T&T Landfill Discharge to the Owhiro Stream: Assessment of effects on freshwater quality and ecology

April 2017

Report Prepared for Greater Wellington Regional Council

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EXECUTIVE SUMMARY

Context

T&T Landfill Ltd operate a construction and demolition landfill at Happy Valley Road, in the Owhiro Stream catchment, Wellington. A number of ephemeral watercourses flow into the landfill site, go sub-surface and re-emerge at the toe of the landfill and into a tributary of the Owhiro Stream, before reaching the Owhiro Stream itself. The Owhiro Stream runs along Happy Valley Road for another 2 kilometres before flowing into the coastal waters of Owhiro Bay, within the Taputeranga Marine Reserve, on the Wellington South Coast.

On 15th November 2016, the area received intense rainfall. It is our understanding that the entry point of one of the ephemeral tributaries under the landfill was blocked off, presumably as a result of a land slip, causing a large ponding area. The water from within the ponding area subsequently seeped under the landfill over the course of several weeks, reappearing at the toe of the landfill into the unnamed tributary, before flowing into the Owhiro Stream itself. In the following weeks, Greater Wellington Regional Council (GWRC) received complaints about discolouration and foaming in the Owhiro Stream.

Assessment undertaken

Water quality sampling was undertaken in response to the complaints during the period 22nd November 2016 to 18th January 2017. Sampling was initially limited to immediately upstream and downstream of the source of the discharge, then extended to tributaries above the landfill site to the mouth of the Owhiro Stream. Monitoring of macroinvertebrate communities was also undertaken in the tributaries and the Owhiro Stream itself upstream and downstream of the landfill. This report provides an assessment of the effects of the discharge on the Owhiro Stream's water quality and aquatic ecology, based on data collected upstream and downstream of the discharge during and following the November 2016 event.

Water quality and ecological data are also collected under the conditions of the resource consent held by the landfill. These data were also analysed to provide an assessment of the "background" effects of the discharge from the landfill and a comparison point for the data collected specifically in response to the November 2016 event.

Results – ongoing/ background effects

Long-term monitoring data indicates that the T&T Landfill causes a number of significant adverse changes in water quality and ecology on a consistent basis. In particular, it causes consistent degradation of water clarity, deposition of iron/manganese precipitate and increases in the concentrations of ammoniacal nitrogen and a number of metals in the T&T Tributary and the Owhiro Stream. Clear "spikes" in contaminant concentrations were measured in January and August 2012, June 2013 and October 2016. The ecological data available (2010) indicates significant adverse effects on macroinvertebrate communities of both the tributaries and the Owhiro Stream itself.

In 2012, a report prepared by NIWA described an event similar to that of November 2016 (the damming of a side tributary) with similar consequences, i.e. prolonged exceedances of the iron guideline and

increased ammoniacal-nitrogen concentrations. The report recommended improvements to the drainage system, diversion of the tributaries around the landfill and treatment by way of a wetland.

Results –effects of the November 2016 event

The November 2016 event resulted in significant effects on water clarity and colour in both the tributary and the Owhiro Stream, largely exceeding RMA S107(1)(d) narrative standard. The effects on water clarity and colour during and following the November 2016 event were greater than the "ongoing" effects seen in quarterly monitoring data and are considered major, due to their intensity (very low water clarity < 0.1m), duration (several weeks) and spatial extent (the whole of the Owhiro Stream downstream of the discharge).

The November 2016 event was also associated with a clear "spike" in concentrations of ammoniacal nitrogen and a number of metals, including iron, manganese, zinc and copper. Ammoniacal-nitrogen concentrations in the T&T Tributary and the Owhiro Stream exceeded the NPSFM National Bottom Line at times and are likely to have caused both chronic and acute toxic effects on aquatic life.

Iron and manganese from the tributary stream exiting the landfill caused the deposition of large amounts of orange/brown precipitate in the tributary and along the whole length of the Owhiro Stream (although in decreasing amounts going downstream). By 18th January 2017, effects appeared to have reduced back to the "ongoing" level of effects.

Significant adverse effects on macroinvertebrate communities occurred in both the T&T Tributary and the Owhiro Stream itself, with a 70 to 80% reduction in the overall number of macroinvertebrates, a near-disappearance of pollution sensitive species and the presence of abnormally coloured and formed freshwater snails downstream of the discharge. A gradual recovery was observed along the length of the Owhiro Stream, with macroinvertebrate communities recovering to levels comparable to upstream of the discharge at the most downstream site sampled, just above the stream mouth to Owhiro Bay.

Conclusions and recommendations

The T&T Landfill appears to be causing significant adverse effects on water clarity and colour and on aquatic life on an ongoing basis. However, the intensity and scale of effects appears to vary in time, with a number of clear spikes in the concentrations of contaminants measured in January and August 2012, June 2013 and October2016.

The November 2016 event led to greater effects than the normal ongoing/background effects. However, it does not appear to have been a unique event, similar conditions having been reported in 2012. It is also possible that the June 2013 and October 2016 spikes in contaminants were the result of similar events.

On the basis of the above conclusions, we can only recommend that some urgency be given to implementing mitigation measures, including:

- diversion of the tributaries around the landfill to reduce as much as practicable, the amount of water circulating under and through the fill area. We understand that surface diversion channels are being considered. We recommend that their design incorporates input from a water quality scientist/ecologist to ensure that the diversion channels do not prevent fish passage and do not

lead to other effects (for example, some shading should be provided to avoid significant increases in temperature);

- capture and treatment of the remainder of the leachate at the toe of the landfill. We understand that a wetland treatment is being considered. As with all wetland treatment systems, adequate design of the wetland will be critical to treatment efficiency, particularly given the physical constraints of the site (only a very small wetland will be able to be constructed). We also note that wetland treatment is not generally considered efficient for removal of ammoniacal nitrogen, and additional treatment may be required if elevated ammoniacal nitrogen are recorded again in the future.

