Ecological survey of Donald Creek and Otauira Stream, 2016

Prepared for:

South Wairarapa District Council

Ecological survey of Donald Creek and Otauira Stream, 2016

Author(s):

K. D. Hamill (River Lake Ltd)

Prepared for:

South Wairarapa District Council

Released by: ………………………………

Keith Hamill

Principal Environmental Scientist

River Lake Ltd
PO Box 853, Whakatane 3158,
New Zealand

Mobile: +64 27 308 7224
Email: keith@riverlake.co.nz

Date: 16 January 2017
Status: Final
Reference: wk-1070

Cover photo: Fyke net in Otauira Stream.

Contents

1 Introduction

1.1 Background

Featherston Wastewater Treatment Plant (WWTP) discharges treated wastewater to Donald Creek. Donald Creek enters the Otauira Stream about 2.5km downstream of the discharge, and Otauira Stream flows another 2.6 km before entering the northern end of Lake Wairarapa. The South Wairarapa District Council (SWDC) is undertaking a programme to upgrade the WWTP to partial land disposal but there is likely to still be a discharge to Donald Creek for a period of time and under wet conditions that typically occur during winter and spring.

River Lake Ltd was commissioned to undertake an ecological survey of Donald Creek and Otauira Stream to assess the effects of the discharge during spring conditions and to inform the assessment of environmental effects. This report discusses the results of ecological monitoring undertaken in early October and early November 2016.

1.2 Past ecological surveys of the stream

Ecological surveys of Donald Creek were undertaken at two sites in April 2010 and five sites in March 2013 to assess the effects of the WWTP (Coffey 2010, Coffey 2013). Shading by trees was thought to mask the full effect of the nutrient enrichment so additional sites were sampled in 2013. Also, some willows were killed during 2013 to make the stream more open. The key findings of these surveys were:

- The WWTP discharge caused conspicuous change in colour at the point of discharge.
- Some heterotrophic growths were found downstream (ca.5% cover for both surveys).
- Periphyton cover and biomass was significantly higher downstream of the discharge (about 15 % cover of long filamentous algae in 2010). In 2013 the difference in periphyton cover and biomass was particularly apparent at the unshaded sites and very little periphyton was present at the shaded sites.
- In 2010, the periphyton community was dominated by *Fragilaria* sp., *Gomphonema* sp. and *Phormidium* sp. upstream of the discharge, while *Stigeoclonium* sp. dominated downstream. In 2013 the periphyton community was dominated by *Stigeoclonium* sp. upstream and *Fragilaria* sp. downstream.
- All macroinvertebrate metrics indicated a statistically significant decline in water quality downstream of the discharge.

Planktonic green algae were common in the periphyton samples and Daphnia was common in invertebrate samples – both indicative of a WWTP pond discharge. In 2013 sites immediately downstream of the discharge had planktonic algae from the oxidation ponds as a scum on substrate and moss.

Forbes (2013) undertook ecological monitoring of Donald Creek about monthly between November 2012 and April 2013. This consisted of water quality samples and visual assessments of periphyton cover and analysis of periphyton relative abundance. Sites were located about just upstream, about 60m downstream and about 160m downstream. Key findings of the monitoring were:

- A reduction in substrate size downstream with more sand and silt at the downstream sites.

- All sites were clear of periphyton during November. During summer the amount of periphyton cover increased and this was particularly noticeable at the downstream sites. During April, 'sludge' (medium mats) covered about 10% of the bed and coarse filamentous green algae covered almost 20% of the bed at the 160m downstream site.

- Periphyton biomass at the 160m downstream site during February was 138 mg chlorophyll-*a*/m^2 and 42 g AFDM/m^2; during April it was 91 mg chlorophyll-*a*/m^2 and 17.5 g AFDM/m^2. Upstream samples were not collected.

- The downstream sites had substantially lower water clarity (about 0.6m compared to 2.6m upstream), higher suspended solids (ca.6 to 9 mg/L compared to 4 mg/L upstream), higher BOD (about 4 to5 mg/L compared to <1 mg/L upstream), noticeably higher soluble inorganic nitrogen (SIN) (1 mg/L compared to 0.6 mg/L upstream) and dramatically higher dissolved reactive phosphorus (ca. 0.3 mg/L compared to ca. 0.01 mg/L upstream).

In previous reports Otauira Stream is also known as Abbot Creek; Donald Creek is also known as Boar Creek.

2 Methods

2.1 Timing and flow conditions

Ecological surveys were undertaken in Donald Creek and Otauira Stream twice during spring. The surveys occurred on 10th -11th October 2016 and on 1 November 2016; and the stream flows at the time of the surveys were 320 L/s and 259 L/s respectively. A large flood had occurred on 18 September (3450 L/s) – about four weeks prior to the October survey (Figure 2.1). Debris from the flood was visible in the stream at the time of the survey.

The water level in the stream at the time of the survey was typical of spring base flow conditions (the median flow in October for an 11 year synthetic flow record (2005-2016) was 332 L/s). The annual median flow in Donald Creek upstream of the Featherston WWTP discharge is 241 litres per second (Butcher 2016).

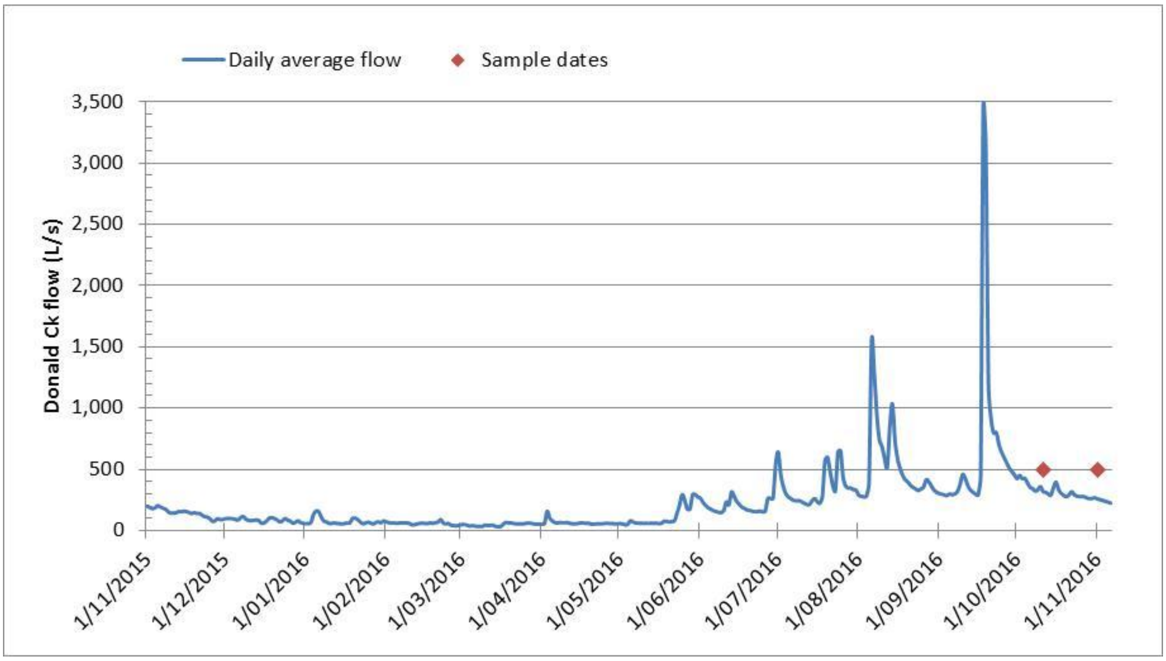

Figure 2.1: Daily average flow in Donald Creek and time of the stream surveys 10 -11 October and 1 November 2016.

2.2 Sites

The ecological survey sampled four sites on Donald Creek and two sites on Otauira Stream. The description and location of the sites are show in Figure 2.2 and Table 2.1). The sites on Donald Creek are consistent with those sampled in 2013 by Coffey (2013). The sites 25m upstream of the discharge and 60m downstream of the discharge were within a remnant of protected bush, the sites 100m upstream and 650m downstream were surrounded by pasture. The 650m downstream site had noticeably slower flows and smaller substrate than the other sites. A small tributary (Longburn water race) enters Donald Creek from the true left about 430m downstream of the discharge.

The sites on Otauira Stream were located upstream and downstream of the confluence with Donald Creek. These sites had not been previously sampled by Coffey (2013).

The fish survey on Donald Creek placed nets over a 140 m reach from about 90m upstream to 60m downstream of the discharge. The fish survey on Abbot Creek placed nets over 200 m reach from about 100 m upstream to 100 m downstream of the confluence.

Table 2.1: Location of sample sites for ecological monitoring

Stream site	Site code in (Coffey 2013)	Location description	Co-ordinates (Lat. Long)
Donald Ck 100m u/s	1	100m upstream of the discharge. Samples collected from a 30m reach around this location.	-41.136319°, 175.326433°
Donald Ck 25m u/s	2	25m upstream of the discharge. Samples collected from a 30m reach upstream this location	-41.136969°, 175.326672°
Donald Ck 60m d/s	4	60m downstream of the discharge. Samples collected from a 30m reach around this location	-41.137651°, 175.327198°
Donald Ck 650m d/s	5	650m downstream of the discharge. Samples collected from a 30m upstream of this location.	-41.141920°, 175.325360°
Otauira Stm 70m u/s		70m upstream of the confluence with Donald Creek. Samples collected from a 30m reach around this location	-41.148163°, 175.310549°
Otauira Stm 100m d/s		100m downstream of the confluence with Donald Creek. Samples collected from a 30m reach around this location	-41.149298°, 175.309069°

Figure 2.1: Location of sample sites on Donald Creek and Otauira Stream (also known as Abbot Creek). The bottom map shows a detail of Donald Creek.

2.3 Habitat

In-stream habitat quality was recorded to help interpret data from macroinvertebrate and periphyton sampling. At each site, habitat was assessed using the National Rapid Habitat Assessment Protocol (Clapcott 2015) and a Habitat Quality Score (HQS) calculated. In each sample reach observations were made of water depth, stream bed particle size, discolouration of water column, and evidence of foaming.

Water depth and velocity was measured mid-stream of run sections using the ruler method described in Harding et al. (2009).

The particle size distribution of substrate on the stream bed was assessed using the Wolman pebble count method (Clapcott et al. 2011). The particle size classes used were: clay silt (<0.063mm), sand (0.063-2 mm), small gravel (2-16 mm), medium gravel (16-32mm), large gravel (32-64mm), small cobble (64-128 mm), large cobble (128-256 mm), boulder (>256 mm) and bedrock.

The amount of fine resuspendible sediment in the streambed was qualitatively assessed using the Shuffle Index (method 5 in Clapcott et al. 2011). This was applied in runs where the flow was between 0.2 and 0.6 m/sec and depth was between 20 and 50 cm. The index measures the extent to which a tile placed on the stream bed is obscured after vigorous disturbance: Score 1 = 'No or small plume; Score 2 = 'Plume briefly reduces visibility at tile'; Score 3 = 'Plume partially obscures tile but quickly clears'; Score 4 = 'Plume partially to fully obscures tile but slowly clears'; Score 5 = 'Plume fully obscures tile and persists even after shuffling ceases'.

A photograph was taken of each sample site (see Appendix 1).

2.4 Macrophytes

Aquatic macrophyte cover was assessed over a 30m reach at each site using the rapid assessment protocol in the 'Regional Guidelines for Ecological Assessment of Freshwater Environments: aquatic plant cover in wadeable streams' (Collier et al. 2014). This involved assessing emergent and submerged macrophyte cover and type occupying a one metre wide belt across the stream at five transects spaced along the reach being assessed.

The following metrics were calculated:

- Macrophyte Total Cover (MTC): This reflects the extent and cover over the bottom. It is calculated as: {∑(%emergent + %submerged)} / 5 transects.

- Macrophyte Channel Clogginess (MCC): This reflects the extent and cover through the water column. It is calculated as: {∑(%emergent + %surface reaching) + (% below surface * 0.5)} / 5 transects.

2.5 Periphyton

2.5.1 Periphyton cover (including benthic cyanobacteria)

Periphyton cover was assessed at each of the five transects at each site. Periphyton cover was visually assessed at each site using the method and field sheets in Collier et al. (2014) which is based on the Rapid Assessment Method 2 (RAM2) in Biggs and Kilroy (2000). It involves assessing periphyton cover and type on a total of 25 points on five transects located at least 5m apart. For each transect five rocks were assessed across the stream. Each transect approximately corresponded with the location of replicate macroinvertebrate samples. Benthic cyanobacteria were separately identified as part of the periphyton visual assessment.

The sites were searched for any heterotrophic growth and these were recorded at the same time as the periphyton survey. None were found at any site.

The following ecological indices were calculated from the periphyton cover: [1]

- Periphyton Enrichment Index (PEI). This is a measure of nutrient enrichment. Higher scores reflect greater algal cover by periphyton categories indicative of nutrient enrichment. The index is a measure of the relative abundance of different types of algae and thus any transects without periphyton are ignored in the calculation. It is calculated as: PEI = {[∑(% cover in each category per transect * Indicator score) / Total % cover per transect] / No. transects with periphyton} *11.

- Periphyton Proliferation Index (PPI). This is an indicator of biomass. It is the percent of total cover by long filaments and thick mats. It is strongly related to % EPT taxa.

