Report

Blenheim Sewage Treatment Plant Annual Consent Compliance Report - 1 July 2017 - 30 June 2018

Prepared for Marlborough District Council (Client)

By CH2M Beca Limited

7 November 2018

Revision History

Revision Nº	Prepared By	Description	Date
A	Julia van Eeden	Draft for client review	10/10/2018
B	Julia van Eeden	Final incorporating client comments.	7/11/2018

Document Acceptance

Action	Name	Signed	Date
Prepared by	Julia van Eeden	[signature]	7/11/18
Reviewed by	Sarah Burgess	[signature]	7/11/18
Approved by	Graeme Jenner	[signature]	7/11/18
on behalf of	CH2M Beca Limited		

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Appendices

1 Introduction

1.1 Purpose of Report

The purpose of this report is to assess the compliance of the discharges from the Blenheim Sewage Treatment Plant (BSTP) with the conditions of Consent U071181, for the reporting period 1 July 2017 to 30 June 2018.

The BSTP and outfall sampling locations are shown in Consent U071181 which is included in **Appendix A.**

1.2 Background

Marlborough District Council (MDC) owns and operates the BSTP site at Hardings Road, which treats wastewater from residential and commercial premises (termed domestic flows), from within the Blenheim urban area, as well as industrial flows (mainly from wineries).

1.2.1 Treatment Upgrading History

Prior to 2002, the BSTP consisted of a number of treatment ponds which treated domestic wastewater from Blenheim and industrial flows from Canterbury Meat Packers and the Riverlands Industrial Estate. The industrial ponds were formerly owned by the PPCS Meat Processing Plant, but were purchased by MDC in 2002, after the PPCS operation closed. The former PPCS factory site was subdivided and is now known as Cloudy Bay Business Park. Various new industries, including two wineries, have moved onto this site and the number of wineries in the Riverlands Industrial Estate has also increased.

Between 2006 and 2008, MDC made a series of upgrades and changes to the treatment pond system to accommodate significant peak trade waste loads received during the wine vintage, which occurs in the period March to May each year. The changes included diverting major industrial flows from the domestic to the industrial ponds, and increasing the aeration capacity of the industrial ponds in order to treat the increased load. Small trade waste discharges in Blenheim continue to contribute about 15% of the domestic flow into the BSTP.

MDC was granted consents in late 2010 to upgrade the BSTP treated wastewater disposal system. This upgrading (completed in February 2014), included the construction of a series of wetland cells which convey the combined treated flows from both the domestic and industrial pond systems, before discharging to a new outfall in the Wairau Estuary. The 1.6km long wetland system provides some further “polishing” treatment of the combined flows. Approximately 160ha of MDC-owned land around the BSTP is also available for wastewater irrigation, on a soil moisture deficit basis, from spring to autumn.

1.2.2 Current Treatment Systems

The current BSTP consists of two separate treatment systems. A fine screen, as well as facultative and maturation ponds, are used to treat the domestic flows while the industrial stream is treated using fine screening and mechanically aerated and facultative ponds. During the vintage, wastewater from the industrial ponds is redirected through twin DAF units for solids separation and recycling to create an activated sludge process.

Prior to February 2014, treated wastewater from the domestic system was continuously discharged to the Opawa River, and treated industrial flows were discharged to the Wairau Estuary on the ebb tide. Historically, some industrial effluent from the now-closed PPCS Meat Processing Plant was also applied to land during the summer months.

On 5 February 2014, discharge of treated wastewater from the domestic system to the Opawa River was ceased. The flow from Domestic Pond 5 is now conveyed to Pond 6 and combined with industrial wastewater before being discharged to the new wetland Pond 7. The combined treated wastewater is then conveyed through a further six ponds before being discharged from Pond 14 to the Wairau Estuary via a new larger capacity outfall. The completed upgrade also provides for land application of the combined treated wastewater, when soil and groundwater conditions allow, via K-line irrigation and drip lines.

A schematic of the current treatment systems and combined estuarine discharge is shown in Figure 1-1.

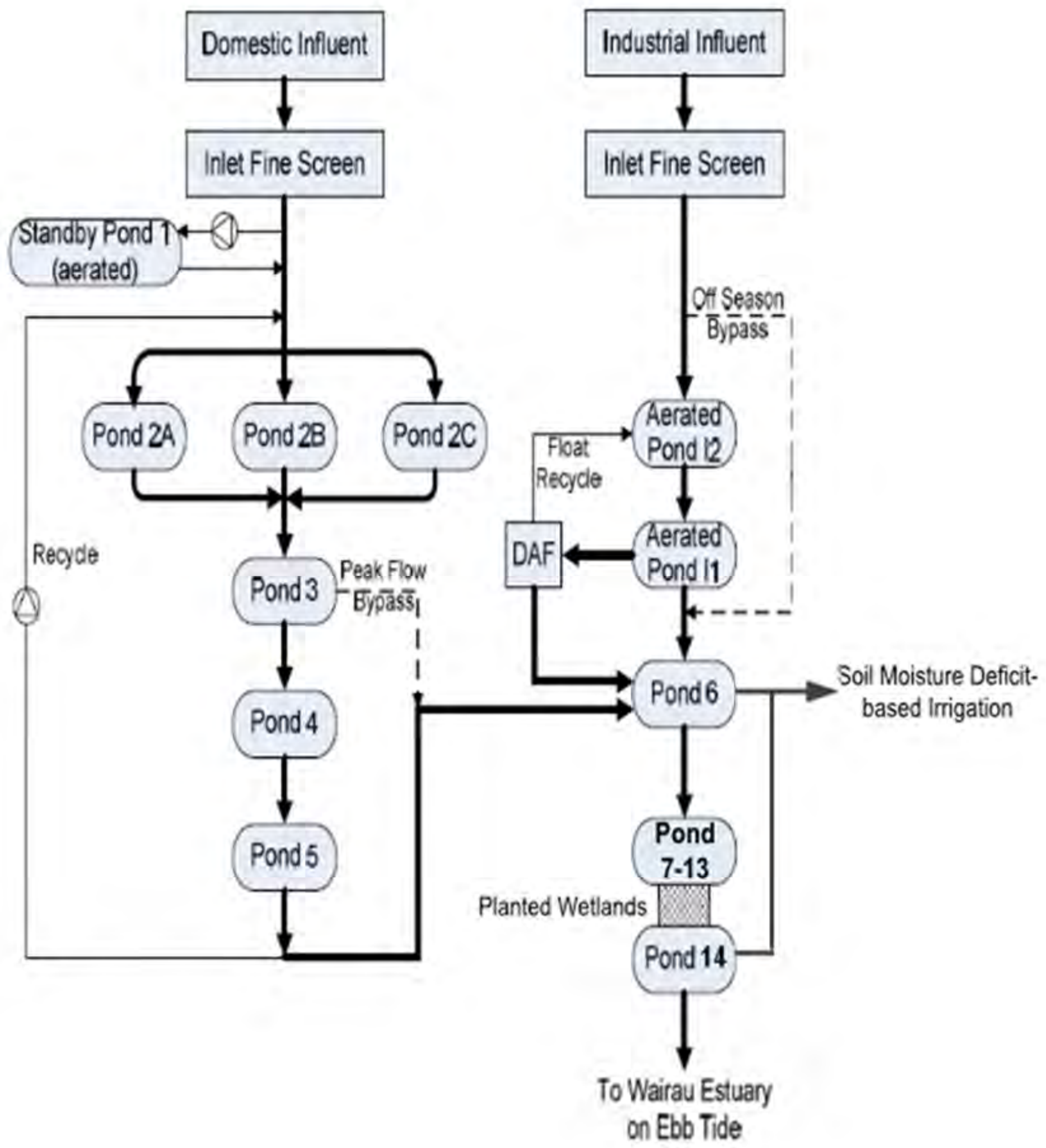


Figure 1-1 – BSTP Wastewater flow schematic (post- February 2014)

2 Compliance with Consent U071181

2.1 Consent Purpose

Consent U071181 authorises discharges from the BSTP treatment ponds to land, air and the Wairau Estuary. Consent conditions which do not have on-going monitoring requirements are not covered in this report. Only those conditions that have numerical or qualitative monitoring requirements are assessed. For clarity, consent conditions are quoted in *italics*, with other commentary in normal font.

2.2 Reporting

2.2.1 Condition 7

The Consent Holder shall provide to the Manager, Regulatory Department, Marlborough District Council, on or before 31 August in each year of the term of consent, from and including 2011, an Annual Monitoring Report (AMR) which must contain at least the following information:

7.*1 General*

a) An analysis of the extent to which the Consent Holder has, in operating the BSTP and exercising these consents, complied with these Conditions of Consent and the extent and cause of any noncompliance, in each case with a summary of the environmental effects of the operation of the BSTP during the preceding 12 month period from 1 July- 30 June inclusive (the Reporting Period).

This annual monitoring report (AMR) has been produced to achieve compliance with this condition.

b) An identification and discussion of any operational difficulties, changes or improvements made to the wastewater treatment or operating processes, which would cause any material difference in environmental outcomes from the previous Reporting Period.

This annual monitoring report (AMR) has been produced to achieve compliance with this condition.

c) A comparison of results obtained over the Reporting Period with the results from previous reporting periods.

Comparisons with previous years are noted in relevant sections of the report.

d) An identification of any maintenance works needed, proposed or undertaken to ensure compliance with these Conditions of Consent.

MDC has recently received the draft Stage 2 report from GHD regarding options to increase the treatment capacity of the industrial ponds. A programme and proposed upgrade plan is currently underway for 2019 and MDC is also planning to upgrade aeration of domestic Pond 1 and to investigate sludge removal in Pond 6.

e) An identification of any improvements or changes required and the timetable for implementation.

None identified.

7.2 Discharge of Treated Wastewater to land

a) The volume of treated wastewater applied to each of the Areas 1 – 3.

See Section 2.3.1.

b) A summary and analysis (including graphical and statistical representations) of all data collected as a requirement of the Specific Conditions applicable to the discharge consent to discharge treated wastewater to land.

See Section 2.3.1.

c) *A record and discussion of any complaints received regarding the discharge to land and the consent holder's response to those complaints.*

No complaints received. See Section 2.3.7.

d) An analysis of any environmental effects, positive, neutral and adverse, which are attributable to the discharge of treated wastewater to land.

See Section 2.3.

7.3 Discharge of Odour

a) Identification and discussion of any complaints received with respect to odour as per Condition 42 of the Discharge Permit to Air and any action taken to address the complaints.

See Section 2.4.1.

b) The measurements of Dissolved Oxygen (DO) concentrations as per Conditions 44 and 45 of the Discharge Permit to Air.

See Sections 2.4.2 and 2.4.3.

c) An analysis of the data in terms of consent compliance and environmental effects.

See Sections 2.4.2 and 2.4.3.

d) A discussion of any relevant operational changes or improvements carried out during the Reporting Period.

None identified.

e) A comparison of results in the Reporting Period to previous reporting periods and a discussion of any trends.

Comparisons with previous years are noted in relevant sections of the report.

f) Any complaints received in regard to the operation of the BSTP and the action(s) taken to address each complaint.

No complaints were received regarding the operation of the BSTP. See Section 2.4.1.

7.4 Wastewater Monitoring and Benthic and Water Quality Monitoring

a) A summary of all the monitoring data collected as a requirement of the conditions of the discharge permit to discharge treated wastewater to the Wairau Estuary during the Reporting Period.

See Section 2.5.

b) An analysis of the data in terms of consent compliance and environmental effects during the Reporting Period.

See Section 2.5.

c) A discussion of any relevant operational changes or improvements carried out during the Reporting Period.

See Section 2.5.

d) A comparison of results with previous years and a discussion of any trends during the Reporting Period.

Comparisons with previous years' results are noted in relevant sections of the report.

e) Any complaints received in regard to the operation of the BSTP and the action(s) taken to address each complaint.

No complaints were received regarding the operation of the BSTP. See Section 2.4.1

7.5 Outfall Pipelines

a) A record of any maintenance works undertaken in accordance with Condition 52 of the Coastal Permit for the new and existing outfall pipelines.

The annual inspection of the new Wairau Bar effluent pipeline was undertaken on 31 January 2018 (report in **Appendix B**). The buoy was refurbished as it had broken away from its mooring.

2.3 Discharge to Land

2.3.1 Condition 7.2

Condition 7.2 requires that the AMR must include:

The volume of treated wastewater applied to each of the Areas 1-3 in the reporting period.

Table 2-1 shows the volume of treated wastewater and total applied volume per hectare that was discharged to each irrigation area during the reporting period.

Table 2-1: Total Volume of treated wastewater discharged to each irrigation area (June 2017 - July 2018)

Irrigation Area	Volume of Wastewater Applied (m^3)	Area (ha)	Total application rate (m^3/ha)
1	70,546	42	1,680
2	65,162	32	2,036
3	119,276	86	1,387

The volumes applied to Areas 1 and 3 are similar to those applied in the 2016/2017 monitoring year. The volume applied to Area 2 has increased compared to the previous year's application (ie 1,304 m^3/ha). However, the application rates in 2016/17 and 2017/18 were still significantly lower than the volumes applied in 2015/2016.

2.3.2 Condition 24

The following net nitrogen loading limits shall be observed:

a) The maximum annual application of nitrogen shall not exceed a net loading of 200 kilograms of nitrogen per hectare per year.

b) Monthly applications shall not exceed a net loading of 50 kilograms of nitrogen per hectare.

Treated wastewater from Pond 6 (some of which is recirculated from Pond 14) is available for irrigation when soil and groundwater conditions are suitable. In the 2017/18 year, irrigation of wastewater occurred from November to April. The mass of nitrogen applied to each irrigation segment during this period has been calculated based on the volumes applied and the nitrogen concentrations measured in samples taken during this period. The annual total nitrogen load for each land segment is shown in **Appendix D**.

The average annual nitrogen load across all segments was 33.2 kg/ha/yr. This is similar to the average load recorded in the 2016/17 annual report and below the average load of 52.5 kg/ha/yr reported for the 2015/2016 monitoring period. Segment DLA-02 had the highest total load of 101 kg/ha/yr. In all cases, the nitrogen application rates were lower than the consent limit of 200kg/ha/yr.

The highest monthly nitrogen application rate in occurred in December 2017, when 51.7 kg/ha was applied to segment DLA-02. This was the only occasion over the monitoring period when the calculated nitrogen application rate exceeded the consent limit of 50kg/ha/month.

2.3.3 Condition 29

Groundwater shall be sampled monthly while irrigation is occurring in each area identified in Plan Consent No A in Appendix 1 [see **Appendix B** for the revised consent and **Appendix C** for the MDC acceptance] *to these conditions of consent, except that if irrigation has occurred for less than 14 days in the previous month no sampling is required. For each Irrigation Area, the wells identified within that area shown on Plan Consent No B attached in Appendix 1* [see **Appendix B** for the revised consent and **Appendix C** for the MDC acceptance] *to these conditions of consent, shall be sampled. The samples shall be analysed for.*

a) Ammoniacal nitrogen.

b) Nitrate nitrogen.

c) Conductivity.

d) E-coli.

The water level in each bore shall be measured and recorded at the time the sample is taken.

Irrigation of treated wastewater occurred from November 2017 to April 2018. This period is indicated by the vertical black lines on Figures 2-1 to 2-3. Samples were taken from each of the six wells between October 2017 and April 2018.

The groundwater monitoring results in Figures 2-1 to 2-3 show that all parameters tested were reasonably consistent over the monitoring period, apart from several spikes in the E. coli and ammonia nitrogen concentrations.

There were two notable spikes in E.Coli concentration, the largest of which was a value of 24,200 MPN/100ml recorded in five wells (10031, MSC-049, MSC-055, MSC-070 and 10027), on 19 December 2017 (Figure 2-3). This exceeded the maximum recorded in 2016/17 of 9,800 MPN/100ml. The other notable spike occurred in Well 10031 on 25 October 2017, where the E.coli concentration was measured at 3,650 MPN/100ml.

A spike in the ammonia-nitrogen concentration of 70 mg/L, occurred on 25 October 2017 in Well 10031, however this is not illustrated on the graph (as it occurred prior to the start of irrigation). A spike of 25 mg/L also occurred in Well 10031 on 29 November 2017. Well 10031 is close to the river and downgradient of Pond 6. The concentrations of ammonia recorded in the wastewater (at the wetlands outlet) when the spikes occurred, ranged from 5.7 – 14 mg/L. These values were higher than wastewater ammonia levels recorded from January 2018 onwards (i.e. 0.01 – 0.57 mg/L).

Possible sources of the ammonia spike in Well 10031 are seepage from the pond or wetlands or conversion to ammonia in the well if there was a source of organic nitrogen and the right conditions (e.g. temperature, pH and oxygen) existed.

While Pond 6 is relatively old, there is sufficient sludge in the bottom to assume some self-sealing. Ponds 7-14 are newer, and were designed to minimise seepage through bund construction and selecting their depth to be within low permeability soil layers. However, a small amount of seepage is still likely as less “self-sealing” will have occurred in the relatively short time since construction.

The site is also very flat which makes determining groundwater flow direction difficult. Over summer, when groundwater levels are lower, it might be expected that groundwater would generally flow away from the Opawa River. However earlier in the season, groundwater flow direction would vary and could influence wells such as W10031 which are in close proximity to the river. This could also have contributed to the high E.coli results observed in five of the wells in December 2017 and faecal coliform spike in Pond 6 in January 2018.

Electrical conductivity was consistently high in Well 10031 (Figure 2-2), which has been the case since the start of monitoring in 2015. As this well is located close to the tidally-influenced river, it is likely to contain higher salinity water (there is a strong relationship between conductivity and salinity).

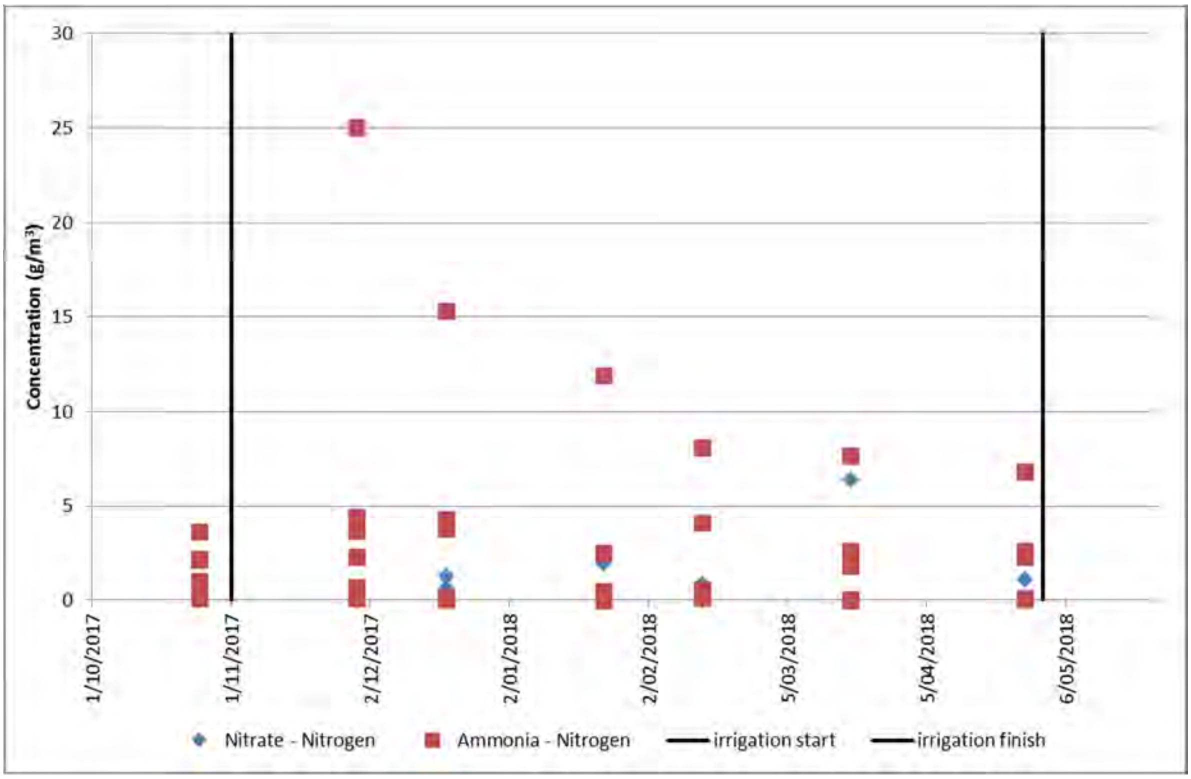


Figure 2-1: Groundwater testing results from six wells – Nitrate N and Ammoniacal N

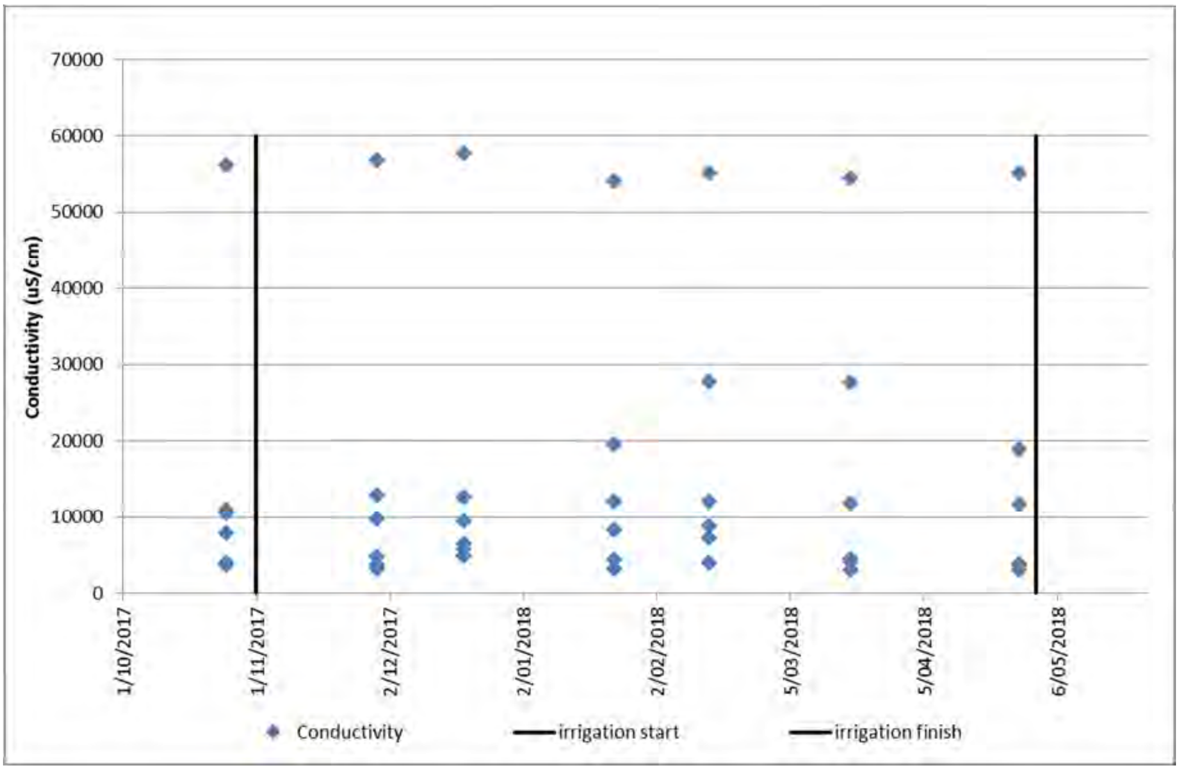


Figure 2-2: Groundwater testing results from six wells - electrical conductivity

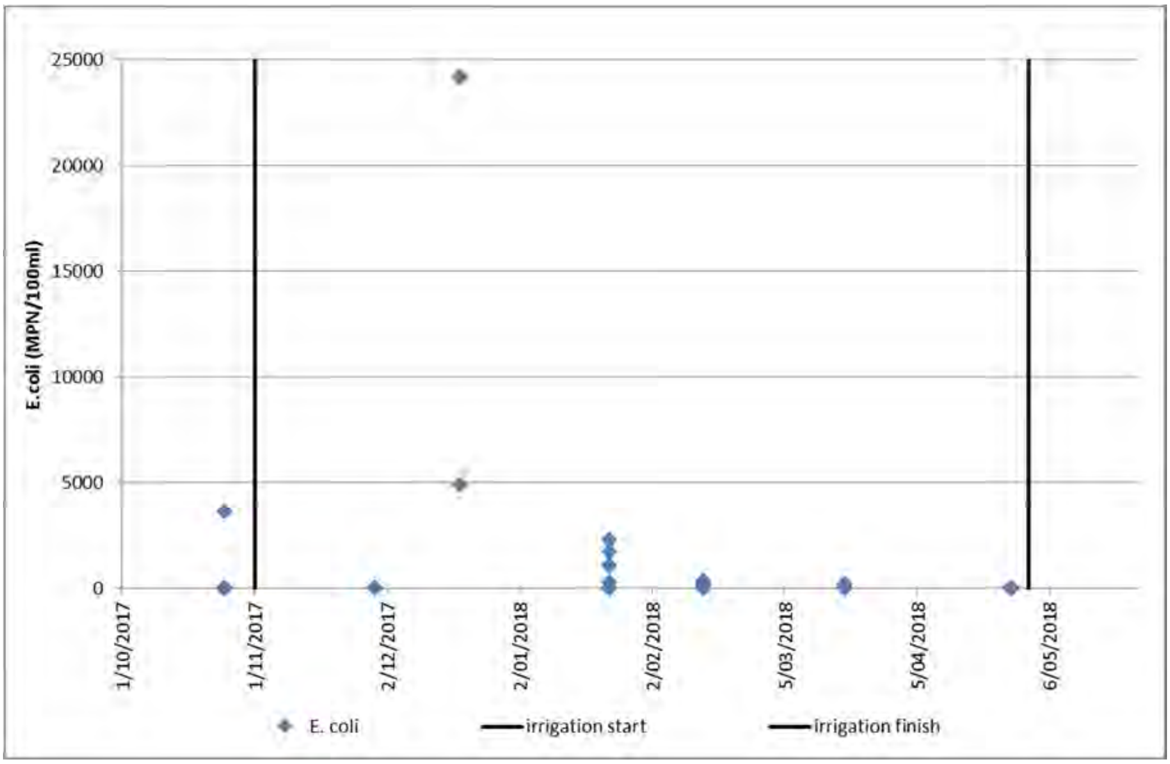


Figure 2-3: Groundwater testing results from six wells – E. coli

2.3.4 Condition 30

The groundwater level in the wells shown on Plan Consent No B attached in Appendix 1 [see **Appendix B** for the Revised Plan Consent and **Appendix C** for the MDC acceptance] *to these conditions of consent shall be monitored prior to wastewater irrigation commencing and at least fortnightly thereafter while irrigation is occurring. If the groundwater level measured in any monitoring well, for a particular irrigation area, is closer than 0.3 metres from the ground surface, irrigation shall cease in that area. Irrigation shall not recommence until the groundwater level is greater than 0.3 metres below the ground surface.*

As per Condition 30 of the consent, the groundwater levels were recorded and are shown in Table 2-2. Levels were recorded every month, rather than fortnightly as required by the consent, probably due to a change in personnel undertaking the measurements. All groundwater depths measured during the period October 2017 to April 2018 were greater than 0.3 m below ground, which reflects observations from previous years.

