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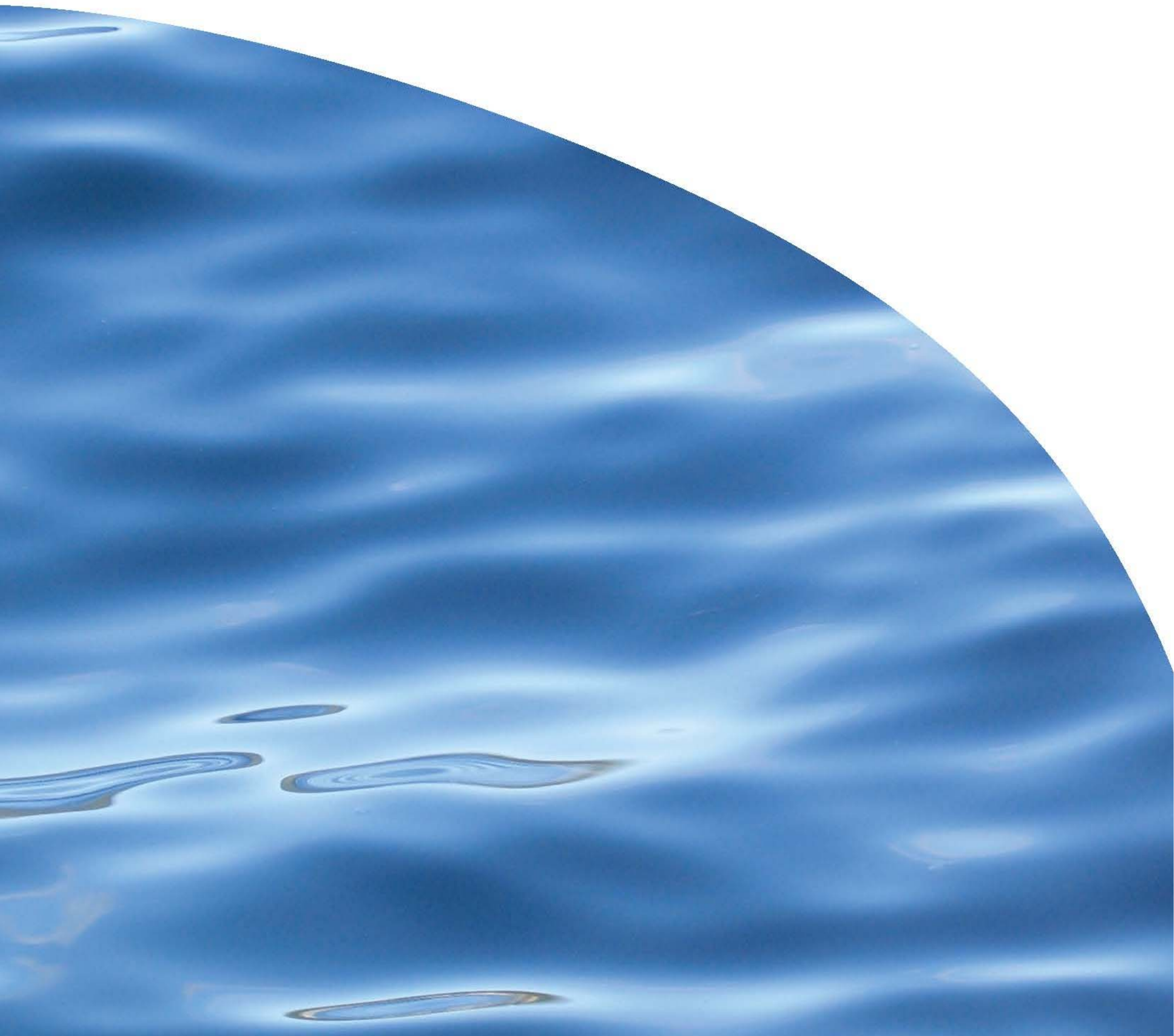
# ASSESSMENT OF AMMONIA EFFECTS ON THE WAIRORO STREAM FAUNA NEAR THE KAIKOHE WASTEWATER TREATMENT PLANT



# ASSESSMENT OF AMMONIA EFFECTS ON THE WAIRORO STREAM FAUNA 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 of the Wairoro Stream. 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. On 30% of consent monitoring occasions between November 2005 and March 2014, the total ammonia-N concentrations were above the consented pH-dependent limit. In response, the council commissioned Cawthron Institute (Cawthron) to investigate whether the total ammonia concentrations in the Wairoro Stream are having a significant adverse effect on stream fauna.

Macroinvertebrate communities are useful for assessing environmental effects as they integrate environmental conditions operating over relatively long time periods. On 15 April 2014, benthic macroinvertebrate samples and a water quality sample for nitrogen analysis were collected from the Wairoro Stream at two sites upstream (50 m and 410 m) and three sites downstream (150 m, 330 m and 1,100 m) of the unnamed tributary receiving the WWTP discharge. A water quality sample was also taken from the unnamed tributary. Additional water quality measurements were recorded and general observations on habitat (*e.g.* periphyton and macrophyte growth) noted for each site.

Consented ammonia limits were breached at FNDC's compliance monitoring site (150 m downstream of the discharge) and at the next site further downstream (330 m downstream of the discharge) on the day of the ecological survey. There were obvious upstream–downstream differences in periphyton biomass and community structure as well as the presence of macrophytes — consistent with nutrient addition from the discharge (especially total ammonia-N). Thin biofilms and no macrophytes were seen at the upstream sites while extensive growth of long filamentous green algae and macrophytes were seen downstream of the discharge. There were also obvious upstream–downstream differences in macroinvertebrate communities. Communities upstream of the discharge consisted of mayflies and caddisflies (pollution-sensitive taxa) and few true flies (pollution-tolerant taxa) while downstream the converse was true. Macroinvertebrate densities were significantly higher downstream of the discharge than upstream. Macroinvertebrate community indices for stream ecosystem health (EPT metrics, MCI and QMCI) showed that stream health downstream of the discharge was more degraded than upstream.

We found no evidence to suggest macroinvertebrates were experiencing significant acute or chronic ammonia toxicity effects. New Zealand aquatic macroinvertebrates in the Wairoro Steam are more sensitive to ammonia toxicity than the native fish most likely to be present in the stream (*i.e.* longfin and shortfin eels). Past breaches of the pH-dependent total ammonia-N consent limit reported during monitoring by FNDC have all been at concentrations lower than the maximum threshold of acute ammonia toxicity for New Zealand macroinvertebrates and fish.

We conclude that the breaches in total ammonia-N concentrations are unlikely to be having a significant adverse toxic effect (acute or chronic) on the stream fauna. However, this conclusion may not hold when consented limits are breached for an extended period of time (*e.g.* as occurred during the FNDC monitoring period from 21 December 2009 to 6 May 2010). On the other hand, total ammonia-N in the discharge is having an indirect effect on macroinvertebrate community structure and abundance via its stimulatory effect on periphyton. Ammonia is one of the nutrients that contribute to excessive periphyton and macrophyte growth seen downstream of the discharge.

Finally we note that on 6% of monitoring occasions between November 2005 and March 2014, the total ammonia-N concentrations recorded below the downstream boundary of the mixing zone (our sampling site 150 m downstream of the discharge into the Wairoro Stream) did not meet the national bottom line of 2.20 mg N/L (annual maximum at pH 8 and 20°C) given in the National Policy Statement for Freshwater Management (NPS-FM) issued July 2014. Given our general observations of high periphyton cover and biomass and low dissolved oxygen (DO) concentrations, the national bottom line for periphyton (indicating trophic state) and DO may also be breached by the discharge. The low DO below the discharge is likely related to organic enrichment and / or high periphyton biomass.

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# 1. INTRODUCTION

## 1.1. Background

The Far North District Council (FNDC) currently hold a resource consent (CON20100241701) to discharge treated wastewater from the Kaikohe wastewater treatment plant (WWTP) to an unnamed tributary of the Wairoro Stream.

Under condition 7(e) of this consent the FNDC is to ensure that the discharge entering the Wairoro Stream via the unnamed tributary does not cause acute toxicity, or significant effects of chronic toxicity to natural aquatic life by reason of a concentration of toxic substances. Total ammoniacal nitrogen (total ammonia-N)[1] is one of the toxicants singled out in the consent and trigger limits are set in condition 7(i) (Appendix 1). The condition specifies that effects are to be assessed approximately 80 m downstream of the discharge point from the unnamed tributary into the Wairoro Stream (80 m being the downstream boundary of the mixing zone) and compared with conditions at an upstream site approximately 25 m upstream of the confluence with the unnamed tributary.

The total ammonia-N limits have been breached on 30% of consent monitoring occasions between November 2005 and March 2014. FNDC commissioned the Cawthron Institute to investigate whether non-compliance has effects on the ecology of Wairoro Stream. The results of this ecological study will help inform the decision on whether to apply for a variation of consent or to upgrade the WWTP.

This report describes the results of a longitudinal ecological study addressing the above brief. Although the main focus of the report is total ammonia-N toxicity effects on invertebrates and fish, we also include other aspects of water quality where appropriate to put ammonia in context with other potentially limiting factors. To do this, we briefly analyse and discuss water quality monitoring data collected by FNDC from the Wairoro Stream as part of their resource consent requirements. Assessment of effects on macroinvertebrates and fish was based on the field study and a desk-top study, respectively.

## 1.2. Effects of ammonia on aquatic organisms

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).

[1] Total ammoniacal nitrogen and total ammonia nitrogen are synonyms. In this report we use the term total ammonia nitrogen, which is shortened to total ammonia-N.

Ammonia ($NH_3$) is a non-persistent and non-bioaccumulative toxicant to aquatic life (ANZECC & ARMCANZ, 2000). 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 fish, this can lead to proliferation in gill tissues to cause increased ventilation rates and asphyxia; reduction in blood oxygen-carrying capacity; disruption of the metabolic functioning of the liver and kidneys; and in extreme circumstances, convulsions, coma and death (Alabaster & Lloyd, 1982; USEPA, 2013). Among macroinvertebrates, bivalves and gill-breathing snails are particularly sensitive to ammonia, which can cause impaired respiration and feeding, metabolic alteration, and mortality (USEPA, 2013).

## 1.3. Current guidelines relating to ammonia toxicity in freshwaters

### *1.3.1. ANZECC trigger values for ammonia in freshwater*

In New Zealand, trigger values for the protection of freshwater species against toxic levels of ammonia are provided in the ANZECC (2000)[2] guidelines for receiving waters (Table 1). These trigger values were derived from chronic[3] toxicity data collected for five aquatic animal species (including New Zealand species) covering four taxonomic groups using a 95% species protection level. The ANZECC trigger values are the ammonia guidelines used for the Wairoro Stream monitoring in the resource consent (Appendix 1, condition 7(i)).

[2] The ANZECC (2000) guidelines are currently being reviewed and updated (Warne *et al.* 2014).
[3] Chronic tests determine sublethal effects of a toxin on a test species over a number of generations of a portion of an organism's life cycle (Hickey 2000). Sub-lethal effects include reduced growth or reproductive success.

Table 1. 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 |

### *1.3.2. United States Environmental Protection Agency criteria for ammonia in freshwater*

The U.S. Environmental Protection Agency (USEPA) recently published national recommended ambient water quality criteria for the protection of aquatic life from the toxic effects of ammonia (USEPA, 2013) reflecting latest scientific knowledge. It provides both acute and chronic criteria given as concentrations of the pollutant with specific associated duration and frequency information.

