of fair ecological health. Periphyton biomass data collected up until June 2017 indicates that the site is also unlikely to meet the periphyton biomass outcome in the pNRP (Table 36), and it is predicted that the site will be graded as fair once three years of monitoring has been completed (based on the grading system set out in Snelder *et al.* (2013)).

Table 35: Annual maximum periWCC scores recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016. Values highlighted in red fail to meet pNRP outcomes.

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Kaiwharawhara S. @ Ngaio G.	40	95	79	81.75	48.5	70

Table 36: Grading of periphyton biomass samples from rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016 (Snelder *et al.*, 2013). The highest possible grade (if all remaining samples were below the excellent threshold) and the predicted grade (if the observed patterns in the existing data continue for the remainder of the sampling period) have been calculated for each site. Whether the pNRP outcome is likely to be met has been assessed from the predicted grade.

Site	pNRP outcome	≤ 50 (Exc.)	> 50 - ≤ 120 (Good)	> 120 - ≤ 200 (Fair)	> 200 (Poor)	Curr. Grade	Pred. grade	Likely to meet outcome
	mg chl-*a*/m²							
Kaiwharawhara S. @ Ngaio G.	120	7	2	2	0	Good	Fair	×

Macrophytes

Macrophyte cover was very high in the Waiwhetu Stream at White Lines East between 2012 and 2016, and excessive plant growth is likely contributing in some way to the degraded state of resident macroinvertebrate communities. Annual maximum cover in all years was at or approaching 100% (Table 37), far above the guideline for the protection of instream aesthetic and recreational values (50% cover (Matheson *et al.*, 2012)). It is, therefore, extremely unlikely that this site is meeting the pNRP macrophyte outcome.

Table 37: Annual maximum total macrophyte cover recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016. Values highlighted in red fail to meet pNRP outcomes.

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Waiwhetu S. @ Whites Line East	50	97	100	93	94	97

Cyanobacteria

For the most part cyanobacteria does not appear to pose a health risk in in the Wellington Harbour stream catchments sub-zone. Annual maximum cyanobacteria in the Kaiwharawhara Stream at Ngaio Gorge was extremely low (at or approaching 0%) in all years between 2012 and 2016, and the site consistently met the pNRP outcome for cyanobacteria (Table 38). To the best of our knowledge cyanobacteria is also unlikely to pose a health risk in other streams in the sub-zone, and GWRC has not received any reports of blooms from members of the public (Mark Heath pers. comm.)

Table 38: Annual maximum benthic cyanobacteria cover recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes (based on the suggested guidance in Greenfield *et al.* (2015b)).

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Kaiwharawhara S. @ Ngaio G.	20	-	0	0	0	1

Fine sediment cover

Fine sediment cover is likely to be a key driver of the severe degradation in macroinvertebrate community health in the Kaiwharawhara and Waiwhetu streams. Annual maximum fine sediment cover in both streams exceeded the guideline value for the protection of biodiversity (<20% cover (Clapcott *et al.*, 2011)) in all years that monitoring was conducted (Table 39). Furthermore, sediment cover was persistently elevated in both the Kaiwharawhara Stream and the Waiwhetu Stream; exceeding the guideline 75% of the time in the Waiwhetu and 50% of the time in the Kaiwharawhara (Figure 18).

Table 39: Annual maximum fine sediment cover recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016. Values highlighted in red fail to meet the guideline set out in Clapcott *et al.* (2011) for the protection of benthic biodiversity.

Site	Clapcott *et al.* (2011) guideline (%cover)	2012	2013	2014	2015	2016
Kaiwharawhara S. @ Ngaio G.	20	-	95	40	40	-
Waiwhetu S. @ Whites Line East	20	-	70	35	60	-

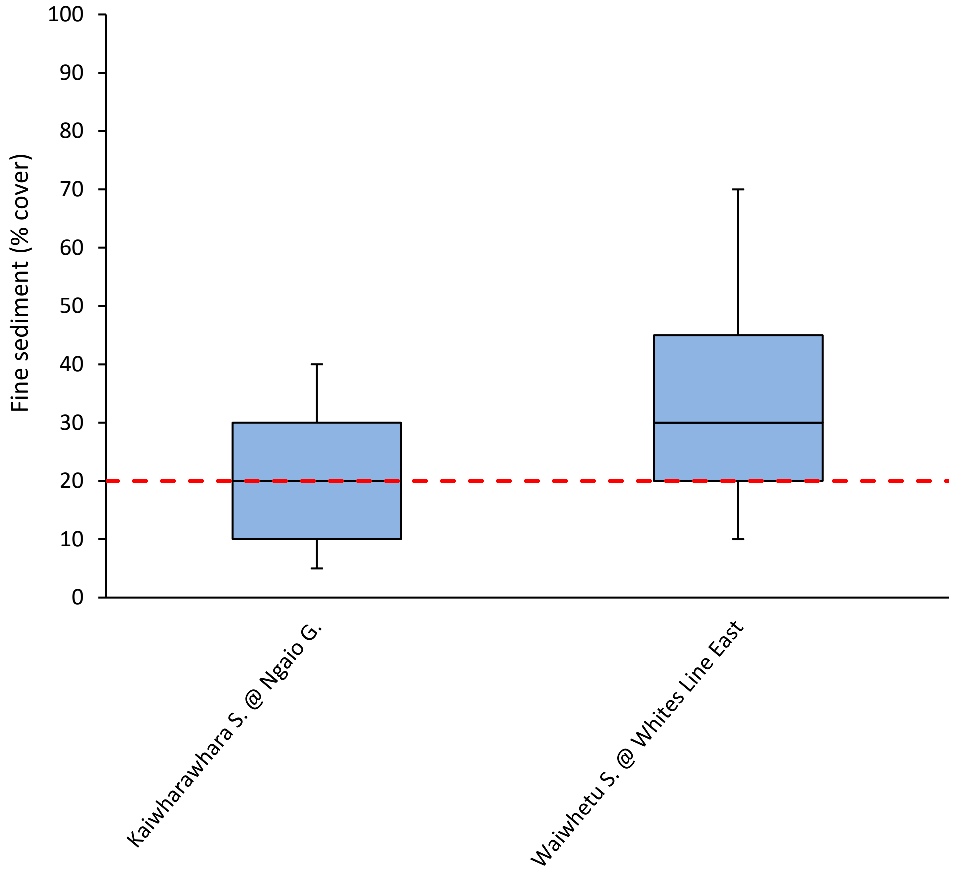

Figure 18: Distribution of fine sediment cover data recorded in rivers in the Wellington Harbour stream catchments sub-zone. The red line indicates the Clapcott *et al.* (2011) guideline for the protection of biodiversity

Water temperature and dissolved oxygen

Based on the guidelines presented in Davies-Colley *et al.* (2013), annual maximum temperatures recorded in the Kaiwharawhara Stream at Ngaio Gorge were graded as good (18°C- 20°C) in 2012 and 2013, excellent (<18°C) in 2014 and 2016 and fair (20°C- 24°C) in 2015 (Table 40). That the maximum temperature recorded in 2015 was above 20°C indicates that there may be some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish at this site. However, continuous monitoring would be needed to confirm this.

Annual maximum temperatures in the Waiwhetu Stream at White Lines East were graded as good in all years except 2012 when it was graded as excellent (Table 40). That recorded temperatures were generally low, does not necessarily mean that the thresholds presented in Davies-Colley *et al.* (2013) were not breached at any point during this period.

Table 40: Annual maximum temperature recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the guidelines set out in Davies-Colley *et al.* (2013) for rivers with a maritime climate).

Site	Davies-Colley *et al.* (2013) guidelines (°C)	2012	2013	2014	2015	2016
Kaiwharawhara S. @ Ngaio G.	≤18 (Exc.) ≤20 (Good)	19.3	18.3	17.8	20.6	17.4
Waiwhetu S. @ Whites Line East	≤24 (Fair) >24 (Poor)	19	17	19	20	19.1

Based on the guidelines presented in Davies-Colley *et al.* (2013), annual 1-day minimum DO concentrations in the Kaiwharawhara Stream at Ngaio Gorge were consistently graded as excellent (>7.5 mg/L) (Table 41). That DO concentrations did not breach any of the thresholds presented in Davies-Colley *et al.* (2013), does not necessarily mean that the thresholds were not breached at any point during this period, and it is possible, though unlikely, that low DO is a stressor in this stream.

Low DO in the Waiwhetu Stream at White Lines East may be contributing to the degraded state of macroinvertebrate communities at this site. Minimum DO concentrations recorded at this site in 2012, 2013 and 2016 were graded as good (5.0 – 6.5 mg/L) (Table 41). However, in 2014 and 2015 the minimum concentrations were graded as poor (<4.0 mg/L) and fair (4.0 – 5.0 mg/L) respectively (Table 41). That such low DO concentrations (2.0 mg/L) were recorded in the Waiwhetu stream during the day (when DO is normally highest) suggests that there may be significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels, and there is a likelihood of local extinctions of keystone species and loss of ecological integrity (Davies-Colley *et al.*, 2013).

Table 41: Annual minimum DO concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the 1-day minimum concentration guidelines set out in Davies-Colley *et al.* (2013)).

Site	Davies-Colley *et al.* (2013) guidelines (mg/L)	2012	2013	2014	2015	2016
Kaiwharawhara S. @ Ngaio G.	≥7.5 (Exc.) ≥5.0 (Good)	9.49	9.68	9.15	9.69	9.88
Waiwhetu S. @ Whites Line East	≥4.0 (Fair) <4.0 (Poor)	5	5	2	4	7.12

3.3.2. Current state of water quality

<u>*Nutrients as a driver of plant growth*</u>

Median DIN and DRP concentrations in the Kaiwharawhara Stream at Ngaio Gorge exceeded the Biggs *et al.* (2000) guidelines for the protection of both biodiversity and trout habitat and angling values from nuisance periphyton growths (Figure 19 and Figure 20). These data suggest that nutrient concentrations are likely contributing to, or at least not limiting, elevated periphyton growth at this site.

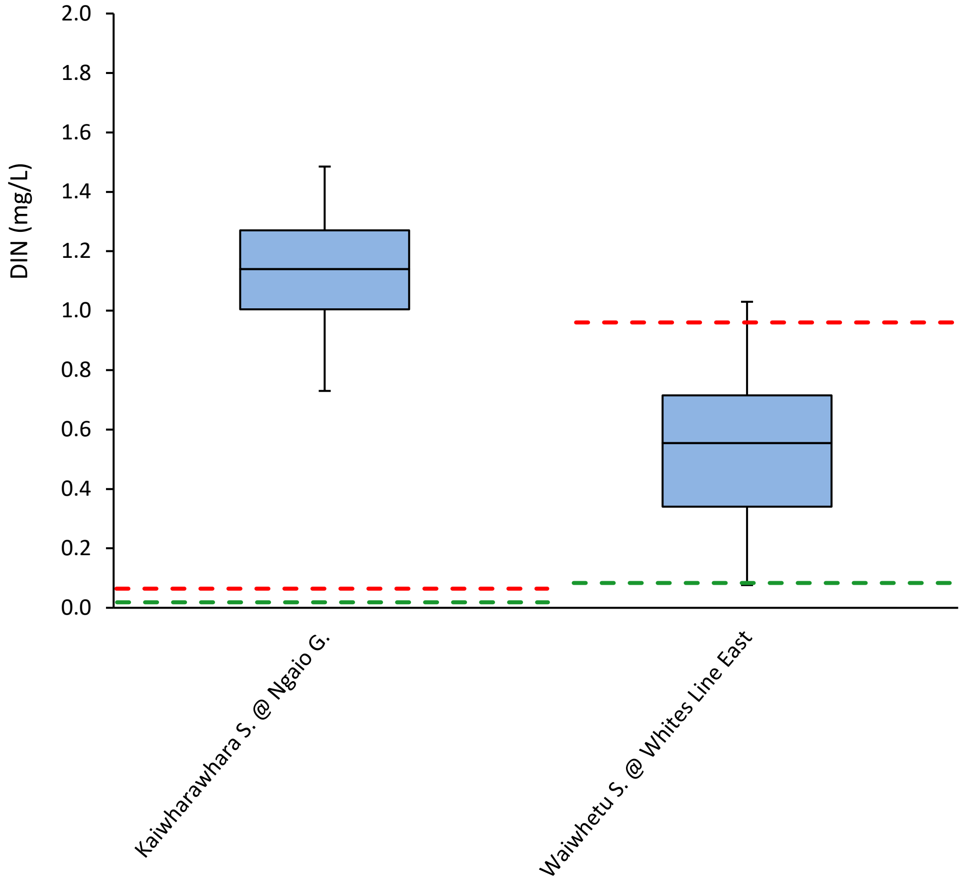

Figure 19: Distribution of DIN concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone. For the Kaiwharawhara the red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively. For the Waiwhetu the red and green lines indicate the concentrations at which there is a 0.9 and 0.7 probability of nuisance macrophyte growths respectively (Matheson *et al.*, 2012).

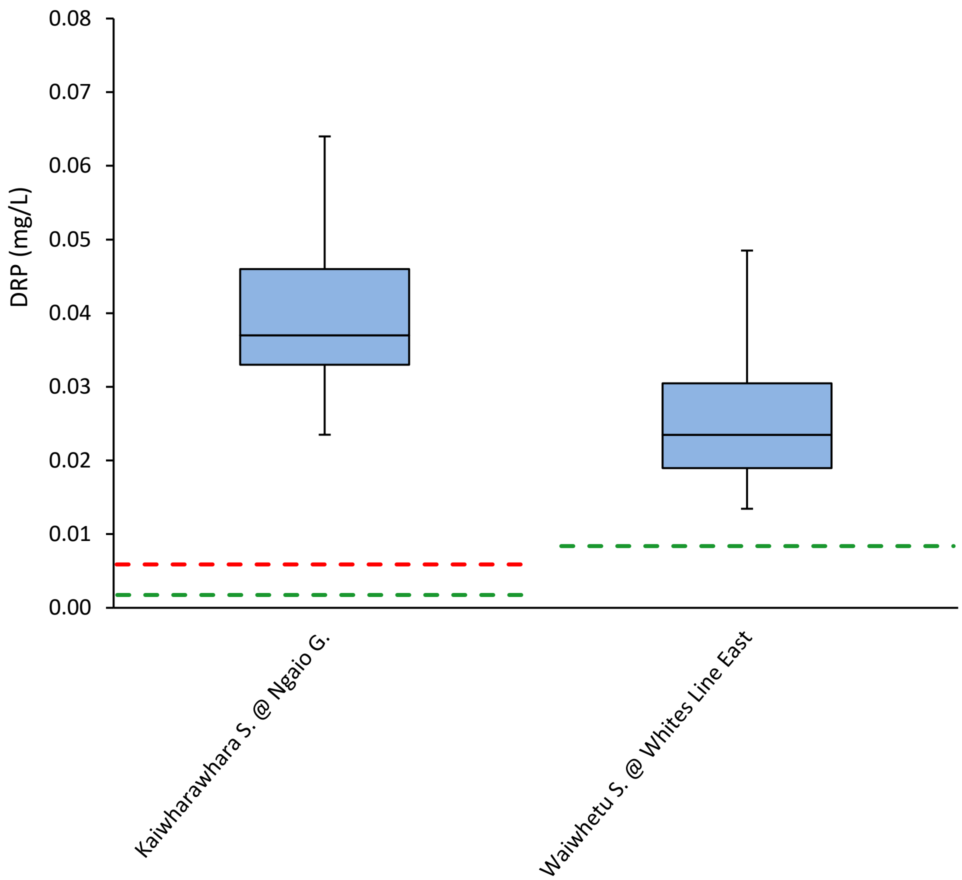

Figure 20: Distribution of DRP concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone. For the Kaiwharawhara the red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively. For the Waiwhetu the green line indicates the concentrations at which there is a 0.7 probability of nuisance macrophyte growths (Matheson *et al.*, 2012).

Water quality data suggests that plant available nutrient concentrations are sufficiently high in the Waiwhetu Stream to cause nuisance macrophyte growths. Both DIN and DRP concentrations recorded at the White Lines East monitoring site were, at a minimum, in the "adequate" range for macrophyte growth, with median values exceeding the level indicative of a 70% probability of nuisance growth (Matheson *et al.*, 2012) (Figure 19).

Nutrient availability is just one of a number of factors that influence macrophyte growth in spring-fed streams, and elevated DIN and DRP concentrations will not always result in nuisance macrophyte growths. However, as nuisance macrophyte growths have been regularly observed in the Waiwhetu Stream since 2012, it is apparent that factors such as light availability, flow conditions and rooting substrate are not limiting macrophyte growth, and that current DIN and DRP are facilitating nuisance macrophyte growth.

Nutrients as toxicants

The degraded state of macroinvertebrate communities in the Kaiwharawhara and Waiwhetu Streams is unlikely to be the result of nitrate toxicity. Overall median and 95th percentile NO_3-N concentrations in the Waiwhetu Stream at White Lines East were below the threshold for the protection of 99% of species from nitrate toxicity (Hickey, 2013) (Figure 21). The 95th percentile NO_3-N concentration in the Kaiwharawhara Stream at Ngaio Gorge was also below the threshold for the protection of 99% of species (Hickey, 2014), and while the median concentration was above the 99% protection threshold, it was well below the 95% protection threshold (Hickey, 2014).