- Periphyton Sliminess Index (PSI). This is an indicator of biomass. It is the weighted percent cover of each thickness category and is calculated as: PSI = {(%Thin mat/fil) + (%Short filaments * 2) + (% Medium mat * 3) + (% Long filaments * 4) + (%Thick mat*5)} / 5. It is strongly related to macroinvertebrate diversity and condition.

- Periphyton Weighted Composite Cover (Peri WCC): This is a measure of periphyton cover of mats >3mm thick and filaments green algae > 2cm long. PeriWCC = % filamentous algae + (% mat algae/2) (Matheson et al 2012).

2.5.2 Periphyton biomass and identification

Periphyton biomass was assessed using the Quantitative Method 1b (QM-1b) in Biggs and Kilroy (2000). Five replicate periphyton samples were collected from large gravel / cobbles at each site (one rock per transect). This involved removing all periphyton from a set area of 6cm diameter on the surface of gravels / cobbles representative of periphyton cover on stable substrate at each of five transects.

On 10 October five (5) replicates were collected from each site on Otauira Stream, Donald Creek 100m u/s and Donald Creek 650m d/s (area sampled of 0.002827 m^2 per replicate and 0.0141372 m^2 per site). For Donald Creek sites 25m upstream and 60m downstream a single replicate was collected which consisted of periphyton scraped from three and four cobbles respectively (sample area of 0.008482 m^2 and 0.01131 m^2 respectively).

On 1 November a single replicate was collected from each site, each periphyton biomass replicate consisted of 5 cobbles with 6cm diameter area scraped (total area sampled of 0.0141372 m^2 per site).

Periphyton biomass samples were frozen and sent to the laboratory for analysis. Samples collected on 10 and 11 October were analysed for chlorophyll *a,* samples collected on 1 November were analysed for chlorophyll *a* and Ash Free Dry Mass (AFDM). Chlorophyll *a* was extracted using the hot ethanol method as described in Biggs and Kilroy (2000).

The results were compared with the NZ Periphyton Guidelines (Biggs 2000). The ratio of AFDM to chlorophyll *a* was used to calculate the autotrophic index (a measure of organic enrichment).

A single bulked sample was collected from each site and analysed for <u>periphyton community composition</u>. The bulked sample consisted of a sub-sample from each rock sampled for periphyton biomass. Samples were refrigerated and sent to the laboratory for identification. The relative

[1] Note that Collier et al. (2014) modified the formula for calculating PEI from that in the previous version (Collier et al. 2007). Furthermore, the periphyton scoring differs from the scores in Biggs & Kilroy (2000) because they have been subtracted from 10.

abundance was assessed using the method in Biggs and Kilroy (2000) i.e. using a relative scoring system from 1 (rare) to 8 (absolutely dominant/monoculture).

The NZ Provisional Periphyton Guidelines (Biggs 2000) sets guidelines to maintain 'trout habitat and angling' as peak biomass <35 g AFDM/m^2 (Ash Free Dry Mass), or <200 mg chlorophyll *a*/m^2 for diatoms/cyanobacteria dominated communities and <120 mg chlorophyll *a*/ m^2 for filamentous dominated communities. Periphyton cover guidelines are set at <30% filamentous algae over the stream bed. Guidelines set for maintaining benthic biodiversity are < 50 mg chlorophyll *a*/m^2.

Matheson et al. (2012) proposed an alternative index of cover called the Periphyton Weighted Composite Cover (Peri WCC). They proposed an aesthetic nuisance guideline of >30% Peri WCC, but also identified that a Peri WWC of <40% corresponded to macroinvertebrate communities in 'good' condition (i.e. QMCI of >5 and MCI >100).

2.6 Macroinvertebrates

The use of macroinvertebrates for assessing the condition of streams is widespread in New Zealand and overseas. The structure and composition of macroinvertebrate communities is a good indicator of stream condition as they are found in almost all freshwater environments, are relatively easy to sample and identify, and different taxa show varying degrees of sensitivity to pollution.

Aquatic macroinvertebrates were collected from riffle/run habitat using a Surber sampler and following Protocol C3 of Stark et al. (2001). All macroinvertebrate samples were preserved in alcohol and processed using Protocol P3 (full count with sub-sampling option) of the Protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001).

On 10 October, five (5) replicates were collected from each site on Otauira Stream, Donald Creek 100m u/s, Donald Creek 60m downstream and Donald Creek 650m d/s with each replicate consisting of at least two Surber samples (area sampled > 1 m^2 per site)[2]. For the Donald Creek site 25m upstream a single replicate was collected which consisted of six Surber samples bulked into a single container (total sample area of 0.6 m^2 for the site).

On 1 November, a single replicate was collected from each site, this replicate consisted of five (5) Surber samples collected from along the reach (a total sample area of 0.5m^2).

Macroinvertebrate results were expressed on an areal basis i.e. per square metre. The following ecological indices were calculated to assess the biological health of the river and potential effects on the stream ecology:

- Taxa Richness: This is a measure of the types of invertebrate taxa present in each sample.
- EPT richness and EPT abundance (Ephemeroptera-Plecoptera-Trichoptera). This measures the number of pollution sensitive mayfly, stonefly and caddisfly (EPT) taxa in a sample excluding *Oxyethira* and *Paroxyethira*.
- % EPT abundance.
- Macroinvertebrate Community Index (MCI). The MCI is an index for assessing the water quality and 'health' of a stream using the presence/absence of macroinvertebrates (Stark 1985).

[2] See results for actual area sampled at each site.

- Quantitative MCI (QMCI). The QMCI is similar to the MCI but is based on the relative abundance of taxa within a community (Stark 1993, Stark 1998).

The MCI and QMCI reflect the sensitivity of the macroinvertebrate community to pollution and habitat change, with higher scores indicating higher water quality. Generally accepted water quality classes for different MCI and QMCI scores and soft-bottomed version are shown in Table 2.2.

Table 2.2: Suggested quality thresholds for interpretation of the MCI & QMCI from Stark (1998)

Quality Class	Description	MCI	QMCI
Excellent	Clean water	> 120	> 6.0
Good	Doubtful quality or possible mild pollution	100 – 120	5.0 - 6.0
Fair	Probable moderate pollution	80 – 100	4.0 – 5.0
Poor	Probable severe pollution	< 80	< 4.0

In addition to sampling benthic macroinvertebrates, the aquatic vegetation and soft sediment within the sample reaches were searched for kākahi (freshwater mussel) and the presence of bivalves such as fingernail clams (*Sphaerium* sp). A kick-net was used to search soft sediment for the fingernail clam. Bivalves are known to be particularly sensitive to the presence of ammonia, so their presence in a stream has implications for waste water discharges.

2.7 Fish survey

Fish were recovered by using baited fyke nets and baited gee minnow traps placed in the stream over-night on 10 to 11 October 2016. Six fine-mesh fyke nets and 6 Gee-minnow traps were placed in each stream on consecutive nights. The survey reach in Donald Creek spanned 140m and the survey reach in Otauira Stream spanned 200m.

The fyke nets were fine mesh (mesh size ca. 4mm) with net dimensions of: 6 hoops, with 60cm wide front D mouth, and 3m long trap and 5m long leader (Joy et al. 2013). The gee-minnow traps had a 4mm mesh size and 2.5cm diameter mouth. All nets and traps were baited with cheese.

2.8 Water Quality

A single water quality grab sample was collected from each site at the time of the survey and a field meter was used to measure water temperature, electrical conductivity and dissolved oxygen. Water samples were sent to Hill Laboratory and analysed for the following variables: pH, total suspended solids (TSS), nitrate-N, nitrite-N, ammoniacal-N, total kjeldahl nitrogen (TKN), dissolved reactive phosphorus (DRP), total phosphorus (TP), $cBOD_5$, and *E.coli* bacteria.

Grab samples were collected prior to walking in the stream for biological sampling. Samples were collected from mid-stream using standard sampling protocols. In addition to this water quality sampling, South Wairarapa District Council collects regular water quality samples from the discharge and Donald Creek.

2.9 Mixing zone survey

The mixing zone at the time of the survey was assessed on 10 October using specific electrical conductivity (EC) as a conservative tracer. EC at 1m intervals across the stream was measured along transects progressively down the stream.

Specific electrical conductivity (EC) is often used as a conservative tracer in mixing studies. The WWTP discharge has higher EC compared to Donald Creek (i.e. about 187.5 µS/cm compared to 136 µS/cm upstream), which allows EC to be used to estimate dilution at points downstream. Dilution was calculated using a mass balance approach over a 'control volume' of the river after mixing. The formula for the dilution factor (D) for downstream sampling points is:

$$D = (EC_{eff} – EC_{u/s})/(EC_{d/s} – EC_{u/s})$$

Where: D = dilution factor; ECeff = electrical conductivity of the effluent; ECu/s = EC of the river upstream; ECd/s = EC of the river downstream.

2.10 Statistical Analysis

The statistical significance of macroinvertebrate and periphyton indices was compared using an equivalence test in the software 'TimeTrends'. A difference was considered statistically significant if the *p*-value was < 0.05; and a difference was considered "*practically important*" if the difference was +/- 20% change compared to the upstream control sites. Allowing up to a 20% change recognises that habitats can seldom be perfectly matched and even small changes in substrate size, flow and location can impact on macroinvertebrate composition to some extent.

Equivalence tests incorporate both testing of means (using a student t-test) and testing of a meaningful change (interval testing). One advantage of equivalence tests is that increasing the sampling effort may make it either more or less likely that an equivalence hypothesis will be rejected, unlike the statistical test where more data means that the hypothesis is more likely to be rejected.

3 Results

3.1 Habitat and Macrophytes

3.1.1 Donald Creek

Donald Creek has similar water depth (in runs) between the upstream and downstream sites but there was a general increase in stream width (wetted width), and a decrease in water velocity (mid-stream in runs). The size of the substrate also reduced; with large gravel comprising 28% of the substrate at the 100m upstream site and being absent from the 650m downstream site (Table 3.1 and Table 3.2).

The substrate in Donald Creek was loosely packed and easily moved. Sand was moving on the stream bed in Donald Creek sites upstream and 60m downstream of the discharge. Very little substrate was embedded by fine sediment except at the 650m downstream site. Aquatic moss (*Drepanocladus* sp.) was present on some of the cobbles at the 70m downstream site (Table 3.4).

The 650m downstream sites had more resuspendable fine sediment on the stream bed compared to the other sites. This was apparent in the Shuffle Index; the 650m downstream site disturbing the stream bed released fine sediment that obscured the stream bed and took several seconds to clear (Table 3.1). At this site, cattle were in the stream and the stream margins were heavily pugged.

The habitat score was higher for sites within the bush remnant either side of the discharge (25m upstream and 60m downstream). This was because the riparian vegetation provided better diversity of fish cover (e.g. woody debris, root mats, undercut banks, overhanging vegetation), less bank erosion and more riparian shade. Logs within the stream helped provide hydraulic heterogeneity – particularly at the 60m downstream site (Table 3.1). The immediate riparian margin was dominated by *Apium* sp, pasture grasses, buttercup (*Ranunculus* sp.). In the bush remnant black berry and the pest plant wandering jew (*Tradescantia* sp.) was common.

Donald Creek had low macrophyte cover in the shaded sites (25m upstream and 60m downstream), and moderate macrophyte cover in the unshaded sites (100m upstream and 650m downstream) (Table 3.3). The predominant macrophyte in the stream was water celery (*Apium nodifolrum*) – this is a sprawling emergent macrophyte that was also very common on the riparian margins. The site at 650m downstream had *Apium* sp. present but also had a range of submerged species including: *Elodea canadensis*, *Callitriche stagnalis* (starwort), *Potamogeton crispus* (curled pondweed), some *Glyceria fluitans* (floating sweet grass) and the native *Nitella hookeri*.

Periphyton was more common in the unshaded sites; although the shaded sites did have sufficient light for periphyton to grow (e.g. the 60m ds site had open sky beyond a 30^{o} angle). The periphyton was predominantly thin films or diatom mats (sludge) but tuffs of the red algae *Batrachospermum* sp. was common on the stream bed at 650m d/s site on both sample occasions (Figure 3.1).

3.1.2 Otauira Stream

Otauira Stream is a gravel bed stream. Upstream of the confluence with Donald Creek the runs are wide (10.6m) and shallow (15cm), but downstream it becomes more confined, narrower (7.6m) and deeper (45cm) (Table 3.1).

The substrate on Otauira Stream was dominated by large gravel and small cobbles. Cobbles were more common at the downstream site – perhaps reflecting the confined channel (Table 3.2). Aquatic mosses was common on cobbles at downstream site but were rare upstream – perhaps indicating more stable substrate. At both Otauira Stream sites the substrate in was moderately to tightly packed with very little being embedded by fine sediment.

Both sites on Otauira Stream had reasonably high habitat scores due to very low fine sediments, high diversity and abundance of habitat for invertebrate colonisation (e.g. cobbles, gravel, sand, wood, macrophytes, and leaves), very little bank erosion and moderate riparian width. However habitat scores were lowered by both sites having very little riparian shade.

Otauira Stream had very little macrophyte cover upstream of the confluence with Donald Creek, while the downstream site had about 10% cover of the sprawling emergent *Apium nodifolrum*. *Apium* sp. extended up on to the riparian margins where buttercup (*Ranunculus* sp.), black berry and willow were also common (Table 3.3).