The USEPA (2013) recommends the following:

- An acute criterion of 17 mg total ammonia-N/L at pH 7 and 20°C for a 1-hour average duration. This criterion should not be exceeded more than once in three years on average.
- A chronic criterion of 1.9 mg total ammonia-N/L at pH 7 and 20°C for a 30-day rolling average duration. In addition, the highest 4-day average within the 30 days should not exceed 2.5 times the chronic criterion concentration (*e.g.* 2.5 × 1.9 mg total ammonia-N/L = 4.8 mg total ammonia-N/L at pH 7 and 20°C). These values should not be exceeded more than once in three years on average.

## 1.4. Ammonia in context of the National Policy Statement for Freshwater Management

The latest National Policy Statement for Freshwater Management (NPS-FM) issued on 4 July 2014 by the Ministry for the Environment specifies attribute states for ammonia, ranging from state A (= high level of protection) to D (= below a national bottom line), to prevent its toxic effects on aquatic life and provide for ecosystem health. Each attribute state has numeric limits informed by current scientific knowledge (Davies-Colley *et al.* 2013). The national bottom line (boundary between attribute states C and D) is set at an annual median and maximum value of 1.30 mg and 2.20 mg total ammonia-N/L (pH 8, temperature of 20°C), respectively. These concentrations have been defined using the 80% species protection level. In narrative form, concentrations observed below this national bottom line are expected to start impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species). Since ecosystem health is a compulsory national value (in the NPS-FM), this bottom line will have to be complied with in regional plans.

Boundaries between other attribute states will become applicable if a community decides to aim for higher states of ecosystem health in a freshwater unit. The boundary between attribute states A and B has been defined using the 99% species protection level and is set at an annual median and maximum value of 0.03 mg and 0.05 mg total ammonia-N/L, respectively. The boundary between state B and C has been defined using the 95% species protection level and is set at 0.24 mg and 0.40 mg total ammonia-N/L, respectively.

# 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$^2$. The ecological survey was undertaken during base flow conditions as indicated by flow data recorded downstream in the Punakitere River at the Taheke flow recorder site[4] (Figure 1). We sampled at the end of a long flow recession to assess the effects of ammonia toxicity *in situ* under a near-worst-case scenario for stream fauna — when the WWTP discharge is least diluted by the Wairoro Stream.

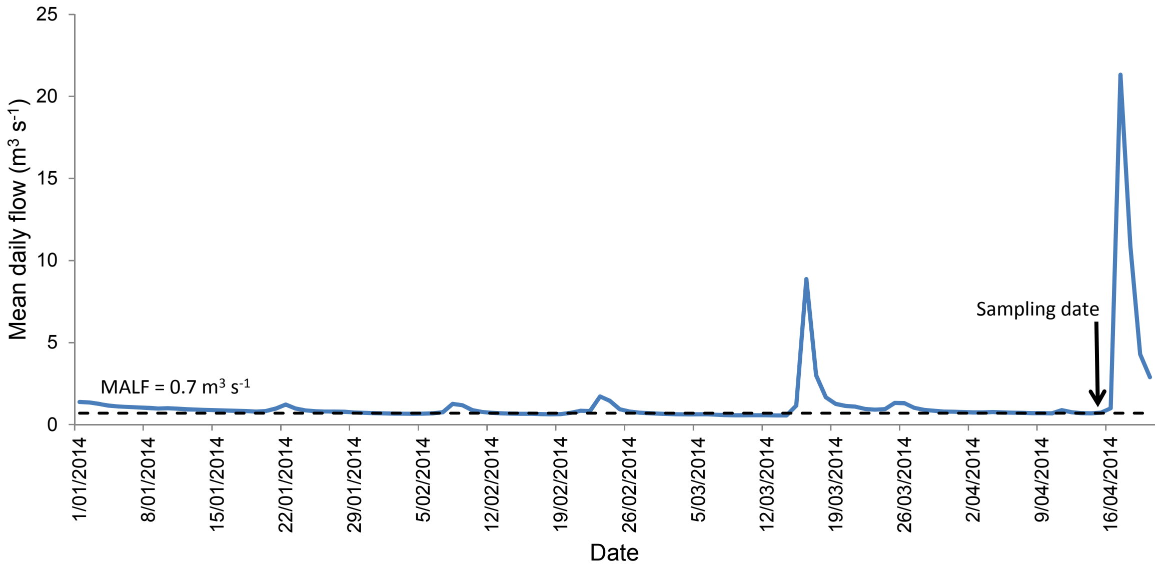


Figure 1. Discharge recorded at the Northland Regional Council flow station 'Punakitere River at Taheke' for three and a half months prior to the Cawthron ecological survey undertaken on 15 April 2014 (see arrow). Dotted line represents the mean annual low flow (MALF) of the Punakitere River.

On 15 April 2014, water quality and macroinvertebrate communities were assessed at five Wairoro Stream sites in the vicinity of the point discharge from the Kaikohe WWTP via an unnamed tributary (Figure 2). We sampled at the two FNDC Wairoro Stream water quality compliance monitoring sites, upstream and downstream of the discharge (sites 103316 and 100807, respectively — see Appendix 1) and at three

[4] Flow records were not available for the Wairoro Stream. However, flow information from the Punakitere River at Taheke flow recorder site (monitored by the Northland Regional Council) can be used as a rough indication of what flow conditions may have been like in the Wairoro Stream. The Wairoro Stream is a tributary of the Punakitere River and the flow recorder site is located downstream of the Wairoro Stream confluence with the Punakitere River. On 15 April the daily mean flow recorded at the Punakitere at Taheke flow recorder was 0.721 m$^3$/s (mean annual low flow in the river is approximately 0.700 m$^3$/s). The most significant fresh in the Punakitere River prior to sampling in the Wairoro Stream was 8.873 m$^3$/s recorded on 16 March 2014.

further sites. This longitudinal survey consisted of two sites located upstream (410 m and 50 m) and three sites downstream of the confluence with the unnamed tributary (150 m, 330 m and 1,100 m) (Table 2, Figure 2). Note that these distances, used throughout this report, were measured in Google Earth and that those for sites 103316 and 100807 (*i.e.* 50 m upstream and 150 m downstream of the discharge) differ from distances given in the consent (*i.e.* 25 m upstream and 80 m downstream of the discharge). In addition to the five sampling sites in the Wairoro Stream, water quality was assessed at an existing FNDC monitoring site in the unnamed tributary (site 100560) (Figure 2).

The longitudinal survey allowed 1) comparison of conditions between upstream and downstream sites to assess likely impacts of the discharge and 2) tracking of potential improvement with increasing distance from the discharge.

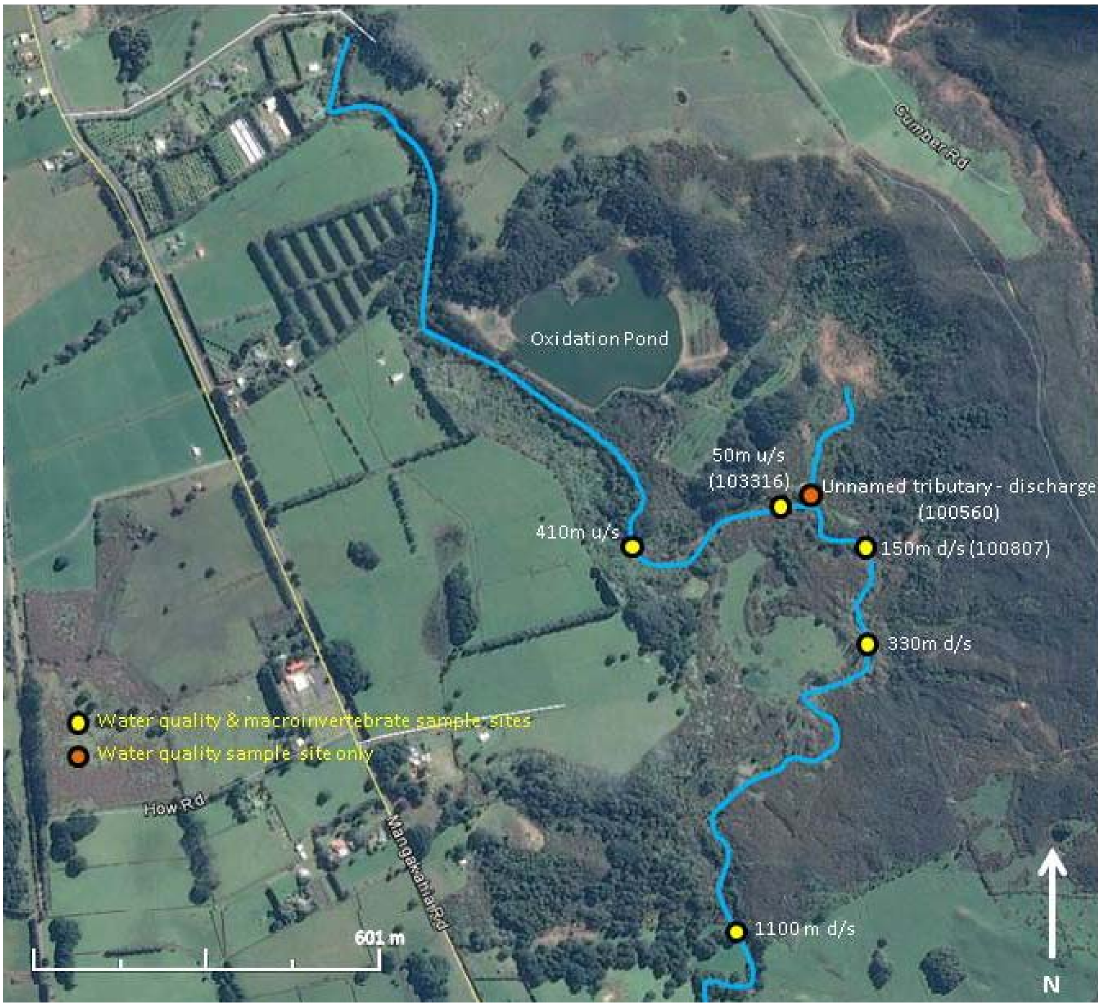


Figure 2. Field sampling sites in the Wairoro Stream and an unnamed tributary containing treated effluent from the Kaikohe wastewater treatment plant (WWTP). Sites upstream and downstream of the confluence with the unnamed tributary are denoted u/s and d/s, respectively. The satellite image was downloaded from Google Earth in August 2014. See Appendix 1 for a more detailed schematic of the WWTP layout.

Table 2. Global positioning system (GPS) coordinates (NZMG) of all sites sampled on 15 April 2014. Water quality was sampled at all sites, and macroinvertebrates sampled at the Wairoro Stream sites but not the unnamed tributary.

| Site | Northing | Easting |
|---|---|---|
| 410 m upstream | 6641088 | 2585305 |
| 50 m upstream (site 103316) | 6641127 | 2585588 |
| Unnamed tributary – discharge (site 100560) | 6641124 | 2585639 |
| 150 m downstream (site 100807) | 6641038 | 2585734 |
| 330 m downstream | 6640884 | 2585741 |
| 1,100 m downstream | 6640385 | 2585510 |

## 2.2. Sample collection and analysis

### *2.2.1. Water quality and general field observations*

Spot measurements of water temperature (ºC), dissolved oxygen concentration (mg/L) and percentage saturation (%), and specific conductivity (µS/cm), were taken with a YSI 85 hand-held water quality meter. Turbidity (NTU) was measured using a Hach 2100P Turbidimeter and pH with a hand-held Hanna 98127 meter.

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) as well as total-N (TN). 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.