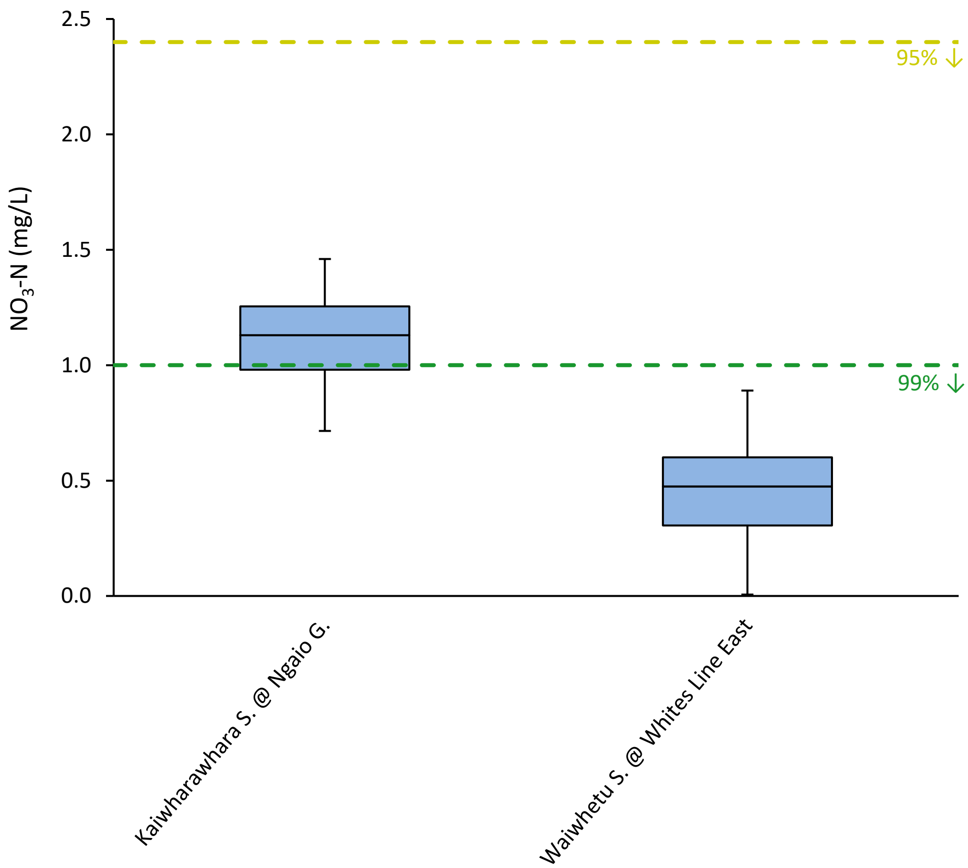

Figure 21: Distribution of NO_3-N concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone. The coloured lines represent species protection guidelines (Hickey, 2013).

Ammonia toxicity is also unlikely to be impacting aquatic ecosystem health in the Kaiwharawhara Stream at Ngaio Gorge and the Waiwhetu Stream at Whites Line East. Overall median and maximum (thresholds not plotted on Figure 22) NH_3-N concentrations at both monitoring sites were below the threshold for the protection of 99% of species from ammonia toxicity (Hickey, 2014) (Figure 22).

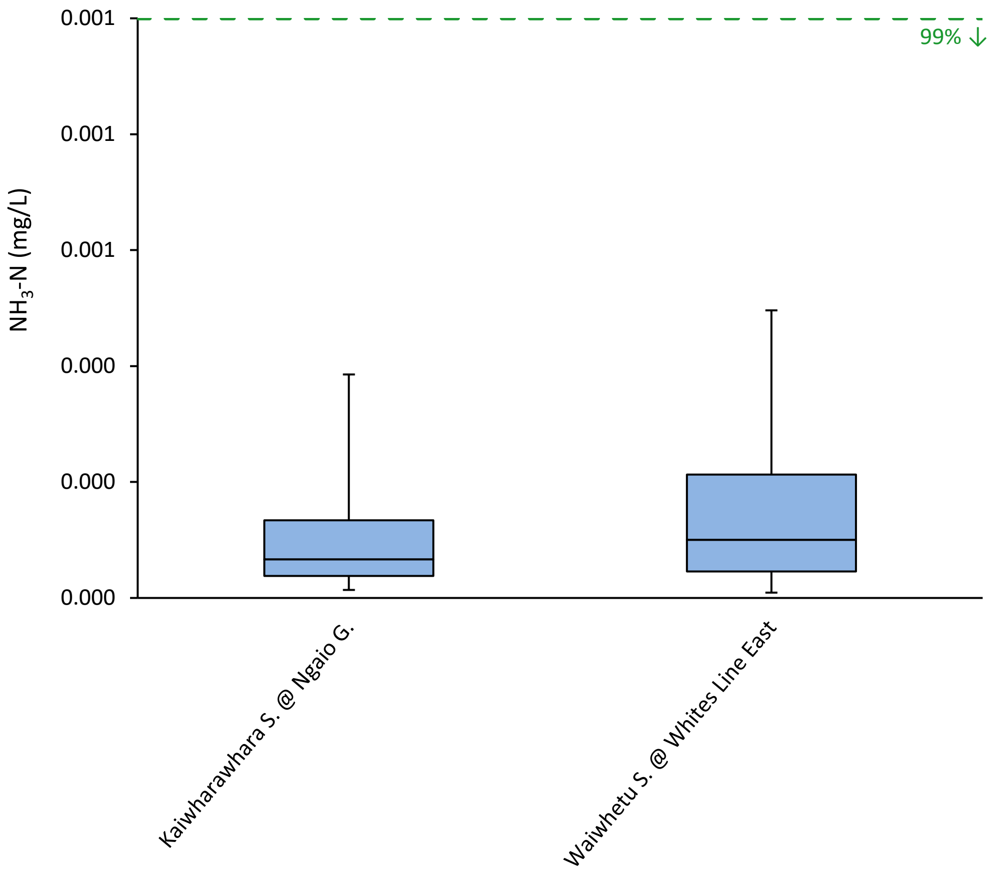

Figure 22: Distribution of NH_3-N concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone. The green line represents the 99% species protection guideline (Hickey, 2014).

Metals as toxicants

While nutrients may not pose a chronic toxicity risk in the Waiwhetu and Kaiwharawhara Streams, chronic toxicity from elevated concentrations of dissolved metals may be contributing to the degraded ecological state of these streams. Between 2012 and 2016 median dissolved copper concentration in the Kaiwharawhara Stream exceeded the updated guideline for the protection of 95% of species from chronic toxicity, and median zinc concentration exceeded the guideline for the protection of 90% of species (Figure 23 and Figure 24). While the median dissolved copper concentration in the Waiwhetu Stream did not exceed the guideline for the protection of 95% of species, dissolved zinc concentrations were far higher than those observed in the Kaiwharawhara and exceeded guidelines for the protection of 80% of species (Figure 23 and Figure 24). These data suggest that in terms of dissolved metal concentrations, both the Kaiwharawhara and Waiwhetu Stream are highly disturbed systems.

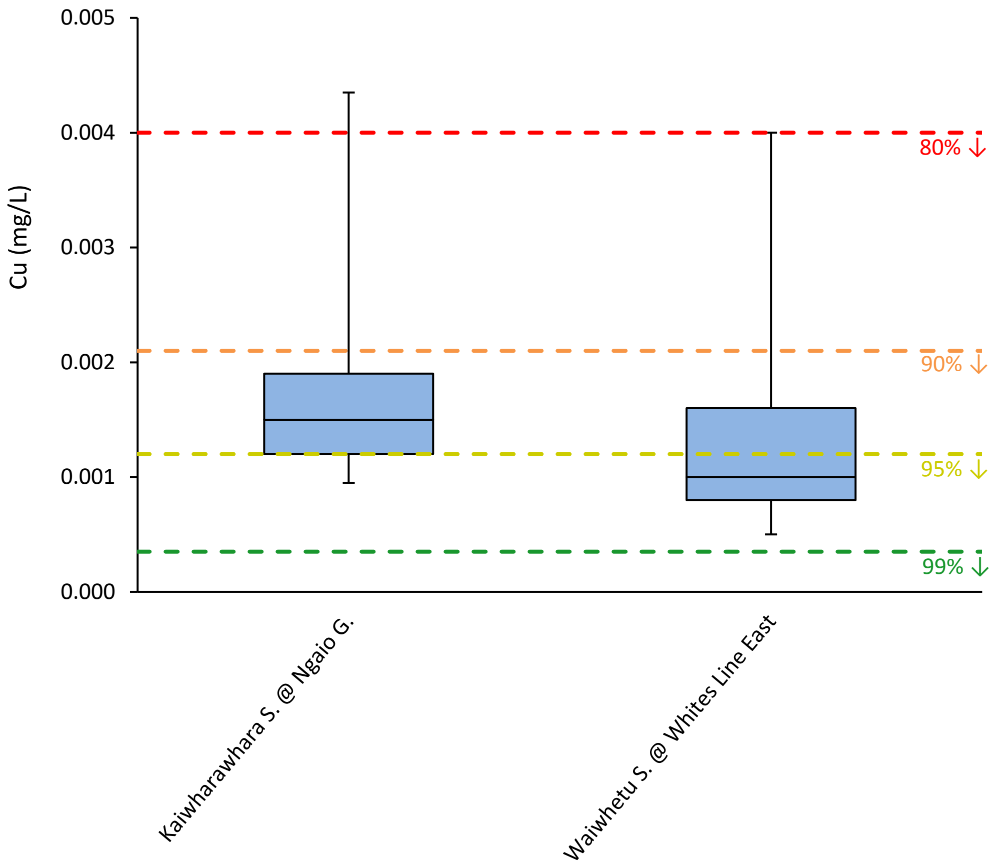

Figure 23: Distribution of Cu concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone. The coloured lines represent species protection thresholds (Australian and New Zealand guidelines for fresh and marine water quality).

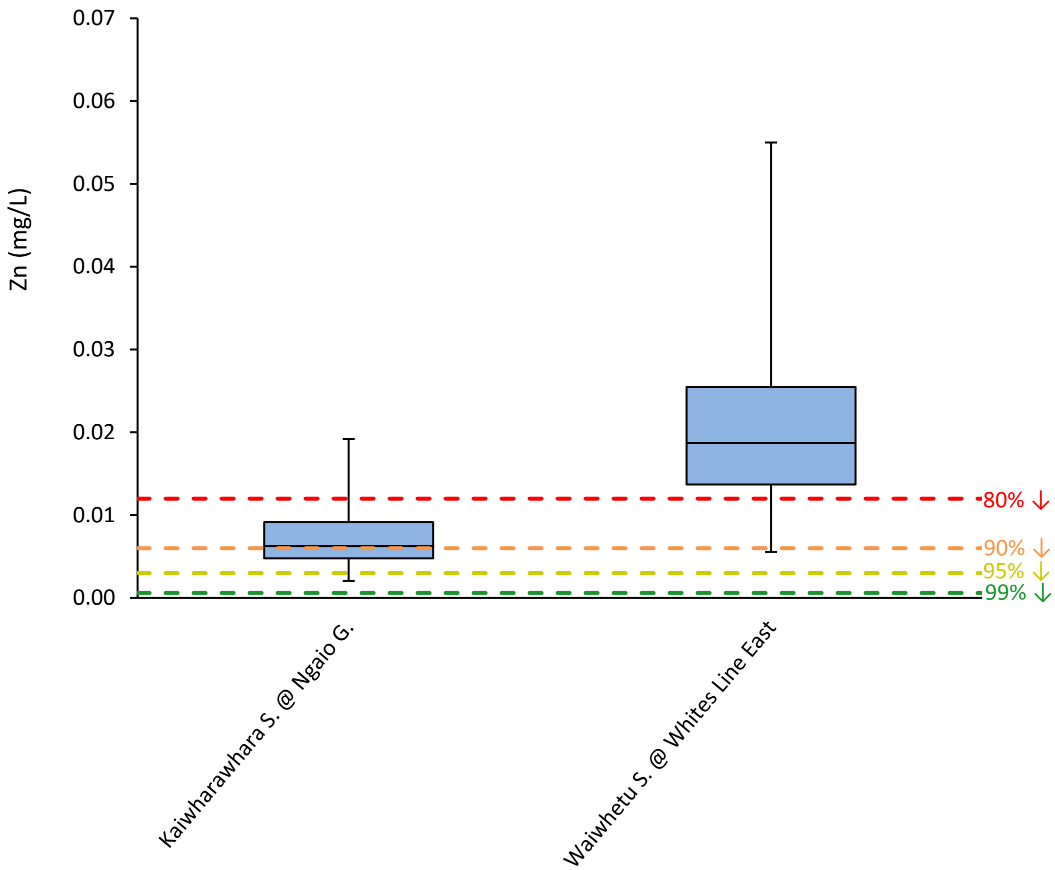

Figure 24: Distribution of Zn concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone. The coloured lines represent species protection thresholds (Australian and New Zealand guidelines for fresh and marine water quality).

TSS

It does not appear that TSS is affecting aquatic ecosystem health at the monitoring sites in the Kaiwharawhara and Waiwhetu Streams. TSS concentrations at both sites were generally well below the commonly cited threshold of 25 mg/L for the onset of detrimental effects for fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001) (Figure 25).

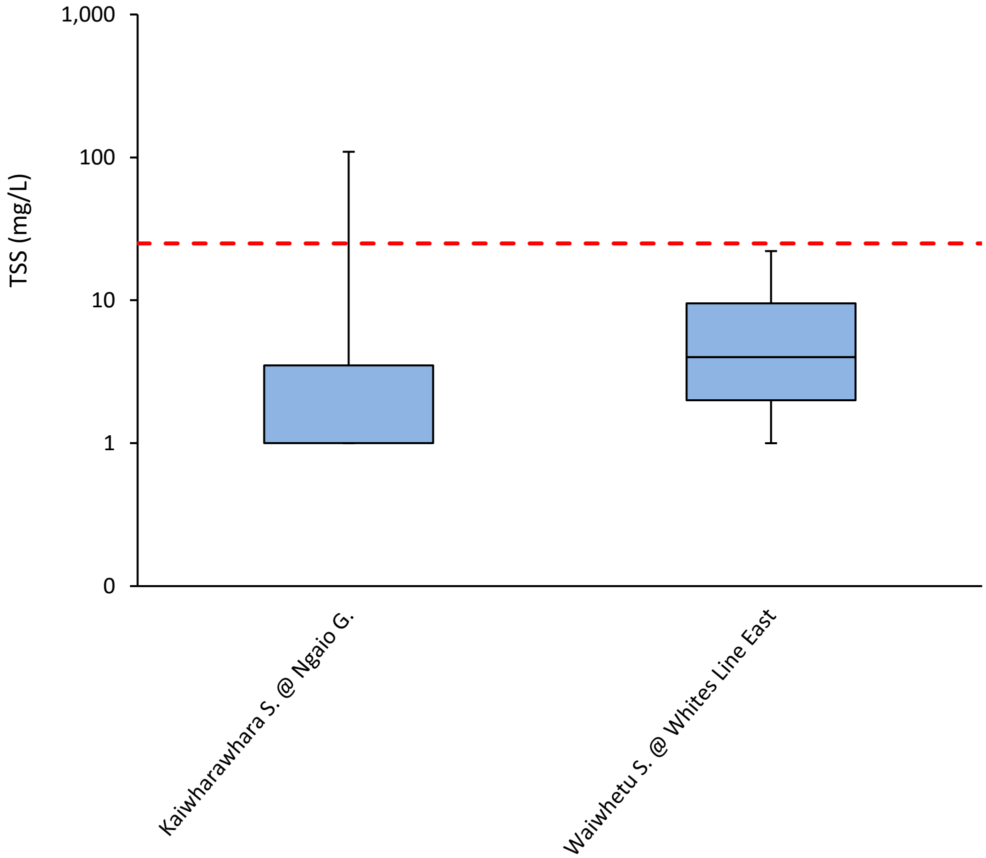

Figure 25: Distribution of TSS concentrations recorded in rivers in the Wellington Harbour stream catchments sub-zone. The red line represents the commonly cited threshold of 25 mg/L for the onset of detrimental effects on fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001).

E. coli

An assessment of *E. coli* concentrations measured at each GWRC, WCC and HCC monitoring sites against the different attribute states of the NPS-FM 2014 is provided in Table 42. Statistics have been calculated once for each site using data from the period between 01/07/2012 and 30/06/2017 inclusive.

E. coli concentrations at all GWRC, WCC and HCC monitoring sites in the Wellington Harbour stream catchments sub-zone were considered unsuitable for primary contact recreation and were in the D or E attribute states under the NPS-FM 2014 (Table 42).

Table 42: *E. coli* data recorded in rivers in the Wellington Harbour stream catchments sub-zone from 2012 to 2016 graded against the NPS-FM 2014 attribute state thresholds. Shaded cells represent the following attribute states; blue = A, green = B, yellow = C, Orange = D and red = E.

Data source	Site	% above 540 cfu/100ml	% above 260 cfu/100ml	Median (cfu/100ml)	95th %ile (cfu/100ml)	NPS-FM attribute state	Suitable for prim. contact rec.
GWRC RWQE	Kaiwharawhara S. @ Ngaio G.	50	72	530	5150	E	×
	Waiwhetu S. @ Whites Line East	42	77	495	5800	E	×
WCC & HCC *E. coli*	Kaiwharawhara S. near harbour	38	65	390	5250	E	×
	Ngauranga S. near harbour	69	95	1050	11000	E	×
	Otari Park S.	23	41	160	5965	D	×
	Tyers St. @Gorge	42	67	460	6875	E	×
	Awamutu S. @ Hutt Park	56	85	615	7980	E	×
	Waiwhetu S. @ Rishworth St.	68	79	704	1696	E	×
	Waiwhetu S. @ Tilbury St.	79	98	1450	10620	E	×

3.3.3. Trends in water quality and ecology

No environmentally meaningful trends in water quality were observed in the Kaiwharawhara Stream at Ngaio Gorge (Table 43). However, meaningful improving trends in DIN and NO_3-N were observed in the Waiwhetu Stream at Whites Line East (Table 43).

Table 43: Temporal trends (10yr) in various physico-chemical and ecological parameters in streams in the Wellington Harbour stream catchments sub-zone. Adapted from Snelder (2017).

Parameter	Kaiwharawhara S. @ Ngaio G.		Waiwhetu S. @ Whites Line East	
	Trend direction	Ann. Δ	Trend direction	Ann. Δ
MCI	Uncertain		Uncertain	
Mat algal cover	Uncertain		N/A	
Fil. algal cover	Uncertain		N/A	
Peri. biomass	Uncertain		N/A	
DIN	Uncertain		Decreasing	9%
DRP	Uncertain		Uncertain	
E. coli	Uncertain		Uncertain	
NO_3-N	Uncertain		Decreasing	8%
NH_4-N	Uncertain		Uncertain	
TSS	Uncertain		Uncertain	

	Uncertain
(light blue)	Improving. Not environmentally meaningful
(blue)	Improving. Environmentally meaningful
(light orange)	Degrading. Not environmentally meaningful
(orange)	Degrading. Environmentally meaningful

3.3.4. NPS-FM 2014 attribute state grading

<u>Periphyton biomass</u>

Periphyton biomass data collected up until June 2017 indicates that the Kaiwharawhara Stream at Ngaio Gorge Road is likely to be assigned to attribute state C under the in the NPS-FM 2014 (Table 44). This suggests the site has periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat.