With regards to ongoing monitoring, we make the following recommendations:

- It appears that events similar to that of November 2016 have already occurred in the past following heavy rainfall, leading to "spikes" in contaminant concentrations being discharged to the Owhiro Stream. The frequency of the current water quality monitoring regime (every three months) means that short- to medium-term spikes may not be identified. It would seem appropriate to undertake systematic water quality sampling in the 2-4 week period following heavy rainfall. Site inspections may also help identify any water ponding areas;
- There does not appear to be any data on the presence or abundance of organic micro-contaminants in the Owhiro Stream. Given the unknown nature of the waste underlying the T&T clean fill operation, some analyses of SVOC/VOCs in sediment at various points down the catchment would be useful to provide some base information on the presence of these contaminants in the catchment.

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1. Introduction

1.1. Background

T&T Landfill Ltd operate a construction and demolition landfill at Happy Valley Road, in the Owhiro catchment, Wellington. A number of ephemeral watercourses flow into the landfill site, go sub-surface and re-emerge at the toe of the landfill into a pond ("stilling basin"), and then into a tributary of the Owhiro Stream ("The T&T Tributary"), before reaching the Owhiro Stream itself. The Owhiro Stream runs along Happy Valley Road for another 2 kilometres before flowing into the coastal waters of Owhiro Bay, within the Taputeranga Marine Reserve, on the Wellington South Coast.

Consent WGN070260 [30627] allows for "*the discharge of contaminants including sediment-laden stormwater, leachate contaminants from historical sanitary landfills, and existing and future construction and demolition landfill material to tributaries of the Owhiro Stream*". A variation to this consent was granted in July 2011 subject to a suite of conditions.

On 15th November 2016, the area received intense rainfall. It is our understanding that the entry point of one of the ephemeral tributaries under the landfill was blocked off, presumably as a result of a land slip, causing a large ponding area (refer to Plate 1). The water from within the ponding area subsequently seeped under the landfill over the course of several weeks, reappearing at the toe of the landfill into the unnamed tributary, before flowing into the Owhiro Stream itself.

In the following weeks, Greater Wellington Regional Council (GWRC) received complaints about discolouration and foaming in the Owhiro Stream. Water quality monitoring was undertaken at a number of sites over the following month, initially limited to immediately upstream and downstream of the source of the discharge, then more extensively from tributaries above the landfill site to the mouth of the Owhiro Stream. Monitoring was discontinued on 18th January 2017.

1.2. Aim and Scope

This report was commissioned by Greater Wellington Regional Council to provide an assessment of the nature and scale of the effects of the discharge of contaminants from the T&T Landfill on the water quality and instream ecology of the Owhiro Stream during and following the November 2016 event. It is primarily based on monitoring data collected during the period December 2009 – December 2016 (water quality) and December 2016 (ecology) (MWH: 21 December 2016 and Aquanet Consulting: 22 December 2017).

The assessment is made solely on technical grounds and is limited to surface water quality and aquatic ecology considerations.

Plate 1: Ponding area, as observed on 19th December 2016. The extent of the ponding area is marked by the line of dead vegetation along the top of the photograph.

1.3. Structure of the report

This report is comprised of seven sections:

Section 2 outlines the data available for analysis, presents a map of monitoring sites and explains approaches used in data analysis. It also sets out the water quality and ecological targets or thresholds against which the monitoring data were assessed.

Section 3 considers the potential effects of the November 2016 event on the receiving environment.

Section 4 presents an assessment of the background state of water quality in the Owhiro Stream and tributaries associated with the T&T Landfill, using quarterly monitoring data.

Section 5 considers the effects of the discharge from the T&T Landfill based on water quality and ecological monitoring undertaken in response to the November 2016 event.

Section 6 presents an assessment of the state of ecological (macroinvertebrate and periphyton) health in the Owhiro Stream.

Section 7 presents conclusions from the main findings of Sections 2 to 6, as well as recommendations.

2. Methods

2.1. Available data and data preparation

The data used for the assessment presented in this report are summarised in Table 1 below.

Water quality data can be compared to guidelines or thresholds to gain an appreciation of the risk of effects (e.g. toxic effects) caused by the various contaminants detected in samples. Guidelines used in this report include:

- Water quality tolerance limits as set out in current consent conditions (Table 2);
- Water quality trigger values set out in the ANZECC (2000) and revised ANZECC (NIWA 2017) guidelines (Table 2);
- NPSFM 2014 Attribute States for ammoniacal nitrogen;
- Ecological guidelines for periphyton biomass and cover, and macroinvertebrate biotic indices as set out in the relevant sections.

Table 1: Summary of data used in this assessment.

Site	Type	Parameters	Frequency	Period	Source
TTE, TTW, TTD, OSU, OSD	River water quality	pH, Alkalinity, Conductivity, COD, Ammoniacal-N, Total Metals (Arsenic, Chromium, Lead, Zinc, Iron, Manganese, Copper), Calcium, TSS, Total Hardness	Quarterly	January 2008 to December 2016	MWH
Various locations from upstream of the Landfill area down to Owhiro Bay			One- off	22 November 2016 28 November 2016 6 December 2016 14 December 2016 18 January 2017	GWRC
MWH Sites: TTE, TTW, TTD, OSU, OSD	Biological indicators	Macroinvertebrate indices (MCI, QMCI, %EPT taxa, %EPT individuals, No. of taxa, No. of individuals)		2010 and 21 December 2016	MWH
Aquanet sites: US T&T Landfill, DS T&T Landfill, Owhiro US Murchison Bridge, Owhiro Bay		%Periphyton cover [Aquanet sites]		22 December 2016	Aquanet

Table 2: Water quality guidelines acceptable under current consent conditions (Resource Consent N. WGN070260 [30627], Condition 8) and ANZECC (2000) trigger values 90% protection level (95% protection level in brackets).