General instream observations of periphyton cover were also noted at each site. This is because ammonia (and other forms of nitrogen, and phosphorus) can have a strong influence on periphyton and macrophyte growth, which in turn can influence the taxonomic structure of macroinvertebrate communities.

### *2.2.2. Macroinvertebrates*

Three replicate macroinvertebrate samples were collected from each site with a Surber sampler (0.0625 $m^2$, 0.5 mm mesh) according to protocol C3 in Stark *et al*. (2001). At each site, three samples were taken across 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 P3 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.

Macroinvertebrate densities (No. $m^{-2}$), relative contribution of each taxon, as well as EPT metrics and the two biotic indices — the Macroinvertebrate Community Index (MCI) and the Quantitative Macroinvertebrate Community Index (QMCI) — were calculated for pooled samples for each site. Densities, EPT metrics, MCI and QMCI were also calculated for each individual sample for statistical analyses. For each response variable, a Student's *t*-test using the Welch approximation to the degrees of freedom was run in the statistical programme R. This compared means between samples taken upstream and downstream of the Kaikohe WWTP discharge.

#### 2.2.3. 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) such as true-fly larvae and worms. Hence, high EPT density (No. $m^{-2}$), high EPT taxon richness, and the proportion of EPT to overall density ($\%EPT_{Density}$) and taxon richness ($\%EPT_{Taxa}$) are generally indicative of a community less impacted by pollution.

#### 2.2.4. Calculation and interpretation of the Macroinvertebrate Community Index and the Quantitative Macroinvertebrate Community Index

The MCI and its quantitative version, the QMCI, are 'stream health' indices developed for assessment of organic pollution and nutrient enrichment in stony streams and rivers (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, QMCI values theoretically range from 0 to 10. Unlike the MCI, which is based on the presence of each scoring taxa, the QMCI 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 QMCI bands (Table 3).

Table 3. Interpretation of Macroinvertebrate Community Index (MCI) and the Quantitative Macroinvertebrate Community Index (QMCI) values from stony riffles (from Stark & Maxted 2007)

| Water quality class | MCI | QMCI |
|---|---|---|
| Excellent | > 120 | > 6.00 |
| Good | 100–119 | 5.00–5.99 |
| Fair | 80–99 | 4.00–4.99 |
| Poor | < 80 | < 4.00 |

### *2.2.5. Fish*

No fish records were available in the New Zealand Freshwater Fish Database (www.niwa.co.nz/freshwater-and-estuaries/nzffd; accessed July 2014) for the Wairoro Stream segment that contained our sampling sites. However, we were able to use fish data collected and recorded from other segments of the Wairoro Stream (and its tributaries) as a surrogate for determining what species are most likely present in the study reach. We also assessed the probability of fish species presence in the study reach and further upstream using a fish distribution model developed by Leathwick *et al*. (2008). 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).

# 3. RESULTS AND DISCUSSION

## 3.1. Water quality

### *3.1.1. Spot water quality measurements*

Spot measurements of pH, temperature, dissolved oxygen (DO) concentration and percentage saturation, specific conductivity and turbidity at five Wairoro Stream sites and in the unnamed tributary can be found in Table 4. It should be noted that temperature, pH and DO follow diurnal cycles in streams, hence the comparisons between sites in this report only relate to the time of day sampled and do not account for the daily maximums and minimums that may occur.

**Temperature and pH**

On average there was little difference in temperature and pH among the sites (Table 4). Water temperatures in the Wairoro Stream downstream of the confluence with the unnamed tributary were within 1.5°C of upstream. This complies with resource consent condition 7(a), which states that the natural temperature of the water shall not be changed by more than 3°C as a result of the discharge (Appendix 1). The pH at all sites except 1,100 m downstream complied with the range set in the resource consent of 6.5 to 9.0. The reason for the low pH of 6.4 recorded at the furthest downstream sampling site is unknown, but is unlikely to be related to the Kaikohe WWTP discharge because higher pH was recorded at sites between there and the discharge.

An analysis of FNDC compliance monitoring data collected from January 2010 to March 2014 showed a pH range of 6.7 to 7.9 upstream (site 103316) and 6.7 to 8.0 downstream (site 100807). Temperature ranges over the same period were 10.3°C to 24.4°C upstream and 10.3°C to 29.3°C downstream. The highest temperatures were generally recorded during summer months.

Most New Zealand macroinvertebrates can deal with a short exposure to high water temperatures (~mid to high 20s). An exception is the common mayfly *Deleatidium* spp., which has an upper thermal limit in the low to mid 20s (Quinn *et al.* 1994). New Zealand native fish are relatively tolerant to high temperatures (maxima of ~30°C). Of the species considered by Richardson *et al*. (1994) including eels, bullies and galaxiids (whitebait), adult eels appear to have the highest upper critical thermal limits (39.7°C for adult shortfin eels (*Anguilla australis*) and 37.3°C for adult longfin eels (*Anguilla dieffenbachii*) — at an acclimation temperature of 15°C) (Richardson *et al.*, 1994). All bully species tested and most galaxiids had critical thermal maximums greater than 30°C.

Table 4. Spot measurements of daytime pH, temperature, dissolved oxygen (DO) concentration and percentage saturation, specific conductivity and turbidity at five Wairoro Stream sites and in the unnamed tributary carrying the discharge of the Kaikohe wastewater treatment plant (WWTP).

| Site | Time | pH | Temperature (°C) | DO (mg/L) | DO (%) | Specific conductivity (µS/cm) | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|
| 410 upstream | 15:20 | 7.0 | 17.3 | 9.3 | 97 | 98 | 1.7 |
| 50 m upstream | 09:45 | 6.8 | 16.7 | 9.0 | 93 | 99 | 1.7 |
| Unnamed tributary | 09:05 | 7.3 | 17.9 | 3.2 | 34 | 324 | 61.4 |
| 150 m downstream | 11:35 | 6.8 | 17.0 | 8.0 | 83 | 166 | 5.6 |
| 330 m downstream | 13:10 | 6.8 | 17.9 | 6.7 | 97 | 166 | 4.1 |
| 1,100 m downstream | 16:45 | 6.4 | 17.9 | 3.8 | 40 | 161 | 1.7 |

### 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. In order to comply with resource consent condition 7(c) (Appendix 1), daily minimum DO concentration in the Wairoro Stream at the monitoring site downstream of the confluence with the unnamed tributary shall not be reduced by more than 20% compared to that of the upstream monitoring site. The spot DO level recorded at the 150 m downstream site complied with this condition, but the DO levels at the two further downstream sites were reduced by 26% and 58% relative to the upstream monitoring site (Table 4). However, without knowledge of DO levels over the course of a day (*i.e.* to determine the daily minima) the spot measurement taken at the 150 m downstream site does not necessarily constitute compliance with the consent condition for DO.

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 mayflies, stoneflies and most caddisflies) (ANZECC & ARMCANZ, 1992). In the context of the NPS-FM, the highest level of protection for river ecosystem health below a discharge is provided (attribute state A) when a 7-day minimum[5] of DO over the summer period is ≥8 mg/L or a 1-day minimum[6] is ≥7.5 mg/L (MfE 2014). While the spot DO levels at the Wairoro Stream compliance monitoring sites upstream and downstream of the discharge met DO guidelines suggested by ANZECC & ARMCANZ (1992) and the NPS-FM, this does not necessarily constitute compliance because the daily minima are not known. Daytime spot DO levels decreased further downstream (Table 4), and by 1,100 m downstream of the discharge the concentration was below the national

[5] The mean value of seven consecutive daily minimum values.
[6] The lowest daily minimum across the whole summer period.

bottom line for protection of ecosystem health (*i.e.* 4 mg/L), indicating high biological oxygen demand, possibly resulting from organic enrichment and/or decaying periphyton in slow-flowing water.

Differences in oxygen levels between the sites upstream and downstream of the discharge are likely related to the obvious differences in periphyton biomass and communities. In contrast to the two upstream sites where only thin brown biofilms were observed, there was extensive growth of moss, aquatic macrophytes, and long bright-green filamentous algae downstream of the discharge (particularly 1,100 m downstream). While high periphyton and macrophyte biomass is usually associated with high DO levels during the day, owing to photosynthesis, the observed low oxygen levels may have been due to a high oxygen demand from senescent and decaying algal communities. Biological oxygen demand (BOD) from organic pollution may have also played a role.

#### Conductivity and turbidity

Specific conductivity in the Wairoro Stream at the sites downstream of the discharge was higher than at the two sites upstream, and there was no downstream attenuation. The Kaikohe WWTP discharge increased turbidity (*i.e.* decreased water clarity) in the Wairoro Stream. Water clarity increased with distance from the discharge. By 1,100 m downstream of the discharge, turbidity was the same as that measured at the upstream sites (Table 4).

### *3.1.2. Total nitrogen*

Total nitrogen (TN)[7] concentrations were noticeably lower at the sites upstream than those downstream of the Kaikohe WWTP discharge (Figure 3). Total nitrogen concentrations at upstream sites were lower than the ANZECC (2000) trigger value of 0.614 mg TN/L (for slightly disturbed lowland ecosystems), while downstream sites greatly exceeded this value (~ 3.5 TN/L to 4 mg TN/L). This reflects the N-enriched discharge entering the Wairoro Stream via the unnamed tributary (35 mg TN/L) with a large proportion of total ammonia (Figure 3).

[7] Total nitrogen = Total Kjeldahl nitrogen (TKN) + nitrite-N + nitrate-N. TKN = organic N + total ammonia-N

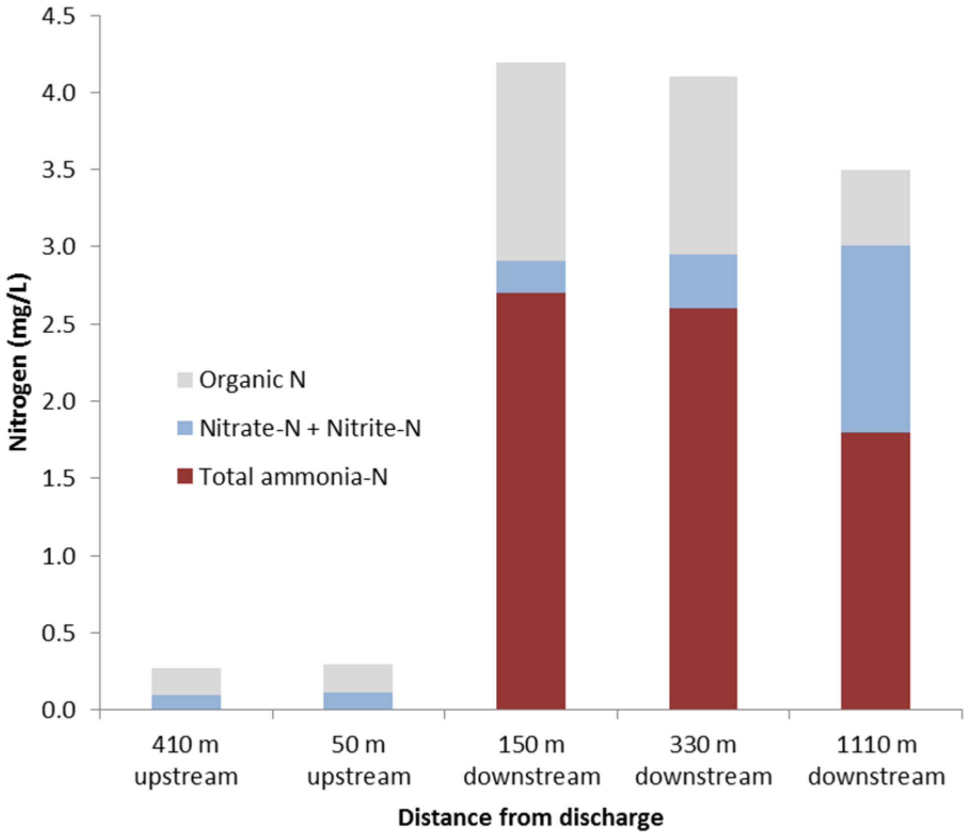


Figure 3. Total nitrogen (mg/L) found in single water samples collected from five Wairoro Stream sites upstream and downstream of the discharge from Kaikohe wastewater treatment plant (WWTP) via an unnamed tributary on 15 April 2014. Bars on the graph are divided into the component nitrogen elements that contribute to total nitrogen, *i.e.* Total nitrogen (TN) = Total Kjeldahl nitrogen (TKN) + nitrite-N + nitrate-N, where TKN = organic N + total ammonia–N. See Appendix 2 for laboratory results for the water samples collected from the Wairoro Stream.