Table 2-2: Recorded groundwater levels prior to and during irrigation period

	Depth to groundwater (m)					
Date	**MSC-049**	**MSC-055**	**MSC-070**	**MSC-071**	**10027**	**10031**
25/10/2017	1.10	1.95	0.80	1.70	1.90	1.45
29/11/2017	1.55	2.40	1.50	2.02	2.10	1.70
19/12/2017	1.48	1.91	2.10	1.73	2.20	1.50
23/01/2017	0.94	2.16	1.71	1.92	2.21	1.24
14/02/2018	0.80	2.41	1.92	1.81	2.21	1.53
19/03/2018	0.90	2.31	1.60	2.10	1.40	1.12
27/04/2018	0.73	1.42	1.80	1.80	1.24	1.13

2.3.5 Condition 31

The potable water in well P28/4446 and one well on Lot 2 DP12207 shall be monitored as follows:

c) Sampling of both wells shall continue at monthly intervals during the wastewater irrigation season with a final sample being taken no later than 30 days after wastewater irrigation ceases each season.

d) Sampling shall continue for a period of 5 years after wastewater irrigation commences. If E. coli are detected then the sampling shall continue for a further 5 years from that time.

As per the consent requirements, potable water from Wells P28w/4446 and P28w/4447 was tested monthly during the irrigation period (see Table 2-3). All E. coli results were <1 cfu/100 ml and therefore no further action is considered necessary.

This is the fifth year of monitoring for E. coli in the potable water wells under this consent. In this five-year period, no samples have tested positive for E.coli, although one sample was missed in the 2014/2015 period. There is no reason to think that the missed sample would have contained E. coli and hence the requirements of this condition are considered to be discharged.

Table 2-3: Potable Water Monitoring - E. Coli Concentration (cfu/100 ml)

Date	P28w/4446	P28w/4447
19/06/2017	<1	<1
7/07/2017	<1	<1
31/07/2017	<1	<1
5/09/2017	<1	<1
11/10/2017	<1	<1
7/11/2017	<1	<1
4/12/2017	<1	<1
9/01/2018	<1	<1
5/02/2018	<1	<1
7/03/2018	<1	<1
3/04/2018	<1	<1
9/05/2018	<1	<1

2.3.6 Condition 32

Conditions 32a and b were revised in 2012 and accepted by MDC Regulatory. The condition is now as follows with amendments in **bold**:

Prior to commencing the discharge;

a) A weather station shall be installed at the office building shown on Plan Consent No B attached in Appendix 1 to these conditions of consent. The weather station shall measure and record wind speed and direction and rainfall and have sufficient instrumentation to allow calculation of evapotranspiration. The wind speed and direction recorded at the weather station shall be deemed to represent the wind speed and direction for Areas 1 ***and 2.***

b) An anemometer and wind vane shall be installed at the location ***shown as Wind Measurement Site (Area 3)*** *on Plan Consent No B attached in Appendix 1 to these conditions of consent. The anemometer and wind vane shall measure and record wind speed and direction. The wind speed and direction recorded shall be deemed to represent the wind speed and direction for* ***Irrigation Area 3****.*

c) The weather station, anemometers and wind vanes shall be maintained in an operational condition throughout the term of this consent.

The two weather stations are set up and operating in accordance with the amended requirements of Condition 32. The proposed amendment letter and acceptance by MDC Regulatory can be provided if requested or alternatively, can be found in the previous three monitoring reports.

2.3.7 Condition 35

The Consent Holder shall maintain a register of any complaints received relating to any aspect of the land discharge system. The record shall include the date and time of complaint, cause of the complaint, weather conditions at the time of complaint and action taken in response to the complaint. The register shall be made available to the Manager, Regulatory Department, Marlborough District Council, on request. A summary of complaints received by the consent holder shall be included in the AMR required by Condition 7.

As no complaints regarding the land discharge system were received during the reporting period, compliance with the requirements of Condition 35 was achieved. No complaints have been received regarding Condition 35 for the land discharge system for the previous three monitoring periods.

2.3.8 Condition 36

For the duration of these consents, the Consent Holder shall install and maintain appropriate signage on any access points to the BSTP warning that partially treated wastewater is discharged to the land. Written confirmation of the signage wording, size and placement shall be provided to the Manager, Regulatory Department, Marlborough District Council, within three months of the commencement of this consent.

Signage has been installed according to the requirements of Condition 36.

2.4 Discharge to Air

2.4.1 Condition 42

Any complaints received in regard to odour shall be recorded in a Complaints Register specifying the complaint, time and date, weather conditions and action required. A copy of the complaints shall be made available to the Manager, Regulatory Department, Marlborough District Council, on request. A summary of these complaints shall be part of the AMR required by Condition 7 of these Conditions of Consent.

No odour complaints were received in this monitoring period therefore the requirements of Condition 42 were achieved. While an odour complaint was received during the previous monitoring period (23 November 2016), after investigation it was concluded it was caused by wine loss from tanks in the Cloudy Bay Business Park or the Riverlands Industrial Estate which were damaged in the 2016 Seddon earthquake and did not relate to the industrial pond's operations.

2.4.2 Condition 44

The Consent Holder shall measure the Dissolved Oxygen (DO) concentrations in the wastewater near the outlet of Ponds 2A, 2B, 2C, 6 and 10 every Wednesday, except when a Wednesday falls on a public holiday, when the measurement shall be taken on the nearest following working day. The DO concentration shall be measured between 11 am and 2pm and shall not be less than 2 grams of DO per cubic metre, on a rolling 10 percentile weekly measurement basis.

Figure 2-4 shows the weekly DO outlet results for the reporting period and Table 2-4 summarises these results in relation to the consent limit. The DO concentrations were measured in Pond 14 instead of Pond 10 (as noted in the condition), as this is now the final wetland cell before discharge to the Estuary. Samples were generally taken weekly but they were not consistently taken on Wednesdays. Figure 2-4 shows that DO concentrations in the domestic pond (Ponds 2A, 2B and 2C), remained high, except for a period in June 2018. Table 2-4 shows that consent DO limits were being met in all ponds sampled, which is similar to results reported in previous years.

Samples were generally recorded as being taken within 11am and 2pm as required by the condition. However, on four occasions this requirement was not met and on two occasions, the time of sampling was not recorded. As solar radiation (and therefore algal photosynthesis), is usually greatest between 11am and 2pm, pond DO concentrations should be always measured (for compliance purposes), during this period. On the occasions where sampling occurred outside of these hours, on three occasions it was completed by 3pm.

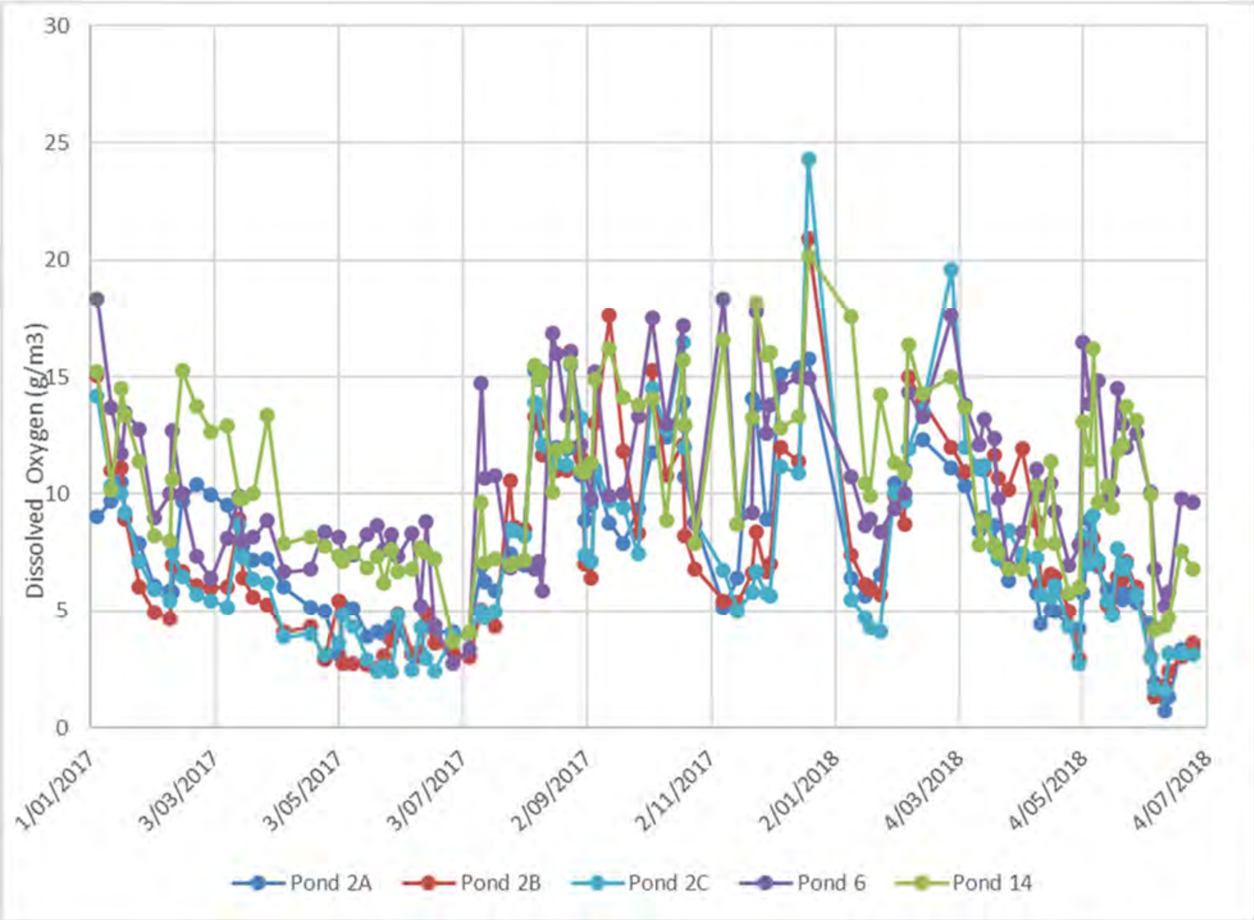


Figure 2-4: Dissolved oxygen monitoring results at the outlet of Ponds 2A, 2B, 2C, 6 and 14

Table 2-4: Comparison of dissolved oxygen monitoring results for Ponds 2A, 2B, 2C, 6 and 14 with consent limit

	10th percentile
Consent Limit	**>2.0g/m³**
Pond 2A	4.0
Pond 2B outlet	3.0
Pond 2C outlet	3.0
Pond 6 outlet	6.8
Pond 14 outlet	6.8

2.4.3 Condition 45

The DO of the wastewater in Ponds I1 and I2 shall be measured daily between 11am and 2pm during peak loading periods associated with the annual vintage, with DO concentrations maintained at not less than 0.5 grams per cubic metre on a 50 percentile basis. The time of the peak loading periods shall be determined by consultation between the Consent Holder and the Manager, Regulatory Department, Marlborough District Council. The results of the measurements shall be included in the AMR required by Condition 7.

The annual peak vintage period occurs between March and May in each year. Probes record DO concentrations in Ponds I1 and I2 every six minutes over this period. Daily averages of the DO concentration between 11am and 2pm each day are shown in Figure 2-5. This figure shows that the average daily DO concentration in Pond I2 was close to zero from 5 – 9 March 2018 and for short periods on 2 March, 14 March, 18 March, and 22 March. The DO also dropped below the 0.5g/m³ consent limit for the period from 31 March 2018 through to 14 April 2018. However, as shown in Table 2-5, the 50th percentile DO concentration in both ponds over the vintage period was well above the 0.5 g/m³ limit. Similar instances of DO dropping to zero during vintage have also been reported in previous monitoring periods.

The very low and similar DO concentrations recorded in Pond I2 over a period in early March 2018 does not appear to correspond to a significant increase in BOD and may be due to an instrument error. However, the low DO in Pond I2 later in March and during April 2017 coincides with significant increases in BOD loading, although does not appear to have adversely affected DO concentrations downstream in Pond 6, as shown in Figure 2-4. This is assumed to be due to the larger volume of Pond 6 providing a buffer against the incoming low DO wastewater and good BOD reduction in Ponds I1 and I2. The shorter periods of low DO in Pond I2 are assumed to be due to the rising BOD and the aeration schedule. The drop-off in DO as influent BOD increases is consistent with pond performance in previous years.

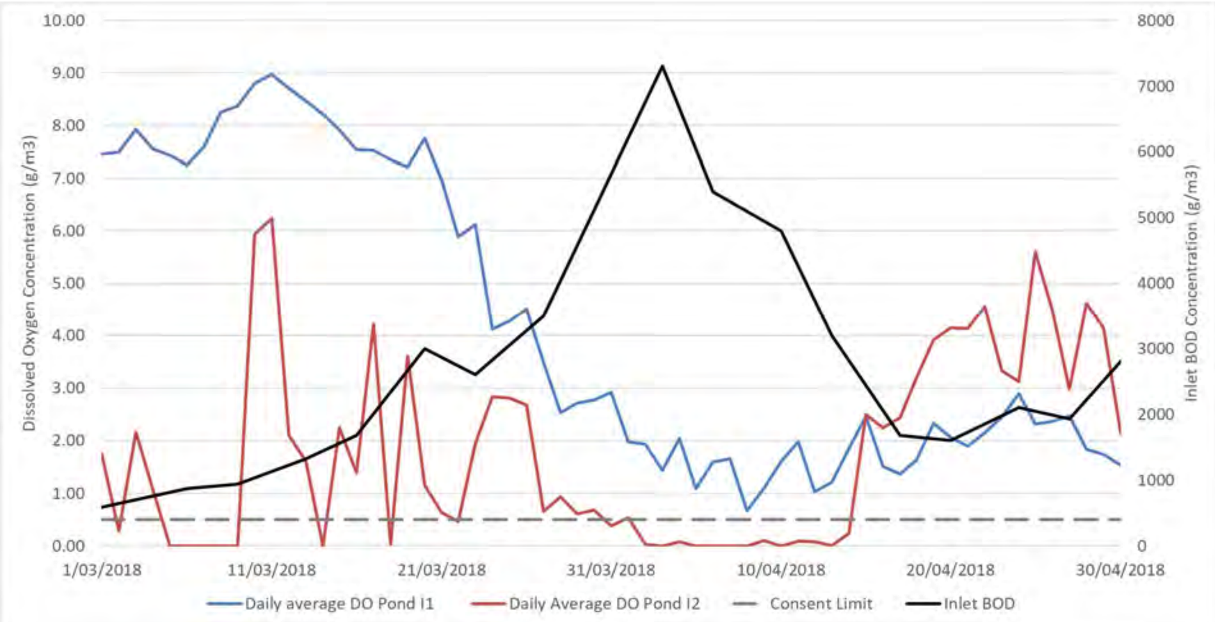


Figure 2-5: Dissolved oxygen daily averages in Ponds I1 and I2 compared to inlet BOD concentration

Table 2-5: Dissolved oxygen monitoring results for Ponds I1 and I2 during March to May

	50th percentile during peak period
Consent Limit	**>0.5g/m³**
Pond I1	3.2
Pond I2	1.1

2.5 Discharge to Wairau Estuary

2.5.1 Condition 51

The Consent Holder shall undertake annual external visual inspections of the outfall pipeline structures for the duration of the consent. A report shall be submitted to the Manager, Regulatory Department, Marlborough District Council, within 20 working days of the inspection being carried out. The report shall include but not be limited to:

a) The date and time of the inspection.

b) The condition of the outfall structures.

c) Any maintenance work that may be required, and if it is required, when the work will be carried out

An inspection of the outfall pipeline was carried out during the 2017/2018 monitoring period (see report by N-VIRO Mooring Systems in **Appendix B** dated 31 January 2018). The outcomes of this inspection are summarised below:

- Visibility at the buoy was good but water visibility zero
- Nozzle is only part exposed from the river bed
- Nozzle condition feels acceptable (can only be inspected on touch due to visibility)
- Buoy had been refurbished after breaking away from its mooring
- New 6m by 12mm chain replaced
- 2 new shackles and 1 new anode replaced

2.5.2 Condition 54

The existing buoy marking the location of the end of the existing outfall shall be marked with the words ***Sewer Outfall*** *and the lettering used shall be bold and clear such that it can easily be read from a distance of 10 metres.*

The existing buoy has been marked according to the requirements of the condition.

2.5.3 Condition 55

The total discharge of treated wastewater authorised by this consent shall not exceed an average daily volume of 28,500 cubic metres, where the average volume is calculated on a continuous basis over a period of 365 consecutive days. The maximum discharge volume per day shall not exceed 103,680 cubic metres.

The daily treated wastewater discharge volumes to the Wairau Estuary for 2017/18 year and the previous 3 years are shown in Figure 2-6. The average daily discharge volume over the current monitoring period was 18,365 m^3 while the maximum daily discharge volume was 32,631 m^3 recorded on the 27 February 2018.

Table 2-6 – Treated Wastewater Discharge Volumes 2014/15 – 2017/18

	2014/2015	2015/2016	2016/2017	2017/2018
Average Daily Discharge (m^3)	10,973	11,078	15,868	18,365
Maximum Daily Discharge (m^3)	30,745	28,285	52,733	32,631

Whilst average daily discharge volumes have increased each year from 2014/15, these volumes are well below the consent limit. The maximum daily discharge has fluctuated significantly over the 4 year period but remains well below the consent limit. It is noted that there are three days of flow data missing from 14-16 July 2018.

Figure 2-6: Daily discharge volume to Wairau Estuary

2.5.4 Condition 56

The Consent Holder shall install flow measuring devices after the outlet from wetland Pond 10 and Pond 6 (as shown on Plan Consent No C attached in Appendix 1 [see **Appendix B** for the Revised Plan Consent and **Appendix C** for the acceptance of this] *to these conditions of consent) and record the daily volume of treated wastewater discharged to the Wairau Estuary. A copy of these records shall be made available to the Manager, Regulatory Department, Marlborough District Council, on request. A summary of this data shall be provided in the AMR required by Condition 7.*

A flow meter has been installed at the outlet from the wetlands, which is at Pond 14 (numbered Pond 10 at the preliminary design stage). A flow meter has also been installed at the outlet to Pond 6 to record wastewater flow to irrigation areas.

2.5.5 Condition 59

The discharge of treated wastewater from the upgraded BSTP shall not cause any of the following effects outside the mixing zone described in Condition 58:

a) The natural temperature of the receiving water to change by more than 3 degrees Celsius;

b) Any conspicuous change in colour or clarity of the receiving water such that visual clarity of water is reduced by more than 50% as per the Water Quality Guidelines No 2 Ministry for the Environment (1994);

c) The concentration of dissolved oxygen of the receiving water to fall below 80 percent of the saturation content

While the above effects have not been directly monitored in the receiving water, the results of wastewater monitoring (see Figures 2-7 to 2-10), indicate that there are unlikely to be any significant effects on water quality after reasonable mixing. Beca (2007) indicated that, based on computer modelling, the “worst case” initial dilution in the Estuary under existing average flows would be 50:1. In addition, the treated wastewater is only discharged under ebb tide conditions when there is a strong outflow from the Estuary. On this basis, none of the effects noted in Condition 59, are likely to have occurred after reasonable mixing, as a result of the discharge.

Successive surveys of the Estuary by Cawthron, in 2001, 2007, and 2016 (see **Appendix C**), show that the outfall “*was having no discernible effect on sediment quality or the seabed dwelling community”.* A wastewater plume that remains submerged for some distance downstream of the outfall, strong tidal flows, sediment re-suspension and bed movement mitigate against any adverse effects occurring on the bed of the Estuary. The strong tidal flows results in significant re-oxygenation of the bed so that the potential for the creation of anoxic sediments is also very low.

The decommissioning of the Opawa River outfall and discharge of the combined wastewater to an area of rapid flushing in the Estuary, as well as the relatively high quality treated wastewater (including low concentrations of ammonia), means that there is a very low likelihood of significant adverse effects occurring in the receiving water as a result of the discharge.

2.5.6 Condition 61

The Consent Holder shall take grab samples of treated wastewater at the outlet of Pond 10 following commissioning of the new wetland. Samples shall be analysed for the parameters and frequency shown in Table 1 (reproduced as Table 2-7 in this report)*. The results shall be reported in the AMP required by Condition 7.*

Condition 61 of the consent requires that grab samples be taken at the outlet of Pond 10 which was the number of the final wetland pond at the consent procurement (preliminary design) stage. However, following changes made during detailed design, Pond 14 is now the final wetland cell before discharge to the Estuary. Grab samples are therefore collected from the outlet of this pond. The results of sampling at the outlet of the wetland are shown in Figures 2-7 to 2-11.

Table 2-7: Wastewater Monitoring Requirements

Parameter	Unit	Frequency of Analysis
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g/m^3	Monthly
Suspended Solids (SS)	g/m^3	Monthly
Faecal Coliforms and Enterococci	cfu/100ml	Monthly
Ammoniacal Nitrogen (NH_3-N)	g/m^3	Monthly
Total Nitrogen (TN)	g/m^3	Monthly
Dissolved Inorganic Nitrogen	g/m^3	Monthly
Dissolved Reactive Phosphorus	g/m^3	Monthly
Total Phosphorus (TP)	g/m^3	Monthly
pH	pH units	Monthly
Temperature	Celsius	Monthly
Metals/metalloids: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc	g/m^3	Annually

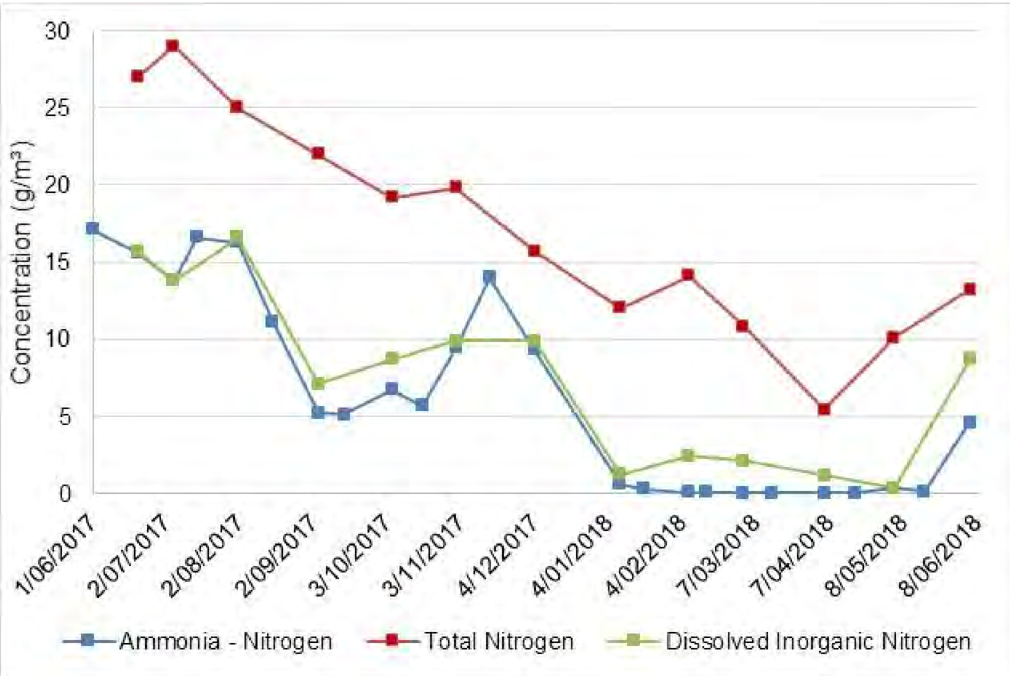


Figure 2-7: Wastewater monitoring results Pond 14 outlet – nitrogen species

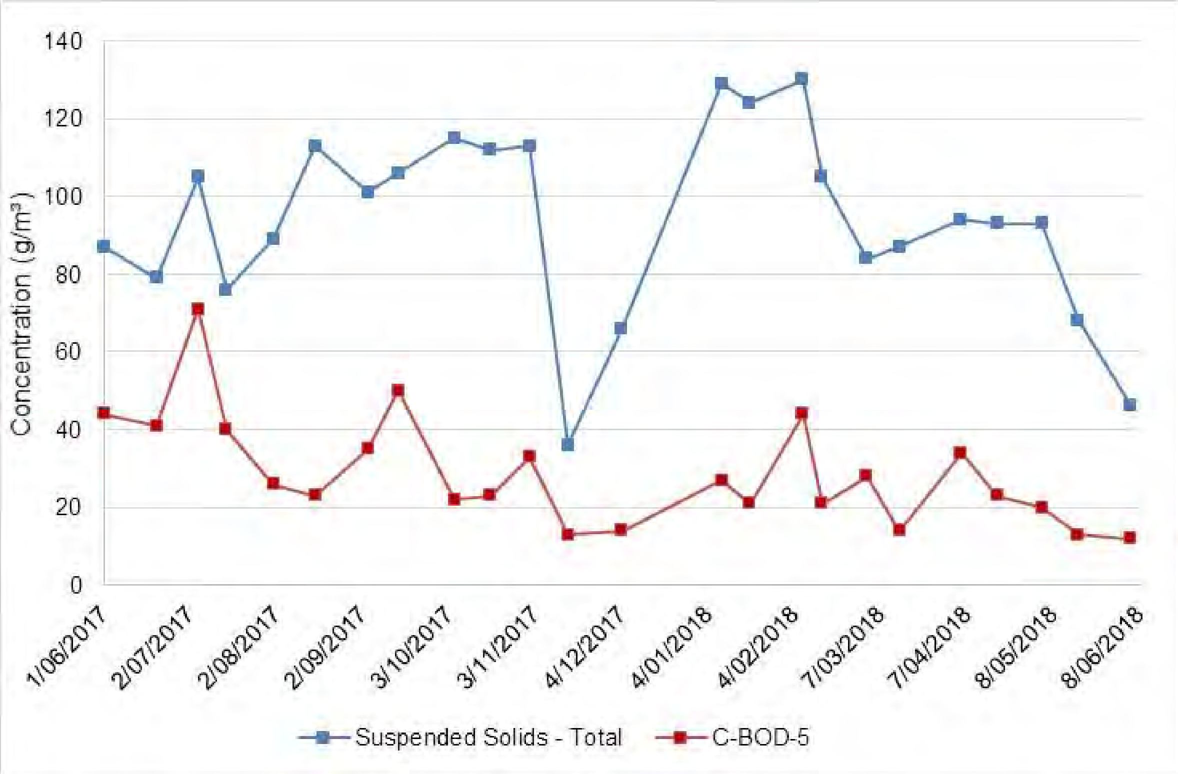


Figure 2-8: Wastewater monitoring results Pond 14 outlet – $cBOD_5$ and suspended solids