Parameter	Tolerance range allowable under Consents WGN070260 [30627], Condition 8	ANZECC (2000) Trigger values Ecosystem protection 90% trigger values (95% trigger levels in brackets)[1]	Recent revisions (NIWA 2017) of ANZECC Trigger values for Ecosystem protection 90% trigger values (95% trigger values in brackets)
pH	-0.4 to 0.4	7.2 – 7.8	
Conductivity (µS/m)	72.4		
Alkalinity (g/m^3)	226		
Total Suspended Solids (g/m^3)			
COD (g/m^3)	21		
Total Hardness (g/m^3)			
Ammoniacal Nitrogen (g/m^3)	0.346	1.43 (0.9)	
Total Iron (g/m^3) [2]	2.748		
Total Manganese (g/m^3) [2]	1.461	2.5 (1.9)	
Total Lead (g/m^3)	0.0059	0.0056 (0.0034)	
Total Copper (g/m^3)	0.004	0.0018 (0.0014)	0.0021 (0.0012)
Total Zinc (g/m^3)	0.13	0.015 (0.008)	0.006 (0.003)
Total Arsenic (g/m^3)	0.013	(AsV) 0.042 (0.013)	
Total Chromium (g/m^3)	0.001	(AsVI) 0.006 (0.001)	

[1] Note that 90% is a relatively low protection level, generally applicable to degraded waterbodies, and it is more common to apply a slightly higher level of protection (95% species protection) to natural streams such as the Owhiro Stream. Both the 90% and the 95% species protection levels have been included in the discussion of results.

[2] Manganese and iron may cause effects via the deposition of iron bacteria floc, which is a separate effect from toxicity. The 2012 NIWA report recommends the use of a guideline of 1 mg/l for the sum of iron + manganese concentrations to prevent bed smothering by iron/manganese floc. This has also been included in the discussion of results.

2.2. Receiving Environment

The two unnamed tributaries upstream of the landfill are considered natural streams and, along with the one at the toe of the landfill where they emerge as one stream, represent the primary receiving environment for the discharge from the T&T Landfill. The Owhiro Stream is also a natural stream which supports a range of ecological and recreational values. It constitutes the secondary receiving environment for the discharge. The Owhiro Stream flows into the ocean at Owhiro Bay, which represents the final receiving environment. Effects on the coastal receiving environment are not directly covered in this assessment.

A map of the overall T&T Landfill site area, unnamed tributaries and Owhiro Stream is shown in Figure 1.

Sites on the tributaries upstream and downstream of the T&T Landfill and on the Owhiro Stream mainstem, monitored for water quality and ecology (as identified in Table 1 above) are listed in Table 3 and shown in Figures in the following sections.

