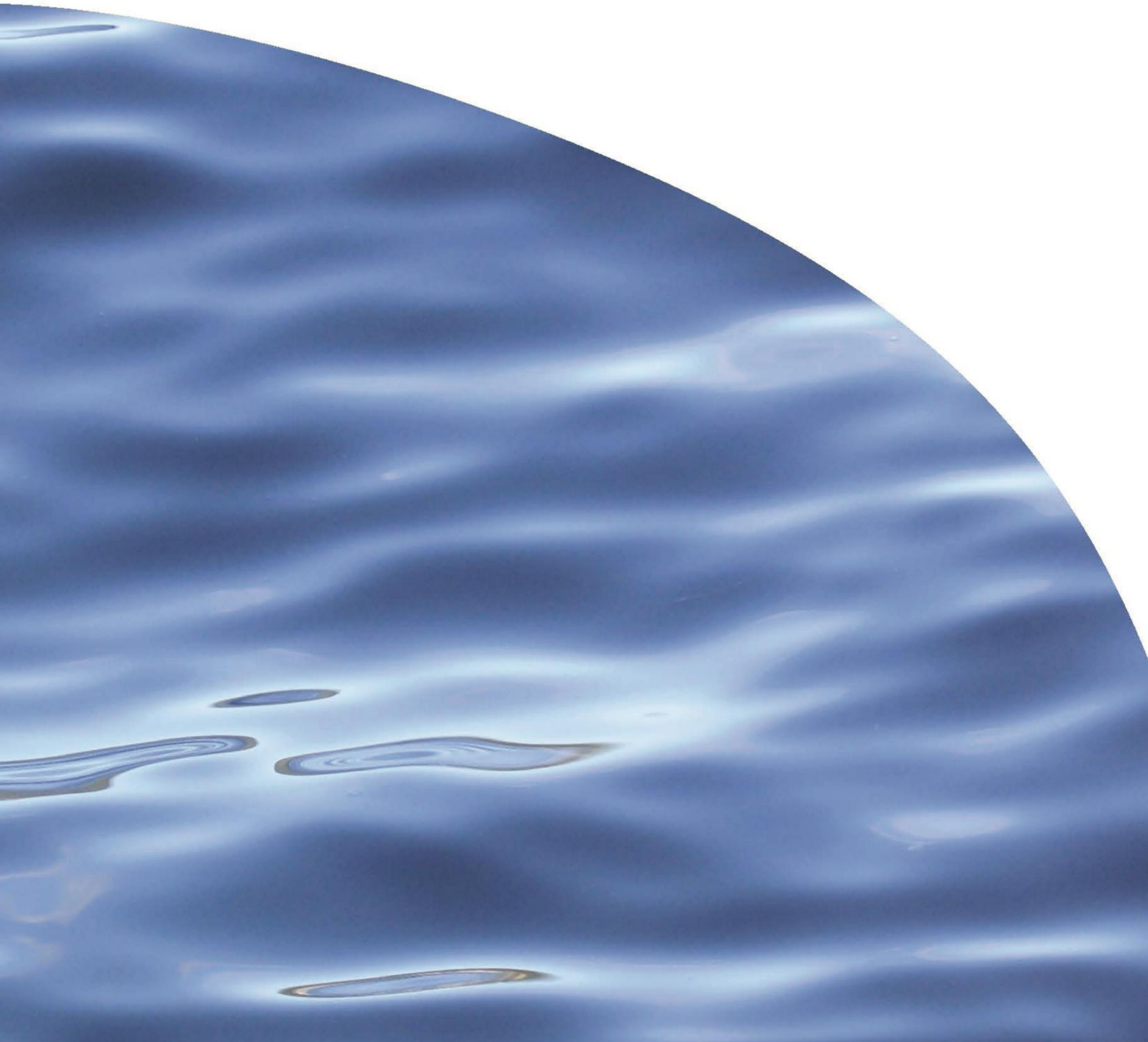
REPORT NO. 3601

# ECOLOGICAL SURVEY OF THE WAIRORO STREAM NEAR THE KAIKOHE WASTEWATER TREATMENT PLANT



# ECOLOGICAL SURVEY OF THE WAIRORO STREAM NEAR THE KAIKOHE WASTEWATER TREATMENT PLANT

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Prepared for Far North District Council

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# EXECUTIVE SUMMARY

The Far North District Council (FNDC) holds a resource consent to discharge treated wastewater from the Kaikohe wastewater treatment plant (WWTP) to an unnamed tributary that then enters the Wairoro Stream. This consent is due to expire in November 2021. The council intends to upgrade the plant with improvements in organics removal, nitrogen removal (nitrate and ammonia) and disinfection of bacteria. However, this upgrade will not be in place before the consent expiry date. Cawthron was commissioned to undertake an assessment of ecological effects of the current WWTP discharge in the Wairoro Stream, which included an ecological survey of the stream.

On 14 October 2020, Cawthron staff surveyed the Wairoro Stream. The 2020 ecological survey, FNDC monitoring data, and results from a previous ecological survey undertaken by Cawthron in 2014 all indicate that the water quality of the Wairoro River upstream of the WWTP discharge is not high. Nevertheless, it was evident from the 2020 and 2014 ecological surveys that below the discharge there is a further reduction in water quality, shown as a change in macroinvertebrate and periphyton communities.

Analysis of spot sample water quality data, in conjunction with long-term FNDC monitoring data, confirmed that the following parameters are a cause for concern in respect of achieving the current discharge consent standards, and the standards set in the PRP: nutrients, ammonia, and *E. coli*. More recently, there have been indications in the FNDC monitoring data that dissolved oxygen concentrations at the downstream site are falling below the NPS-FM 2020 national bottom line, although they comply with that limit upstream. Reduction of nutrient concentrations in the discharge should indirectly positively affect the ecology of Wairoro Stream, largely through reducing periphyton growth.

Periphyton cover upstream of the discharge were indicative of good water quality with no evidence of excessive algal growth. Downstream of the discharge there was a pronounced increase in periphyton cover indicative of increased enrichment (nutrients). The Cawthron 2014 and 2020 reports suggested that enrichment impacts of the discharge on Wairoro Stream ecology may extend a long distance downstream (up to 2000 m). However, the likelihood of other sources of enrichment entering the stream between the discharge and the lowermost sampling sites (e.g. diffuse runoff from nearby farmland), limits the feasibility of this assessment; whether this is occurring will most likely be answered once the WWTP has been upgraded.

In the 2020 ecological survey the biotic indices for ecosystem health (Macroinvertebrate Community Index and Semi-Quantitative Macroinvertebrate Community Index) in the Wairoro Stream (up and downstream of the discharge) were only just above, or did not meet, the national bottom line requirements in the National Policy Statement for Freshwater Management 2020. There was evidence to suggest that the discharge may not be fully mixed across the whole width of the stream at the sampling location 50 m downstream of the

discharge. Nutrient and bacterial concentration from samples collected mid channel were lower at 50 m downstream, than at 80 m downstream of the discharge.

In the interim period (before the new plant is built), the present nutrient content of the discharge is unlikely to result in further degradation of ecological communities; the invertebrate and periphyton communities between 2014 and 2020 surveys provided evidence of this. However, recent reductions in dissolved oxygen downstream of the discharge below the national bottom line warrants further investigation, as dissolved oxygen is essential to the life-supporting capacity of a waterway. This assumes that the water quality of the discharge does not reduce further and/or the volume discharged does not increase.

For future monitoring (to assess effects on stream ecology) we recommend:

- Based on some recent spot DO levels recorded at the downstream FNDC monitoring site falling below the national bottom line for protection of ecosystem health, DO should be closely monitored. If there is further evidence for low DO concentrations below the national bottom line, the causes of this should be investigated and ideally addressed.
- A dye study during a summer low flow event would be useful for defining the mixing zone (i.e. the point at which full mixing occurs) relative to the current and proposed mixing zones of 50 and 80 m, respectively. This would help define the point where full mixing occurs and guide appropriate monitoring locations.
- Water quality and ecological surveys should be undertaken in the summer months (December-February) when stream water flows are low and ambient temperatures are highest, i.e. when the effects of the discharge on the ecological integrity of the stream will be greatest.
- Monthly monitoring at a site up and downstream (we suggest approximately 50 m in either direction) of the discharge should be sufficient for most of the water quality parameters, although increased frequency of sampling nutrients, DO and *E. coli* should be considered during the summer months.
- In addition to spot measurements, continuous DO measurements be taken upstream and downstream of the discharge at least once during summer over the course of a week using a combined DO/temperature logger to ascertain the 1-day and 7-day minima (bringing the DO records in line with the PRP and NPSFM 2020 standards).
- Temperature be monitored continuously over the summer period each year so that a Cox-Rutherford Index (CRI) value, averaged over the five hottest days can be calculated (as per the PRP standard for temperature).
- A further ecological survey (using the methods adopted in the 2020 survey) may be warranted in the interim period depending on when the plant upgrade is completed. We recommend ecological monitoring be undertaken on an annual basis for two consecutive years following the plant upgrade to establish a baseline of information. Monitoring frequency could then be revised to a longer time frame e.g. 3- or 5-year intervals, depending on whether the results of the two-year monitoring regime show improvement relative to the pre-upgrade 2014 and 2020 ecological surveys.

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# 1. INTRODUCTION

The discharge consent for the Kaikohe wastewater treatment plant (WWTP) expires in November 2021. The plant, which is located 1.2 km southeast of the town, includes an anaerobic pond, followed by an oxidation pond and constructed wetland. From the wetland, wastewater discharges via an unnamed tributary to the Wairoro Stream. The discharge is authorised by Northland Regional Council (NRC) consent AUT.0002417.01.03 which expires 30 November 2021. The Far North District Council (FNDC) owns and operates the treatment plant. In September 2020, FNDC commissioned Cawthron to provide an assessment of the ecological effects of the discharge on the receiving environment.

FNDC identified four main issues to be considered in any assessment. These are:

1. Assumed water quality standards (water quality standards for ecosystem health in rivers)—The Proposed Regional Plan for Northland (PRP) (appeals version) regulates the discharges from wastewater treatment plants. Policy D.4.1 (3) states that the consent authority will not generally grant a proposal if it will, or is likely to, exceed or further exceed water quality standards in H.3 of the PRP. Assumed water quality standards for the Kaikohe WWTP from Policy H.3.1 of the PRP are provided in Table 1.
2. Ammonia and elevated nutrients in discharge—Current non-compliance with ammonia standards at a downstream sampling point is noted. In 2014, Far North District Council (FNDC) commissioned the Cawthron Institute to undertake an assessment of the effects of ammonia on the fauna of the stream (Wagenhoff & Shearer 2014). Under the consent, total ammoniacal nitrogen (total ammonia-N) concentrations must not cause acute toxicity or significant effects of chronic toxicity to natural aquatic life in the Wairoro Stream downstream of the discharge. This 2014 report concluded that despite repeated breaches, total ammonia-N concentrations were probably not having significant adverse effects on the macroinvertebrate community. However, the report did suggest there was some measurable impact of the discharge as a whole, on the macroinvertebrate community at least 1.1 km downstream of the discharge (this distance represents the downstream extent of sample sites used in the 2014 survey). The cause of the impact was attributed at least partly to elevated nutrient levels and periphyton growth. Recently, consultants undertaking a hydrological survey showed there may be limited dilution of contaminants in the discharge within the river system, which means the adverse effects identified in an ecological survey undertaken by Cawthron in 2014 (Wagenhoff & Shearer 2014) may occur much further downstream than the 1.1 km extent of that study.
3. Compliance point—The current compliance point to achieve discharge standards for the treatment plant is 80 m downstream of the point of discharge to the Wairoro Stream. However, under the PRP, Northland Regional Council (NRC) is

likely to consider 50 m to be the zone of reasonable mixing and compliance for the upgraded FNDC plant.

4. Plant upgrade—It is anticipated the plant will need to be upgraded to reduce ammonia / nitrogen levels in the discharge and achieve the standards in Table 1, 50 m downstream of the discharge point. These standards are from the proposed Regional Plan for Northland and FNDC expects the Kaikohe WWTP will have to conform to these standards.

Table 1. Water Quality Standards for ecosystem health from policy H.3.1 of the proposed Regional Plan for Northland (appeals version) supplied to Cawthron by FNDC in August 2020. Water quality standards apply after reasonable mixing. *E. coli* standards are equivalent to Attribute State A of the NPSFM 2020.

| Attribute | Compliance metric and standards for other rivers |
|---|---|
| Ammonia (toxicity)<br>(mg $NH_4$-N/L) | Annual median ≤ 0.24*<br>Annual maximum ≤ 0.40* |
| Nitrate (toxicity)<br>(mg $NO_3$-N/L) | Annual median ≤ 1.0<br>Annual 95th percentile ≤ 1.5 |
| Dissolved oxygen<br>(mg/L) | 7-day mean minimum ≥ 5.0<br>1-day minimum ≥ 4.0 |
| Temperature (°C) | Summer period measurement of the Cox-Rutherford Index (CRI), averaged over five hottest days ≤ 24 °C |
| pH | Annual minimum and maximum (> 6 and < 9) |
| *E. coli* (cfu/100mL) | % exceedances over 540 are < 5<br>% exceedances over 260 are < 20<br>Median ≤ 130<br>95th percentile ≤ 540 |

*Based on pH 8 and temperature of 20 degree Celsius. Compliance with water quality standard should be undertaken after pH adjustment.

With these considerations in mind and in the context of the National Policy Statement for Freshwater Management 2020 (NPSFM 2020), which came into effect in September 2020, Cawthron undertook a field survey to assess the chemical and biological impacts of the discharge on the Wairoro Stream. The conclusions from this were supplemented by a desktop study of water quality monitoring data supplied by FNDC in October 2020. This would allow:

1. An assessment of the current impacts of the discharge on water quality and biota, particularly in terms of eutrophication issues.
2. An initial assessment of the adequacy of current and proposed compliance points regarding assumptions about the reasonable mixing zone and to provide representative water quality assessments.

3. An assessment of the WWTP discharge in respect of current consent conditions, PRP assumed water quality standards and NPSFM 2020 attribute standards. Although parameters linked to eutrophication issues were the main focus, these are discussed in the context of the quality of the discharge as a whole.
4. An identification of strategies to avoid or mitigate any adverse effects on the water quality / ecology of the Wairoro Stream and recommendations for on-going monitoring for long-term effects of the discharge on the receiving environment.

It should be noted that the Council must give effect to the NPSFM 2020 as soon as is reasonably practicable and no later than 31 December 2024. The ecological assessment below was based on the water quality standards and guidelines in the PMP supplied to Cawthron by FNDC in August 2020 (Table 1), although the latest appeals version of the PRP (i.e. Proposed Regional Plan for Northland, Appeals Version - May 2021) was also taken into account.

# 2. METHODS

## 2.1. Study design and field sites

The Wairoro Stream is a fourth-order stream within a predominately pastoral catchment of 30 $km^2$. Flow for the Wairoro Stream is recorded above the township of Kaikohe at the town's water intake weir. The median flow at the weir is estimated to be around 430 L/s (FNDC pers comm.). The 'Wairoro at FNDC weir' flow recorder is approximately 4.5 km above the Wairoro Stream plant with several small tributaries entering the stream between the weir and WWTP. However, flow in the Wairoro Stream has been recently modelled at Cumber Road (approximately 1 km above the WWTP), and based on that modelled output, the following predicted flow statistics were calculated: a 7-day mean annual low flow (MALF) of 122 L/s, minimum flow of 36.5 L/s, median flow of 528 L/s and average number of high flow events per year greater than 3 times the median ($FRE_3$) of 16 (WWLA 2020).

The maximum volume of water that can be discharged from the WWTP under the current consent is 1,710 $m^3$/day (Appendix 1), although based on flow data collected from April 2013 to March 2018 average plant flow was 1,436 $m^3$/day and the 95th percentile flow 2,456 $m^3$/day (FNDC pers comm.). To place the size of the WWTP discharge in context to the Wairoro Stream, the volume of water in the Wairoro Stream at Cumber Road based on modelled minimum flow and MALF values presented above would be 3,154 and 10,541 $m^3$/day[1], respectively.

Ideally, the ecological survey would be undertaken during base flow conditions when dilution of the WWTP discharge in the stream is at its lowest. This allows assessment of the effects of contaminants under a near-worst-case scenario. However, due to highly variable weather conditions and a limited time window, sampling was eventually carried out on 14 October 2020 after a day's heavy rainfall, as indicated by flow data recorded upstream at the 'Wairoro at FNDC weir' flow recorder site (Figure 1).On 14 October 2020, flow at recorder was 0.095 $m^3$/s (95 L/s) at 9.15am when sampling of the Wairoro Stream commenced, and it was 0.090 $m^3$/s (90 L/s) when sampling ceased at 3.05pm. A gradual decline in water level was observed over this period in the Wairoro Stream.

[1] It is likely the minimum flow and MALF in $m^3$/day will be a bit higher than this in Wairoro Stream near the WWTP, as a small tributary enters the stream below the Cumber Rd bridge.

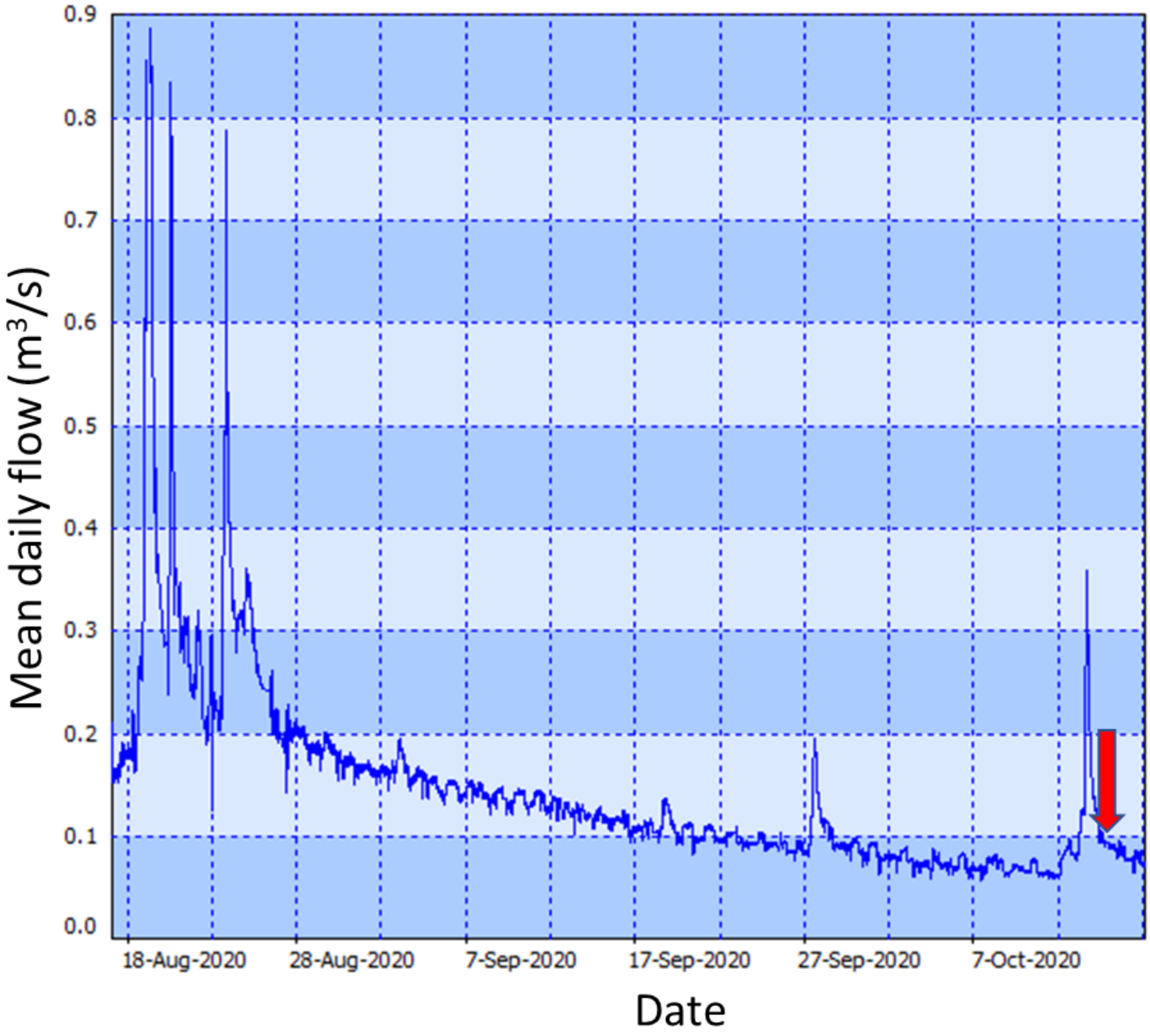


Figure 1. Discharge recorded at the Northland Regional Council flow station 'Wairoro at FNDC weir' for two months prior to the Cawthron ecological survey undertaken on 14 October 2020 (see red arrow).

Sampling for the present study included five sites sampled from a previous ecological survey undertaken by Cawthron in 2014 (Wagenhoff & Shearer 2014) plus three additional sites. Of the original 2014 survey sites, two were in the Wairoro Stream upstream of the discharge point, two were downstream of the discharge and one was in the unnamed tributary carrying the treated effluent discharge. The three new sites were 50 m, 80 m and approximately 2000 m downstream of the discharge point (Table 2, Figure 2). These sites include two FNDC Wairoro Stream water quality compliance monitoring sites: site 103316, which is our 50 m upstream of discharge site, and site 100807. which is our 150 m downstream of discharge site. A third FNDC water quality site 100560) is in the unnamed tributary discharge site) (Table 2, Figure 2 and Appendix 1). The longitudinal survey design allowed 1) comparison of conditions between upstream and downstream sites to assess effects of the discharge and 2) tracking of potential improvement with increasing distance from the discharge.