Both sites had relatively little periphyton cover – mostly consisting of thin films or diatom mats. Interesting the upstream site had more periphyton present during the 11 October survey compared to the 1 November survey, while the downstream site had more periphyton present on 1 November.

On 12 October 2016, Otauira Creek had about 1.5 times the flow of Donald Creek[3], but by 1 November 2016 the flow in Otauira Stream was considerably less than the flow in Donald Creek. This reflects the numerous springs that contribute to the flow in Donald Creek.

[3] Based on EC measurements taken at sites upstream and downstream of the confluence after full mixing.

Table 3.1: Summary of habitat variables at sites on Donald Creek and Otauira Stream, 10 – 11 October 2016

Site Name	Width (m)	depth (m)	velocity (m/s)	% macrophyte	Algae PSI	habitat score	Dominant substrate
Donald 100m us	3.4	25	0.89	8.4	21.4	55.0%	LG, SG, S, MG
Donald 25m us	3.7	25	1.06	3.2	11.5	68.5%	SG, MG
Donald 60m ds	4.2	24	0.96	1.8	14.4	73.0%	SG, MG
Donald 650m ds	7.1	25	0.73	28.4	25.8	38.5%	SG, MG
Otauira 70m us	10.6	15	1.6	0	32.6	66.0%	LG, MG
Otauira 100m ds	7.6	45	1.2	9.8	14.6	69.0%	SC, MG, LG

Table 3.2: Substrate particle size distribution and Shuffle Index of resuspendable sediment at sites on Donald Creek and Otauira Stream, 10 – 11 October 2016

Site	Shuffle Index	Particle size distribution							
		Clay	Si	S	SG	MG	LG	SC	LC
Donald 100m us	2	1.3%	3.8%	22.8%	22.8%	20.3%	27.8%	1.3%	0.0%
Donald 25m us	2	0.0%	0.0%	17.8%	42.2%	28.9%	11.1%	0.0%	0.0%
Donald 60m ds	2	0.0%	0.0%	16.7%	43.3%	20.0%	16.7%	3.3%	0.0%
Donald 650m ds	3	0.0%	3.6%	17.9%	42.9%	35.7%	0.0%	0.0%	0.0%
Otauira 70m us	1	0.0%	0.0%	3.9%	6.6%	34.2%	42.1%	13.2%	0.0%
Otauira 100m ds	2	0.0%	0.0%	5.9%	7.4%	29.4%	25.0%	32.4%	0.0%

Si = silt, S =sand, SG=small gravel, MG=medium gravel, LG=large gravel, SC=small cobble, LG=large cobble, B=boulder

Table 3.3: Macrophyte cover at each site on 11 October 2016. Mean of five transects.

Site		Donald 100m us	Donald 25m us	Donald 60m ds	Donald 650m ds	Otauira 70m us	Otauira 100m ds
Wetted area (m)		3.4	3.7	4.2	7.1	10.6	7.6
Channel width (m)		3.8	4.3	4.5	7.4	11.4	8.0
Submerged plants	**Total submerged**	4	0	0	26.4	0	0
	Surface reaching	2.4	0	0	15	0	0
	Below surface	1.6	0	0	11.4	0	0
Emergent plants	**Total emergent**	4.4	3.2	1.8	2	0	9.8
Macrophyte Total Cover (MTC)		8.4	3.2	1.8	28.4	0	9.8
Macrophyte Channel Clogginess (MCC)		7.6	3.2	1.8	22.7	0	9.8

3.2 Periphyton and benthic cyanobacteria

3.2.1 Periphyton

There was very little periphyton at any site in Donald Creek during the October 16 survey. Stones had a thin film of algae making them slippery, but there were little visible growths or 'sludges'.

A statistical analysis of the periphyton cover and biomass in Donald Creek during the October survey found no statistically significant changes in PEI, PSI and chlorophyll *a* (due to the small number of replicates relative to the variability within the sites). However the increase in the PPI at the 650m downstream site was statistically significant (t-test *p*-value =0.03) because this was the only site where long filamentous algae was recorded – albeit in small amounts. These were tuffs of the red algae *Batrachospermum* sp. about 3cm long (Figure 3.1).

For Otauira Stream moderate cover of the diatoms *Frustulia* and *Cymbella* sp. were present as 'sludges' on the cobbles at the site upstream of the confluence, but there was very low cover downstream. A statistical analysis of the periphyton cover and biomass from the October survey found that the decrease in PSI and PEI at the downstream site was statistically significant (t-test *p*-value =0.002, strong evidence of a difference >10%). However the lower mean chlorophyll *a* values were not statistically significant due to the small number of replicates relative to the variability (Table 3.4, Table 3.6).

By the time of the November survey Donald Creek had considerably more periphyton cover, but all sites were still below the NZ Periphyton Guidelines for maintaining 'trout habitat and angling', and all sites were well below the PeriWCC guideline of 30% for maintaining aesthetic values . The 25m upstream site had the lowest periphyton cover and biomass. The 650m downstream site had higher periphyton cover as reflected by the indexes PPI and PeriWCC; this was due to patches of the red algae *Batrachospermum* sp. The other cover indexes of PEI and PSI showed no clear difference between upstream and downstream sites (Table 3.5).

The periphyton biomass indicator of AFDM showed a pattern similar to the PEI, with no clear difference between the Donald Creek downstream sites and the 100m upstream sites. However, chlorophyll *a* was noticeably higher at the two downstream sites (Table 3.6). The biomass samples from the 650m downstream sites included a clump of *Batrachospermum* sp. It appeared that the periphyton from the 60m downstream sites was particularly rich in chlorophyll *a*.

During the November survey Otauira Stream had more periphyton cover (EPI and PSI) and higher biomass (AFDM and chlorophyll *a*) downstream of the confluence compared to upstream. This was a reversal of the pattern observed in early October. The change may be due to the interaction between periphyton growth rate and density of macroinvertebrates that graze the periphyton.

Most of the algae species in the periphyton community are typical of mesotrophic to eutrophic conditions (i.e. the diatoms *Nitzschia, Melosira, Cymbella*). *Cymbella* sp. rapidly colonises substrate after floods, which may explain its dominance in the samples from early October. *Achnanthidium* sp. is widespread throughout New Zealand but is often in streams with moderate to high water velocity – perhaps explaining its presence at the 25m upstream site. *Batrachospermum* sp. was common at the 650m downstream site; it is typical of clean cool streams, often spring fed or shady forest streams, and is often associated with high soluble organic carbon such as stable Westland stream (Biggs 2000, Kilroy and Biggs 2000) (Table 3.6).

At sites with smaller substrate (e.g. Donald Creek 650m downstream), the periphyton biomass measurements may have been biased upward compared to the cover measurement because larger rocks were sought for scrapping. These were also the more stable rocks and more likely to have higher periphyton biomass. Green filamentous algae was rare in both stream but was observed on submerged logs at the Donald Creek 60m downstream site.

3.2.2 Benthic cyanobacteria

During the October site visit, occasional patches of benthic cyanobacteria were only found in Donald Creek at the site 650m ds, but in such low cover that it was not found on the periphyton transects. During the 1

November site visit small patches of cyanobacteria were found in Donald Creek at sites 100m upstream of the discharge and 650m downstream.

In Otauira Stream upstream of the confluence, small patches of the benthic cyanobacteria were present on the stream bed on 11 October but cover was so low that it was not detected in the periphyton transects. No cyanobacteria were found on 1 November 2016. Benthic cyanobacteria were not found in Otauira Stream downstream of the confluence on either site visit.

3.2.3 Heterotrophic growths

Each site was searched for the presence of heterotrophic growths and none were found at any site on either sampling occasion.

The Autotrophic Index (AI) is sometimes used as an indicator of organic enrichment. Dissolved organic waste tends to favour the growth of heterotrophic periphyton taxa such as the filamentous bacterium. A shift towards these organisms can be indicated by an increase in the autotrophic index. A higher AI indicates more organic pollution and an AI value >400 can indicate pollution (Collins and Weber 1978 in Biggs 2000). However, care is needed in interpreting AI results if AFDM concentrations are low or if communities are dominated by mucilaginous diatom (e.g. *Gomphoneis, Cymbella, Synedra*) that can have naturally high AI values.

The AI values calculated from samples collected on 1 November give no indication of heterotrophic growths within the periphyton community at sites downstream of the discharge. The only site with a high AI score was on Donald Creek upstream of the discharge and this may be because the low periphyton biomass exaggerates any inaccuracies in the chlorophyll *a* and AFDW measurements (Table 3.6).

Table 3.4: Mean periphyton cover in Donald Creek and Otauira Stream on 11 October 2016. Patches of benthic cyanobacteria occurred at some sites but at low levels not detected by the survey method.

		Donald Creek				Otauira Stream	
Thickness category	**score**	**100m us**	**25m us**	**60m ds**	**650m ds**	**70 us**	**100m ds**
Thin film (any colour)	1	85.2	57.5	70.5	87	63.2	73.2
Medium green mat	5	0	0	0	0	0	0
Medium brown mat	3	7.2	0	0.5	6	33.2	0
Medium black mat	1	0	0	0	0	0	0
Thick green/light brown mat	6	0	0	0	0	0	0
Thick black/dark brown mat	3	0	0	0	0	0	0
Short filaments	5	0	0	0	0	0	0
Long green filaments	9	0	0	0	0	0	0
Long brown filaments	6	0	0	0	6	0	0
Bryophytes		0	0	3	1	0	0
Cyanobacteria		0	0	0	0	0	0
Total algal % cover		92.4	57.5	71	99	96.4	73.2
Periphyton Enrichment Index		12.6	11.0	11.2	15.7	18.5	11.0
Periphyton Proliferation Index		0	0	0	6	0	0
Periphyton Slimyness Index		21.4	11.5	14.4	25.8	32.6	14.6
Periphyton Weighted Composite Cover		0	0	0	6	0	0

Thickness categories: Thin <0.5mm, medium 0.5-3mm, thick >2mm. Short <2cm, Long >2cm.

Table 3.5: Mean periphyton cover in Donald Creek and Otauira Stream on 1 November 2016.

		Donald Creek				Otauira Stream	
Thickness category	**score**	**100m us**	**25m us**	**60m ds**	**650m ds**	**70 us**	**100m ds**
Thin film (any colour)	1	57	92.4	62.6	57.3	95	68.2
Medium green mat	5	0	0	0	0	0	0.4
Medium brown mat	3	36.6	7.6	27.6	18.3	3.4	28.6
Medium black mat	1	3.4	0	0.2	0	0	0
Thick green/light brown mat	6	0	0	0	2	0	0
Thick black/dark brown mat	3	1.8	0	0	1	0	0
Short filaments	5	0	0	4	0	0	0
Long green filaments	9	0	0	0.4	0	0	0
Long brown filaments	6	0	0	0	8.5	0	0
Bryophytes		0	0	3.2	1.5	0	0
Cyanobacteria		5.2	0	0	1	0	0
Total algal % cover		98.8	100	94.8	87	98.4	97.2
Periphyton Enrichment Index		19.6	12.7	19.5	22.5	11.8	17.7
Periphyton Proliferation Index		1.8	0	0.4	9.2	0	0
Periphyton Slimyness Index		37.2	23.0	31.1	25.8	21.0	31.0
Periphyton Weighted Composite Cover		0.9	0	0.4	8	0	0

Thickness categories: Thin <0.5mm, medium 0.5-3mm, thick >2mm. Short <2cm, Long >2cm.

Table 3.6: Periphyton biomass and dominant species in Donald Creek and Otauira Stream, see Appendix 3 for full results of relative species composition and October replicates.

11-Oct-16

			Chlorophyll *a* (mg/m^2)			
Stream	**Site**	**n**	**median**	**mean**	**range**	**Dominant periphyton species**
Otauira Stream	70m Upstream	5	14.5	13.0	6.9 - 17.6	*Frustulia, Cymbella,*
	100m Downstream	5	4.1	7.0	1.8 - 22.7	*Frustulia, Cymbella, Melosira*
Donald Creek	100m Upstream	5	9.3	11.5	3.4 - 21.9	*Cymbella, Frustulia, Melosira*
	25m Upstream	1	1.8	1.8		*Cymbella, Frustulia, Achnanthidium*
	60m Downstream	1	7.2	7.2		*Cymbella, Melosira, Frustulia*
	650m Downstream	5	3.7	4.4	1.6 - 8.5	*Batrachospermum, Cymbella, Frustulia*

1-Nov-16

Stream	**Site**	**Chlorophyll *a* (mg/m^2)**	**AFDM (g/m^2)**	**Autotrophic Index**	**Dominant periphyton species**
Otauira Stream	70m Upstream	7.5	4.6	610	*Nitzschia, Naviculoid diatoms, Cymbella, Melosira*
	100m Downstream	48.3	11.8	244	*Naviculoid diatoms, Cymbella*
Donald Creek	100m Upstream	47.9	14.0	292	*Naviculoid diatoms, Cymbella, Frustulia*
	25m Upstream	41.1	6.7	163	*Naviculoid diatoms, Frustulia*
	60m Downstream	119.4	10.0	84	*Naviculoid diatoms, Frustulia*
	650m Downstream	98.2	16.3	166	*Naviculoid diatoms, Frustulia*

Autotrophic Index = AFDM in mg/m^2 : chlorophyll a in mg/m^2

Figure 3.1: Tuffs of the red algae *Batrachospermum* sp. on the stream bed at the site Donald Creek 650m ds.