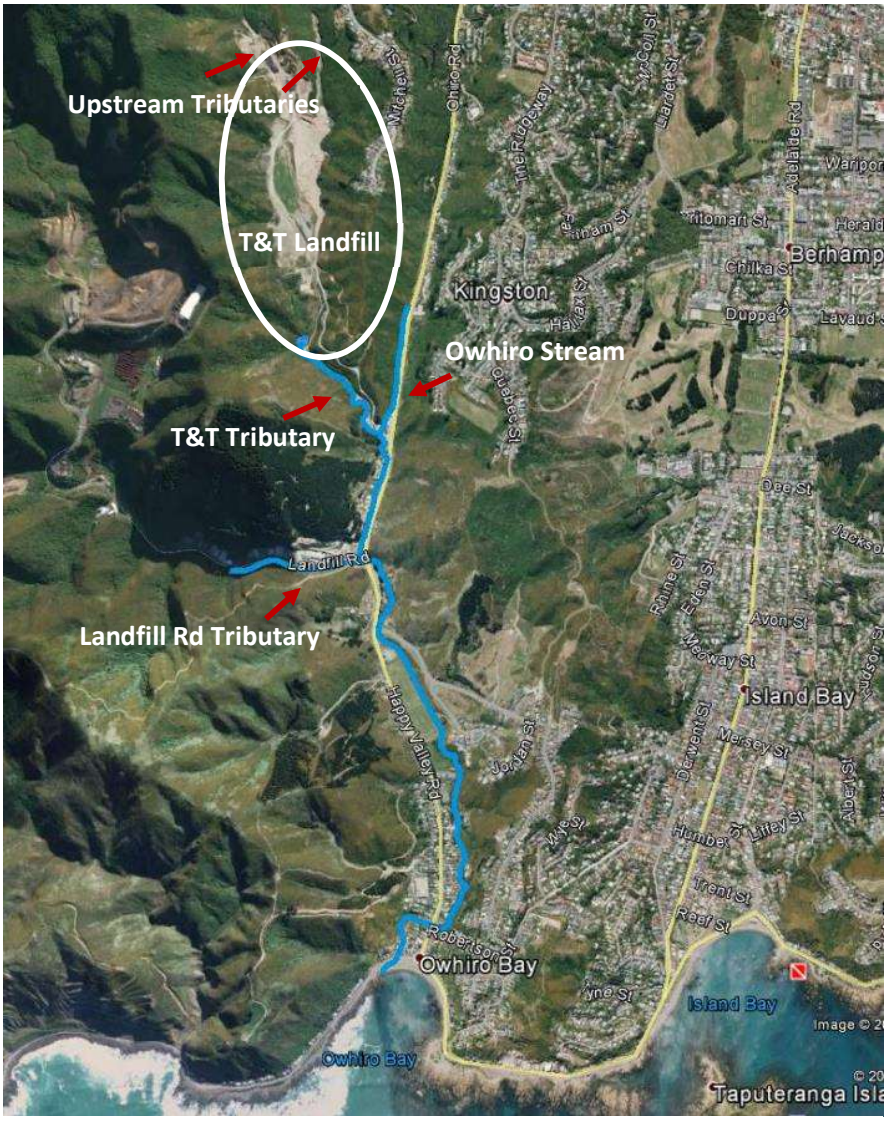


Figure 1: Map showing overall area where the T&T Landfill is situated and adjoining tributaries and Owhiro Stream mainstem.

Table 3: Sites on the Owhiro Stream and tributaries sampled for water quality (January 2008 – January 2017) and macroinvertebrates (December 2016).

	Location as per		Sampled for	
Sample Date	**GWRC at time of monitoring**	**For this Report**	Water Quality	**Ecology (December 2016 only)**
Quarterly (2008-2016)	TTW	TTW	√	√
	TTE	TTE	√	√
	TTD	TTD	√	√
	OSU	OSU	√	√
	OSD	OSD	√	√
22/11/2016	JS01 T & T Pond Inlet	Stilling Basin Inlet	√	
	JS02 T&T Pond	Stilling Basin	√	
	JS03 T&T 5m Downstream	5m D/S Stilling Basin	√	
	JS05 T&T Owhiro Stream Upstream	Owhiro Stream U/S	√	
	JS04 T&T Site Boundary	T & T Trib	√	
	JS07 T&T Owhiro Stream Downstream	Owhiro Stream D/S	√	
28/11/2016	HDP20161128A T&T Fill Toe Pond	Stilling Basin	√	
	HDP20161128B T&T Fill AT Kiosk	T & T Trib	√	
	HDP20161128C T&T Fill Culvert 285	D/S Confl. with Owhiro Stream	√	
	HDP20161128D D/S Landfill Stream	D/S Confl. with Landfill Rd Trib	√	
06/12/2016	PP-5-Stilling Basin T+T	Stilling Basin	√	
	PP-6-100m Downstream From Stilling Basin	100m D/S Stilling Basin	√	
	PP-4-Immediately Upstream of Confluence in T+T Branch	T & T Entrance U/S	√	
	PP-3-Upstream of Confluence Happy Valley Branch	Owhiro Stream	√	
	PP-2-Downstream of Confluence	T & T Entrance D/S	√	
	PP-1-Owhiro Mouth	Owhiro Bay	√	
14/12/2016	CB12 Mitchell Dam	Mitchell Dam	√	
	CB11 Mitchell St Gully Pool	Mitchell St Gully Pool	√	
	CB10 Mitchell St Gully	Mitchell St Gully	√	
	CB09 Stilling Basin	Stilling Basin	√	
	CB08 Below Stilling Basin	Below Stilling Basin	√	
	CB06 T & T entrance Upstream	T & T Entrance U/S	√	
	CB07 Owhiro Stream Upstream	Owhiro Stream	√	
	CB05 T & T entrance Downstream	T & T Entrance D/S	√	
	CB03 Landfill Road Upstream (A-E)	Landfill Rd U/S	√	
	CB04 Bridge at 330 Owhiro	330 Owhiro Rd	√	
	CB02 Landfill Road Downstream (A-E)	Landfill Rd D/S	√	
	CB01 Mooch Owhiro Stream (A-E)	Owhiro Bay	√	
18/01/2017	JS10 (A->E) Mitchell Dam	Mitchell Dam	√	

	Location as per		Sampled for	
Sample Date	GWRC at time of monitoring	For this Report	Water Quality	Ecology (December 2016 only)
	JS09 (A->E) Stilling Basin	Stilling Basin	√	
	JS08 (A->E) Below Stilling Basin	Below Stilling Basin	√	
	JS06 (A->E) T&T Entrance Upstream	T&T Entrance U/S	√	
	JS07 (A->E) Owhiro Stream Upstream	Owhiro Stream	√	
	JS05 (A->E) T&T Entrance Downstream	T&T Entrance D/S	√	
	JS03 (A->E) Landfill Road Upstream	Landfill Rd U/S	√	
	JS04 (A->E) 330 Owhiro Road	330 Owhiro Rd	√	
	JS02 (A->E) Landfill Road Downstream	Landfill Rd D/S	√	
	JS01 (A->E) Mouth Owhiro Stream	Owhiro Bay	√	
22/12/2016		Upstream T&T Landfill		√
		Downstream T&T Landfill		√
		Owhiro Upstream Murchison Bridge		√
		Owhiro Bay		√

2.3. Data analysis

2.3.1. Surface Water

Water quality data collected on a quarterly basis from the tributaries and Owhiro Stream mainstem are presented in Section 4.

Comparisons of upstream/downstream results from quarterly monitoring for the Owhiro Stream were carried out using a Wilcoxon Signed Rank Test in Statistix 9, as recommended in Scarsbrook and MacBride (2007).

Water quality data collected in response to the November 2016 event from the tributaries and Owhiro Stream mainstem are presented in Section 5.