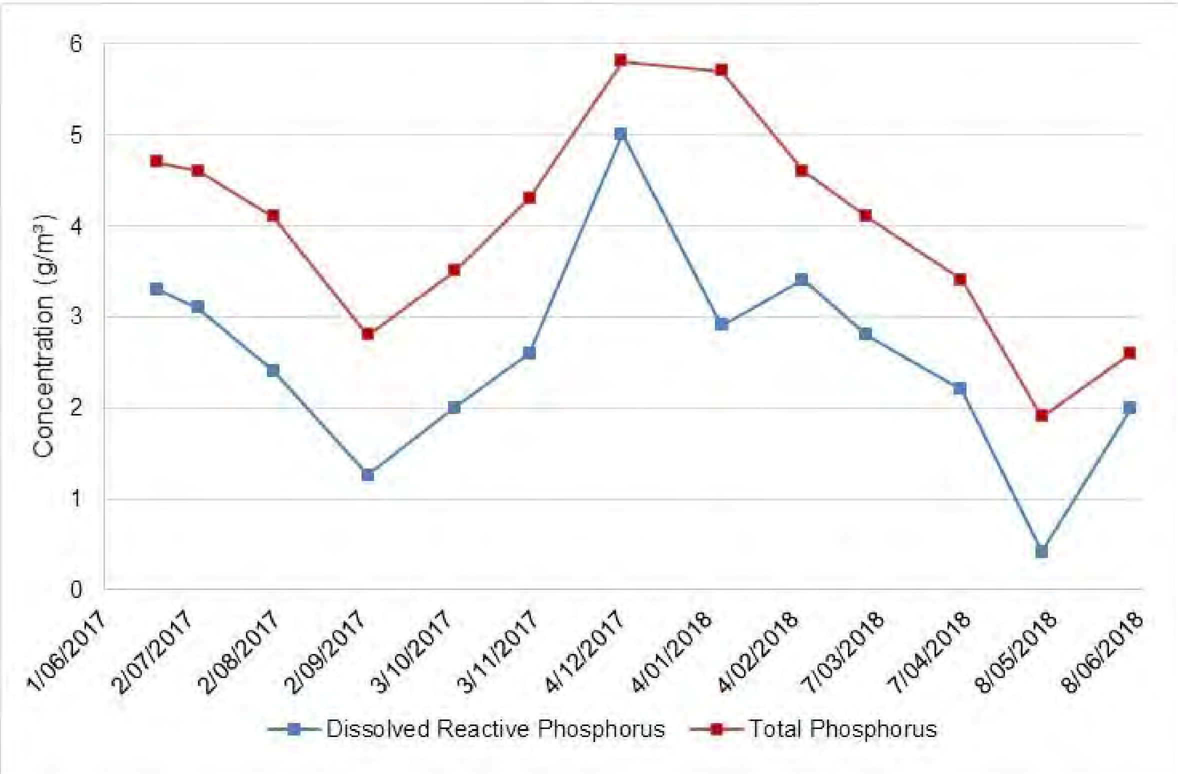


Figure 2-9: Wastewater monitoring results Pond 14 outlet – phosphorus species

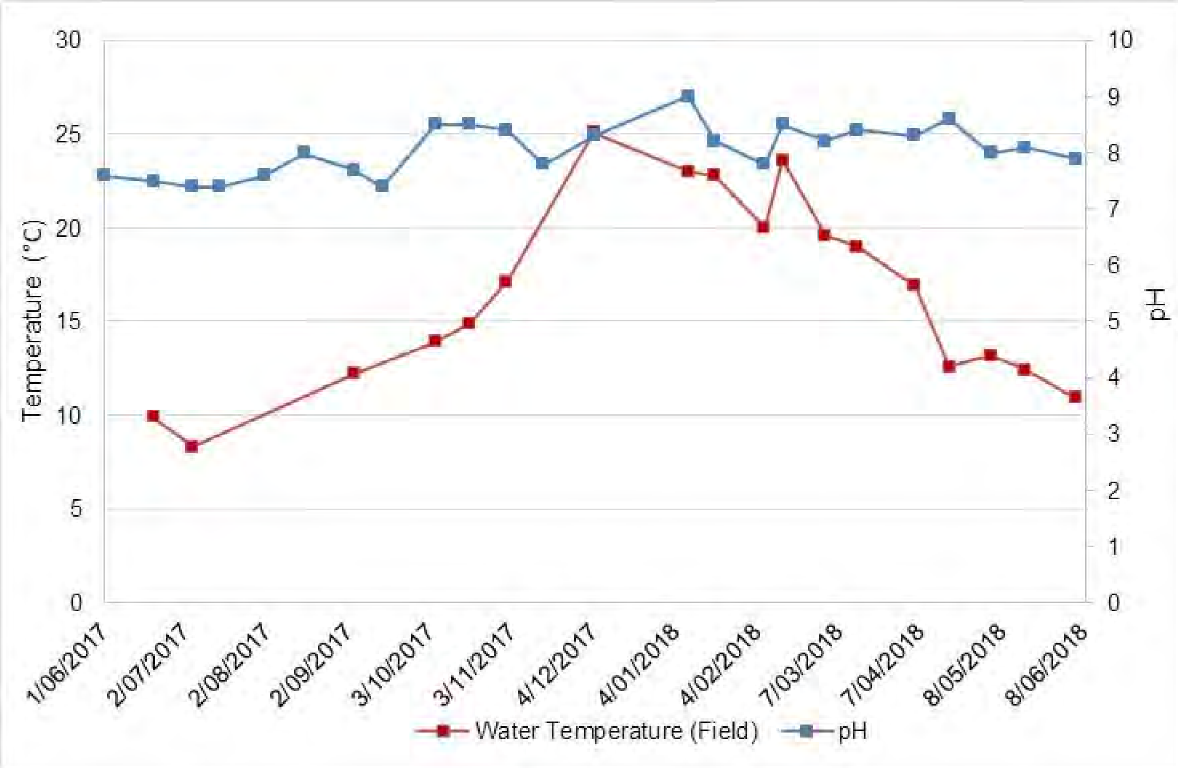


Figure 2-10: Wastewater monitoring results Pond 14 outlet – temperature and pH

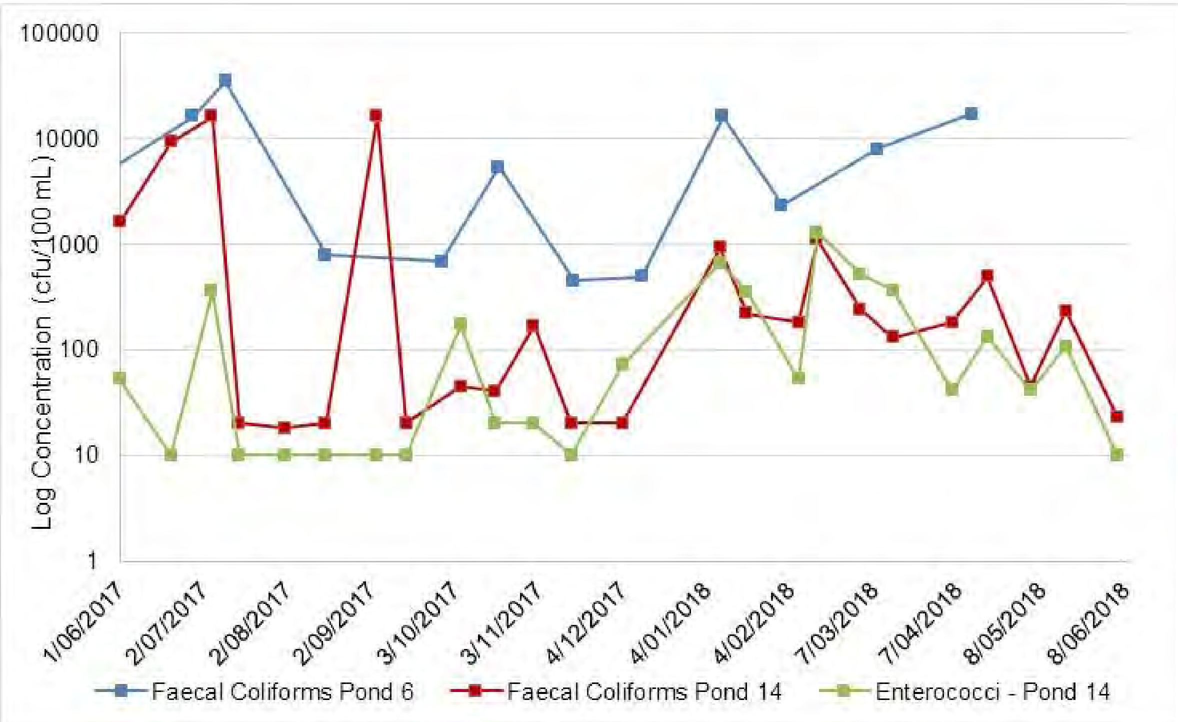


Figure 2-11: Wastewater monitoring results – Faecal coliforms at the outlet of Pond 6 and Faecal coliforms and Enterococci at Pond 14 (on a Logarithmic Scale)

MDC collects samples from the outlet twice every month, which is reflected in the number of data points in the graphs above.

The nitrogen trends for the 2017/2018 monitoring period reflect patterns observed in previous years where nitrogen load drops from approximately September onwards and begin to rise again in May.

BOD, suspended solids, phosphorus species, temperature and pH values measured all reflect similar annual trends to previous monitoring years. Apart from the occasional spike, no overall trends up or down were observed for the faecal coliforms or enterococci values in Ponds 6 and 14.

Metal and metalloids measured at Pond 14 are summarised in Table 2-8:

Table 2-8: Wastewater monitoring results – metals and metalloids at Pond 14

Date	Arsenic - Total (g/m^3)	Cadmium - Total (g/m^3)	Chromium - Total (g/m^3)	Copper - Total (g/m^3)	Lead - Total (g/m^3)	Nickel - Total (g/m^3)	Zinc - Total (g/m^3)
09/01/2018	0.004	<0.000	0.001	0.002	0.001	0.002	0.005

With the exception of arsenic (average of 0.0035 g/m^3 for 2016/2017), all metal and metalloid values reported are lower than the previous monitoring year. These generally meet the ANZECC (2000) trigger values for a 99 percent level of protection of freshwater and marine ecosystems.

2.5.7 Condition 62 - Wastewater Monitoring Limits

The treated wastewater sampled under Condition 61 shall comply on an annual basis with the ammoniacal nitrogen and faecal coliform limits listed in Table 2 [reproduced in the Consent Limits columns of Table 2-9].

The monitoring results and consent limits for ammoniacal nitrogen and faecal coliform concentrations are given in Table 2-9. Figure 2-11 shows the results of the wastewater faecal coliform and enterococci monitoring (after Pond 14), as well as results of faecal coliform monitoring at the outlet of Pond 6 (i.e. before the wetlands). While the wastewater ammoniacal nitrogen and faecal coliform sample results were well below the median consent limits, the faecal coliform results exceeded the 90th percentile limit. This is due to two instances (in July and September 2017), when the faecal coliform concentration was recorded as greater than 16,000 cfu/100ml.

Wastewater faecal coliform concentrations recorded at the outlet of Pond 6 are an average 1-1.5 log higher than the concentrations recorded after Pond 14. These results show that Ponds 7 to 14 (i.e. wetlands), are effective in providing further disinfection of the wastewater before discharge to the Estuary. Pond 6 results do not have a consent compliance limit.

Table 2-9: Wastewater microbiological monitoring results and consent limits for Pond 14

Parameter	Units	Median		90th Percentile	
		Consent Limits under existing flows	Results	Consent Limits under existing flows	Results
Ammoniacal Nitrogen (NH_3-N)	g/m^3	30	5.2	40	161
Faecal coliforms	cfu/100ml	700	175	2,150	6,920

The median ammoniacal nitrogen value is higher than that reported in previous monitoring periods (2016/2017 – 0.42, 2015/2016 – 0.07, 2014/2015 – 0.46). However, the 90th percentile values are similar. With the exception of the high 90th percentile value for faecal coliforms reported in 2017/18, median faecal coliforms concentrations are similar to those reported over the last three years.

2.5.8 Conditions 63-70

The Consent Holder shall carry out benthic surveys and water quality monitoring in the receiving environment to identify changes (notably adverse ecological impacts), as a result of the treated wastewater discharge. The survey design shall be consistent with the survey conducted by the Cawthron Institute (Technical Report on Effects of Outfall Discharge in Appendix D of Assessment of Environmental Effects for Upgrading of Blenheim Sewage Treatment Plant, September 2007).

Condition 64 requires that benthic and water quality surveys commence 2 years after commissioning of the new outfall. A survey was carried out by Cawthron Institute in February 2016). The survey was repeated again in January 2018 (see report issued 26 April 2018 in **Appendix C**). Surveys are required to be repeated at 5 yearly intervals for the duration of the consent.

The 2018 survey results are summarised as follows:

- Some minor environmental and ecological differences were apparent between the 2006, 2016 and 2018 surveys such as:
  - A change in the dominant infauna species at some sites over the years (such as the snail *Potamopygus estuarinus*), although this is unlikely to be caused by the discharge
  - Evidence of increased concentrations of metals in near-bed waters downstream of the mixing zone, but little evidence on the boundary of the mixing zone itself.
  - Concentrations of TSS and TN were higher at the mixing zone and bar near-bed sample in 2016 and 2018, however the BSTP outfall is not considered to be the sole source of these higher concentrations.
  - In 2018, enteroccoci concentration levels were below the limit of detection at all stations measured, in comparison to higher values recorded in 2016. This suggests that the outfall discharge is unlikely to be the predominant source of the enterococci contamination to the estuary. Similar findings were found for faecal coliforms.
  - Turbidity levels were similar at all three stations, however slightly lower than 2016.
- No overall adverse ecological effects of the BSTP discharge (and no breaches of the water quality consent conditions) were detected.
- These results are likely due to the quality of the discharge and its release only on the ebb tide, as well as the rapid tidal flushing that occurs within the vicinity of the outfall.

The survey is due to be repeated in February 2023, with the outcomes to be presented in the 2022/2023 monitoring report.

3 Summary

3.1 Overview

3.1.1 Groundwater

Groundwater testing was carried out monthly while irrigation was occurring, rather than the required sampling frequency of fortnightly. It is recommended that testing be carried out at the frequency required by the consent.

The results were reasonably consistent over all the wells tested. However, an E. coli concentration of 24,200 MPN/100ml was recorded in five of the wells tested on 19 December 2017 (Figure 2-3) and similarly a concentration of 3,650 MPN/100ml was measured in Well 10031 on 25 October 2017.

Ammonia-nitrogen concentrations of 70 mg/L and 25 mg/L, occurred on 25 October 2017 and 29 November 2017 respectively, in Well 10031. Well 10031 is located in Irrigation Area 2. Possible sources of elevated ammonia in this well could be seepage from either the pond or wetlands which correlates with the higher ammonia concentrations measured in the wastewater for those two months.

The nitrogen load applied while irrigating remained below the yearly limit, required by Condition 24, however there was one exceedance of the monthly limit of 50 kg/Ha.

Potable water from wells p28w/4446 and p28w/4447 was tested monthly, and all results were <1 cfu/100ml. This concludes the five years of monitoring post commissioning required by the consent.

3.1.2 Pond dissolved oxygen

DO concentrations in the treatment ponds met the consent limits.

3.1.3 Outfall flow

Outfall flow volumes met the consent limits.

3.1.4 Treated wastewater

Treated wastewater at the outlet of Pond 14 was monitored at the required frequency. Ammoniacal nitrogen and faecal coliform concentrations were below the consent limits with the exception of the faecal coliform 90th percentile value. While there are no consent limits for metals, concentrations in the wastewater generally met the ANZECC (2000) trigger values for a 99 percent level of protection of freshwater and marine ecosystems.

3.1.5 Ecological effects

The second post-upgrade benthic and water quality survey of the Estuary, required under the consent, was carried out during the 2018/18 reporting period. The study concluded that there were some minor environmental and ecological changes between the 2006, 2016 and 2018 surveys but overall, no adverse ecological effects due to the discharge were detected.

3.2 Compliance with Consent Conditions

From an assessment of the results of monitoring in the period 1 July 2017 to 30 June 2018, all consent conditions were met with the exception of:

- Condition 24 – one monthly sample exceeded a net loading of 50 kilograms of nitrogen per hectare.
- Condition 30 – Groundwater levels were not measured at the required fortnightly intervals, but all recorded levels during irrigation were compliant with the “greater than the 0.3 metre below ground surface” requirement.

- Condition 44 – Wastewater DO samples were generally taken weekly between 11am and 2pm, but not consistently on Wednesdays. There were six occasions where the timing of the sampling was outside the required hours, or not recorded.
- Condition 62 - the faecal coliform results measured in the outlet of Pond 14 exceeded the 90th percentile consent limit.

It is recommended that as far as practicable, all sampling be carried out according to consent requirements.

Overall, the BSTP treatment ponds and wetlands appear to be performing well. While some minor improvements in the sampling regime are required, there is overall compliance with consent conditions.

Appendix A

Consent U071181 including Site Plan and Monitoring Locations

| U071181

PART I: CONSENTS GRANTED

1. Land Use Consents:

A To disturb land, clear indigenous vegetation and excavate land for the purposes of constructing a wetland, an outfall pipeline, sludge ponds and drying beds.

B To use land for the purpose of disposing treated wastewater to land.

2. Discharge Permits:

C To discharge treated wastewater to land.

D To discharge seepage from treatment ponds, wetlands, sludge ponds and drying beds.

E To discharge odour to air from treatment ponds, wetlands, sludge ponds and drying beds and from the land used for the disposal of treated wastewater.

F To discharge treated wastewater to the Opawa River.

3. Coastal Permit:

G. Coastal Permit to:

a) use and maintain an existing outfall pipeline and a new outfall pipeline in the Coastal Marine Area of the Wairau Estuary

b) occupy space in the Coastal Marine Area of the Wairau Estuary with an existing outfall pipeline and a new outfall pipeline

c) discharge treated wastewater to the Wairau Estuary from a new outfall pipeline

PART II: GENERAL CONDITIONS

1. The consents identified in Part I above are to be exercised in a manner which is consistent with the proposal and methodologies described in the documents, information and analysis provided by the Consent Holder in support of its Application for Resource Consents and held on Council file U071181.

2. Unless an alternative term is identified in the Specific Conditions, the resource consents granted have a term of 35 years from the date that the consents commence.

3. The Consent Holder shall, at least one month prior to the commencement of the works that are the subject of this consent, submit to the Manager, Regulatory Department, Marlborough District Council, final copies of the following draft management plans:

   a) Blenheim Sewage Treatment Plant: Construction Management Plan - Wetlands, Sludge Ponds and Drying Beds, 5 July 2010, as amended by the evidence of H Archer dated 6 September 2010

   b) Blenheim Sewage Treatment Plant: Construction Management Plan - Outfall and Outfall Pump Station, 5 July 2010, as amended by the evidence of H Archer dated 6 September 2010

   c) Blenheim Sewage Treatment Plant: Buffer Planting Plan (undated)

   d) Wastewater Irrigation Management Plan Blenheim Sewage Treatment Plant, version 3, 6 September 2010

   e) Blenheim Sewage Treatment Plant: Operation and Management Plan, Revision C, July 2010

f) Blenheim Sewage Treatment Plant – Wetland Management Plan, 5 July 2010, as amended by the evidence of H Archer dated 6 September 2010

4. The final versions of the management plans listed in Condition 3 shall be prepared by qualified and experienced personnel with expertise in the matters that the individual management plans address. The management plans may be prepared as separate plans or as part of a combined plan.

5. When preparing the final versions of the management plans listed in condition 3, the Consent Holder shall take into account any comments provided by the Manager, Regulatory Department, Marlborough District Council, on the draft management plans. No works may commence until the final management plans have been approved in writing by Council, through the Manager, Regulatory Department.

6. All work shall be carried out in accordance with the approved final management plans, except that the Consent Holder may, at any time, submit to the Manager, Regulatory Department, Marlborough District Council, amendments to the plans for approval, provided those amendments improve the efficiency and/or quality of the construction works or operational activities, or avoid, remedy or mitigate an adverse effect.

7 The Consent Holder shall provide to the Manager, Regulatory Department, Marlborough District Council, on or before 31 August in each year of the term of consent, from and including 2011, an Annual Monitoring Report (AMR) which must contain at least the following information:

7.1 General

a) An analysis of the extent to which the Consent Holder has, in operating the BTSP and exercising these consents, complied with these Conditions of Consent and the extent and cause of any noncompliance, in each case with a summary of the environmental effects of the operation of the BTSP during the preceding 12 month period from 1 July – 30 June inclusive (the Reporting Period).

b) An identification and discussion of any operational difficulties, changes or improvements made to the wastewater treatment or operating processes, which would cause any material difference in environmental outcomes from the previous Reporting Period.

c) A comparison of results obtained over the Reporting Period with the results from previous reporting periods.

d) An identification of any maintenance works needed, proposed or undertaken to ensure compliance with these Conditions of Consent.

e) An identification of any improvements or changes required and the timetable for implementation.

7.2 Discharge of Treated Wastewater to Land

a) The volume of treated wastewater applied to each of the Areas 1 – 3 (as shown at Plan Consent No A in Appendix 1 to these conditions of consent) in the Reporting Period.

b) A summary and analysis (including graphical and statistical representations) of all data collected as a requirement of the Specific Conditions applicable to the discharge consent to discharge treated wastewater to land.

c) A record and discussion of any complaints received regarding the discharge to land and the consent holder's response to those complaints.

d) An analysis of any environmental effects, positive, neutral and adverse, which are attributable to the discharge of treated wastewater to land.

7.3 Discharge of Odour

a) Identification and discussion of any complaints received with respect to odour as per Condition 42 of the Discharge Permit to Air and any action taken to address the complaints.

b) The measurements of Dissolved Oxygen (DO) concentrations as per Conditions 44 and 45 of the Discharge Permit to Air.

c) An analysis of the data in terms of consent compliance and environmental effects.

d) A discussion of any relevant operational changes or improvements carried out during the Reporting Period.

e) A comparison of results in the Reporting Period to previous reporting periods and a discussion of any trends.

f) Any complaints received in regard to the operation of the BSTP and the action(s) taken to address each complaint.

7.4 Wastewater Monitoring and Benthic and Water Quality Monitoring

a) A summary of all the monitoring data collected as a requirement of the conditions of the discharge permit to discharge treated wastewater to the Wairau Estuary during the Reporting Period.

b) An analysis of the data in terms of consent compliance and environmental effects during the Reporting Period.

c) A discussion of any relevant operational changes or improvements carried out during the Reporting Period.

d) A comparison of results with previous years and a discussion of any trends during the Reporting Period.

e) Any complaints received in regard to the operation of the BSTP and the action(s) taken to address each complaint.

7.5 Outfall Pipelines

a) A record of any maintenance works undertaken in accordance with Condition 52 of the Coastal Permit for the new and existing outfall pipelines.

8. With the agreement of the residents around the BSTP the Consent Holder shall set up a Community Liaison Group (CLG) which will consist of representatives of the community of residents affected by the BTSP who wish to participate and representatives of the Consent Holder. The CLG will meet every six months for the first two years following the commencement of these consents and, thereafter, at times to be agreed by the parties. The CLG's administration costs, including the taking and distribution of minutes, will be the responsibility of the Consent Holder.

9. All water and wastewater samples required to be taken under these Conditions of Consent shall be analysed in accordance with Standard Methods for the Examination of Water and Wastewater prepared and published by the American Public Health Association, the American Waterworks Association and the Water Environment Federation or any other suitable and comparable methodology approved by the Consent Authority.

10. Any laboratory carrying out analyses required under these Conditions of Consent shall be accredited for those analyses to NZS/ISO/IEC/17025 or equivalent, or to any other comparable standard approved by the Consent Authority.

11. The Consent Holder shall undertake a Performance Review of the BSTP five years after the commencement of the consents. The Performance Review shall include, but not be limited to:
   a) compliance with consent conditions
   b) analysis and conclusion of monitoring results
   c) other available treatment technologies that may be options for the future

12. The Consent Holder shall undertake a Best Practice and further Performance Review of the BSTP ten years after the commencement of the consents. The Best Practice Review shall include, but not be limited to, research of available treatment technologies that would enable the removal of the discharge to the Wairau Estuary and improve the quality of the discharge.

13. The Consent Authority may review these Conditions of Consent by serving notice in September or October of any year for any of the following purposes:
   a) To deal with any adverse effect on the environment which may arise from the exercise of these consents, which was not foreseen at the time of the granting of the consents.
   b) To require the consent holder to adopt the best practicable option to remove or reduce any adverse effect on the environment.
   c) To address any matters raised in the AMR required by General Condition 7.
   d) To comply with the relevant requirements of a Council resource management plan.
   e) To implement any outcomes of the Performance and Best Practice Reviews required under Conditions 11 and 12.

14. The Consent Holder shall be responsible for all costs associated with the monitoring of these resource consents and Conditions of Consent as required by Section 36 of the Resource Management Act 1991 and Marlborough District Council's Schedule of Fees.

15. The Consent Holder shall be responsible for all costs incurred by the Consent Authority associated with the review of or requested changes to any Management Plans which form part of this consent.

16. A copy of all resource consents granted under U071181, including conditions imposed, shall be readily available at Marlborough District Council's office building.

PART III: SPECIFIC CONDITIONS

A. Applicable to Land Use Consent to disturb land, clear indigenous vegetation and excavate land for the purposes of constructing a wetland, an outfall pipeline, sludge ponds and drying beds.

17. This consent will have a term of three years from the date this consent commences.

18. The works the subject of this consent shall be undertaken in terms of Plan Consent No C in Appendix 1 to these conditions of consent.

19. The Consent Holder shall notify the Manager, Regulatory Department, Marlborough District Council, in writing of the proposed date of commencement of the construction works, at least 1 week prior to the start date of the works.