3.3 Benthic macroinvertebrates

3.3.1 Donald Creek

The aquatic macroinvertebrate community in Donald Creek during October showed taxa richness at the combined downstream sites but a small decline in the percentage of EPT taxa and small decline in the MCI (about 8%). There was no significant difference in the QMCI scores between the combined upstream and downstream sites. The highest MCI and QMCI scores were at the site 25m upstream of the discharge and the lowest 650m downstream, in contrast the lowest QMCI score was at the 100m upstream site. The abundance of EPT taxa and the % abundance of EPT taxa was reasonably low at all of the sites (Figure 3.2, Table 3.7, Table 3.8 and Table 3.9).

The November survey showed a similar pattern, with slightly lower MCI scores at the two downstream sites (up to 7% lower), and no consistent upstream to downstream difference in QMCI scores. However the 60m downstream site had considerably lower QMCI scores than all other sites; this site had considerably fewer *Paracalliope* amphipods, fewer *Potamopyrgus* snails, and fewer EPT taxa but similar abundance of pollution sensitive EPT taxa (e.g. mayflys) as had the upstream sites (Figure 3.2, Table 3.7 and 3.10). The difference in species composition at the 60m downstream site may be partially related to differences in the quantity of habitat sampled (e.g. in October, replicate B had considerably higher abundance of these taxa, Appendix 3).

On both sampling occasions the abundance of mayfly (*Deleatidium* sp.) was low at the 650m downstream site (Table 3.9 and 3.10). This may relate to the smaller substrate size, higher amount of fine sediment and cattle disturbance observed at this site.

3.3.2 Otauira Stream

The macroinvertebrate survey of Otauira Stream during October 2016 found that the downstream site had higher total abundance, higher % EPT abundance and higher QMCI scores, but lower MCI scores and % EPT taxa. *Astrosimulium* (sandfly larvae) and *Orthocladiinae* were very abundant at both sites, but the downstream site was characterised by considerably more *Deleatidium* mayfly and *Potamopyrgus* snails, while the upstream site had more *Oligochaeta* worms (Figure 3.2, Table 3.7, Table 3.8).

The November survey found that the MCI score was still a little lower downstream (7% lower) but all other indices were very similar between the two sites. *Astrosimulium* (sandfly larvae) and *Orthocladiinae* remained numerically dominant at both sites, but the total abundance per square metre had increased.

Also the abundance of *Deleatidium* mayfly (and to a lesser extent *Potamopyrgus* snails) had increased at the upstream site (Figure 3.2, Table 3.7 and 3.10).

Mayfly and snails graze periphyton and the increased abundance of these taxa at the upstream site is likely to explain the reduction in periphyton cover and abundance at the upstream site between October and November surveys (Table 3.7).

3.3.3 Kākahi and fingernail clams

The sample sites on Donald Creek and Otauira Stream were searched for freshwater mussel (kākahi)[4] and the fingernail clam (*Sphaerium* sp., Sphaeriidae). These species tend to live in sandy or silt areas in streams seeps and lakes. Young kākahi are sometimes found on or amongst macrophytes and many *Sphaerium* sp can climb onto macrophytes to live. Both species are filter feeders and both are sensitive to ammonia concentrations in the water. Kakahi can live for over 30 years, while the fingernail clam (*Sphaerium* sp.) typically lives for 1 to 3 years and can be mature by 3 months.

No kākahi were found at any of the sites. However, the fingernail clam was found at all the Donald Creek sites and in Otauira Stream downstream of the confluence during October. On both sample dates it was most abundant at the 650m downstream site. They were associated with sandy substrate and their distribution within sites was patchy (see Appendix 3).

The downstream sites had lower abundance of *Sphaerium* sp*.* during the November survey compared to October. It is possible that this related to higher total ammonia during November (see below), but it probably reflects the patchy distribution of fingernail clam (preferring coarse sandy substrate) and the smaller area of streambed sampled during the November survey.

[4] Two species of kākahi are found near Lake Wairarapa, *Echyridella menziesii* and *E. aucklandica.*

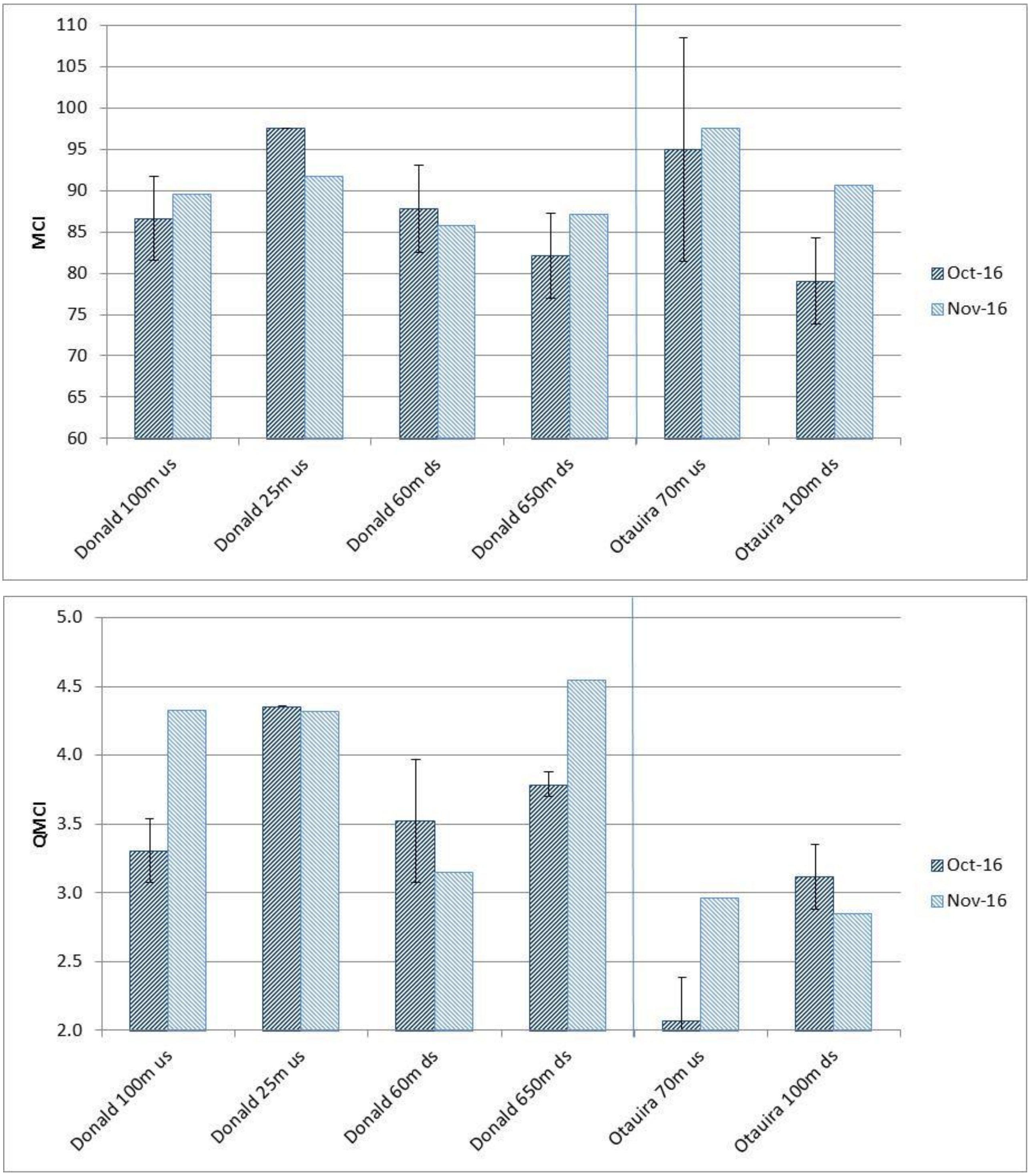

Figure 3.2: Median MCI and QMCI scores for Donald Creek and Otauira Stream during the surveys in October and November 2016. The error bars show one standard deviation of replicate samples.

Table 3.7: Summary macroinvertebrate and algae metrics for sampling on 11 October 2016 (median) and 1 November 2016.

11-Oct-16

Variable	Donald 100m us	Donald 25m us	Donald 60m ds	Donald 650m ds	Otauira 70m us	Otauira 100m ds
Chlorophyll-*a*	9.3	1.8	7.2	3.7	14.5	4.1
AFDM						
PSI	20	12.6	15.2	26	30.4	14.8
Number of taxa	18	25	23	22	18	22
Number of EPT taxa	4	8	5	7	5	4
% EPT taxa	22%	32%	22%	29%	31%	19%
% EPT abundance	5%	4%	4%	2%	1%	12%
MCI score	87	98	88	82	95	79
QMCI score	3.3	4.4	3.5	3.8	2.1	3.1

1-Nov-16

Variable	Donald 100m us	Donald 25m us	Donald 60m ds	Donald 650m ds	Otauira 70m us	Otauira 100m ds
Chlorophyll-*a*	48	41	119	98	7.5	48
AFDM	14.0	6.7	10.0	16.3	4.6	11.8
PSI	37	23	31	26	21	31
Number of taxa	25	29	17	25	25	28
Number of EPT taxa	7	9	4	8	9	10
% EPT taxa	28%	31%	24%	32%	36%	36%
% EPT abundance	1%	2%	6%	1%	6%	6%
MCI score	90	92	86	87	98	91
QMCI score	4.3	4.3	3.2	4.5	3.0	2.9

EPT exclude *Oxyethira* and *Paroxythira.*

Table 3.8: Results of statistical analysis (equivalence test) between upstream and downstream sites on Donald Creek and Otauira Creek, 11 October 2016.

Donald Creek	Direction	*p* -value	Evidence strength
Chlorophyll-*a*		ns	Weak, inconclusive
PSI		ns	Weak, inconclusive
Number of taxa	ds>us	0.02	Moderate but close to the limits
Number of EPT taxa		ns	Weak, inconclusive
% EPT taxa		ns	Weak, inconclusive
% EPT abundance	ds<us	0.04	Moderate but close to the limits
MCI score	ds<us	0.008	Moderate but a trivial difference
QMCI score		ns	No evidence of difference

Otauira Stream	Direction	*p* -value	Evidence strength
Chlorophyll-*a*		ns	Weak, inconclusive
PSI	ds<us	0.002	Strong - confident in difference
Number of taxa	ds>us	0.002	Strong - confident in difference
Number of EPT taxa		ns	Weak, inconclusive
% EPT taxa	ds<us	0.03	Moderate but close to the limits
% EPT abundance	ds>us	0.004	Strong - confident in difference
MCI score	ds<us	0.03	Moderate but close to the limits
QMCI score	ds>us	<0.001	Strong - confident in difference

Table 3.9: Macroinvertebrates per m^2 in the Otauira Creek and Donald Creek, 11 October 2016. Average of replicates (see Appendix for full results).

Taxon	MCI score	Otauira Creek Upstream	Otauira Creek Downstream	Donald Creek 100m Upstream	Donald Creek 25m Upstream	Donald Creek 60m Downstream	Donald Creek 650m Downstream
Sample area (m2)		1	1	1	0.6	1.3	1.5
ACARINA	5	2	6	4	5	6	1.3
CNIDARIA							
Hydra species	3		1			43	2
COLEOPTERA							
Dytiscidae	5	1		1			
Elmidae	6		6	10	20	6.4	
Hydraenidae	8			1			
Scirtidae	8	2					
Staphylinidae	5	41					
COLLEMBOLA	6	3	3	16	5	4.6	0.7
CRUSTACEA							
Cladocera	5					247.2	2.7
Copepoda	5		1			61	
Ostracoda	3		14	14		60.4	587.3
Paracalliope fluviatilis	5	2	61	252	1086.7	662.2	2337.3
Talitridae	5		1	1	8.3	2.8	10.7
DIPTERA							
Aphrophila species	5		2			1.8	
Austrosimulium species	3	626	689	1367	198.3	478.4	349.3
Chironomus species	1		5			2	1.3
Corynoneura scutellata	2		3			5.6	1.3
Empididae	3		2				0.7
Ephydridae	4						1.3
Eriopterini	9	1					
Hexatomini	5			1			
Limonia species	6	1					
Maoridiamesa species	3	73	19	6		1.8	0.7
Molophilus species	5	1					
Orthocladiinae	2	1166	675	124	6.7	77.2	118.0
Paralimnophila skusei	6					0.4	
Polypedilum species	3	21	3				
Psychodidae	1	1	3			1	
Stratiomyidae	5			1	1.7	0.8	2.7
Tanypodinae	5	6	18				0.7
Tanytarsini	3	32	31	4		2	2
Zelandotipula species	6			1			
EPHEMEROPTERA							
Acanthophlebia species	7			1			
Austroclima species	9	1		4	11.7	8	1.3
Coloburiscus humeralis	9	6					
Deleatidium species	8	24	220	40	20	20.6	6.7
Neozephlebia scita	7	3					
Zephlebia species	7	2			1.7		
HEMIPTERA							
Microvelia macgregori	5		1	5	1.7	2.4	1.3
Sigara species	5			1	1.7	3.4	0.7
HIRUDINEA	3					1.8	0.7
MEGALOPTERA							
Archichauliodes diversus	7		3		1.7	1	
MOLLUSCA							
Ferrissia species	3			1		4	2
Gyraulus species	3			2			
Physa / Physella species	3		2	11	5	34.6	79.3
Potamopyrgus antipodarum	4	2	319	600	1313.3	2015.6	2082.7
Sphaeriidae	3		15	2	1.7	74.2	417.3
NEMATODA	3		6			23	8
NEMERTEA	3						5.3
ODONATA							
Xanthocnemis zealandica	5		2	1			
OLIGOCHAETA	1	900	317	165	40	1407.4	808
PLATYHELMINTHES	3	1	7	15	38.3	54.4	58
PLECOPTERA							
Spaniocerca species	8	1					
Zelandobius species	5				1.7		0.7
TRICHOPTERA							
Aoteapsyche species	4	1					
Hudsonema amabile	6				5	3.8	8
Hydrobiosella species	9	1					
Hydrobiosidae early instar	5	3					
Hydrobiosis clavigera group	5					2	0.7
Hydrobiosis species	5	1				2	
Hydrobiosis umbripennis group	5	8	16	38	18.3	33.8	29.3
Neurochorema species	6		2				
Oecetis species	6		1				
Olinga species	9	1	1				
Oxyethira albiceps	2	29	73	13	8.3	4.2	36.7
Paroxyethira species	2	2					
Plectrocnemia maclachlani	8	3					
Psilochorema species	8	1		3		1	2
Pycnocentria species	7		8		10	6.4	29.3
Pycnocentrodes species	5	5	20	43	43.3	143.4	43.3
Triplectides species	5		2			1.2	2
Zelolessica species	10	1	1				
Number of invertebrates		2975	2559	2748	2855	5513	7043
Number of taxa		37	38	32	25	41	39
Number of EPT taxa		16	9	6	8	10	10
% EPT taxa		43%	24%	19%	32%	24%	26%
% EPT abundance		2%	11%	5%	4%	4%	2%
MCI score		109	87	93	98	87	84
QMCI score		2.1	3.1	3.4	4.4	3.3	3.8