2.3.2. NPSFM 2014 Assessment for ammoniacal-nitrogen

The NPSFM ammoniacal-nitrogen attribute utilises a protection level approach similar to that of the ANZECC Guidelines, but with thresholds based on a more recent and more complete dataset. In effect, it represents a review of the ANZECC trigger values. It defines four “bands”. Band A corresponds to the 99% protection level, Band B to 95%, Band C to 80%. Band D is below the “National Bottom Line”. The NPSFM Attribute State thresholds are based on a water pH of 8.0, and specifies that data should be corrected for pH and temperature.

As no temperature data were available, assessments against the NPSFM Attribute States for ammoniacal-nitrogen were corrected for pH and assumed a temperature of 20°C.

2.3.3. Ecological communities

Ecological data collected at sites upstream and downstream of the T&T Landfill discharge to the Owhiro Stream in 2010 (MWH), on 21st December 2016 (MWH) and 22nd December 2016 (Aquanet) are presented in Section 6.

2.3.4. Macroinvertebrate communities

Macroinvertebrates are good indicators of water quality as they show a wide range of responses depending on their degree of sensitivity to pollution. For example, some taxa such as Gastropoda and Chironomidae are generally considered to be tolerant of poor quality water, while others such as Ephemeroptera and Plecoptera prefer good water quality. The macroinvertebrate community at a given site may be considered a result of the prevailing water quality at that site. Consequently, macroinvertebrates are used widely both in New Zealand (Stark 1985, Winterbourn 1999) and overseas (Rosenberg and Resh 1993, Hynes 1994) as indicators of water quality.

Biological indices can be calculated to assess relationships between macroinvertebrate communities and water quality at a study site. The Macroinvertebrate Community Index (**MCI**) (Stark 1985) considers the presence of macroinvertebrates based on an assigned score which is dependent on their tolerance to pollution (1= highly tolerant, 10 = highly sensitive). The Quantitative Macroinvertebrate Community Index (**QMCI**) is similar to the MCI, but also takes into account the number of individuals of each species collected. Table 4 provides an interpretation of MCI and QMCI scores.

It is noted that MCI and QMCI were primarily developed as indicators of organic enrichment (although they are known to react to other factors such as deposited sediment), and are not well adapted to assessing the effects of chemical contamination (e.g. by metals). The analysis of effects should therefore not be limited to examination of MCI and QMCI scores. Other indices, such as species diversity (number of taxa), invertebrate density (number of individuals) and indices associated to EPT taxa (as described below) should all be considered.

Ephemeroptera, Plecoptera and Trichoptera (mayflies, stoneflies and caddisflies) (EPT) consist of insects which are generally sensitive to pollution. The percentage of **EPT taxa** is the proportion of all taxa collected that belong to one of these groups. The percentage of **EPT individuals** measures the proportion of the individual macroinvertebrates collected that are mayflies, stoneflies and caddisflies.

Table 4: Interpretation of MCI and QMCI values after Boothroyd & Stark (2001) for stony streams.

Interpretation	MCI	QMCI
Excellent / Clean water	>119	>5.9
Good / Possible mild pollution	100-119	5.0-5.9
Fair / Probable moderate pollution	80-99	4.0-4.9
Poor / Probable severe pollution	<80	0-4.0

Macroinvertebrate sampling and identification undertaken by Aquanet followed Protocols C3 (Hard bottom, quantitative), P3 (Full count with subsampling option) and QC3 (Quality control for full count with subsampling option) from the Ministry for the Environment "Protocols for sampling macroinvertebrates in wadeable streams" (Stark *et al*., 2001). Macroinvertebrate sampling and identification undertaken by MWH in December 2016 also followed these protocols although the number of replicates differed between sites.

Differences in biotic indices between sites were assessed using an Analysis of Variance (ANOVA) in Statistix 9. Values at $P < 0.05$ indicate a statistically significant change.

3. Key Contaminants and Potential effects of Discharge

3.1. Key contaminants

Although T&T Landfill currently operate as a clean fill operation, it is our understanding that the site was in the past used as a landfill for waste of an unknown nature. As a result, the nature of the contaminants borne by any leachate/discharge from the landfill is not fully known. Leachate and/or discharges associated with decaying organic matter generally have a strong dark colouration, a high organic content (BOD, COD), and elevated ammoniacal nitrogen concentrations. Anoxic conditions can also lead to the dissolution of metals, which can then be exported from the landfill into the receiving environment.

Routine monitoring required under the consent requires the analysis of a number of water quality variables, including ammoniacal nitrogen, total suspended solids (TSS) and metals.

It is common to analyse landfill leachate discharges for the presence of organic microcontaminants, such as PAHs, PCBs, pesticides, etc. Although the T&T landfill currently operates as a clean fill operation, the unknown nature of the underlying waste means that the presence of these contaminants, and their discharge into the receiving environment cannot be discounted. We have not been able to source any data on organic microcontaminants in the Owhiro Stream catchment.

3.2. Potential effects

The potential effects of any discharge to water depend on the nature and composition of the discharge (in particular, the contaminants it contains and their concentration) and the nature and sensitivity of the receiving environment.

Potential effects of the discharge include:

1. Effects on visual/aesthetic values.
   a. Visual water clarity is a key aesthetic attribute of streams, rivers and lakes. Effects on water clarity are typically associated with particles/solids suspended in the water column. They can be measured directly (black disc, clarity tube), or by associated or surrogate measures (e.g. TSS, turbidity).
   b. Effects on water colour may also occur independently from effects on water clarity. Landfill leachate is often dark in colour, and can cause water discolouration in the receiving environment.
   c. The deposition of sediment and/or precipitate can cause adverse effects on both visual, recreational, (but also ecological, as detailed below) values of a stream.

d. Of particular relevance to the situation under consideration, anoxic conditions can lead to the dissolution of metals such as manganese and iron, which can then form an orange-coloured floc when oxic conditions (oxygen) are reinstated. The floc can deposit on the stream bed, colouring and smothering the bed substrate, with consequential potential effects on both visual/aesthetic and ecological values of the stream. The mechanisms of the formation of the iron/manganese floc by iron-oxidising bacteria are well described in the 2012 NIWA and the 2016 MWH reports and not repeated here.