Table 2. Sites sampled in the 2020 survey for assessing environmental effects of discharge. '2014' refers to sites established in an earlier ecological survey undertaken by Cawthron in 2014 (Wagenhoff & Shearer 2014).

| Site | Description | Year established |
|---|---|---|
| 1 | 410 m upstream | 2014 |
| 2 | 50 m upstream (site 103316) | 2014 |
| 3 | Unnamed tributary – discharge (site 100560) | 2014 |
| 4 | 50 m downstream | 2020 |
| 5 | 80 m downstream | 2020 |
| 6 | 150 m downstream (site 100807) | 2014 |
| 7 | 1100 m downstream | 2014 |
| 8 | 2000 m downstream | 2020 |

Sampling at each site repeated that of the 2014 ecological survey and included macroinvertebrate community analysis, water chemistry and microbiological analysis. In addition, periphyton cover was assessed to address concerns about nutrient enrichment and periphyton proliferation referred to in the 2014 report. The 2014 report also voiced concerns that the impact of nutrient enrichment was evident up to and including the most distant downstream site in that study (1100 m) and speculated how far downstream the nutrient enrichment impacts went. The new 2000 m downstream site was designed to allow some assessment of this.


Figure 2. Field sampling sites in the Wairoro Stream and an unnamed tributary containing treated effluent from the Kaikohe wastewater treatment plant (WWTP). Sites upstream and downstream of the confluence with the unnamed tributary are denoted u/s and d/s, respectively. The satellite image was downloaded from Google Earth in September 2020. See Appendix 1 for a more detailed schematic of the WWTP layout.

## 2.2. Sample collection and analysis

### *2.2.1. Water quality*

Spot measurements of water temperature (ºC), dissolved oxygen concentration (mg/L) and percentage saturation (%), and specific conductivity (µS/cm), were taken with a YSI ProPlus hand-held water quality meter. Turbidity (NTU) was measured using a Hach 2100P Turbidimeter.

Water samples were collected to measure stream water concentrations of dissolved inorganic forms of nitrogen (Nitrate-N, Nitrite-N, total ammonia-N), total Kjeldahl nitrogen (TKN), total nitrogen (TN), turbidity, suspended solids, total phosphorus (TP), dissolved reactive phosphorus (DRP) and the faecal indicator bacteria *Escherichia coli* (*E. coli*) Samples were placed on ice shortly after collection and couriered to Hill Laboratories at the end of the day, where they were then analysed using standard laboratory methods.

All water quality sampling was carried out in mid-stream at each site, assuming reasonable mixing at each site including FNDC compliance points, to provide representative samples for water quality monitoring. Sampling at mid-stream ensured consistency in sampling among sites.

An electronic log-book of consent water quality monitoring was also provided by FNDC, and data pertaining to the period 2010-2020 is referred to in the report where relevant.

### 2.2.2. Periphyton

In addition to assessing percentage cover of periphyton at each site, the rapid assessment protocol RAM 2 of Biggs and Kilroy 2000 was carried out to enable broad differences in mat types (as defined by colour, thickness and filament length) to be documented, scored and interpreted in terms of stream health and habitat conditions. The only site where periphyton assessment was not carried out was site 3, the unnamed tributary discharge (site 100560), owing to health and safety concerns over contact with the contaminated discharge water when retrieving stones from the stream to undertake the assessment.

### 2.2.3. Macroinvertebrates

Macroinvertebrate samples were collected from each site with a kick-net (0.5 mm mesh), following the hard-bottomed semi-quantitative protocol C1 from Stark et al. (2001). At each site, samples were taken midstream in a run or riffle as these habitats tend to have greatest macroinvertebrate density and diversity. Samples were preserved in 70% ethanol.

In the laboratory, macroinvertebrate samples were processed according to protocol P1 from Stark et al. (2001). Macroinvertebrates were identified to the lowest possible taxonomic level using the keys in Winterbourn et al. (2006), then counted and recorded.

### 2.2.4. EPT metrics

EPT taxa comprise the taxonomic insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), all of which have aquatic larval stages. They tend to be more sensitive to pollution than other macroinvertebrates (except for Hydroptilidae[2]), such as true-fly larvae and worms. Hence, high EPT taxon richness (%$EPT_{Taxa}$) are generally indicative of a community less impacted by pollution.

### *2.2.5. Calculation and interpretation of the Macroinvertebrate Community Index and the Semi-Quantitative Macroinvertebrate Community Index*

The Macroinvertebrate Community Index (MCI) and its variants the semi-quantitative MCI (SQMCI) and quantitative MCI (QMCI), are ‘stream health’ indices developed for assessment of organic pollution and nutrient enrichment in stony streams and rivers (Stark 1998, Stark & Maxted 2007). They rely on prior allocation of scores (range of 1 to 10) to macroinvertebrate taxa (usually genera) based upon their tolerance to pollution. Taxa that are characteristic of unpolluted conditions and/or coarse stony substrates score more highly than taxa that may be found predominantly in polluted conditions or amongst fine organic sediments.

Calculation of the MCI involves summing the scores for each taxon present, dividing by the number of scoring taxa and multiplying by 20 (a scaling factor). In theory, MCI values can range between 0 (when no taxa are present) and 200 (when all taxa have a score of 10). However, it is rare to find MCI values greater than 150, and only extremely polluted, sandy/muddy sites have values smaller than 50. Similarly, SQMCI and QMCI values theoretically range from 0 to 10. Unlike the MCI, which is based on only the presence of each scoring taxa, the semi-quantitative and quantitative versions includes percentage community composition to weight the overall index value towards the scores of the dominant taxa. Stream health can be categorised as ‘excellent’, ‘good’, ‘fair’ or ‘poor’ on the basis of MCI and SQMCI bands.

### *2.2.6. Fish*

No fish records were available in the New Zealand Freshwater Fish Database[3] for the Wairoro Stream segment that contained our sampling sites. Fish observations were made at each site during water and macroinvertebrate sampling.

[2] Note: small algal-piercing caddis flies belonging to the group Hydroptilidae (*Oxyethira* sp. and *Paroxyethira* sp.) are excluded from the %EPT calculation, as unlike other caddis fly taxa they are more commonly associated with the effects of enrichment/pollution (hence their low MCI taxon score of 2 – see Appendix 4).

[3] NZ Freshwater Fish Database |NIWA; accessed December 2020.

# 3. RESULTS AND DISCUSSION

## 3.1. Water quality

The water quality results for the 2020 ecological survey and the FNDC water quality monitoring data are first analysed in the context of the prevailing consent conditions (Appendix 1, Part 7). The approach we have adopted is to discuss the water chemistry results in the context of the existing consent conditions (that were based primarily on ANZECC guidelines) in this section and then in Section 4 to consider them in the context of the Water Quality Standards of Policy H3.1 of the PRP for Northland (appeals version) and the NPSFM 2020.

The Australian and New Zealand Environment and Conservation Council (ANZECC 2000) default guideline values (DGVs) and 'trigger values' were partially used to inform discharge standards set out in the consent issued in 2005. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality were revised in 2018, with a greater adoption of an eco-regionalisation approach and an emphasis on councils collecting 'weight of evidence' data to set DGVs for their, ideally, site-specific local conditions/situations. The Water Quality Guidelines' DGVs have no formal legal status, and their use is not mandatory, unless specified as being so by the relevant jurisdictional authority. Whilst some DGVs have changed, many are still in development and some remain the same as in 2000.

Spot samples were taken on 14 October 2020 and included pH, temperature, dissolved oxygen (DO) concentration and percentage saturation, specific conductivity and turbidity at the eight sites (Table 3). Temperature, pH and DO follow diurnal cycles in streams so it should be noted that comparisons between sites in this report relate to the time of day sampled and do not account for daily maxima and minima. The results from analysis of water samples for dissolved inorganic forms of nitrogen, TKN, TN, turbidity, suspended solids, TP, DRP and *E. coli* are shown in Appendix 2.

Table 3. Spot measurements of daytime pH, temperature, dissolved oxygen (DO) concentration and percentage saturation, specific conductivity and turbidity at seven Wairoro Stream sites and in the unnamed tributary carrying the discharge of the Kaikohe WWTP.

| Site | Time | pH | Temperature (°C) | DO (mg/L) | DO (%) | Specific conductivity (µS/cm) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|
| 410 m upstream | 14:25 | 6.34 | 14.0 | 9.77 | 95.1 | 108.6 | 11 |
| 50 m upstream | 15:.05 | 6.68 | 14.1 | 9.65 | 94.0 | 108.7 | 11 |
| Unnamed tributary | 13:28 | 6.75 | 16.3 | 2.82 | 28.6 | 532.4 | 28 |
| 50 m downstream | 12:40 | 7.05 | 14.1 | 8.69 | 82.1 | 118.0 | 12 |
| 80 m downstream | 11:55 | 6.28 | 14.1 | 9.66 | 94.0 | 134.9 | 13 |
| 150 m downstream | 11:29 | 6.40 | 14.0 | 9.63 | 92.7 | 135.3 | 14 |
| 1100 m downstream | 09:13 | 6.72 | 13.2 | 8.73 | 82.0 | 130.8 | 16 |
| 2000 m downstream | 10:12 | 6.59 | 14.1 | 8.88 | 86.1 | 178.2 | 17 |

At the discharge site no sewage fungus was noted in the unnamed tributary, but a strong odour and foam near the discharge was evident (C MacNeil, pers. obs.).

### *3.1.1. Temperature*

Resource consent condition 7 (a) states that the natural temperature of the water shall not be changed by more than 3.0 °C, as a result of the discharge (Appendix 1). There was little difference between the temperatures of the seven Wairoro stream sites (a range of only 0.9 °C between the highest temperature sites (14.1 °C) and the lowest temperature site (13.2 °C)). By contrast, the tributary discharge site was 2.2 °C higher than the highest temperatures recorded at downstream sites in the Wairoro Stream and 2.3 °C higher than the 50 m upstream site. In summary, the evidence from the ‘one-off’, spot-sample survey is that the stream site temperature range complied with the consent condition.

On 23 October 2020, FNDC supplied Cawthron with the logbook for routine consent monitoring at their upstream and downstream monitoring sites for the Kaikohe WWTP. This covered the period from January 2010 to October 2020. Brief analysis of this data-set showed only 1% (2 out of nearly 200 samples) of routine monitoring samples were non-compliant for temperature during this 10-year period. On both occasions (in February 2011 and January 2012) temperatures were higher downstream than upstream and at a level that could have potentially been an issue for aquatic species. Invertebrate communities can survive short-term temperature spikes provided they can find some thermal refuges (e.g. areas of cool upwelling water). There have been no breaches of the temperature consent condition in the past 5 years of consent monitoring (i.e. 2015–2020).

### *3.1.2. pH*

pH ranges complied with resource consent conditions 7(b), Appendix 1. The pH at all downstream sites complied with the range set in the resource consent of 6.5 to 9.0. The pH at the 50 m and 80 m downstream sites was 7.05 and 6.28 respectively. In addition, the pH of the discharge site was 6.75, only marginally different from the 50 m upstream site (6.68) and the 410 m upstream site (6.34). FNDC log-book consent monitoring data covering the period from January 2010 to October 2020, showed 6% (12 out of 206 samples) of samples were non-compliant for pH during this 10-year period. On all 12 occasions pH was less than 6.5, and on 7 of the 12 occasions the upstream pH level were also below 6.5. The most likely effect of low pH on aquatic fauna (invertebrate and fish) downstream of the discharge would be indirect i.e. through the interaction of pH with other water quality parameters. For example, as pH decreases the toxicity potential of toxicants such as ammonia increase.

### *3.1.3. Dissolved oxygen*

The DO concentration in the water represents the balance between oxygen-consuming (e.g. respiration) and oxygen-releasing processes (e.g. photosynthesis). Dissolved oxygen can vary widely over a 24-hour period, especially where there is significant nutrient enrichment. Lowest levels of DO are normally at dawn just before photosynthesis resumes. Condition 7 (c) states the concentration of dissolved oxygen (daily minimum) should not be reduced by more than 20%. To comply with the condition, the daily minimum DO concentration in the Wairoro Stream at the monitoring site downstream of the confluence with the unnamed tributary must not be reduced by more than 20% compared with the upstream monitoring site.

The spot DO levels recorded at all five downstream sites in the 2020 survey (ranging from 50–2000 m) complied with this condition (but see discussion below regarding spot readings versus general compliance) (Table 3). There was only a 10% reduction in dissolved oxygen concentration between the 50 m downstream site and the upstream monitoring site. The 80 m downstream site's dissolved oxygen concentration was similar to the upstream monitoring site (i.e. 9.66 compared to 9.65 mg/L) and there was only a 0.2% reduction in dissolved oxygen concentration at the 150 m downstream site compared to the upstream monitoring site (Table 3).

Generally, DO levels less than 6 mg/L (or 80% saturation) are considered insufficient to support sensitive fish (such as trout) and macroinvertebrates (such as the EPT macroinvertebrates i.e. mayflies, stoneflies and most caddisflies) (ANZECC & ARMCANZ, 1992, 2000). All the river sites sampled had oxygen levels well in excess of this on 14 October 2020. While these point sample results are encouraging for demonstrating compliance with consent conditions, without knowledge of DO levels over the course of a day (i.e. to determine the daily minima) the spot measurements taken during the 2020 ecological survey cannot constitute confirmation of compliance with the consent condition for DO.

For example, examining the logbook for the Kaikohe WWTP, non-compliance between upstream and downstream monitoring sites) over the period January 2010 to October 2020 occurred for 7.5% of samples (15 out of 199). Figure 3 shows spot DO levels recorded by FNDC (January 2010 to October 2020) at their monitoring sites upstream and downstream of the discharge. Dissolved oxygen downstream of the discharge were above the NPSFM 2020 national bottom line of 4 mg/L on all but four occasions. On one of those occasions (August 2019) the downstream value was an improvement on the upstream value. On the other three occasions (March 2010, February 2020 and March 2020), the upstream value was above the national bottom line and downstream below the line (Figure 3). Although not a common occurrence in relation to the discharge, DO reductions such as this should be closely monitored and if similar reductions are recorded, investigated further. Spot water quality measurements are useful for highlighting where a potential problem may lie, but continuous monitoring for at least a week is required to provide information around the extent and duration of the reduction.

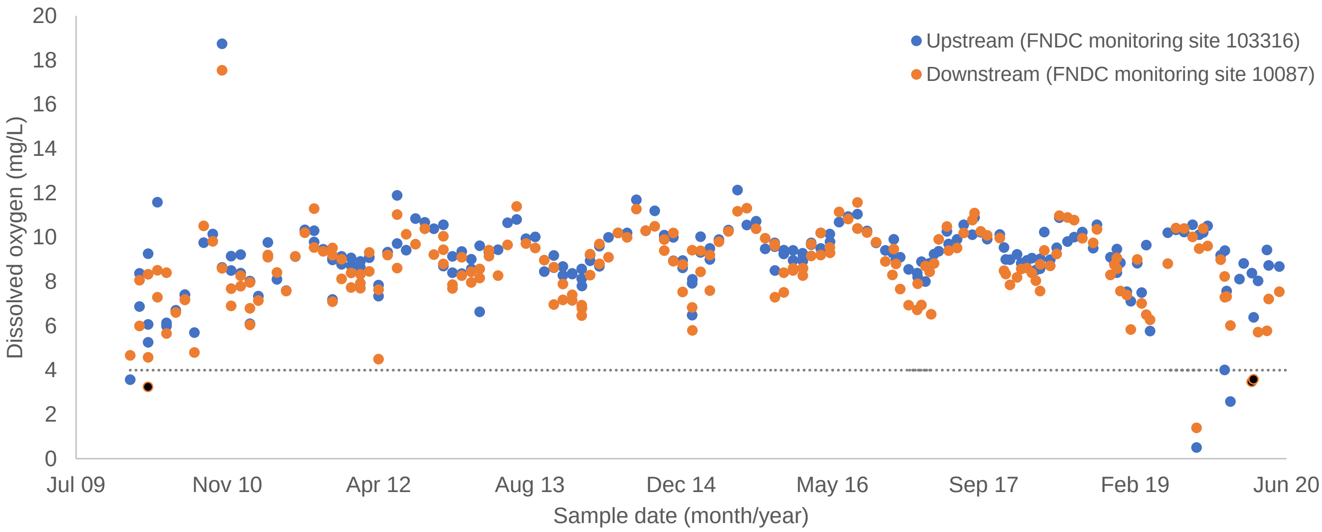


Figure 3. Spot DO measurements taken by FNDC at monitoring sites upstream and downstream of the Kaikohe WWTP. Dotted line represents the DO NPSFM 2020 national bottom line for the protection of ecosystem health. Black dots surrounded by an orange circle denote three sampling occasions where the downstream DO level was below the NPSFM 2020 national bottom line while the equivalent upstream site level was above the line.

Differences in oxygen levels between the sites upstream and downstream of the discharge are likely related to differences in periphyton biomass and communities (see Section 3.2). In comparison with the two upstream sites, there was extensive growth of moss, aquatic macrophytes, and long bright-green filamentous algae at the sites furthest downstream of the discharge (1100 m and 2000 m). While high periphyton and macrophyte biomass is usually associated with high DO levels during the day, owing to photosynthesis, the observed low oxygen levels at these two bottom sites may have been due to high oxygen demand from senescent and decaying algal communities. Biological oxygen demand ($BOD_5$) from organic pollution may have also played a role. The high percentage cover of long green filamentous algae at the 1100 m downstream site was also noted in the Wagenhoff and Shearer (2014) report, indicating this situation may have persisted for several years.

### *3.1.4. Conductivity and turbidity*

Specific conductivity and turbidity in the Wairoro Stream at the sites downstream of the discharge were higher than at the two upstream sites (Table 3). The Kaikohe WWTP discharge increased turbidity (i.e. decreased water clarity) in Wairoro Stream. Interestingly, the 50 m downstream site had lower conductivity and turbidity than the four sites further downstream (Table 3). While the discharge tributary had much higher conductivity and turbidity than any of the Wairoro Stream sites, the 2000 m downstream site had the highest conductivity and turbidity of the seven Wairoro Stream sites and may indicate poor mixing or the impact of, so far, unrecognised diffuse pollution and/or undetected point source pollution.

No guidelines currently exist that specifically set standards for change in conductivity in a stream. However, the differences in conductivity between the upstream and downstream survey sites suggest the WWTP discharge is affecting Wairoro Stream. Conductivity at all Wairoro Stream sites was much higher than in 95 rivers surveyed throughout New Zealand (Close & Davies-Colley 1990). Possible reasons for this include leaching of salts and ions from an underlying geological feature and/or cumulative land use effects (e.g. run-off from land into the stream as a consequence of agricultural/horticultural activities).

### *3.1.5. Total nitrogen, total ammonia-N and dissolved inorganic nitrogen*

**Total nitrogen**

Total nitrogen (as TN (Total Kjeldahl nitrogen TKN + nitrite-N + nitrate-N where TKN = organic N + total ammonia-N)) concentrations were markedly lower at the two upstream sites than those of the Kaikohe WWTP discharge in the unnamed tributary (Figure 4). The total nitrogen concentration of 0.69 mg /L at the 410 m upstream site was only marginally higher than the ANZECC (2000) trigger value of 0.614 mg TN/L (for slightly disturbed lowland ecosystems), while the concentration at the 50 m upstream site was just below it (0.60 mg TN/L). All downstream sites greatly exceeded this trigger value (range 1.10–2.50 mg TN/L). This reflects the N-enriched discharge entering the Wairoro Stream via the unnamed tributary (32 mg TN/L) (Figure 4).

Interestingly the total nitrogen concentration at the 50 m downstream site was less than half that of the 80 m downstream site (1.10 compared to 2.6 mg TN/L), and total ammonia-N at the 50 m downstream site was just over a quarter of that at the 80 downstream site (0.42 compared to 1.63 mg TN/L). This suggests relatively poor mixing across the stream by the 50 m downstream site such that the effects of the discharge on Wairoro Stream are not detected with mid-stream sampling. After the 80 m downstream site, a gradual decline in total nitrogen and total ammonia-N follow the pattern expected as mixing increases further from the discharge (Figure 4).

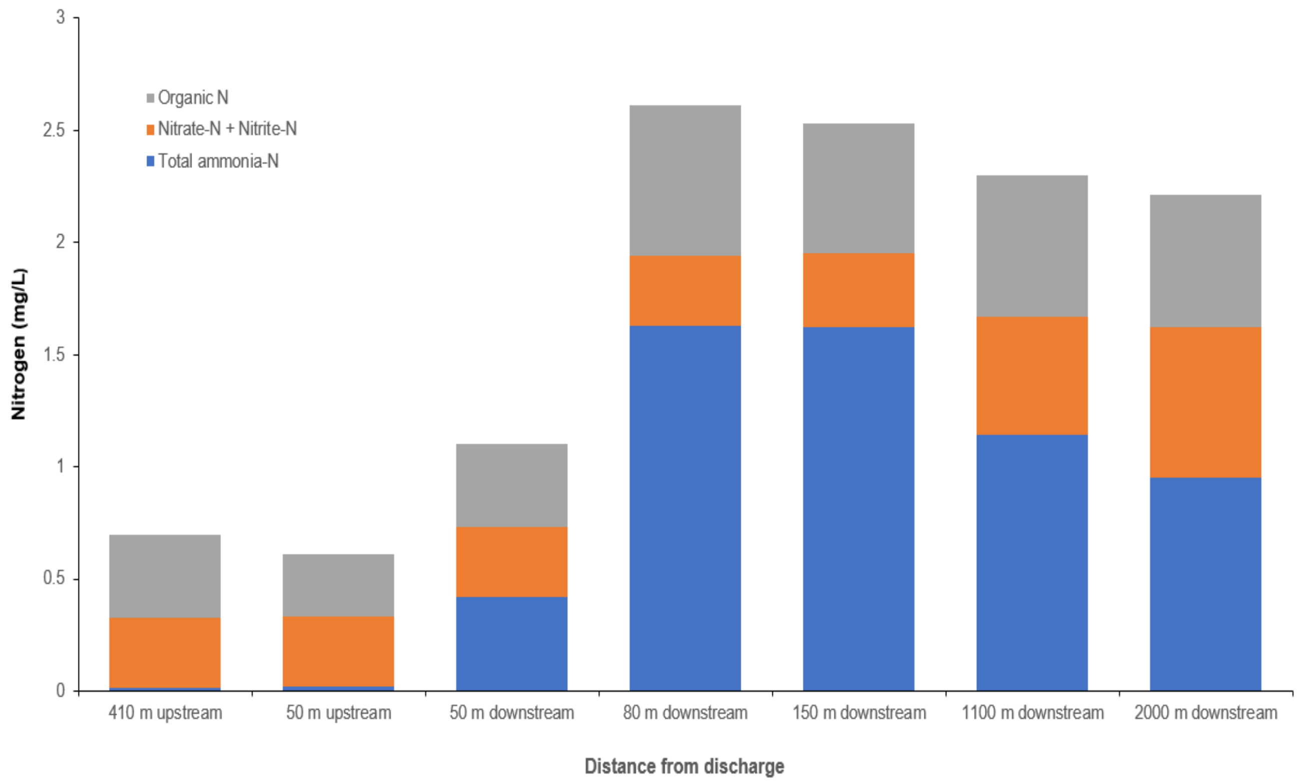


Figure 4. Total nitrogen (mg/L) found in single water samples collected mid-stream from seven Wairoro Stream sites upstream and downstream of the discharge from the Kaikohe WWTP via an unnamed tributary on 14 October 2020. Bars on the graph are divided into the component nitrogen elements that contribute to total nitrogen (Total nitrogen (TN) = Total Kjeldahl nitrogen (TKN) + nitrite-N + nitrate-N, where TKN = organic N + total ammonia–N). See Appendix 2 for Hill Laboratories' results for the water samples collected from the Wairoro Stream.