Ammonia toxicity

When corrected for temperature and pH, unionised ammonia (NH_3-N) concentrations at monitoring sites in the Kaiwharawhara and Waiwhetu Streams were assigned to attribute state A for ammonia toxicity under the NPS-FM 2014 (based on the overall average of annual median and maximum concentration) (Table 44). NH_3-N concentrations fell within the A attribute state in all years between 2012 and 2016 in the Waiwhetu Stream at Whites Line East, and only slipped into attribute state B in one year at the Kaiwharawhara Stream at Ngaio Gorge site. This suggests that, for most of the time, there were no ammonia toxicity effects on any species at sites in these streams.

Nitrate toxicity

NO_3-N concentrations in the Waiwhetu Stream at Whites Line East were assigned to attribute state A for nitrate toxicity under the NPS-FM 2014 in all years (Table 44).

NO_3-N concentrations in the Kaiwharawhara Stream were assigned to attribute state B for nitrate toxicity (based on the overall average of annual median and 95th percentile concentrations) (Table 44), and concentrations were within this attribute state in all years.

E. coli

E. coli concentrations in the Kaiwharawhara Stream at Ngaio Gorge and the Waiwhetu Stream at Whites Line East were assigned to attribute state E (Table 44), meaning both sites are considered unsuitable for contact recreation under the NPS-FM 2014. Attribute state E is the lowest possible grade under the NPS-FM 2014 and indicates that for more than 30% of the time the estimated risk is of *campylobacter* infection is >50 in 1000 (>5% risk) and that the predicted average infection risk of infection is >7%.

Table 44: Water quality and ecology results from GWRC RWQE monitoring sites in the Wellington Harbour stream catchments sub-zone collected since 2012 compared to numeric attributes as specified in the NPS-FM 2014.

Parameter	Site	Lowest attribute state	Overall average attribute state
Periphyton biomass	Kaiwharawhara S. @ Ngaio G.		C*
NO_3-N	Kaiwharawhara S. @ Ngaio G.	B	B
	Waiwhetu S. @ Whites Line East	A	A
NH_3-N	Kaiwharawhara S. @ Ngaio G.	B	A
	Waiwhetu S. @ Whites Line East	A	A
E. coli	Kaiwharawhara S. @ Ngaio G.	E	E
	Waiwhetu S. @ Whites Line East	E	E

*Predicted attribute state based on current patterns in biomass

3.3.5. Nutrient loads

Between 2012 and 2016 the annual DIN load from the Kaiwharawhara Stream to the Wellington Harbour ranged from 6.5 to 9.3 tonnes (μ = 7.33 t/yr), the annual TN load ranged from 7.7 to 11.4 tonnes (μ = 9.44 t/yr), the annual DRP load ranged from 0.20 to 0.29 tonnes (μ = 0.25 t/yr) and the annual TP ranged from 0.31 and 0.80 tonnes (μ = 0.44 t/yr) (Table 45).

The Waiwhetu Stream contributed significantly less nitrogen to the Wellington Harbour than the Kaiwharawhara but discharged a similar quantity of phosphorus. The annual DIN load from the Waiwhetu stream to the Wellington Harbour ranged from 2.4 to 7.0 tonnes (μ = 4.77 t/yr), the annual TN load ranged from 4.2 to 8.9 tonnes (μ = 7.03 t/yr), the annual DRP load ranged from 0.11 to 0.33 tonnes (μ = 0.21 t/yr) and the annual TP ranged from 0.32 and 0.92 tonnes (μ = 0.49 t/yr) (Table 45).

Table 45: Annual nutrient loads at monitoring sites in the Wellington Harbour stream catchments sub-zone. Loads were calculated using the averaging method and the Beale's ratio estimator method. The results presented here are averages of the results of these two methods.

Site	Year	DIN	TN	DRP	TP
		t/yr			
Kaiwharawhara St. @ Ngaio G.	2012	7.12	8.97	0.20	0.42
	2013	6.96	8.89	0.22	0.34
	2014	6.74	10.31	0.28	0.80
	2015	6.51	7.67	0.24	0.31
	2016	9.31	11.36	0.29	0.35
	Average	**7.33**	**9.44**	**0.25**	**0.44**
Waiwhetu St. @ Whites Line East	2012	4.98	8.39	0.33	0.92
	2013	7.02	8.94	0.21	0.32
	2014	3.84	5.67	0.16	0.36
	2015	2.43	4.19	0.11	0.40
	2016	5.58	7.96	0.24	0.44
	Average	**4.77**	**7.03**	**0.21**	**0.49**

3.3.6. Human drivers of degradation

The main driver of ecological degradation in the Wellington Harbour stream catchments sub-zone is most likely urban land-use. Approximately 38% of the Kaiwharawhara Stream catchment, and 53% of the Waiwhetu Stream catchment is in urban land-use, and the water quality and ecology of both streams are typical of those impacted by this sort of development.

Streams that run through urban areas are subjected to a number of stressors, and typically exhibit degraded animal communities, a state referred to as "urban stream syndrome". A common, and detrimental symptom of the urban stream syndrome is a highly modified flow regime. Urbanisation increases the area of impervious surfaces in a catchment. Consequently, the main precipitation transport mechanism in urban landscapes is surface run-off; the potential for groundwater recharge or subsurface drainage tends to be very low due to the impermeable barrier between soil and atmosphere (Walsh *et al.*, 2005a). To prevent flooding during rain events, towns and cities have storm water networks that transport surface run-off from impervious surfaces directly, and efficiently, to rivers and streams. The effect on those streams is an increase in flashiness (i.e. higher frequency and intensity of flood events), as rain water that would naturally be stored in soils, or groundwater, and slowly released into surface water networks is, instead, discharged almost instantly (Walsh *et al.*, 2005b). High flow events are an important source of disturbance in stream ecosystems, the frequency and intensity of which, exerts substantial influence over stream community composition (Resh *et al.*, 1988). When urbanisation results in low base flows punctuated by frequent and severe floods, species diversity tends to decrease, and communities become dominated by species that are resilient/ resistant to disturbance (Resh *et al.*, 1988). Both the Kaiwharawhara and Waiwhetu Streams suffer from highly modified flow regimes (Ward, 1997; Watts, 2004), which is most likely impacting their ecology.

The effects of urbanisation on stream ecosystems are not limited to water quantity, but also quality. Surface run-off from roads, industrial sites and roofs 'picks up' sediment and metals, such as copper and zinc, which are then transported into stream networks via storm water infrastructure (Forman and Alexander, 1998). Excessive sedimentation has a range of negative effects in streams (Section 1.4.2) and, at high concentrations, the metals commonly found in stormwater runoff are toxic to aquatic fauna (Section 1.4.4). The input of these contaminants from storm water can reduce the abundance of stream fauna and alter community structure. Urban development (including industrial land-use in the Kaiwharawhara and Waiwhetu catchments) has led to sedimentation and high metal concentrations in both streams (Section 3.3.1 and Section 3.3.2), which is most likely contributing to degraded ecological health.

Urbanisation also denudes streams of their natural form. The loss of riparian habitat vegetation is a common effect of urbanisation, as areas close to the waterway are often cleared for development. Riparian vegetation plays several important roles in ecosystem function and its removal during urbanisation has a substantial, detrimental impact on aquatic ecosystems. The engineering, channelization and even piping of streams to increase drainage performance and developable areas is also common in urban environments. Channelisation reduces instream habitat complexity by creating straight waterways that lack velocity heterogeneity and defined pool-riffle sequences, have low cover, and have uniform bed substrates dominated by fine sediments (Wheeler *et al.*, 2005). The result is homogenous environments that can support fewer species than natural streams. Most of the Waiwhetu Stream's riparian zone has been de-vegetated, and sections of both the Kaiwharawhara and Waiwhetu Streams have been extensively modified (part of the Waiwhetu is now a concrete channel, and sections of the Kaiwharawhara have been piped), which has likely had a negative effect on ecosystem health in impacted reaches.

Another key driver of degradation in the Waiwhetu Stream is historic discharges from industrial sites. Industrial land-use makes up 20% of the Waiwhetu Stream catchment. The most significant industrial areas are downstream of the GWRC monitoring site, and their effects are not detectable in the data presented in this report, However, historic untreated discharges from the Gracefield-Seaview industrial area in the lower Waiwhetu Stream catchment, led to significant heavy metal contamination of the bed sediments of the tidal reaches of the stream, leading to a major remediation project in 2010.

In terms of the high level of faecal contamination in the Wellington Harbour stream catchments sub-zone, the main source is human wastewater. Wastewater is occasionally discharged to both the Kaiwharawhara and Waiwhetu Stream intentionally through constructed over flows, and occasionally via unconstructed overflows. Cross connections between the stormwater and wastewater network may also be contributing to high faecal contamination. Faecal source tracking conducted by GWRC in 2014 found high levels of human contamination in both streams.

Most streams monitored by WCC and HCC for *E. coli* also suffer from high levels of faecal contamination, and the source of this is most likely human.

3.3.7. Knowledge gaps

Although there are some obvious knowledge gaps in the Wellington Harbour stream catchments sub-zone, it is our understanding that work is already being undertaken to fill most of them.

The ecological state of much of the open water bodies in the sub-zone is unknown. However, WCC and GWRC are currently in the first stage of an urban stream biodiversity monitoring programme, which involves sampling macroinvertebrates and fish throughout Wellington City. The long-term goal of this programme is to set up a permanent monitoring programme at key sites. Both the Ngauranga and Kaiwharawhara Stream catchments have been surveyed as part of this programme, but macroinvertebrate samples were not processed at the time of writing this report.

The ecological state of the piped stream network that runs under Wellington City is also largely unknown. These streams make up a significant proportion of the stream network in the zone (the total length of the piped sections of the Kumutoto, Pipitea, Tiakiwai, Tutaenui, Waipiro, and Waitangi Streams is around five km), and understanding the ecology of these systems is vital. GWRC and WCC recognise this, and have recently commissioned EOS ecology to investigate how these systems can be sampled as part of the Urban Streams Biodiversity Monitoring Programme.

Regular comprehensive water quality data is also sparse in the sub-zone, and little is known about state of the Korokoro or Ngauranga Streams, apart from *E. coli* levels. However, it is likely that most these knowledge gaps will be filled in the next five years as part of the monitoring for Wellington Water Limited's (WWL) global stormwater consent. This monitoring is also likely to provide a better understanding of key sources of stormwater and wastewater contaminants in streams in the Wellington Harbour stream catchments sub-zone.

3.3.8. Summary

Macroinvertebrate communities are in a severely degraded state in the Kaiwharawhara and Waiwhetu streams, and both fail to meet the pNRP outcome for MCI. A number of factors are likely responsible for this degradation, most of which are driven by the significant urban land-use in these catchments. Periphyton growth in the Kaiwharawhara Stream and macrophyte growth in the Waiwhetu Stream are not limited by nutrient availability, and pNRP outcomes for periphyton biomass and cover (Kaiwharawhara Stream), and macrophyte cover (Waiwhetu Stream) are regularly breached. Accordingly, nuisance plant growth is likely contributing to degraded stream health in Kaiwharawhara and Waiwhetu Streams. High levels of deposited fine sediment, and elevated concentrations of dissolved metals from stormwater inputs are also likely to be significant contributors of degraded ecosystem health in both systems. While the impacts of hydrology on stream health cannot be quantified from the data assessed in this report, it is likely that impervious surface cover, and the resulting changes in flow regime are also contributing to degraded macroinvertebrate communities.

In terms of recreational value, the rivers and streams in the Wellington Harbour stream catchments sub-zone are in a very poor state. While benthic cyanobacteria do not generally pose a health risk to recreational users, faecal contamination, mostly from human sources, is high throughout the sub-zone, and none of the streams monitored by GWRC, WCC or HCC are considered suitable for primary contact recreation.

Improving trends in nitrogen species were observed in the Waiwhetu Stream, but otherwise trends in water quality and ecology in the Kaiwharawhara and Waiwhetu streams were not detected.

3.4. Southern and western coastal stream catchments sub-zone

3.4.1. Ecology and habitat

Macroinvertebrates

Long-term macroinvertebrate monitoring data exists for two sites in the southern and western coastal stream catchments sub-zone; the Karori Stream at Makara Peak Mountain Bike Park (henceforth referred to as Karori Stream at Makara Peak) and the Makara Stream at the Kennels.

The MCI outcomes in the pNRP were not met at the monitoring site in the Karori Stream in any of the years that monitoring was conducted between 2012 and 2016 (Table 46). Rolling three-year median and annual MCI scores were indicative of fair (MCI between 90 and 105) ecological condition in three years, and poor ecological condition (MCI less than 90) in two (based on Wellington specific MCI thresholds set out in Clapcott and Goodwin (2014)). In contrast the pNRP, MCI outcomes were consistently met at the Makara Stream site, and rolling three-year median and annual MCI scores were indicative of good ecological condition in all years that monitoring was conducted.

Table 46: Rolling 3-year median MCI scores (and annual MCI scores) recorded in rivers in the southern and western coastal stream catchments sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not.

Site	pNRP outcome	2012	2013	2014	2015	2016
Karori S. @ Makara Peak	105	95 (101)	95 (92)	92 (85)	85 (85)	85 (93)
Makara S. @ Kennels	105	120 (123)	120 (107)	114 (114)	-	-

Fish

Seven native fish species found in the southern and western coastal stream catchments sub-zone between 2000 and 2017: longfin eel, shortfin eel, redfin bully, upland bully, koaro, inanga and banded kokopu. All of these species, except shortfin eel, banded kokopu and upland bully are classified as either at risk or threatened (Goodman *et al.*, 2014). Predominately marine species also make forays into the streams in the southern and western coastal stream catchments sub-zone, and black flounder and common smelt were recorded between 2000 and 2017.

Brown trout was the only introduced sports fish found in the southern and western coastal stream catchments sub-zone between 2000 and 2017.

Inanga spawning has not been confirmed in any of the streams in the southern and western coastal stream catchments sub-zone (Marshall and Taylor, 2017; Taylor and Kelly, 2001; Taylor and Marshall, 2016).

Periphyton

Periphyton growth is unlikely to be a major contributor of the moderate degradation in macroinvertebrate community health in the Karori Stream at Makara Peak. PeriWCC at this site only exceeded the pNRP outcome in 2013, when maximum cover was indicative of fair ecological condition (Table 47); in all other years, periphyton cover was indicative of either good (2012 and 2016) or excellent (2014 and 2015) ecological condition.

Periphyton growth is likely to be only sporadically impacting macroinvertebrate community health in the Makara Stream at the Kennels. While the pNRP outcome for periWCC was exceeded in 2013 and 2015, when maximum cover was indicative of fair ecological condition (Table 47), in all other years, annual maximum periWCC was indicative of excellent ecological condition. Periphyton growth not posing a threat to ecosystem health in the Makara Stream is supported by the good health of the resident macroinvertebrate community.

Table 47: Annual maximum periWCC scores recorded in rivers in the southern and western coastal stream catchments from 2012 to 2016. Values highlighted in green meet the pNRP outcomes, values highlighted in red do not.

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Karori S. @ Makara Peak	40	35	53	10	13	21
Makara S. @ Kennels	40	18	48	1	42	5

Macrophytes

Macrophyte cover was generally low in the Makara Stream at the Kennels between 2012 and 2016, and excessive plant growth is unlikely to be significantly impacting resident macroinvertebrate communities. Annual maximum cover in all years was under 30% (Table 48), well below the guideline for the protection of instream aesthetic and recreational values (50% cover (Matheson *et al.*, 2012)). It is, therefore, likely that this site is meeting the pNRP macrophyte outcome.

Table 48: Annual maximum total macrophyte cover recorded in rivers in the southern and western coastal stream catchments sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes.

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Makara S. @ Kennels	50	18	9.4	27	14	

Cyanobacteria

Cyanobacteria does not appear to pose a health risk in the southern and western coastal stream catchments sub-zone. Annual maximum cyanobacteria cover in the Karori Stream at Makara Peak and the Makara Stream at the Kennels was extremely low (at or approaching 0%) in all years between 2012 and 2016, and both sites consistently met the pNRP outcome for cyanobacteria (Table 49). To the best of our knowledge cyanobacteria is also unlikely to pose a health risk in other streams in the sub-zone, and GWRC has not received any reports of blooms from members of the public (Mark Heath pers. comm.).

Table 49: Annual maximum benthic cyanobacteria cover recorded in rivers in the southern and western coastal stream catchments sub-zone from 2012 to 2016. Values highlighted in green meet the pNRP outcomes (based on the suggested guidance in Greenfield *et al.* (2015b)).

Site	pNRP outcome (%cover)	2012	2013	2014	2015	2016
Karori S. @ Makara Peak	20	0	0	0	2	0
Makara S. @ Kennels	20	0	0	1	0	0

Fine sediment cover

Fine sediment cover is likely to be a key driver of the moderate degradation in macroinvertebrate community health in the Karori Stream. Annual maximum fine sediment cover at Makara Peak exceeded the guideline value for the protection of biodiversity (<20% cover (Clapcott *et al.*, 2011)) in all years that monitoring was conducted (Table 50). Furthermore, sediment cover was persistently elevated at the site; exceeding the 20% cover guideline more than 50% of the time (Figure 26).

Fine sediment cover was also very high in the Makara Stream between 2012 and 2016. Annual maximum fine sediment cover at the Kennels site was equal to or greater than 90% in all years (Table 50), and sediment cover was above the 20% cover guideline value on all sampling occasions (Figure 26). Fine sediment cover well above the guideline level at the site is contradictory to the observed good health of the resident macroinvertebrate community, and further investigation is required to determine why a macroinvertebrate response was not observed.

Table 50: Annual maximum fine sediment cover recorded in rivers in the southern and western coastal stream catchments sub-zone from 2012 to 2016. Values highlighted in red fail to meet the guideline set out in Clapcott *et al.* (2011) for the protection of benthic biodiversity.