Table 3.10: Macroinvertebrates per m^2 in the Otauira Creek and Donald Creek, 1 November 2016.

TAXON	MCI score	Otauira Creek Upstream	Otauira Creek Downstream	Donald Creek 100m Upstream	Donald Creek 25m Upstream	Donald Creek 60m Downstream	Donald Creek 650m Downstream
Sample area (m2)		0.5	0.5	0.5	0.5	0.5	0.5
ACARINA	5			2			
COLEOPTERA							
Elmidae	6		8	10	46	26	6
Hydraenidae	8	4					
Scirtidae	8	2					
Staphylinidae	5	2					
COLLEMBOLA	6					8	
CRUSTACEA							
Cladocera	5			3092	2		12318
Copepoda	5			2840			1760
Ostracoda	3		4	186	12		84
Paracalliope fluviatilis	5		18	2280	3942	204	2260
Talitridae	5		4		16		
DIPTERA							
Aphrophila species	5		10				
Austrosimulium species	3	3060	1074	676	522	1140	128
Chironomus species	1	16	18	130	4		92
Corynoneura scutellata	2	32	2	4			
Empididae	3			2			
Maoridiamesa species	3	96	318	8	2	40	2
Muscidae	3		2				
Orthocladiinae	2	1474	1614	668	264	586	478
Polypedilum species	3	56	26		8	28	
Psychodidae	1		2				
Tanypodinae	5	62	6		2		
Tanytarsini	3	244	82		8		
EPHEMEROPTERA							
Austroclima species	9		2	12	8	6	6
Coloburiscus humeralis	9	4	2				
Deleatidium species	8	252	172	36	102	32	6
Zephlebia species	7		2	2	2		
HEMIPTERA							
Microvelia macgregori	5					4	
Sigara species	5						4
MEGALOPTERA							
Archichauliodes diversus	7			2	2		
MOLLUSCA							
Physa / Physella species	3			2	38	6	28
Potamopyrgus antipodarum	4	66	226	1800	4308	212	3212
Sphaeriidae	3			4	4		22
ODONATA							
Xanthocnemis zealandica	5				2		2
OLIGOCHAETA	1	128	14	500	36	26	728
PLATYHELMINTHES	3	40			14	4	20
PLECOPTERA							
Acroperla species	5						2
Spaniocercoides species	8	2					
Zelandobius species	5		4		4		
Zelandoperla species	10		2				
TRICHOPTERA							
Hudsonema amabile	6						2
Hydrobiosella species	9				2		
Hydrobiosis clavigera group	5		2		2		
Hydrobiosis umbripennis group	5	30	38	98	38	76	94
Olinga species	9	8					
Oxyethira albiceps	2	128	224	158	160	130	450
Paroxyethira species	2	20					
Plectrocnemia maclachlani	8	14					
Psilochorema species	8	4		2	4		
Pycnocentria species	7	4	2	2			2
Pycnocentrodes species	5	2	4	22	72	44	2
Triplectides species	5						2
Number of invertebrates		5750	3882	12538	9626	2572	21710
Number of taxa		25	28	25	29	17	25
Number of EPT taxa		9	10	7	9	4	8
% EPT taxa		36%	36%	28%	31%	24%	32%
% EPT abundance		6%	6%	1%	2%	6%	1%
MCI score		98	91	90	92	86	87
QMCI score		3.0	2.9	4.3	4.3	3.2	4.5

3.4 Fish

The fish community in Otauira Stream and Donald Creek was dominated by longfin eel and common bully. A greater diversity of fish was caught in Otauira Stream – longfin, shortfin, common bully, inanga and a small rainbow trout (Table 3.11); this may reflect its closer proximity to Lake Wairarapa. Most of the eel caught in the fyke nets were large, in Otauira Stream seven of the longfin eel were over 1m long, and in Donald Creek four of the longfin eel caught were greater than one metre. The average longfin eel size in both streams (excluding elva) was 84cm, and the largest eel caught was 145cm long (Figure 3.3).

Two medium sized rainbow trout were observed in Donald Creek at the site 650m downstream during the 1 November site visit.

The placement of nets in relation to the WWTP discharge or the Donald Creek confluence didn't appear to make any difference in the number of fish caught.

The wastewater treatment plant operators have recorded a large number of eel living in the wastewater treatment ponds. On one occasion 80 eel were counted in the ponds when an incident resulting in low dissolved oxygen in the ponds, forcing the eel towards the water surface.

Longfin eel and inanga have a threat classification of 'At-Risk – Declining', and their presence in the streams is encouraging (Goodman et al. 2014). The abundance of longfin eel probably reflects the habitat. Large longfin eels prefer deep, slow flowing water. In larger rivers they move from deep water during the day into shallower water at night. More importantly their abundance is related to the presence of in-stream cover (e.g. woody debris), bank cover and low fishing pressure (Garnooth and Brooker 2009).

Table 3.11: Fish caught in Otauira Stream and Donald Creek in October 2016. Each had one night of trapping with six fine-mesh fyke nets and six gee-minnow traps.

Otauira Stream

Species		**0+**	**Small**	**Medium**	**Large**	**Total**
Longfin eel	*Anguilla dieffenbachii*	15	2	1	14	**32**
Shortfin eel	*Anguilla australis*				1	**1**
Common bully	*Gobiomorphus cotidianus*	58	23	16	3	**100**
Inanga	*Galaxias maculatus*			1	2	**3**
Rainbow trout	*Oncorhynchus mykiss*		1			**1**

Donald Creek

Species		**0+**	**Small**	**Medium**	**Large**	**Total**
Longfin eel	*Anguilla dieffenbachii*	1	2		11	**14**
Shortfin eel	*Anguilla australis*					**0**
Common bully	*Gobiomorphus cotidianus*		6	2		**8**

eel sizes: 0+ <10cm, small 10-30cm, Medium 30-50cm, Large >50cm

common bully sizes: 0+ <2cm, small 2-6cm, Medium 6-15cm, Large >15cm

inanga: 0+ <4, small 4-6cm, medium 6-8cm, large >8 cm

Figure 3.3: Two longfin eel in a fyke net set in Donald Creek, October 2016.

3.5 Water Quality

3.5.1 Water quality

Dissolved oxygen (DO) fluctuates diurnally; it is typically high during the day due to photosynthesis by plants and algae, and is low at night due to respiration. The minimum daily DO is particularly important for aquatic life. The dissolved oxygen (DO) concentration in the discharge soon after day break on 11 October was 4.3 mg/L (40% saturation). In Donald Creek, five metres downstream on the true right bank (i.e. only partial mixing) the DO was 8.8 mg/L (81% saturation), and upstream of the discharge it was 9.3 mg/L (88%).

Franklin (2014) developed DO criteria for protecting New Zealand fish communities. Imperative targets protect adults and the majority of fish species. The guideline criterion protects salmonids and early life stages of all species, this requires the instantaneous minimum DO of >5 mg/L and the 7-day mean minimum DO of >6 mg/L. The NPS-FW used an instantaneous minimum DO of >4mg/L as a national bottom-line (Davies Colley et al. 2013). All instream DO measurements were well about these guideline values (Table 3.12).

Water quality samples collected on 12 October 2016 found that upstream of the discharge Donald Creek had high concentrations of soluble inorganic nitrogen (SIN) and reasonably low concentrations of soluble phosphorus (DRP). The discharge elevated the SIN by a relatively small amount (20%), but this was mostly in the form of total ammoniacal nitrogen (ammonium). The ammonium was within guideline values on this occasion. DRP was considerably elevated by the discharge (Table 3.13).

At the time of sampling, upstream of the discharge in Donald Creek, periphyton growth was likely to be limited by DRP but not SIN, while downstream of the discharge nutrient availability was unlikely to place any limit on periphyton growth. In Otauira Stream, both DRP and SIN were likely to be limiting periphyton growth upstream of the confluence, while downstream the DIN was in excess of periphyton growth requirements and the DRP was likely to exert only a little control on periphyton growth.[5]

[5] Rier and Steven (2006) found nutrient saturation at dissolved inorganic N (DIN) and DRP concentrations of 0.31 mg/L and 0.038 mg/L respectively; while peak growth rates occurred at DIN and DRP concentrations of 0.086 mg/L and 0.016 mg/L respectively. This is consistent with other studies that have found little growth limitation at DRP concentrations above 0.02 to 0.08 mg/L (Hill and Fanta 2008, Bothwell 1989). Kilroy et al. (2012) found that

On 1 November 2016 water quality samples were collected from Donald Creek as part of regular monitoring by South Wairarapa District Council (sites referred to as 'Longwood'). The concentration of total ammonia and DRP at the downstream sites were higher compared to previous months. The DRP concentration (0.123 mg/L) was sufficiently high to not exert any control on periphyton growth. The total ammonia concentration (0.51 mg/L) was borderline for protection of sensitive species like the fingernail clam (No Observed Effect Concentration (NOEC) of 0.54 mg/L, Hickey 2014), but was within ANZECC guidelines for protection for 95% species protection (i.e. 0.9 mg/L), and within the bottom-line set in the NPS-FM (i.e. annual median of 1.3 mg/L and annual maximum of 2.2 mg/L)[6].

Table 3.12: Field measurements from Donald Creek and Otauira Stream on 10-12 October 2016. Temp =Temperature, EC = specific electrical conductivity, DO = dissolved oxygen.

Date	time	site	Temp. (oC)	spec EC (uS/cm)	DO (mg/L)	DO %
10/10/2016	9:40	Donald 100m us	10.8	136.9	11	100
10/10/2016	12:10	Donald 25m us	13.9	135.8	10.6	103
10/10/2016	13:10	discharge	14.7	187.3	6.8	67
10/10/2016	14:30	Donald 60m ds	15.1	139.5	10	100
10/10/2016	16:05	Donald 650m ds	16.5	143.5	8.8	90
11/10/2016	12:15	Otauira 70m us	11.6	101	11.5	106
11/10/2016	14:10	Otauira 100m ds	12.9	125	10	97

Table 3.13: Water quality of Donald Creek and Otauira Stream on 12 October 2016

Variable	Guideline	Donald 25m us	Donald 60m ds	Otauira us	Otauira ds
pH	6.5 - 9.0	7.4	7.3	7.3	7.2
TSS (mg/L)		< 3	4	< 3	3
TN (mg/L)		1.3	1.8	0.16	1.29
NH4-N (mg/L)	0.27 / 0.46	< 0.010	0.195	0.01	0.048
NNN (mg/L)		1.1	1.12	0.069	0.97
SIN (mg/L)	0.1	1.105	1.315	0.079	1.018
DRP (mg/L)	0.011	0.007	0.055	0.005	0.028
TP (mg/L)		0.01	0.081	0.008	0.041
dissolved BOD5 (mg/L)	2	< 2	< 2	< 2	< 2
E. coli bacteria (cfu/100mL)	260 / 550	579	461	435	649

TSS = total suspended solids, NH_4-N = total ammoniacal nitrogen, NNN = nitrate nitrite nitrogen, TN = total nitrogen, DRP = dissolved reactive phosphorus, TP = total phosphorus, $cBOD_5$ = carbonacious biological oxygen demand.

periphyton biomass in rivers from the Manawatu region did not exceed guideline values if mean soluble inorganic nitrogen was < 0.1 mg/L.

[6] Guideline values assume pH 8 and 20^{o}C.