B Applicable to Land Use Consent use land for the purpose of disposing of treated wastewater to land

Advisory Note: There are no special conditions for this land use consent.

C Applicable to Discharge Consent to discharge treated wastewater to land

20. This consent will have a term of fifteen years from the date this consent commences.

21. The discharge shall only be of treated wastewater from the BTSP taken from the outlet of Pond 6, or from any point between Pond 6 and the outlet of Pond 10.

22. The discharge of wastewater to land shall be via drip irrigation or spray irrigation in the areas shown on Plan Consent No A. Only surface or subsurface drip irrigation shall be used within 25 metres of the site boundary and public walking tracks, except that on the western boundary adjoining neighbouring land, only surface or subsurface drip irrigation shall be used within 80 metres of the site boundary. For all other areas of the site, spray irrigation may be used.

23. The treated wastewater shall only be applied to the land using a deficit irrigation management regime. Deficit irrigation is defined as irrigation of a depth of wastewater that does not exceed the soil moisture deficit at the time of application. The soil moisture deficit shall be calculated in accordance with the Wastewater Irrigation Management Plan (IMP). The Consent Holder shall maintain records of rainfall and evapotranspiration that shall be made available to the Manager, Regulatory Department, Marlborough District Council, on request and which must be summarised in the AMR required by Condition 7.

24. The following net Nitrogen Loading Limits shall be observed:
    a) The maximum annual application of nitrogen shall not exceed a net loading of 200 kilograms of nitrogen per hectare per year.
    b) Monthly applications shall not exceed a net loading of 50 kilograms of nitrogen per hectare.
    c) Net loadings shall be calculated by taking into account the amounts of nitrogen contained in the pasture removed from the Irrigation Areas 1-3 of the site.

25. Spray irrigation shall not commence within 150 metres of adjacent property boundaries until the buffer planting required by the Buffer Planting Plan has grown to a height of at least 2 metres.

26. Spray irrigation of wastewater shall not occur within 10 metres of flowing surface water. Drip irrigation of wastewater shall not occur within 3 metres of flowing surface water.

27. Records shall be maintained of: the area of land used in each discharge event; the date, time and duration of the event; the wind speed and direction; and the wastewater application rate and dry matter quantities removed from specific areas and associated nitrogen content. A copy of these records shall be made available to

the Manager, Regulatory Department, Marlborough District Council, on request. A summary of this data shall be provided in the AMR required by Condition 7.

28. Groundwater shall be sampled monthly for a minimum of six months prior to commissioning of the irrigation system. Groundwater shall be sampled from the wells shown on Plan Consent No B in Appendix 1 to these conditions of consent. The samples shall be analysed for:

a) Ammoniacal nitrogen.

b) Nitrate nitrogen.

c) Conductivity.

d) *E-coli.*

The water level in each bore shall be measured and recorded at the time the sample is taken.

29. Groundwater shall be sampled monthly while irrigation is occurring in each area identified in Plan Consent No A in Appendix 1 to these conditions of consent, except that if irrigation has occurred for less than 14 days in the previous month no sampling is required. For each Irrigation Area, the wells identified within that area shown on Plan Consent No B attached in Appendix 1 to these conditions of consent, shall be sampled. The samples shall be analysed for:

a) Ammoniacal nitrogen.

b) Nitrate nitrogen.

c) Conductivity.

d) *E-coli.*

The water level in each bore shall be measured and recorded at the time the sample is taken.

30. The groundwater level in the wells shown on Plan Consent No B attached in Appendix 1 to these conditions of consent shall be monitored prior to wastewater irrigation commencing and at least fortnightly thereafter while irrigation is occurring. If the groundwater level measured in any monitoring well, for a particular irrigation area, is closer than 0.3 metres from the ground surface, irrigation shall cease in that area. Irrigation shall not recommence until the groundwater level is greater than 0.3 metres below the ground surface.

31. The potable water in well P28/4446 and one well on Lot 2 DP12207 shall be monitored as follows:

a) A sample of water shall be taken from well P28/4446, within 30 days of wastewater irrigation commencing in Area 3 south of Hardings Road or Area 1 north of Hardings Road.

b) A sample of water shall be taken from one potable supply well on Lot 2 DP12207, within 30 days of wastewater irrigation commencing in Area 1 north of Hardings Road.

c) Sampling of both wells shall continue at monthly intervals during the wastewater irrigation season with a final sample being taken no later than 30 days after wastewater irrigation ceases each season.

d) Samplying shall continue for a period of 5 years after wastewater irrigation commences. If *E.coli* are detected then the sampling shall continue for a further 5 years from that time.

e) The samples shall be tested for *E.coli.* If *E.coli* are detected:

(i) The Consent Holder shall immediately advise the well owner and the Manager, Regulatory Department, Marlborough District Council. A further sample shall be taken and tested for *E.coli* within 5 working days.

(ii) The Consent Holder shall undertake an investigation into the likely causes of contamination and any measures recommended to avoid further contamination. Within 14 days of the first sample the Consent Holder shall provide a written report on the investigation to the well owner and the Manager, Regulatory Department, Marlborough District Council.

32 Prior to commencing the discharge;

a) A weather station shall be installed at the office building shown on Plan Consent No B attached in Appendix 1 to these conditions of consent. The weather station shall measure and record windspeed and direction and rainfall and have sufficient instrumentation to allow the calculation of evapotranspiration. The wind speed and direction recorded at the weather station shall be deemed to represent the wind speed and direction for Irrigation Area 1.

b) An anemometer and wind vane shall be installed at each of the two locations shown on Plan Consent No B attached in Appendix 1 to these conditions of consent. The anemometers and wind vanes shall measure and record wind speed and direction. The wind speed and direction recorded shall be deemed to represent the wind speed and direction for Irrigation Areas 2 and 3 respectively.

c) The weather station, anemometers and wind vanes shall be maintained in an operational condition throughout the term of this consent.

33. Spray irrigation shall cease within 150 metres of the adjacent property boundaries as shown on Plan Consent No B attached in Appendix 1 to these conditions of consent for each Irrigation Area when the wind speed exceeds 15 kilometres per hour (as an average over 15 minutes) in the direction of the adjacent property boundaries as recorded at the respective weather recording device for that Irrigation Area. Drip irrigation may continue in such circumstances.

34. Treated wastewater shall only be applied to land at a rate such that ponding for a period greater than 12 hours does not occur.

35. The Consent Holder shall maintain a register of any complaints received relating to any aspect of the land discharge system. The record shall include the date and time of complaint, cause of the complaint, weather conditions at the time of complaint and action taken in response to the complaint. The register shall be made available to the Manager, Regulatory Department, Marlborough District Council, on request. A summary of complaints received by the consent holder shall be included in the AMR required by Condition 7.

36 For the duration of these consents, the Consent Holder shall install and maintain appropriate signage on any access points to the BSTP warning that partially treated wastewater is discharged to the land. Written confirmation of the signage wording, size and placement shall be provided to the Manager, Regulatory Department, Marlborough District Council, within three months of the commencement of this consent.

D. Applicable to Discharge Consent to discharge seepage from treatment ponds, wetlands, sludge ponds and drying beds.

37. The discharge the subject of this consent is limited to discharge from the base of the treatment ponds, the base of the wetlands and the base of the sludge ponds and drying beds.

38. The discharge shall only be exercised to the extent that it does not cause flooding or ponding on adjoining ground surfaces.

E. Applicable to Discharge Consent to discharge odour to air from treatment ponds, wetlands, sludge ponds and drying beds and from the land used for the disposal of treated wastewater.

39. The Consent Holder shall take all practicable steps to minimise the potential for generation of objectionable or offensive odour that causes an adverse effect at the legal boundary of any property adjoining the consent site.

40. For the purpose of monitoring compliance with Condition 39, an objectionable or offensive odour that causes an adverse effect is considered to have occurred if the Manager, Regulatory Department, Marlborough District Council, deems it so, applying the FIDOL (frequency, intensity, duration, offensiveness and location) criteria as set out in the Good Practice Guide for Assessing and Managing Odour in New Zealand (Ministry for Environment, 2003).

41. The Consent Holder shall respond as quickly as practicable to any complaints about odour and shall take all practicable measures to minimise the odour and prevent reoccurrence.

42. Any complaints received in regard to odour shall be recorded in a Complaints Register specifying the complaint, time and date, weather conditions and action required. A copy of the complaints shall be made available to the Manager, Regulatory Department, Marlborough District Council, on request. A summary of these complaints shall be part of the AMR required by Condition 7 of these Conditions of Consent.

43. Should an event occur which results in an objectionable or offensive odour at the boundary of any property, the Manager, Regulatory Department, Marlborough District Council, may request the Consent Holder to provide a written report within 15 days of the request being made, specifying:
    a) The cause or likely cause of the event and any factors which influenced its severity.
    b) The nature and timing of any measures implemented by the consent holder to avoid, remedy or mitigate any adverse effects.
    c) The steps to be taken, if any, in the future to prevent a recurrence of similar events.

44. The Consent Holder shall measure the Dissolved Oxygen (DO) concentrations in the wastewater near the outlet of Ponds 2A, 2B, 2C, 6 and 10 every Wednesday, except when a Wednesday falls on a public holiday, when the measurement shall be taken on the nearest following working day. The DO concentration shall be measured between 11am and 2pm and shall not be less than 2 grams of DO per cubic metre, on a rolling 10 percentile weekly measurement basis.

45. The DO of the wastewater in Ponds I1 and I2 shall be measured daily between 11am and 2pm during peak loading periods associated with the annual vintage, with DO concentrations maintained at not less than 0.5 grams per cubic metre on a 50 percentile basis. The time of the peak loading periods shall be determined by consultation between the Consent Holder and the Manager, Regulatory Department, Marlborough District Council. The results of the measurements shall be included in the AMR required by Condition 7.

F. Applicable to Discharge Consent to discharge treated wastewater to the Opawa River.

46. This consent shall have a term of three years from the date the consent commences.

47. The conditions of consent U961050.6 as shown in Appendix 2 to these conditions of consent will remain in force and will apply to this consent until the wetland is established and the new outfall pipeline is completed so that the Opawa outfall is able to be decommissioned.

G. Applicable to Coastal Permit to:

a) use and maintain an existing outfall pipeline and a new outfall pipeline in the Coastal Marine Area of the Wairau Estuary

b) occupy space in the Coastal Marine Area of the Wairau Estuary with an existing outfall pipeline and a new outfall pipeline

c) discharge treated wastewater to the Wairau Estuary that has passed through a wetland (Pond 10)

Advice Note: *This coastal Permit does not authorise the discharge of wastewater from the existing outfall pipeline where that wastewater has not passed through the new wetland (Pond 10). That discharge is authorised under existing discharge consent U950167.1 which expires on 1 October 2011.*

48. This consent shall have a term of fifteen years from the date that it commences.

49 The outfall pipelines shall be located in general accordance with Plan Consent No C attached in Appendix 1 to these conditions of consent with the outlets at about NZMG E 2,598,349 NZMG N 5,966,313.

50. The outfall pipelines shall be maintained in an operational condition at all times.

51. The Consent Holder shall undertake annual external visual inspections of the outfall pipeline structures for the duration of the consent. A report shall be submitted to the Manager, Regulatory Department, Marlborough District Council, within 20 working days of the inspection being carried out. The report shall include but not be limited to:

a) The date and time of the inspection.

b) The condition of the outfall structures.

c) Any maintenance work that may be required, and if it is required, when the work will be carried out.

52. Should the report required by Condition 51 identify the requirement for maintenance, confirmation of the completion of the works shall be forwarded to the Manager, Regulatory Department, Marlborough District Council, within twenty working days of the completion of the works.

53. The outfall pipelines shall not interfere with any public right of navigation.

54. The existing buoy marking the location of the end of the existing outfall shall be marked with the words *Sewer Outfall* and the lettering used shall be bold and clear such that it can easily be read from a distance of 10 metres.

55. The total discharge of treated wastewater authorised by this consent shall not exceed an average daily volume of 28,500 cubic metres, where the average volume is calculated on a continuous basis over a period of 365 consecutive days. The maximum discharge volume per day shall not exceed 103,680 cubic metres.

56. The Consent Holder shall install flow measuring devices after the outlet from wetland Pond 10 and Pond 6 (as shown on Plan Consent No C attached in Appendix 1 to these conditions of consent) and record the daily volume of treated wastewater discharged to the Wairau Estuary. A copy of these records shall be made available to the Manager, Regulatory Department, Marlborough District Council, on request. A summary of this data shall be provided in the AMR required by Condition 7.

57. The discharge of treated wastewater shall generally take place over a four hour period, commencing one hour after high tide, except that longer discharge periods may be used after a prolonged wet weather event when peak wastewater flows and/or high rainfall cause the storage capacity of the ponds/wetland to be exceeded.

58. The proposed mixing zone for the discharge to the Wairau Estuary shall be as shown on Plan No D in Appendix 1 to these conditions of consent.

59. The discharge of treated wastewater from the upgraded BSTP shall not cause any of the following effects outside the mixing zone described in Condition 58 above:
    a) The natural temperature of the receiving water to change by more than 3 degrees Celsius;
    b) Any conspicuous change in colour or clarity of the receiving water such that visual clarity of water is reduced by more than 50% as per the Water Quality Guidelines No 2 Ministry for the Environment (1994);
    c) The concentration of dissolved oxygen of the receiving water to fall below 80 percent of the saturation content.

60. There shall be no undesirable biological growths as a result of the discharge.

Wastewater Monitoring

61. The Consent Holder shall take grab samples of treated wastewater at the outlet of Pond 10 following commissioning of the new wetland. Samples shall be analysed for the parameters and frequency shown in Table 1. The results shall be reported in the AMP required by Condition 7.

62. The treated wastewater sampled under Condition 61 shall comply on an annual basis with the ammonical nitrogen and faecal coliform limits listed in Table 2.

Table 1: Monitoring Parameters

Parameter	Unit	Frequency of Analysis
Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)	g/m^3	Monthly
Suspended Solids (SS)	g/m^3	Monthly
Faecal Coliforms and Enterococci	cfu/100ml	Monthly
Ammoniacal Nitrogen (NH_3-N)	g/m^3	Monthly
Total Nitrogen (TN)	g/m^3	Monthly
Dissolved Inorganic Nitrogen (DIN)	g/m^3	Monthly
Dissolved Reactive Phosphorus (DRP)	g/m^3	Monthly
Total Phosphorus (TP)	g/m^3	Monthly
pH	pH units	Monthly
Temperature	°Celsius	Monthly
Metals/metalloids: arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc	g/m^3	Annually

Table 2: Wastewater Limits

Parameter	Unit	Median		90 Percentile	
		Estimated Existing Flow	Future Design Flow	Estimated Existing Flow	Future Design Flow
Ammoniacal Nitrogen (NH_3-N)	g/m^3	30	15	40	20
Faecal coliforms	cfu/100 ml	700	350	2150	1075

Advice Note: *The future design flows are an average daily volume of 28,500 cubic metres and to meet the limits the initial dilution has been calculated as 25:1. When lower flows are being discharged, the wastewater concentration limits can be increased after discharge based on a back calculation from the assessed initial dilution. The Cawthron Institute (Technical Report on Effects of Outfall Discharge in Appendix D of Assessment of Effects for Upgrading of Blenheim Sewage Treatment Plant, September 2007) has determined that an initial dilution of 50:1 can be achieved at an average daily volume of 14,250 cubic metres (estimated existing flow).*

Table 3: Benthic Survey Parameters

Station Location			Replicates per Station		
Station Code	**NZMG E (m)**	**NMG N (m)**	**Infauna**	**Sediment Chemistry**	**Shellfish**
OF P	2,598,336	5,966,320	3	4	1[a]
25DS P	2,598,350	5,966,340	3	4	1
50DS P	2,598,357	5,966,361	3	4	1
100DS P	2,598,404	5,966,466	3	4	1
200DS P	2,598,476	5,966,466	3	4	1
300DS P	2,598,539	5,966,546	3	4	1
OF O	2,598,326	5,966,314	3	4	1[a]
25DS O	2,598,353	5,966,301	3	4	1
50DS O	2,598,335	5,966,368	3	4	1
100DS O	2,598,361	5,966,417	3	4	1
200DS O	2,598,434	5,966,500	3	4	1
300DS O	2,598,496	5,966,582	3	4	1[a]

Key:

OF Outfall
DS Downstream
P Plume
O Outside (of the plume)

a No target species of shellfish found at this station during 2006 survey

Receiving Environment Monitoring

63. The Consent Holder shall carry out benthic surveys and water quality monitoring in the receiving environment to identify changes (notably adverse ecological impacts), as a result of the treated wastewater discharge. The survey design shall be consistent with the survey conducted by the Cawthron Institute (Technical Report on Effects of Outfall Discharge in Appendix D of Assessment of Environmental Effects for Upgrading of Blenheim Sewerage Treatment Plant, September 2007).

Benthic Survey

64. A benthic survey shall be carried out in accordance with the station designation, locations, and replication as set out in Table 3:
    a) Within two years of commissioning the new outfall pipeline, but not less than 12 months after commissioning.
    b) Within four years of commissioning the new outfall pipeline, but not less than three years after commissioning.
    c) Thereafter at five yearly intervals.

65. Twelve stations (six pairs, located both inside and outside the wastewater plume) shall be sampled at discreet distances (i.e. <5m, 25m, 50m, 100m, 200m and 300m) downstream from the discharge.
    a) Infauna shall be collected via 13 cm diameter cores (approx 10 cm depth) and samples shall be processed using a 0.5 mm sieve with taxa collected counted and identified to the lowest practicable taxonomic level.
    b) Sediment samples shall be collected via 6 cm (minimum) diameter cores manually driven into the benthic sediments to a depth of 10-15 cm. The colour and the visible presence/absence of any anoxic patches or layers within the cores shall be recorded. One of the four replicate cores per station shall be split and photographed to provide a permanent visual record. The top 5 cm of the remaining three cores shall be sub-sampled for analysis of the following:
        i) Sediment texture – particle grain size distribution
        ii) Organic content (total organic carbon or ash-free dry weight)
        iii) Metals/Metalloids – arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), and zinc (Zn)

66. Where present, 15-20 shellfish of the target species *Paphies austral* (pipi) shall be collected and composite tissue samples analysed for faecal coliforms and trace metals/metalloids (As, Cd, Cr, Cu, Hg, Pb, Ni, Zn).

Water Quality

67. At the same time as the seabed surveys, near surface (within 1m) and near-bottom (within 1m) water quality samples shall be taken at the following sites during the ebb tide discharge: 300-550 metres upstream of the discharge; at the downstream edge of the mixing zone (300 metres downstream of the discharge) and at the bar entrance (500-600 metres downstream).

68. The water quality at each site shall be visually assessed for:
    a) Scums, foams and other floatable material
    b) Conspicuous changes in colour or clarity

69. Water quality samples shall be taken and tested for the following:
   a) Presence of any objectionable odour
   b) Biochemical oxygen demand (BOD), total suspended solids (TSS), faecal coliforms, Enterococci, and trace metals/metalloids (As, Cd, Cr, Cu, Hg, Pb, Ni, Zn).
   c) Nutrients (Total-N, Ammonical-N, Dissolved reactive phosphorus)
   d) Standard hydrological parameters (pH, temperature, dissolved oxygen, salinity and turbidity)

70. The Consent Holder shall forward a record of the outcomes of Conditions 63 to 69 to the Manager, Regulatory Department, Marlborough District Council, within one month of the analysis of the monitoring being completed.

Iwi Liaison

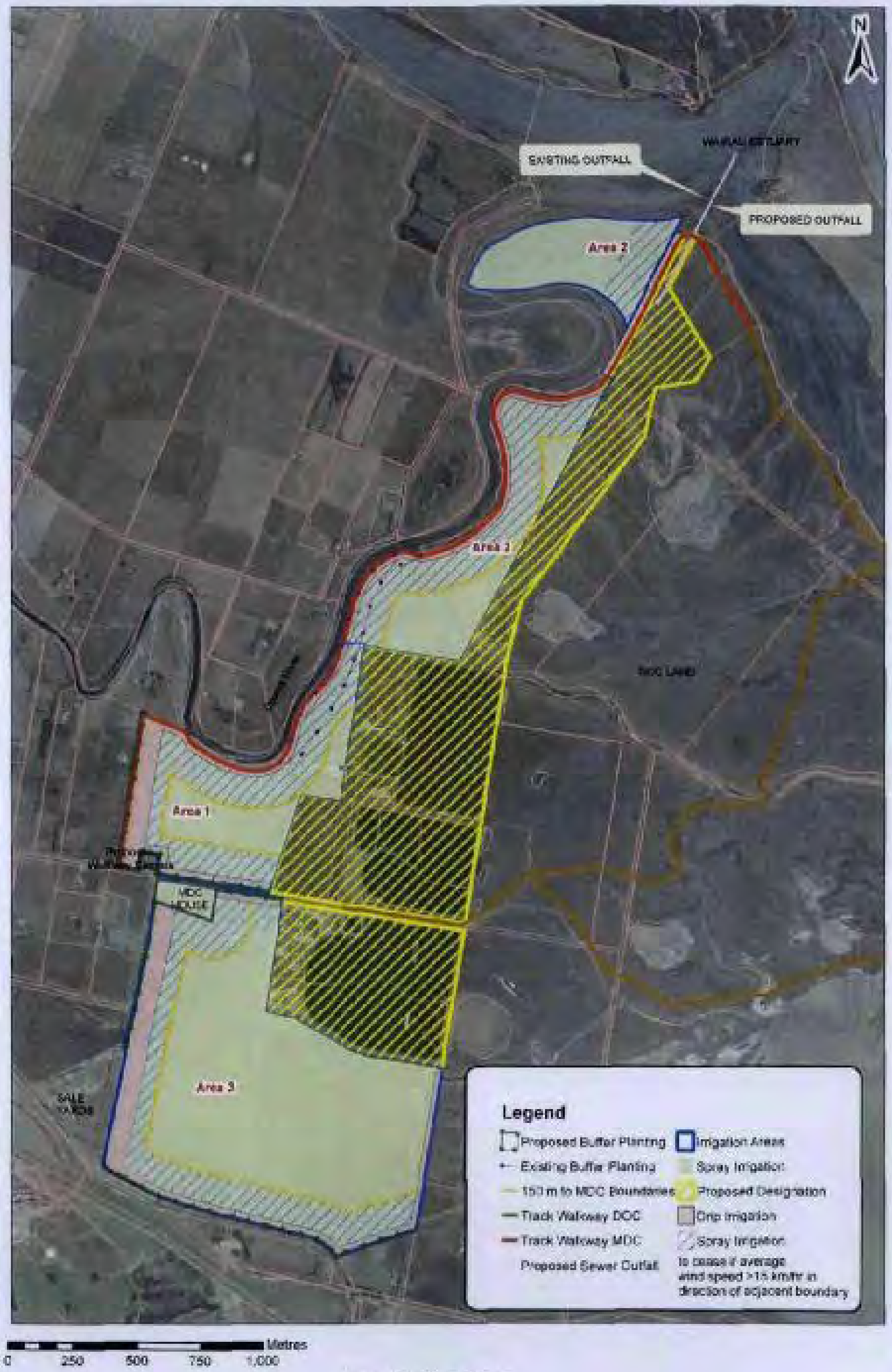
71. The Consent Holder shall make a senior Marlborough District Council representative available to meet with Ngati Toa, Ngati Rarua and Rangitane at six monthly intervals throughout the duration of the consent, to review treatment plant performance, including the results of any monitoring.

Changes/Modifications

72. Any changes in the scope, frequency or timing of the monitoring programme identified as being necessary by the Consent Authority shall be addressed in the course of any review of conditions initiated by the Consent Authority under Section 128 of the RMA, as contemplated by Condition 13.