2. Effects on freshwater aquatic life
   a. Each of the effects described above in relation to water clarity and colour, and the deposition of fine sediment and iron floc can have consequential effects on aquatic life. Poor water clarity can for example reduce the efficiency of sight-feeding for fish. Ecological effects of deposited fine sediment and/or iron floc primarily arise as a consequence of filling/clogging of the interstices between stones in the river bed. This interstitial space is where many invertebrate and fish species live and/or spawn;
   b. Toxic effects from ammonia: In sufficient concentrations, ammonia can cause both chronic (as a result of long-term exposure) and acute (short term exposure) toxic effects on aquatic life. The toxicity of ammonia increases with water pH and temperature.
   c. Toxic effects from metals: Various metals (Zinc, copper, lead, etc.) or metalloids (arsenic) can also cause both chronic and acute toxic effects on aquatic life.
   d. Periphyton growth: Ammoniacal-nitrogen is a macro-nutrient directly available to plant growth. Under stable flow conditions, it can promote excessive growth of algae on rocks on the bottom of the stream, with consequential potential effects on aesthetic, recreational and ecological values.

3. Effects on the marine environment are not specifically covered in this report due to a lack of monitoring data. However, all of the above potential effects on freshwater aesthetic and ecological values also have to potential to occur in the near-shore marine environment of Owhiro Bay.

The actual effects of the discharge are discussed in Sections 4, 5 and 6, on the basis of monitoring data.

4. Ongoing/Background Effects of the discharge

4.1. Quarterly Water Quality data

Water quality determinants required under the current Consent, measured quarterly (i.e. every three months) in the tributaries upstream and downstream of the T&T Landfill and in the Owhiro Stream are discussed below. Figure 2 shows the location of monitoring sites.

Figure 2: Sites monitored quarterly under Consent Condition 7 (red arrows) on the Western (TTW) and Eastern (TTE) tributaries above the T&T Landfill, on the T&T Tributary downstream of the landfill (TTD) and on the Owhiro Stream mainstem upstream (OSU) and downstream (OSD) of the confluence with the T&T Tributary.

The quarterly water quality data collected under the consent conditions provides a useful indication of the on-going, or "background" effects of the discharge on water quality in the unnamed tributary and the Owhiro Stream. It is important to note that the monitoring frequency (quarterly, i.e. every three month) means that water quality is unknown between monitoring events. In particular, a number of peaks in concentrations of contaminants may occur without being detected between sampling rounds.

4.1.1. Total Suspended Solids (TSS)

The discharge causes an overall significant increase in TSS concentrations in both the Unnamed Tributary and the Owhiro Stream (Figure 3). Upstream of the landfill, both the unnamed tributaries and the Owhiro Stream generally present very low TSS concentrations indicative of clear water. Large increases (more than a doubling) in TSS concentrations from upstream to downstream of the discharge are apparent on nearly all sampling occasions, indicative of consistent significant adverse effects on water clarity (and possibly colour). Four distinct "peaks" in downstream TSS concentrations are apparent in January and August 2012, June 2013 and October2016.

4.1.2. Ammoniacal Nitrogen

Ammoniacal nitrogen concentrations are generally very low upstream of the T&T Landfill, both in the unnamed tributaries and in the Owhiro Stream (Figure 4). Increases in ammoniacal nitrogen concentrations have occurred consistently between 2010 and 2016 between upstream and downstream of the landfill, both in the unnamed tributaries and in the Owhiro Stream. Four significant "peaks" in concentration occurred at the downstream sites, January and August 2012, June 2013 and October2016.

Assessment against NPSFM 2014

The Owhiro Stream upstream of the confluence with the Tributary from the T&T Landfill (OSU) and the Tributaries upstream of the T&T Landfill site (TTW & TTE) sit within Band A for both median and maximum unionised concentrations (Figure 5). Downstream sites on both the Owhiro Stream (OSD) and T&T Landfill Tributary (TTD) sit within Band B for median unionised concentrations and Band C for maximum concentrations.

Attribute State A indicates that there will be no observed effect on any species tested; Attribute State B indicates that ammoniacal nitrogen concentrations will start impacting occasionally on the 5% most sensitive species; Attribute State C indicates that ammoniacal nitrogen concentrations will start impacting regularly on the 20% most sensitive species.