### 3.1.3. Total ammonia-N

Figure 4 shows total ammonia-N concentrations measured over a 9-year period (November 2005 to March 2014) at the FNDC compliance monitoring site 100807 downstream of the discharge. The ammonia consent limits have been exceeded 30% of the time (*i.e.* on 43 of 144 monitoring occasions). The ammonia breaches often occurred in summer; the longest continual breach in consent conditions being from 21 December 2009 to 6 May 2010.

In our survey, the Kaikohe WWTP discharge contained high levels of total ammonia (27 mg N/L measured in the unnamed tributary, Appendix 2). Hence, the Wairoro Stream concentrations were noticeably higher at the downstream sites compared to those at the upstream sites (Figure 3). At the upstream sites total ammonia-N levels were below detection limit (< 0.010 mg/L) while total ammonia-N levels downstream from the discharge were highly elevated. We recorded 2.7 and 2.6 mg/L at the 150 m (site 100807) and 330 m downstream sites, respectively. This exceeded the consent limit (*i.e.* the ANZECC (2000) trigger value) of 2.33 mg/L for measured pH of 6.8 (Figure 4).Total ammonia-N at the 1,100 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.

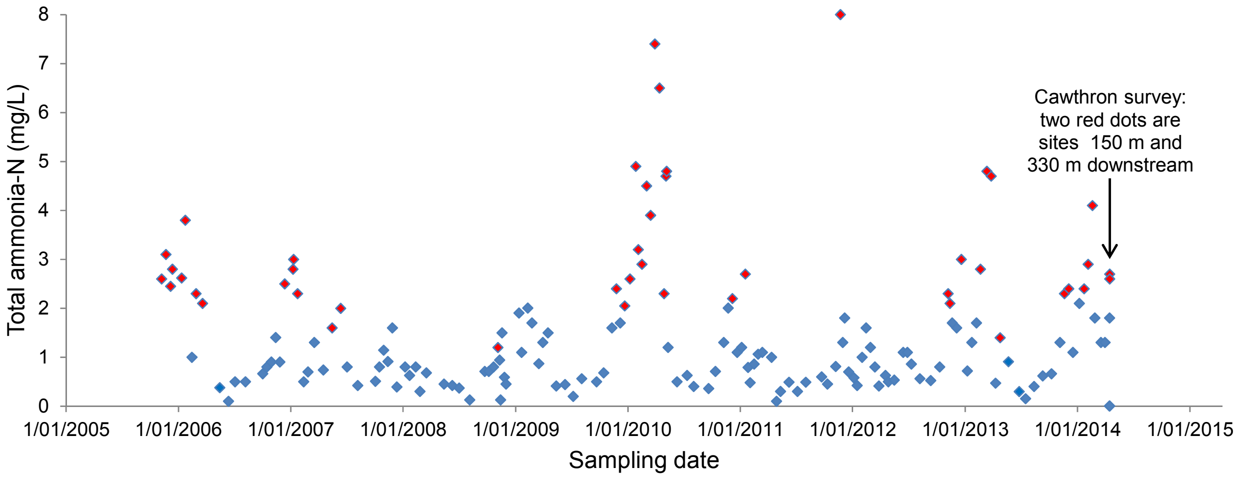


Figure 4. Total ammonia-N (mg/L) concentrations recorded in the Wairoro Stream during the Far North District Council's bi-monthly compliance monitoring (November 2005–March 2014) at site 100807 and in the Cawthron study (15 April 2014) at the 150 m (site 100807), 330 m and 1,100 m downstream sites. The red data points indicate non-compliance with regards to ANZECC (2000) trigger values for ammonia toxicity set out in the consent (Table 1).

The toxicity of total ammonia-N is very sensitive to pH with higher toxicity at higher pH due to dissociation of $NH_3$. River pH often varies on a diurnal cycle (peaking in summer at about 2 pm to 4 pm in the afternoon) due to photosynthesis of algae and macrophytes.

As reported in Section 3.1.1, 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).

Section 1.4 of this report describes the numeric attribute states for ammonia toxicity in the context of the NPS-FM. On 6% of the monitoring occasions between November 2005 and March 2014, the total ammonia-N concentrations recorded below the downstream boundary of the mixing zone (site 100807, our sampling site 150 m downstream of the discharge) did not meet the NPS-FM national bottom line of 2.20 mg N/L (annual maximum at pH 8 and 20°C).

### 3.1.4. Dissolved inorganic nitrogen and dissolved reactive phosphorus in relation to periphyton growth

Nutrients are one of the primary factors controlling algal growth. 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 cause faster periphyton growth and greater periphyton cover and biomass. Greater periphyton biomass causes changes to the aquatic macroinvertebrate community via changes to habitat and / or high diurnal fluctuation in pH and DO.

Linking periphyton biomass to stream nutrient concentrations can be problematic. The rate of periphyton biomass increase (accrual rate) is strongly linked with the nutrients (predominantly N and P) available for growth during the period between flushing flows (accrual period). Biggs (2000) provides approximate nutrient concentration guidelines for differing lengths of algal accrual to prevent periphyton blooms reaching nuisance levels.

The most commonly used nutrient guidelines are those for accrual periods of 20 days and 40 days, corresponding to concentrations of 0.295 mg DIN/L and 0.034 mg DIN/L (Biggs 2000). In this survey, DIN concentrations downstream of the discharge even exceeded the lesser conservative accrual guideline (*i.e.* 20 days) (Figure 5). The difference in DIN concentrations between the upstream and downstream sites was associated with much higher biomass of periphyton, especially of filamentous green algae downstream compared to upstream (Section 3.1.1). Moreover, downstream sites had extensive cover of aquatic macrophytes whereas no macrophytes were seen upstream.

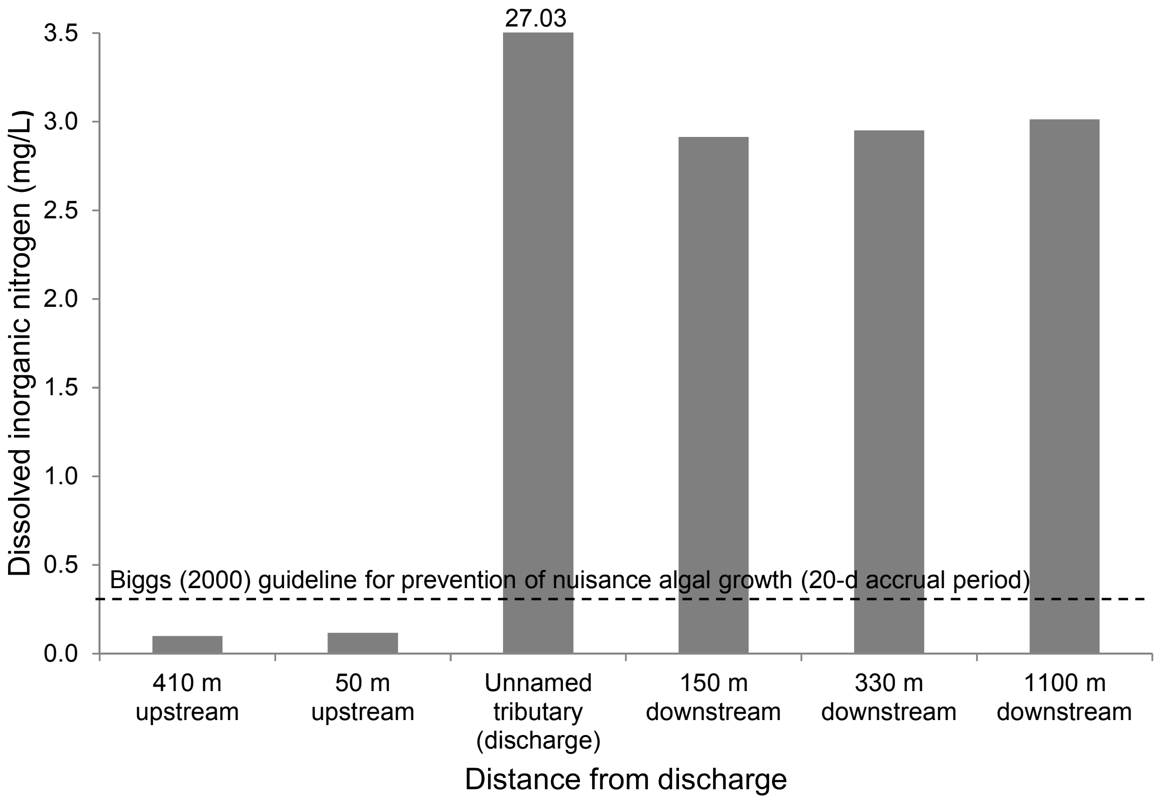


Figure 5. Dissolved inorganic nitrogen (mg/L) measured in single water samples collected from five Wairoro Stream sites upstream and downstream of the discharge from Kaikohe wastewater treatment plant (WWTP) via an unnamed tributary on 15 April 2014. Dotted line is the Biggs (2000) guideline for the prevention of nuisance algal growth (*i.e.* algal blooms) based on a 20-day accrual period.

Monitoring data collected by FNDC from January 2010 to March 2014, indicate that DIN concentrations were consistently higher downstream of the discharge than upstream. Concentrations upstream of the discharge exceeded the Biggs (2000) 20- and 40-day accrual guidelines 41% and 96% of the time, respectively. Downstream of the discharge both guidelines were exceeded 98% of the time. Although not measured in this survey, the FNDC monitoring data show that DRP also exceed periphyton accrual guidelines (Biggs 2000). Dissolved reactive phosphorus (DRP) guidelines for 20-day and 40-day accrual periods are 0.026 mg/L and 0.003 mg/L, respectively (Biggs 2000). These guidelines were exceeded at the FNDC upstream monitoring site 5% and 96% of the time, respectively. Downstream of the discharge, both DRP guidelines were exceeded 95% and 98% of the time, respectively.

The trophic state of rivers is considered in the NPS-FM in terms of periphyton biomass (mg chl-a/$m^2$). Although we did not measure periphyton biomass, the coverage and thickness of periphyton can provide a surrogate. The thick coverage of periphyton noted downstream of the WWTP discharge including the presence of long filamentous green algae (a sign of nutrient enrichment) indicates the discharge is adversely altering the trophic state of the Wairoro Stream. The national bottom line for periphyton biomass is 200 mg chl-a/m$^2$ being exceeded on no more that 17% of samples collected in a monthly monitoring regime over a 3-year period. Based on the coverage and thickness of periphyton we observed below the WWTP discharge, it is highly likely that the national bottom line for periphyton is being breached in the Wairoro Stream.