Appendix 1

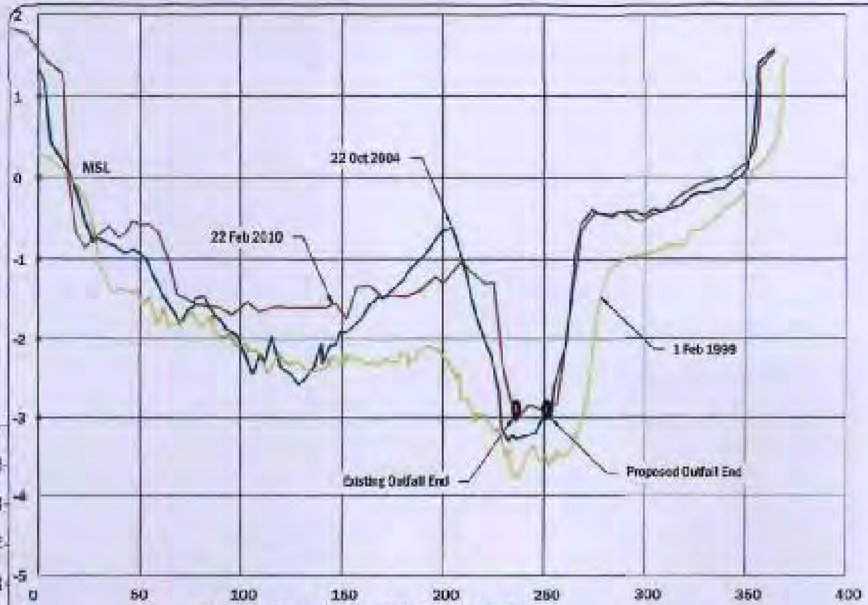
Plan Consent No A
Plan Consent No B
Plan Consent No C
Plan Consent No D



PLAN CONSENT NO A

PLAN CONSENT NO B

PLAN CONSENT NO. C



Cross Section WR XS 0.4

Plan : Cross Section WR XS 0.4 Scale 1:2000

Plan : Zone of Reasonable Mixing

Scale 1:4000

Station Code	NZMG E	NZMG N
OFP	2,598,349	5,966,313
25D SP	2,598,367	5,966,331
50D SP	2,598,384	5,966,349
100D SP	2,598,418	5,966,386
200D SP	2,598,460	5,966,462
300D SP	2,598,538	5,966,546
OFO	2,598,308	5,966,346
25D SO	2,598,324	5,966,365
50D SO	2,598,339	5,966,385
100D SO	2,598,370	5,966,424
200D SO	2,598,434	5,966,500
300D SO	2,598,486	5,966,582

MARLBOROUGH DISTRICT COUNCIL
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TEL (03) 520-7400, FAX (03) 520-7496

Blenheim Sewerage
BSTP
Wairau Estuary Outfall and Cross Section

Rev	Date		Revision
A	31/5/10	SOs	For Resource Consent

As Shown

A3

2/604

Plan Consent No. D

Appendix B

Annual Inspection of the MDC Wairau Bar Effluent Pipeline

n-Viro® MOORING SYSTEMS

12 Kent Street PICTON 7220 New Zealand

Phone: 03 573 8045
Fax: 03 573 8991
Website: www.n-viro.com
Email: donna@nviro.com

Annual Inspection of the NEW MDC Wairau Bar Effluent Pipeline

31 January 2018 **ON:WO-041701RAD**

- **Pipeline condition: Nozzle is only part exposed from the river bed**

- **Nozzle condition: Zero visibility, diver working by feel, reports it feels okay**

- **Buoy condition: Fitted the refurbished buoy that had broken away from its mooring and had been washed up on the beach**

- **Small chain condition: Replaced 6m x 12mm of new galvanised chain**

- **Shackle condition: Replaced 2x new shackles and 1x anode**

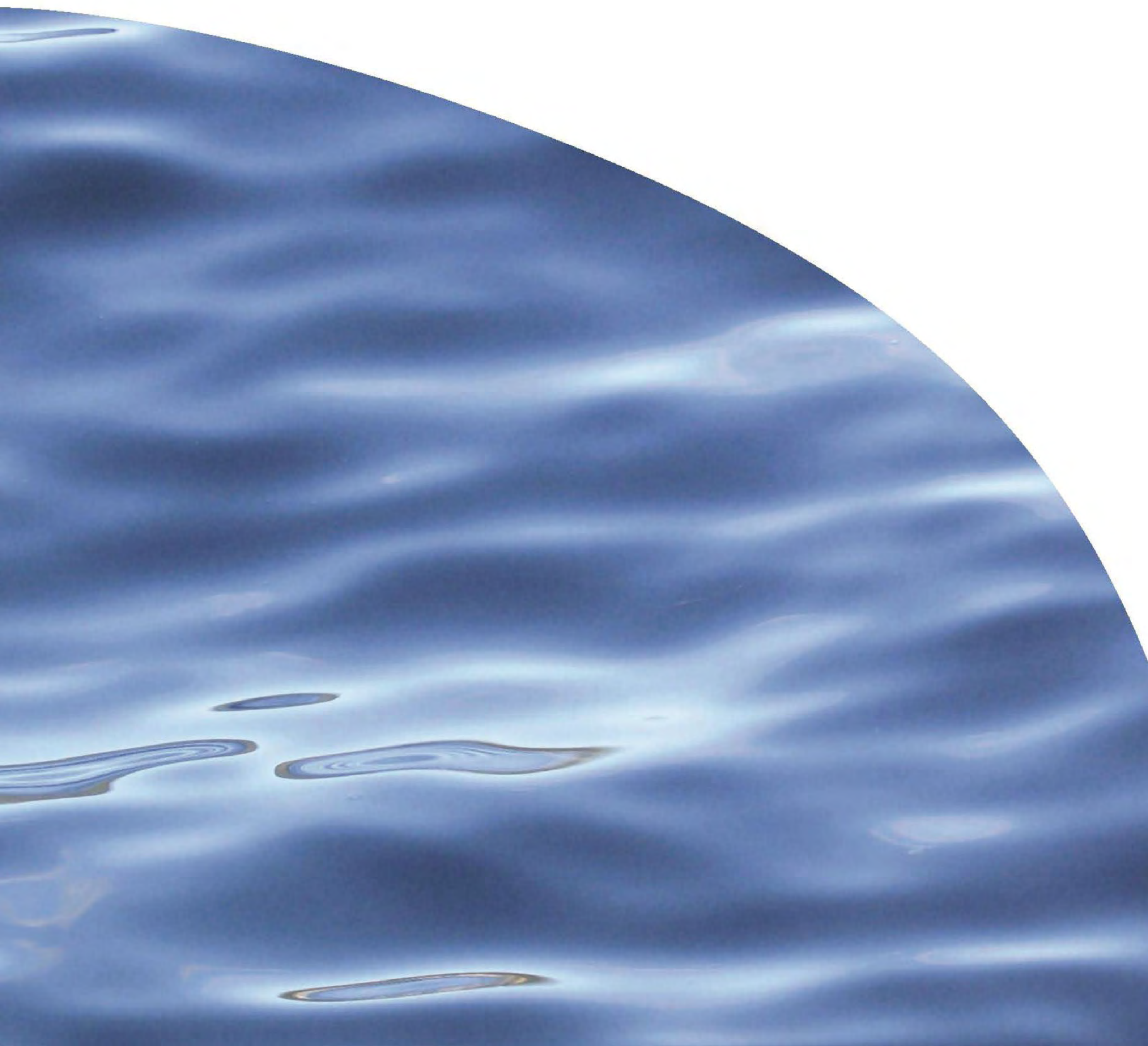
- **Visibility: Visibility at the buoy was good above water but water visibility zero**

Appendix C

Benthic Survey

REPORT NO. 3162

BLENHEIM SEWAGE TREATMENT PLANT RECEIVING-ENVIRONMENT MONITORING 2018



BLENHEIM SEWAGE TREATMENT PLANT RECEIVING-ENVIRONMENT MONITORING 2018

DON MORRISEY

Prepared for Marlborough District Council

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EXECUTIVE SUMMARY

The Blenheim Sewerage Treatment Plant (BSTP) is owned and operated by the Marlborough District Council (MDC) and treats residential and commercial wastewater from the Blenheim urban area, as well as from some nearby industries.

In 2010 the MDC was granted resource consent for the upgrade and operation of the BSTP and the upgrade was completed in 2014. Consent conditions require benthic and water-quality monitoring surveys of the receiving environment of the wastewater discharge in the Wairau Estuary. Monitoring shall be done within two years (but not less than 12 months) of commissioning of the new outfall pipeline, within four years (but not less than three years) of commissioning, and at five-yearly intervals thereafter. The consent requires for any changes, notably adverse ecological impacts, as a result of the treated wastewater discharge to be identified.

The Cawthron Institute was commissioned to carry out the second round of monitoring (within four years of commissioning) and the benthic and water-quality surveys were done in late January 2018.

Summary of results

- Some minor environmental and ecological differences were apparent between the 2006, 2016 and 2018 surveys.
- No adverse ecological effects of the BSTP discharge (and no breaches of the water quality consent conditions) were detected.
- To date, the quality of the discharge, its release on the ebb tide, and rapid tidal flushing around the outfall have prevented any unacceptable ecological effects.

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1. INTRODUCTION

The Blenheim Sewerage Treatment Plant (BSTP) is owned and operated by the Marlborough District Council (MDC) and treats residential and commercial wastewater from the Blenheim urban area, as well as from some nearby industries. In 2010 the MDC was granted resource consent (U071181) for the upgrade and operation of the BSTP. Prior to the granting of this consent, Cawthron Institute (Cawthron) produced a technical report on effects of outfall discharge as a component of an assessment of environmental effects (Appendix D of CH2M Beca 2007, referenced as Barter et al. 2006).

The upgrade was completed in February 2014 and included the construction of a series of wetland cells. The combined treated flows are conveyed by these cells from the domestic and industrial pond systems to a new outfall in the Wairau Estuary (CH2M Beca 2014). Consent conditions G63 through 69 (Part II) require benthic and water-quality surveys in the receiving environment to identify changes, notably adverse ecological impacts, caused by the treated wastewater discharge. Consent conditions G59 and G60 (Part II) also outline conditions relating to water quality and biological growths in relation to the discharge (Appendix 1). The survey design is to be consistent with that of Barter et al. (2006) and the first two rounds of monitoring are required to be undertaken within 12–24 and 36–48 months of commissioning of the new outfall pipeline. The first round was completed in January-February 2016 and the results reported by Berthelsen & Morrisey (2016). The second round was completed in January 2018 and the results are presented in this report.

1.1. Report scope and objectives

Cawthron was commissioned to undertake monitoring of the BSTP receiving environment by early February 2018. The scope of this work was to:

- undertake **benthic surveys** at twelve stations (six pairs, located inside and outside the wastewater plume) at specified distances downstream of the outfall. Benthic surveys to include monitoring of the following:
    - infaunal communities
    - shellfish contamination
    - sediment characteristics and contamination
- undertake near-surface and near-bed **water quality sampling** at three stations at specified distances from the outfall during the ebb tidal discharge
- **report** the results and contrast them with those of Barter et al. (2006) and Berthelsen & Morrisey (2016). Include the identification of any adverse ecological impacts or other change related to the treated wastewater discharge.

2. METHODS

All fieldwork was undertaken on 22 and 23 January 2018. The sampling methods for benthic surveys and water sampling are outlined below; however, Barter et al. (2006) can be referred to for further details on the benthic surveys. Previous studies showed a narrow and consistent pattern in the location of the effluent plume which allowed the side-by-side comparison of the in-plume vs out-of-plume sampling approach adopted here.

2.1. Subtidal benthic surveys

2.1.1. Survey stations

Benthic surveys were conducted at six distances (< 5 m, 25 m, 50 m, 100 m, 200 m and 300 m) downstream of the outfall in the Wairau Estuary. At each distance, sampling was conducted at two different stations, one inside the wastewater discharge plume and one outside of the plume. In total twelve stations were sampled (Figure 1, Appendix 2).

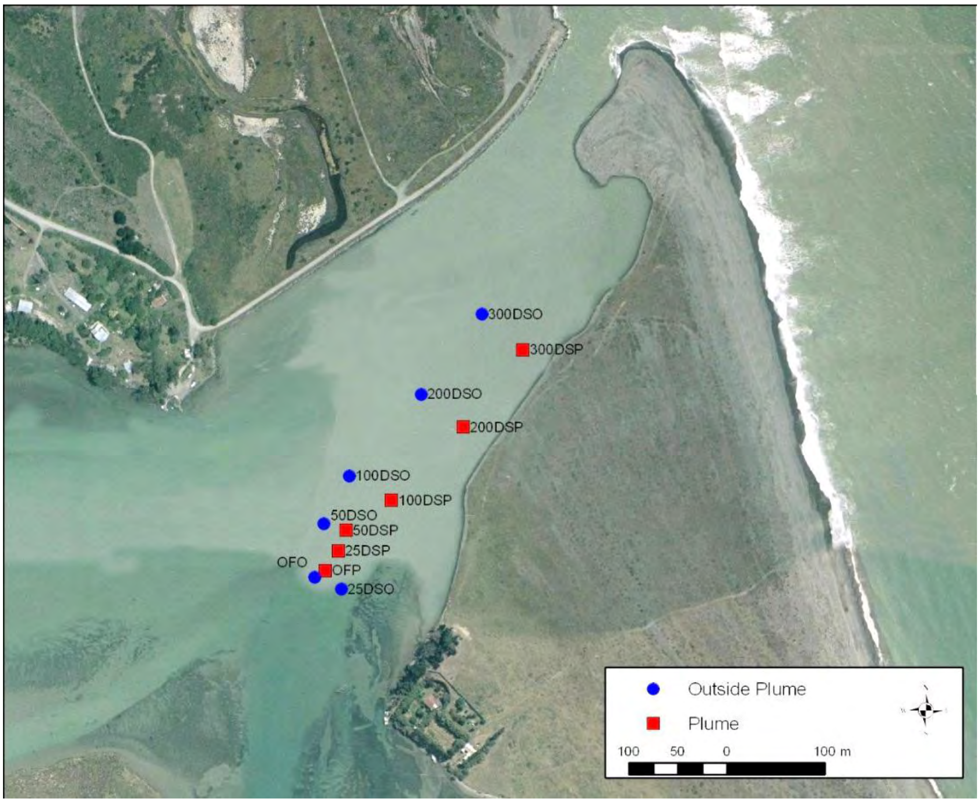


Figure 1. Location of the twelve subtidal ecology and sediment/shellfish quality stations downstream of the BSTP outfall in the Wairau Estuary, showing inside and outside plume sampling points for each station.

2.1.2. Sediment

Sediment samples (three replicate cores) were collected by SCUBA divers at each of the twelve stations (described above). The corers (60 mm in diameter) were driven manually into the sediment to a depth of between 10 and 15 cm, capped *in situ* and returned to the support vessel. Each sample was extruded from the corer and the colour profile, the presence or absence of anoxic patches within the sample, and depth of any apparent redox potential discontinuity (aRPD)[1] layer were all recorded. The cores were then photographed to provide a visual record. The top 5 cm of each core was subsampled to create two samples, one in which the replicates were composited for the analysis of trace metals/metalloids arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), zinc (Zn) and one for the analysis of particle grain size and organic content. The samples were placed into plastic bags and stored chilled until arrival at Hill Laboratories who conducted the analyses (Table 1).

Table 1. Summary of analytes and analytical methods used by Hill Laboratories for sediments.

Analyte	Method Description
Sediment grain size	Wet-sieved using dispersant, gravimetry (calculation by difference) Screen sizes: > 2 mm = Gravel < 2 mm to > 1 mm = Coarse Sand < 1 mm to > 500 µm = Medium Sand < 500 µm to > 250 µm = Medium/Fine Sand < 250 µm to > 125 µm = Fine Sand < 125 µm to > 63 µm = Very Fine Sand < 63 µm = Mud (Silt & Clay)
Organic Matter	Calculation: 100g–Ash (dry wt)
Trace metals/metalloids	Dried sample, < 2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level

Results of sediment chemical analyses were compared with national sediment quality guidelines (ANZECC 2000), where applicable. The Interim Sediment Quality Guideline-Low (ISQG-Low) and Interim Sediment Quality Guideline-High (ISQG-High) trigger values represent two distinct threshold levels above which biological effects are predicted. The lower threshold (ISQG-Low) indicates a *possible* biological effect and is intended as a trigger value for further investigation, while the upper threshold (ISQG-High) indicates a *probable* biological effect.

[1] The apparent redox potential discontinuity depth (aRPD) refers to the often distinct colour change, between surface and underlying sediments, brought about by the changing redox environment with depth in the profile. This gradient of colour change is in reality continuous but may be reduced to an average transition point (sediment depth) for descriptive purposes.

2.1.3. Infauna

Infauna were collected at each of the twelve stations in three replicate cores. PVC corers (130 mm diameter) were manually driven 100 mm into the sediments by divers, then the sediments were withdrawn and brought back to the support vessel where the cores were sieved through a 0.5-mm mesh. The sieve residue containing the infauna was preserved in 70% ethanol with 5% glyoxal as a fixative. Infauna were counted and identified to the lowest practicable level of taxonomic resolution.

Numbers of individuals and numbers of species were obtained for each sample and used to calculate the Shannon-Weiner diversity and Pielou’s evenness indices (Table 2). These indices are useful for comparisons between stations and with historical information.

Table 2. Description of infauna community indices.

Index	Description
Abundance (N)	Total number of individual organisms in a sample.
Species richness (S)	Total number of species in a sample.
Diversity (H’ $\log_e$)	Shannon-Wiener diversity index ($\log_e$ base). A diversity index that describes, in a single number, the different types and amounts of animals present in a collection. Varies with both the number of species and the relative distribution of individual organisms among the species. The index ranges from 0 for communities containing a single species to high values for communities containing many species with each represented by a small number of individuals.
Evenness (J’)	Pielou’s evenness. A measure of equitability, or how evenly the individuals are distributed among the different species. Values can theoretically range from 0.00 to 1.00, where a high value indicates an even distribution and a low value indicates an uneven distribution or dominance by a few taxa.

The infaunal assemblages at each station were compared using the multivariate method of non-metric multidimensional scaling ordination. Data were $\log_{(x+1)}$-transformed before analysis to reduce the influence of the dominant species (nMDS; Kruskal & Wish 1978). This strong transformation was used because the numbers of animals in samples were highly dominated by two taxa (see Section 3.2). This analysis compares replicate samples and groups them based on their faunal similarity —the more similar two samples are to each other, the closer they are placed in the plot. One-way similarity percentage analysis (SIMPER), using station as the factor and based on a 70% cut-off for low contributions, was used to identify taxa responsible for similarities among samples. All multivariate analyses were based on Bray-Curtis similarities and conducted using the software PRIMER v7 (Clarke et al. 2014; Clarke & Gorley 2015).

2.1.4. Shellfish

When present, approximately 15–22 pipi (*Paphies australis*) were collected manually by a diver from each station. The pipi were stored chilled until they were analysed for faecal coliforms and trace metals/metalloids (As, Cr, Cu, Hg, Ni, Pb, Zn) (Table 3).

Table 3. Summary of analytes and analytical methods used for shellfish.

Analyte	Laboratory	Method Description
Faecal coliforms	Cawthron Analytical Services	Compendium 4th edition 2001
Trace metals/metalloids	Hill Laboratories	Biological materials digestion, ICP-MS (Chromium also with dynamic reaction cell)

Concentrations of metals in shellfish were compared against the 2015 Australia New Zealand Food Standard Code: Standard 1.4.1, Contaminants and natural toxicants. (ANZFSC 2015). Shellfish bacteriological results were compared against the Ministry of Health Reference Criteria for Food (MOH 1995).

2.2. Water quality surveys

2.2.1. Survey stations

Water quality surveys were conducted at three stations: 400 m upstream of the discharge, at the downstream edge of the mixing zone 300 m downstream of the discharge, and at the bar entrance 550 m downstream of the discharge (Figure 2, Appendix 3).

Figure 2. Location of the three water quality sampling stations in the Wairau Estuary. Distances are in relation to the BSTP outfall.

2.2.2. Water quality

Two water samples, one within 1 m of the surface (near-surface) and one within 1 m of the seabed (near-bed), were collected during the ebb tide discharge at each of the three water quality survey stations. Water samples were collected using a vertically-mounted van Dorn sampler (2 L). Each water sample was split into two subsamples, one for analysis of faecal coliforms and enterococci by Cawthron Analytical Services and one for analysis of total suspended solids (TSS), biochemical oxygen demand (as BOD_5), total ammoniacal-N, dissolved reactive phosphorus and trace metals/metalloids by Hill Laboratories (Table 4). The salinity and pH of all water samples was measured in the field using a YSI Pro plus Multimeter (calibrated January 2018). One CTD (Conductivity Temperature Depth) instrument cast (using a Seabird SBE19plus V2) was also conducted from the surface to the bed and back at each of the water sampling stations to measure chlorophyll-*a*, light (as photosynthetically active radiation, PAR), salinity, temperature and turbidity. The CTD output was trimmed during post-processing to include downcast data only and to exclude data shallower than 1 m depth (where the data tend to be randomly noisy).

Table 4. Summary of analytes and analytical methods for water quality.

Analyte	Laboratory	Method Description
Faecal Coliforms	Cawthron Analytical Services	APHA Seawater Shellfish 4th Edn
Enterococci	Cawthron Analytical Services	APHA (online) 9230D
Total Arsenic Total Chromium Total Copper Total Zinc	Hill Laboratories	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultra-trace. APHA 3125 B 22nd ed. 2012.
Total Cadmium Total Lead	Hill Laboratories	Nitric acid digestion, ICP-MS, ultra-trace level. APHA 3125 B 22nd ed. 2012.
Total Mercury	Hill Laboratories	Bromine Oxidation followed by Atomic Fluorescence. US EPA Method 245.7, Feb 2005.
Total Nickel	Hill Laboratories	Nitric acid digestion, ICP-MS with universal cell, ultra-trace. APHA 3125 B 22nd ed. 2012.
Total Suspended Solids	Hill Laboratories	Saline sample. Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 22nd ed. 2012.
Total Nitrogen Digestion	Hill Laboratories	Caustic persulphate digestion. APHA 4500-N C 22nd ed. 2012
Total Ammoniacal-N	Hill Laboratories	Saline, filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH4-N = NH4+-N + NH3-N). APHA 4500-NH3 F (modified from manual analysis) 22nd ed. 2012.
Dissolved Reactive Phosphorus	Hill Laboratories	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 22nd ed. 2012.
Total Biochemical Oxygen Demand	Hill Laboratories	Incubation 5 days, DO meter, no nitrification inhibitor added, seeded. APHA 5210 B (modified) 22nd ed. 2012.

Values of water-quality variables were compared against ANZECC (2000) default trigger values for physical and chemical stressors, where these are available. These trigger values were designed for slightly disturbed south-east Australian estuaries and marine water (total nitrogen and total ammoniacal-N) and slightly-to-moderately disturbed marine water systems (metals/metalloids). Bacteriological results (faecal coliform and enterococci) for water were compared against ANZECC (2000) guidelines for primary and secondary contact as well as against (Ministry for the Environment's (MfE) (2003) guidelines for surveillance, alert and action modes. Water temperature, dissolved oxygen and visual clarity were compared against the relevant consent conditions for water quality of the BSTP discharge receiving environment.

3. RESULTS

3.1. Sediment

In the following results, benthic survey stations are described according to their distance downstream (DS) of the outfall (25, 50, 100, 200 and 300 m) with OF representing stations within < 5 m of the outfall. Position inside and outside of the plume are represented by P and O respectively.

3.1.1. Visual description of sediment cores

A 5-cm deep layer of soft silt was present over grey-brown sand at stations OFO, 25DSO, 50DSP and 100DSP. Terrestrial woody debris (twigs) was present at the interface between silt and sand at 25DSO and woody debris was also present in the sediment at 200DSP. At 300DSP there was a redox discontinuity at 5 cm below the sediment surface and a layer of macroalgal material and silt below this. None of the other stations showed a distinct discontinuity and sediments were generally grey or grey-brown (Appendix 4).

3.1.2. Physico-chemical properties of the sediment

There were no obvious patterns in sediment grain size in relation to distance from the outfall, or position inside and outside the discharge plume (Figure 3). Sediment cores from most stations were generally dominated by grains smaller than 0.5 mm (medium sand). Proportions of silt and clay particles (the smallest particle, < 0.063 mm) ranged between c. 4% at 25DSP, 100DSO, 200DSO and 200DSP and 54% at 100DSP. Coarse and very coarse sand were only present at 25DSO and 300DSO and gravel (> 2 mm, probably shell hash) was only present at 100DSO.

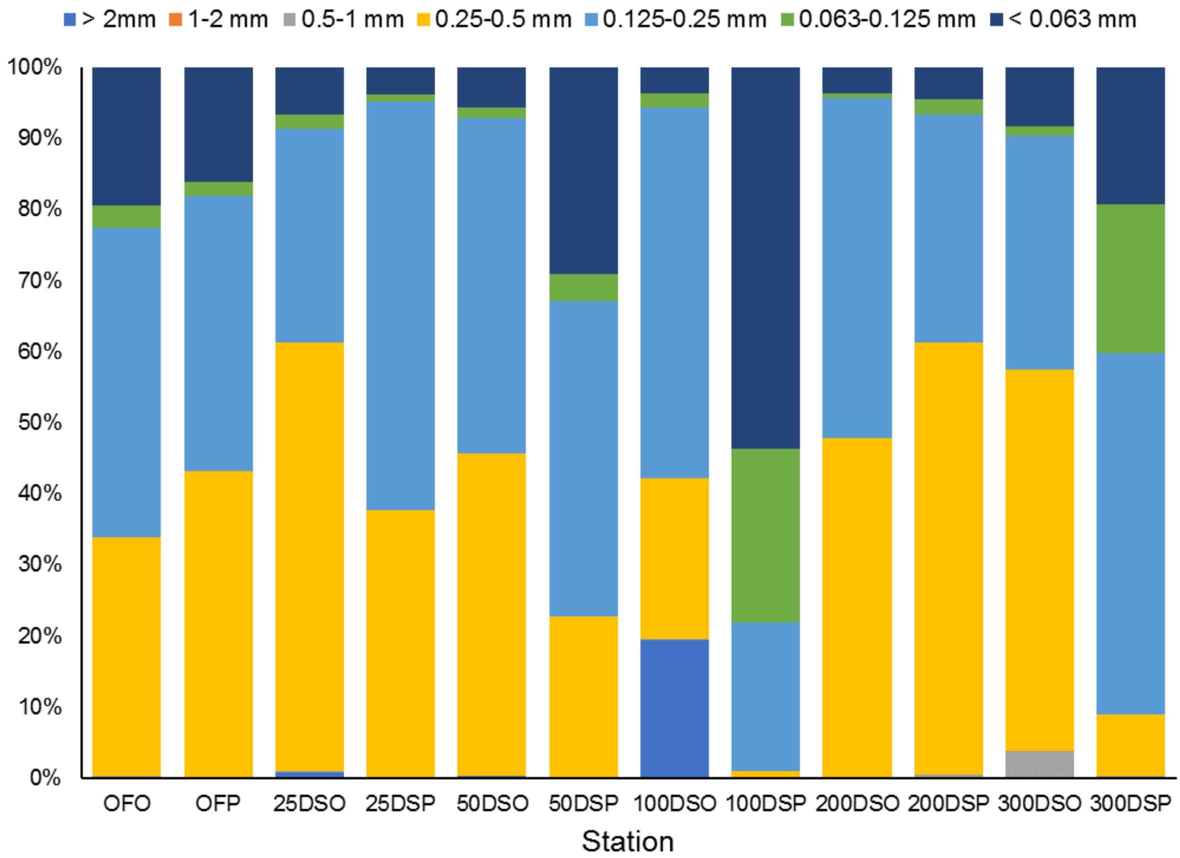


Figure 3. Percent particle grain size distribution in sediments sampled in 2018 at twelve stations from the BSTP outfall to 300 m downstream, inside (P) and outside (O) the discharge plume. Note: where values were reported as < 0.1%, the value was halved for plotting.

There were no obvious patterns in the organic content (as percentage of dry weight) of sediments in relation to the distance gradient downstream from the outfall but concentrations were generally higher inside the plume, particularly at the 100DSP station (Figure 4). Organic content values ranged from 1.3–2.6%, with the highest value at 100DSP and the lowest at 50DSO. These values are typical of estuarine and coastal sediments and do not suggest any enrichment.