Table 3.14: Water quality of Donald Creek 1 November 2016. These sites were sampled by South Wairarapa District Council.

Variable	Donald 25m us (L2)	Donald 100m ds (L3)	Donald 360m ds (L4)	Donald 500m ds (L6)	Trib to Donald at 430m ds (L5)
temperature	11.7	13.2	13		13.3
EC (uS/cm)	139	170	146	151	152
pH	8.07	7.82	8.14	7.99	8.1
TSS (mg/L)	<5	15	<5	<3	4
Turbidity (NTU)	1.04	10.1			
TN (mg/L)	1.15	1.93	1.79	2.19	2.21
NH4-N (mg/L)	<0.01	0.51			
NNN (mg/L)	1.04	1			
SIN (mg/L)	1.04	1.51			
DRP (mg/L)	0.011	0.123			
TP (mg/L)	0.013	0.174	0.145	0.119	0.127
total BOD5 (mg/L)	<3	15			
E. coli bacteria (cfu/100mL)	460	300	220	280	350

3.5.2 Foam and colour

Small amount of foam were observed in Donald Creek at sites both upstream and downstream of the WWTP discharge, and a small amount of foam was observed in Otauira Stream downstream of the Donald Creek confluence on 11 October (Figure 3.4). Foam was not obvious in the WWTP discharge drain at the time of the survey and it is likely the foam observed was due to the decomposition of aquatic macrophytes (e.g. *Apium sp.*) releasing organic material that foams in the turbulent water.

There was no conspicuous difference in either water clarity or colour between upstream and downstream of the discharge on either sampling occasion. It was difficult to tell the difference between water samples in a clear bottle (see Appendix 1).

Figure 3.4: Foam observed in Donald Creek upstream of the WWTP discharge (top) and in Abbot Creek downstream of the Donald Creek confluence (bottom), 11 October 2016.

3.6 Mixing zone

The mixing zone was assessed by measuring specific electrical conductivity (EC) across the stream width at distances progressively further downstream of the discharge. The discharge enters from the true right bank and was fully mixed across Donald Creek by 45m downstream – downstream of a willow log lying across the stream. Considerable dilution had occurred even within 12m of the discharge; after full mixing the dilution factor was about 11.4, while after only 12m the dilution factor on the true right bank was already 9.5 times (Figure 3.5). The dilution factor at the time of the survey was similar to the annual average of 12 times.

At the time of the survey on 10 October, Donald Creek was flowing at 356 L/s and the discharge was flowing at 34.1 L/s. The EC of the discharge was 187.3 µS/cm. The EC of the Donald Creek immediately upstream was about 135 µS/cm.

The mixing zone is likely to be different during summer when there is considerably less flow in Donald Creek (e.g. the median flow in March is 80 L/s).

The ca. 50m required to obtain full mixing is considered reasonable for this stream because the effluent plume along the true right bank did not interfere with the confluence of any tributary, the habitat value on the true right bank were similar to those on the true left, and the site is difficult for the public to access so the zone of non-compliance is not interfering with recreation or aesthetic values.

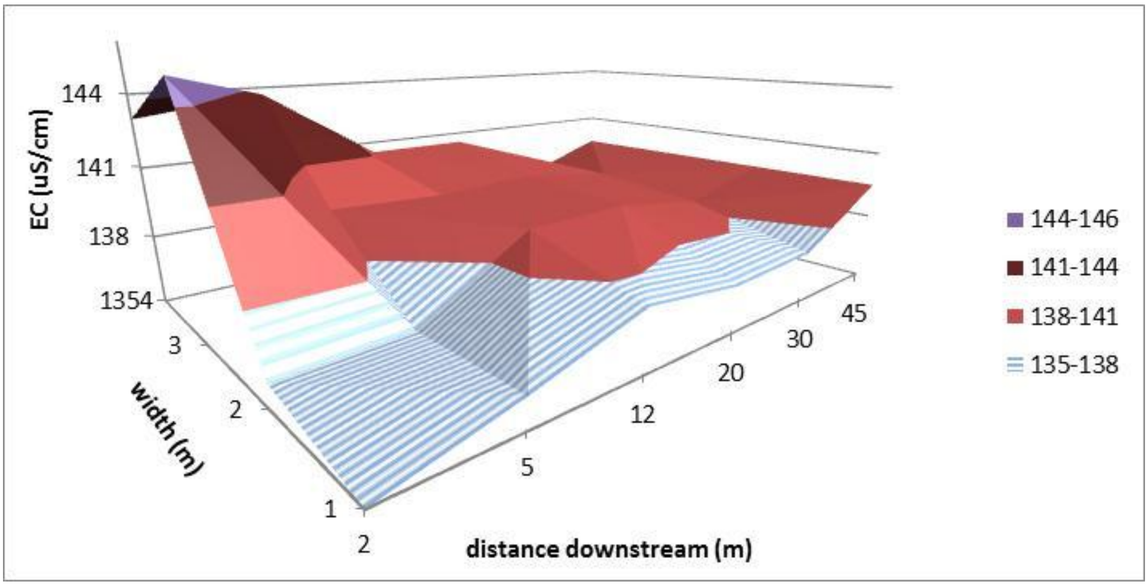

Figure 3.5: Specific electrical conductivity at 1m intervals across the stream and from 2m to 45m downstream of the discharge.

4 Discussion

4.1 Summary of the spring survey

4.1.1 Donald Creek

Donald Creek had macroinvertebrate communities indicative of 'fair' water quality and 'probably moderate pollution' (based on MCI scores). Good riparian cover and diversity of hydraulic regimes supported populations of large longfin eel and common bully. Sampling during spring found that sites downstream of the discharge had more periphyton and lower MCI scores, but the magnitude of these effects were relatively small; periphyton biomass was within guideline values and the change in MCI score was <7%. In addition to the discharge, the lower MCI scores at the 650m downstream site would also be partially caused by a smaller substrate size, localised sediment input and direct disturbance by cattle in the stream.

4.1.2 Otauira Stream

Otauira Stream upstream of the confluence with Donald Creek had macroinvertebrate communities indicative of 'fair' water quality and 'probably moderate pollution' based on MCI scores; but QMCI scores indicated poorer conditions. MCI scores were lower downstream of the confluence but other indices had an inconsistent pattern, and in October the QMCI was significantly higher at the downstream site. The fish community was dominated by longfin eel and common bully.

There was an interesting pattern of periphyton cover and biomass being higher upstream of the confluence in October when the abundance of invertebrate grazers (e.g. snails and mayfly) was low, but in November higher densities of invertebrate grazers (>300/m^2) corresponded to very low periphyton cover and biomass.

4.2 Comparison with summer surveys

Previous surveys of Donald Creek have been conducted during summer low flow conditions and have found the discharge having considerably more impact on the stream than what was found during our spring surveys (October and November 2016). Previous surveys undertaken in late summer of 2010 and 2013 found that the discharge caused a significant reduction of all macroinvertebrate metrics. Periphyton cover was also elevated at the downstream sites but not as much as expected – possibly due to shading and the deposition of planktonic algae from the oxidation ponds as a scum on substrate[7]. During these summer surveys the effluent caused a noticeable plume and a small amount of heterotrophic growth (5% cover) was present on the streambed (Coffey 2010, 2013).

The spring surveys found the effect of the discharge to be relatively mild compared to those observed during late summer. There was some increase in periphyton cover and biomass but these were within guideline values to maintain aesthetic values and 'trout habitat and angling' (Biggs 2000). The macroinvertebrate community had slightly lower MCI scores at the two downstream sites (up to 7% lower), and no consistent upstream to downstream difference in QMCI scores (Figure 4.1).

In contrast to late summer, spring surveys found no conspicuous change in water colour or clarity from the discharge, and there were no visible heterotrophic growths present in the stream.

This stark seasonal difference in the effect of the discharge is likely to reflect seasonal differences in stream flow, effluent quality and water temperature. The flow in Donald Creek is highly seasonal with a distinct low flow period from about December to April (inclusive) (Figure 4.2). The flow in Donald Creek at the time of the summer survey on 13 April 2010 and 4 March 2013 was 98 L/s and 50 L/s respectively – providing considerably less dilution than during winter and spring. The higher flow also causes movement of sand on the stream bed which will contribute to scouring of periphyton. Some aspects of effluent quality are also worse during summer, with algae proliferation within the ponds affecting the colour and turbidity of the discharge as found by Forbes (2013). Seasonal algae proliferation within the ponds will also cause more extreme dissolved oxygen fluctuations within the effluent. Furthermore, warmer water during summer months can accentuate stress on stream biota, particularly with relation to impacts from ammonia or low dissolved oxygen (Davies-Colley et al. 2013).

When considering options to reduce the effects of the discharge on Donald Creek, the priority should be to reduce discharges during summer and periods of low flow.

[7] Some willows were killed in 2013 which appeared to reduce the effect of shading by 2016. Unlike the previous surveys, the 2016 survey found some emergent macrophyte cover at all sites, indicating less difference between sites due to shading.

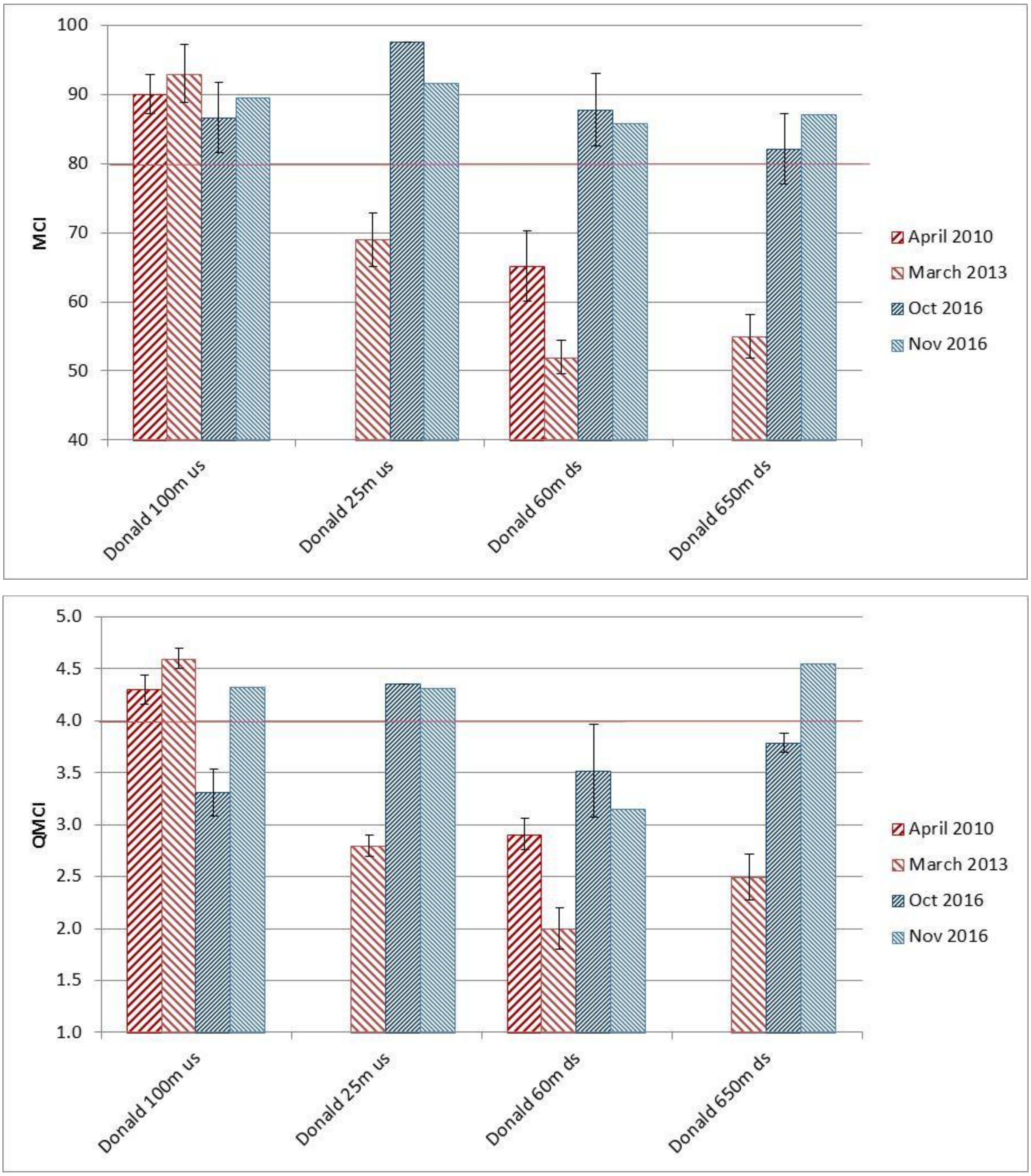

Figure 4.1: Median MCI and QMCI scores for Donald Creek for surveys in April 2010, March 201, October 2016 and November 2016 (Coffey 2010, 2013). The error bars show one standard deviation of replicate samples. The red horizontal line indicates scores indicative of 'poor' water quality /habitat.