### 3.1.5. Downstream attenuation of nitrogenous elements below the discharge

Total nitrogen and total ammonia-N concentrations were similar at the 150 m and 330 m downstream sites (Figure 3) signifying that nitrogen was not being processed between these sites, probably because algal and bacterial production are not nitrogen limited at such high concentrations of readily available dissolved inorganic forms. Total nitrogen and total ammonia-N were lower at the 1,100 m downstream site while oxidised forms (nitrate-N and nitrite-N) were higher compared to the other two sites suggesting that ammonia was being processed by nitrification. Oxidised forms of nitrogen at the observed concentrations are less toxic to aquatic life than ammonia; hence these results indicate that toxicity of the discharge is moderated with distance downstream.

## 3.2. 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 very 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.

### 3.2.1. Macroinvertebrate density and community structure

Mean macroinvertebrate densities and the contributions of dominant taxa (community structure) differed noticeably between the upstream and downstream sites (Figure 7). Macroinvertebrate communities at the upstream sites were dominated by pollution-sensitive EPT taxa (only Ephemeroptera and Trichoptera) and snails (Figure 7; Table 5). By contrast, downstream sites were dominated by true-fly larvae, oligochaete worms and snails. Increased densities and the shift in macroinvertebrate community structure observed at downstream compared to upstream sites was likely due to the effects of nutrient enrichment on periphyton and macrophyte growth (see Section 3.1.4). 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 biomass, particularly the presence 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 by comparison (< 4 mm long). Small algal-piercing hydroptilid caddisflies, which are also strongly associated with extensive algal growth, were present only at the downstream sites (Figure 6).

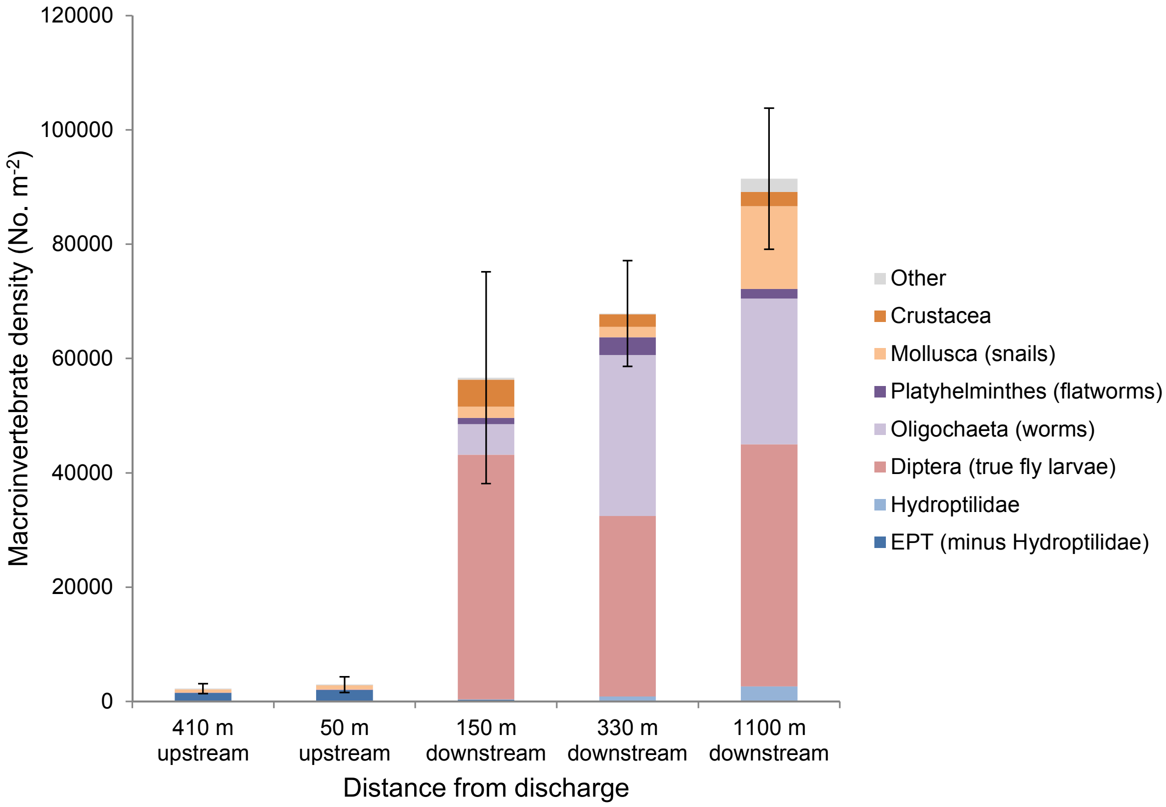


Figure 6. Mean macroinvertebrate density and the contribution of dominant taxa at five study sites in the Wairoro Stream upstream and downstream of the discharge from Kaikohe wastewater treatment plant (WWTP) via an unnamed tributary, sampled on 15 April 2014. EPT = Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies). Error bars are standard errors of the means.

Table 5. Percentage composition of the macroinvertebrate community at five study sites in the Wairoro Stream upstream and downstream of the discharge from Kaikohe wastewater treatment plant (WWTP) via an unnamed tributary, sampled on 15 April 2014. Values are given only if > 5% and a star (*) if individuals were present but less abundant.

| **Taxon** | **410 m upstream** | **50 m upstream** | **150 m downstream** | **330 m downstream** | **1,100 m downstream** |
|---|---|---|---|---|---|
| **Ephemeroptera (mayflies)** | | | | | |
| *Zephlebia versicolor* | 18.9 | 13.7 | * | | |
| **Megaloptera (dobsonflies)** | | | | | |
| *Archichauliodes diversus* | 5.0 | * | | | |
| **Diptera (true flies)** | | | | | |
| *Chironomus zelandicus* | | | 18.5 | * | |
| cf *Kiefferulus opalensis* | | | | 13.3 | * |
| Orthocladiinae | * | * | 17.5 | 13.0 | 11.3 |
| *Polypedilum* sp. | * | * | 27.8 | 7.7 | * |
| *Tanytarsus vespertinus* | * | | 11.1 | 10.2 | 29.6 |
| **Trichoptera (caddisflies)** | | | | | |
| *Pycnocentrodes* sp. | 36.6 | 49.2 | * | * | |
| **Oligochaeta (worms)** | * | * | 9.5 | 41.5 | 27.9 |
| **Platyhelminthes (flatworms)** | | | * | 4.6 | * |
| **Mollusca (snails)** | | | | | |
| *Physa* sp | | * | * | * | 13.8 |
| *Potamopyrgus antipodarum* | 20.6 | 22.4 | * | * | * |
| **Crustacea (crustaceans)** | | | | | |
| Ostracoda | | | 8.3 | * | * |

### 3.2.2. EPT metrics, Macroinvertebrate Community Index and the Quantitative Macroinvertebrate Community Index

We found no pronounced differences in EPT taxon richness between sites upstream and downstream of the discharge, except for the 1,100 m downstream site where only two taxa were found. However, we did find large differences between upstream and downstream sites for EPT density and $\%EPT_{Density}$, both being much lower at the downstream sites (Table 6).

Table 6. EPT metrics at five sites in the Wairoro Stream upstream and downstream of the discharge from the Kaikohe wastewater treatment plant (WWTP) via an unnamed tributary. Values are calculated from the pooled results of the three Surber samples taken at each site on 15 April 2014.

| Site | EPT taxon richness | %$EPT_{Taxa}$ | EPT density | %$EPT_{Density}$ |
|---|---|---|---|---|
| 410 m upstream | 14 | 61 | 1525 | 68 |
| 50 m upstream | 10 | 45 | 2043 | 69 |
| 150 m downstream | 15 | 37 | 304 | 0.5 |
| 330 m downstream | 10 | 31 | 165 | 0.2 |
| 1,100 m downstream | 2 | 8 | 11 | 0.01 |

Macroinvertebrate Community Index and the QMCI values indicate that stream health at the upstream sites was ‘good’ and at downstream sites generally ‘poor’ (Figure 7), according to bands developed by Stark & Maxted (2007) (Table 3). The lower MCI values at the downstream sites were due to the presence of more pollution-tolerant (low-scoring) taxa that were not found upstream, *e.g.* the true-fly larva *Chironomus zelandicus* (score of 1), the hydroptilid caddisfly *Oxyethira albiceps* (score of 2), flatworms and *Hydra* sp. (each with a score of 3). The lower QMCI at the three downstream sites revealed that the relative abundance of sensitive (higher-scoring) taxa was lower than pollution-tolerant (low-scoring) taxa (Figure 7; Appendix 3).

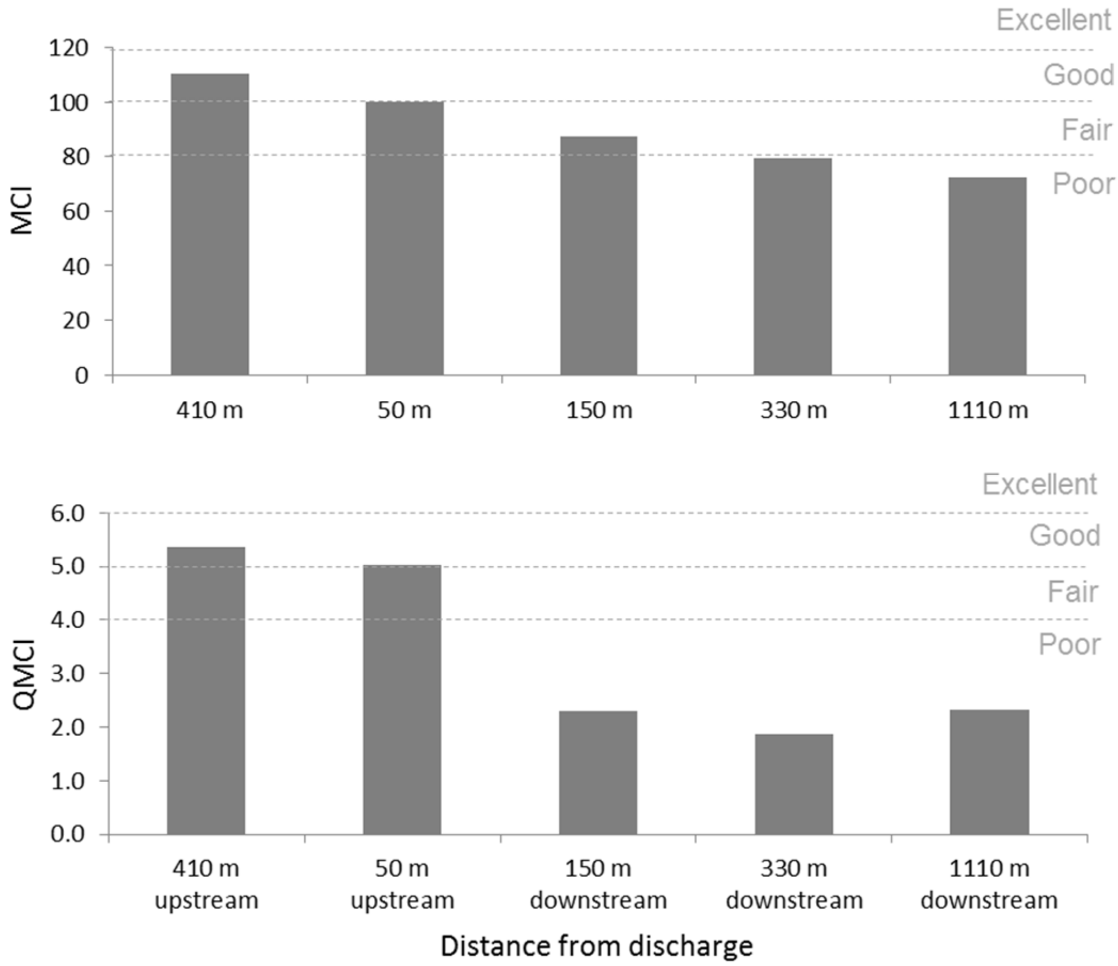


Figure 7. Macroinvertebrate Community Index (MCI) and the Quantitative Macroinvertebrate Community Index (QMCI) values at five study sites in the Wairoro Stream upstream and downstream of the discharge from Kaikohe wastewater treatment plant (WWTP) via an unnamed tributary, sampled on 15 April 2014. See Table 3 for the good, fair, poor definitions for MCI and QMCI.