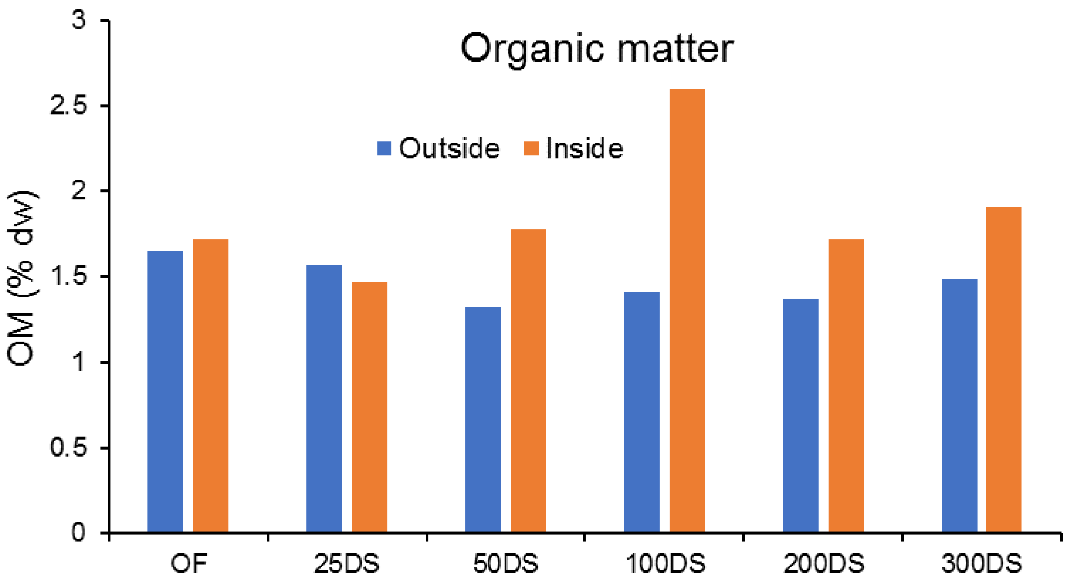


Figure 4. Organic matter content (as percentage of dry weight) of sediments sampled in 2018 at twelve stations from the BSTP outfall to 300 m downstream, inside (orange) and outside (blue) the discharge plume.

All trace metals in sediments, excluding nickel, were below ANZECC (2000) ISQG-Low guidelines. Nickel exceeded the ISQG-Low (but not ISQG-High) criteria at all stations and was highest at 25DSP, 50DSP OFO, 100DSO and 100DSP. Concentrations of nickel are natural high in rocks and soils in parts of the Wairau River catchment (Cavanagh et al. 2015).

Concentrations of arsenic, cadmium, copper, lead and zinc were highest at 25DSO and 100DSP, with generally similar, lower concentrations at other stations (Figure 5). There are no clear spatial patterns in relation to distance from the outfall, or by position inside or outside the plume. Chromium concentrations were similar at all stations, while those of mercury were generally— but not always— higher outside the plume, where concentration decreased with distance from the outfall (excluding the relatively low concentration at OFO). None of these metals exceeded their respective ANZECC ISQG-Low trigger value.

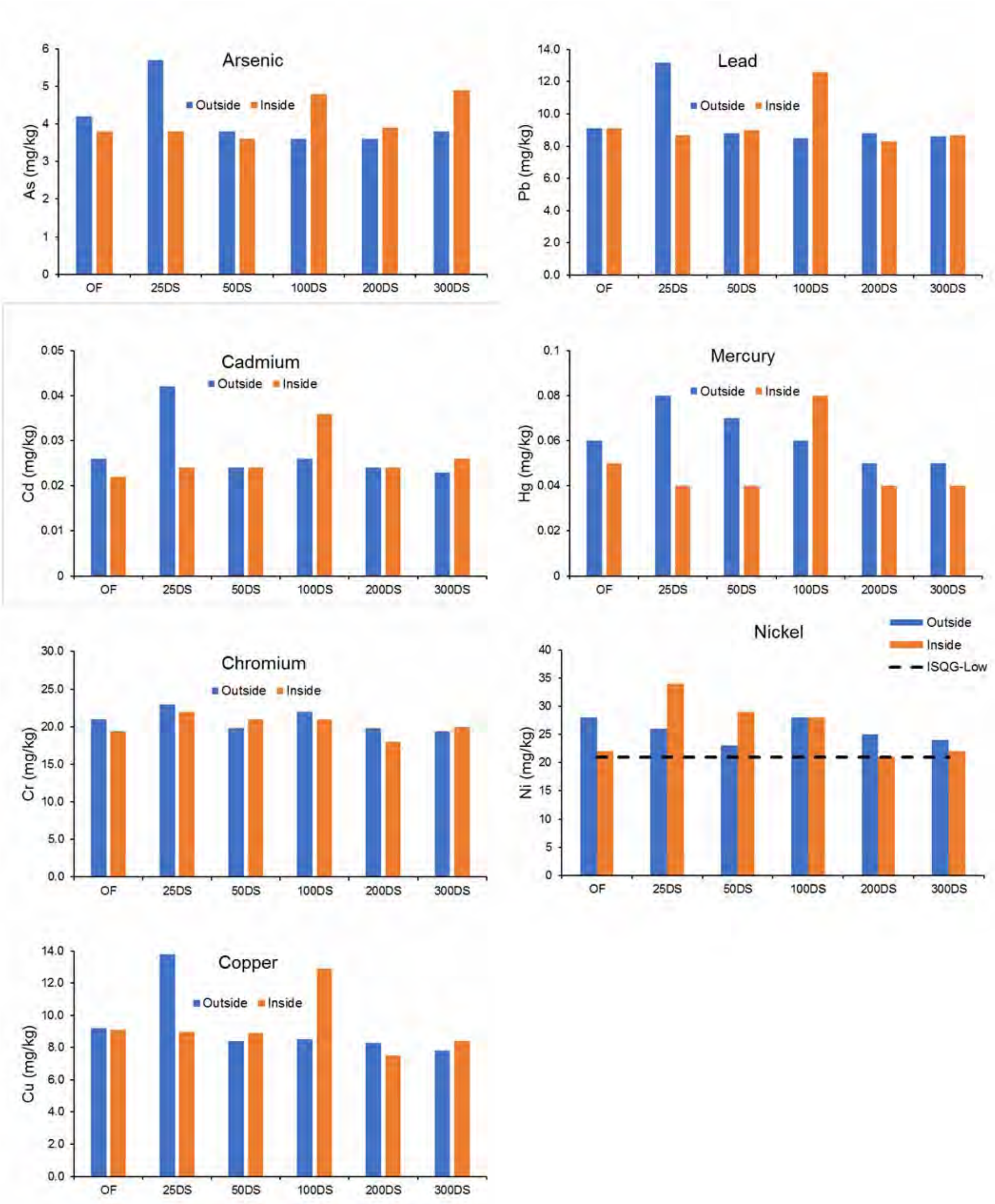


Figure 5. Trace metal and metalloid concentrations in sediments sampled in 2018 at twelve stations from the BSTP outfall to 300 m downstream (DS), inside and outside the discharge plume. Data are values from composites of three sediment cores per station. The ISQG-Low trigger value for nickel (ANZECC 2000) is shown by the dotted black line. Concentrations of all other metals/metalloids were below their respective ISQG-Low.

3.1.3. Comparison with the 2006 and 2016 surveys

Sulphide odour was detected in sediment cores in 2016 although these cores were generally closer to the outfall and both within and outside the plume, compared to 2006 where a sulphide odour was detected at stations 200DSP and 300DSP. No odours were detected in 2018. A slight redox layer was recorded within some cores in 2016, but core colour was generally variable in both 2006 and 2016, with no obvious gradient in relation to distance from the outfall or overall pattern in relation to position inside or outside the plume. The only sample to show a redox layer in 2018 was DSP300.

Silt and clay (mud) was not as dominant in the sediment at stations OFO and OFP in 2016 (around 10–20%) or 2018 (4–54%) as it was in 2006 (around 60–80%). In 2016 and 2018 grain size did not display any obvious gradient in relation to distance downstream from the outfall, or any overall pattern in relation to position inside and outside the plume. In 2006, however, stations closer to the outfall had higher proportions of silt and clay particles and from 100–300 m downstream sediments consisted largely of fine–medium sand.

In 2016 and 2018 there were no obvious patterns in organic content in relation to distance from the outfall and position inside and outside the discharge plume. In 2006 organic content was highest at stations OFO and 25DSO.

In all three surveys, concentrations of all metals except nickel were below ISQG-Low criteria. Nickel concentrations in sediment cores were well below the ISQG-High criterion (52 mg/kg) in 2016 and 2018 although they were close at one station in 2006. However, more stations were above the ISQG-Low criterion in 2016 and 2018 compared to 2006. Concentrations of metals/metalloids in sediment did not display any obvious patterns relative to the distance gradient downstream of outfall or position inside and outside the plume in the 2016 and 2018 surveys. In 2006, however, some metals (chromium, copper, mercury, lead, zinc) were slightly elevated near the outfall compared to other stations.

3.2. Infauna

3.2.1. Numbers of taxa and individuals

The number of taxa per core ranged from 1–12 taxa across all stations. The highest average number of taxa (9.3 ± 1.45 SE taxa per core) occurred at 25DSP and the lowest (2.0 ± 0.58 SE taxa per core) at 300DSO (Figure 6). There was no pattern in numbers of taxa with distance from the outfall but numbers were generally higher at the station inside the plume than at the corresponding distance outside.

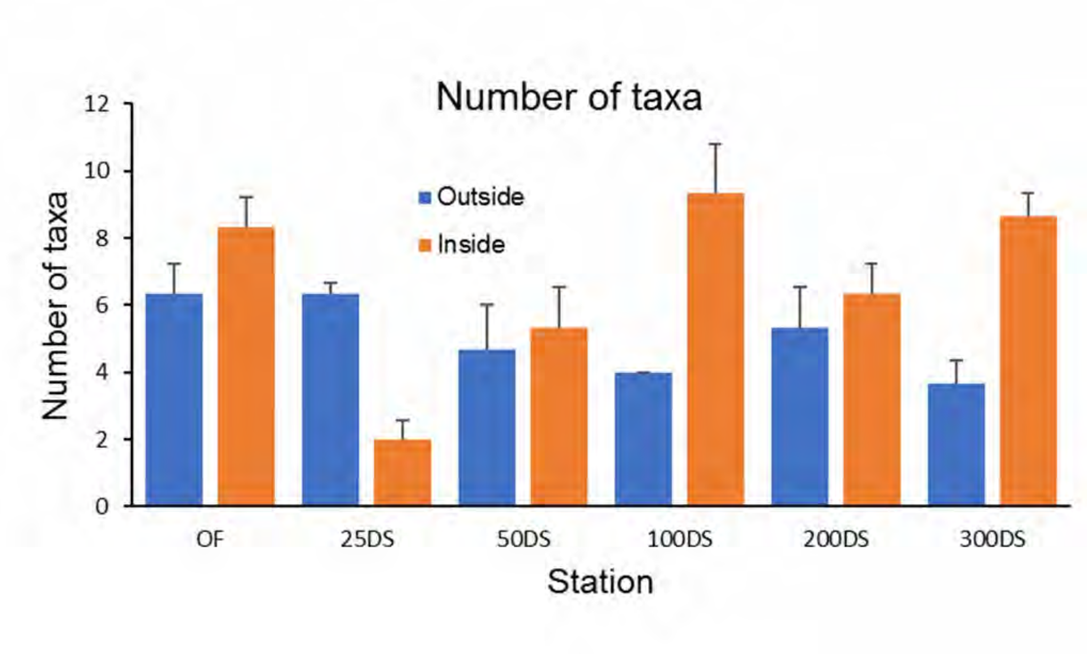
The abundances of individuals per core ranged from 10–577 individuals across all stations and were dominated by corophiid amphipods. The average abundance was highest at 100DSP (384.3 ± 100.4 SE individuals per core) and lowest at 25DSP (28.3 ± 11.0 SE individuals per core) (Figure 6: the full set of infauna count data is presented in Appendix 5). Average abundances were also relatively high at OFP, 25DSO, 50DSO, 50DSP and 300DSP, and at all these stations at least some replicate samples had high numbers of the polychaete worm *Scolelepis* sp. and, in particular, corophiid amphipods (up to 506 individuals per core).

There was no pattern in the numbers of individuals with distance from the outfall or between inside and outside the plume (Figure 6).

3.2.2. Diversity and evenness

Pielou's evenness ranged from 0.12–0.87 per core across all samples. The average evenness was highest at 200DSP (0.68 ± 0.006 SE) and lowest at 100DSP (0.19 ± 0.02 SE) (Figure 7). There was no pattern with distance from the outfall or between inside and outside the plume.

The Shannon-Weiner diversity of infauna communities ranged from 0–1.33 per core across all samples. The average diversity was highest at 200DSP (1.2 ± 0.07 SE) and lowest at 25DSP (0.2 ± 0.09 SE) (Figure 7). There was no pattern with distance from the outfall or between inside and outside the plume.



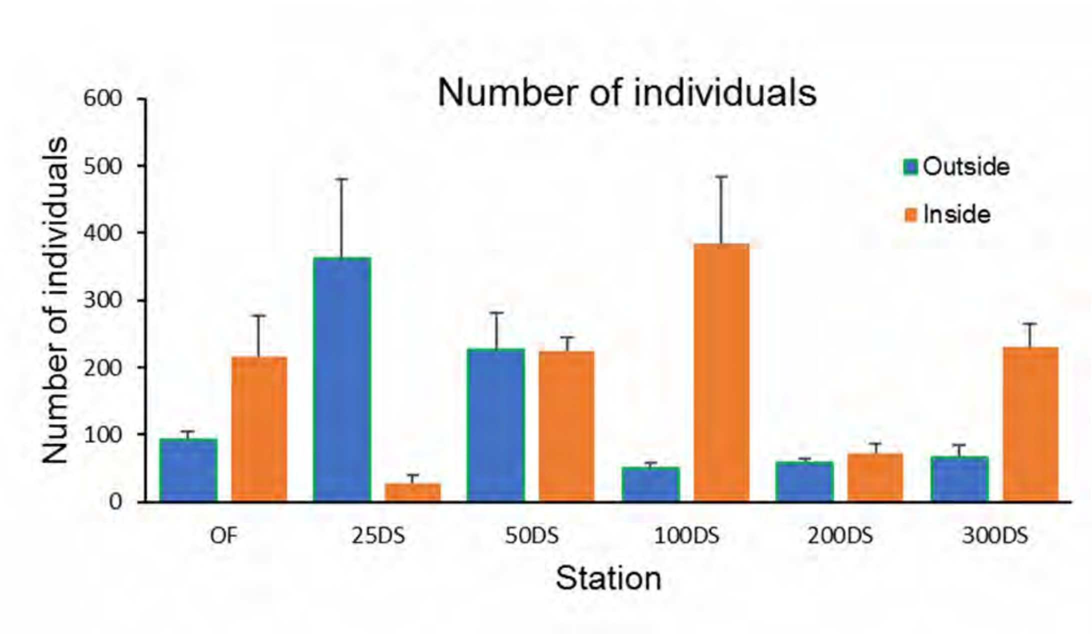


Figure 6. Numbers of taxa and individuals in samples from twelve stations from the BSTP outfall to 300 m downstream (DS), inside and outside the discharge plume in 2018. Data are mean values per core (± SE), n = 3.

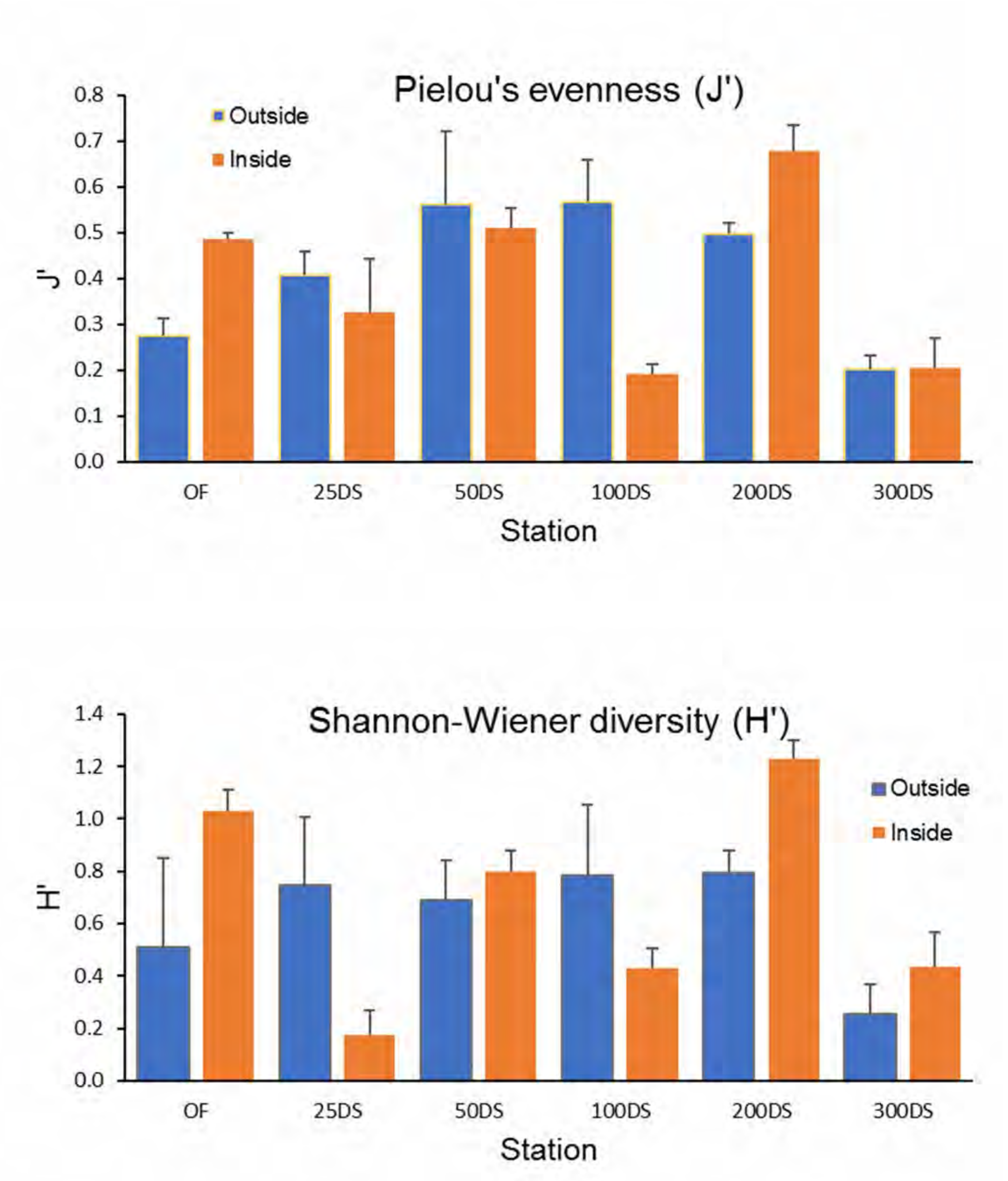


Figure 7. Pielou's evenness and Shannon-Weiner diversity in samples from twelve stations from the BSTP outfall to 300 m downstream (DS), inside and outside the discharge plume in 2018. Data are mean values per core (± SE) and n = 3.

3.2.3. Community analyses

Multivariate analysis (using the procedure SIMPER: Appendix 6) showed that faunal similarity among replicate cores within stations ranged from 60.6% at 300DSP to 83.3% at 200DSP. Corophiid amphipods (Figure 8) were the dominant taxon within infaunal communities at all stations. The polychaete worm *Scolelepis* sp. also contributed to similarity among replicates at seven stations, pipi (*Paphies australis*) at three, chironomid midge larvae at two and mysid shrimps and oligochaete worms at one station each. The dominant role of corophiids in characterising stations is not surprising given how high their abundances were compared with other taxa.

Scolelepis was present at all but one station (the exception being 25DSP) and was particularly abundant at OFP, 25DSO, 50DSO, 50DSP and 100DSP. Organic and mud contents of sediments were relatively high at some of these stations (OFO, OFP, 50DSP and 100DSP: see Section 3.1.2), consistent with the reported tolerance of *Scolelepis* for these factors (Robertson & Stevens 2012). As noted in Section 3.1.2, however, there were no clear relationships between these variables and distance away from the outfall or inside versus outside the plume.

Figure 8. Amphipod from the family Corophiidae.

When nMDS was used to visualise relationships among samples in terms of their faunas, there was a general grouping of replicates by station (Figure 9). There was no evidence that samples were grouped according to distance from the outfall, either inside or outside the plume. For any distance from the outfall, the samples from the stations inside and outside the plume tended to form separate groups (Figure 9). However, this is likely to be due to natural spatial variation rather than an effect of the plume, evidenced by the fact that there is no consistent, overall separation of samples from the stations inside and outside the plume— ‘inside’ and ‘outside’ samples are intermingled in the nMDS plot.

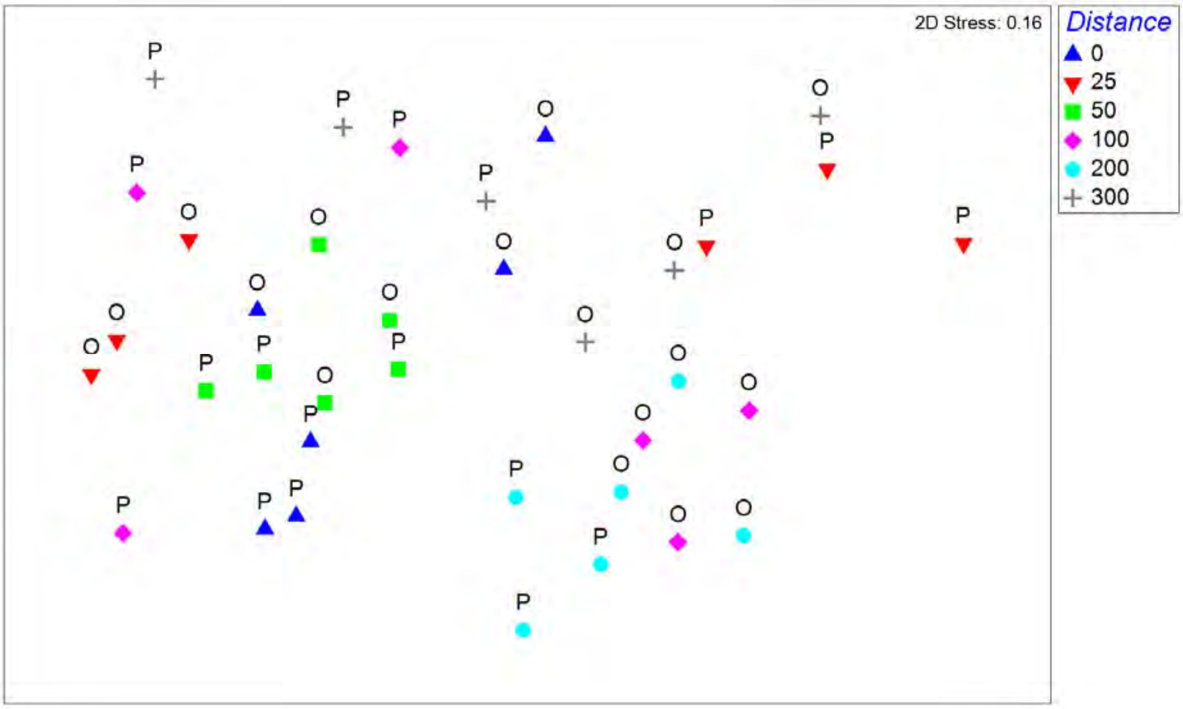


Figure 9. Non-metric MDS of infauna communities in 2018 collected at twelve stations from the BSTP outfall to 300 m downstream, inside (P) and outside (O) the discharge plume. The stress value indicates how well the two-dimensional plot preserves the relationships among samples: 0.16 is considered acceptable.

3.2.4. Comparison with 2006 and 2016

Infaunal abundance was similar in 2018 to 2016 and higher than in 2006 (ranges of abundance 19–145, 0–601 and 10–577 individuals per core for 2006, 2016 and 2018, respectively). The higher abundances in 2016 and 2018 were due to corophiid and (in 2016) other types of amphipods, which were present at lower abundances in 2006. It is not uncommon for small crustaceans, such as amphipods, to show large fluctuations in abundance through time, presumably in response to a range of environmental factors. *Potamopyrgus estuarinus* (an estuarine snail) was the dominant species from all stations 100–300 m downstream of the outfall in 2006. This species was not dominant at any of the stations in 2016 or 2018. In none of the years were capitellid polychaetes, indicative of organic enrichment, dominant at any sites and they were very uncommon in 2018 (11 individuals across all 36 samples).

The maximum number of taxa per core in 2018 was similar to that in 2006 but lower than that in 2016 (8–11, 0–18 and 1–12 taxa per core in 2006, 2016 and 2018, respectively). The range of values of Shannon-Wiener diversity was correspondingly larger in 2016 than 2018 (0–2.46 and 0–1.33, respectively). In none of the years were there clear differences in faunal diversity with distance from the outfall or between inside and outside the plume.

3.3. Shellfish bioaccumulation

3.3.1. Shellfish metal/metalloids

Pipi were found at six stations: 100DSO, 200DSO, 300DSO, 100DSP, 200DSP and 300DSP. The concentrations of each metal/metalloid were generally relatively uniform across the different stations, except for higher concentrations of arsenic, chromium, copper, lead and nickel at station DSP300, and slightly higher concentrations of mercury at 300DSO (Figure 10). Except for arsenic, the concentrations of all other applicable metal/metalloids at all stations were lower than the maximum concentrations permitted by the ANZFSC (2015).

Arsenic concentrations ranged between 1.3–2.4 mg/kg and all were higher than the maximum permitted concentration for molluscs for human consumption (1 mg/kg) listed by the ANZFSC (2015). Although the permitted concentration for arsenic was exceeded, there were no distinct trend for bioaccumulation along the gradient of the plume from the outfall, with the highest concentration recorded at the station furthest away.