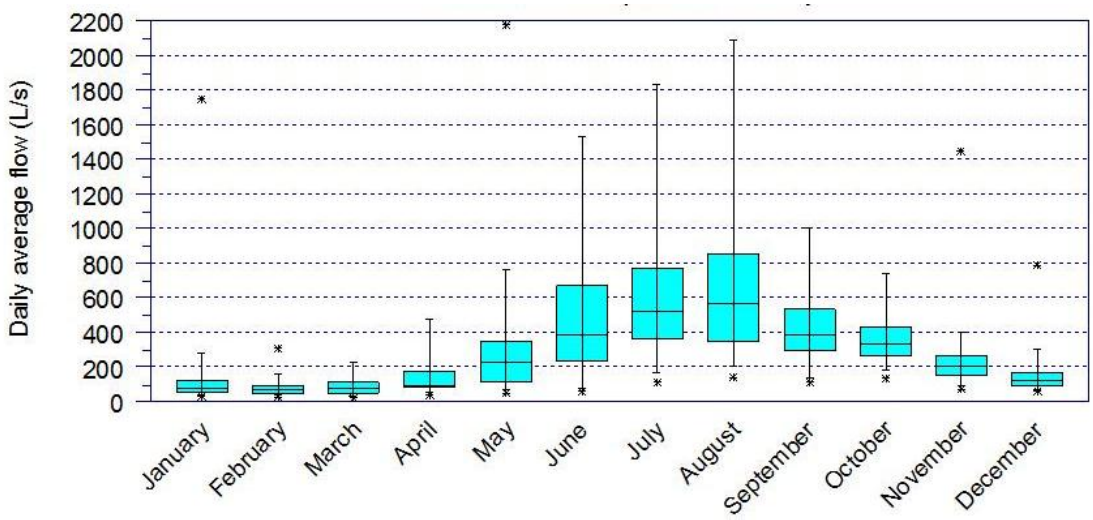

Figure 4.2: Seasonal variation in flow in Donald Creek (2005-2016). The graph shows the median, 50%ile (within the box), 95 %ile error bars and extreme values. The annual median flow is 241 L/s (Butcher 2016). The median flow for the months January to March is about 75 L/s.

5 Conclusions

Sampling during October and November 2016 found that the WWTP discharge was having only a small impact on the periphyton cover and macroinvertebrate communities in Donald Creek. This is in stark contrast to the effects reported during late summer (2010 and 2013). The difference in the effect of the discharge in spring compared to summer is likely to reflect seasonal differences in stream flow, effluent quality and water temperature.

It is recommended that upgrade and land treatment options give priority to reducing the effects of the discharge during summer and periods of low flow.

References

ANZECC 2000. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Biggs B.J.F 2000. NZ *Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams*. Prepared for the Ministry for the Environment.

Biggs B.J.F. and Kilroy, K.C. 2000. *Stream periphyton monitoring manual*. Ministry for the Environment, Wellington.

Bothwell M.L. 1989. Phosphorus-limited growth dynamics of lotic periphytic diatom communities: areal biomass and cellular growth rate response. *Canadian journal of aquatic sciences* 46(8):1293-1301.

Butcher G. 2016. *Hydrological Assessment of Donalds Creek, Featherston*. Professional Ground Water and Environmental Services report prepared for: South Wairarapa District Council, April 2016.

Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M. and Death, R.G. 2011. *Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values.* Cawthron Institute, Nelson, New Zealand.

Clapcott J 2015. *National rapid habitat assessment protocol development for streams and rivers*. Prepared for Northland Regional Council. Cawthron Report No. 2649. 29 p. plus appendices.

Coffey B. 2010. *Ecological Survey of Donald (Boar) Creek to meet Conditions 21 to 24 of Consent WAR 970080 that permit the discharge of contaminants to water from the Featherston Wastewater Treatment Plant*. Brian T. Coffey and Associates Limited: CM Featherston WWTP 970080/21-24, 04.2010. A report prepared for the Greater Wellington Regional Council on behalf of the South Wairarapa District Council.

Coffey B. 2013. *Ecological Survey of Donald Creek to meet Conditions 21 to 24 of Consent WAR 970080 that permit the discharge of contaminants to water from the Featherston Wastewater Treatment Plant*. Brian T. Coffey and Associates Limited: CM Featherston WWTP 970080/21-24, 04.2013. A report prepared for the Greater Wellington Regional Council on behalf of the South Wairarapa District Council.

Collier K. and Kelly J. 2005. *Regional guidelines for ecological assessments of freshwater environments: macroinvertebrate sampling in wadeable streams*. Environment Waikato Technical Report TR2005/02.

Collier K., Hamer M., Champion, P. 2014. *Regional guidelines for ecological assessments of freshwater environments: Aquatic plant cover in wadeable streams - version 2*. Environment Waikato Technical Report 2014/03.

Davies-Colley R., Franklin P., Wilcock B., Clearwater S., Hickey C. 2013. *National Objectives Framework - Temperature, Dissolved Oxygen & pH Proposed thresholds for discussion*. Prepared for Ministry for the Environment. NIWA Client Report No: HAM2013-056.

Franklin PA 2014. Dissolved oxygen criteria for freshwater fish in New Zealand: a revised approach. *New Zealand Journal of Marine and Freshwater Research 48* (1):112-126

Forbes A. 2013. *Martinborough, Greytown, and Featherston Treated Wastewater Discharges: Low-flow Assessment of Ecological Effects.* A report prepared for the South Wairarapa District Council by Forbes Ecology, July 2013.

Gaynooth, E., Brooker, D. 2009. *Biomass of longfin eels in medium to large rivers. Ministry of Fisheries*. New Zealand Fisheries Assessment Report 2009/44. 24 p

Goodman, J.M., Dunn, N.R., Ravenscroft, P.J., Allibone, R.M., Boubee, J.A.T., David, B.O., Griffiths, M., Ling, N., Hitchmough, R.A. and Rolfe, J.A. 2014. *Conservation status of New Zealand freshwater fish, 2013.* New Zealand Threat Classification Series 7. Department of Conservation, Wellington. 12 p.

Harding J.S., Clapcott J.E., Quinn J.M., Hayes J., Joy M., Storey R., Greig H., Hay J., James T., Beech M., Ozane R., Meredith A., Boothroyd I. 2009. *Stream habitat assessment protocols for wadeable rivers and streams of New Zealand.* University of Canterbury, NZ.ISBN 978-0-473-15151-5

Hickey C. 2014. *Derivation of indicative ammoniacal nitrogen guidelines for the National Objectives Framework.* Memo prepared for Ms Vera Power, Ministry for the Environment, by NIWA.

Hill W.R., Fanta S.E. 2008. *Phosphorus and light co-limit periphyton growth at subsaturating irradiances*. Freshwater Biology 53(2): 215-225

Joy, M., David, B. & Lake, M., 2013. *New Zealand Freshwater Fish Sampling Protocols: Part one – wadeable rivers and streams*. Massy University, Palmerston North.

Kilroy C., Wech J., Booker D., Brown L., Chakraborty M., Nicholson C., Patterson M., Markha J., Roygard J. 2012. *Periphyton in the Manawatu-Whanganui region: review of three years of monitoring*. Prepared by NIWA for Horizons Regional Council. NIWA Client Report No: CHC2012-105.

Matheson, F., Quinn J., Hickey C. 2012. *Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phases 1 and 2 final report.* Prepared for the Ministry of Science and Innovation EnviroLink Fund. August 2012. NIWA Client Report HAM2012-018.

Rier S.T., Stevenson R.J. 2006. Response of periphytic algae to gradients in nitrogen and phosphorus in streamside mesocosms. *Hydrobiologia* 561:131–147

Stark JD; Boothroyd IKG; Harding JS; Maxted JR; Scarsbrook MR 2001. *Protocols for sampling macroinvertebrates in wadeable streams*. *New Zealand Macroinvertebrate Working Group Report no. 1.* Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

Stark J. D. 1985: *A macroinvertebrate community index of water quality for stony streams*. Water and soil miscellaneous publication 87.

Stark J.D. 1998. SQMCI: A biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32*: 55-66.

Stark J.D., Maxted J.R. 2007. A user guide for the Macroinvertebrate Community Index. Prepared for the Ministry for the Environment. Cawthron Report No.1166. 58 p.

Welch, E.B., Quinn, J.M., Hickey, W. 1992. Periphyton biomass related to point-source nutrient enrichment in seven New Zealand streams. *Water Resources 26* (5): 669-675.

Appendix 1: Site photographs

Photo A1: Donald Creek 100m upstream (facing upstream), 11 October 2016.

Photo A2: Donald Creek 25m upstream (facing upstream), 11 October 2016.

Photo A3: Donald Creek 60m downstream (facing upstream), 11 October 2016.

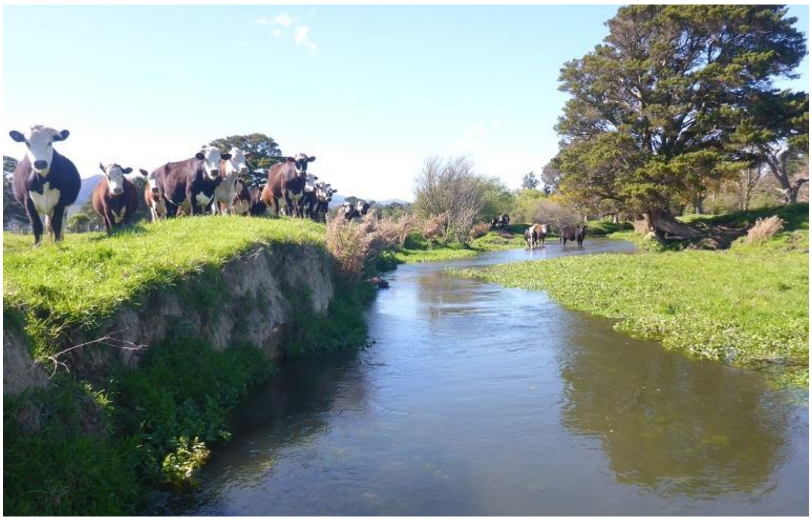

Photo A4: Donald Creek 650m downstream (facing upstream), 11 October 2016.

Photo A5: Donald Creek 650m downstream (facing upstream), 1 November 2016. Cattle pugging on stream margins.

Photo A6: Water clarity in Donald Creek on 11 October 2016, from left to right, Donald Creek upstream, Donald Creek downstream, and the effluent before mixing.

Photo A7: Substrate in Donald Creek 100m upstream, algae on large gravel (1 November 2016)

Photo A8: Small substrate in Donald Creek 650m downstream, with patches of the red algae *Batrachospermum* sp. (1 November 2016).

Photo A9: Otauira Stream at the confluence with Donald Creek (left hand side), 11 October 2016.

Appendix 5: Periphyton cover

Table A1: Periphyton cover in Donald Creek and Otauira Stream, 1 November 2016.

Donald Creek 100m us

		Transect					
Thickness category	**score**	**A**	**B**	**C**	**D**	**E**	**mean**
Thin film (any colour)	1	62	40	48	72	63	57
Medium green mat	5	0	0	0	0	0	0
Medium brown mat	3	38	52	47	28	18	36.6
Medium black mat	1	0	0	0	0	17	3.4
Thick green/light brown mat	6	0	0	0	0	0	0
Thick black/dark brown mat	3	0	4	5	0	0	1.8
Short filaments	5	0	0	0	0	0	0
Long green filaments	9	0	0	0	0	0	0
Long brown filaments	6	0	0	0	0	0	0
Submerged bryophytes		0	0	0	0	0	0
Cyanobacteria		0	4	5	0	17	5.2
Total algal % cover		100	96	100	100	98	**98.8**
No. transects with periphyton cover							**5**
Periphyton Enrichment Index		19	24	22	17	15	**19.6**
Periphyton Proliferation Index		0	4	5	0	0	**1.8**
Periphyton Slimyness Index		35	43	43	31	34	**37.2**
Peri Weighted Composite Cover		0	2	3	0	0	**0.9**

Donald Creek 25m us

		Transect					
Thickness category	**score**	**A**	**B**	**C**	**D**	**E**	**mean**
Thin film (any colour)	1	100	100	74	96	92	92.4
Medium green mat	5	0	0	0	0	0	0
Medium brown mat	3	0	0	26	4	8	7.6
Medium black mat	1	0	0	0	0	0	0
Thick green/light brown mat	6	0	0	0	0	0	0
Thick black/dark brown mat	3	0	0	0	0	0	0
Short filaments	5	0	0	0	0	0	0
Long green filaments	9	0	0	0	0	0	0
Long brown filaments	6	0	0	0	0	0	0
Submerged bryophytes		0	0	0	0	0	0
Cyanobacteria		0	0	0	0	0	0
Total algal % cover		100	100	100	100	100	**100**
No. transects with periphyton cover							**5**
Periphyton Enrichment Index		11	11	17	12	13	**12.7**
Periphyton Proliferation Index		0	0	0	0	0	**0.0**
Periphyton Slimyness Index		20	20	30	22	23	**23.0**
Peri Weighted Composite Cover		0	0	0	0	0	**0.0**