### Ammonia

Total ammonia is the sum of the ionised ammonium ion ($NH_4^+$) and ammonia ($NH_3$); the latter can be toxic to aquatic organisms. Neither form exists on its own, and the proportion of $NH_3$ increases at higher temperatures and pH (ANZECC & ARMCANZ 2000). Ammonia ($NH_3$) is a non-persistent and non-bioaccumulative toxicant to aquatic life (ANZECC & ARMCANZ 2000). However, if the concentration in the water is high enough, animals are not able to efficiently excrete it, resulting in build-up in internal tissue and blood. In extreme cases, death may result.

Trigger values for the protection of freshwater species against toxic levels of ammonia were provided in the ANZECC (2000) guidelines for receiving waters (Table 4). The ANZECC trigger values are the ammonia guidelines used for the Wairoro Stream monitoring in the resource consent (Appendix 1, condition7(i)). The consent also notes that if the background concentration of total ammonia-N as measured at Northland Regional Council Site Number 103316 upstream of the discharge point exceeds these concentrations, then the exercise of the consents should not result in an increase of total ammonia-N of more than 0.10 mg/L.

In the 2014 Cawthron survey, the Kaikohe WWTP discharge contained high levels of total ammonia (27 mg N/L) and hence, the Wairoro Stream concentrations were noticeably higher at the downstream sites compared to those upstream of the WWTP discharge (Wagenhoff & Shearer, 2014). In the same survey, total ammonia-N concentrations were below detection limit (< 0.010 mg/L) at the upstream sites but were highly elevated downstream from the discharge. Concentrations of 2.7 and 2.6 mg/L were recorded at the 150 m (site 100807) and 330 m downstream sites, respectively. These exceeded the consent limit (i.e. the ANZECC (2000) trigger value) of 2.33 mg/L for measured pH of 6.8 (Table 4). Total ammonia-N at the 1100 m downstream site was elevated (1.8 mg/L) but did not exceed the limit of 2.49 mg/L at measured pH of 6.4. The toxicity of total ammonia-N is very sensitive to pH, with higher toxicity at lower pH due to dissociation of $NH_3$. FNDC spot monitoring data collected from January 2010 to March 2014 showed that the pH range was similar upstream and downstream of the Kaikohe WWTP discharge (i.e. pH 6.7 to 8.0).

Table 4. Freshwater trigger values for total ammonia-N in mg/L at different pH (temperature is not taken into consideration), adapted from table 8.3.7 in the ANZECC (2000) guidelines. This table is also the guideline used in consent condition 7(i) (see Appendix 1). Grey shading marks the high reliability trigger value of 0.90 mg total ammonia-N/L (at pH 8.0) providing 95% species protection level.

| pH | Freshwater trigger value for total ammonia-N (mg/L) |
|---|---|
| 6.0 | 2.57 |
| 6.1 | 2.56 |
| 6.2 | 2.54 |
| 6.3 | 2.52 |
| 6.4 | 2.49 |
| 6.5 | 2.46 |
| 6.6 | 2.43 |
| 6.7 | 2.38 |
| 6.8 | 2.33 |
| 6.9 | 2.26 |
| 7.0 | 2.18 |
| 7.1 | 2.09 |
| 7.2 | 1.99 |
| 7.3 | 1.88 |
| 7.4 | 1.75 |
| 7.5 | 1.61 |
| 7.6 | 1.47 |
| 7.7 | 1.32 |
| 7.8 | 1.18 |
| 7.9 | 1.03 |
| 8.0 | 0.90 |
| 8.1 | 0.78 |
| 8.2 | 0.66 |
| 8.3 | 0.56 |
| 8.4 | 0.48 |
| 8.5 | 0.40 |
| 8.6 | 0.34 |
| 8.7 | 0.29 |
| 8.8 | 0.24 |
| 8.9 | 0.21 |
| 9.0 | 0.18 |

Of the spot ammonia samples taken on 14 October 2020, none of the seven Wairoro Stream samples came close to exceeding the trigger values. Interestingly, in the 2014 ecological survey total ammonia-N trigger levels were exceeded despite the tributary discharge ammonia levels being very similar between the 2020 and 2014 surveys (26 mg/L in 2020 and 27mg/L in 2014, respectively). A likely explanation for this is the

2020 samples were collected soon after a fresh (see Figure 1), so the dilution of ammonia in the Wairoro Stream may have been higher than in 2014 (where sampling was undertaken during low flow conditions).. The pH range throughout the whole survey site was relatively conservative, only ranging from 6.28–7.05, with little change upstream or downstream of the discharge.

Figure 5 shows total ammonia-N concentrations measured over a 15-year period (November 2005 to October 2020) at the FNDC compliance monitoring site 100807 downstream of the discharge. Ammonia consent limits were breached frequently, equating to approximately 33% of recorded values (i.e. 96 of 290 sampling visits when ammonia values were recorded) showing non-compliance with ANZEEC trigger values. Breaches often occurred in the drier summer months when dilution would have been lowest.

From February to May 2020, there were continuous significant breaches with very high levels of ammonia recorded (up to 21 mg/L) and the highest level ever recorded in the fifteen-year monitoring period (Figure 5). This may reflect a prolonged dry spell (Northland at the time was experiencing a drought) and, in general, high ammonia concentrations have been recorded during the drier summer months in previous years. Two of the ammonia samples taken downstream of the discharge on 25 February 2020 (21 $g/m^3$) and 3 March 2020 (20 $g/m^3$) (see Figure 5) were at a concentration that would affect several sensitive invertebrate species (i.e. acute toxicity ammonia $EC_{50}$s[4] for the mayfly *Deleatidium*, sandy cased caddis *Pycnocentria*, and the snail *Potamopyrgus* are 17.5, 16.3 and 9.8 respectively (Hickey 2000)—see also table 4 in Wagenhoff and Shearer 2014). However, an additional sample collected by FNDC staff on 26 February 2020 showed an ammonia concentration of 13 $g/m^3$ indicating some variability in the dilution (i.e. invertebrates downstream of the discharge were not necessarily being exposed to very high levels of ammonia over the course for several days).

Overall, elevated ammonia concentrations downstream of the discharge remains a significant problem and one of the major issues that is expected to be dealt with in the plant upgrade (FNDC, pers comm.).

[4] Acute toxicity is given as an $EC_{50}$ (effective concentration) – the concentration of ammonia which, for a given exposure time period (in this case 96 hours), 50% of the individuals of the test species were found to be dead or moribund.

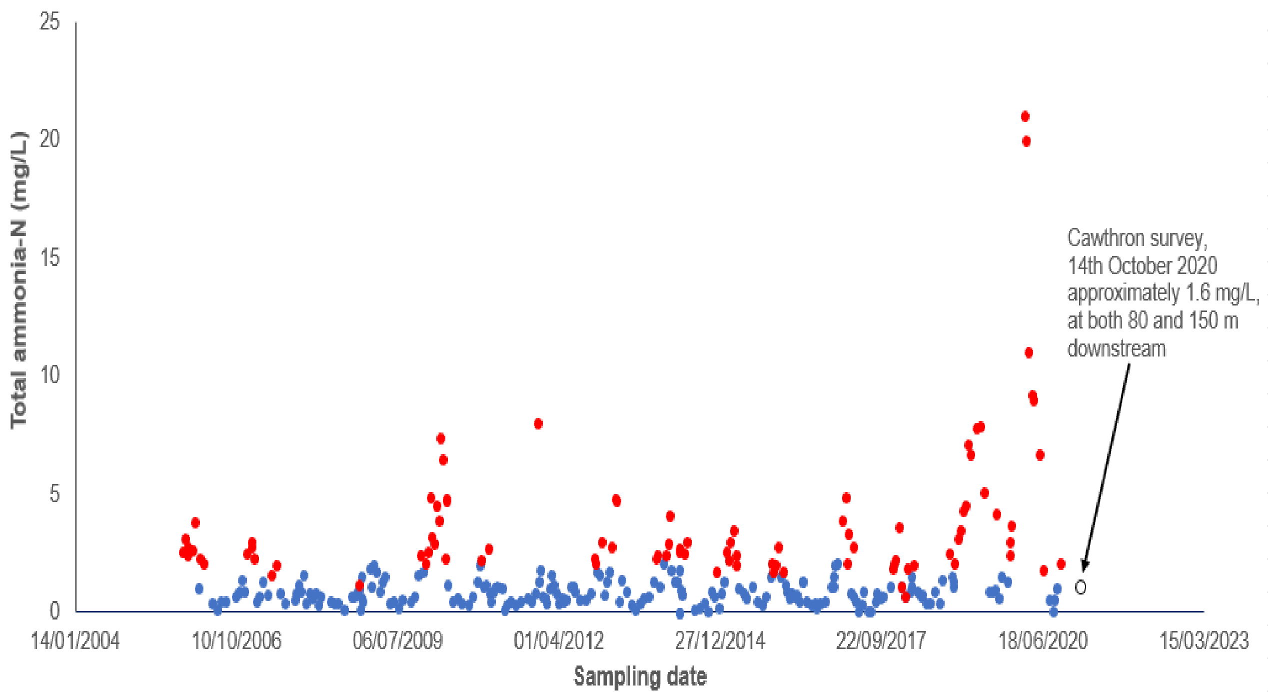


Figure 5. Total ammonia-N (mg/L) concentrations recorded in the Wairoro Stream during the Far North District Council's bi-monthly compliance monitoring (November 2005–October 2020) at site 100807. The red data points indicate non-compliance with regards to ANZECC (2000) trigger values for ammonia toxicity set out in the consent (Table 1). The white circle data point represents the value recorded by the Cawthron study (14 October 2020) at the 80 m and 150 m (site 100807) downstream sites.

### Dissolved inorganic nitrogen

Although not directly linked to consent conditions or Assumed Water Quality Standards, it is worth considering one component of TN, when investigating enrichment of the Wairoro Stream. This is dissolved inorganic nitrogen (DIN), which comprises nitrate, nitrite and ammonium. These forms of nitrogen are readily available to aquatic plants and often control the formation of algal blooms (see Section 3.2). Although linking periphyton biomass to stream nutrient levels is problematic, the rate of periphyton biomass increase (accrual rate) is strongly linked with nutrients available for growth during the period between flushing flows (accrual period) (Biggs 2000). Approximate guidelines for concentrations of nutrients such as DIN have been suggested by Biggs (2000) for differing lengths of algal accrual to prevent periphyton blooms reaching nuisance levels. Biggs (2000) provides guideline values of 0.295 mg DIN/L for a 20-day accrual period and 0.034 DIN/L for a 40-day accrual period. Spot sampling on 14 October 2020 showed that all five downstream sites exceeded these values (i.e. 0.730–1.950 mg DIN/L—predominately due to increases in ammonia levels (Appendix 2)). Moreover, even the two upstream sites also exceeded both sets of guidelines (i.e. 0.327 and 0.330 mg DIN/L for the 410 m and 50 m upstream sites, respectively). Similarly high DIN values were recorded at downstream sites in the

2014 Cawthron survey. In addition, the DIN concentration in the discharge tributary was 27.03 mg/L in 2014 and 26.03 mg/L in 2020, which indicates that a similar level of nutrient input from the discharge has persisted between surveys. Despite the high DIN levels upstream of the discharge, the increase downstream will need to be addressed in order to ensure periphyton/macrophyte growth is moderated (i.e. reduce the WWTP effect through adding to an existing cumulative enrichment effect occurring in the stream). The plant upgrade is expected to address this issue if the discharge achieves the ammonia standards set out in the PRP (Table 1).

#### 3.1.6. Phosphorus

Nutrients are a primary factor controlling algal growth and the two nutrients considered limiting for algal and macrophyte growth are nitrogen (N) and phosphorus (P). High concentrations of dissolved inorganic nitrogen (DIN = ammonia-N + nitrate-N + nitrite-N) and dissolved reactive phosphorus (DRP) can cause excessive algal growth, which degrades stream habitat and the aesthetic and recreational values of a river. High nutrient loads can cause faster periphyton growth and greater periphyton cover and biomass can reach nuisance levels. Greater periphyton biomass causes changes to the aquatic macroinvertebrate community via changes to habitat and / or high diurnal fluctuation in pH and DO.

Total phosphorus and dissolved reactive phosphorus concentrations in the Wairoro Stream spot sample survey of 2020 followed the same pattern as nitrogen and ammonia, with much lower concentrations at the two upstream sites and much higher values at the downstream sites (Figure 6). In addition, the pattern of much lower values at the 50 m downstream site relative to the 80 m downstream site was repeated, and this again suggesting there may be limited mixing at the 50 m downstream site. Mixing may only be sufficient at the 80 m site for a mid-stream water sample to adequately assess the impact of the discharge on the Wairoro Stream's chemistry.

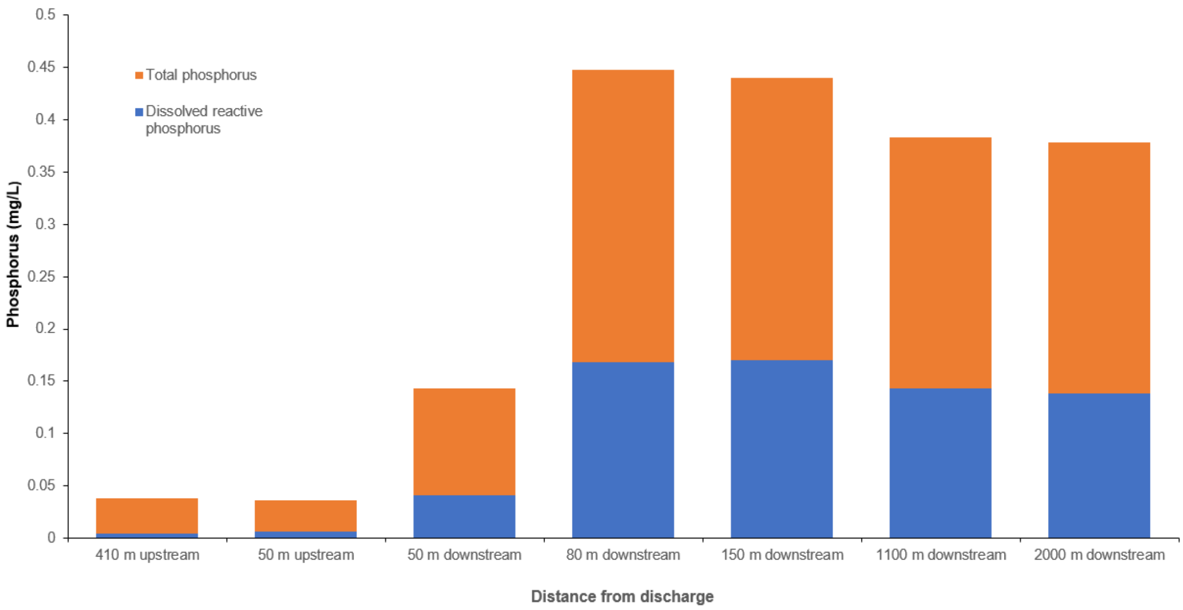


Figure 6. Total phosphorus-TP (mg/L) and dissolved reactive phosphorus-DRP (mg/L) recorded from seven sites in Wairoro Stream upstream and downstream of the Kaikohe WWTP discharge on 14 October 2020.

### *3.1.7. Escherichia coli*

Resource consent condition 7(h) states that the increase in the median *E. coli* concentration at the downstream compliance point shall not exceed 50 cfu/100mL (Appendix 1). The specifics of the monitoring requirement underlying this condition are given in section 4.2.2. of the consent which states that the median difference for the set of 20 paired samples shall not exceed an increase of 50 *E. coli* per 100mL.

In the spot samples taken by Cawthron in 2020, the *E. coli* level at the 50 m upstream site was 4,700 cfu/100mL, compared to 5000, 8000 and 9000 cfu/100mL at the 50 m, 80 m and 150 m downstream sites, respectively (Figure 7). Although these are 'one-off' spot samples, levels of *E. coli* in the upstream monitoring sites were generally lower than those downstream of the discharge. The results suggest compliance with this consent condition may at times be difficult. The highest *E. coli* levels were found at the furthest downstream sites (9,000, 15,000 and 9,000 for the 150 m, 1100 m and 2000 m sites respectively). The *E. coli* level at the 1100 m site was 300 cfu/100mL higher than that in the tributary discharge from the WWTP itself (15,000 compared to 12,000 cfu/100mL) and higher than the 150 m site. Moreover, *E. coli* concentration at the 410 m upstream site was higher than the 50 m upstream site. These results indicate the presence of sources of organic pollution to Wairoro Stream other than the WWTP discharge. This also indicates that although the discharge does appear to be increasing *E. coli* levels in the downstream sites, not all of these increases may be due to the discharge. There is a lot of 'noise' in the system as regards potential inputs of *E. coli.*, regardless of the presence of the WWTP.

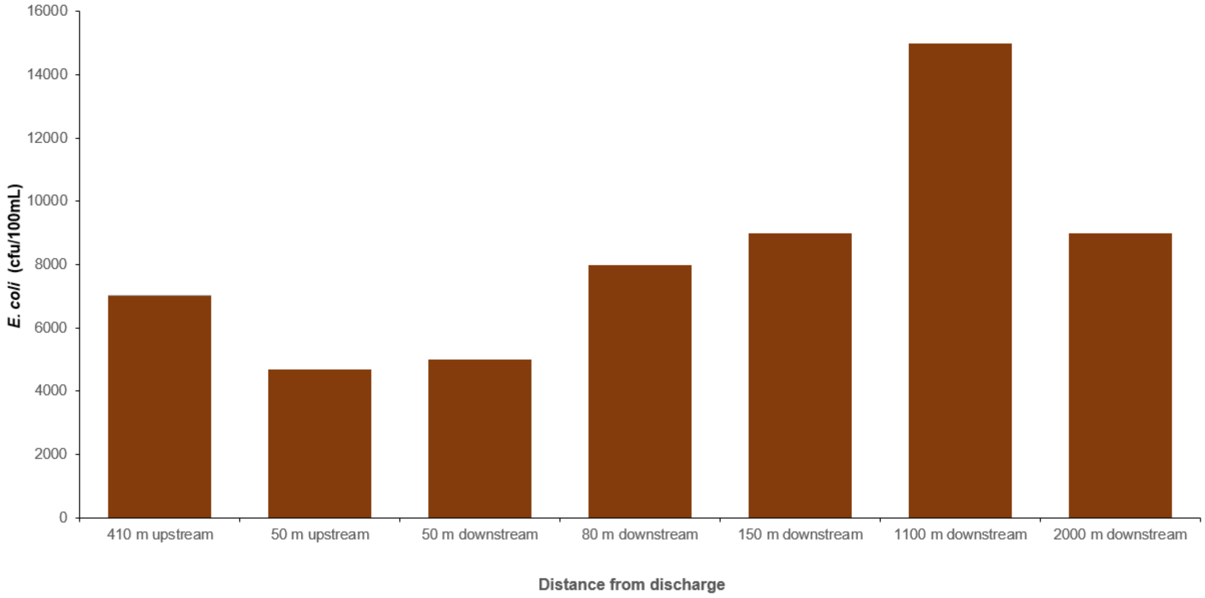


Figure 7. *E. coli* levels recorded from seven sites in Wairoro Stream upstream and downstream of the Kaikohe WWTP discharge on 14 October 2020.

*E. coli* levels in the Wairoro Stream survey followed the same general pattern as nitrogen, ammonia and phosphorus levels. The pattern of a much lower value in the 50 m downstream site relative to the 80 m downstream site was repeated, again suggesting there may be incomplete mixing of the discharge at this site.

Analysis of FNDC *E. coli* monitoring data from 2010–2020 shows approximately 28% of the median values recorded by routine monitoring were non-compliant, (non-compliant meaning there was a greater than 50 cfu/100mL increase of *E. coli* at the downstream monitoring point relative to the upstream monitoring point) (Figure 8). From 2014 to 2020 there was a noticeable increase in frequency of non-compliance (Figure 7).