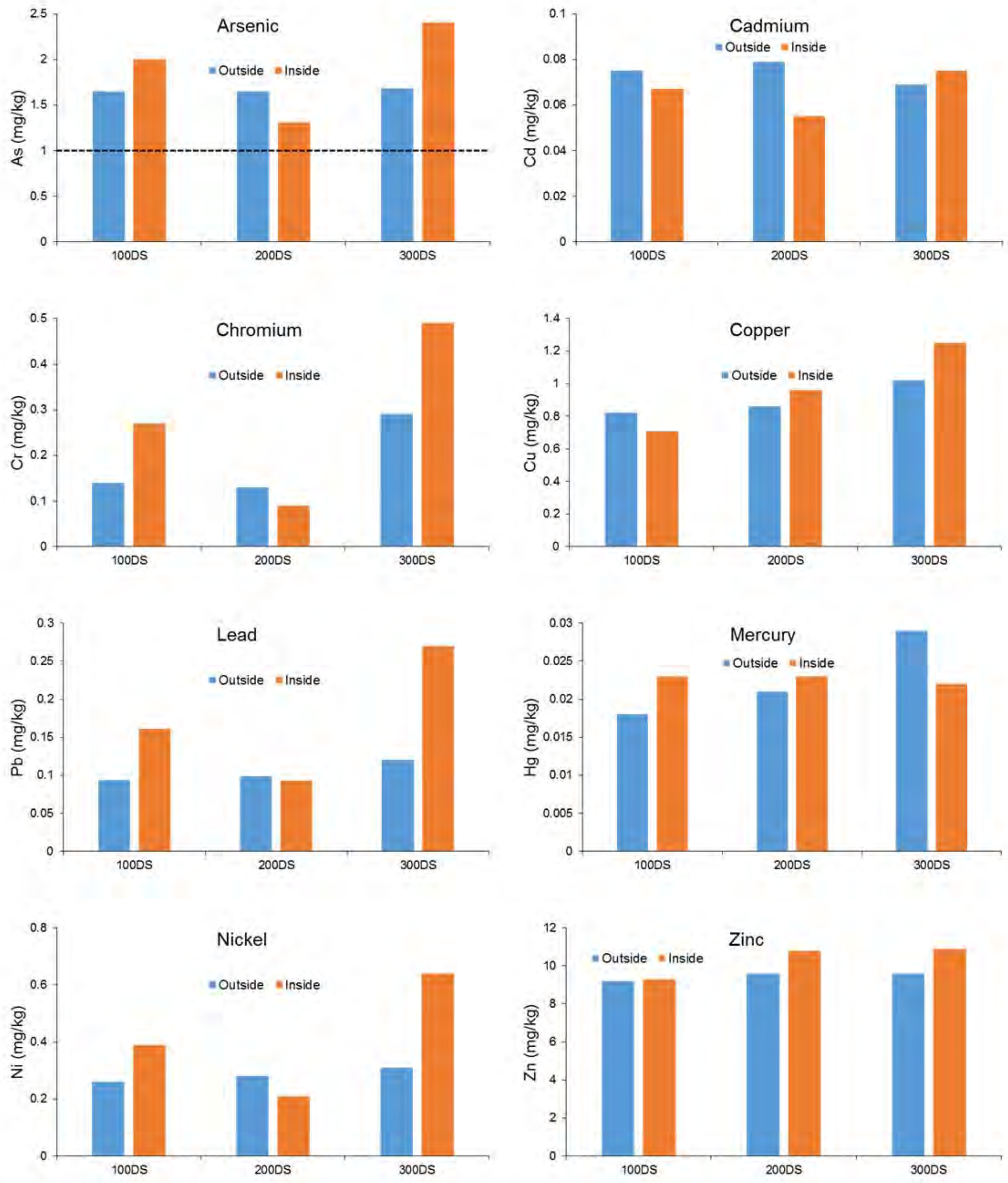


Figure 10. Trace metal/metalloid concentrations in tissues of shellfish (pipi, *Paphies australis*) sampled in 2018 from six stations 100 m to 300 m downstream (DS) of the outfall, outside (blue) and inside the plume (orange). Data are from tissue composites of approximately 20–25 shellfish per station. Where metal/metalloid levels were not detected, the value displayed is half of the detection limit. The dotted line indicates the maximum permitted concentration of arsenic in shellfish for human consumption (ANZFSC 2015).

3.3.2. Bacteria in shellfish

Faecal coliform concentrations were highest at 100DSP (5,400 MPN/100g), 200DSO and 200DSP (both 790 MPN/100g), and 100DSO (460 MPN/100g) (Figure 11). Concentrations above 330 MPN/100g are considered unacceptable for harvested and unprocessed shellfish for human consumption by the Ministry of Health Reference Criteria for Food (MoH 1995). Concentrations at the other two stations where pipi occurred (300DSO and 300DSP) were at the level considered marginally acceptable (230 MPN/100g: MoH 1995). Within the outfall plume there was a decreasing trend in concentration with distance from the outfall.

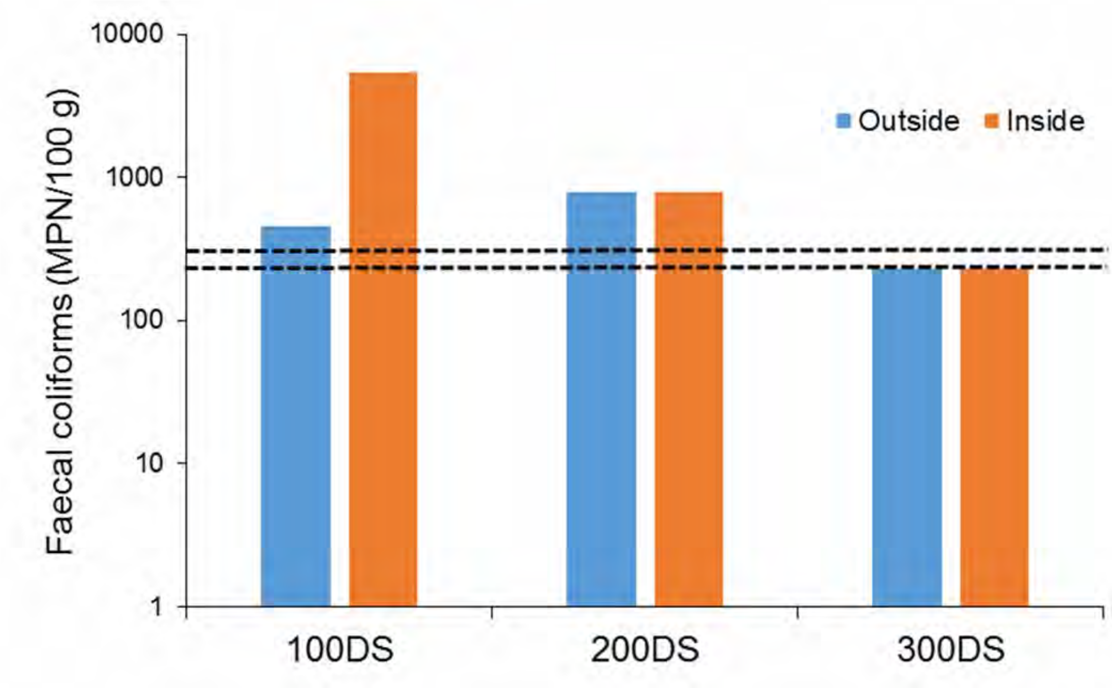


Figure 11. Faecal coliform concentrations (MPN/100g, log_{10} scale) in tissue of shellfish (pipi, *Paphies australis*) sampled in 2018 from six stations 100 m to 300 m downstream (DS) of the outfall, outside (blue) and inside the plume (orange). Data are from tissue composites of approximately 20–25 shellfish per station. The upper dotted line shows the concentration considered unacceptable for human consumption and the lower line shows the marginally acceptable concentration (MoH 1995).

3.3.3. Comparison with 2006 and 2016

As in 2006 and 2016, the concentrations of arsenic (but no other metal/metalloids) in 2018 were higher than recommended guidelines at all stations where pipi were present. Concentrations of zinc were higher in 2016 than in 2006 or 2018 at some stations (both inside and outside the plume). In 2006 and 2018, concentrations of chromium and nickel were higher at 300DSP than at all other stations sampled in the same year (as noted in Section 3.3.1, concentrations of arsenic, copper and lead were also higher in 2018 but this was not so in 2006). Station 300DSP was not distinctive in this respect in 2016. Apart from these exceptions, concentrations of metals were relatively consistent among the three rounds of sampling for those stations where pipi were present every time.

As reported in Section 3.3.2, concentrations of faecal coliforms in pipi exceeded the MoH (1995) guideline for unacceptability for human consumption at four stations in 2018 (100DSO, 100DSP, 200DSO and 200DSP). Two samples (300DSO and 300D) were marginally acceptable. Two samples were unacceptable in 2006 (25DSO and 50DSP: Table 5) and one was marginally acceptable (200DSP). None of the samples exceeded the unacceptability guideline in 2016 but two (OFP and 25DSP) were marginally acceptable. These results indicate temporal and spatial variability in coliform contamination of shellfish downstream of the outfall. The absence of pipi at some or all of the OF, 25DS and 50DS stations in 2016 and 2018 makes it difficult to determine whether the high concentrations recorded at some locations close to the outfall in 2006 are a consistent feature.

Table 5. Concentrations (MPN/100 g) of faecal coliform bacteria in shellfish (pipi) collected in 2006, 2016 and 2018. Red cells in the table show concentrations exceeding the Ministry of Health (MoH 1995) criterion of unacceptability for human consumption (330 MPN/100 g) and those in orange are at the guideline for marginal acceptability (230 MPN/100 g). Pipi were not present at some stations in some years.

Station	2006	2016	2018
OFO	Not present	40	Not present
OFP	Not present	230	Not present
25DSO	5400	Not present	Not present
25DSP	50	230	Not present
50DSO	130	Not present	Not present
50DSP	490	Not present	Not present
100DSO	170	170	460
100DSP	20	130	5400
200DSO	80	170	790
200DSP	230	20	790
300DSO	Not present	90	230
300 DSP	<20	80	230

3.4. Water

3.4.1. Visual observations

During the low-tide period on 22 January, an eddy of surface foam, approximately 20 m diameter, was observed c. 20 m south of the surface 'boil' of the new outfall (Figure 13). It is unclear whether the foam derives from the discharge or is derived from elsewhere and is simply accumulated and trapped in an eddy that may be created by the discharge. No other floating material (other than twigs) or odour was observed at any of the water sampling stations.

Water clarity at all stations was low and there were no conspicuous differences in water colour or clarity between the stations. As per the relevant consent requirements (condition 60 part II), no undesirable biological growths were observed either on the water surface or around the vicinity of the outfall while SCUBA diving.

3.4.2. Metal/metalloids

No arsenic, mercury or nickel was detected in water at any of the stations (Table 6). Cadmium occurred at the mixing zone bed station and at the near-bed and near-surface stations at the bar. Cadmium concentrations exceeded the ANZECC (2000) guideline concentrations for slightly-moderately disturbed marine waters at the last two of these stations. Chromium was detected in the near-bed water samples at all three stations. Copper was recorded in near-surface and near-bed samples at the bar station, where the concentrations exceeded the ANZECC (2000) trigger value. Lead was recorded in the near-bed samples from the mixing zone and bar stations and the bar surface station. Zinc was recorded at all stations and concentrations exceeded the ANZECC (2000) trigger in all cases except the upstream near-surface station.

The exceedances of the ANZECC (2000) trigger values for cadmium, copper and zinc by nine of the samples collected in 2018 contrasts with the situation in 2016, when concentrations of all metals were below their trigger values.

Table 6. Water metal/metalloid concentrations (mg/m^3) for near-surface and near-bed water samples from the three water-sampling stations: upstream (US), mixing zone (MZ) and bar (Bar) in 2018. Red cells indicate concentrations that exceed the ANZECC (2000) trigger values for slightly - moderately disturbed marine waters (no trigger is defined for arsenic and the US EPA's Aquatic Life Criterion[b] for arsenic is shown instead).

Station	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
US-surface	< 4.2	< 0.21	< 1.1	< 1.1	< 1.1	< 0.08	< 7	10.2
US-bed	< 4.2	< 0.21	1.5[a]	< 1.1	< 1.1	< 0.08	< 7	16.2
MZ-surface	< 4.2	< 0.21	< 1.1	< 1.1	< 1.1	< 0.08	< 7	16.2
MZ-bed	< 4.2	0.63	1.6	< 1.1	1.8	< 0.08	< 7	44
Bar-surface	< 4.2	0.74	< 1.1	1.8	2	< 0.08	< 7	46
Bar-bed	< 4.2	2	1.7	2.2	3.5	< 0.08	< 7	100
ANZECC	**36[b]**	**0.7**	**4.4[c]**	**1.3**	**4.4**	**0.1**	**7**	**15**

[a] The replicate analyses performed on this sample as part of laboratory Quality Assurance procedures showed greater variation than would normally be expected. This may reflect the heterogeneity of the sample. The average of the results of the replicate analyses has been reported.

[b] US EPA *National Recommended Water Quality Criteria – Aquatic Life Criteria* (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table), accessed 11 December 2017.

[c] In the 2016 report the trigger for chromium III (27.4 mg/m^3) was used but the trigger for chromium VI, the more toxic form of this metal, has been substituted here.

3.4.3. Nutrients, TSS and BOD

Total nitrogen and ammoniacal-nitrogen values were higher in near-bed samples at all stations than in near-surface samples. Total nitrogen concentrations were highest in the bar and mixing zone near-bed samples (0.24 g/m^3: Table 1) and were below the ANZECC (2000) trigger value of 0.3 g/m^3 for physical and chemical stressors of slightly disturbed estuarine ecosystems[2]. Total ammoniacal nitrogen was highest (0.020 g/m^3) at the upstream near-bed sample, exceeding the ANZECC (2000) trigger value of 0.015 g/m^3 for physical and chemical stressors of slightly disturbed estuarine ecosystems[3]. Ammoniacal nitrogen was below the detection limit (< 0.005 g/m^3) in all near-surface samples. Phosphorus was highest (0.015 g/m^3) in the upstream near-bed and lowest (0.0106 g/m^3) at the mixing zone near-surface sample. All samples exceeded the ANZECC trigger value (0.005 g/m^3).

[2] Note that there are no nutrient trigger values specifically for New Zealand estuarine and coastal waters and ANZECC (2000) suggest that triggers for south-eastern Australian waters should be used until values are developed for New Zealand. However, this is generally considered to be unsatisfactory because background concentrations are typically higher in New Zealand water.

[3] This trigger relates to the role of ammoniacal nitrogen as a nutrient with the potential to cause excessive algal and cyanobacterial growth. Ammonia can also act directly on organisms as a toxicant and the ANZECC (2000) trigger for this role is 0.91 g/m^3 for slightly-moderately disturbed systems. All values recorded in this study were well below this trigger.

Total suspended solids (TSS) were highest (10 g/m^3) in the bar near-bed sample and lowest (< 3 g/m^3) in the near-surface samples (Table 1). Concentrations of TSS and ammoniacal nitrogen were below detection limits in near-surface samples. Concentrations of ammonia decreased from the upstream station to the bar whereas TSS increased. Biological oxygen demand was below the detection limit (2 g O_2/m^3) in all water samples.

3.4.4. Bacteria in water

Concentrations of enterococci (commonly used as indicators of suitability of waters for contact recreation) were < 10/100 ml in all samples (Table 7) and, therefore, much lower than the limit for primary water contact in the ANZECC (2000) water quality guidelines (maximum of 60–100 organisms/100 mL in any single sample). Concentrations were well below those that would trigger the Alert/Amber mode action level of 140 enterococci/100 mL in a single sample specified in the MfE (2003) guidelines.

Table 7. Concentrations of faecal indicator bacteria (faecal coliforms and enterococci), total suspended solids (TSS), total nitrogen (TN), ammoniacal nitrogen, dissolved reactive phosphate (DRP) and five-day biochemical oxygen demand (BOD_5) for near-surface and near-bed water samples from the three water-sampling stations: upstream (US), mixing zone (MZ) and bar (Bar) in 2018. Red cells indicate concentrations that exceed the ANZECC (2000) trigger values for nutrients for south-eastern Australian estuaries. Guidelines for bacteriological water quality (contact activities and shellfish gathering) from ANZECC (2000) and the Ministry for the Environment (MfE 2003) are also shown.

Station	Faecal coliforms (MPN/100 ml)	Enterococci (MPN/100 ml)	TSS (g/m^3)	TN (g/m^3)	Ammoniacal N (g/m^3)	DRP (g/m^3)	BOD_5 (g O_2/m^3)
US-surface	23	<10	< 3	0.187	< 0.005	0.0109	< 2
US-bed	2	<10	5	0.220	0.020	0.0150	< 2
MZ-surface	27	<10	< 3	0.198	< 0.005	0.0106	< 2
MZ-bed	2	<10	7	0.240	0.011	0.0130	< 2
Bar-surface	8	<10	< 3	0.220	< 0.005	0.0121	< 2
Bar-bed	<2	<10	10	0.240	0.010	0.0114	< 2
ANZECC	**150**	**60–100**		**0.3**	**0.015**	**0.005**	
MfE	**Median 14, no more than 10% of samples > 43**	**140**					

Faecal coliforms are used as indicators of suitability for contact recreation and are also the preferred indicator for shellfish gathering[4]. Faecal coliform concentrations were highest in the upstream surface and mixing-zone surface samples (23 MPN/100mL and 27 MPN/100mL, respectively) and lowest in the near-bed samples (≤ 2 MPN/100mL). All faecal coliform concentrations were lower than the guidelines for shellfish gathering (MfE 2003) and primary water contact in the ANZECC (2000) water quality guidelines (see Table 7).

3.4.5. Water physico-chemical parameters

Salinity at the water surface was low and decreased with distance from the mouth of the estuary, while salinity was reasonably constant at the bed stations and typical of full-strength seawater (Table 8). This suggests the presence, at the time of sampling, of a warmer, seaward-flowing surface layer of river water overlying an intruding wedge of cooler seawater. The salinity profiles (Figure 12) also showed low salinity in the upper part of water column, gradually increasing with depth at the bar station or with a relatively sharp increase in the middle of the water column at the mixing-zone and upstream stations.

The pH at the estuary bed was relatively constant across the stations, and consistent with the range for seawater, but consistently higher in the low-salinity surface water (Table 8).

Table 8. Salinity, pH, temperature, dissolved oxygen (DO) concentration and percent saturation for near-surface and near-bed water samples from the three water-sampling stations: upstream (US), mixing zone (MZ) and bar (Bar). All measurements were made on 23 January 2018. 'NR' not recorded.

Station	Time	Salinity (psu)	pH	Temp (°C)	DO (mg/L)	DO (% sat.)
US-surface	13:26	0.2	8.99	20.8	8.62	95.6
US-bed		33.1	7.76	16.2	8.05	100.6
MZ-surface	13:10	0.6	9.05	21.0	8.70	97.4
MZ-bed		33.1	7.85	16.6	8.24	103.9
Bar-surface	12:47	1.2	8.66	21.1	8.57	99.1
Bar-bed		33.8	7.90	NR	8.21	102.4

Turbidity values at 0.5 m and the seabed were 4.2 and 3.0 NTU[5] at the mixing zone, 9.5 and 5.8 NTU at the bar station, and 3.5 and 3.0 NTU at the upstream station (Figure 12). Turbidity at the bar station was highest at the surface and relatively

[4] See http://www.mfe.govt.nz/publications/fresh-water/microbiological-water-quality-guidelines-marine-and-freshwater-recreatio-17, accessed February 2018.
[5] Nephelometric Turbidity Units

constant (4–6 NTU) throughout the rest of the water column. The upstream and mixing-zone stations showed turbidity maxima of 4.6 NTU and 7.2 NTU, respectively, in mid-water.

In regards to the consent conditions relating to other water parameters:

- Temperature at the three surface stations ranged between 20.8–21.1 C° (Table 8). It was therefore within the consent requirement (condition 59a Part II) of less than a 3 C° natural temperature change within the receiving environment outside of the mixing zone.
- Dissolved oxygen ranged between 8.24–8.70 mg/L at the mixing zone station, 8.21–8.57 mg/L at the bar and 8.05–8.62 mg/L at the upstream station (Table 8). Oxygen saturation was above 95% at all of the stations and the receiving water was therefore within the consent requirement (condition 59c Part II: ≥ 80% of saturation).
- No conspicuous change in colour or clarity associated with the discharge was observed visually and therefore the receiving water was assumed to be within the consent requirement (condition 59b Part II).
- During the low-tide period on 22 January, an eddy of surface foam, approximately 20 m diameter, was observed c. 20 m south of the surface ‘boil’ of the new outfall (Figure 13). It is unclear whether the foam derives from the discharge or is derived from elsewhere and is simply accumulated and trapped in an eddy that may be created by the discharge.

3.4.6. Comparison with 2016

Note that methodological differences prevent comparison with data from 2006.

ANZECC (2016) trigger values for dissolved metals were presented incorrectly in table 5 of the previous report (Berthelsen & Morrisey 2016), where the values shown as g/m^3 were actually mg/m^3. To clarify the comparisons below, table 5 from the previous report is presented below (Table 9), with all concentrations expressed as mg/m^3 (consistent with the 2018 results shown in Table 6).

Concentrations of copper exceeded the ANZECC (2000) trigger value in the bar near-bed and near-surface samples in both 2016 (Table 9) and 2018 (Table 6), and in the mixing-zone near-bed sample in 2016. Concentrations of cadmium also exceeded the trigger value in the bar near-bed and near-surface samples in 2018 but not in 2016 (when the concentration in all samples was below the limit of detection). Concentrations of lead were highest in the bar near-bed sample in both years but only exceeded the trigger value in 2016. In 2018, zinc concentrations were above the trigger value in all samples except upstream near-surface, but only exceeded it in the bar near-bed sample in 2016. Zinc concentrations were generally higher in 2018 (maximum value 100 mg/m^3) than in 2016 (maximum value 17.9 mg/m^3).

Table 9. Water metal/metalloid concentrations (mg/m^3) for near-surface and near-bed water samples from the three water-sampling stations: upstream (US), mixing zone (MZ) and bar (Bar) in **2016**. Red cells indicate concentrations that exceed the ANZECC (2000) trigger values for slightly - moderately disturbed marine waters (no trigger is defined for arsenic and the US EPA's Aquatic Life Criterion[b] for arsenic is shown instead).

Station	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
US-surface	< 4.2	< 0.21	< 1.1	< 1.1	< 1.1	< 0. 08	< 7	< 4.2
US-bed	< 4.2	< 0.21	< 1.1	< 1.1	1.9	< 0. 08	< 7	8.1
MZ-surface	< 4.2	< 0.21	< 1.1	< 1.1	< 1.1	< 0. 08	< 7	< 4.2
MZ-bed	< 4.2	< 0.21	1.2	2.0	2.2	< 0. 08	< 7	9.3
Bar-surface	< 4.2	< 0.21	< 1.1	1.5	< 1.1	< 0. 08	< 7	4.3
Bar-bed	< 4.2	< 0.21	1.2	2.8	4.5	< 0.08	< 7	17.9
ANZECC	**36[a]**	**0.7**	**4.4[b]**	**1.3**	**4.4**	**0.1**	**7**	**15**

[a] US EPA *National Recommended Water Quality Criteria – Aquatic Life Criteria* (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table), accessed 11 December 2017.
[b] In the 2016 report the trigger for chromium III (27.4 mg/m^3) was used but the trigger for chromium VI, the more toxic form of this metal, has been substituted here.

Total nitrogen concentrations were generally similar between 2016 and 2018 but the maximum concentration in 2016 (0.85 g/m^3 in the bar near-bed sample) was higher than that in 2018 (0.24 g/m^3 at the mixing-zone and bar near-bed samples). Although concentrations of ammoniacal nitrogen were generally similar between 2016 and 2018, the highest concentration in 2016 (0.079 g/m^3 in the bar near-bed sample) was higher than that in 2018 and occurred downstream of the outfall rather than upstream (0.020 g/m^3 in the upstream near-bed sample). The highest concentration of DRP recorded in 2016 (0.023 g/m^3 in the bar near-bed sample) was slightly higher than that in 2018 (0.015 g/m^3 in the upstream near-bed sample). In 2016, near-bed DRP concentrations increased from upstream to the bar whereas in 2018 they showed the reverse pattern.

Concentrations of TSS in 2016 were much higher in the mixing-zone and bar near-bed samples (33 g/m^3) than in the other samples collected that year. They were also higher than in any of the samples collected in 2018 (maximum concentrations 7 g/m^3 at the mixing-zone near-bed sample and 10 g/m^3 in the bar near-bed sample).

Concentrations of enterococci were < 10 MPN/100 ml in all samples in 2018 but ranged from < 10–42 MPN/100 ml in 2016, being highest in the upstream near-bed and mixing-zone near-surface samples. Concentrations were less than the ANZECC (2000) and MfE (2003) guidelines for water-contact activities. Concentrations of faecal coliforms were also lower in 2018 (from < 2 to 27 MPN/100 ml) than in 2016 (7-70 MPN/100 ml) but all were less than the ANZECC (2000) guideline (median value of 150 MPN/100 ml). Four samples from 2016 and two from 2018 had a higher concentration than the MfE (2003) criterion for shellfish gathering of a median of 14 MPN/100 ml over a gathering season (and no more than 10% of samples shall be > 43 MPN/100 ml). However, a simple comparison of these criteria with one-off samples is potentially misleading.

Salinities were lower at the bed and higher at the water surface in 2018 than in 2016 but both sets of data demonstrated the outflow of a layer of river water over a lower body of seawater. Concentrations of dissolved oxygen were high at all stations in both years and complied with consent conditions.

Differences in the variables measured between the two times of sampling are likely to be due, at least in part, to differences in the state of the tide (i.e., stage of the ebb, since all samples were taken on the outflowing tide) and the volumes of river flow at the times of sampling.