Site	Clapcott *et al.* (2011) guideline (%cover)	2012	2013	2014	2015	2016
Karori S. @ Makara Peak	20	-	30	60	70	-
Makara S. @ Kennels	20	-	90	90	95	-

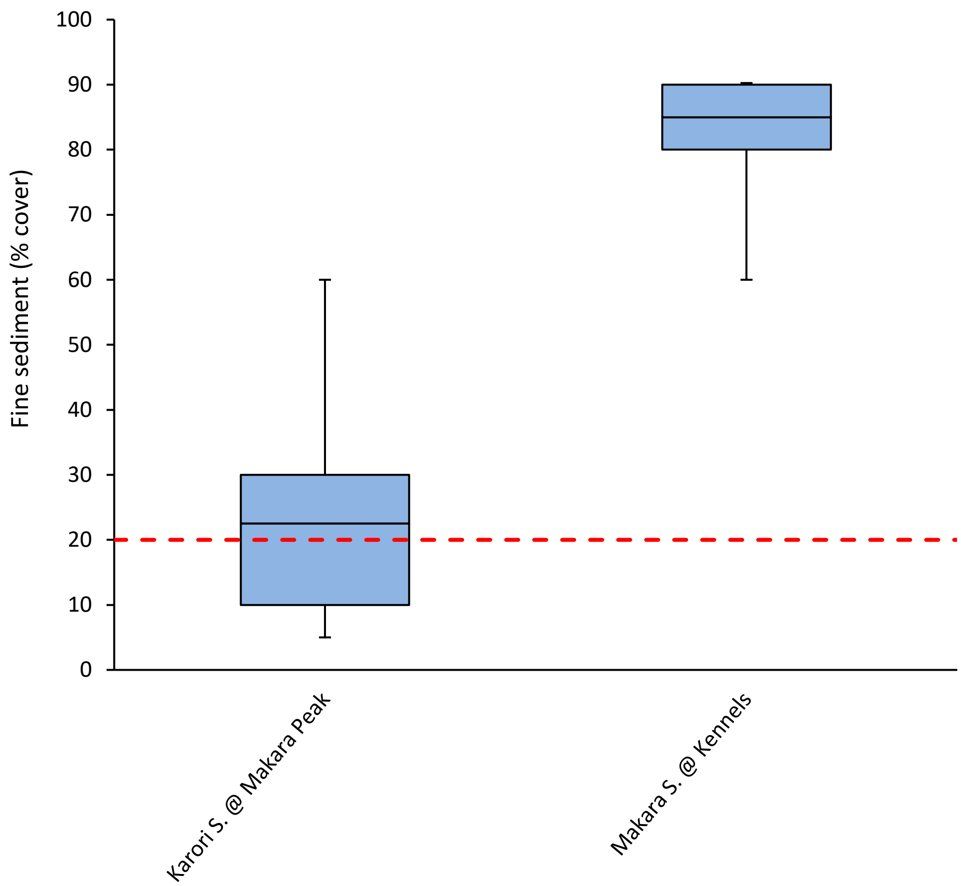

Figure 26: Distribution of fine sediment cover data recorded in rivers in the southern and western coastal stream catchments sub-zone. The red line indicates the Clapcott *et al.* (2011) guideline for the protection of biodiversity.

Water temperature and dissolved oxygen

Based on the guidelines presented in Davies-Colley *et al.* (2013), annual maximum temperatures recorded in the Karori Stream at Makara Peak were graded as good (18°C- 20°C) in 2015 and excellent (<18°C) in all other years (Table 51).

Annual maximum temperatures in the Makara Stream at the Kennels were graded as excellent in 2013 and 2016, good in 2012 and 2014, and fair (20°C- 24°C)) in 2015 (Table 51). That the maximum temperature recorded in 2015 was above 20°C indicates that there may be some thermal stress on occasion, with elimination of certain sensitive insects and absence of certain sensitive fish at this site. However, continuous monitoring would be needed to confirm this.

Table 51: Annual maximum temperature recorded in rivers in the southern and western coastal stream catchments sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the guidelines set out in Davies-Colley *et al.* (2013) for rivers with a maritime climate).

Site	Davies-Colley *et al.* (2013) guidelines (°C)	2012	2013	2014	2015	2016
Karori S. @ Makara Peak	≤18 (Exc.) ≤20 (Good)	17.7	15.8	16.8	18.5	15.9
Makara S. @ Kennels	≤24 (Fair) >24 (Poor)	18.9	17.4	18.9	20.9	17.9

Based on the guidelines presented in Davies-Colley *et al.* (2013), annual 1-day minimum DO concentrations in the Karori Stream at Makara Peak and the Makara Stream at the Kennels were consistently graded as excellent (>7.5 mg/L) (Table 52). Although DO concentrations did not breach any of the thresholds presented in Davies-Colley *et al.* (2013), it does not necessarily mean that the thresholds were not breached at any point during this period.

Table 52: Annual minimum DO concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone from 2012 to 2016. Excellent values are shaded green, good values are shaded yellow, fair values are highlighted in orange, and poor values are shaded in red (based on the 1-day minimum concentration guidelines set out in Davies-Colley *et al.* (2013)).

Site	Davies-Colley *et al.* (2013) guidelines (mg/L)	2012	2013	2014	2015	2016
Karori S. @ Makara Peak	≥7.5 (Exc.) ≥5.0 (Good)	9.57	10	9.37	9.21	9.67
Makara S. @ Kennels	≥4.0 (Fair) <4.0 (Poor)	8.94	9.13	8.52	7.62	9.32

3.4.2. Current state of water quality

Nutrients as a driver of plant growth

Median DIN and DRP concentrations in the Karori Stream at Makara Peak, and the Makara Stream at the Kennels exceeded the Biggs *et al.* (2000) guidelines for the protection of biodiversity trout habitat and angling values from nuisance periphyton growths (Figure 27 and Figure 28). As nuisance periphyton growths have not been regularly observed at either site, despite sufficient nutrient concentrations it is likely that some other factor is limiting growth, potentially shade, or bed substrate.

Water quality data suggests that plant available nutrient concentrations are also sufficiently high in the Makara Stream to cause nuisance macrophyte growths. Both DIN and DRP concentrations recorded at the Kennels monitoring site were in the "adequate" range for macrophyte growth, with median values exceeding the level indicative of a 70% probability of nuisance growth (0.1 mg/L and 0.01 mg/L for DIN and DRP respectively (Matheson *et al.*, 2012)) (Figure 27 and Figure 28). Nutrient availability is just one of a number of factors that influence macrophyte growth, and elevated DIN and DRP concentrations will not always result in nuisance macrophyte growths. As nuisance macrophyte growths have not been regularly observed in the Makara Stream since 2012, it is likely that factors such as light availability, flow conditions and rooting substrate are limiting macrophyte growth, despite current DIN and DRP concentrations being sufficiently high to facilitate nuisance macrophyte growth

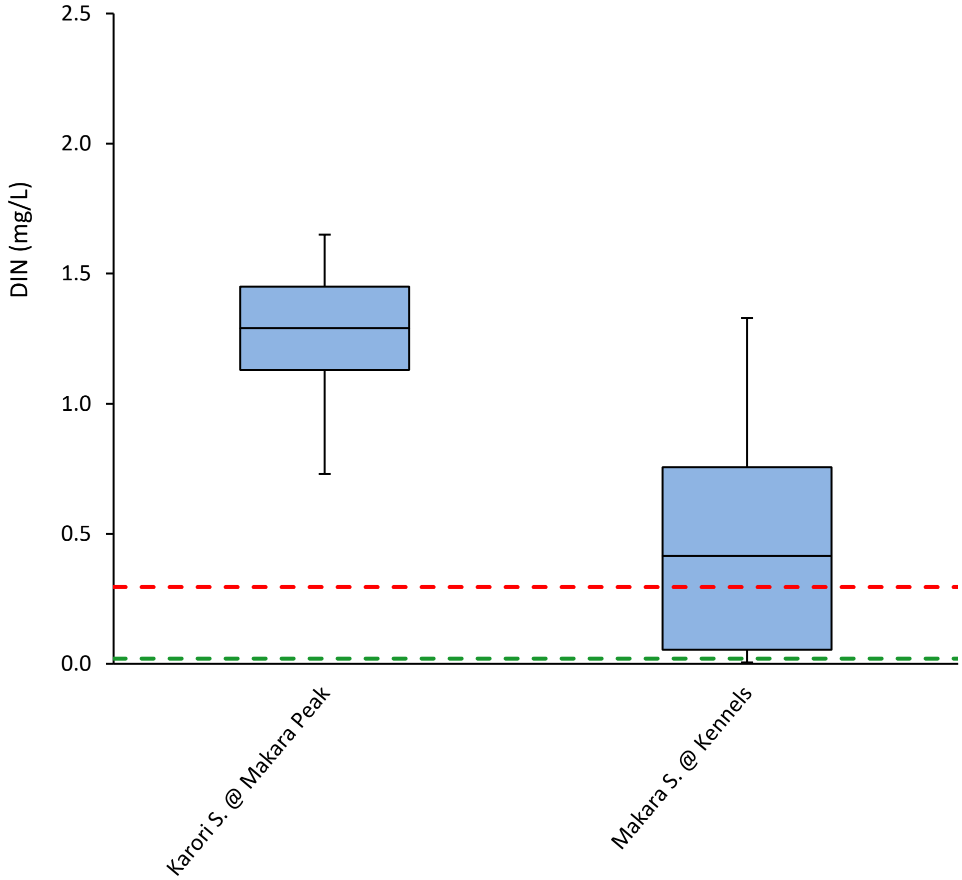

Figure 27: Distribution of DIN concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone. The red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively.

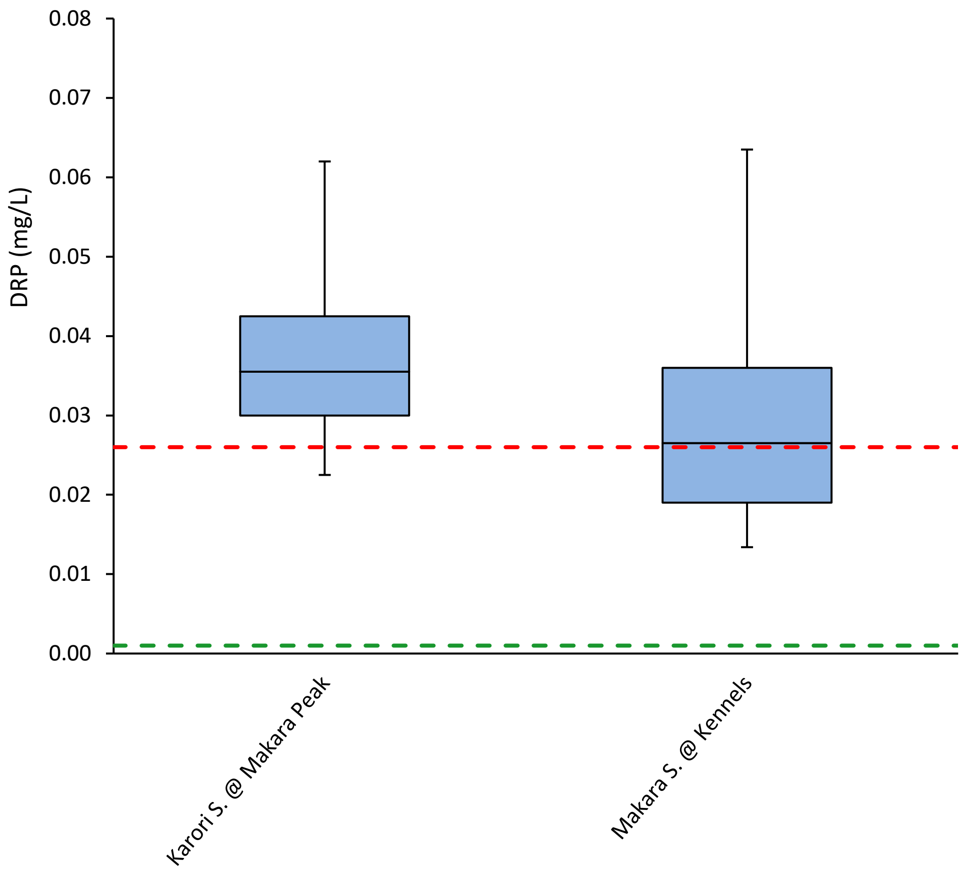

Figure 28: Distribution of DRP concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone. The red and green lines indicate the recommended thresholds (as annual averages) for the protection of trout habitat and angling values and benthic biodiversity respectively.

Nutrients as toxicants

Nitrate toxicity is unlikely to be having a significant impact on ecosystem health in the Karori and Makara Streams. Median and 95th percentile (thresholds not plotted on Figure 29) NO_3-N concentrations at Makara Stream at the Kennels monitoring site were below the thresholds for the protection of 99% of species from nitrate toxicity (Hickey, 2013) (Figure 29). These data suggest that nitrate levels in the Makara Stream are sufficiently low to protect even pristine environments with high biodiversity and conservation values from toxicity effects (Hickey, 2013). While the overall median and 95th percentile NO_3-N concentrations in the Karori Stream at Makara Peak Mountain Bike Park were above the thresholds for the protection of 99% of species from nitrate toxicity (Hickey, 2013) (Figure 29), they were below the 95% protection threshold (Hickey, 2014) (Figure 29).

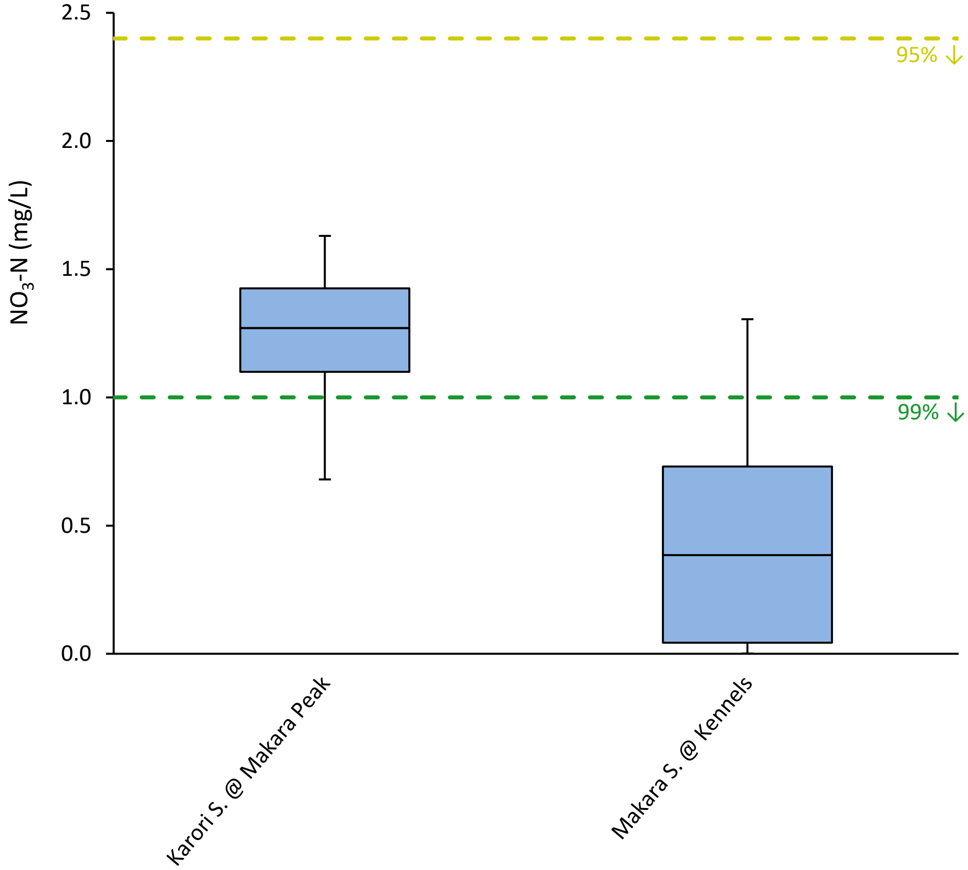

Figure 29: Distribution of NO_3-N concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone. The coloured lines represent species protection guidelines (Hickey, 2013).

Ammonia toxicity is also unlikely to be impacting aquatic ecosystem health in the Karori Stream at Makara Peak and the Makara Stream at the Kennels. Overall median and maximum (thresholds not plotted on Figure 30) NH_3-N concentrations at both monitoring sites were below the threshold for the protection of 99% of species from ammonia toxicity (Hickey, 2014) (Figure 30).

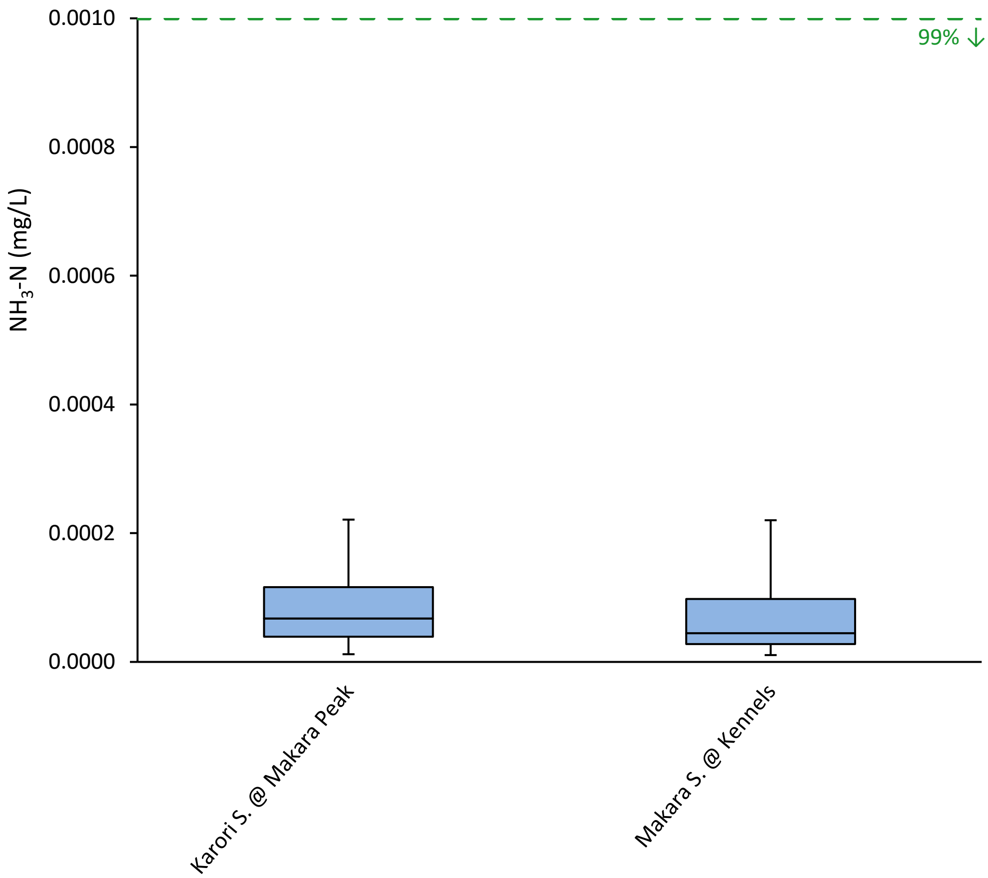

Figure 30: Distribution of NH_3-N concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone. The green line represents the 99% species protection guideline (Hickey, 2014).