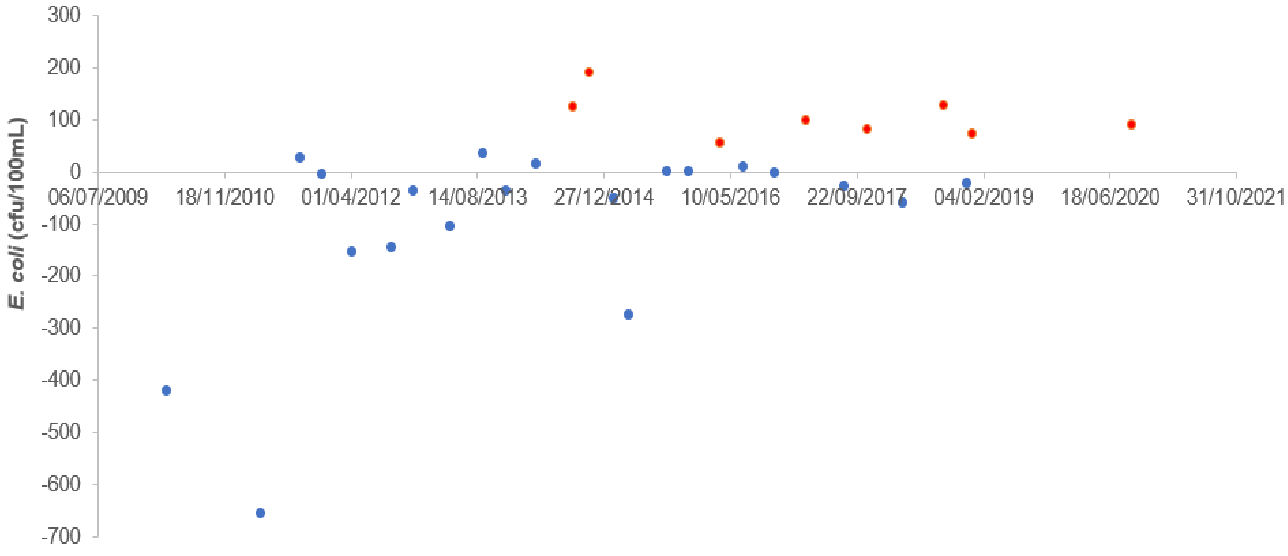


Figure 8. Differences in median *E. coli* levels between upstream and downstream compliance points (each point represents the median difference for a set of 20 paired upstream and downstream samples, with blue data points indicating compliance with consent condition and red data points indicating non-compliance).

## 3.2. Periphyton

Nutrients (nitrogen and phosphorus) can have a strong influence on periphyton (or algae) and macrophyte growth, as can light and temperature. Periphyton growth in turn can influence the taxonomic structure of macroinvertebrate communities. The amount and types of periphyton (or algae) growing on the riverbed are also indicative of river ecosystem health (Biggs 2000). Excessive growth of filamentous green algae is typical in unshaded sites that have abundant nutrients. High nutrient levels can encourage long strands of filamentous algae and/or thick diatom/cyanobacterial mats on the riverbed to grow. These growths are often unsightly and can reduce the quality of habitat for other river life. By contrast, in more healthy systems, periphyton growths are dominated by thin films or mats of brown diatoms, which form an important food source for macroinvertebrates. As periphyton growth increases, a corresponding change in macroinvertebrate community can also occur, from taxa generally associated with good water quality (e.g. mayflies and stoneflies) to taxa associated with poor water quality (e.g. chironomids and worms). Trout and native fish may also be affected by excessive periphyton growth. As periphyton proliferates, sloughed algae drifting in the water column may reduce the efficiency of visual drift feeding by trout and native galaxiids. Macroinvertebrate communities become dominated by small taxa (chironomid midge larvae and snails) which are less preferred by, and have lower food value to, adult trout than larger taxa such as mayflies and stoneflies. Periphyton respiration and decomposition during excessive proliferations can cause fish kills.

From *in situ* assessments made on 14 October 2020, mean periphyton scores at the two upstream sampling sites were higher (8.47 and 6.54) than all five downstream sites (3.51–5.87; see Table 5, Appendix 3). The two furthest downstream sites had the lowest scores of all (4.245 and 3.51 for sites 1100 m and 2000 m downstream, respectively).

Biggs (2000) suggested that periphyton cover of < 30% of filamentous green algae would provide for the protection of recreation and aesthetics (as well as trout habitat and angling) in a river. Percentage cover of these algae was very low at the majority of sites, ranging from 0 for the site 410 m upstream of the discharge to 7.5 for the site 150 m downstream of the discharge (Table 5, Appendix 3). The two furthest downstream sites both marginally exceeded the 30% guideline of Biggs (2000), with 33.5% and 36.5% cover for sites 1100 m and 2000 m downstream, respectively (Table 5, Appendix 3). Percentage cover of filamentous green algae increased with distance downstream from the discharge (Table 5). The percentage cover of filamentous green algae at the two upstream sites were indicative of good water quality (i.e., no evidence of excessive algal growth), while the two furthermost downstream sites had much higher percentage cover by green algae reflecting communities indicative of poorer, nutrient enriched water quality (with excessive 'nuisance' algal growth evident). The downstream sites from 50 m to 150 m had intermediate filamentous green algae percentage cover scores.

The periphyton site scores show a similar pattern to the periphyton cover data. There are currently no formal guidelines for assessing periphyton scores. However, NIWA (Biggs et al. 2002) suggested the following interpretation of the scores:

- No score – no algae present
- 'Very poor' up to 1.9 mainly long filamentous green algae at a site indicating moderate to high enrichment from phosphorus and/or nitrogen
- 'Poor to moderate' 2–3.9 moderate level of enrichment from phosphorus and/or nitrogen
- 'Moderate' 4–5.9 slight enrichment from phosphorus and/or nitrogen
- 'Good' 6–7.9 communities generally composed of species that are able to grow under moderate to low nutrient conditions
- 'Very good' 8–10 periphyton communities that usually signify low concentrations of nutrients.

Under these periphyton score categories the 410 m upstream site would rank as 'very good', 50 m upstream as 'good', from 50 m downstream to 1100 m downstream as 'moderate' and 2000 m downstream as 'poor' (Table 5).

Overall, the 2020 periphyton survey data suggest that the discharge is having a moderate influence on periphyton community, although it is likely an additional source of nutrients may be influencing the two most downstream sites. A confounding influence of the periphyton assessment is that the October sampling was undertaken directly after a fresh that was preceded by a month-long period of stable flows (see 'Wairoro at FNDC weir' flow data provided in Figure 1). It is possible that the fresh may have removed (flushed) some long filamentous algae accruing in the Wairoro Stream prior to sampling, as during the survey the substrate downstream of the discharge was notably more slippery than upstream (C MacNeil, pers. obs.).

Table 5. Mean periphyton cover scores and percentage contribution of long filamentous green algae cover assessed with RAM-2 periphyton protocol for seven sites in Wairoro Stream upstream and downstream of the Kaikohe WWTP discharge, and one site in an unnamed tributary receiving the discharge, on 14 October 2020.

| Site | Mean periphyton score | % long filamentous green algae |
|---|---|---|
| 410 upstream | 8.47 | 0 |
| 50 m upstream | 6.54 | 6.0 |
| Unnamed tributary | N/A | N/A |
| 50 m downstream | 5.07 | 4.0 |
| 80 m downstream | 5.87 | 5.5 |
| 150 m downstream | 5.68 | 7.5 |
| 1100 m downstream | 4.25 | 33.5 |
| 2000 m downstream | 3.51 | 36.5 |

## 3.3. Macroinvertebrates

Aquatic macroinvertebrates include insects, snails, worms, crustaceans and other taxa which have different habitat requirements and differ in their tolerance to pollution. They are abundant, have limited mobility (cf. fish), life spans of about 1–2 years, and populations often composed of multiple cohorts. These features make macroinvertebrate communities useful for assessing environmental effects as they integrate environmental conditions operating over relatively long time periods. Therefore, they are indicators of environmental conditions preceding our sampling, adding value to spot water quality measurements made on the day. A list of all the taxa found and their relative abundances is provided in Appendix 4.

### *3.3.1. Macroinvertebrate community structure*

Fifty-one macroinvertebrate taxa were recorded overall from the Wairoro Stream sampling, although at least three of the taxa likely originated from the oxidation pond (the mosquito larva *Culex* sp. and the small (< 2 mm) copepod and cladoceran crustaceans). All three taxa are more commonly found in still waters such as ponds than in streams and rivers. At most sites, the most abundant taxa were worms, and chironomid larvae (Orthocladiinae, *Polypedilum* sp., *Chironomus zealandicus*). The non-biting midge larva *Chironomus zealandicus* was arguably the best indicator species for showing the downstream extent of enrichment effects of the discharge.[5] Very few *Chironomus* were collected upstream of the discharge. At the discharge point, 50, 80 and 150 m downstream of the discharge they were found in high abundance. By 110 m downstream of the discharge fewer *Chironomus* were found, albeit at higher abundance than at the upstream 50 and 80 m upstream sites (Appendix 4).

Taxonomic richness is the broadest measure of the state of an invertebrate community. High taxonomic richness indicates a diverse habitat, able to support a range of species. Highly diverse ecosystems may be desirable because they can be more resilient to environmental disturbance and support a broader range of ecosystem functions (Elmqvist et al. 2003). Taxonomic richness ranged from 9 (discharge site) to 31 (50 m upstream of the discharge) (Figure 9). Unsurprisingly, the lowest taxa richness was at the site most affected by organic enrichment from the discharge, the unnamed tributary site (Figure 9), where the fauna was dominated by abundant pollution tolerant animals—worms (oligochaetes and roundworms) and the chironomid larva *Polypedilum* sp.

The contributions of dominant taxa (community structure) differed noticeably between the 410 m upstream and downstream sites (Table 6). However, at the 50 m upstream site, there were some taxa/abundance similarities with the downstream sites, suggesting that there was some enrichment of unknown source at this upstream site.

[5] The red appearance of *Chironomus* (hence the common name 'bloodworm') is due to the presence of haemoglobin-like proteins. These proteins coupled with undulatory movements in their burrows allow *Chironomus* to obtain oxygen in poorly oxygenated habitats common in organically enriched sediments and thick periphyton matrices.

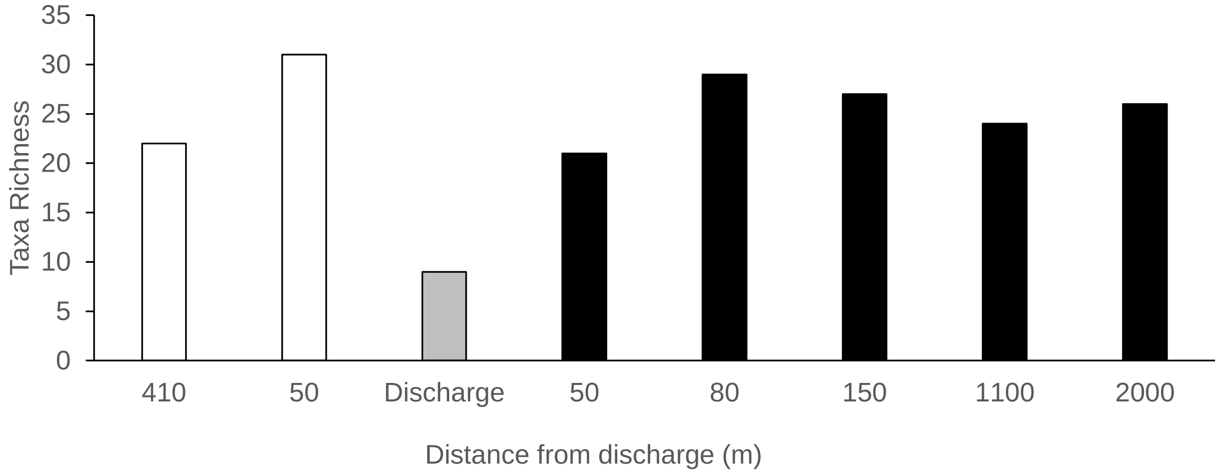


Figure 9. Invertebrate taxonomic richness at seven sites sampled in Wairoro Stream in the vicinity of the Kaikohe WTTP discharge and at one site in an unnamed tributary receiving the discharge on 14 October 2020 (*n* = one kicknet per site). Open bars represent the sites upstream of the discharge, grey a sampling point at the discharge, and black the sites downstream of the discharge.

Table 6. Taxa found in the Stark (1998) relative abundance categories of 'very abundant' (VA) and 'very very abundant' (VVA) at seven sites in Wairoro Stream in the vicinity of the discharge from the Kaikohe wastewater treatment plant (WWTP) and at one site in the unnamed tributary that initially receives the discharge on 14 October 2020. * indicates the taxon was present in the sample but not in the abundance categories of VA or VVA.

| | Distance from discharge (m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Upstream** | | **Downstream** | | | | | |
| **Taxon** | **410** | **50** | **0** | **50** | **80** | **150** | **1100** | **2000** |
| *Chironomus zealandicus* | | * | VA | VVA | VA | VA | * | * |
| Orthocladiinae | * | VVA | * | VA | VA | VA | VA | VVA |
| *Polypedilum* sp. | * | VA | VVA | * | VVA | VA | * | VA |
| *Tanytarsus vespertinus* | * | VA | | | VA | VA | * | VA |
| *Oxyethira albiceps* | * | * | | * | * | * | VA | VA |
| Nematoda | | | VA | VA | | | | |
| Oligochaeta | * | VA | VVA | * | * | VVA | * | * |
| *Potamopyrgus antipodarum* | * | VA | | VVA | * | * | * | * |
| *Hydra* sp. | | | | VVA | * | * | | * |

The shifts in macroinvertebrate community structure observed at downstream versus upstream sites were likely because of nutrient enrichment enhancing periphyton and macrophyte growth. The presence of *Potamopyrgus* downstream of the discharge suggests ammonia toxicity is probably not a reason for the difference between up and downstream invertebrate communities, as this species was the most sensitive to the presence of ammonia of the invertebrates tested by Hickey (2000). Mayfly and many caddisfly species are grazers (feed on periphyton) and are often larger than many other macroinvertebrates (i.e. adult body lengths of 9 mm; sometimes longer). They prefer habitat where algal biomass is low to moderate. High periphyton biomass, particularly of long filamentous green algae, can impede their movement. True-fly larvae and snails are strongly associated with extensive algal and macrophyte growth. They tend to be smaller than other macroinvertebrates (< 4 mm long). Small algal-piercing hydroptilid caddisflies, which are also strongly associated with extensive algal growth, were present only at the downstream sites (Appendix 4).

### *3.3.2. EPT metrics, Macroinvertebrate Community Index and the Semi-Quantitative Macroinvertebrate Community Index*

The enrichment-sensitive EPT were noticeably absent from the discharge site (Table 7, Figure 10), with mayflies and stoneflies also absent 50 m downstream of the discharge (Appendix 4). Conversely, taxa that tend to be tolerant of highly enriched environments, such as dipterans and oligochaete worms, were present at all sites (Appendix 4). EPT taxon richness and %$EPT_{Taxa}$ were both lower at the downstream sites than upstream, although by 80 m downstream of the discharge there was evidence of some recovery in the invertebrate community from the enriching effects of the discharge (Table 7, Figure 10).

Table 7. Biotic metrics at seven sites in Wairoro Stream upstream and downstream of the discharge from the Kaikohe WWTP and at one site in an unnamed tributary delivering the discharge on 14 October 2020.

| Site | EPT taxa richness | %$EPT_{Taxa}$ | MCI | SQMCI |
|---|---|---|---|---|
| 410 m upstream | 11 | 50 | 104 | 4.08 |
| 50 m upstream | 12 | 39 | 92 | 2.96 |
| Discharge | 0 | 0 | 49 | 2.00 |
| 50 m downstream | 3 | 15 | 72 | 2.25 |
| 80 m downstream | 10 | 35 | 84 | 2.96 |
| 150 m downstream | 8 | 30 | 87 | 1.84 |
| 1100 m downstream | 8 | 33 | 92 | 3.29 |
| 2000 m downstream | 9 | 35 | 93 | 2.45 |

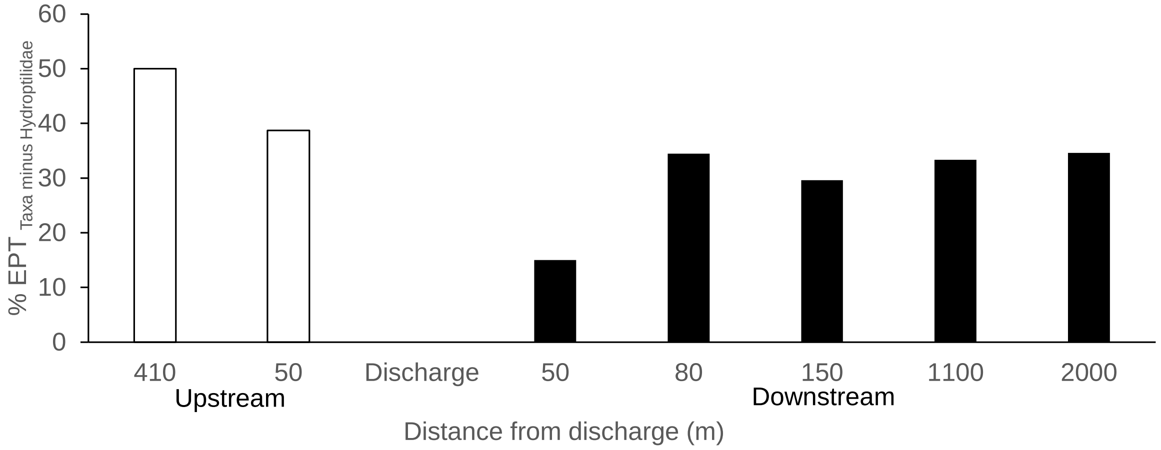


Figure 10. Percent EPT (Ephemeroptera, Plecoptera, Trichoptera) by taxa at seven sites sampled in the Wairoro Stream in the vicinity of the Kaikohe WWTP discharge point and at one site in an unnamed tributary delivering the discharge on 14 October 2020 (n = one kicknet per site). Open bars represent the sites upstream of the discharge, grey a sampling point at the discharge, and black the sites downstream of the discharge.

Macroinvertebrate Community Index values indicated that stream health at the 410 m upstream site was ‘good’, ‘poor’ at the discharge and 50 m downstream, while all other sites indicate ‘fair’ water quality according to bands developed by Stark and Maxted (2007) (Table 8). The MCI scores at the two upstream sites and furthermost downstream sites were just above the national bottom line of 90 in the NPSFM 2020 (MfE 2020). All other sites were below the national bottom line (Figure 11). Overall, these results indicate that the Kaikohe WWTP discharge is having adverse effects on macroinvertebrate communities in Wairoro stream (based on the presence or absence of taxa), but the effects are localised as the MCI score 150 m downstream of the discharge into the stream is nearing that of the 50 m upstream site.

The SQMCI values indicated only ‘good’ water quality at the 410 m upstream site and ‘poor’ at all other sites based on the bands in Table 8, but all sites were below the NPSFM 2020 QMCI[6] national bottom line (Table 7, Figure 11). In this context, the overall health of the Wairoro Stream is poor even before the WTP discharge enters the waterway. However, a decrease in SQMCI score downstream of the WWTP relative to upstream suggests that the discharge is affecting (degrading) stream health further.

The SQMCI scores account for not only the presence or absence of taxa, but also their relative abundances. Thus, despite the fact that a good variety of taxa occurred upstream and ≥ 80 m downstream of the discharge (Figure 9) the higher abundance

[6] The QMCI and SQMCI are both calculated on the presences of taxa and their relative abundances to each other in a sample. As such, they are very closely correlated (see Stark 1998), so it is appropriate to compare SQMCI values to the NPS-FM QMCI attribute numeric values.

of more pollution-tolerant (low-scoring) taxa at each site lowered the SQMCI scores. For example, at 50 m upstream of the discharge, taxa richness was 31, including 12 EPT taxa, but the dominant animals by abundance were the sandfly *Austrosimulium* spp. (MCI score: 3), the midges Orthocladiinae (MCI score: 2), the net-spinning caddis *Hydropsyche* (*Aoteapsyche* spp.) (MCI score: 4) and the snail *Potamopyrgus antipodarum* (MCI score: 4) (Appendix 4). At 150 m downstream, where taxa richness was 27 including 8 EPT taxa, worms (MCI score: 1) were extremely abundant, followed by an assortment of very abundant midge larvae that had MCI scores ranging between 1–3 (Appendix 4).

Table 8. Interpretation of MCI and SQMCI scores in stony stream with respect to water quality and/or pollution levels. Adapted from Stark and Maxted (2007).

| Water/pollution status | MCI range | SQMCI range |
|---|---|---|
| Excellent (clean water) | 120 | 6.00 |
| Good (possible mild pollution) | 100–119 | 5.00–5.99 |
| Fair (probable moderate pollution) | 80–99 | 4.00–4.99 |
| Poor (probable severe pollution) | < 80 | < 4.00 |

## 3.1. Fish

No fish were noted during the water quality / ecological survey. However, Wagenhoff and Shearer (2014) used a fish distribution model developed by Leathwick et al. (2008) to assess the probability of fish species being present in the Wairoro study reach and further upstream. The model uses information from the New Zealand Freshwater Fish Database to produce probability scores that rank the likelihood of a fish species being present from 0 (unlikely to be present) to 1.0 (high likelihood of being present). Based on this model, both longfin and shortfin eel had a high probability of being present (84% and 73%, respectively). The common bully was the next most likely species to occur (31%). Wagenhoff and Shearer (2014) also pointed out that banded kōkopu had a moderate probability (50–60%) of occurring upstream of the survey reach.