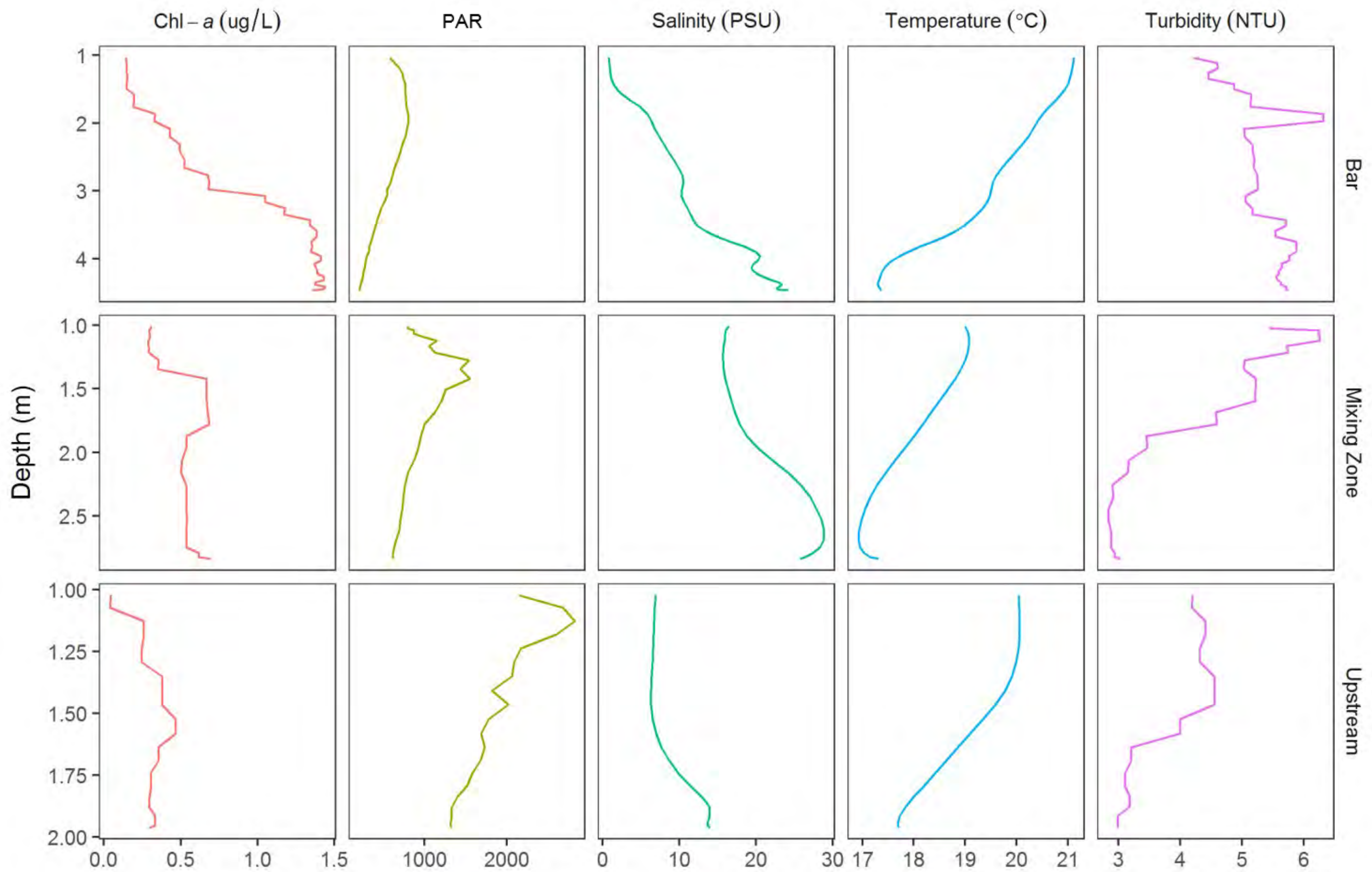


Figure 12. Hydrological profiles in 2016 from three stations at varying distances from the BSTP outfall: 400 m upstream, 300 m downstream in the mixing zone and 550 m downstream at the bar entrance (Bar). The plots show values of chlorophyll-*a*, light (as photosynthetically active radiation, PAR), salinity, temperature and turbidity (in Nephelometric Turbidity Units) over the range of water depths at each station (c. 4.8 m at the bar, c. 2.8 m in the mixing zone and c. 2.0 m upstream). Data from the first metre of the water column have been deleted to remove artefactual noise.

Figure 13. Foam trapped in an eddy c. 20 m south of the new outfall in the lower Wairau Estuary. The lower photograph shows the 'boil' where the discharge from the outfall reaches the surface, and the eddy of foam beyond it.

4. DISCUSSION

4.1. Ecological changes associated with the wastewater discharge

4.1.1. Sediment

No changes likely to have adverse ecological effects have been detected among the three surveys in sediment grain-size and chemistry (metals/metalloids and organic content). In 2018 there were no strong patterns in these sediment parameters in relation to the overall distance gradient downstream of the outfall or position inside and outside the plume. Therefore, it is unlikely that the discharge from the outfall has strongly influenced these variables.

4.1.2. Infauna

Infaunal abundance was similar in 2018 to 2016 and higher than in 2006 and the maximum number of taxa per core in 2018 was similar to that in 2006 but lower than that in 2016. There were no strong patterns in relation to distance from the outfall or position inside and outside of the plume that would suggest an effect of the discharge. Although there was a change in the identity of the dominant species at some sites among years, particularly the dominance of the snail *Potamopyrgus estuarinus* in 2006 but not in subsequent surveys, this is unlikely to be caused by the discharge as these changes occurred both within and outside the plume.

4.1.3. Shellfish

Differences in concentrations of metals/metalloids in shellfish collected inside and outside the plume were not consistent with distance from the outfall. This suggests that the discharge was not necessarily the source of these metals/metalloids and highest concentrations of all but cadmium and mercury were recorded at the station furthest from the outfall. Soils in the catchment of the Wairau River are naturally elevated in several metals/metalloids, including arsenic and nickel (Cavanagh et al. 2015).

Except for arsenic, concentrations of metals/metalloids in shellfish were below the ANZFSC (2015) guidelines for human consumption across all three times of sampling (2006, 2016 and 2018). All arsenic concentrations in 2018 were above the ANZFSC (2015) guideline but, because this occurred at all stations, it could not be attributed to the discharge. However, because tissues of marine organisms accumulate arsenic mainly in the organic form of arsenobetaine compounds, as opposed to the more toxic inorganic forms (to which the FSANZ standard relates), they represent a low risk to consumers (Klaric et al. 2004).

Faecal coliform concentrations in 2018 were higher within the plume at the station closest to the outfall (100DS) than at stations further away (where concentrations were the same inside and outside the plume). Concentrations at all stations 100 m and 200 m downstream exceeded the acceptability criteria for food (MoH 1995), and were marginally acceptable at the stations 300 m downstream. This provides some suggestion that the bacterial contamination may derive from the outfall but the fact that concentrations were the same inside and outside the plume at the stations 200 m and 300 m downstream is also consistent with more general contamination of the estuary, potentially from a variety of sources.

4.1.4. Water quality

Concentrations of copper and, in 2018, cadmium exceeded the ANZECC (2000) guideline trigger values in near-bed and near-surface samples from the bar station (550 m downstream of the outfall). There was also evidence of increased concentrations of lead in the bar near-bed samples. Zinc concentrations exceeded the ANZECC trigger value in the bar near-bed sample in 2016 and in all samples, apart from upstream near-surface, in 2018. The zinc concentration was highest at the bar station in 2018, with similarly lower values at the upstream and mixing-zone stations. There is, therefore, evidence of increased concentrations of metals in near-bed waters downstream of the mixing zone but little evidence at the boundary of the mixing zone itself. This does not suggest that the outfall is a predominant source of metals to estuarine waters. Presumably they derive from natural and anthropogenic sources in the river catchment.

Concentrations of TSS and total nitrogen (TN) were higher at the mixing-zone and bar near-bed samples in 2016 and 2018, consistent with the outfall being a source of these determinands. However, although ammoniacal-N and phosphorus also showed this pattern in 2016, concentrations of both were highest at the upstream station in 2018. This, plus the fact that concentrations of TSS and TN were as high, or higher, at the bar than at the boundary of the mixing zone, makes it unlikely that the discharge from the BSTP outfall was the sole cause of these higher concentrations. BOD_5 at all water stations was below detectable levels and was therefore not considered to be influenced by the discharge. High concentrations of nitrogen and phosphorus are likely to derive from farming activities in the river catchment.

While higher concentrations of enterococci were present at the mixing zone station in 2016 compared to 2006, similarly high concentrations were present at the upstream station. In 2018, concentrations were below limits of detection at all stations. These data indicate that the outfall discharge is unlikely to be the predominant source of enterococcal contamination to the estuary. Although in the near-bed samples the highest faecal coliform level occurred at the bar station in 2016, the concentration at the mixing zone station was lower than at the bar and upstream stations. In 2018, concentrations were very low in near-bed samples from all station, while concentrations in near-surface samples were lowest at the bar and similar at the mixing zone and upstream. Again, these data indicate that the main source of faecal coliform contamination was unlikely to be the outfall discharge.

Dissolved oxygen levels were high at all stations in 2016 and 2018 and therefore the discharge did not appear to have affected this variable significantly. Temperature variation among the stations was within the consented maximum difference of 3 °C in 2016 and 2018.

Turbidity levels were similar at all three stations and slightly lower than in 2016, probably because of differences in recent rainfall and the state of the tide.

There were no detected breaches of the water quality conditions in the discharge consent in 2016. As was suggested in the 2016 report, it is recommended that future water quality surveys also sample water on the Vernon Lagoons side upstream of the outfall on the ebb tide to get a more complete picture of water quality within the area.

4.2. Summary

Overall, although some minor environmental and ecological differences were apparent among the 2006, 2016 and 2018 surveys, no adverse ecological effects of the BSTP discharge (and no breaches of the water quality consent conditions) were detected overall. The lack of significant adverse effects on receiving water or bed sediment quality is likely due to the quality of the discharge, coupled with high initial dilution and rapid flushing during the ebb tide-only discharge (CH2M Beca 2014).

The 2018 survey fulfils the consent condition (Condition 64.b) for a survey within four years of commissioning of the outfall. Subsequent surveys will be at five-yearly intervals (Condition 64.c), with the next scheduled for early 2023.

5. ACKNOWLEDGMENTS

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7. APPENDICES

Appendix 1. Consent (U071181) conditions 58, 59 (a-c) and 60 G (Part II).

58. The proposed mixing zone for the discharge to the Wairau Estuary shall be as shown on Plan No D in Appendix 1 to these consent conditions.

59. The discharge of treated wastewater from the upgraded BSTP shall not cause any of the following effects outside the mixing zone described in Condition 58 above:

a) The natural temperature of the receiving water to change by more than 3 degrees Celsius;
b) Any conspicuous change in colour or clarity of the receiving water such that visual clarity of water is reduced by more than 50% as per the Water Quality Guidelines No 2 Ministry for the Environment (1994);
c) The concentration of dissolved oxygen of the receiving water to fall below 80 percent of the saturation content.

60. There shall be no undesirable biological growths as a result of the discharge.

Appendix 2. Locations (in decimal degrees) of 2018 benthic survey stations in the Wairau Estuary. Water depth and date and time of sampling are also shown ('0' indicates that the station was out of the water at the time of sampling).

Station code	Location	Latitude (WGS84)	Longitude (WGS84)	Depth (m)	Date, time
OF P	Inside plume, < 5 m from outfall	-41.50520712	174.0582631	0	22 Jan 16:05
25DS P	Inside plume, 25 m downstream	-41.50502551	174.0584279	0	22 Jan 16:30
50DS P	Inside plume, 50 m downstream	-41.50483566	174.0585087	0	22 Jan 17:00
100DS P	Inside plume, 100 m downstream	-41.50455141	174.0590671	2.1	22 Jan 15:07
200DS P	Inside plume, 200 m downstream	-41.50387725	174.0599187	4.2	23 Jan 11:00
300DS P	Inside plume, 300 m downstream	-41.50315004	174.0606616	3.9	22 Jan 12:30
OF O	Outside plume, < 5 m from outfall	-41.50526223	174.0581442	0	22 Jan 15:48
25DS O	Outside plume, 25 m downstream	-41.50537633	174.0584695	2.0	23 Jan 10:12
50DS O	Outside plume, 50 m downstream	-41.50477504	174.0582442	0	22 Jan 17:30
100DS O	Outside plume, 100 m downstream	-41.50433101	174.0585485	1.0	22 Jan 13:55
200DS O	Outside plume, 200 m downstream	-41.50357571	174.0594107	3.2	22 Jan 11:44
300DS O	Outside plume, 300 m downstream	-41.50283061	174.0601414	2.8	22 Jan 10:50

Appendix 3. Locations (in decimal degrees) of 2018 water-sampling stations in Wairau Estuary. Water depth and date and time of sampling are also shown.

Station code	Location	Latitude (WGS84)	Longitude (WGS84)	Depth (m)	Date, time
Bar	550 m downstream from the outfall	-41.504611	174.05375	5.8	23 Jan 12:47
Mixing zone	300 m downstream from the outfall	-41.503369	174.059906	3.2	23 Jan 13:10
Upstream	400 m upstream from the outfall	-41.501289	174.061192	2.8	23 Jan 13:26

Appendix 4. Sediment core photos.

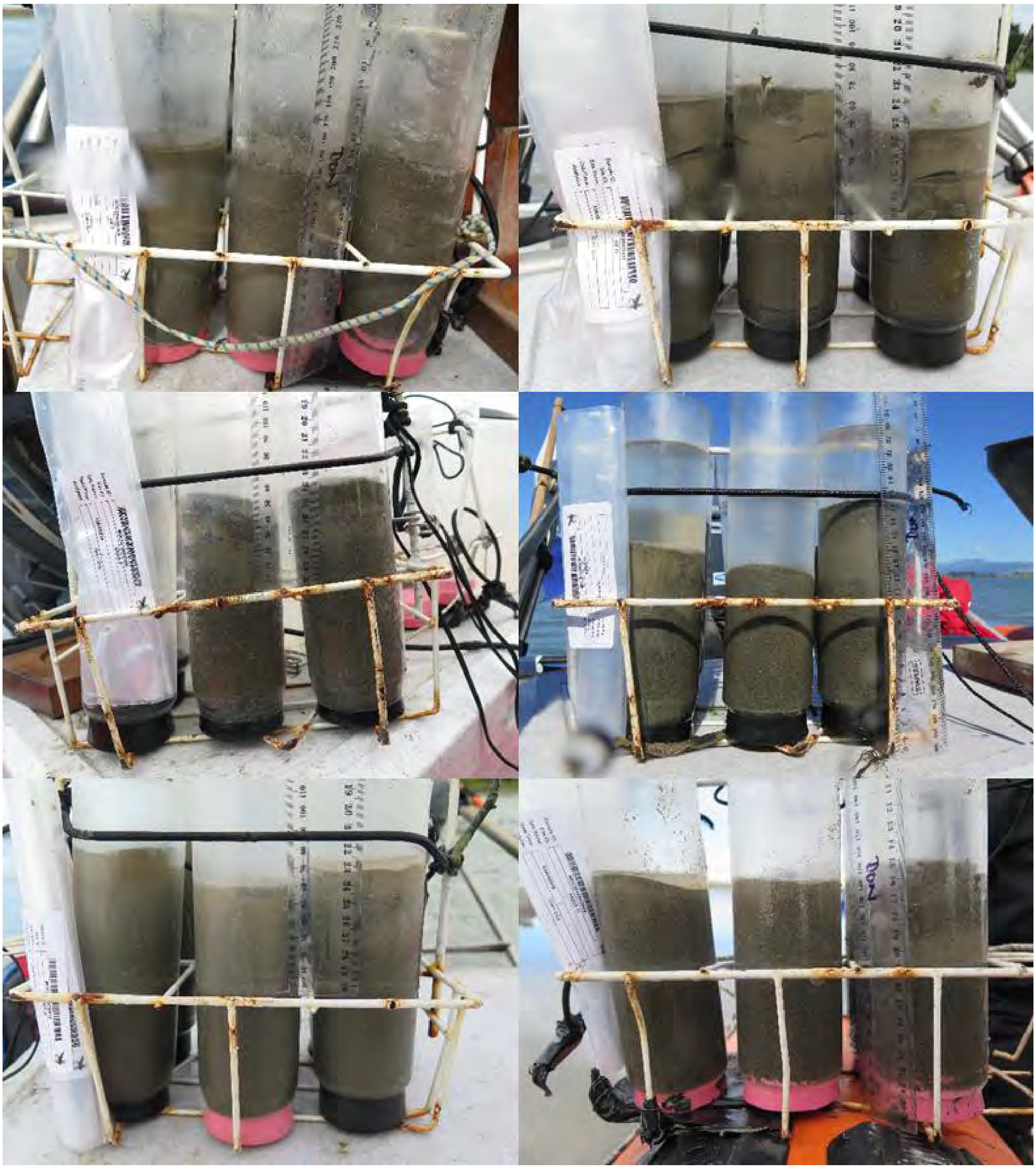

Figure A4.1 Sediment cores from stations OFP, 25DSP, 50DSP (left-hand column, top to bottom, respectively), OFO, 25DSO and 50 DSO (right-hand column, top to bottom, respectively).

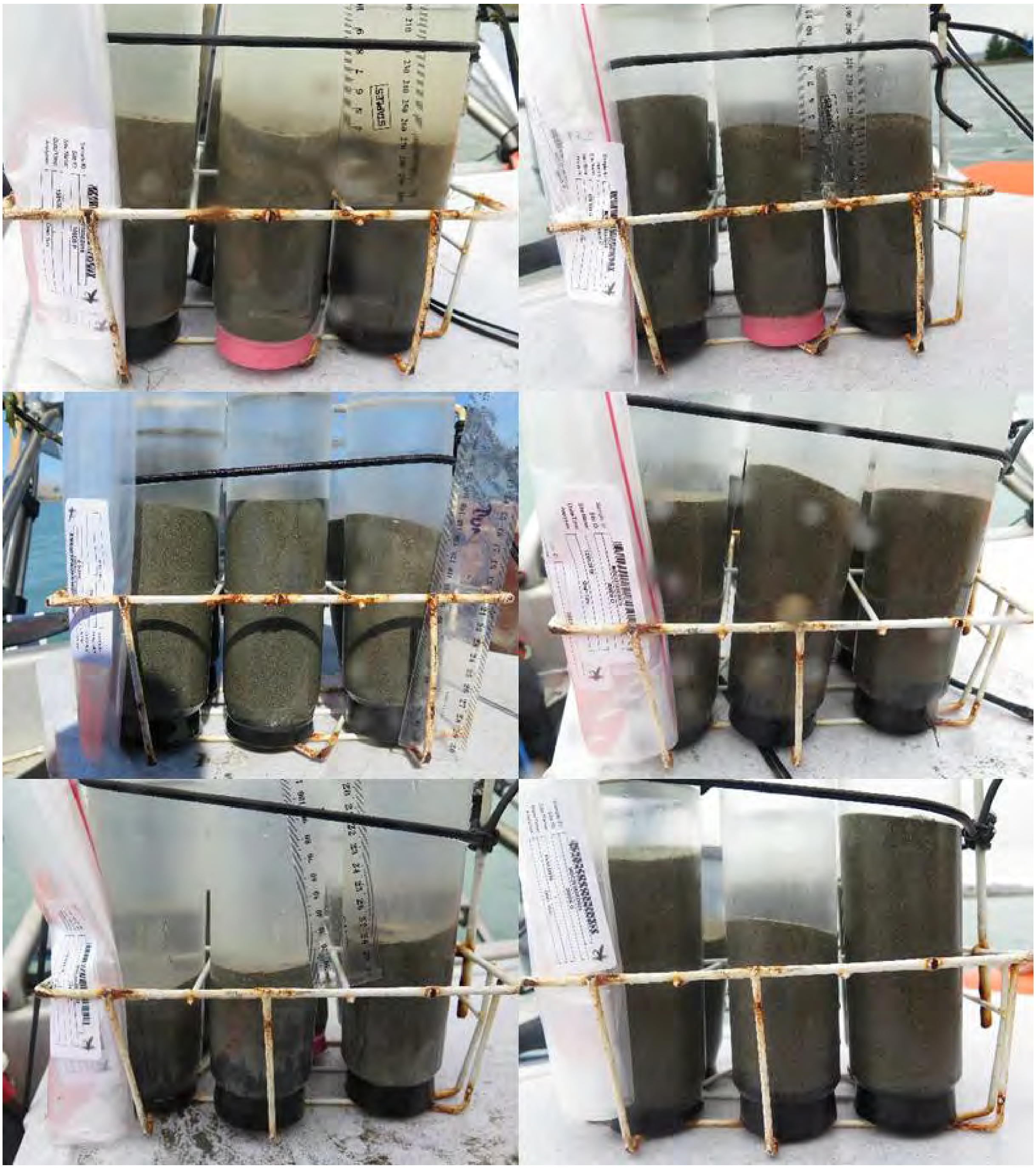

Figure A4.2 Sediment cores from stations 100DSP, 200DSP, 3000DSP (left-hand column, top to bottom, respectively), O100DSO, 200DSO and 300 DSO (right-hand column, top to bottom, respectively).

Appendix 5. Infauna data from all benthic survey stations in 2018. Pink rows are insect larvae and other typically low-salinity taxa.

Gen group	Taxon	OF O-A	OF O-B	OF O-C	OF P-A	OF P-B	OF P-C	025DS O-A	025DS O-B	025DS O-C	025DS P-A	025DS P-B	025DS P-C	050DS O-A	050DS O-B	050DS O-C	050DS P-A	050DS P-B	050DS P-C	100DS O-A	100DS O-B	100DS O-C	100DS P-A	100DS P-B	100DS P-C	200DS O-A	200DS O-B	200DS O-C	200DS P-A	200DS P-B	200DS P-C	300DS O-A	300DS O-B	300DS O-C	300DS P-A	300DS P-B	300DS P-C
Amphipod	Amphipoda	0	0	0	0	0	0	10	0	9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Crab	Austrohelice crassa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Barnacle	Austrominius modestus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	4	0	0	0	0	1	0
Bivalve	Austrovenus stutchburyi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
Bivalve	Bivalvia Unid (juv)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Crab	Brachyura (juv)	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Polychaete	Capitella capitata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	5	0	0	0	0	0	0	0	0	0	0	1	3
Copepod	Copepoda	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipod	Corophiidae	97	65	81	143	88	84	104	384	377	9	27	46	101	218	117	158	143	186	54	31	25	506	225	310	42	38	53	26	46	58	29	81	81	171	282	180
Crab	Decapoda (larvae unid)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crab	Halicarcinus sp	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crab	Halicarcinus whitei	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaete	Heteromastus filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3
Isopod	Munnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Mysid	Mysidacea	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	12	11	19	0	2	2	0	1	0
Nematode	Nematoda	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertean	Nemertea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	1
Oligochaete	Oligochaeta	1	0	0	0	0	0	1	3	1	0	0	0	0	0	0	0	2	0	0	0	0	15	6	1	0	0	0	0	0	0	0	0	0	0	1	3
Bivalve	Paphies australis	0	0	0	7	1	3	0	0	0	1	0	1	1	0	3	4	2	2	8	11	11	3	1	0	11	9	10	8	6	7	0	1	1	2	1	0
Gastropod	Potamopyrgus antipodarum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0
Gastropod	Potamopyrgus estuarinus	2	0	0	2	1	2	0	6	3	0	0	0	0	0	0	0	0	0	0	5	1	5	1	4	1	0	1	2	1	5	0	1	0	0	0	0
Polychaete	Prionospio sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Polychaete	Scolelepis sp	8	2	2	166	92	24	10	80	33	0	0	0	19	90	123	56	19	57	0	0	2	35	2	13	2	1	0	3	5	3	0	1	0	3	5	19
Isopod	Sphaeromatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Insect	Aphrophila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Insect	Archichauliodes diversus	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Insect	Chironomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	0	0	0	0	0	0	0	1	0	0	0	0	0
Insect	Chironomus sp	1	2	0	10	2	6	9	41	15	0	0	0	1	0	3	0	10	16	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Cladoceran	Cladocera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Insect	Diptera indet (pupae)	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insect	Molophilus	0	0	0	2	3	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insect	Molophilus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insect	Oxyethira sp	6	1	1	0	0	3	0	0	2	0	0	1	1	0	1	0	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 6. One-way SIMPER analysis based on Bray Curtis similarity (with a 70% cutoff for low contributions) of infauna communities from all benthic survey stations in Wairau Estuary (n = 3). Data were $\log_{(x+1)}$ transformed before analysis.

Station: OFO
Average similarity: 68.23

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	4.39	44.50	7.73	65.22	65.22
Scolelepis sp.	1.46	11.48	7.08	16.83	82.05

Station: OFP
Average similarity: 77.62

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	4.63	27.36	13.04	35.24	35.24
Scolelepis sp.	4.29	22.48	4.34	28.96	64.20
Chironomus sp.	1.81	8.33	3.65	10.74	74.94

Station: 25DSO
Average similarity: 76.24

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	5.51	31.03	16.94	40.70	40.70
Scolelepis sp.	3.44	16.86	6.88	22.11	62.82
Chironomus sp.	2.94	15.05	39.05	19.74	82.55

Station: 25DSP
Average similarity: 74.44

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	3.16	68.83	6.02	92.46	92.46

Station: 50DSO
Average similarity: 77.98

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	4.93	41.41	11.04	53.10	53.10
Scolelepis sp.	4.11	30.83	4.56	39.53	92.64

Station: 50DSP Average similarity: 75.58					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	5.09	36.38	9.29	48.14	48.14
Scolelepis sp.	3.70	24.53	3.74	32.46	80.59

Station: 100DSO Average similarity: 74.47					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	3.58	42.38	31.00	56.91	56.91
Paphies australis	2.39	29.20	15.75	39.21	96.11

Station: 100DSP Average similarity: 65.79					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	5.80	34.06	6.71	51.77	51.77
Scolelepis sp.	2.44	9.53	2.37	14.48	66.25
Oligochaeta	1.80	6.72	1.64	10.22	76.47

Station: 200DSO Average similarity: 74.43					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	3.80	41.15	10.31	55.28	55.28
Paphies australis	2.40	25.97	11.17	34.89	90.18

Station: 200DSP Average similarity: 83.27					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	3.74	27.79	11.21	33.37	33.37
Mysidacea	2.68	20.13	9.07	24.18	57.55
Paphies australis	2.07	15.94	9.43	19.15	76.70

Station: 300DSO Average similarity: 68.95					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	4.07	60.28	12.83	87.43	87.43

Station: 300DSP Average similarity: 60.61					
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Corophiidae	5.33	38.53	11.61	63.56	63.56
Scolelepis sp.	2.06	11.27	11.46	18.59	82.15

Appendix D

Nitrogen Load to Land

Irrigation Area	Total Annual Nitrogen Load per Area (kg/ha)		
	2015/16	2016/17	2017/18
DLA-01	117.3	41.1	54.6
DLA-02	28.2	94.7	101.0
DLA-03	27.5	53.0	58.6
DLA-04	20.7	51.6	68.0
DLA-05	42.2	55.8	72.5
DLA-06	20.7	73.7	82.5
DLA-07	60.7	16.8	97.1
KLA-01 Nth	13.0	7.8	10.7
KLA-01 Sth	118.3	12.7	37.3
KLA-02 Nth	61.9	2.5	20.4
KLA-02 Sth	49.0	39.3	20.5
KLA-03 Nth	76.0	35.5	28.8
KLA-03 Sth	63.9	11.6	15.3
KLA-04 Nth	56.5	6.3	28.5
KLA-04 Sth	75.7	40.8	21.9
KLA-05	68.8	26.6	24.9
KLA-06 Nth	11.0	18.6	24.9
KLA-06 Sth	123.6	24.1	14.6
KLA-07	70.1	24.5	23.5
KLA-08 Nth	40.5	30.4	25.5
KLA-08 Sth	52.4	7.6	15.5
KLA-09 Nth	87.6	13.2	25.6
KLA-09 Sth	3.6	20.7	17.5
KLA-10 Nth	0.0	26.2	14.8
KLA-10 Sth	93.4	10.7	27.5
KLA-11 Nth	2.1	4.9	19.9
KLA-11 Sth	103.1	27.3	17.2
KLA-12 East	0.4	9.9	4.2
KLA-12 West	36.7	15.6	22.6
KLA-13 East	72.3	11.2	31.2
KLA-13 West	7.6	26.5	0.6
KLA-14	76.7	32.1	33.2