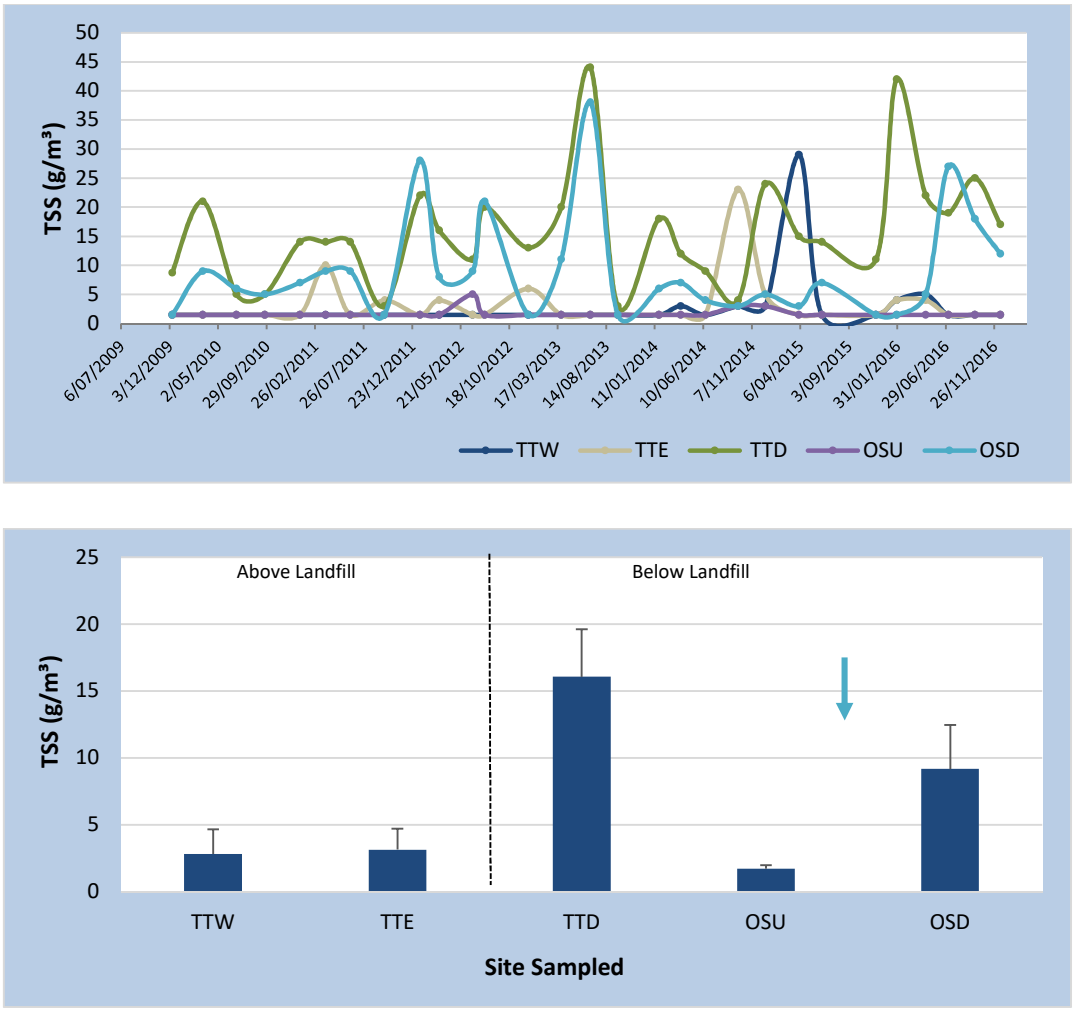


Figure 3: Total Suspended Solids (TSS) concentrations over time (upper) and Mean TSS concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