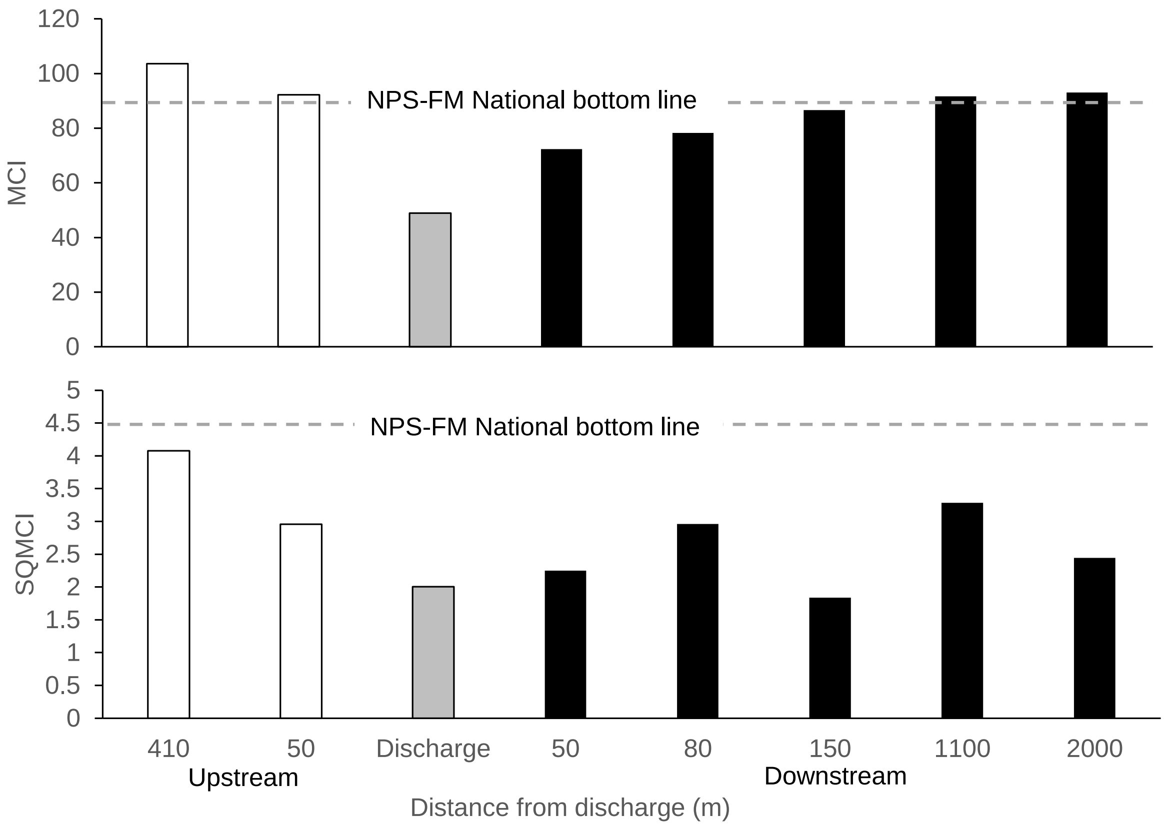


Figure 11. Macroinvertebrate Community Index (MCI) and the Semi-Quantitative Macroinvertebrate Community Index (SQMCI) values at seven sites sampled in Wairoro Stream in the vicinity of the Kaikohe WWTP discharge point and at one site in an unnamed tributary delivering the discharge on 14 October (n = one kicknet per site). Open bars represent the sites upstream of the discharge, grey a sampling point at the discharge, and black the sites downstream of the discharge. Dotted line indicates the National Bottom Line for MCI and QMCI (an equivalent to SQMCI) from the National Policy Statement for Freshwater Management (2020). See Table 8 for the water quality bands for MCI and SQMCI.

Based on model predictions, the shortfin and longfin eel are the only two species with a high probability of being present in the Wairoro Stream in the segment where the survey was conducted. All of the fish species are likely to be found in the headwaters of Wairoro Stream (i.e. further upstream of the discharge) and further downstream (including the mainstem of the Punakitere River); therefore they will pass through the survey reach on their way to and from the sea as part of their life cycle. The most likely effect of the current WWTP discharge on fish would be elevated downstream levels of ammonia creating a chemical barrier to fish passage. However, analysis of FNDC ammonia data in relation to toxicity effects on the fish by Wagenhoff and Shearer (2014) and more recent FNDC monitoring data show this is very unlikely. Overall, the high mobility of the fish species likely to be in the Wairoro Stream (i.e. ability to move away from unsuitable environmental conditions), and the access they have throughout the Wairoro Stream and further downstream to refuges mean the impacts on fish will be minimal if the current WWTP discharge is continued while a plant upgrade is being implemented.

# 4. WATER QUALITY STANDARDS FROM PROPOSED REGIONAL PLAN AND THE NPSFM 2020

The Water Quality Standards Policy H.3.1 of the PRP for Northland (appeals version) is presented in Table 9. Apart from *E. coli*, the standards are based on limits to protect aquatic ecosystem health from general degradation or toxic effects on instream fauna (e.g. ammonia and nitrate). The *E. coli* standards are based on protecting human health when undertaking contact recreation activities such as swimming.

Because the PRP standards are sometimes based on summarised data (e.g. median values) comparisons of one-off spot measurements with these standards should be treated with caution. However, spot measurements can provide, at the least, a coarse indication of which parameters are of major concern in terms of probable non-compliance. Table 9 shows the spot sample results recorded at various sites on 14 October 2020, in relation to the metrics and values in the Water Quality Standards from the PRP.

At sites 50, 80 and 150 m downstream of the discharge ammonia concentrations recorded in spot samples collected during the 2020 ecological survey exceeded the annual maximum PRP value of 0.40 mg/L (Table 9). Ammonia concentrations at 80 and 150 m downstream of the discharge were four times higher than this value.

Nitrate, temperature and pH were all below or within the PRP limits upstream and downstream of the discharge during the 2020 survey (Table 9). Spot pH measurements collected monthly over a 10-year monitoring period (2010–2020) by FNDC were almost all within the > 6 to < 9 range. Where there were exceptions, the pH values were lower than 6 (never > 9), and in most cases the values at both the upstream and downstream monitoring sites would be low. Over the same 10-year monitoring period, the maximum temperature recorded at the FNDC upstream monitoring site was 24.4 °C and downstream 29 °C. Temperature in the Wairoro Stream during the 2020 ecological survey was a standard 14 °C at all of the sites in Table 9. However, these values cannot be interpreted in relation to the PRP standard for temperature, which relies on diurnal temperature variation information so that the mean of the daily mean and daily maximum (the Cox-Rutherford index) can be estimated. The *E. coli* standard in the PRP is equivalent to the highest attribute state of the NPSFM 2020 (attribute state A). Based on the FNDC and our survey data, *E. coli* are often higher downstream of the discharge than upstream. In the 2020 ecological survey, *E. coli* levels upstream and downstream breached the PRP standard of 540 cfu/100mL. Over a 10-year period of FNDC monitoring data, *E. coli* levels were higher than 540 cfu/100 mL 47% of the time at the upstream sites and 48% at the downstream site.

Although not recorded at a time of day when dissolved oxygen levels are at minima, spot dissolved oxygen (DO) levels recorded during the 2020 survey were above the

PRP 1-day minimum standard of 4 mg/L upstream and downstream of the discharge (Table 9). The PRP standard of a 1-day DO minimum of 4 mg/L is also the national bottom line in the NPSFM 2020 (Table 10). As mentioned earlier in this report in section 3.1.2 there have been three occasions (March 2010, February 2020 and March 2020) where the FNDC monitoring data upstream value was above the national bottom line and downstream below the line. Given DO minima generally occur pre-dawn, low spot sample measurements taken in daylight hours are a concern as DO is an essential requirement for maintaining ecological integrity. How serious such breaches could be for the stream ecosystem depend on the extent and duration of low DO values. Such information can be collected by installing combined DO/temperature loggers that record DO (and temperature which can affect oxygen uptake) continuously e.g. a measurement taken and logged once every 10 minutes throughout the course of a day.

Table 9. Water Quality Standards for Ecosystem Health from Policy H.3.1 of the proposed Regional Plan for Northland (appeals version) supplied to Cawthron by FNDC in August 2020, in comparison to spot sample results from various sampling sites in the Wairoro Stream during the October 2020 survey. Water quality standards apply after reasonable mixing. *E. coli* % exceedance standards are equivalent to Attribute State A of the NPSFM 2020.

| **Attribute** | **Compliance metric and standards for ‘other’ rivers** | **50 m US** | **50 m DS** | **80 m DS** | **150 m DS** |
|---|---|---|---|---|---|
| Ammonia(mg $NH_4$-N/L) | Annual median ≤ 0.24<br>Annual maximum ≤ 0.40 | 0.02 | 0.42 | 1.63 | 1.62 |
| Nitrate (mg $NO_3$-N/L) | Annual median ≤ 1.0<br>Annual 95th percentile ≤ 1.5 | 0.31 | 0.30 | 0.30 | 0.32 |
| Dissolved oxygen (mg/L) | 7-day mean minimum ≥ 5.0<br>1-day minimum ≥ 4.0 | 9.65 | 8.69 | 9.66 | 9.63 |
| Temperature (°C) | Summer period measurement of the Cox-Rutherford Index (CRI), averaged over five hottest days ≤ 24 °C | 14.1 | 14.1 | 14.1 | 14.0 |
| pH | Annual minimum and maximum (> 6 and < 9) | 6.68 | 7.05 | 6.28 | 6.40 |
| *E. coli* (cfu/100mL) | % exceedances over 540 are < 5<br>% exceedances over 260 are < 20<br>Median ≤ 130<br>95th percentile ≤ 540 | 4700 | 5000 | 8000 | 9000 |

NPSFM 2020 attributes not listed in Table 9 but relevant to discussion in this report around the effects of the discharge on ecological health are dissolved reactive phosphorus (DRP) and the macroinvertebrate community indices MCI and QMCI (Table 10). Spot dissolved reactive phosphorus (DRP) concentrations in the Wairoro Stream at 50, 80 and 150 m downstream of the WWTP discharge were in the lowest NPSFM water quality band 'D' (Table 10). In contrast the 50 m upstream DRP value was equivalent to the highest NPSFM water quality band 'A' (Table 10). Median DRP levels calculated from samples collected monthly over a 10-year monitoring period (2010–2020) by FNDC were 0.01 g/m$^3$ upstream and 017 g/m$^3$ downstream of the WWTP discharge. These values would place the Wairoro Stream in NPSFM 2020 attribute band 'B' for upstream of the discharge, and 'D' downstream.

Because most aquatic invertebrates have an annual life cycle they are exposed to changes in water quality condition over at least a year, thus the biotic macroinvertebrate indices provide a better measure of average water quality condition over time than spot water quality measurements. As has already been noted in section 3.3.2, in respect of the macroinvertebrates, the 50 m upstream site would meet the NPSFM 2020 national bottom line for the MCI, while scores at the 50, 80 and 150 m downstream sites would not (Table 10). None of the sites would meet the NPSFM 2020 national bottom line for the QMCI (of which the SQMCI calculated in this report is an equivalent value) (Table 10).

Table 10. Selected attributes from the NPSFM 2020 and associated bottom lines and bands (A-D/E, excellent/pristine to poor/highly impacted) relevant to parameters recorded at various sites in the Wairoro Stream during October 2020 spot sampling (US = upstream of discharge, DS = downstream of discharge). Note: The Semi-Quantitative Macroinvertebrate Community Index (SQMCI) presented in this report is equivalent to the Quantitative MCI in the NPSFM 2020.

| **Attribute (NPSFM 2020)** | **National bottom line / band** | **50 m US** | **50 m DS** | **80 m DS** | **150 m DS** |
|---|---|---|---|---|---|
| Ammonia (mg NH4-N/L) | Annual median 0.24<br>Annual maximum 0.40 | 0.02 | 0.42 | 1.63 | 1.62 |
| Nitrate (mg $NO_3$-N mg/L) | Annual median 2.4<br>Annual 95th percentile 3.5 | 0.31 | 0.30 | 0.30 | 0.32 |
| Dissolved oxygen (mg/L) | 7-day mean minimum 5.0<br>1-day minimum 4.0 | 9.65 | 8.69 | 9.66 | 9.63 |
| *E. coli* (cfu/100mL) | Median concentration:<br>A ≤ 130<br>B ≤ 130<br>C ≤ 130<br>D > 130<br>E > 260<br>95th percentile:<br>A ≤ 540<br>B ≤ 1000<br>C ≤ 1200<br>D > 1200<br>E > 1200 | 4700 | 5000 | 8000 | 9000 |
| Macroinvertebrates | MCI score 90<br>QMCI score 4.5 | 92<br>2.96 | 72<br>2.25 | 84<br>2.96 | 87<br>1.84 |
| Dissolved reactive phosphorus (DRP mg/L) | Median concentration:<br>A ≤ 0.006<br>B > 0.006 and ≤ 0.01<br>C > 0.010 and ≤ 0.018<br>D > 0.018<br>95th percentile:<br>A ≤ 0.021<br>B > 0.021 and ≤ 0.030<br>C > 0.030 and ≤ 0.054<br>D > 0.054 | 0.006 | 0.041 | 0.168 | 0.170 |

# 5. CONCLUSIONS AND RECOMMENDATIONS

The 2020 ecological survey undertaken by Cawthron concurs with the conclusions from a similar survey undertake in 2014—the Kaikohe WWTP discharge is having a negative ecological impact in the receiving environment (Wairoro Stream). The WWTP upgrade is expected to address concerns around nutrient (and bacterial) concentrations in the discharge, which (subject to meeting standards set out the PMP and NPSFM) will improve the quality of water being discharged in Wairoro Stream. Reduction of nutrient input will improve the ecological condition (i.e. algal growth, macroinvertebrate communities) downstream of the discharge. However, in the interim period (before the new plant is built) and based on the results of two ecological surveys (2014 and 2020), it is very unlikely nutrients in the current discharge will worsen the ecological state of Wairoro Stream below what has already been seen (i.e. a status quo situation should exist). This assumes that the water quality of the discharge does not reduce further and/or the volume discharged does not increase.

An assessment of ammonia levels on macroinvertebrate communities was conducted in 2014 (Wagenhoff & Shearer 2014) and also showed that ammonia levels are generally not at levels that would be considered toxic to aquatic fauna. Over the 15-year period of FNDC monitoring data, the only exceptions to this were two recent sampling occasions (February and March 2020) where ammonia levels were unusually high. The reasons for the high values are not clear, however, follow-up sampling showed lower values, and it is likely that aquatic fauna were not exposed to the high levels for a prolonged period of time (i.e. more than a day). Although there are some indirect effects of high nutrient concentrations from the discharge on invertebrate communities (i.e. increased growth of aquatic plants and algae changing invertebrate habitat), as long as there is an upstream source of colonists there will not be any short- or long-term legacy effects as a result of the current discharge being allowed to continue. Nevertheless, in the interim period before the new plant is built, we understand FNDC would look for opportunities to improve performance and water quality. Pond desludging may remove nutrients and the indirect effect they have on the Wairoro Stream ecology through increased periphyton growth.

Although the effect of the discharge on DO levels has been shown to be generally minimal, a couple of recent drops at the downstream site below the NPSFM 2020 national bottom line for protection of aquatic ecosystems (while upstream levels were above) indicate there may very occasionally be an issue to be addressed as DO is essential to a waterway's life-supporting capacity.

Although discussion around *E. coli* concentrations has been included in this report, monitoring objectives around *E. coli* concentrations relate to effects on human health. Because the scope of this report focuses on water quality effects on the aquatic ecosystem (ecological health), recommendations relating to *E. coli* monitoring are not specifically addressed below.

There was an unusual pattern noted in the 2020 survey with the nutrient parameters and *E. coli*, where concentrations at the 80 m downstream site were higher than at the 50 m downstream site (Figure 4, Figure 6, Figure 7 Appendix 2). This could potentially be the result of poor mixing at 50 m downstream of the discharge on the day of sampling i.e. the discharge may, on entering the stream, have been hugging the true left bank for a distance downstream before mixing across the stream. Because water samples (and spot measurements) were taken midstream it is possible that the water quality samples at 50 m downstream were sampling an outer edge of a discharge plume that was still in the process of dispersing horizontally across the stream.

The current compliance point at which the discharge is expected to be reasonably mixed in the Wairoro Stream for the Kaikohe WWTP is 80 m downstream of the discharge, although this will likely be changed under the NRC PRP to 50 m. The 2014 and 2020 ecological surveys indicate that the ecology of the stream is currently being affected by the discharge beyond both these mixing zones.

The question around the extent of the effect of the discharge beyond 150 m downstream is confounded by the possibility of other diffuse sources of organic enrichment (e.g. runoff from nearby farms). It is likely these effects will become more evident once the new plant has been built and in operation.

From our analysis of the FNDC water quality monitoring data and the two ecological surveys we recommend that:

- DO in the Wairoro Stream be investigated further if standard spot DO monitoring indicate downstream values are below the NPSFM national bottom line (when upstream values are above), because DO is essential to the life-supporting capacity of a stream/river. Spot water quality measurements are useful for highlighting where a potential problem may lie, but do not provide enough information around how bad a problem may be. In the case of DO, there is a daily cycle with oxygen levels generally lowest pre-dawn, so a low measurement during the day (when levels should be high) suggests a problem. To assess the impact of a reduction in DO would require continuous DO measurements be taken upstream and downstream of the discharge for a prescribed period of time using a combined DO/temperature logger to define the oxygen cycle and determine duration and extent of a low DO event.
- A dye release study (e.g. Shearer et al. 2014) during a summer low flow event be considered for defining the horizontal dispersion of the discharge once it enters the Wairoro Stream, i.e. the point at which full mixing occurs) relative to the current and proposed mixing zones (80 and 50 m, respectively). This would provide the necessary resolution to establish/confirm patterns of effluent mixing and dilution in the Wairoro Stream, and answer a question raised in this 2020 ecological survey around whether the discharge is fully mixed by 50 m downstream—some of the water quality results (nutrient and *E. coli*) indicated this

may not be the case. This study could be done under 'worst-case' receiving environment conditions (i.e. median WWTP effluent and low stream flow) using Rhodamine® WT liquid dye, which disperses readily in water, is easily detectable, is stable and non-toxic (Shearer et al. 2014).

The NPS-FM 2020 section 3.18 Monitoring, part (3) states that *Monitoring methods must recognise the importance of long-term trends, and the relationship between results and their contribution to evaluating progress towards achieving long-term visions and environmental outcomes for FMUs and parts of FMUs*. Attributes listed in the NPS-FM 2020 have recommendations for the frequency of monitoring required for grading a site or determining the state of an attribute. Taking this into account and the attributes listed in the PRP, we have provided below recommendations relating to future water quality/ecological monitoring in Wairoro Stream in the vicinity of the WWP discharge.

For future monitoring of the discharge to assess effects on stream ecology, we recommend:

- water quality and ecological surveys be concentrated in the summer months (December-February) when stream water flows are low and ambient temperatures are highest i.e. the effects of the discharge on the ecological integrity of the stream will be greatest. This suggestion is also in keeping with NPSFM 2020 recommendations around time of year sampling should be undertaken for some water quality parameters, invertebrate community (MCI and QMCI) and periphyton monitoring for effects assessments.
- monthly monitoring (spot measurement) at a site up and downstream of the discharge (in lieu of further information with regards to a change in the mixing zone we conservatively suggest 50 m in either direction) should be sufficient as a monitoring requirement for most of the water quality parameters including ammonia, nitrate, pH, DRP and *E. coli*, with particular attention paid to considering an increased frequency of sampling around the summer months around nutrients.
- In addition to spot measurements continuous DO measurements be taken upstream and downstream of the discharge at least once during summer over the course of a week using a combined DO/temperature logger to ascertain the 1-day and 7-day minima (bringing the DO records in line with the PRP and NPSFM 2020 standards).
- temperature be monitored continuously over the summer period each year so that a Cox-Rutherford Index (CRI) value, averaged over the five hottest days can be calculated as per the PRP standard (Table 9). An ideal scenario would be to have a combined temperature and dissolved oxygen logger deployed at the upstream monitoring site and downstream compliance point so a daily record of both attributes could be obtained.

- Depending on the time between now and implementation of the new upgrade a further ecological survey may not be warranted. However, we recommend ecological monitoring be undertaken on an annual basis for two consecutive years following the plant upgrade to establish a baseline of information, which could then be reduced to either a 3 or 5-year monitoring cycle (depending on the outcome of the two-year monitoring regime results showing improvement relative to the pre-upgrade 2014 and 2020 ecological surveys).

Any upgrade to the WWTP is expected to improve the water quality of the WWTP discharge such that regional (i.e. the PRP) and, where appropriate, national (NPSFM 2020) standards are met. However, the Wairoro Stream water quality in the 2014 and 2020 ecological survey results (and FNDC monitoring data) at upstream sites did not, or would not, meet current regional and national water quality standards on some occasions. It would be unrealistic therefore, to expect that the improvements to the WWTP discharge quality will translate into improvements the Wairoro Stream ecosystem health such that national and regional standards will be met. In relation to the receiving environment, a more realistic target for the WWTP upgrade should be improvement of water quality (and macroinvertebrates indices) in the Wairoro Stream downstream of the discharge to a standard that is comparable that collected from an upstream monitoring site or sites.

# 6. ACKNOWLEDGEMENTS

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# 8. APPENDICES

Appendix 1. Resource consent issued to Far North District Council relating to the Kaikohe wastewater treatment plant (WWTP) discharge.

CON20100241701
REPLACEMENT DOCUMENT

NORTHLAND REGIONAL COUNCIL

# Resource Consent

*Pursuant to the Resource Management Act 1991, the Northland Regional Council (hereinafter called "the Council") does hereby grant a Resource Consent to:*

**FAR NORTH DISTRICT COUNCIL, PRIVATE BAG 752, KAIKOHE 0440**

To undertake the following activities associated with the operation of the Kaikohe wastewater treatment system on Lot 2, DP 45233, Blk XV, Omapere SD; Sec 27, SO 40585 Blk IV Punakitere SD; Sec 2, SO 12295 Blk IV Punakitere SD; Sec 30 Blk IV Punakitere SD.

*(Note: all location co-ordinates in this document refer to Geodetic Datum 2000, New Zealand Transverse Mercator Projection):*

(01) To discharge treated wastewater to an unnamed tributary of Wairoro Stream, at or about location co-ordinates 1674845E 6079488N.

(02) To discharge contaminants to ground via seepage from the base of an anaerobic pond, oxidation pond and a constructed wetland, at or about location co-ordinates 1674525E 6079466N.

(03) To discharge contaminants (primarily odour) to air from the Kaikohe wastewater treatment system, at or about location co-ordinates 1674525E 6079466N.

Subject to the following conditions:

**(01) and (02) Discharge to Water and to Ground**

1 The volume of treated wastewater discharged to the unnamed tributary of the Wairoro Stream shall not, based on a 30 day rolling average of dry weather discharges, exceed 1,710 cubic metres per day. Compliance with this condition shall be based on the average daily discharge volume of the 30 most recent "dry weather discharge days". For the purposes of this consent, a "dry weather discharge day" is any day on which there is less than 1 millimetre of rainfall, and that day occurs after three consecutive days either without rainfall or with rainfall of less than 1 millimetre on each day.