Metals as toxicants

While nutrients may not pose a toxicity risk in the Karori Stream, chronic toxicity effects from elevated median concentrations of dissolved metals may be contributing to the degraded ecological state of the Makara Peak site. Between 2012 and 2016 the median dissolved copper concentration in the Karori Stream exceeded the guideline for the protection of 95% of species from toxicity effects, and the median zinc concentration exceeded the guideline for the protection of 80% of species (Figure 31 and Figure 32). These data suggest that in terms of dissolved metal concentration the Karori Stream is a highly disturbed system.

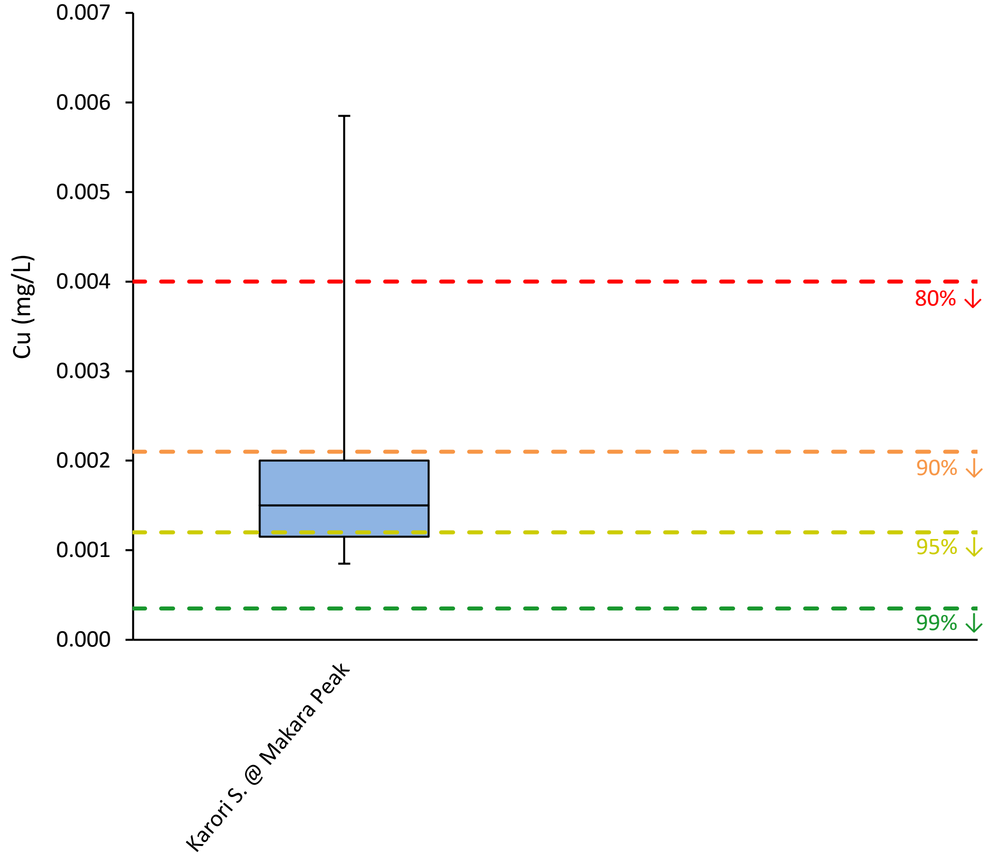

Figure 31: Distribution of Cu concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone. The coloured lines represent species protection thresholds (Australian and New Zealand guidelines for fresh and marine water quality).

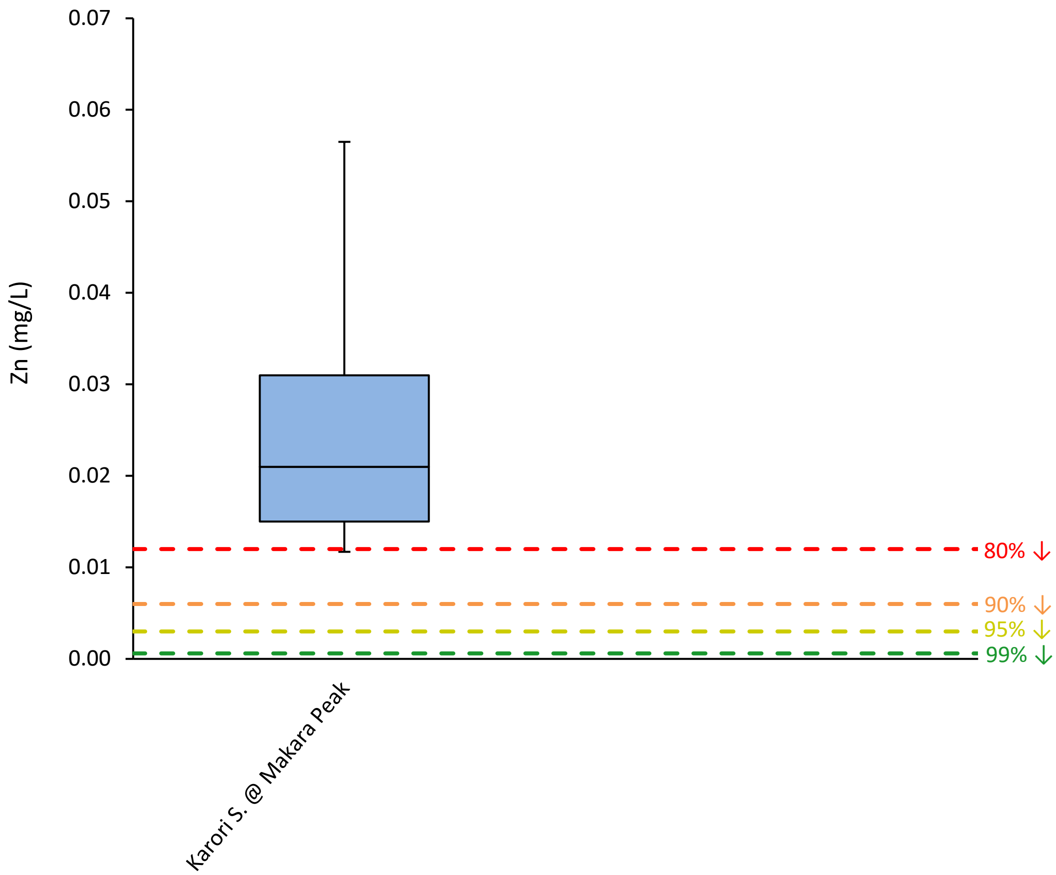

Figure 32: Distribution of Zn concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone. The coloured lines represent species protection thresholds (Australian and New Zealand guidelines for fresh and marine water quality).

TSS

It does not appear that TSS is affecting aquatic ecosystem health at the monitoring sites in the Karori and Makara Streams. TSS concentrations at monitoring sites in both streams were generally well below the commonly cited threshold of 25 mg/L for the onset of detrimental effects for fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001) (Figure 33).

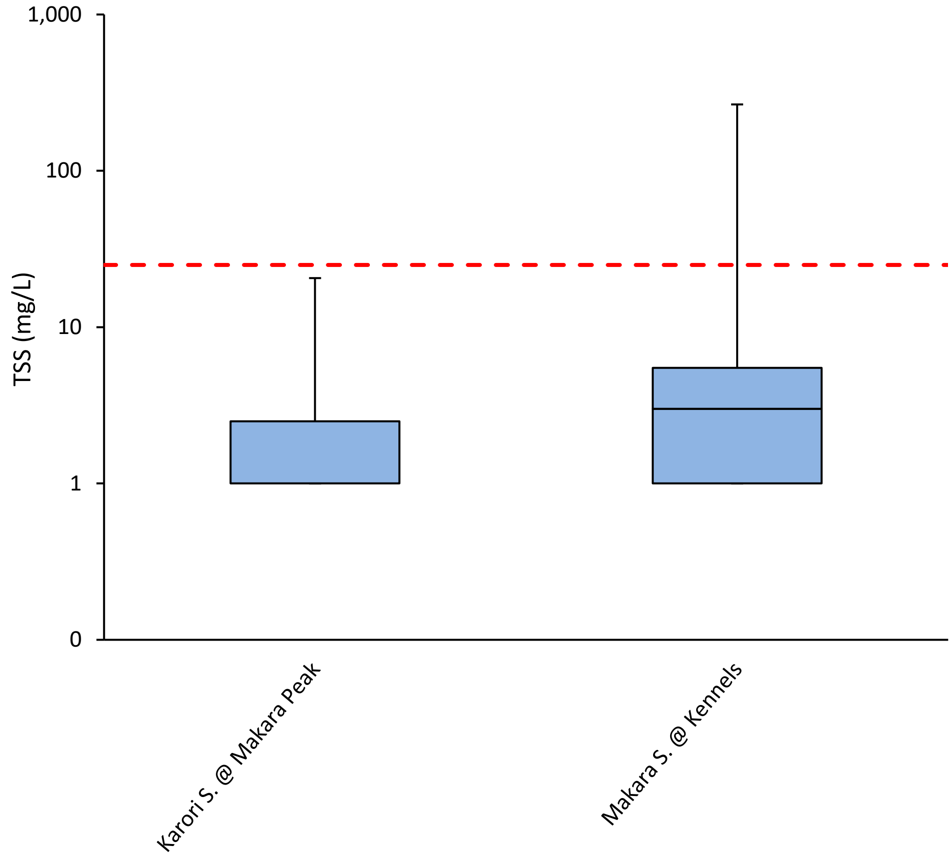

Figure 33: Distribution of TSS concentrations recorded in rivers in the southern and western coastal stream catchments sub-zone. The red line represents the commonly cited threshold of 25 mg/L for the onset of detrimental effects on fish (APEM, 2007; Rowe *et al.*, 2003; Singleton, 2001).

E. coli

An assessment of *E. coli* concentrations measured at each GWRC, WCC monitoring sites against the different attribute states of the NPS-FM 2014 is provided in Table 53. Statistics have been calculated once for each site using data from the period between 01/07/2012 and 30/06/2017 inclusive.

E. coli concentrations at all GWRC and WCC monitoring sites in the southern and western coastal stream catchments sub-zone were considered unsuitable for primary contact recreation and were in the D or E attribute states under the NPS-FM (Table 53).

Table 53: *E. coli* data recorded in rivers in in the southern and western coastal stream catchments sub-zone from 2012 to 2016 graded against the NPS-FM 2014 attribute state thresholds. Shaded cells represent the following attribute states; blue = A, green = B, yellow = C, Orange = D and red = E.

Data source	Site	% above 540 cfu/100ml	% above 260 cfu/100ml	Median (cfu/100ml)	95th %ile (cfu/100ml)	NPS-FM attribute state	Suitable for prim. contact rec.
GWRC RWQE	Karori S. @ Makara Peak	83	97	1450	6450	E	No
	Makara S. @ Kennels	30	62	365	6500	E	No
WCC *E. coli*	South Karori Road	48	77	520	4980	E	No
	Karori S. @ WTP- 100m u/s.	31	47	245	4750	E	No
	Karori S. @ WTP- 100m d/s.	30	45	230	6100	D	No
	Owhiro S. @ Kingston	23	35	120	3850	D	No
	Lower Careys Gully S.	15	23	135	2590	D	No
	Owhiro S. @ Happy Valley Tip Br.	23	46	230	7825	D	No
	Owhiro S. d/s Happy Valley Tip	22	50	260	4925	D	No
	Owhiro Bay S. Outlet	67	89	860	8315	E	No

3.4.3. Trends in water quality and ecology

No environmentally meaningful trends in water quality were observed in the Karori or Makara streams (Table 54).

Table 54: Temporal trends (10yr) in various physico-chemical and ecological parameters in streams in the southern and western coastal stream catchments sub-zone. Adapted from Snelder (2017).

	Karori S. @ Makara Peak		Makara S. @ Kennels	
Parameter	**Trend direction**	**Ann. Δ**	**Trend direction**	**Ann. Δ**
MCI	Uncertain		Uncertain	
Mat algal cover	Uncertain		N/A	
Fil. algal cover	Uncertain		Uncertain	
Peri. biomass	Uncertain		Uncertain	
DIN	Uncertain		Uncertain	
DRP	Uncertain		Uncertain	
E. coli	Uncertain		Uncertain	
NO_3-N	Uncertain		Uncertain	
NH_4-N	Uncertain		Uncertain	
TSS	Uncertain		Uncertain	

Uncertain
Improving. Not environmentally meaningful
Improving. Environmentally meaningful
Degrading. Not environmentally meaningful
Degrading. Environmentally meaningful

3.4.4. NPS-FM 2014 attribute state grading

Ammonia toxicity

When corrected for temperature and pH, unionised ammonia (NH_3-N) concentrations at monitoring sites in the Karori and Makara Streams were assigned to attribute state A for ammonia toxicity under the NPS-FM 2014 (based on the overall average of annual median and maximum concentration) (Table 55). NH_3-N concentrations in both streams fell within the A attribute state in all years between 2012 and 2016.

Nitrate toxicity

NO_3-N concentrations in the Karori Stream at Makara Peak were assigned to attribute state B for nitrate toxicity (based on the overall average of annual median and 95th percentile concentrations) (Table 55), and concentrations were within this attribute state in all years.

NO_3-N concentrations in the Makara Stream at the Kennels were assigned to attribute state A for nitrate toxicity under the NPS-FM 2014 (based on the overall average of annual median and 95th percentile concentrations) and concentrations were within this attribute state in all but one year between 2012 and 2016 (in 2012 the 95th percentile concentration fell within attribute state B) (Table 55).

E. coli

E. coli concentrations in the Karori Stream at Makara Peak and the Makara Stream at the Kennels were assigned an overall attribute state of E (Table 55), meaning both sites are considered suitable for contact recreation under the NPS-FM 2014. Attribute state E is the lowest possible grade under the NPS-FM 2014 and indicates that for more than 30% of the time the estimated risk is of *campylobacter* infection is >50 in 1000 (>5% risk) and that the predicted average infection risk of infection is >7%.

Table 55: Water quality and ecology results from GWRC RWQE monitoring sites in the southern and western coastal stream catchments sub-zone collected since 2012 compared to numeric attributes as specified in the NPS-FM 2014.

Parameter	Site	Lowest attribute state	Overall average attribute state
NO_3-N	Karori S. @ Makara Peak	B	B
	Makara S. @ Kennels	B	A
NH_3-N	Karori S. @ Makara Peak	A	A
	Makara S. @ Kennels	A	A
E. coli	Karori S. @ Makara Peak	E	E
	Makara S. @ Kennels	E	E

3.4.5. Human drivers of degradation

The main driver of ecological degradation in the Karori Stream catchment above the Makara Peak monitoring site is urban land-use. Approximately 51% of the Karori Stream catchment upstream of the GWRC monitoring site is in urban land-use. It is, therefore, unsurprising, that the water quality and ecology at this site are symptomatic of the urban stream syndrome (see Section 3.3.6 for a description of the urban stream syndrome).

A significant proportion of the Karori Stream catchment upstream of the GWRC monitoring site is covered in impervious surfaces and the headwater stream network has largely been replaced by a piped stormwater network. Consequently, it is likely that the flow regime in the upper catchment has been modified to the point that it is detrimentally impacting resident macroinvertebrate communities. Urban development in the upper Karori catchment has also led to sedimentation and high dissolved metal concentrations (Section 3.4.1 and Section 3.4.2), which will be degrading ecological health. The impact of these changes in water quality and quantity on ecosystem health in the Karori Stream are likely exacerbated by the significant habitat modification that has accompanied urban development; today much of the upper catchment has been piped or engineered into concrete channels. It is important to note that urban land cover only makes up 11% of the entire Karori Stream catchment (Table 1), and the impact of this land-use is likely limited to the upper catchment, where it is concentrated.

Ecosystem health in the Makara Steam at the Kennel's is generally good (based on MCI, periphyton and macrophyte data presented in Section 3.4.1), and human activities do not appear to be significantly impacting ecosystem health, despite the stream being highly modified, and lacking significant indigenous riparian vegetation (Kingett Mitchell Ltd, 2005). However, it is possible that there are some localised impacts of human activities that are simply not being detected at the GWRC monitoring site. If these exist they will most likely be driven by agricultural land-use, which makes up 64% of the catchment area (Table 1).

In terms of the high level of faecal contamination observed in this sub-zone, the main source in the Karori Stream at Makara Peak is human wastewater. Wastewater is occasionally discharged into the Karori at eight over flows, and faecal source tracking conducted by GWRC in 2014 found high levels of human faecal contamination in the stream. Most streams monitored by WCC for *E. coli* also suffer from high levels of faecal contamination, and the source of this is most likely human as well. In contrast, faecal contamination in the Makara Stream most likely comes from livestock (sheep and beef cattle), as there is a large amount of agricultural urban land-use in the catchment and an almost complete absence of urban land-cover.

3.4.6. Knowledge gaps

The ecological state of much of the open water bodies in the sub-zone is unknown. However, WCC and GWRC are currently in the first stage of an urban stream biodiversity monitoring programme, which involves sampling macroinvertebrates and fish throughout Wellington City. The long-term goal of this programme is to set up a permanent monitoring programme at key sites. The Karori Stream catchment has been surveyed as part of the joint WCC/GWRC urban stream ecological monitoring programme, but the macroinvertebrate samples have not been processed yet. It is, however, unlikely that the Makara Stream catchment will be surveyed as part of this project.