Donald Creek 60m ds

Thickness category	score	A	B	C	D	E	mean
		Transect					
Thin film (any colour)	1	84	84	40	49	56	62.6
Medium green mat	5	0	0	0	0	0	0
Medium brown mat	3	4	10	56	24	44	27.6
Medium black mat	1	0	0	0	1	0	0.2
Thick green/light brown mat	6	0	0	0	0	0	0
Thick black/dark brown mat	3	0	0	0	0	0	0
Short filaments	5	0	0	0	20	0	4
Long green filaments	9	0	0	0	2	0	0.4
Long brown filaments	6	0	0	0	0	0	0
Submerged bryophytes		0	10	6	0	0	3.2
Cyanobacteria		0	0	0	0	0	0
Total algal % cover		88	94	96	96	100	**94.8**
No. transects with periphyton cover							**5**
Periphyton Enrichment Index		12	13	24	28	21	**19.5**
Periphyton Proliferation Index		0	0	0	2	0	**0.4**
Periphyton Slimyness Index		19	23	42	34	38	**31.1**
Peri Weighted Composite Cover		0	0	0	2	0	**0.4**

Donald Creek 650m ds

Thickness category	score	A	B	C	D	E	mean
		Transect					
Thin film (any colour)	1	70	36	46	77		57.25
Medium green mat	5	0	0	0	0		0
Medium brown mat	3	12	24	16	21		18.25
Medium black mat	1	0	0	0	0		0
Thick green/light brown mat	6	0	8	0	0		2
Thick black/dark brown mat	3	0	4	0	0		1
Short filaments	5	0	0	0	0		0
Long green filaments	9	0	0	0	0		0
Long brown filaments	6	18	12	2	2		8.5
Submerged bryophytes		0	6	0	0		1.5
Cyanobacteria		0	4	0	0		1
Total algal % cover		100	84	64	100		**87**
No. transects with periphyton cover							**4**
Periphyton Enrichment Index		24	31	18	17		**22.5**
Periphyton Proliferation Index		18	24	2	2	0	**9.2**
Periphyton Slimyness Index		36	43	20	30	0	**25.8**
Peri Weighted Composite Cover		18	18	2	2	0	**8.0**

Otauira Stream 70m us

Thickness category	score	Transect A	B	C	D	E	mean
Thin film (any colour)	1	100	79	100	100	96	95
Medium green mat	5	0	0	0	0	0	0
Medium brown mat	3	0	13	0	0	4	3.4
Medium black mat	1	0	0	0	0	0	0
Thick green/light brown mat	6	0	0	0	0	0	0
Thick black/dark brown mat	3	0	0	0	0	0	0
Short filaments	5	0	0	0	0	0	0
Long green filaments	9	0	0	0	0	0	0
Long brown filaments	6	0	0	0	0	0	0
Submerged bryophytes		0	0	0	0	0	0
Cyanobacteria		0	0	0	0	0	0
Total algal % cover		100	92	100	100	100	**98.4**
No. transects with periphyton cover							**5**
Periphyton Enrichment Index		11	14	11	11	12	**11.8**
Periphyton Proliferation Index		0	0	0	0	0	**0.0**
Periphyton Slimyness Index		20	24	20	20	22	**21.0**
Peri Weighted Composite Cover		0	0	0	0	0	**0.0**

Otauira Stream 100m ds

Thickness category	score	Transect A	B	C	D	E	mean
Thin film (any colour)	1	46	57	78	74	86	68.2
Medium green mat	5	2	0	0	0	0	0.4
Medium brown mat	3	45	41	22	23	12	28.6
Medium black mat	1	0	0	0	0	0	0
Thick green/light brown mat	6	0	0	0	0	0	0
Thick black/dark brown mat	3	0	0	0	0	0	0
Short filaments	5	0	0	0	0	0	0
Long green filaments	9	0	0	0	0	0	0
Long brown filaments	6	0	0	0	0	0	0
Submerged bryophytes		0	0	0	0	0	0
Cyanobacteria		0	0	0	0	0	0
Total algal % cover		93	98	100	97	98	**97.2**
No. transects with periphyton cover							**5**
Periphyton Enrichment Index		23	20	16	16	14	**17.7**
Periphyton Proliferation Index		0	0	0	0	0	**0.0**
Periphyton Slimyness Index		37	36	29	29	24	**31.0**
Peri Weighted Composite Cover		0	0	0	0	0	**0.0**

Appendix 3: Periphyton

Table A2: Periphyton community composition. Relative abundance scoring system from 1 (rare) to 8 (absolutely dominant/monoculture) based on Biggs and Kilroy (2000).

11-Oct-16

	Otauira Stream		Donald Creek			
	70m u/s	100m d/s	100m u/s	25m u/s	60m d/s	650m d/s
Filamentous green algae						
Stigeoclonium					1	
Filamentous red algae						
Batrachospermum					1	1
Filamentous diatoms						
Achnanthes			2			
Melosira	**5**	1	2			
Diatoms						
Cymbella	**5**	3	3	2	2	2
Epithemia	2					
Frustulia	4	2	3	3	3	3
Gomphonema		1	2	2		
Naviculoid diatoms	**6**	3	3	3	3	3
Nitzschia	**7**					
Synedra	3	1	1			1

1-Nov-16

	Otauira Stream		Donald Creek			
	70m u/s	100m d/s	100m u/s	25m u/s	60m d/s	650m d/s
Filamentous red algae						
Batrachospermum						**7**
Filamentous diatoms						
Achnanthes			1			
Melosira	1	3	**5**		**5**	3
Cyanobacteria						
Oscillatoria/Phormidium						2
Diatoms						
Achnanthidium				3		
Cymbella	3	3	**7**	4	**6**	4
Frustulia	4	4	**6**	3	4	4
Gomphonema	2	2	3	2		
Naviculoid diatoms	1	3	3	2	2	
Pinnularia		1				
Synedra			2			
Phytoplankton						
Scenedesmus					1	

Table A3: Periphyton chlorophyll a in Donald Creek and Otauira Stream on 11 October 2016

Stream	Site	Sample	Chlorophyll *a* (mg/m^2)
Otauira Stream	70m Upstream	A	17.6
		B	9.3
		C	14.5
		D	6.9
		E	16.8
	100m Downstream	A	22.7
		B	4.4
		C	2.0
		D	1.8
		E	4.1
Donald Creek	100m Upstream	A	9.3
		B	6.1
		C	3.4
		D	16.6
		E	21.9
	25m Upstream		1.8
	60m Downstream		7.2
	650m Downstream	A	1.6
		B	2.9
		C	5.5
		D	3.7
		E	8.5

Appendix 3: Macroinvertebrate results

Macroinvertebrates per square metre, 11 October 2016.

		Otauira Creek										Donald Creek															
Taxon	**MCI score**	**Upstream**					**Downstream**					**100m Upstream**					**25m Upstream**	**60m Downstream**					**650m Downstream**				
Sample area (m2)		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.2	0.2	0.2	0.2	0.5	0.3	0.3	0.3	0.3	0.3
ACARINA	5				5	5	15				15	5			5	10	5	10	15		5				3.3		3.3
CNIDARIA																											
Hydra species	3							5										5	210								10
COLEOPTERA																											
Dytiscidae	5	5										5															
Elmidae	6						5	15	10			10	10	5	5	20	20	5	15		10	2					
Hydraenidae	8												5														
Scirtidae	8	5		5																							
Staphylinidae	5					205																					
COLLEMBOLA	6			5		10				10	5	5		30	20	25	5			5	10	8		3.3			
CRUSTACEA																											
Cladocera	5																	435	425	80	240	56			13.3		
Copepoda	5									5								135	145	10	15						
Ostracoda	3						5	5	5	5	50	10	35	5	15	5		30	80	15	165	12	1097	380	737	720	3.3
Paracalliope fluviatilis	5	5		5			70	40	20	90	85	280	645	130	150	55	1087	155	1050	870	370	866	2480	2840	1547	2983	1837
Talitridae	5								5						5		8				10	4	16.7	13.3		6.7	16.7
DIPTERA																											
Aphrophila species	5							5		5									5			4					
Austrosimulium species	3	1055	855	615	70	535	140	690	815	1165	635	1355	765	1765	1675	1275	198	165	325	685	725	492	170	363	110	1067	36.7
Chironomus species	1						15		5		5									5	5				6.7		
Corynoneura scutellata	2							10		5								10			10	8		3.3	3.3		
Empididae	3							5	5																3.3		
Ephydridae	4																									3.3	3.3
Eriopterini	9	5																									
Hexatomini	5											5															
Limonia species	6		5																								
Maoridiamesa species	3	25	125	135	45	35	5	15	25	30	20				10	20				5		4	3.3				
Molophilus species	5		5																								
Orthocladiinae	2	390	1120	2370	1005	945	410	930	570	590	875	90	100	90	195	145	7	50	80	105	85	66	76.7	170	80	227	36.7
Paralimnophila skusei	6																					2					
Polypedilum species	3	5	5	15	70	10				5	10																
Psychodidae	1					5			5		10							5									
Stratiomyidae	5													5			2					4		10		3.3	
Tanypodinae	5			20	5	5	35	15	10	10	20														3.3		
Tanytarsini	3		25	75	5	55	50	30	35	15	25		5		15				10					6.7	3.3		
Zelandotipula species	6														5												
EPHEMEROPTERA																											
Acanthophlebia species	7											5															
Austroclima species	9				5							10		5		5	12	10	10		10	10				6.7	
Coloburiscus humeralis	9	10	5	10	5																						
Deleatidium species	8	65		30	15	10	170	435	215	125	155	70	10	40	25	55	20	5	20	30	30	18	6.7	3.3	6.7		16.7
Neozephlebia scita	7	5			5	5																					
Zephlebia species	7				10												2										
HEMIPTERA																											
Microvelia macgregori	5							5						10	10	5	2					12		3.3		3.3	
Sigara species	5															5	2	5		5	5	2		3.3			
HIRUDINEA	3																		5			4				3.3	
MEGALOPTERA																											
Archichauliodes diversus	7						5		10								2		5								
MOLLUSCA																											
Ferrissia species	3													5					20				6.7	3.3			
Gyraulus species	3												10														
Physa / Physella species	3						5			5			15	10	15	15	5	10	80	20	55	8	113	93	93	70	26.7
Potamopyrgus antipodarum	4	5				5	150	500	60	460	425	945	1185	135	375	360	1313	525	4260	1790	1735	1768	2870	1913	1897	2497	1237
Sphaeriidae	3						25	5	5	20	20				10		2		220	10	115	26	773	660	173	377	103
NEMATODA	3						5		25									10	100	5			20	13.3	6.7		
NEMERTEA	3																						3.3	6.7	10		6.7
ODONATA																											
Xanthocnemis zealandica	5										10		5														
OLIGOCHAETA	1	560	1220	1920	435	365	195	335	245	650	160	170	175	95	240	145	40	235	5020	55	585	1142	1073	790	653	737	787
PLATYHELMINTHES	3		5					20	5		10	20	30	10	10	5	38	40	145		45	42	93.3	76.7	40	73.3	6.7
PLECOPTERA																											
Spaniocerca species	8					5																					
Zelandobius species	5																2							3.3			
TRICHOPTERA																											
Aoteapsyche species	4				5																						
Hudsonema amabile	6																5		15			4	10	10	6.7	6.7	6.7
Hydrobiosella species	9	5																									
Hydrobiosidae early instar	5	5		10																							
Hydrobiosis clavigera group	5																			10				3.3			
Hydrobiosis species	5	5																	10								
Hydrobiosis umbripennis group	5	10	20		10		25	15	15	15	10	25	50	40	40	35	18	25	5	45	40	54	33.3	50	16.7	43.3	3.3
Neurochorema species	6						5				5																
Oecetis species	6										5																
Olinga species	9	5									5																
Oxyethira albiceps	2		10	60	50	25	70	35	50	35	175		30	15	20		8	5	10			6	10	40	16.7	106.7	10
Paroxyethira species	2				5	5																					
Plectrocnemia maclachlani	8			5	10																						
Psilochorema species	8		5										5		5	5			5							6.7	3.3
Pycnocentria species	7						10	5		20	5						10		15		5	12	6.7	66.7	13.3	46.7	13.3
Pycnocentrodes species	5	10	5	5		5	40	5	40	10	5		35	40	100	40	43	90	375	25	75	152	60	50	13.3	26.7	66.7
Triplectides species	5										10											6		3.3		3.3	3.3
Zelolessica species	10	5					5																				
Number of invertebrates		2185	3410	5285	1760	2235	1460	3125	2180	3275	2755	3010	3115	2435	2950	2230	2855	1965	12680	3775	4350	4794	8923	7583	5457	9017	4237
Number of taxa		20	14	16	18	18	23	22	22	21	26	16	18	18	22	19	25	22	29	19	23	29	20	28	24	22	22
Number of EPT taxa		10	4	5	8	4	6	4	3	4	8	4	4	4	4	5	8	4	8	4	5	7	5	8	5	7	7
% EPT taxa		50%	29%	31%	44%	22%	26%	18%	14%	19%	31%	25%	22%	22%	18%	26%	32%	18%	28%	21%	22%	24%	25%	29%	21%	32%	32%
% EPT abundance		6%	1%	1%	4%	1%	17%	15%	12%	5%	7%	4%	3%	5%	6%	6%	4%	7%	4%	3%	4%	5%	1%	3%	1%	2%	3%
MCI score		115	83	95	96	81	87	78	74	79	84	96	86	87	85	94	98	80	90	79	88	90	77	82	75	87	85
QMCI score		2.6	2.0	1.9	2.1	2.5	3.4	3.4	3.1	2.9	3.1	3.5	3.7	3.3	3.2	3.3	4.4	3.9	2.9	4.0	3.5	3.4	3.7	3.8	3.7	3.8	3.9