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Appendix 1. *continued*.

**Advice Note:** *The rainfall measurements used to determine a dry weather discharge shall be based on the nearest appropriate rainfall recorder site. The recorder site shall be selected in consultation with the Northland Regional Council.*

2 The Consent Holder shall maintain in good working order a flow meter on the outlet of the constructed treatment wetland that has an accuracy of ±5% to measure the volume of wastewater discharged to the unnamed tributary of the Wairoro Stream.

3 The Consent Holder shall keep records of the daily volume of treated wastewater discharged to the unnamed tributary of the Wairoro stream, as measured by the meter required by Condition 2, the local daily rainfall measurement, and the 30 day rolling average dry weather discharge volume, as defined in Condition 1. These records shall be recorded in a format agreed to by the Northland Regional Council and shall be forwarded to the Northland Regional Council by 15 May of each year for the preceding six months of November to April, and by 15 November of each year for the preceding months of May to October

4 The Consent Holder shall monitor the exercise of these consents in accordance with the Monitoring Programme in Schedule 1 **(attached)**.

5 The Consent Holder shall prepare monthly reports on the monitoring undertaken in accordance with Conditions 3 and 4. These reports shall include, but not be limited to, all the raw data, the averages and/or medians calculated for compliance purposes, and a summary showing the level of compliance with any consent conditions for which limits have been defined. The monthly reports shall be in a format agreed to by the Northland Regional Council and shall be forwarded to the Northland Regional Council prior to the tenth working day of the following month. Where the monitoring is required to be undertaken over a period greater than a month, then the results of that monitoring event shall be included in the next scheduled monitoring report. If the monitoring results indicate a non-compliance with any consent condition, then the Consent Holder shall report the results to the Northland Regional Council within 24 hours of receiving the analysis results.

6 The Consent Holder shall provide and maintain easy and safe access to each of the following sampling points (all shown on NRC Plan 3514, **attached**):

(a) Northland Regional Council Sampling Site Number 100562, discharge point from the wastewater treatment system into natural wetland, at or about location co-ordinates 1674845E 6079488N.

(b) Northland Regional Council Sampling Site Number 100560, unnamed tributary of the Wairoro Stream at the point where the unnamed tributary discharges into the Wairoro Stream, at or about location co-ordinates 1674854E 6079181N.

Appendix 1. *continued*.

(c) Northland Regional Council Sampling Site Number 103316, Wairoro Stream approximately 25 metres upstream of the discharge point from the unnamed tributary into Wairoro Stream, at or about location co-ordinates 1674725E 6079148N.

(d) Northland Regional Council Sampling Site Number 100807, Wairoro Stream approximately 80 metres downstream of the discharge point from the unnamed tributary into Wairoro Stream, at or about location co-ordinates 1674866E 6079142N.

7 Notwithstanding any other conditions of these consents, the exercise of these consents shall not give rise to any of the following effects on the water quality of the Wairoro Stream, as measured at Northland Regional Council Monitoring Site 100807, Wairoro Stream approximately 80 metres downstream of the discharge point from the unnamed tributary into Wairoro Stream, when compared with the water quality at Northland Regional Council Monitoring Site 103316, Wairoro Stream approximately 25 metres upstream of the discharge point from the unnamed tributary into Wairoro Stream:

(a) The natural temperature of the water shall not change by more than 3 degrees Celsius;

(b) The natural pH of the water shall be within the range 6.5 to 9.0;

(c) The concentration of dissolved oxygen (daily minimum) shall not be reduced by more than 20%;

(d) The production of conspicuous oil or grease films, scums or foams, floatable or suspended materials, or emissions of objectionable odour;

(e) Acute toxicity, or significant adverse effects of chronic toxicity, to natural aquatic life by reason of a concentration of toxic substances.

(f) The hue of the waters shall not be changed by more than 10 Munsell units.

(g) The waters shall not be tainted so as to make them unpalatable to farm animals, nor contain toxic substances to the extent that they are unsuitable for consumption by farm animals. The microcystin concentration expressed as microcystin-LR shall not exceed 2.3 micrograms per litre and/or the concentration of potentially toxic blue green algae species shall not exceed 11,500 cells per millilitre, for samples taken in accordance with Section 4.2.3 of the Monitoring Programme in Schedule 1 (**attached**).

(h) The increase in the median *Escherichia coli* concentration shall not exceed 50 per 100 millilitres, for samples taken in accordance with Section 4.2.2 of the Monitoring Programme in Schedule 1 (**attached**).

Appendix 1. *continued*.

(i) The concentration of total ammoniacal nitrogen shall not exceed the following:

| pH of Water at the Time of Sampling | Total Ammoniacal Nitrogen ($[NH_3 + NH_4]$-N) (grams per cubic metre) |
|---|---|
| 6.0 | 2.57 |
| 6.1 | 2.56 |
| 6.2 | 2.54 |
| 6.3 | 2.52 |
| 6.4 | 2.49 |
| 6.5 | 2.46 |
| 6.6 | 2.43 |
| 6.7 | 2.38 |
| 6.8 | 2.33 |
| 6.9 | 2.26 |
| 7.0 | 2.18 |
| 7.1 | 2.09 |
| 7.2 | 1.99 |
| 7.3 | 1.88 |
| 7.4 | 1.75 |
| 7.5 | 1.61 |
| 7.6 | 1.47 |
| 7.7 | 1.32 |
| 7.8 | 1.18 |
| 7.9 | 1.03 |
| 8.0 | 0.90 |
| 8.1 | 0.78 |
| 8.2 | 0.66 |
| 8.3 | 0.56 |
| 8.4 | 0.48 |
| 8.5 | 0.40 |
| 8.6 | 0.34 |
| 8.7 | 0.29 |
| 8.8 | 0.24 |
| 8.9 | 0.21 |
| 9.0 | 0.18 |

In the event that the background concentration of total ammoniacal nitrogen, as measured at Northland Regional Council Site Number 103316, Wairoro Stream approximately 25 metres upstream of the discharge point from the unnamed tributary into Wairoro Stream, exceeds the above concentrations, then the exercise of these consents shall not result in an increase of the total ammoniacal nitrogen concentration of more than 0.10 grams per cubic metre.

8 The Consent Holder shall compare actual influent suspended solids and five day biochemical oxygen demand loadings, as required to be monitored in accordance with Section 1 of the Monitoring Programme in Schedule 1 (**attached**), with the design loadings for the wastewater treatment system. The results of this comparison shall be reported in the Annual Review Report required to be prepared in accordance with Condition 15.

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Appendix 1. *continued*.

9 The Consent Holder shall undertake an assessment of the degree of stormwater/groundwater inflow and infiltration into the Kaikohe sewage reticulation system. If there is unacceptable inflow and infiltration occurring, then a programme for inflow and infiltration reduction shall be provided to the Northland Regional Council. In the event that an inflow and infiltration reduction programme is required to reduce inflow to the sewer, the results of investigations, work undertaken, progress made and priorities for further work, shall be included in the Annual Review Report, required to be prepared in accordance with Condition 15.

**(03) Discharge to Air**

10 The Consent Holder's operations shall not give rise to any discharge of contaminants at or beyond the legal boundary of the area occupied by the Kaikohe wastewater treatment system, which is deemed by a suitably trained and experienced Enforcement Officer of the Northland Regional Council to be noxious, dangerous, offensive or objectionable to such an extent that it has, or is likely to have, an adverse effect on the environment.

**General Conditions**

11 The Consent Holder shall, within two years of the date of commencement of these consents, install an appropriately designed influent screen prior to the inlet to the anaerobic pond. For the purpose of this condition, an "appropriately designed influent screen" is one that includes a practical system for removing large solids that would not degrade within the treatment system; is self cleaning and is sized to allow wastewater to pass through the screen under all influent flow regimes. Residues caught by the screen shall be disposed of to a facility for which the necessary resource consents are held.

12 The Consent Holder shall, within six months of the date of commencement of these consents, submit a Management Plan covering all aspects of the operation and maintenance of the wastewater treatment system, including the discharge structure, to the Northland Regional Council for certification of its adequacy. The Management Plan shall include, but not be limited to, the following:

(a) Specification of the design wastewater volume, dimensions, design loading and expected treatment performance of each component of the treatment system in which wastewater treatment occurs.

(b) A schedule of inspection, servicing, and maintenance actions to be carried out on the wastewater treatment system. This will include identification of the timing of desludging of the anaerobic lagoon and oxidation pond, and any required maintenance of the treatment wetland cells.

Appendix 1. *continued*.

(c) Where it is not practical to schedule low frequency maintenance activities, such as the desludging of the anaerobic lagoon, oxidation pond, and treatment wetlands, a monitoring programme shall be provided to demonstrate that the design treatment capacity is maintained, and criteria shall be provided to trigger required maintenance. Particular attention shall be given to the method used for measuring the depth of wastewater and sludge in the treatment system components.

When desludging of a treatment system component is required, a detailed plan of the proposed desludging shall be provided to the Northland Regional Council at least one month prior to commencement of any desludging works.

(d) Contingency measures for unauthorised discharges.

(e) Methods to be used to combat nuisances that might arise in the treatment system including midges and other insects, and blue-green algae (cyanobacteria).

***Advice Note:*** *Algicides, including copper sulphate, and insecticides shall not be used within the Wastewater Treatment System without the prior written approval of the Northland Regional Council.*

13 The operation and maintenance of the wastewater treatment system shall be undertaken in accordance with the certified Management Plan required to be prepared in accordance with Condition 12, but also always subject to the conditions of these consents. Any changes to the Management Plan shall be made with the prior written agreement of the Northland Regional Council.

14 The Consent Holder shall, in consultation with the Northland Regional Council, review the Management Plan two years after the date of commencement of these consents, and thereafter at no greater than five yearly intervals. Any changes to the Management Plan, as a result of a review, shall be subject to the prior written agreement of the Northland Regional Council. The Consent Holder shall meet all reasonable costs of each review.

15 The Consent Holder shall forward to the Northland Regional Council by 1 August each year an Annual Review Report covering the previous year (1 July to 30 June) that shall include, but not be limited to, the following:

(a) A summary of all activities required by the Management Plan; and

(b) A summary of the results of all monitoring required to be undertaken in accordance with Schedule 1 (**attached**).

Appendix 1. *continued*.

***Advice Note:*** *The Monitoring Programme in Schedule 1 (**attached**) includes a requirement to measure concentrations of total nitrogen and phosphorus being discharged under this consent to the Wairoro Stream. The Annual Review Report required by Condition 16 should identify trends in concentrations and mass loadings of total nitrogen and total phosphorus being discharged from the treatment plant. One of the goals of the district-wide nutrient management programme that the Consent Holder is developing, including management of nutrients discharged from the Kaikohe wastewater treatment system, should be the prevention of any further increase in the mass discharges of total nitrogen and total phosphorus over a specified period of time.*

16 The Consent Holder shall, in consultation with the Northland Regional Council, review the Monitoring Programme in Schedule 1 (**attached**) by 1 August each year. The review shall consider compliance with the consent conditions, and shall also include review of sampling methods, sites, determinands and frequencies. No changes may be made to the monitoring programme without the prior written agreement of the Northland Regional Council. The Consent Holder shall meet the reasonable costs of each review.

***Advice Note:*** *In the past there has been limited monitoring of the discharge and the receiving environment. This consent imposes a more extensive and intensive monitoring programme and the Consent Holder has requested a review of that programme after 18 months of the date of commencement of the consent with a view to reduction of the monitoring if there is ongoing compliance with the standards set in this consent.*

17 Notwithstanding Condition 13, the wastewater treatment system shall be correctly operated and maintained in an effective and workmanlike manner.

18 The Consent Holder shall, for the purposes of adequately monitoring these consents as required under Section 35 of the Act, on becoming aware of any discharge of contaminants associated with the Consent Holder's operations otherwise than in conformity with these consents, immediately notify the Northland Regional Council of the discharge. In addition, if the discharge of contaminants, excluding those to air, is outside of the area legally occupied by the wastewater treatment plant, the Consent Holder shall also immediately notify the Medical Officer of Health, Northland Health Ltd. The Consent Holder shall then supply a written report to the Northland Regional Council within one week detailing:

(a) The nature of the non-compliance;

(b) The location of the discharge and receiving environment;

(c) The time of discharge;

(d) The duration of discharge;

(e) The quantity of contaminant discharged;

Appendix 1. *continued*.

(f) The nature of contaminant discharged (eg. raw sewage, primary, secondary treated sewage);

(g) The measures taken to mitigate the effects on the environment and public health; and

(h) The proposed measures to prevent similar discharges in future.

19 The Consent Holder shall, for the purposes of adequately monitoring these consents as required under Section 35 of the Act, maintain records of any complaints relating to the operation of these consents received by the Consent Holder, as detailed below:

(a) The name and address of the complainant (where provided);

(b) The date and time the complaint is received;

(c) The duration of the event that gave rise to the complaint;

(d) The location from which the complaint arose;

(e) The weather conditions prevailing at that time;

(f) Any events in the management and operation of any processes that may have given rise to the complaint; and

(g) Any actions taken by the Consent Holder, where possible, to minimise contaminant emissions.

The Consent Holder shall notify the Northland Regional Council as soon as is practicable of any complaint received. Records of the above shall also be sent to the Northland Regional Council immediately upon request.

20 The Northland Regional Council may, in accordance with Section 128 of the Resource Management Act 1991, serve notice on the Consent Holder of its intention to review the conditions of these consents. Such notice may be served annually during the month of May. The review may be initiated for any one or more of the following purposes:

(a) To deal with any adverse effects on the environment that may arise from the exercise of these consents and which it is appropriate to deal with at a later stage, or to deal with any such effects following assessment of the results of the monitoring of these consents and/or as a result of the Northland Regional Council's monitoring in the area.

(b) To require the adoption of the best practicable option to remove or reduce any adverse effect on the environment.

(c) To provide for compliance with rules in any regional plan that has been made operative since the commencement of these consents.

(d) To deal with any inadequacies or inconsistencies the Northland Regional Council considers there to be in the conditions of these consents, following the establishment of the activities the subject of these consents.

Appendix 1. *continued*.

(f) The nature of contaminant discharged (eg. raw sewage, primary, secondary treated sewage);

(g) The measures taken to mitigate the effects on the environment and public health; and

(h) The proposed measures to prevent similar discharges in future.

19 The Consent Holder shall, for the purposes of adequately monitoring these consents as required under Section 35 of the Act, maintain records of any complaints relating to the operation of these consents received by the Consent Holder, as detailed below:

(a) The name and address of the complainant (where provided);

(b) The date and time the complaint is received;

(c) The duration of the event that gave rise to the complaint;

(d) The location from which the complaint arose;

(e) The weather conditions prevailing at that time;

(f) Any events in the management and operation of any processes that may have given rise to the complaint; and

(g) Any actions taken by the Consent Holder, where possible, to minimise contaminant emissions.

The Consent Holder shall notify the Northland Regional Council as soon as is practicable of any complaint received. Records of the above shall also be sent to the Northland Regional Council immediately upon request.

20 The Northland Regional Council may, in accordance with Section 128 of the Resource Management Act 1991, serve notice on the Consent Holder of its intention to review the conditions of these consents. Such notice may be served annually during the month of May. The review may be initiated for any one or more of the following purposes:

(a) To deal with any adverse effects on the environment that may arise from the exercise of these consents and which it is appropriate to deal with at a later stage, or to deal with any such effects following assessment of the results of the monitoring of these consents and/or as a result of the Northland Regional Council's monitoring in the area.

(b) To require the adoption of the best practicable option to remove or reduce any adverse effect on the environment.

(c) To provide for compliance with rules in any regional plan that has been made operative since the commencement of these consents.

(d) To deal with any inadequacies or inconsistencies the Northland Regional Council considers there to be in the conditions of these consents, following the establishment of the activities the subject of these consents.

Appendix 1. *continued*.

(e) To deal with any material inaccuracies that may in future be found in the information made available with the application. Notice may be served at any time for this reason.

(f) To change existing conditions relating to, or impose new limits on, the quality of the discharges and/or the receiving waters.

The Consent Holder shall meet all reasonable costs of any such review.

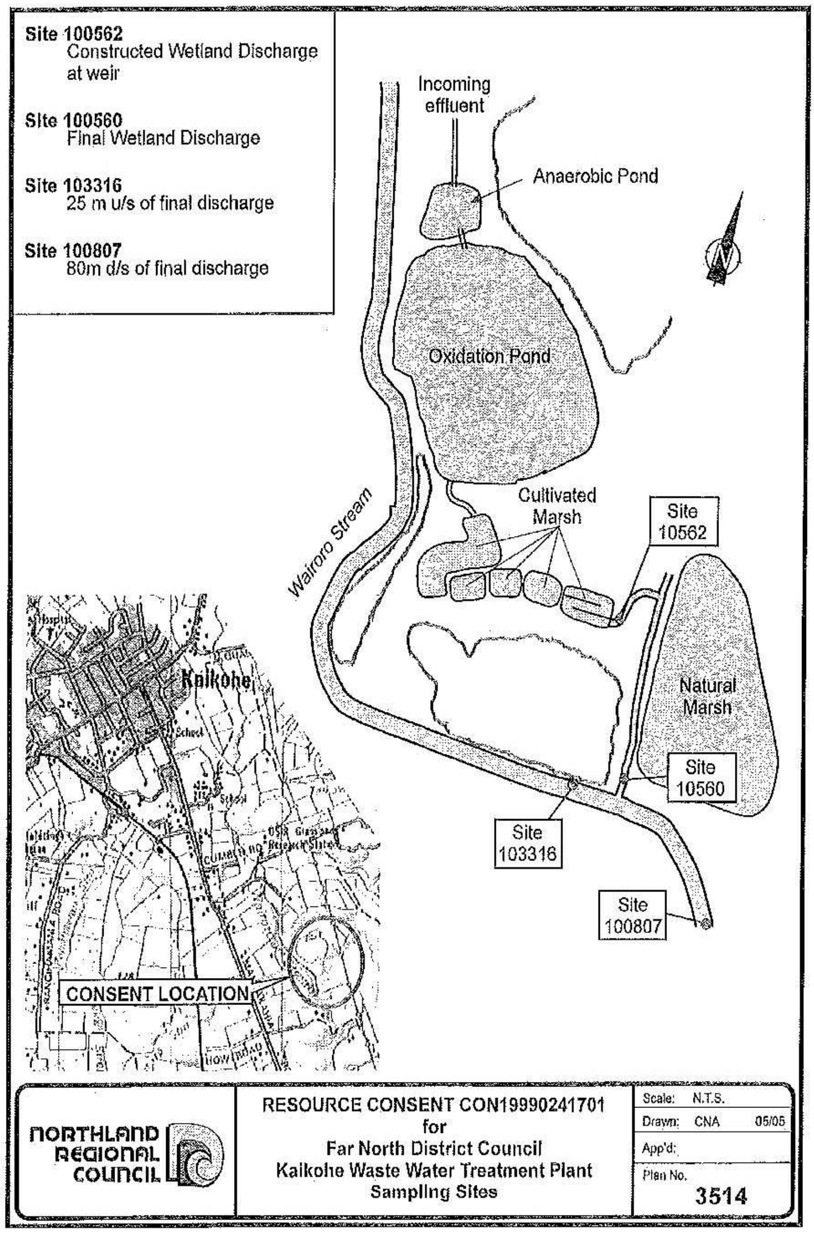
**EXPIRY DATE: 30 NOVEMBER 2021**

**This consent was issued by D L Roke on Fourth day of August 2005 under delegated authority from the Council.**

**This change to consent is granted this Nineteenth day of April 2011 under delegated authority from the Council by:**

**Robert Lieffering**
**Consents Senior Programme Manager**

Appendix 1. *continued*.

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Appendix 1. *continued*.

SCHEDULE 1

## MONITORING PROGRAMME

The Consent Holder (or its authorised agent) shall monitor Resource Consent 2417 in accordance with the following monitoring programme.

### 1. TREATMENT SYSTEM MASS LOADINGS

#### 1.1 Wastewater Discharge Volume

The discharge volume from the treatment plant and the local daily rainfall over the same 24-hour period shall be recorded. The Consent Holder shall then use this data to calculate the 30 day rolling average dry weather discharge volume, as defined in Condition 1.

#### 1.2 Biochemical Oxygen Demand and Total Suspended Solids

The influent 5-day biochemical oxygen demand[See Note 1] and total suspended solids daily mass loadings shall be determined annually during February-March, on a minimum of four consecutive days under dry weather discharge conditions. A dry weather discharge day is defined in Condition 1.

24 hour flow proportional influent samples shall be taken for determination of the mass loadings.

#### 1.3 Significant Intermittent Loadings

An assessment of the effects on final effluent quality of any significant intermittent loadings to the Kaikohe wastewater treatment system from activities such as discharges by septic tank cleaning contractors and discharges from sources of potentially high organic loading such as stock truck washing facilities shall be provided in the Annual Review Report.

### 2. FACULTATIVE (OXIDATION) POND AND TREATMENT WETLAND DISSOLVED OXYGEN MONITORING

The concentration and percentage saturation of dissolved oxygen shall be measured every three months at three points at approximately equal intervals around the edge of the oxidation pond, and at the outlet from each of the five treatment wetland cells.

Appendix 1. *continued*.

Dissolved oxygen measurements in the facultative pond shall be taken at least 60 centimetres from the water's edge and at a constant depth of 5 centimetres below the water surface.

Dissolved oxygen monitoring of the facultative pond and treatment wetlands shall be carried out on one of the days on which final effluent and receiving water monitoring is undertaken, and shall be carried out prior to the sampling of the final effluent and receiving water. The time shall be recorded for all samples.

During each visit for monitoring purposes, any significant odours at or beyond the property boundary shall be noted and reported to the Northland Regional Council within 24 hours of the visit. "Property boundary" is defined in Condition 10 of these consents.