Regular comprehensive water quality data is also sparse in the sub-zone, and little is known about state of the Silver Stream catchment (a major tributary of the Karori), the Ohariu Stream/Mill Creek catchment (a major tributary of the Makara) or the Oteranga Stream catchment (which discharges directly to the coast). As these are largely rural catchments, it is unlikely that they will be monitored for Wellington Water Limited's (WWL) global stormwater consent. Therefore, targeted investigations would be needed to fill these knowledge gaps.

While, the Owhiro Stream is not assessed in this report, as GWRC no longer monitor it for water quality or ecological state, Aquanet has produced a detailed report on the catchment for GWRC, entitled "*Owhiro Stream and its catchment – Summary of existing water quality and freshwater ecology information, recommendations for future monitoring"* (Ausseil, 2017). This is available at http://www.gw.govt.nz/assets/Harbours/Owhiro-Stream-SummaryFinal1-November-2017.pdf

3.4.7. Summary

Macroinvertebrate communities are in a good state in the Makara Stream at the Kennels but are moderately degraded in the Karori Stream at Makara Peak Mountain Bike Park, and this site is not meeting the pNRP outcome for MCI. A number of factors are likely responsible for the ecological degradation in the upper Karori Stream, most of which are driven by the significant urban land-use in the upstream catchment. High levels of deposited fine sediment, and elevated concentrations of dissolved metals from stormwater inputs are all likely to be contributors of degraded ecosystem health in the upper Karori. While the impacts of hydrology on stream health cannot be quantified from the data assessed in this report, it is likely that impervious surface cover, and the resulting changes in flow regime are also contributing to degraded macroinvertebrate communities. Interestingly, periphyton growth in the Karori Stream and macrophyte and periphyton growth in the Makara Stream are not limited by nutrient availability, but both sites met the pNRP outcomes for plant growth. This suggests that some other factor, most likely shade, is limiting plant growth in these streams.

In terms of recreational value, the rivers and streams in the southern and western coastal stream catchments sub-zone are in a very poor state. While benthic cyanobacteria do not generally pose a health risk to recreational users, faecal contamination, from human sources in Karori catchment, and agricultural sources in the Makara catchment, is high throughout the streams in the sub-zone, and none of the streams monitored by GWRC or WCC are considered suitable for primary contact recreation.

Trend analysis indicates that trends in water quality and ecology in the Karori and Makara Streams cannot be detected

4. Discussion

4.1. State

Macroinvertebrate monitoring data suggests that aquatic ecosystem health is degraded throughout much of Whaitua Te Whanganui-a-Tara, and that there are areas in need of improvement throughout the four main sub-zones.

Monitoring sites with a large amount of indigenous forest in the upstream catchment generally had healthy macroinvertebrate communities. MCI scores in the Orongorongo River and the Hutt River at Manor Park, were indicative of good ecosystem health, and scores in the Pakuratahi, Akatarawa and Whakatikei Rivers and the upper Wainuiomata and Hutt Rivers were indicative of either excellent or near excellent ecosystem health.

Sites with a significant amount of either urban or rural development in their upstream catchment, were generally degraded. MCI scores were indicative of only fair ecological condition in the Wainuiomata River downstream of White Bridge, the Mangaroa River and the Hutt River at Boulcott. Macroinvertebrate community health was in an even poorer state in the urban streams monitored by GWRC, and MCI scores in the Kaiwharawhara, Waiwhetu Stream, and Karori Streams, were generally indicative of poor ecological condition. The Makara Stream was the only waterway monitored that had a heavily developed catchment and MCI scores indicative of good ecological condition. The poor macroinvertebrate communities in developed catchments in Whaitua Te Whanganui-a-Tara is the result of stressors from the surrounding land use (e.g. sedimentation, nutrient enrichment and stormwater contamination).

The risk of ammonia and nitrate toxicity effects is low throughout Whaitua Te Whanganui-a-Tara (Hickey, 2014, 2013). There is however, a significant risk of toxicity effects from dissolved metals in the Karori, Kaiwharawhara and Waiwhetu Streams. Concentrations of either dissolved copper or zinc exceeded guidelines for the protection of 90% of species in all three of these streams, and in terms of dissolved metal concentrations they are considered highly disturbed systems.

The role of aquatic plants on ecosystem health differs throughout Whaitua Te Whanganui-a-Tara. Despite DIN and DRP concentrations exceeding thresholds to protect benthic biodiversity from nuisance periphyton growths (Biggs, 2000), the pNRP periphyton cover and biomass[17] outcomes were generally met in the Wainuiomata River at Manuka Track, the Hutt, Pakuratahi, Akatarawa and Whakatikei rivers, and the Karori and Makara streams. In terms of periphyton growth these rivers are in good or excellent ecological condition, and nuisance blooms are unlikely to be impacting macroinvertebrate community health. In contrast the Wainuiomata River at White Bridge, and sites on the Orongorongo and Mangaroa rivers and the Kaiwharawhara Stream all failed to meet the pNRP periphyton cover and biomass outcomes[17], and algal growth in these rivers is indicative of only fair (Orongorongo River and Kaiwharawhara Stream) or poor (Wainuiomata River at White Bridge and Mangaroa River) ecological condition. Accordingly, there is a risk that periphyton blooms are having a negative effect on macroinvertebrate communities in these systems, and this is most likely the case the lower Wainuiomata and Mangaroa Rivers. Macrophyte

[17] Biomass not measured at all sites.

cover was also very high in the Waiwhetu Stream at White Lines East, and excessive plant growth may be degrading the state of resident macroinvertebrate communities.

The findings of this assessment highlight the risk posed by fine sediment input into some rivers in Whaitua Te Whanganui-a-Tara. Although suspended sediment concentrations are low throughout the whaitua, benthic fine sediment cover in the lower Wainuiomata River, the Whakatikei River and the Karori, Makara, Kaiwharawhara and Waiwhetu streams exceeded guideline values for the protection of biodiversity (Clapcott *et al.*, 2011). Benthic fine sediment has a range of negative ecological effects on macroinvertebrates, and has been shown to be an important predictor of macroinvertebrate community composition in some streams (Greenwood *et al.*, 2012). Given the detrimental effects of deposited fine sediment on macroinvertebrates, it is likely that the high degree of sedimentation in lower Wainuiomata River, and the Karori, Kaiwharawhara and Waiwhetu Streams is contributing to the degraded state of their resident macroinvertebrate communities.

The role of flow as a driver of ecosystem health has not been explored in depth in this report. However, it is likely a significant regulator of ecosystem function in Whaitua Te Whanganui-a-Tara, particularly in the Hutt River, which has a large consumptive take on it for municipal water supply, and the Kaiwharawhara, Waiwhetu and Kaori Streams which have a large amount of impervious surface cover upstream of GWRC monitoring sites. Other unmeasured factors, including instream and riparian habitat degradation, stock access and river engineering activities are also likely to be affecting ecosystem health in some way. However, the available data did not allow for the impact of these factors to be assessed in this report.

Faecal contamination is generally limited to the urban streams in the whaitua, and the only non-urban streams that were found to be unsuitable for contact recreation due to high *E. coli* levels were the Mangaroa River and the Makara Stream. In contrast, all urban streams monitored by GWRC, WCC and HCC, except Speedy's Stream, were found to be unsuitable for contact recreation due to faecal contamination.

Toxic cyanobacteria regularly poses a health risk at bathing sites along the mid and lower reaches of the Hutt River, and is a well-publicised issue. *Microcoleus* blooms in the Hutt River have caused 11 dog deaths in the past, and regularly limits recreational use. Although GWRC RWQE monitoring does show that sites in Hutt, Pakuratahi and Akatarawa Rivers are unlikely to meet the pNRP cyanobacteria outcome, the extent of the cyanobacteria problems in the Hutt River are not detected in the data analysed in this report. Specifically, the significant blooms (>50% cover) that occurred at popular swimming sites in the summer of 2011/12, and 2017/18 are not apparent.

4.2. Trends

For the most part water quality and ecology is either not changing in a detectable manner or is improving in Whaitua Te Whanganui-a-Tara. Improving trends in DIN and NO_3-N were observed in the Wainuiomata River at White Bridge, the Orongorongo, Pakuratahi, and Mangaroa rivers and the Waiwhetu Stream. *E. coli* was found to be improving in all monitoring sites on the Hutt and in the Akatarawa rivers, and decreasing trends in NH_4-N were detected in the Wainuiomata River at White Bridge. The only degrading trends observed was a decrease in MCI in the Pakuratahi River, an increase in periphyton cover and biomass in the Wainuiomata River at White

Bridge and an increase in DRP in the Wainuiomata River at Manuka Track. The reasons for this degradation are unclear, especially for the Pakuratahi and upper Wainuiomata sites, where the upstream catchments are almost entirely covered in indigenous forest.

4.3. Links between of freshwater quality and coastal water quality and ecology

The major contributor of nutrient load to the Wellington Harbour is the Hutt River catchment. Between 2012 and 2016 the Hutt River discharged 95.5% of the measured nitrogen load to the harbour and 96.5 of the measured phosphorus load. Over the same period, the Kaiwharawhara Stream discharged 2.5% of the measured nitrogen load and 1.6% of the measured phosphorus load, while the Waiwhetu Stream discharged 2% of the measured nitrogen load nitrogen load and 1.9% of the measured phosphorus load.

4.4. Human drivers of degradation

Ecological degradation in the Kaiwharawhara, Waiwhetu and Karori streams are likely driven by a combination of stressors directly related to urban land-cover. Such degradation is common in urban streams and has even been named the "urban stream syndrome" (Meyer *et al.*, 2005). The main stressors known to drive the urban stream syndrome is the reduction in baseflow and increase in flood frequency associated with a high degree of impervious surface cover, high concentrations of toxic dissolved metals, sedimentation and habitat degradation caused by channel modification (Walsh *et al.*, 2005b). The Karori, Kaiwharawhara and Waiwhetu Streams, all exhibit a high degree of sedimentation and have dissolved metal concentrations above guideline levels. All have been extensively modified and have reaches that are either piped or in concrete channels. Furthermore, the Kaiwharawhara and Waiwhetu are known to exhibit a flashy flow regime. The main cause of degradation in these urban streams is the design of the stormwater infrastructure in their catchments. For the state of these streams to improve, water sensitive urban design is needed to improve stormwater hydrology and treatment. Ecosystem health and water quality improvements could also be made by daylighting piped reaches of stream, increasing water sensitive urban design use in new developments (e.g. bioretention, wetlands, rain gardens etc.) and implementing hard engineering habitat enhancement in concreted reaches.

Ecological degradation in the Mangaroa River and lower Wainuiomata River is driven by stressors related to agricultural land-use. The mechanism through which agricultural land-use is impacting ecosystem health in both rivers appears to be eutrophication, primarily nitrogen enrichment. This in turn has led to nuisance periphyton blooms, which are impacting macroinvertebrate community health. Indeed, periphyton growth is so prolific in these systems that that they are unlikely to meet the national bottom line for this attribute under the NPS-FM 2014. Sedimentation is also a significant problem in the lower Wainuiomata River. While the types of land-use causing nutrient enrichment in the Mangaroa and Wainuiomata River are known, the actual locations of the major sources of nutrients in these catchments are not. This needs to be remedied before any potential improvement mechanisms can be recommended.

The drivers of ecological degradation in the lower reaches of the Hutt River are not entirely clear. Periphyton biomass data indicates that the site is not overly impacted by nuisance periphyton blooms, fine sediment cover is generally low, and there is no risk of ammonia, nitrate and metal toxicity. As such, it is likely that the moderately degraded state of ecological communities is the cumulative effect of a number of different activities and land-uses, including pastoral land-use, urban land-use, water abstraction for municipal supply and river engineering works for flood protection.

The main sources of the significant faecal contamination in urban streams in Whaitua Te Whanganui-a-Tara is untreated human wastewater, and this is supported by faecal source tracking conducted by GWRC in 2014 (unpublished data). Untreated wastewater enters these streams through constructed and unconstructed over flows, cross connections between stormwater and wastewater infrastructure and/or broken pipes. Upgrades to the stormwater and wastewater infrastructure are needed if urban streams in Whaitua Te Whanganui-a-Tara are to be suitable for primary contact recreation. Faecal contamination in the Makara Stream and Mangaroa River (the only non-urban rivers unsuitable for primary contact recreation) most likely comes from livestock (sheep and beef cattle), as there is a large amount of agricultural urban land-use in these catchments, and an almost complete absence of urban land-cover. Although fencing stock out of these rivers may help reduce the level of contamination in these streams, it is likely that other land-management efforts, including critical source control, will be needed to ensure these rivers are suitable for primary contact recreation.

The drivers of cyanobacteria blooms in the Hutt River are not fully understood. However, blooms are most common in the middle reaches of the river where DIN concentrations are highest (Heath and Greenfield, 2016). Therefore, activities that drive high nutrient concentrations may be increasing the incidence and magnitude of blooms (Heath and Greenfield, 2016). In the Hutt River catchment, the primary sources of DIN are pastoral land-use in the Mangaroa River, and the upwelling of nitrogen rich groundwater between the Whakatikei River confluence and Taita. While the sources of groundwater nitrogen entering the Hutt River are not known, it is likely that nutrient leaching from intensively managed areas such as parks, golf courses and racecourses, combined with leaking and/or cross connected wastewater and stormwater infrastructure are contributors (Heath and Greenfield, 2016).

4.5. Knowledge gaps

Major knowledge gaps in Whaitua Te Whanganui-a-Tara are:

- There is a lack of water quality and ecological data for the Gollans Stream and Cameron's Creek catchments which drain in to Lakes Kohangatera and Kohangapiripiri respectively;
- Data to determine the current state and trends in freshwater fish communities are largely lacking. This represents a significant gap in our existing understanding of river and stream ecological health in the whaitua (and sub-zones). Apart from inanga and trout spawning habitat, significant habitats for other species, such as lamprey spawning, are undocumented;
- The major surface water and groundwater sources of nitrogen in the Wainuiomata, Mangaroa and Hutt River catchments are not fully understood;
- The drivers of cyanobacteria growth in the Hutt River require further research;
- The ecological state (specifically fish, macroinvertebrates and habitat) of the piped stream network that runs under Wellington City and remaining surface streams is largely unknown;

- Little is known about state of the Silver Stream catchment (a major tributary of the Karori), the Ohariu Stream/Mill Creek catchment (a major tributary of the Makara) or the Oteranga Stream catchment (which discharges directly to the coast); and
- The role of physical habitat modification (riparian vegetation removal, flood control work etc.) on ecosystem health cannot be assessed from the available monitoring data.

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APPENDICES

Appendix 1: pNRP river class descriptions

pNRP river class	Description	FENZ[18] Class	Description
1	Steep, hard sedimentary	C7	Small to medium-sized streams occurring in inland locations with mild climates and low frequency of days with significant rainfall. Stream gradients are generally steep and substrates are generally coarse gravels. Predominant location: Lowland hills of the Tararua, Rimutaka and Aorangi ranges.
		C10	Small streams occurring in inland locations with cool climates and moderate frequency of days with significant rainfall. Gradients of these streams are generally very steep and substrates are generally cobbly. Predominant locations: Small, mid-elevation streams in the Tararua, Rimutaka and Aorangi ranges
		UR	A combination of 23 100-level classes that occur entirely within the upper Tararua or Rimutaka ranges.
2	Mid-gradient, coastal and hard sedimentary	C5	Small streams occurring in moderately coastal locations with mild, maritime climates and low frequency of days with significant rainfall. Stream gradients are generally moderate and substrates are predominantly coarse gravels. Predominant location: Wellington south coast, eastern Wairarapa coast and western Tararua foothills.
		C1	Small coastal streams with mild maritime climates and low frequency of days with significant rainfall. Stream gradients are generally very steep and substrates are predominantly coarse gravels. Predominant location: South Wairarapa coast, Rimutaka Range and Kapiti Island.
		C6b	A variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by class C5 streams. Location: Horokiri and Pauatahanui streams as well as some stream segments on the eastern Wairarapa coast.
3	Mid-gradient, soft sedimentary	C8	Small inland streams with mild climates and low frequency of days with significant rainfall. Stream gradients are moderate and substrates are generally coarse gravels. Predominant location: Eastern Wairarapa hill country and northern foothills of Tararua Range.
4	Lowland, large, draining ranges	C6a	This class is a variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by C7 rivers. These are larger rivers occurring in moderately inland locations with warm climates and low frequency of days with significant rainfall and a predominance of coarse gravelly substrates. Stream gradients are gentle. Predominant location: Lower reaches of larger rivers draining the Tararua Range.
5	Lowland, large, draining plains and eastern Wairarapa	C6c	A variant of 100-level class C6 and includes C6 rivers that have an upstream catchment dominated by class A and/or C8 rivers and streams. Predominant location: Larger rivers draining eastern Wairarapa hill country and lowland areas of the Kapiti Coast.

[18] The Freshwater Environments of New Zealand (FENZ) database is the basis of the river classes included in the proposed Plan, and was selected as it "has a greater ability to represent natural ecological variation in rivers and streams than the rule-based River Environment Classification" (Warr, 2009)

pNRP river class	Description	FENZ[18] Class	Description
6	Lowland, small	A	A combination of 100-level classes A4 and A2. These are small streams occurring in inland or coastal locations with very low frequency of days with significant rainfall. Gradients of these streams are very gentle to gentle and substrates are predominantly silty or sandy. Predominant location: Central Wairarapa Valley and Kapiti Coast.
		B	A combination of 100-level classes B1 and B3 of very limited extent in the Wellington region but has been retained due to the peat-dominated nature of the catchments which is likely to result in unique ecological characteristics. Location: Mangaroa Valley, Lake Wairarapa, Paraparaumu.