Among the downstream sites, EPT metrics, MCI and QMCI suggest that stream health declines progressively downstream and is particularly low at the 1,100 m downstream site. However, closer examination of the taxa found at this site shows an unusual community structure compared to the other downstream sites indicative of slow- or still-water communities. For example, abundant *Physa* sp. (snail), copepods and cladocerans (both are planktonic crustaceans), the absence of mayflies and the presence of damselflies. This site was dominated by boulders, with slow-water pockets behind them making the Surber sampling challenging and resulting in samples including slow-water habitats among boulders.

### *3.2.3. Statistical analyses of differences between upstream and downstream macroinvertebrate communities*

The means (including all samples) of macroinvertebrate density and all community indices except EPT taxon richness were significantly different ($p < 0.05$) downstream versus upstream of the Kaikohe WWTP discharge (Table 7). There were higher macroinvertebrate densities and number of taxa downstream than upstream. The EPT metrics, MCI and QMCI had lower values downstream than upstream indicating a decline of stream health due to the Kaikohe WWTP discharge.

Table 7. Student's *t*-test results for comparisons of upstream (n = 6) versus downstream (n = 9) group means for various macroinvertebrate metrics and indices.

| | | | | Group means | |
|---|---|---|---|---|---|
| **Response variable** | **t-value** | **df** | ***p*-value** | **upstream** | **downstream** |
| Density | 7.99 | 8.1 | <0.001 | 2603 | 71996 |
| Taxon richness | 3.97 | 11.4 | 0.002 | 12.8 | 23.3 |
| EPT taxon richness | -0.78 | 9.9 | 0.45 | 6.0 | 4.4 |
| EPT density | -3.11 | 5.1 | 0.03 | 1784 | 160 |
| $\%EPT_{Density}$ | -8.97 | 5.0 | <0.001 | 65.4 | 0.26 |
| $\%EPT_{Taxa}$ | -3.72 | 9.2 | 0.005 | 17.2 | 42.8 |
| MCI | -6.07 | 10.9 | <0.001 | 99 | 72 |
| QMCI | -13.83 | 6.7 | <0.001 | 5.15 | 2.17 |

## 3.3. Fish

Based on the fish distribution model developed by Leathwick *et al*. (2008), the longfin eel (*Anguilla dieffenbachii*) and shortfin eel (*Anguilla australis*) have a high probability of being present in the Wairoro Stream (*i.e.* 84% and 73%, respectively). The common bully (*Gobiomorphus cotidianus*) is the next most likely species to be present (31%), with other species having less than 20% probability of occurrence. The banded kōkopu (*Galaxias fasciatus*) is a migratory species that has a moderate probability of occurrence (~50%–60%) upstream of the Wairoro Stream survey reach.

Longfin and shortfin eels are diadromous (*i.e.* they undergo migrations to and from the sea during their life cycle). Their distribution within any stream is therefore dependent on their ability to move upstream from the sea. Man-made structures such as perched culverts, weirs and dams can be barriers to fish migration, particularly for those species that are weak swimmers or are unable to jump or climb. Heavily polluted water can also be a barrier to fish migration. Eels are the best climbers, and can often tolerate water quality conditions unsuitable for other fish. Both shortfin and longfin eels are widespread, but shortfins do not usually move as far upstream as longfins (McDowall, 1990).

The common bully is also diadromous and the most familiar and common of New Zealand's bullies. In streams, it generally inhabits the margins where cover can be found, *e.g.* overhanging banks, rocks, logs and other woody debris (McDowall, 1990). Bullies have some ability to climb small obstacles, although McDowell (1990) noted that they are generally found in streams that have no barriers.

Of the fish mentioned above, longfin eels are listed as a species of conservation concern in the latest Department of Conservation threatened species classification (Goodman *et al.* 2013); they are considered as being in decline due to human-induced impacts such as habitat loss.

## 3.4. Effects of elevated ammonia levels on macroinvertebrates and fish in the Wairoro Stream

### *3.4.1. Definition of significant adverse effect*

The initial request by FNDC was to determine if total ammonia concentrations in the Wairoro Stream downstream of the Kaikohe WWTP discharge are having a significant adverse effect on stream fauna. In New Zealand, the terms 'significant adverse effects on aquatic life' and 'protection of life-supporting capacity' are interconnected terms widely used in relation to the Resource Management Act (1991). However, there is no established definition for them. Hamill (2013) defined significant adverse effects on aquatic life and protection of life-supporting capacity as follows: "The significance of an effect on aquatic life is determined not just by the magnitude and nature of the effect, but also by [its] spatial extent, duration and frequency. Similarly the life-supporting capacity of a river can be interpreted in terms of the type of species, the diversity of species, and the abundance of species over space and time. When a river is exposed to moderate pressures such as nutrient enrichment, different species respond in different ways and deciding whether an effect is sufficiently 'significant' or threatens the 'life-supporting capacity' depends to a large extent on the [human] values associated with the water body, and the purpose for which it is being managed."

Hamill (2013) further states: "The magnitude of an effect considers the importance and degree of any effect on aquatic life from a discharge. This covers a spectrum from measurable but relatively harmless changes in aquatic communities, to acute toxicity or major habitat changes. At the high end of the spectrum of effects, we might see fundamental changes in water quality that reduces [a stream's] capacity to support life, such as large drops in oxygen causing fish kills, or high concentrations of ammonia causing acute toxicity. Any chronic toxicity effects (as a result of long term, repeated exposure) would also be at the high end of the spectrum. These types of effects would be widely accepted as 'significant adverse effects' which would compromise the 'life-supporting capacity' of a river even if occurring infrequently."

### 3.4.2. Sensitivity of New Zealand macroinvertebrates and fish to ammonia

Toxicity tests on single species are conducted under controlled conditions in the laboratory. Generally, acute toxicity is better studied than chronic toxicity because these experiments are shorter and less complex.

Acute toxicity is given as an $LC_{50}$ (lethal concentration) or $EC_{50}$ (effective concentration) for a given time period (such as 24 h, 48 h or 96 h) which is the concentration at which 50% of the individuals of the test species were found to be dead or moribund, respectively. For New Zealand native freshwater invertebrates and fish, acute ammonia toxicity studies were summarised by Hickey (2000) and a selection based on the results of the present survey is presented in Table 8. For the fish listed here, the 96 h (4-day) $EC_{50}$ at 15°C (pH 8) given for total ammonia-N ranged from 22.4 mg/L to 95.0 mg/L, and for macroinvertebrates from 9.8 mg/L to 25.9 mg/L. Macroinvertebrates are therefore generally more sensitive to ammonia than fish.

Table 8. The sensitivity of selected New Zealand freshwater macroinvertebrates and fish to ammonia (Hickey 2000). All concentrations are for total ammonia-N and derived from acute toxicity tests with 96 h exposure at 15°C and adjusted to pH 8.

| Species | Adjusted $EC_{50}$ (mg N/L) |
|---|---|
| ***Macroinvertebrates*** | |
| *Deleatidium* spp. (mayfly larvae) | 17.5 |
| *Pycnocentria evecta* (caddisfly larvae) | 16.3 |
| *Potamopyrgus antipodarum* (snail) | 9.8 |
| *Sphaerium novaezelandiae* (fingernail clam) | 22.2 |
| *Lumbriculus variegatus* (oligochaete worm) | 25.9 |
| ***Fish*** | |
| *Gobiomorphus cotidianus* (common bully - juveniles) | 34.8 |
| *Gobiomorphus huttoni* (redfin bully) | 41.2 |
| *Galaxias fasciatus* (banded kōkopu — juveniles) | 22.4 |
| *Galaxias maculatus* (inanga — juveniles) | 59.4 |
| *Galaxias maculatus* (inanga) | 39.0 |
| *Anguilla australis* (shortfin eel — elvers) | 95.0 |
| *Anguilla dieffenbachii* (longfin eel — elvers) | > 53.7 |

### 3.4.3. Acute effects of ammonia on aquatic life in the Wairoro Stream

The maximum total ammonia-N value recorded during nine years (November 2005-March 2014) of monitoring by FNDC including the Cawthron study was 8 mg/L (Figure 4), which was recorded when pH was 7.5 and stream temperature 20°C. This value exceeds the consent condition by 6.39 mg/L, but is still below the $EC_{50}$ of the most sensitive aquatic macroinvertebrate (*Potamopyrgus antipodarum*, 9.8 mg/L) and fish species (common bully, 34.8 mg/L) listed in Table 8. It is also well below the acute criterion specified by USEPA (2013).

The present survey data can be used to compare densities of ammonia-sensitive macroinvertebrate species between upstream and downstream sites. The gill-breathing snail *Potamopyrgus antipodarum* is the most sensitive species (Table 8) and was present in the Wairoro Stream downstream of the WWTP discharge. In fact, *P. antipodarum* densities were, on average, higher at the downstream than the upstream sites (Appendix 3). The cased caddisfly *Pycnocentria evecta* and common mayfly *Deleatidium* spp. (ranked second and third most sensitive to ammonia in Table 8) were both present upstream and downstream of the discharge (except at the 1,100 m downstream site). *Pycnocentria evecta* density was higher at the 150 m downstream site than at the two upstream sites, while *Deleatidium* spp. density was lower at the 150 m downstream site (Appendix 3). The bivalve mollusc *Sphaerium novaezelandiae* has a higher tolerance to ammonia than *P. antipodarum*, *P. evecta*, and *Deleatidium* spp. (Table 8). Sphaeriidae (the taxonomic family to which *Sphaerium novaezelandiae* belongs) were found only at the three downstream sites (Appendix 3). Overall, these results suggest that breaches in the consent condition for total ammonia-N (Figure 4) preceding our survey appear not to have had an acute adverse effect on aquatic macroinvertebrates in the Wairoro Stream.

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. Shortfin and longfin eel are among the fish species most tolerant to ammonia (Table 8). The common bully has a moderate probability of occurring in Wairoro Stream, and has a higher tolerance to ammonia than the most tolerant invertebrate listed in Table 8 (*Lumbriculus variegatus* — an oligochaete worm). Banded kōkopu have the lowest tolerance to ammonia of the fish species listed in Table 8. Although they are likely to be found in the headwaters of Wairoro Stream further upstream of the discharge, they will during their life cycle pass through the survey reach on their way to and from the sea. However, the ammonia levels recorded in the Wairoro Stream below the discharge are unlikely to act as a chemical barrier to migration because their short-term tolerance level is 2.8 times the maximum ammonia level recorded below the discharge.