## 3. DISCHARGE AND RECEIVING WATER MONITORING

### 3.1 Sites

The following sites (shown on NRC Plan 3514, **attached**) shall be monitored.

| NRC Monitoring Site Number | Location Description |
|---|---|
| 100562 | Discharge from treatment plant (outlet from final treatment wetland at flow monitoring point). |
| 100560 | Unnamed tributary, at point where it joins the Wairoro Stream. |
| 103316 | Wairoro Stream 25 metres upstream of the discharge point of the unnamed tributary into which the treated wastewater is discharged. |
| 100807 | Wairoro Stream approximately 80 metres downstream of the discharge point of the unnamed tributary into which the treated wastewater is discharged. |

### 3.2 Sampling Procedures, Determinands and Frequency

#### 3.2.1 Discharge Monitoring

Two triplicate(See Note 2) samples of the discharged wastewater (NRC Sampling Site 100562) shall be taken at least two weeks apart, during each month between November and April (inclusive), and monthly triplicate samples shall be collected for the rest of the year. The time shall be recorded for each sample and all samples shall be taken between 1000 and 1200 hours and analysed for the following determinands:

- Temperature(See Note 3)
- pH

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Appendix 1. *continued*.

- Dissolved oxygen concentration(See Note 3) and percentage saturation
- 5 day biochemical oxygen demand
- Total suspended solids
- Total ammoniacal nitrogen
- Dissolved inorganic nitrogen
- Total nitrogen
- Dissolved reactive phosphorus
- Total phosphorus

During the following three two-month periods each year, October-November; February-March; and July-August, 20 triplicate(See Note 2) samples of treated wastewater from NRC Sampling Site 100562 shall be taken during each period, with a minimum of one day between samples. These samples shall be analysed for *Escherichia coli* (See Note 4) concentration.

Discharge sampling shall be co-ordinated with receiving water sampling and the discharge samples shall be taken prior to the receiving water samples.

### 3.2.2 Receiving Water Monitoring

The flow of the Wairoro Stream, and the flow of the unnamed tributary into which the WTS discharge occurs shall be recorded for each sampling occasion.

***Advice Note:*** *The Wairoro Stream flow should be determined from the most suitable existing flow monitoring site, and pro-rated to the area adjacent to the Kaikohe WTS. The Far North District Council is to install a weir near NRC Monitoring Site 100560 for measuring the flow of the unnamed tributary including the WTS discharge. The weir shall allow the passage of fish.*

The unnamed tributary of the Wairoro Stream into which the wastewater is discharged shall be monitored at a point approximately 30 metres upstream of the point of where the wastewater discharge enters the main stream of the unnamed tributary (Northland Regional Council Site 100560).

The Wairoro Stream shall be monitored 25 metres upstream of the point of discharge of the unnamed tributary (Northland Regional Council Site 103316), and at the downstream boundary of the mixing zone, this being approximately 80 metres downstream of the point of discharge from the unnamed tributary (Northland Regional Council Site 100807).

Appendix 1. *continued*.

Two triplicate(See Note 2) samples per month, taken at least two weeks apart, shall be collected each month between November and April (inclusive) and monthly triplicate samples shall be collected for the rest of the year. Samples shall be analysed for the following determinands:

- Temperature(See Note 3)
- pH
- Dissolved oxygen concentration(See Note 3) and percentage saturation
- Total ammoniacal nitrogen
- Dissolved inorganic nitrogen
- Dissolved reactive phosphorus
- Hue (Munsell units)

The time shall be recorded for each receiving water sample and all receiving water samples shall be taken between 1000 and 1200 hours.

Compliance shall be determined for each sampling occasion.

During the following three two-month periods each year, (October-November; February-March; and July-August) 20 triplicate(See Note 2) samples shall be taken, with a minimum of one day between samples, from the NRC Sampling Sites 100560, 103316 and 100807. Paired samples (See Note 5) shall be taken from Sites 103316, and 100807 and the difference between *Escherichia coli* concentrations shall be determined for each of the 20 paired samples.

The median difference for the set of 20 paired samples shall not exceed an increase of 50 *Escherichia coli* per 100 millilitres.

To assist data interpretation, the monitoring of determinands with different sampling frequencies shall be integrated so that the maximum number of determinands is sampled at one time.

The water quality data from Northland Regional Council Site 100560 shall be considered if non-compliance is recorded, and there is an inconsistency between the wastewater quality data and the Wairoro Stream upstream and downstream data.

Appendix 1. *continued*.

### 3.2.3 Blue-green Algal Toxicity

During periods when blue-green algae are prominent in the oxidation pond discharge, one triplicate sample shall be taken each week from Northland Regional Council Sampling Site 100807 and analysed for microcystins, expressed as microcystin-LR, and for cell counts of potentially toxic blue green algae species.

**Notes:**

(1) The "total" 5-day biochemical oxygen demand shall be measured and nitrogenous inhibitors shall not be added to the samples prior to analysis.

(2) Triplicate sampling shall involve collection of three separate samples taken at least five minutes apart during the same sampling event. Analysis shall be conducted on a composite sample made up of equal volumes of each triplicate sample.

(3) Temperature and dissolved oxygen concentration shall be measured in the field using a meter in accordance with standard procedures and triplicate measurements are not required for these parameters, apart from the measurement of dissolved oxygen in the facultative pond which is to be measured in accordance with Section 2.0.

(4) *Escherichia coli* shall, unless otherwise agreed to by the Northland Regional Council, be measured using the Colilert™ method.

(5) Paired samples are samples taken from the same body of water prior to and after the addition of the wastewater discharge. Paired samples shall be obtained by marking the upstream water with dye (or small drogues such as oranges) at the same time as the upriver sample is taken, and then sampling the marked body of water when it reaches the downstream boundary of the mixing zone.

## 4. RECORD OF SIGNIFICANT ODOURS

A record shall be kept of any significant odour at or beyond legal boundary of the area occupied by the Kaikohe wastewater treatment system. The record shall identify the source and cause of any significant odour, duration of the odour, wind strength and direction, remedial action undertaken, and the degree of success of the remedial action.

Appendix 1. *continued*.

## 5. SAMPLE COLLECTION, SAMPLE TRANSPORT, AND LABORATORY REQUIREMENTS

All samples shall be collected using standard procedures and in appropriate laboratory supplied containers.

All samples shall be transported in accordance with standard procedures and under chain of custody to the laboratory.

All samples shall be analysed at a laboratory with registered quality assurance procedures#, and all analyses shall be undertaken using standard methods, where applicable.

# Registered Quality Assurance Procedures are procedures which ensure that the laboratory meets recognised management practices as would include registrations such as ISO 9000, ISO Guide 25, Ministry of Health Accreditation, IANZ.

Appendix 1. *continued*.

## APPLICATION NUMBER: CON20100241701

**Application Type:** Non Notified Change

**Applicant Name:** FAR NORTH DISTRICT COUNCIL

## REASONS FOR THE DECISION

This consent is granted pursuant to Section 104B of the Resource Management Act 1991 (the Act). In reaching this decision, the Council has considered the matters outlined in Part 2 and Section 104 of the Act. It has been determined that the adverse effects of the proposed change on the environment will be no more than minor, and that the granting of this change achieves the purposes of the Act.

### Summary of Activity

The applicant has applied to delete Condition 6 of the consent which required the upgrade of the treatment system so that it could achieve a 4 log reduction in F-specific bacteriophage (a viral indicator organism), and all other references to this upgrade within the conditions of the consent. The deletion of the reference to the upgrade requires the modification of Condition 8(j) and changes to the monitoring programme for the consent. There are also consequential changes to consent conditions and cross references as a result of changes.

The requested changes to condition are shown below:

6 ~~The Consent Holder shall, within two years of the date of commencement of this consent, upgrade the wastewater treatment system to include an appropriate disinfection system. All wastewater shall then receive treatment within this disinfection system prior to being discharged to the unnamed tributary of the Wairoro Stream. For the purpose of this condition, disinfection is defined as the use of a process designed specifically to reduce the number of viable, potentially infectious micro-organisms in the discharge. The upgraded wastewater treatment system shall achieve at least a four order of magnitude (ie. four logarithm) reduction in the concentration of F-specific bacteriophage within the wastewater as a result of the treatment process. An alternative viral indicator may be used with the prior written approval of the Northland Regional Council. Compliance with the required F-specific bacteriophage reduction shall be determined by the results of monitoring undertaken in accordance with Section 2.0 of the Monitoring Programme in Schedule 1 **(attached)**.~~

*(Consequential change to Condition 7(h) in consent document)*

8(h) The increase in the median *Escherichia coli* concentration shall not exceed 50 per 100 millilitres, for samples taken in accordance with Section 4.2.2 of the Monitoring Programme in Schedule 1 **(attached)**. ~~This condition 8(h) shall cease to have effect once the disinfection system required by condition 6 has been commissioned.~~

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Appendix 1. *continued*.

SCHEDULE 1

MONITORING PROGRAMME

## ~~2 INFLUENT AND DISCHARGE MONITORING FOR VIRAL INDICATORS~~

~~The concentrations of F-specific bacteriophage virus shall be determined both for a sample of untreated influent taken within the treatment plant at the inlet to the anaerobic pond, and for a sample of the final discharge from a point immediately after the disinfection system each month. An alternative viral indicator may be used as provided for in Condition 6. The Consent Holder shall, at least two weeks prior to the beginning of this sampling, provide the proposed sampling procedure for F-specific bacteriophage to Northland Regional Council for written approval.~~

*(Consequential change to Section 3.2 in consent document)*

## 4.2 Sampling Procedures, Determinands and Frequency

### 4.2.1 Discharge Monitoring

Two triplicate(See Note 2) samples of the discharged wastewater (NRC Sampling Site 100562) shall be taken at least two weeks apart, during each month between November and April (inclusive), and monthly triplicate samples shall be collected for the rest of the year. The time shall be recorded for each sample and all samples shall be taken between 1000 and 1200 hours and analysed for the following determinands:

- Temperature(See Note 3)
- pH
- Dissolved oxygen concentration(See Note 3) and percentage saturation
- 5 day biochemical oxygen demand
- Total suspended solids
- Total ammoniacal nitrogen
- Dissolved inorganic nitrogen
- Total nitrogen
- Dissolved reactive phosphorus
- Total phosphorus

During the following three two-month periods each year, October-November; February-March; and July-August, 20 triplicate(See Note 2) samples of treated wastewater from NRC Sampling Site 100562 shall be taken during each period, with a minimum of one day between samples. These samples shall be analysed for *Escherichia coli* (See Note 4) concentration.

~~The *Escherichia coli* sampling may be discontinued following commissioning of a disinfection system which meets the requirements of Condition 6.~~

Appendix 1. *continued*.

Discharge sampling shall be co-ordinated with receiving water sampling and the discharge samples shall be taken prior to the receiving water samples.

### 4.2.2 Receiving Water Monitoring

The flow of the Wairoro Stream, and the flow of the unnamed tributary into which the WTS discharge occurs shall be recorded for each sampling occasion.

**Advice Note:** *The Wairoro Stream flow should be determined from the most suitable existing flow monitoring site, and pro-rated to the area adjacent to the Kaikohe WTS. The Far North District Council is to install a weir near NRC Monitoring Site 100560 for measuring the flow of the unnamed tributary including the WTS discharge. The weir shall allow the passage of fish.*

The unnamed tributary of the Wairoro Stream into which the wastewater is discharged shall be monitored at a point approximately 30 metres upstream of the point of where the wastewater discharge enters the main stream of the unnamed tributary (Northland Regional Council Site 100560).

The Wairoro Stream shall be monitored 25 metres upstream of the point of discharge of the unnamed tributary (Northland Regional Council Site 103316), and at the downstream boundary of the mixing zone, this being approximately 80 metres downstream of the point of discharge from the unnamed tributary (Northland Regional Council Site 100807).

Two triplicate[(See Note 2)] samples per month, taken at least two weeks apart, shall be collected each month between November and April (inclusive) and monthly triplicate samples shall be collected for the rest of the year. Samples shall be analysed for the following determinands:

- Temperature[(See Note 3)]
- pH
- Dissolved oxygen concentration[(See Note 3)] and percentage saturation
- Total ammoniacal nitrogen
- Dissolved inorganic nitrogen
- Dissolved reactive phosphorus
- Hue (Munsell units)

The time shall be recorded for each receiving water sample and all receiving water samples shall be taken between 1000 and 1200 hours.

Compliance shall be determined for each sampling occasion.

Appendix 1. *continued*.

During the following three two-month periods each year, (October-November; February-March; and July-August) 20 triplicate(See Note 2) samples shall be taken, with a minimum of one day between samples, from the NRC Sampling Sites 100560, 103316 and 100807. Paired samples (See Note 5) shall be taken from Sites 103316, and 100807 and the difference between *Escherichia coli* concentrations shall be determined for each of the 20 paired samples.

The median difference for the set of 20 paired samples shall not exceed an increase of 50 *Escherichia coli* per 100 millilitres. ~~Monitoring for *Escherichia coli* shall no longer be undertaken once the disinfection system required by Condition 6 has been commissioned.~~

To assist data interpretation, the monitoring of determinands with different sampling frequencies shall be integrated so that the maximum number of determinands is sampled at one time.

The water quality data from Northland Regional Council Site 100560 shall be considered if non-compliance is recorded, and there is an inconsistency between the wastewater quality data and the Wairoro Stream upstream and downstream data.

## Regional Plan Rule(s) Affected

The change is discretionary under section 127 of the RMA.

## Actual and Potential Effects (Section 104(1)(a) of the Act)

The adverse effects on the environment of the change have been determined to be no more than minor for the following reasons:

(a) The application for the current consent was publicly notified in 1999 and there were 4 submission received, all in opposition. These submissions raised issues regarding the recreational use of the Wairoro Stream and the effect of the discharge on the Hokianga Harbour. In 2005, the reporting officer drafted conditions of consent which included the requirement for an upgrade to achieve a 4 log reduction in F-specific bacteriophage. This requirement was based on the best information available at the time to minimise adverse effects from pathogens, and was included because the applicant had not presented any upgrade details to date nor any evidence to counter claims of adverse effects on recreational use. The draft conditions were discussed at a pre-hearing meeting, which was the third one to be held, where the applicant agreed to the upgrade requirements. From the staff report, there was no agreement by the submitters to all the conditions and therefore a hearing was held. No submitters attended the hearing and consent was granted in August 2005.

(b) The applicant has stated that the current treatment system is capable of achieving a 3 log reduction in F-specific bacteriophage during summer "when most water sports and shell fish gathering is carried out". This statement has been based on an average of 1 log reduction in the anaerobic ponds, 1 to 1.5 log reduction in the oxidation pond, and 1 log reduction in the constructed wetland.

Appendix 2. Spot water quality measurements taken from Wairoro Stream in the vicinity of the Kaikohe WWTP discharge, and from an unnamed stream receiving the discharge, on 14 October 2020. DO = dissolved oxygen, TSS = total suspended solids, TN = total nitrogen, TKN – total Kjeldahl nitrogen, TP = total phosphorus, *E. coli* – *Escherichia coli*, DRP = dissolved reactive phosphorus.

| Site | Time | Temperature (°C) | DO (mg/l) | DO (%) | pH | Conductivity (µs/cm) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|
| 410 m upstream | 14:25 | 14.0 | 9.77 | 95.1 | 6.34 | 108.6 | 11 |
| 50 m upstream | 15:05 | 14.1 | 9.65 | 94.0 | 6.68 | 108.7 | 11 |
| Discharge | 13:28 | 16.3 | 2.82 | 28.6 | 6.75 | 532.4 | 28 |
| 50 m downstream | 12:40 | 14.1 | 8.69 | 82.1 | 7.05 | 118.0 | 12 |
| 80 m downstream | 11:55 | 14.1 | 9.66 | 94 | 6.28 | 134.9 | 13 |
| 150 m downstream | 11:29 | 14.0 | 9.63 | 92.7 | 6.4 | 135.3 | 14 |
| 1100 m downstream | 09:13 | 13.2 | 8.73 | 82 | 6.72 | 130.8 | 16 |
| 2000 m downstream | 10:12 | 14.1 | 8.88 | 86.1 | 6.59 | 178.2 | 17 |

| Site | Time | Turbidity-Hill (NTU) | TSS (g/m$^3$) | TN (g/m$^3$) | TKN (g/m$^3$) | TP (g/m$^3$) | *E. coli* (cfu/100mL) |
|---|---|---|---|---|---|---|---|
| 410 m upstream | 13:45 | 9.8 | 7 | 0.69 | 0.39 | 0.034 | 7,000[a] |
| 50 m upstream | 13:10 | 10.1 | 5 | 0.60 | 0.30 | 0.030 | 4,700 |
| Discharge | 12:50 | 27.0 | 16 | 32.00 | 32.00 | 3.900 | 12,000 |
| 50 m downstream | 12:15 | 11.3 | 9 | 1.10 | 0.79 | 0.102 | 5,000[a] |
| 80 m downstream | 12:00 | 11.5 | 7 | 2.60 | 2.30 | 0.280 | 8,000[a] |
| 150 m downstream | 11:51 | 13.1 | 8 | 2.50 | 2.20 | 0.270 | 9,000[a] |
| 1100 m downstream | 09:00 | 14.4 | 11 | 2.30 | 1.77 | 0.240 | 15,000[b] |
| 2000 m downstream | 10:20 | 15.8 | 12 | 2.20 | 1.54 | 0.240 | 9,000[a] |

[a] Statistically estimated count based on the theoretical countable range for the stated method.

[b] microbial results to be interpreted with caution as sample was > 24 hours old when analysed by laboratory.

| Site | Time | Total Ammoniacal-N (g/m$^3$) | Nitrite-N (g/m$^3$) | Nitrate-N (g/m$^3$) | Nitrate-N + Nitrite-N (g/m$^3$) | DRP (g/m$^3$) |
|---|---|---|---|---|---|---|
| 410 m upstream | 13:45 | 0.017 | 0.003 | 0.300 | 0.31 | <0.004 |
| 50 m upstream | 13:10 | 0.020 | 0.003 | 0.310 | 0.31 | 0.006 |
| Discharge | 12:50 | 26.000 | 0.015 | 0.018 | 0.032 | 3.100 |
| 50 m downstream | 12:15 | 0.420 | 0.005 | 0.300 | 0.310 | 0.041 |
| 80 m downstream | 12:00 | 1.630 | 0.006 | 0.300 | 0.310 | 0.168 |
| 150 m downstream | 11:51 | 1.620 | 0.008 | 0.320 | 0.330 | 0.170 |
| 1100 m downstream | 09:00 | 1.140 | 0.026 | 0.500 | 0.530 | 0.143 |
| 2000 m downstream | 10:20 | 0.950 | 0.037 | 0.640 | 0.670 | 0.138 |

# Appendix 3. Periphyton RAM2 analysis— mean periphyton score calculations from the Stream Periphyton Monitoring Manual (Biggs & Kilroy 2000) for seven sites in Wairoro Stream the vicinity of the Kaikohe WWTP discharge.

| SITE: 1 410m upstream | 14-Oct-20 | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| notes | | Score: | Transect 1 | | | | | Transect 2 | | | | | Transect 3 | | | | | Transect 4 | | | | | Site means: |
| Stone/sample no: | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| Thin mat/film: | green | 7 | | | | | 30 | | | 20 | | | | | | | 20 | | | 20 | | | 22.5 |
| (under 0.5 mm thick) | light brown | 10 | 70 | 40 | | | 20 | 30 | 20 | 10 | 90 | 30 | | 40 | 10 | 10 | 60 | | | | | | 35.8 |
| | black/dark brown | 10 | 30 | 60 | 100 | 90 | | 60 | 40 | 60 | 10 | 70 | | 20 | 90 | 90 | 20 | | | | 30 | 50 | 54.7 |
| Medium mat: | green | 5 | | | | | | | | | | | | 20 | | | | | | | | | 20.0 |
| (0.5-3 mm thick) | light brown | 7 | | | | | | | 40 | | | | | | | | | | | | | | 40.0 |
| | black/dark brown | 9 | | | | | | | | | | | 50 | | | | | | | | | | 50.0 |
| Thick mat: | green/light brown | 4 | | | | 10 | 30 | 10 | | 10 | | | 20 | | | | | 10 | 10 | 40 | 70 | 50 | 26.0 |
| (over 3 mm thick) | black/dark brown | 7 | | | | | 10 | | | | | | 20 | | | | | 90 | 80 | 40 | | | 48.0 |
| Filaments, short | green | 5 | | | | | 10 | | | | | | | | | | | | 10 | | | | 10.0 |
| (under 2 cm long) | brown/reddish | 5 | | | | | | | | | | | 10 | 20 | | | | | | | | | 15.0 |
| Filaments, long | green | 1 | | | | | | | | | | | | | | | | | | | | | 0 |
| (over 2 cm long) | brown/reddish | 4 | | | | | | | | | | | | | | | | | | | | | 0 |
| Mean periphyton score: | | | 10 | 10 | 10 | 9.4 | 6.5 | 9.4 | 8.8 | 8.8 | 10 | 10 | 7.2 | 8 | 10 | 10 | 9.4 | 6.7 | 6.5 | 5.8 | 5.8 | 7 | 8.47 |
| % cover: | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| % cover by long filaments: | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| % cover by thick mats: | | | 0 | 0 | 0 | 10 | 40 | 10 | 0 | 10 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 100 | 90 | 80 | 70 | 50 | 25.0 |
| Std dev of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 1.60 |
| SE of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 0.36 |