Appendix 2: Summary of water quality data for sites sampled as part of GWRC's RWQE programme between July 2012 and June 2017

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
Periphyton cover as periWCC (%)	Akatarawa R. @ Hutt Conf.	60	0.0	0.0	0.0	0.0	0.8	0.8	3.8	11.9
	Hutt R. @ Boulcott	60	0.0	0.0	0.0	0.0	3.1	0.8	14.4	65.5
	Hutt R. @ Te Marua	60	0.0	0.0	0.0	0.0	0.3	0.0	2.4	5.1
	Hutt R. @ Manor Park	60	0.0	0.0	0.0	0.0	1.5	1.5	8.3	13.5
	Kaiwharawhara S. @ Ngaio G.	60	0.0	0.0	0.0	0.8	11.3	6.0	74.5	95.0
	Karori S. @ Makara Peak	60	0.0	0.0	0.0	2.0	5.3	6.2	25.6	53.5
	Makara S. @ Kennels	60	0.0	0.0	0.0	0.0	3.0	0.6	21.8	48.3
	Mangaroa R. @ Te Marua	60	0.0	0.0	0.0	0.0	10.9	14.0	50.6	76.5
	Orongorongo R. @ Orongorongo St.	48	0.0	0.0	0.0	0.0	8.9	12.0	49.1	70.5
	Pakuratahi R. @ Hutt Forks	60	0.0	0.0	0.0	0.0	2.5	2.5	14.4	24.1
	Wainuiomata R. @ Manuka Tr.	59	0.0	0.0	0.0	0.0	0.5	0.4	3.3	6.1
	Wainuiomata R. d/s of White Br.	60	0.0	0.0	0.4	5.1	13.5	24.3	43.2	58.0
	Waiwhetu S. @ Whites Line East	60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Whakatikei R. @ Riverstone	60	0.0	0.0	0.0	1.0	4.1	6.4	16.6	22.3
Cyanobacteria cover (%)	Akatarawa R. @ Hutt Conf.	45	0.0	0.0	0.0	0.0	2.2	3.0	10.6	20.0
	Hutt R. @ Boulcott	28	0.0	0.0	0.0	0.0	3.9	4.6	23.4	25.0
	Hutt R. @ Te Marua	36	0.0	0.0	0.0	0.0	1.0	1.3	6.8	7.5
	Hutt R. @ Manor Park	29	0.0	0.0	0.0	0.0	3.6	4.8	15.2	27.5
	Kaiwharawhara S. @ Ngaio G.	41	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0
	Karori S. @ Makara Peak	40	0.0	0.0	0.0	0.0	0.1	0.0	0.0	2.0
	Makara S. @ Kennels	38	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0
	Mangaroa R. @ Te Marua	32	0.0	0.0	0.0	0.1	2.1	2.8	10.8	18.5
	Orongorongo R. @ Orongorongo St.	27	0.0	0.0	0.0	0.0	1.7	0.0	12.6	18.5
	Pakuratahi R. @ Hutt Forks	38	0.0	0.0	0.0	1.6	5.7	6.0	27.3	53.3
	Wainuiomata R. @ Manuka Tr.	45	0.0	0.0	0.0	0.0	0.2	0.5	1.0	2.0
	Wainuiomata R. d/s of White Br.	38	0.0	0.0	0.3	2.5	5.9	8.3	27.8	33.8
	Waiwhetu S. @ Whites Line East	1	0.0	N/A	N/A	0.0	0.0	N/A	N/A	0.0
	Whakatikei R. @ Riverstone	44	0.0	0.0	0.0	0.5	2.2	3.0	9.2	14.5

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
Fine sediment cover (%)	Akatarawa R. @ Hutt Conf.	33	0.0	0.0	5.0	15.0	14.9	26.3	34.3	40.0
	Hutt R. @ Boulcott	19	0.0	0.0	0.0	5.0	6.1	5.0	27.8	30.0
	Hutt R. @ Te Marua	26	0.0	0.0	0.0	0.0	0.4	0.0	2.0	10.0
	Hutt R. @ Manor Park	23	0.0	3.3	10.0	15.0	18.5	25.0	40.0	40.0
	Kaiwharawhara S. @ Ngaio G.	30	5.0	5.0	10.0	20.0	24.5	30.0	40.0	95.0
	Karori S. @ Makara Peak	30	5.0	5.0	10.0	22.5	24.7	30.0	60.0	70.0
	Makara S. @ Kennels	29	60.0	60.0	80.0	85.0	82.4	90.0	90.3	95.0
	Mangaroa R. @ Te Marua	24	0.0	0.0	0.0	0.0	1.3	0.0	10.0	10.0
	Orongorongo R. @ Orongorongo St.	26	0.0	0.0	5.0	10.0	13.5	20.0	42.0	50.0
	Pakuratahi R. @ Hutt Forks	26	0.0	0.0	5.0	5.0	5.8	5.0	14.0	30.0
	Wainuiomata R. @ Manuka Tr.	34	0.0	0.0	0.0	0.0	1.0	0.0	10.0	10.0
	Wainuiomata R. d/s of White Br.	33	0.0	5.0	10.0	30.0	27.6	40.0	60.0	65.0
	Waiwhetu S. @ Whites Line East	28	10.0	10.0	20.0	30.0	32.9	45.0	70.0	70.0
	Whakatikei R. @ Riverstone	33	0.0	5.0	10.0	25.0	26.2	32.5	60.0	70.0
Temp. (°C)	Akatarawa R. @ Hutt Conf.	60	6.0	7.0	9.4	11.6	11.8	14.2	17.0	19.2
	Hutt R. @ Boulcott	60	8.0	8.3	11.5	13.7	14.1	16.9	19.8	22.6
	Hutt R. @ Te Marua	60	6.2	6.4	8.8	10.9	11.1	13.4	16.4	18.5
	Hutt R. @ Manor Park	60	7.9	8.2	11.2	13.3	13.6	16.2	19.5	22.1
	Kaiwharawhara S. @ Ngaio G.	60	7.1	8.1	11.3	13.7	13.4	15.4	18.4	20.6
	Karori S. @ Makara Peak	60	8.4	9.1	11.5	12.7	13.0	14.6	17.3	18.5
	Makara S. @ Kennels	60	5.6	7.0	10.8	14.0	13.6	16.2	18.9	20.9
	Mangaroa R. @ Te Marua	60	7.1	8.0	10.3	12.4	12.5	14.9	16.9	18.2
	Orongorongo R. @ Orongorongo St.	48	9.3	9.7	11.9	15.0	15.5	18.6	22.2	23.6
	Pakuratahi R. @ Hutt Forks	60	6.8	7.3	9.5	11.5	11.7	14.1	16.4	18.9
	Wainuiomata R. @ Manuka Tr.	59	5.6	7.2	9.1	10.5	10.7	12.5	14.6	15.8
	Wainuiomata R. d/s of White Br.	60	7.5	8.9	11.0	13.3	13.9	17.1	20.2	21.9
	Waiwhetu S. @ Whites Line East	60	9.2	9.9	11.6	14.3	14.3	16.5	18.9	20.2
	Whakatikei R. @ Riverstone	60	6.7	7.3	9.6	11.6	11.8	14.2	16.6	18.7

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
DO (mg/L)	Akatarawa R. @ Hutt Conf.	60	9.6	9.9	10.5	11.0	11.0	11.7	12.5	12.7
	Hutt R. @ Boulcott	60	8.9	9.3	10.0	10.6	10.6	11.1	12.0	12.1
	Hutt R. @ Te Marua	60	9.7	9.8	10.5	11.1	11.1	11.8	12.5	12.6
	Hutt R. @ Manor Park	60	9.6	10.0	10.3	10.8	10.9	11.4	12.2	12.3
	Kaiwharawhara S. @ Ngaio G.	59	9.2	9.7	10.1	10.7	10.7	11.2	12.0	12.8
	Karori S. @ Makara Peak	59	9.2	9.5	10.1	10.4	10.5	11.0	11.5	12.5
	Makara S. @ Kennels	59	7.6	8.5	9.7	10.5	10.5	11.3	12.5	13.6
	Mangaroa R. @ Te Marua	60	9.8	9.9	10.5	10.9	10.9	11.4	12.0	12.1
	Orongorongo R. @ Orongorongo St.	48	8.6	9.0	9.5	10.1	10.2	10.9	11.5	12.5
	Pakuratahi R. @ Hutt Forks	60	9.0	9.2	9.8	10.6	10.5	11.3	12.0	12.1
	Wainuiomata R. @ Manuka Tr.	60	9.6	9.7	10.5	11.1	11.0	11.6	12.3	12.5
	Wainuiomata R. d/s of White Br.	60	7.9	9.4	10.4	11.0	10.9	11.7	12.2	12.3
	Waiwhetu S. @ Whites Line East	60	2.4	4.0	7.0	8.6	8.3	9.6	12.0	14.1
	Whakatikei R. @ Riverstone	60	9.9	10.1	10.6	11.0	11.1	11.6	12.5	12.8
DIN (mg/L)	Akatarawa R. @ Hutt Conf.	60	0.01	0.01	0.05	0.09	0.10	0.14	0.19	0.63
	Hutt R. @ Boulcott	60	0.08	0.09	0.16	0.20	0.20	0.26	0.33	0.33
	Hutt R. @ Te Marua	60	0.03	0.04	0.06	0.08	0.08	0.11	0.14	0.17
	Hutt R. @ Manor Park	60	0.09	0.10	0.16	0.21	0.22	0.27	0.35	0.39
	Kaiwharawhara S. @ Ngaio G.	60	0.52	0.73	1.01	1.14	1.14	1.27	1.49	1.59
	Karori S. @ Makara Peak	60	0.62	0.73	1.13	1.29	1.28	1.45	1.65	1.89
	Makara S. @ Kennels	60	0.01	0.01	0.05	0.42	0.46	0.76	1.33	1.59
	Mangaroa R. @ Te Marua	60	0.17	0.20	0.36	0.44	0.43	0.49	0.61	0.67
	Orongorongo R. @ Orongorongo St.	48	0.01	0.01	0.01	0.04	0.04	0.06	0.11	0.18
	Pakuratahi R. @ Hutt Forks	60	0.06	0.08	0.17	0.20	0.20	0.23	0.29	0.36
	Wainuiomata R. @ Manuka Tr.	59	0.02	0.02	0.06	0.07	0.08	0.09	0.15	0.20
	Wainuiomata R. d/s of White Br.	60	0.01	0.01	0.06	0.17	0.19	0.29	0.47	0.57
	Waiwhetu S. @ Whites Line East	60	0.01	0.08	0.34	0.56	0.55	0.72	1.03	1.46
	Whakatikei R. @ Riverstone	60	0.02	0.03	0.07	0.15	0.16	0.22	0.30	0.68

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
DRP (mg/L)	Akatarawa R. @ Hutt Conf.	60	0.001	0.002	0.002	0.003	0.004	0.005	0.006	0.008
	Hutt R. @ Boulcott	60	0.001	0.001	0.002	0.004	0.004	0.006	0.008	0.008
	Hutt R. @ Te Marua	60	0.002	0.002	0.002	0.004	0.004	0.004	0.006	0.006
	Hutt R. @ Manor Park	60	0.001	0.001	0.002	0.005	0.005	0.006	0.008	0.008
	Kaiwharawhara S. @ Ngaio G.	60	0.021	0.024	0.033	0.037	0.041	0.046	0.064	0.082
	Karori S. @ Makara Peak	60	0.018	0.023	0.030	0.036	0.040	0.043	0.062	0.184
	Makara S. @ Kennels	60	0.012	0.013	0.019	0.027	0.031	0.036	0.064	0.081
	Mangaroa R. @ Te Marua	60	0.001	0.002	0.006	0.010	0.009	0.012	0.015	0.018
	Orongorongo R. @ Orongorongo St.	48	0.001	0.002	0.002	0.005	0.004	0.006	0.008	0.010
	Pakuratahi R. @ Hutt Forks	60	0.001	0.002	0.003	0.004	0.005	0.005	0.008	0.011
	Wainuiomata R. @ Manuka Tr.	59	0.008	0.009	0.010	0.011	0.012	0.012	0.015	0.017
	Wainuiomata R. d/s of White Br.	60	0.006	0.007	0.010	0.011	0.012	0.014	0.023	0.028
	Waiwhetu S. @ Whites Line East	60	0.008	0.013	0.019	0.024	0.026	0.031	0.049	0.052
	Whakatikei R. @ Riverstone	60	0.002	0.005	0.006	0.008	0.008	0.009	0.011	0.012
NO_3-N (mg/L)	Akatarawa R. @ Hutt Conf.	60	0.00	0.01	0.05	0.08	0.10	0.14	0.19	0.62
	Hutt R. @ Boulcott	60	0.08	0.08	0.15	0.20	0.20	0.26	0.32	0.33
	Hutt R. @ Te Marua	60	0.03	0.04	0.06	0.07	0.08	0.10	0.14	0.16
	Hutt R. @ Manor Park	60	0.08	0.09	0.16	0.20	0.21	0.26	0.34	0.36
	Kaiwharawhara S. @ Ngaio G.	60	0.51	0.72	0.98	1.13	1.12	1.26	1.46	1.56
	Karori S. @ Makara Peak	60	0.48	0.68	1.10	1.27	1.25	1.43	1.63	1.86
	Makara S. @ Kennels	60	0.00	0.00	0.04	0.39	0.44	0.73	1.31	1.57
	Mangaroa R. @ Te Marua	60	0.16	0.20	0.35	0.44	0.42	0.48	0.60	0.66
	Orongorongo R. @ Orongorongo St.	48	0.00	0.00	0.01	0.04	0.04	0.06	0.11	0.17
	Pakuratahi R. @ Hutt Forks	60	0.06	0.07	0.16	0.20	0.19	0.23	0.29	0.35
	Wainuiomata R. @ Manuka Tr.	59	0.02	0.02	0.05	0.07	0.07	0.09	0.15	0.19
	Wainuiomata R. d/s of White Br.	60	0.00	0.00	0.05	0.16	0.18	0.29	0.46	0.50
	Waiwhetu S. @ Whites Line East	60	0.00	0.01	0.31	0.48	0.45	0.60	0.89	1.44
	Whakatikei R. @ Riverstone	60	0.02	0.02	0.07	0.14	0.15	0.22	0.29	0.68

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
NH_3-N (mg/L)	Akatarawa R. @ Hutt Conf.	60	0.00000	0.00000	0.00001	0.00001	0.00002	0.00002	0.00004	0.00009
	Hutt R. @ Boulcott	60	0.00000	0.00000	0.00001	0.00001	0.00002	0.00002	0.00005	0.00015
	Hutt R. @ Te Marua	60	0.00000	0.00000	0.00001	0.00001	0.00001	0.00002	0.00003	0.00007
	Hutt R. @ Manor Park	60	0.00000	0.00000	0.00001	0.00001	0.00002	0.00003	0.00008	0.00016
	Kaiwharawhara S. @ Ngaio G.	60	0.00001	0.00001	0.00004	0.00007	0.00015	0.00013	0.00039	0.00247
	Karori S. @ Makara Peak	60	0.00000	0.00001	0.00004	0.00007	0.00009	0.00012	0.00022	0.00032
	Makara S. @ Kennels	60	0.00001	0.00001	0.00003	0.00004	0.00007	0.00010	0.00022	0.00033
	Mangaroa R. @ Te Marua	60	0.00000	0.00001	0.00001	0.00001	0.00002	0.00002	0.00004	0.00005
	Orongorongo R. @ Orongorongo St.	48	0.00001	0.00002	0.00003	0.00006	0.00008	0.00009	0.00024	0.00044
	Pakuratahi R. @ Hutt Forks	60	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00002	0.00005
	Wainuiomata R. @ Manuka Tr.	59	0.00000	0.00000	0.00001	0.00002	0.00002	0.00002	0.00004	0.00005
	Wainuiomata R. d/s of White Br.	60	0.00001	0.00001	0.00002	0.00004	0.00015	0.00008	0.00059	0.00284
	Waiwhetu S. @ Whites Line East	60	0.00001	0.00001	0.00005	0.00010	0.00016	0.00021	0.00050	0.00088
	Whakatikei R. @ Riverstone	60	0.00000	0.00001	0.00001	0.00001	0.00003	0.00003	0.00010	0.00018
Dissolved Cu (mg/L)	Akatarawa R. @ Hutt Conf.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Hutt R. @ Boulcott	60	0.0003	0.0003	0.0003	0.0003	0.0005	0.0005	0.0017	0.0064
	Hutt R. @ Te Marua	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Hutt R. @ Manor Park	60	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0008	0.0010
	Kaiwharawhara S. @ Ngaio G.	60	0.0007	0.0010	0.0012	0.0015	0.0018	0.0019	0.0044	0.0060
	Karori S. @ Makara Peak	60	0.0007	0.0009	0.0012	0.0015	0.0021	0.0020	0.0059	0.0131
	Makara S. @ Kennels	1	0.0007	N/A	N/A	0.0007	0.0007	N/A	N/A	0.0007
	Mangaroa R. @ Te Marua	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Orongorongo R. @ Orongorongo St.	1	0.0005	N/A	N/A	0.0005	0.0005	N/A	N/A	0.0005
	Pakuratahi R. @ Hutt Forks	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wainuiomata R. @ Manuka Tr.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wainuiomata R. d/s of White Br.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Waiwhetu S. @ Whites Line East	60	0.0003	0.0005	0.0008	0.0010	0.0015	0.0016	0.0040	0.0046
	Whakatikei R. @ Riverstone	0	0.0000	N/A	N/A	N/A	N/A	N/A	N/A	N/A