### *3.4.4. Chronic effects of ammonia on aquatic life in the Wairoro Stream*

The consent ammonia toxicity trigger values are based on the ANZECC (2000) guidelines for chronic toxicity. Hence, the frequent exceedance of the trigger values by the Kaikohe WWTP discharge (Figure 3) might be expected to have chronic effects on sensitive species. For example, the fingernail clam *Sphaerium novaezelandiae* burrows, and ammonia bound to sediment may exacerbate toxicity effects for this species. The chronic 60-day total ammonia-N exposure (pH 7.5 and 20°C) of *S. novaezelandiae* based on survival and reproductive success was 3.8 mg/L and 0.80 mg/L, respectively (Hickey & Martin, 1999). Given that ammonia concentration exceeded 0.80 mg N/L on more than half of the monitoring occasions during November 2005 and March 2014 (Figure 4), reproduction is potentially adversely affected. However, Sphaeriidae were found only at the downstream sites in our study, suggesting that ammonia probably is not affecting their survival or reproduction.

*Potamopyrgus antipodarum* has a lower acute $EC_{50}$ than *S. novaezelandiae*, *i.e.* is more sensitive to ammonia (Table 8). High densities of this gill-breathing snail downstream of the discharge suggest chronic ammonia exposure probably is not adversely affecting the survival or reproductive success of this species either. However, unlike for *S. novaezelandiae* there is no published information on the effects of chronic long-term exposure (*i.e.* 60-day) to ammonia on *P. antipodarum*.

Overall, even though our macroinvertebrate data do not suggest that chronic ammonia effects are an issue, we cannot be certain. In chronic toxicity tests, the most sensitive freshwater insect and fish species have been adversely affected when total ammonia-N exceeded 1.79 mg N/L and 1.35 mg N/L (ANZECC & ARMCANZ 2000), levels that are likely to be exceeded for a sustained period of time in summer downstream of Kaikohe WWTP.

# 4. CONCLUSIONS

Our results indicate that, despite breaches in consented concentrations of total ammonia-N in the Wairoro Stream after mixing with the Kaikohe WWTP discharge, there appear to be no acute toxic effects and no obvious chronic effects on macroinvertebrates. Acute and chronic effects on fish predicted to occur in the vicinity of the discharge are also unlikely. However, we caution that chronic effects of ammonia (*e.g.* reduced growth and reproduction) can be difficult to detect.

We conclude that the breaches in total ammonia-N concentrations are probably not having direct significant adverse toxic effects on the stream fauna. However, this conclusion may not hold when consented limits are breached for an extended period.

On the other hand, the macroinvertebrate community results indicate that stream ecosystem health is considerably compromised up to at least 1,100 m downstream of the WWTP discharge, relative to upstream. These are most likely indirect effects resulting from periphyton proliferation stimulated by elevated nutrients in the discharge (ammonia-N and other forms of nitrogen, and phosphorus).

Finally we note that on 6% of monitoring occasions between November 2005 and March 2014, the total ammonia-N concentrations recorded below the downstream boundary of the mixing zone (site 100807, our sampling site 150 m downstream of the discharge into the Wairoro Stream) did not meet the national bottom line of 2.20 mg N/L (annual maximum at pH 8 and 20°C) in the NPS-FM. Given our general observations of high periphyton cover and biomass and low DO concentrations, the national bottom line for periphyton (indicating trophic state) and DO may also be breached below the discharge. The low DO below the discharge is probably related to organic enrichment and / or high periphyton biomass.

# 5. ACKNOWLEDGEMENTS

We thank Chris Joseph (Transfield Services) for help with field work. Ruben Wylie (FNDC) provided monitoring data and information relating to the Kaikohe WWTP.

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# 7. 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.

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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.

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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**

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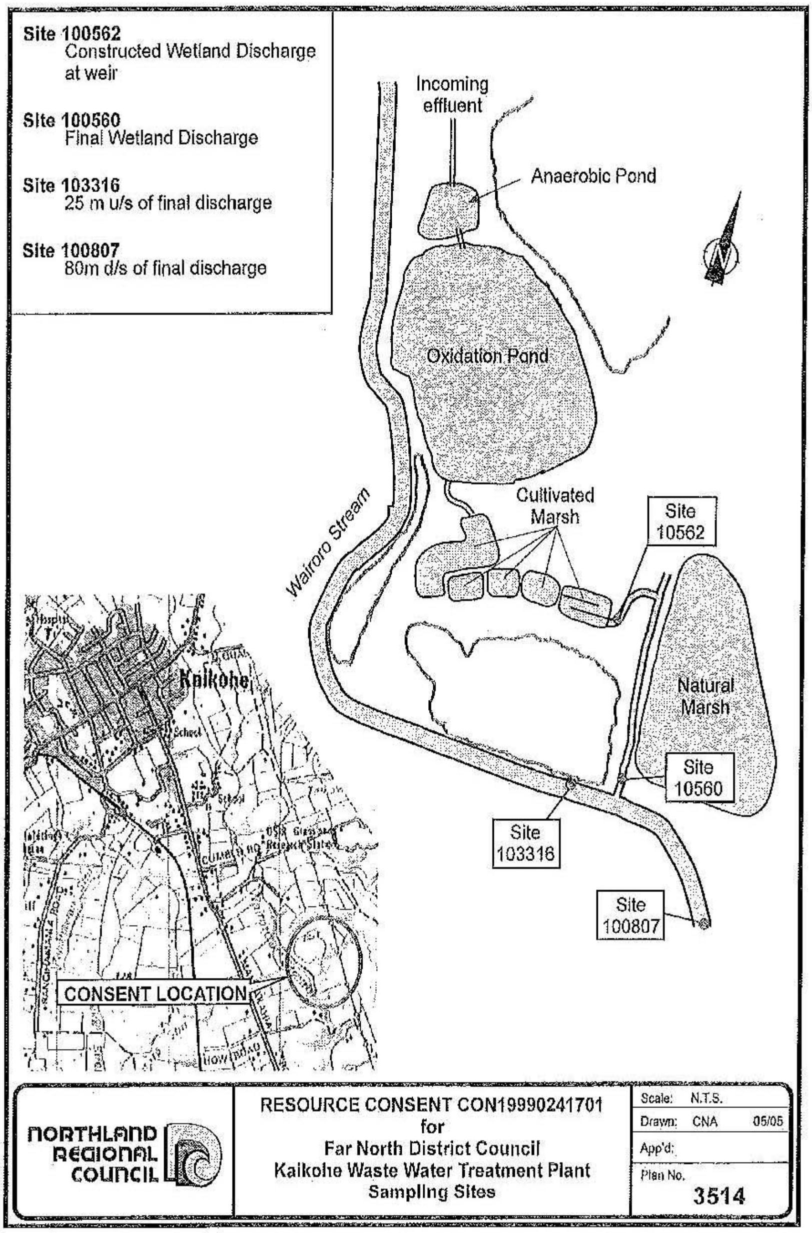
Appendix 1. *continued*.

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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.

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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 Wairere 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.

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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 1. *continued*.

(c) The applicant is still proposing to upgrade the WWTP to deal specifically with ongoing issues relating to high ammonia concentrations in the discharge. There is likely to be some consequential additional pathogen treatment provided as a result of this upgrade.

(d) The current consent has a very stringent effects based standard after reasonable mixing which only allows a median increase of 50 Escherichia coli (E-coli), calculated on 20 samples taken during a two month period. This sampling is required three times a year – October - November, February – March and July - August. It is considered that if the treatment system can meet the receiving water standards for E-coli on the current consent, then the potential adverse effects on the receiving water quality as a result of not upgrading the WWTP to achieve a 4 log removal efficiency will be very minor, and most likely un-measurable.

## Relevant Statutory Provisions (Section 104(1)(b) of the Act)

The Council has determined that granting the change is consistent with the objectives and policies contained in Chapters 7 and 8 of the Regional Water and Soil Plan for Northland.

The activity contravenes Section 15 of the Act, and therefore the Council has also had regard to the matters outlined in Section 105 of the Act. The Council is satisfied that the activity will not give rise to the effects outlined in Section 107 of the Act after reasonable mixing.

**I confirm that these are the true and correct reasons for the decision to grant a change to resource consent CON19990241701**

**Name and Signature of Authorised Person:** ........................................
R Lieffering
Consents Senior Programme Manager

**Date:** **19 April 2011**

Appendix 2. Results of analysis of water samples collected from the Wairoro Stream and the unnamed tributary on 15 April 2014. Note: total ammoniacal-N in these results is equivalent to total ammonia-N in this report (*e.g.* Section 3.1.1); $g/m^3$ is equivalent to mg/L.

**Hill Laboratories**
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# ANALYSIS REPORT

**Page 1 of 2**

| | | | |
|---|---|---|---|
| **Client:** | Cawthron Institute (Nelson) | **Lab No:** | 1264470 SPv1 |
| **Contact:** | Karen Shearer | **Date Registered:** | 17-Apr-2014 |
| | C/- Cawthron Institute (Nelson) | **Date Reported:** | 28-Apr-2014 |
| | Private Bag 2 | **Quote No:** | 60354 |
| | Nelson Mail Centre | **Order No:** | |
| | NELSON 7042 | **Client Reference:** | Waioro Stream (Northland) |
| | | **Submitted By:** | Karen Shearer |

**Sample Type: Aqueous**

| **Sample Name:** | | Kaikohe Discharge 15-Apr-2014 9:35 am | Kaikohe 25m u/s 15-Apr-2014 10:10 am | Kaikohe 100m u/s 15-Apr-2014 2:50 pm | Kaikohe 100807 15-Apr-2014 12:08 pm | Kaikohe 200m d/s 15-Apr-2014 1:00 pm |
|---|---|---|---|---|---|---|
| **Lab Number:** | | 1264470.1 | 1264470.2 | 1264470.3 | 1264470.4 | 1264470.5 |
| Total Nitrogen | $g/m^3$ | 35 | 0.30 | 0.27 | 4.2 | 4.1 |
| Total Ammoniacal-N | $g/m^3$ | 27 | < 0.010 | < 0.010 | 2.7 | 2.6 |
| Nitrite-N | $g/m^3$ | 0.021 | 0.003 | 0.002 | 0.017 | 0.031 |
| Nitrate-N | $g/m^3$ | 0.012 | 0.109 | 0.092 | 0.196 | 0.32 |
| Nitrate-N + Nitrite-N | $g/m^3$ | 0.033 | 0.112 | 0.094 | 0.21 | 0.35 |
| Total Kjeldahl Nitrogen (TKN) | $g/m^3$ | 35 | 0.19 | 0.18 | 4.0 | 3.7 |

| **Sample Name:** | | Kaikohe 1km d/s u/s trib 15-Apr-2014 4:45 pm | | | | |
|---|---|---|---|---|---|---|
| **Lab Number:** | | 1264470.6 | | | | |
| Total Nitrogen | $g/m^3$ | 3.5 | - | - | - | - |
| Total Ammoniacal-N | $g/m^3$ | 1.8 | - | - | - | - |
| Nitrite-N | $g/m^3$ | 0.083 | - | - | - | - |
| Nitrate-N | $g/m^3$ | 1.13 | - | - | - | - |
| Nitrate-N + Nitrite-N | $g/m^3$ | 1.21 | - | - | - | - |
| Total Kjeldahl Nitrogen (TKN) | $g/m^3$ | 2.3 | - | - | - | - |

# SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

**Sample Type: Aqueous**

| Test | Method Description | Default Detection Limit | Sample No |
|---|---|---|---|
| Filtration, Unpreserved | Sample filtration through 0.45µm membrane filter. | - | 1-6 |
| Total Kjeldahl Digestion | Sulphuric acid digestion with copper sulphate catalyst. | - | 1-6 |
| Total Nitrogen | Calculation: TKN + Nitrate-N + Nitrite-N. | 0.05 $g/m^3$ | 1-6 |
| Total Ammoniacal-N | Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. ($NH_4$-N = $NH_4^+$-N + $NH_3$-N). APHA 4500-$NH_3$ F (modified from manual analysis) 22nd ed. 2012. | 0.010 $g/m^3$ | 1-6 |
| Nitrite-N | Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-$NO_3^-$ I 22nd ed. 2012. | 0.002 $g/m^3$ | 1-6 |
| Nitrate-N | Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House. | 0.0010 $g/m^3$ | 1-6 |
| Nitrate-N + Nitrite-N | Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-$NO_3^-$ I 22nd ed. 2012. | 0.002 $g/m^3$ | 1-6 |
| Total Kjeldahl Nitrogen (TKN) | Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-$N_{org}$ D. (modified) 4500 $NH_3$ F (modified) 22nd ed. 2012. | 0.10 $g/m^3$ | 1-6 |

Appendix 3. Macroinvertebrate taxonomy results and calculation of biological indices for five sites sampled in the Wairoro Stream near the Kaikohe wastewater treatment plant (WWTP) discharge (15 April 2014). Samples were collected with a Surber sampler (0.0625 m$^2$, 0.5 mm mesh).

| | MCI | | | | | | | Wairoro Stream sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | taxon | 410 m upstream | | | 50 m upstream | | | 150 m downstream | | | 330 m downstream | | | 1100 m downstream | | |
| **Taxa** | **score** | **a** | **b** | **c** | **a** | **b** | **c** | **a** | **b** | **c** | **a** | **b** | **c** | **a** | **b** | **c** |
| **Ephemeroptera (mayflies)** | | | | | | | | | | | | | | | | |
| *Austoclima sepia* | **9** | - | - | 2 | - | - | - | - | - | - | - | 1 | - | - | - | - |
| *Austoclima* sp. | **9** | - | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - |
| *Coloburiscus humeralis* | **9** | - | - | 1 | - | - | 3 | - | 1 | 1 | - | - | 1 | - | - | - |
| *Deleatidium* sp. | **8** | - | - | 4 | - | - | 3 | - | 1 | - | - | 1 | - | - | - | - |
| *Mauiulus luma* | **5** | - | - | 13 | - | - | 15 | - | 1 | - | - | - | - | - | - | - |
| *Nesameletus* sp. | **9** | 3 | - | 13 | - | - | - | - | 1 | - | - | - | - | - | - | - |
| *Zephlebia* sp. | **7** | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| *Zephlebia versicolor* | **7** | 34 | 9 | 37 | 29 | 3 | 44 | 1 | - | - | - | - | - | - | - | - |
| | | | | | | | | | | | | | | | | |
| **Megaloptera (dobsonflies)** | | | | | | | | | | | | | | | | |
| *Archichauliodes diversus* | **7** | 16 | 3 | 2 | 4 | - | 11 | - | - | - | - | - | - | - | - | - |
| | | | | | | | | | | | | | | | | |
| **Odonata (damselflies)** | | | | | | | | | | | | | | | | |
| *Xanthocnemis zelandica* | **5** | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| Zygoptera | **5** | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| | | | | | | | | | | | | | | | | |
| **Coleoptera (beetles)** | | | | | | | | | | | | | | | | |
| Elmidae | **6** | - | - | - | - | 2 | 2 | 2 | 1 | 2 | - | 3 | 1 | 2 | - | - |
| Hydraenidae | **8** | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| | | | | | | | | | | | | | | | | |
| **Diptera (true flies)** | | | | | | | | | | | | | | | | |
| Anthomyiidae | **3** | - | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - |
| *Aphrophila neozelandica* | **5** | 1 | - | 1 | - | - | - | - | 5 | 1 | - | 2 | - | - | - | - |
| *Austrosimulium* spp. | **3** | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - |
| Chironomidae | **2** | - | - | - | - | 2 | - | - | - | - | - | - | - | - | - | - |
| *Chironomus* sp. A | **1** | - | - | - | - | - | - | 2 | 1 | - | 1 | - | - | - | - | - |
| *Chironomus zelandicus* | **1** | - | - | - | - | - | - | 425 | 420 | 1124 | 192 | 8 | 4 | - | - | - |
| *Corynoneura* sp. | **2** | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| cf *Kiefferulus opalensis* | **2** | - | - | - | - | - | - | - | - | - | 428 | 380 | 884 | 96 | 288 | 192 |
| Orthocladiinae | **2** | 2 | - | 1 | - | 1 | 4 | 170 | 524 | 1160 | 92 | 1180 | 388 | 528 | 432 | 976 |
| *Polypedilum* sp. | **3** | 1 | 1 | - | 2 | - | 4 | 224 | 880 | 1848 | 180 | 456 | 348 | 32 | 80 | - |
| Psychodidae | **1** | - | - | - | - | - | - | 1 | - | 1 | - | - | 1 | - | - | - |
| Tanyderidae | **4** | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - |
| *Tanytarsus funebris* | **3** | - | - | - | - | - | - | 24 | 28 | 4 | 40 | 24 | 16 | 16 | 176 | 48 |
| *Tanytarsus vespertinus* | **3** | 3 | - | 1 | - | - | - | 82 | 484 | 612 | 180 | 516 | 600 | 1072 | 1888 | 2112 |
| | | | | | | | | | | | | | | | | |
| **Trichoptera (caddis flies)** | | | | | | | | | | | | | | | | |
| *Aoteapsyche* spp. | **4** | 1 | - | 4 | - | - | 10 | 1 | 12 | 6 | 4 | 11 | - | - | - | - |
| *Hudsonema amabile* | **6** | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Hudsonema* sp. | **6** | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - |
| *Hydrobiosis copis* | **5** | - | - | - | - | - | 1 | - | 2 | 4 | 3 | 2 | 1 | - | - | - |
| *Hydrobiosis* spp. | **5** | 1 | - | - | - | - | - | - | 2 | 3 | - | 2 | - | - | - | - |

Appendix 3. *continued*.

| Taxa | MCI taxon score | Wairoro Stream sites 410 m upstream a | b | c | 50 m upstream a | b | c | 150 m downstream a | b | c | 330 m downstream a | b | c | 1100 m downstream a | b | c |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trichoptera (caddis flies)** | | | | | | | | | | | | | | | | |
| Leptoceridae | **5** | - | - | - | - | - | - | 1 | - | 2 | - | - | - | - | - | 1 |
| *Neurochorema confusum* | **6** | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | - |
| *Neurochorema* sp. | **6** | 3 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Olinga feredayi* | **9** | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | - |
| *Oxyethira albiceps* | **2** | - | - | - | - | - | - | 6 | 3 | 3 | 40 | 56 | 40 | 1 | 352 | 144 |
| *Paroxyethira* sp. | **2** | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - |
| *Pycnocentria evecta* | **7** | 1 | - | 1 | 1 | - | - | 1 | - | 6 | - | 1 | - | - | - | - |
| *Pycnocentrodes* spp. | **5** | 93 | 15 | 47 | 92 | 21 | 159 | - | 3 | 1 | 1 | 1 | - | - | - | - |
| *Triplectides cephalotes* | **5** | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| *Triplectides obsoletus* | **5** | - | - | 1 | - | - | - | 3 | - | - | 1 | - | - | - | - | - |
| | | | | | | | | | | | | | | | | |
| **Hirudinea (leeches)** | **3** | - | - | - | - | 1 | - | 1 | 1 | - | - | 1 | - | 1 | 1 | 48 |
| **Nemertea (proboscis worms)** | **3** | - | - | - | - | 1 | 2 | - | - | 1 | - | - | - | 1 | 64 | - |
| **Oligochaeta (worms)** | **1** | 2 | - | 1 | 1 | - | - | 194 | 368 | 444 | 2120 | 2268 | 888 | 1344 | 1408 | 2032 |
| **Platyhelminthes (flatworms)** | **3** | - | - | - | - | - | - | 60 | 60 | 88 | 329 | 240 | 20 | 8 | 192 | 112 |
| | | | | | | | | | | | | | | | | |
| **Mollusca (snails)** | | | | | | | | | | | | | | | | |
| *Gundlachia neozelandica* | **3** | 9 | 4 | - | 2 | 1 | 4 | 10 | 13 | 1 | - | 12 | - | - | - | - |
| *Physa* sp. | **3** | - | - | - | - | - | 1 | 44 | 36 | 52 | 80 | 100 | 24 | 768 | 848 | 752 |
| *Potamopyrgus antipodarum* | **4** | 65 | 17 | 5 | 21 | 19 | 84 | 29 | 53 | 96 | 1 | 12 | - | 176 | 16 | 80 |
| Sphaeriidae | **3** | - | - | - | - | - | - | 13 | 12 | 3 | 88 | 4 | 12 | 20 | 4 | 48 |
| | | | | | | | | | | | | | | | | |
| **Crustacea (crustaceans)** | | | | | | | | | | | | | | | | |
| Copepoda | **5** | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | 48 | 16 |
| Cladocera | **5** | - | - | - | - | - | - | 1 | 2 | - | 8 | 8 | - | - | 128 | 48 |
| Ostracoda | **3** | - | - | - | - | - | - | 483 | 136 | 264 | 204 | 52 | 148 | 1 | 64 | 160 |
| | | | | | | | | | | | | | | | | |
| **Coelenterata (hydra)** | | | | | | | | | | | | | | | | |
| *Hydra* sp. | **3** | - | - | - | - | - | - | 27 | 18 | 8 | 8 | 4 | 4 | 80 | - | 64 |
| | | | | | | | | | | | | | | | | |
| **Acarina (mites)** | **5** | - | 1 | 1 | - | - | - | 1 | 1 | - | - | - | - | 96 | 64 | 16 |
| **Collembola (springtails)** | **6** | - | - | - | - | - | - | 1 | 1 | 1 | - | - | - | - | - | - |
| **Taxa Richness** | | 16 | 7 | 19 | 8 | 11 | 16 | 28 | 31 | 29 | 21 | 26 | 18 | 19 | 21 | 17 |
| **Total density (No/m$^{-2}$)** | | 3776 | 800 | 2192 | 2432 | 848 | 5568 | 28944 | 49152 | 91840 | 64016 | 85520 | 54096 | 67904 | 96912 | 109584 |
| **EPT taxon richness** (minus Hydroptilidae) | | 8 | 2 | 12 | 3 | 3 | 8 | 6 | 10 | 8 | 4 | 7 | 3 | 1 | 0 | 1 |
| **EPT density (No/m$^{-2}$)** (minus Hydroptilidae) | | 2192 | 384 | 2000 | 1952 | 400 | 3776 | 128 | 400 | 384 | 144 | 304 | 48 | 16 | 0 | 16 |
| **%EPT$_{taxa}$** (minus Hydroptilidae) | | 50.00 | 28.57 | 63.16 | 37.50 | 27.27 | 50.00 | 21.43 | 32.26 | 27.59 | 19.05 | 26.92 | 16.67 | 5.26 | 0.00 | 5.88 |
| **%EPT$_{density}$** (minus Hydroptilidae) | | 58.05 | 48.00 | 91.24 | 80.26 | 47.17 | 67.82 | 0.44 | 0.81 | 0.42 | 0.22 | 0.36 | 0.09 | 0.02 | 0.00 | 0.01 |
| **MCI** | | 96 | 97 | 112 | 93 | 89 | 104 | 76 | 89 | 76 | 63 | 78 | 67 | 66 | 67 | 65 |
| **QMCI** | | 5.05 | 4.94 | 6.04 | 5.23 | 4.58 | 5.03 | 2.25 | 2.36 | 2.28 | 1.71 | 1.86 | 2.09 | 2.31 | 2.44 | 2.25 |