| SITE: 2 50m upstream | 14-Oct-20 | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| notes | | Score: | Transect 1 | | | | | Transect 2 | | | | | Transect 3 | | | | | Transect 4 | | | | | Site means: |
| Stone/sample no: | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| Thin mat/film: | green | 7 | | | 40 | | | | | 20 | | | | | | 10 | | | | | | | 23.3 |
| (under 0.5 mm thick) | light brown | 10 | 60 | | | 30 | 20 | 40 | | 40 | | 20 | | | | | | | | | | | 35.0 |
| | black/dark brown | 10 | | 40 | 20 | 40 | | 60 | 40 | | | 20 | | | | | | 90 | | | | | 44.3 |
| Medium mat: | green | 5 | | | | | | | | | | | 50 | | | | | | | | | | 50.0 |
| (0.5-3 mm thick) | light brown | 7 | | | | | | | | | | | 50 | | | | | | | | | | 50.0 |
| | black/dark brown | 9 | | | | | | | | | | 20 | | | | | | | | | | | 20.0 |
| Thick mat: | green/light brown | 4 | 40 | 30 | 40 | 30 | 30 | | 60 | | 80 | | | 50 | 60 | 80 | 20 | | | | | | 47.3 |
| (over 3 mm thick) | black/dark brown | 7 | | 30 | | | 20 | | | | | | | 50 | 40 | 10 | | | 100 | 100 | 30 | 60 | 48.9 |
| Filaments, short | green | 5 | | | | | | | | | 20 | | | | | | | 10 | | | 60 | 30 | 30.0 |
| (under 2 cm long) | brown/reddish | 5 | | | | | | | | 20 | | | | | | | 60 | | | | 10 | | 30.0 |
| Filaments, long | green | 1 | | | | | | | | 20 | | | | | | | | | | | | 10 | 15.0 |
| (over 2 cm long) | brown/reddish | 4 | | | | | 30 | | | | | 40 | | | | | 20 | | | | | | 30.0 |
| Mean periphyton score: | | | 7.6 | 7.3 | 6.4 | 8.2 | 5.8 | 10 | 6.4 | 6.6 | 4.2 | 7.4 | 6 | 5.5 | 5.2 | 4.6 | 4.6 | 9.5 | 7 | 7 | 5.6 | 5.8 | 6.54 |
| % cover: | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| % cover by long filaments: | | | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 20 | 0 | 40 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 10 | 6.0 |
| % cover by thick mats: | | | 40 | 60 | 40 | 30 | 50 | 0 | 60 | 0 | 80 | 0 | 0 | 100 | 100 | 90 | 20 | 0 | 100 | 100 | 30 | 60 | 48.0 |
| Std dev of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 1.53 |
| SE of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 0.34 |

| SITE: 4 50m downstream | 14-Oct-20 | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| notes | | Score: | Transect 1 | | | | | Transect 2 | | | | | Transect 3 | | | | | Transect 4 | | | | | Site means: |
| Stone/sample no: | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| Thin mat/film: | green | 7 | | | | | | | | | | | | | | | | | | | | | 0 |
| (under 0.5 mm thick) | light brown | 10 | | | | | | | | | | | | | | | | | | | | | 0 |
| | black/dark brown | 10 | | | | | | | | | | | | | | | | | | | | | 0 |
| Medium mat: | green | 5 | | | | | | | | | | | | | | | | | | | | | 0 |
| (0.5-3 mm thick) | light brown | 7 | | | | | | | | | | | | | | | | | | | | | 0 |
| | black/dark brown | 9 | | | | | | | | | | | | | 20 | | 50 | | | | | | 35.0 |
| Thick mat: | green/light brown | 4 | 100 | 70 | 80 | 20 | 50 | 80 | 60 | 80 | 60 | 100 | 90 | 80 | 40 | 20 | 50 | 20 | 70 | 60 | 20 | 20 | 58.5 |
| (over 3 mm thick) | black/dark brown | 7 | | 30 | 20 | 60 | 50 | 20 | 20 | 20 | 40 | | 10 | 10 | 20 | 80 | | 60 | 30 | 40 | 20 | 70 | 35.3 |
| Filaments, short | green | 5 | | | | | | | | | | | | | | | | | | | | | 0 |
| (under 2 cm long) | brown/reddish | 5 | | | | | | | 20 | | | | | 10 | 20 | | | | | | 30 | | 20.0 |
| Filaments, long | green | 1 | | | | 20 | | | | | | | | | | | | | | | | 10 | 15.0 |
| (over 2 cm long) | brown/reddish | 4 | | | | | | | | | | | | | | | | 20 | | | 30 | | 25.0 |
| MOSS | | | | | | | 25 | 90 | | | | | | | | | 50 | | | | | 90 | |
| Mean periphyton score: | | | 4 | 4.9 | 4.6 | 5.2 | 5.5 | 4.6 | 4.8 | 4.6 | 5.2 | 4 | 4.3 | 4.4 | 5.8 | 6.4 | 6.5 | 5.8 | 4.9 | 5.2 | 4.9 | 5.8 | 5.07 |
| % cover: | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| % cover by long filaments: | | | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 30 | 10 | 4.0 |
| % cover by thick mats: | | | 100 | 100 | 100 | 80 | 100 | 100 | 80 | 100 | 100 | 100 | 100 | 90 | 60 | 100 | 50 | 80 | 100 | 100 | 40 | 90 | 88.5 |
| Std dev of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 0.72 |
| SE of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 0.16 |

| SITE: 5 80m downstream | 14-Oct-20 | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| notes | | Score: | Transect 1 | | | | | Transect 2 | | | | | Transect 3 | | | | | Transect 4 | | | | | Site means: |
| Stone/sample no: | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| Thin mat/film: | green | 7 | | | | | | | | | | | | | | | | | | | | | 0 |
| (under 0.5 mm thick) | light brown | 10 | | | | | | | | | | | | | 40 | | | | | | | | 40.0 |
| | black/dark brown | 10 | | | | | | | | | | | | 40 | 60 | | | | | | | | 50.0 |
| Medium mat: | green | 5 | | | | | | | | | | | | | | | | | | | | | 0 |
| (0.5-3 mm thick) | light brown | 7 | | | | | | | 20 | | | | | | | | | | | | | | 20.0 |
| | black/dark brown | 9 | | | | | | | 60 | | | | | | | | | | | | | | 60.0 |
| Thick mat: | green/light brown | 4 | 20 | 50 | 60 | 60 | 20 | | | 20 | 30 | 40 | 40 | 20 | | 20 | 60 | 70 | 40 | 90 | 40 | 80 | 44.7 |
| (over 3 mm thick) | black/dark brown | 7 | 80 | 50 | 40 | 40 | 80 | 40 | | 80 | 70 | 50 | 50 | | | 80 | 40 | 30 | 60 | 10 | 40 | 20 | 50.6 |
| Filaments, short | green | 5 | | | | | | | | | | | | | | | | | | | | | 0 |
| (under 2 cm long) | brown/reddish | 5 | | | | | | 40 | | | | 10 | | | | | | | | | | | 25.0 |
| Filaments, long | green | 1 | | | | | | 20 | 20 | | | | 10 | | | | | | | | | | 16.7 |
| (over 2 cm long) | brown/reddish | 4 | | | | | | | | | | | | 40 | | | | | | | 20 | | 30.0 |
| MOSS | | | | | | | | | | | | | | | | 10 | | | | | | 90 | |
| Mean periphyton score: | | | 6.4 | 5.5 | 5.2 | 5.2 | 6.4 | 5 | 7 | 6.4 | 6.1 | 5.6 | 5.2 | 6.4 | 10 | 6.4 | 5.2 | 4.9 | 5.8 | 4.3 | 5.2 | 4.6 | 5.84 |
| % cover: | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| % cover by long filaments: | | | 0 | 0 | 0 | 0 | 0 | 20 | 20 | 0 | 0 | 0 | 10 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 5.5 |
| % cover by thick mats: | | | 100 | 100 | 100 | 100 | 100 | 40 | 0 | 100 | 100 | 90 | 90 | 20 | 0 | 100 | 100 | 100 | 100 | 100 | 80 | 100 | 81.0 |
| Std dev of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 1.21 |
| SE of periphyton score: | | | | | | | | | | | | | | | | | | | | | | | 0.27 |

Appendix 3. continued…

*SITE: 6 150m downstrea* 14/10/2020 transect 4, samples 4 and 5 - both had bare substrate evident

| notes | | Score: | Transect 1 | | | | | Transect 2 | | | | | Transect 3 | | | | | Transect 4 | | | | | Site means: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stone/sample no:** | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| Thin mat/film: | green | 7 | | | 40 | | | | | | | | | | | | | | | | | | 40.0 |
| (under 0.5 mm thick) | light brown | 10 | | | 30 | 100 | | | | | | | | | | | | | | | | | 65.0 |
| | black/dark brown | 10 | | 40 | | | | 60 | 60 | | | | | | | | | | | | | | 53.3 |
| Medium mat: | green | 5 | | | | | | | 40 | | | | | | | | | | | | | | 40.0 |
| (0.5-3 mm thick) | light brown | 7 | | | | | | | | | | | | | | | | 100 | | | | | 100.0 |
| | black/dark brown | 9 | | | | | | | | | | | 40 | | | | | | | | | | 40.0 |
| Thick mat: | green/light brown | 4 | 100 | | | | 40 | | | 20 | 60 | 60 | 50 | 50 | 50 | 60 | 70 | | 60 | | 50 | 40 | 54.6 |
| (over 3 mm thick) | black/dark brown | 7 | | | | | 30 | | | 20 | | | | 30 | 50 | 40 | 30 | | 40 | 100 | | 40 | 42.2 |
| Filaments, short | green | 5 | | 60 | | | | | | | | | | | | | | | | | | | 60.0 |
| (under 2 cm long) | brown/reddish | 5 | | | | | 30 | 40 | | | 40 | | 10 | | | | | | | | | | 30.0 |
| Filaments, long | green | 1 | | | 30 | | | | | 60 | | 40 | | | | | | | | | | | 43.3 |
| (over 2 cm long) | brown/reddish | 4 | | | | | | | | | | | | 20 | | | | | | | | | 20.0 |
| **Mean periphyton score:** | | | 4 | 7 | 6.1 | 10 | 5.2 | 8 | 8 | 2.8 | 4.4 | 2.8 | 6.1 | 4.9 | 5.5 | 5.2 | 4.9 | 7 | 5.2 | 7 | 4 | 5.5 | **5.68** |
| **% cover:** | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 50 | 80 | 96.5 |
| **% cover by long filaments:** | | | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 60 | 0 | 40 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.5 |
| **% cover by thick mats:** | | | 100 | 0 | 0 | 0 | 70 | 0 | 0 | 40 | 60 | 60 | 50 | 80 | 100 | 100 | 100 | 0 | 100 | 100 | 50 | 80 | 54.5 |
| **Std dev of periphyton score:** | | | | | | | | | | | | | | | | | | | | | | | 1.79 |
| **SE of periphyton score:** | | | | | | | | | | | | | | | | | | | | | | | 0.40 |

*SITE: 7 1100m downstre* 14-Oct-20

| notes | | Score: | Transect 1 | | | | | Transect 2 | | | | | Transect 3 | | | | | Transect 4 | | | | | Site means: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stone/sample no:** | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| Thin mat/film: | green | 7 | | | | | | | | | | | | | | | | | | | | | 0 |
| (under 0.5 mm thick) | light brown | 10 | | | | | | | | | | | | | | | | | | | | | 0 |
| | black/dark brown | 10 | | | | | | | | | | | | | | | | 50 | | | 20 | | 35.0 |
| Medium mat: | green | 5 | | | | | | | | | | | | | | | | | | | | | 0 |
| (0.5-3 mm thick) | light brown | 7 | | | | | | | | | | | | | | | | | | | | | 0 |
| | black/dark brown | 9 | | | | | | | | | | | | | | | 40 | | | | | | 40.0 |
| Thick mat: | green/light brown | 4 | 100 | | | | 100 | | 60 | 50 | 20 | 60 | 30 | 20 | 40 | | 40 | | 60 | 20 | | 80 | 52.3 |
| (over 3 mm thick) | black/dark brown | 7 | | | | | | | | | | | | 80 | 20 | | | | | | 20 | | 40.0 |
| Filaments, short | green | 5 | | | | | | 100 | | 50 | 80 | | | | | | | | | | | | 76.7 |
| (under 2 cm long) | brown/reddish | 5 | | 100 | | | | | | | | | | | | | 20 | 50 | | | 20 | | 47.5 |
| Filaments, long | green | 1 | | | | 60 | | | 40 | | | 20 | 40 | | 40 | 100 | | | | | | | 50.0 |
| (over 2 cm long) | brown/reddish | 4 | | | 100 | 40 | | | | | | 20 | 30 | | | | | | 40 | 80 | 40 | 20 | 46.3 |
| **Mean periphyton score:** | | | 4 | 5 | 4 | 2.2 | 4 | 5 | 2.8 | 4.5 | 4.8 | 3.4 | 2.8 | 6.4 | 3.4 | 1 | 6.2 | 7.5 | 4 | 4 | 6 | 4 | **4.25** |
| **% cover:** | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100.0 |
| **% cover by long filaments:** | | | 0 | 0 | 100 | 100 | 0 | 0 | 40 | 0 | 0 | 40 | 70 | 0 | 40 | 100 | 0 | 0 | 40 | 80 | 40 | 20 | 33.5 |
| **% cover by thick mats:** | | | 100 | 0 | 0 | 0 | 100 | 0 | 60 | 50 | 20 | 60 | 30 | 100 | 60 | 0 | 40 | 0 | 60 | 20 | 20 | 80 | 40.0 |
| **Std dev of periphyton score:** | | | | | | | | | | | | | | | | | | | | | | | 1.53 |
| **SE of periphyton score:** | | | | | | | | | | | | | | | | | | | | | | | 0.34 |

*SITE: 8 2000m downstre* 14/10/2020 transect 1, samples 1-4 have bare substrate present

| notes | | Score: | Transect 1 | | | | | Transect 2 | | | | | Transect 3 | | | | | Transect 4 | | | | | Site means: |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stone/sample no:** | | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | |
| Thin mat/film: | green | 7 | | | | | | | | | | | | | | | | | | | | | 0 |
| (under 0.5 mm thick) | light brown | 10 | | | | | | | | | | | | | | | | | | | | 40 | 40.0 |
| | black/dark brown | 10 | | | | | | 40 | 40 | | | | | | | | | | | | | 40 | 40.0 |
| Medium mat: | green | 5 | | | | | 20 | | | | | | | | | | | | | | | | 20.0 |
| (0.5-3 mm thick) | light brown | 7 | | | | | | 20 | | | | | | | | | | | | | | | 20.0 |
| | black/dark brown | 9 | | | | | | | | | | | | | | | | | | | | | 0 |
| Thick mat: | green/light brown | 4 | | | | | 40 | | 60 | 40 | 20 | 40 | 80 | 20 | | 100 | 80 | 70 | 30 | 100 | 40 | | 55.4 |
| (over 3 mm thick) | black/dark brown | 7 | | | | | | | | 40 | | 40 | | | | | | | 30 | | | | 36.7 |
| Filaments, short | green | 5 | | | | | | | | | | | | | | | | | | | | | 0 |
| (under 2 cm long) | brown/reddish | 5 | | | | | | | | | | | | | 80 | | 20 | | | | 40 | | 46.7 |
| Filaments, long | green | 1 | 80 | 60 | 80 | 80 | 40 | 40 | | 20 | 80 | 20 | 20 | 80 | 20 | | | 30 | 40 | | 20 | 20 | 45.6 |
| (over 2 cm long) | brown/reddish | 4 | | | | | | | | | | | | | | | | | | | | | 0 |
| **Mean periphyton score:** | | | 1 | 1 | 1 | 1 | 3 | 5.8 | 6.4 | 4.6 | 1.6 | 4.6 | 3.4 | 1.6 | 4.2 | 4 | 4.2 | 3.1 | 3.7 | 4 | 3.8 | 8.2 | **3.51** |
| **% cover:** | | | 80 | 60 | 80 | 80 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 95.0 |
| **% cover by long filaments:** | | | 80 | 60 | 80 | 80 | 40 | 40 | 0 | 20 | 80 | 20 | 20 | 80 | 20 | 0 | 0 | 30 | 40 | 0 | 20 | 20 | 36.5 |
| **% cover by thick mats:** | | | 0 | 0 | 0 | 0 | 40 | 0 | 60 | 80 | 20 | 80 | 80 | 20 | 0 | 100 | 80 | 70 | 60 | 100 | 40 | 0 | 41.5 |
| **Std dev of periphyton score:** | | | | | | | | | | | | | | | | | | | | | | | 1.95 |
| **SE of periphyton score:** | | | | | | | | | | | | | | | | | | | | | | | 0.44 |

Appendix 4. Macroinvertebrate taxa and their relative abundance recorded at sampling sites in the Wairoro Stream above, at, and below the Kaikohe WWTP discharge point (14 October 2020). Also shown are the MCI taxon scores. Samples were collected with a kicknet (0.5 mm mesh). Relative abundance codes: R = rare, C = common, A = abundant, VA = very abundant, VVA = very, very abundant.

| | **MCI** | **Upstream** | | **Discharge** | **Downstream** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Taxon** | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Site 6** | **Site 7** | **Site 8** |
| **Taxa** | **Score** | **410 m** | **50 m** | **Discharge** | **50 m** | **80 m** | **150 m** | **1100 m** | **2000 m** |
| **Ephemeroptera (mayflies)** | | | | | | | | | |
| *Austroclima sepia* | **9** | - | R | - | - | - | - | C | - |
| *Austroclima* sp. | **9** | C | - | - | - | - | - | - | R |
| *Coloburiscus humeralis* | **9** | C | C | - | - | A | C | A | C |
| *Deleatidium* sp. | **8** | R | C | - | - | R | - | - | R |
| *Nesameletus* sp. | **9** | R | R | - | - | - | R | C | R |
| *Zephlebia* sp. | **7** | - | - | - | - | R | - | - | C |
| *Zephlebia versicolor* | **7** | C | C | - | - | A | C | A | - |
| **Plecoptera (stoneflies)** | | | | | | | | | |
| *Acroperla trivacuata* | **5** | R | - | - | - | R | R | - | C |
| **Megaloptera (dobsonflies)** | | | | | | | | | |
| *Archichauliodes diversus* | **7** | - | C | - | R | C | C | R | - |
| **Odonata (damselflies)** | | | | | | | | | |
| Anisoptera | **5** | - | R | - | - | - | - | - | - |
| *Xanthocnemis zelandica* | **5** | - | - | - | - | - | - | - | R |
| Zygoptera | **5** | - | - | - | R | - | - | - | - |
| **Coleoptera (beetles)** | | | | | | | | | |
| Elmidae | **6** | R | C | - | - | R | - | - | R |
| **Diptera (true flies)** | | | | | | | | | |
| Anthomyiidae | **3** | - | - | - | - | R | C | C | R |
| *Aphrophila neozelandica* | **5** | R | - | - | - | R | - | R | R |
| *Austrosimulium* spp. | **3** | A | A | - | R | A | R | C | A |
| *Chironomus zealandicus* | **1** | - | R | VA | VVA | VA | VA | C | A |
| *Culex* sp. | **3** | - | - | R | - | R | - | - | - |
| *Ephydrella* sp. | **5** | - | - | - | - | - | - | R | - |
| *Maoridiamesa* sp. | **3** | - | C | - | R | - | - | R | C |
| Orthocladiinae | **2** | A | VVA | R | VA | VA | VA | VA | VVA |
| *Polypedilum* sp. | **3** | C | VA | VVA | A | VVA | VA | A | VA |
| Psychodidae | **1** | - | R | R | R | R | R | - | - |
| Stratiomyidae | **5** | - | - | - | - | R | R | - | - |
| Tanypodinae | **5** | R | - | - | - | - | R | - | - |
| *Tanytarsus vespertinus* | **3** | R | VA | - | - | VA | VA | A | VA |

Appendix 4. continued…

| Taxa | MCI Taxon Score | Upstream Site 1 410 m | Upstream Site 2 50 m | Discharge Site 3 Discharge | Downstream Site 4 50 m | Downstream Site 5 80 m | Downstream Site 6 150 m | Downstream Site 7 1100 m | Downstream Site 8 2000 m |
|---|---|---|---|---|---|---|---|---|---|
| **Trichoptera (caddis flies)** | | | | | | | | | |
| *Hydropsyche* (*Aoteapsyche*) spp. | **4** | A | C | - | - | A | C | C | C |
| *Hydrobiosis copis* | **5** | R | R | - | - | R | R | - | - |
| *Hydrobiosis* spp. | **5** | - | C | - | - | C | - | R | C |
| *Neurochorema confusum* | **6** | - | - | - | R | - | R | - | - |
| *Neurochorema* sp. | **6** | R | R | - | - | - | - | - | - |
| *Oxyethira albiceps* | **2** | C | A | - | A | A | A | VA | VA |
| *Pycnocentria evecta* | **7** | R | R | - | - | C | R | C | C |
| *Pycnocentrodes* sp. | **5** | R | C | - | C | R | - | R | - |
| *Triplectides obsoletus* | **5** | - | R | - | - | - | - | - | - |
| *Triplectides* sp. | **5** | - | - | - | R | - | - | - | - |
| **Nematoda (roundworms)** | **3** | - | - | VA | VA | - | - | - | - |
| **Nemertea (proboscis worms)** | **3** | - | R | - | - | - | - | - | - |
| **Oligochaeta (worms)** | **1** | R | VA | VVA | A | A | VVA | R | C |
| **Platyhelminthes (flatworms)** | **3** | - | R | - | R | R | A | - | - |
| **Mollusca (snails)** | | | | | | | | | |
| *Potamopyrgus antipodarum* | **4** | A | VVA | - | VA | A | A | C | A |
| Sphaeriidae | **3** | - | R | - | - | - | - | - | - |
| **Crustacea (crustaceans)** | | | | | | | | | |
| Amphipoda | **5** | - | - | - | - | - | - | R | - |
| Copepoda | **5** | - | - | - | R | - | R | - | R |
| Cladocera | **5** | - | - | R | - | - | - | - | - |
| Ostracoda | **3** | - | R | R | C | C | R | R | R |
| *Paranephrops planifrons* | **5** | - | - | - | R | - | - | - | - |
| **Coelenterata (hydra)** | | | | | | | | | |
| *Hydra* sp. | **3** | - | - | - | VVA | A | A | - | R |
| **Acarina (mites)** | **5** | - | R | - | - | - | R | R | - |
| **Collembola (springtails)** | **6** | R | R | - | R | C | C | - | R |
| **Taxa Richness** | | 22 | 31 | 9 | 21 | 29 | 27 | 24 | 26 |
| **%EPT** taxa (minus Hydroptilidae) | | 50.0 | 38.7 | 0.0 | 15.0 | 34.5 | 29.6 | 33.3 | 34.6 |
| **MCI** | | 104 | 92 | 49 | 72 | 84 | 87 | 92 | 93 |
| **SQMCI** | | 4.08 | 2.96 | 2.00 | 2.25 | 2.96 | 1.84 | 3.28 | 2.44 |