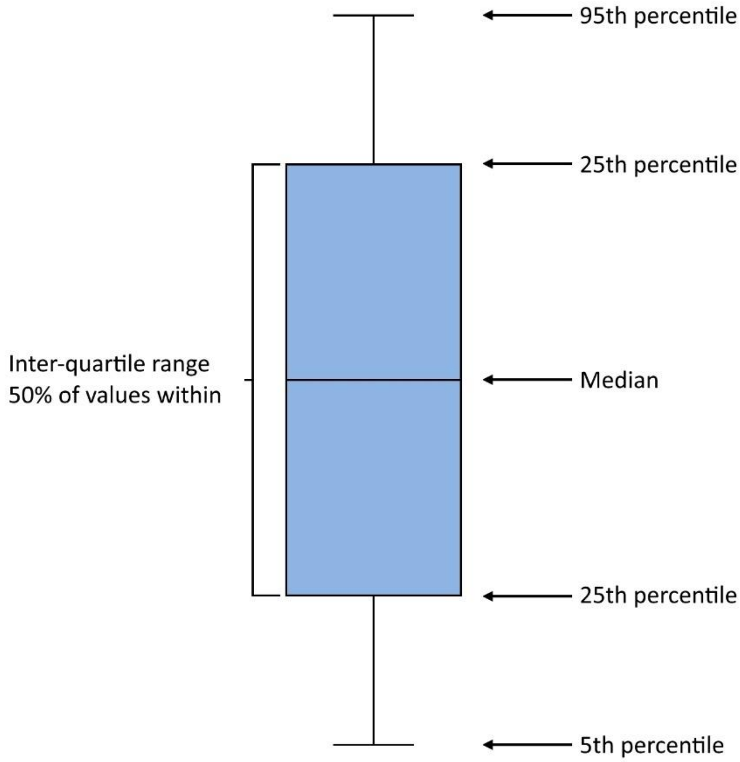
Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
Dissolved Zn (mg/L)	Akatarawa R. @ Hutt Conf.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Hutt R. @ Boulcott	60	0.0005	0.0005	0.0005	0.0005	0.0012	0.0013	0.0044	0.0069
	Hutt R. @ Te Marua	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Hutt R. @ Manor Park	60	0.0005	0.0005	0.0005	0.0005	0.0012	0.0015	0.0044	0.0055
	Kaiwharawhara S. @ Ngaio G.	60	0.0015	0.0021	0.0048	0.0063	0.0078	0.0092	0.0192	0.0240
	Karori S. @ Makara Peak	60	0.0074	0.0117	0.0150	0.0210	0.0252	0.0310	0.0565	0.0820
	Makara S. @ Kennels	1	0.0005	N/A	N/A	0.0005	0.0005	N/A	N/A	0.0005
	Mangaroa R. @ Te Marua	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Orongorongo R. @ Orongorongo St.	1	0.0005	N/A	N/A	0.0005	0.0005	N/A	N/A	0.0005
	Pakuratahi R. @ Hutt Forks	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wainuiomata R. @ Manuka Tr.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wainuiomata R. d/s of White Br.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Waiwhetu S. @ Whites Line East	60	0.0050	0.0056	0.0137	0.0187	0.0224	0.0255	0.0550	0.0660
	Whakatikei R. @ Riverstone	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TN (mg/L)	Akatarawa R. @ Hutt Conf.	60	0.06	0.06	0.11	0.17	0.20	0.22	0.44	1.38
	Hutt R. @ Boulcott	60	0.15	0.19	0.24	0.32	0.34	0.38	0.53	1.83
	Hutt R. @ Te Marua	60	0.06	0.06	0.14	0.16	0.17	0.20	0.29	0.42
	Hutt R. @ Manor Park	60	0.19	0.20	0.25	0.31	0.36	0.39	0.55	1.96
	Kaiwharawhara S. @ Ngaio G.	60	0.56	1.06	1.23	1.39	1.40	1.53	1.78	3.40
	Karori S. @ Makara Peak	60	0.83	1.04	1.36	1.52	1.50	1.64	1.98	2.00
	Makara S. @ Kennels	60	0.13	0.23	0.33	0.65	0.91	1.09	2.45	5.50
	Mangaroa R. @ Te Marua	60	0.34	0.43	0.54	0.60	0.61	0.69	0.81	0.97
	Orongorongo R. @ Orongorongo St.	48	0.06	0.06	0.06	0.06	0.10	0.12	0.19	0.55
	Pakuratahi R. @ Hutt Forks	60	0.16	0.20	0.25	0.30	0.30	0.36	0.44	0.45
	Wainuiomata R. @ Manuka Tr.	59	0.06	0.06	0.12	0.15	0.16	0.19	0.32	0.61
	Wainuiomata R. d/s of White Br.	60	0.06	0.06	0.14	0.28	0.31	0.42	0.67	1.12
	Waiwhetu S. @ Whites Line East	60	0.25	0.32	0.59	0.81	0.79	0.96	1.36	1.65
	Whakatikei R. @ Riverstone	60	0.06	0.06	0.14	0.23	0.30	0.29	0.47	4.60

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
TP (mg/L)	Akatarawa R. @ Hutt Conf.	60	0.002	0.002	0.003	0.006	0.011	0.008	0.014	0.300
	Hutt R. @ Boulcott	60	0.002	0.002	0.006	0.010	0.018	0.013	0.033	0.390
	Hutt R. @ Te Marua	60	0.002	0.002	0.005	0.006	0.007	0.008	0.020	0.032
	Hutt R. @ Manor Park	60	0.002	0.002	0.006	0.009	0.017	0.012	0.031	0.380
	Kaiwharawhara S. @ Ngaio G.	60	0.027	0.032	0.040	0.047	0.061	0.058	0.105	0.470
	Karori S. @ Makara Peak	60	0.028	0.030	0.036	0.042	0.053	0.056	0.086	0.390
	Makara S. @ Kennels	60	0.020	0.024	0.034	0.040	0.073	0.080	0.278	0.580
	Mangaroa R. @ Te Marua	60	0.002	0.007	0.014	0.017	0.018	0.021	0.038	0.046
	Orongorongo R. @ Orongorongo St.	48	0.002	0.002	0.004	0.006	0.013	0.011	0.045	0.184
	Pakuratahi R. @ Hutt Forks	60	0.002	0.002	0.006	0.008	0.010	0.010	0.026	0.036
	Wainuiomata R. @ Manuka Tr.	59	0.007	0.009	0.013	0.015	0.016	0.017	0.032	0.054
	Wainuiomata R. d/s of White Br.	60	0.008	0.011	0.015	0.018	0.021	0.023	0.038	0.064
	Waiwhetu S. @ Whites Line East	60	0.015	0.024	0.035	0.047	0.059	0.067	0.145	0.200
	Whakatikei R. @ Riverstone	60	0.002	0.005	0.008	0.010	0.024	0.013	0.016	0.850
Black Disc (m)	Akatarawa R. @ Hutt Conf.	60	0.07	0.87	2.70	4.72	4.46	5.81	7.63	8.45
	Hutt R. @ Boulcott	60	0.04	0.26	0.84	2.32	2.63	4.24	6.04	8.04
	Hutt R. @ Te Marua	59	0.35	0.46	2.30	4.61	4.22	5.93	7.90	8.70
	Hutt R. @ Manor Park	59	0.05	0.31	1.21	2.50	2.76	4.02	6.11	8.25
	Kaiwharawhara S. @ Ngaio G.	59	0.04	0.42	1.90	3.12	3.28	4.60	6.45	8.00
	Karori S. @ Makara Peak	60	0.10	0.47	1.87	3.18	3.07	4.23	5.26	6.80
	Makara S. @ Kennels	60	0.04	0.17	1.27	1.55	1.46	1.82	2.49	2.66
	Mangaroa R. @ Te Marua	60	0.33	0.41	1.01	1.46	1.54	1.84	3.16	3.86
	Orongorongo R. @ Orongorongo St.	47	0.05	0.12	0.55	2.06	2.64	4.34	6.42	7.92
	Pakuratahi R. @ Hutt Forks	60	0.33	0.57	2.16	4.21	4.26	5.98	8.92	9.98
	Wainuiomata R. @ Manuka Tr.	58	0.66	1.03	2.15	2.73	2.90	3.15	5.41	5.69
	Wainuiomata R. d/s of White Br.	59	0.27	0.65	1.47	2.01	2.09	2.83	3.51	4.96
	Waiwhetu S. @ Whites Line East	58	0.09	0.28	0.65	1.06	1.13	1.51	2.43	2.82
	Whakatikei R. @ Riverstone	59	0.03	0.90	2.53	4.00	3.97	5.11	7.19	9.48

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
TSS and SSC comb. (mg/L)	Akatarawa R. @ Hutt Conf.	60	0.0	0.0	0.0	1.0	7.0	1.0	5.0	370.0
	Hutt R. @ Boulcott	60	1.0	1.0	1.5	5.0	15.3	6.0	36.0	470.0
	Hutt R. @ Te Marua	60	0.0	0.0	0.0	1.0	2.5	1.0	11.5	33.0
	Hutt R. @ Manor Park	60	1.0	1.0	1.0	5.0	12.8	5.3	27.0	440.0
	Kaiwharawhara S. @ Ngaio G.	60	0.0	0.0	0.0	1.0	8.8	1.0	42.0	240.0
	Karori S. @ Makara Peak	60	0.0	0.0	0.0	1.0	3.6	1.0	11.5	122.0
	Makara S. @ Kennels	60	0.0	0.0	1.0	2.5	27.4	5.0	180.5	700.0
	Mangaroa R. @ Te Marua	60	0.0	0.0	0.0	1.0	2.9	3.0	14.5	34.0
	Orongorongo R. @ Orongorongo St.	48	0.0	0.0	0.5	1.0	18.1	5.0	68.0	440.0
	Pakuratahi R. @ Hutt Forks	60	0.0	0.0	0.0	1.0	2.6	1.0	13.5	38.0
	Wainuiomata R. @ Manuka Tr.	59	0.0	0.0	0.0	1.0	0.9	1.0	2.6	13.0
	Wainuiomata R. d/s of White Br.	60	0.0	0.0	0.0	1.0	1.8	2.0	7.5	14.0
	Waiwhetu S. @ Whites Line East	60	0.0	0.0	0.0	2.0	4.7	5.0	20.0	53.0
	Whakatikei R. @ Riverstone	60	0.0	0.0	0.0	1.0	18.0	1.0	6.0	990.0
TSS (mg/L)	Akatarawa R. @ Hutt Conf.	36	1.0	1.0	1.0	1.0	11.7	1.0	5.0	370.0
	Hutt R. @ Boulcott	60	1.0	1.0	1.0	1.0	14.0	6.0	36.0	470.0
	Hutt R. @ Te Marua	36	1.0	1.0	1.0	1.0	4.1	4.5	18.3	33.0
	Hutt R. @ Manor Park	60	1.0	1.0	1.0	1.0	11.4	3.5	27.0	440.0
	Kaiwharawhara S. @ Ngaio G.	36	1.0	1.0	1.0	1.0	14.6	3.5	109.5	240.0
	Karori S. @ Makara Peak	36	1.0	1.0	1.0	1.0	6.1	2.5	20.6	122.0
	Makara S. @ Kennels	48	1.0	1.0	1.0	3.0	33.2	5.5	266.0	700.0
	Mangaroa R. @ Te Marua	36	1.0	1.0	1.0	2.0	4.8	5.0	18.8	34.0
	Orongorongo R. @ Orongorongo St.	36	1.0	1.0	1.0	3.0	24.2	7.0	86.0	440.0
	Pakuratahi R. @ Hutt Forks	36	1.0	1.0	1.0	1.0	4.3	4.0	23.4	38.0
	Wainuiomata R. @ Manuka Tr.	36	1.0	1.0	1.0	1.0	1.5	1.0	3.0	13.0
	Wainuiomata R. d/s of White Br.	36	1.0	1.0	1.0	1.0	3.1	4.0	12.5	14.0
	Waiwhetu S. @ Whites Line East	36	1.0	1.0	2.0	4.0	7.8	9.5	22.1	53.0
	Whakatikei R. @ Riverstone	36	1.0	1.0	1.0	1.0	30.0	1.0	29.4	990.0

Parameter	Site	n	Min	5th %ile	25th %ile	Median	Mean	75th %ile	95th %ile	Max
SSC (mg/L)	Akatarawa R. @ Hutt Conf.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Hutt R. @ Boulcott	23	5.0	5.0	5.0	5.0	5.2	5.5	5.5	5.5
	Hutt R. @ Te Marua	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Hutt R. @ Manor Park	24	5.0	5.0	5.0	5.0	5.1	5.0	5.5	5.5
	Kaiwharawhara S. @ Ngaio G.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Karori S. @ Makara Peak	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Makara S. @ Kennels	12	5.0	5.0	5.0	5.0	29.8	5.0	262.7	290.0
	Mangaroa R. @ Te Marua	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Orongorongo R. @ Orongorongo St.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Pakuratahi R. @ Hutt Forks	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wainuiomata R. @ Manuka Tr.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Wainuiomata R. d/s of White Br.	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Waiwhetu S. @ Whites Line East	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Whakatikei R. @ Riverstone	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E. coli (cfu/100ml)	Akatarawa R. @ Hutt Conf.	60	6.0	11.5	19.5	39.0	115.2	80.0	420.0	2600.0
	Hutt R. @ Boulcott	60	12.0	22.0	32.5	53.0	196.9	100.0	750.0	3600.0
	Hutt R. @ Te Marua	60	1.0	4.5	9.0	16.5	32.6	31.5	135.0	240.0
	Hutt R. @ Manor Park	60	4.0	18.5	32.0	65.0	212.1	120.0	900.0	4000.0
	Kaiwharawhara S. @ Ngaio G.	60	30.0	60.0	200.0	530.0	1914.0	1350.0	5150.0	28000.0
	Karori S. @ Makara Peak	60	160.0	290.0	850.0	1450.0	2746.2	2550.0	6450.0	52000.0
	Makara S. @ Kennels	60	30.0	55.0	210.0	365.0	1218.5	615.0	6500.0	20000.0
	Mangaroa R. @ Te Marua	60	11.0	50.0	110.0	170.0	418.0	330.0	2450.0	3100.0
	Orongorongo R. @ Orongorongo St.	48	0.5	1.0	6.5	13.0	72.3	80.0	432.0	590.0
	Pakuratahi R. @ Hutt Forks	60	12.0	16.5	38.0	80.0	222.1	135.0	1000.0	4400.0
	Wainuiomata R. @ Manuka Tr.	59	0.5	0.5	1.0	4.0	21.5	15.8	100.0	220.0
	Wainuiomata R. d/s of White Br.	60	9.0	18.5	40.5	100.0	279.0	170.0	1000.0	6300.0
	Waiwhetu S. @ Whites Line East	60	13.0	145.0	285.0	495.0	1548.6	1000.0	5800.0	29000.0
	Whakatikei R. @ Riverstone	60	3.0	4.5	11.5	21.5	89.3	39.0	290.0	2400.0

Appendix 3: Box and whisker plot interpretation



Appendix 4: Summary of Attribute States for Total Ammoniacal Nitrogen, Nitrate, *E. coli* and Periphyton, copied from Appendix 2 of the National Policy Statement for Freshwater Management (2014).

Table A4.1: Attribute states for Ammonia (Toxicity) taken from Appendix 2 of the National Policy Statement for Freshwater Management (2014).

Value	Ecosystem health		
Freshwater Body Type	Lakes and Rivers		
Attribute	Ammonia (Toxicity)		
Attribute Unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median*	**Annual Maximum***	
A	≤ 0.03	≤ 0.05	99% species protection level. No observed effect on any species.
B	>0.03 and ≤ 0.24	>0.05 and ≤ 0.40	95% species protection level. Starts impacting occasionally on the 5% most sensitive species.
C	>0.24 and ≤ 1.30	>0.40 and ≤ 2.020	80% species protection level. Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species).
National Bottom Line	**1.30**	**2.20**	
D	>1.30	>2.20	Starts approaching acute impact level (i.e. risk of death) for sensitive species.

*Based on pH 8 and temperature of 20°C
Compliance with the numeric attribute states should be undertaken after pH adjustment.

Table A4.2: Attribute states for Nitrate (Toxicity) taken from Appendix 2 of the National Policy Statement for Freshwater Management (2014) (updated September 2017).

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Nitrate (Toxicity)		
Attribute Unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	**Annual 95th Percentile**	
A	≤ 1.0	≤ 1.5	High conservation value system. Unlikely to be effects even on sensitive species.
B	>1.0 and ≤ 2.4	>1.5 and ≤ 3.5	Some growth effect on up to 5% of species.
C	>2.4 and ≤ 6.9	>3.5 and ≤ 9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
National Bottom Line	**6.9**	**9.8**	
D	>6.9	>9.8	Impacts on growth of multiple species, and starts approaching acute impact level (i.e. risk of death) for sensitive species at higher concentrations (> 20 mg/l).

Note: This attribute measures the toxic effect of nitrate, not the trophic state. Where other attributes measure trophic state, for example periphyton, freshwater objectives, limits and/or methods for those attributes will be more stringent.

Table A4.3: Attribute states for *E. coli* taken from Appendix 2 of the National Policy Statement for Freshwater Management (2014) (updated September 2017).

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	*E. coli*				
Attribute Unit	*E. coli* / 100ml (number of *E. coli* per hundred millilitres)				
Attribute State	Numeric Attribute State				Narrative Attribute State
	% exceedances over 540 cfu/100ml	% exceedances over 260 cfu/100ml	Median concentration (cfu/100ml)	95th percentile of *E. coli* /100ml	Description of risk of *Campylobacter* infection (based on *E. coli* indicator)
A (blue)	<5%	<20%	<130	<540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 1% *.
B (green)	5-10%	20-30%	<130	<1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 2% *.
C (yellow)	10-20%	20-34%	<130	<1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk). The predicted average infection risk is 3% *.
D (orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >3% *.
E (red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is >50 in 1000 (>5% risk). The predicted average infection risk is >7% *.

* The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.

Table A4.4: Attribute states for Periphyton taken from Appendix 2 of the National Policy Statement for Freshwater Management (2014).

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Periphyton (Trophic state)		
Attribute Unit	mg chl-a/m^2 (milligrams chlorophyll-a per square metre)		
Attribute State	**Numeric Attribute State (Default Class)**	**Numeric Attribute State (Productive Class[1])**	**Narrative Attribute State**
	Exceeded no more than 8% of samples[2]	**Exceeded no more than 17% of samples[2]**	
A	≤ 50	≤ 50	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat
B	>50 and ≤ 120	>50 and ≤ 120	Occasional blooms reflecting low nutrient enrichment and/or alteration of the natural flow regime or habitat
C	>120 and ≤ 200	>120 and ≤ 200	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat
National Bottom Line	**200**	**200**	
D	>200	>200	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat

1. Classes are streams and rivers defined according to types in the River Environment Classification (REC). The Productive periphyton class is defined by the combination of REC "Dry" Climate categories (i.e. Warm-Dry (WD) and cool-Dry (CD)) and REC Geology categories that have naturally high levels of nutrient enrichment due to their catchment geology (i.e. Soft-Sedimentary (SS), Volcanic Acidic (VA) and Volcanic Basic (VB)). Therefore, the productive category is defined by the following REC defined types: WD/SS, WD/VB, WD/VA, CD/SS, CD/VB, CD/VA. The default class includes all REC types not in the Productive class.
2. Based on monthly monitoring regime. The minimum record length for grading a site based on periphyton (chl-a) is 3 years.