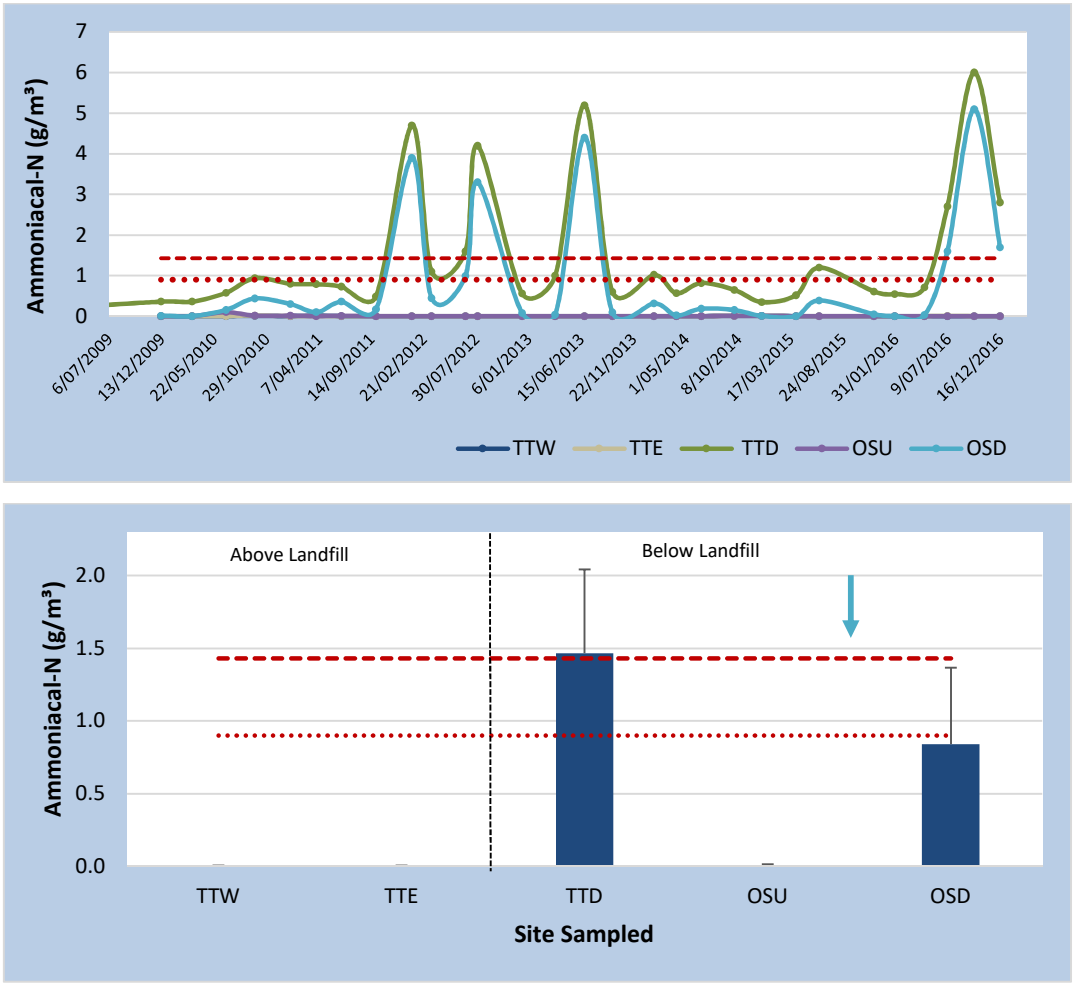


Figure 4: Ammoniacal nitrogen concentrations over time (upper) and average Ammoniacal nitrogen concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. Red lines indicate ANZECC (2000) trigger values for the 90% (dashed) and 95% (dotted) species protection level. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

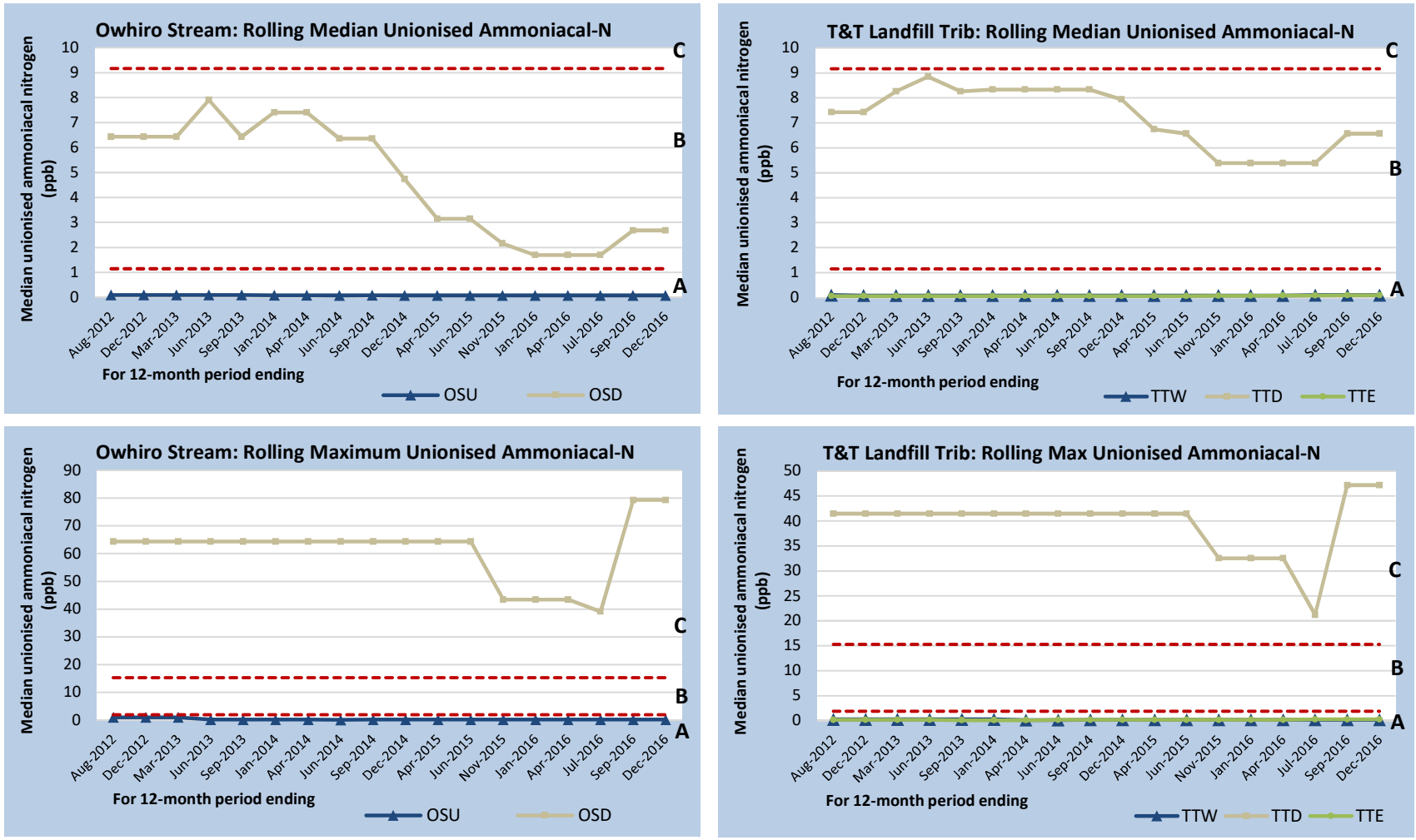


Figure 5: Rolling 12-month Median (upper) and maximum (lower) unionised ammoniacal-nitrogen concentrations for sites sampled in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill (left) and on the Unnamed T&T Landfill Tributaries upstream (East branch: TTE, and West Branch: TTW) and downstream (TTD) (right). Based on quarterly data (2009-2016) provided by MWH. NPSFM 2014 Attribute States (A, B and C) are indicated by red lines.

4.1.3. Iron and Manganese

There was a consistent increase in both iron and manganese concentrations downstream of the discharge (Figure 6). Downstream sites on both the tributary and the Owhiro Stream generally exceed the 1 mg/L NIWA guideline to avoid the formation of iron/manganese deposits, although higher "peaks" are again apparent in January and August 2012, June 2013 and October2016. Manganese concentrations exceeded ANZECC Trigger values for toxicity during these peaks.

4.1.4. Water Hardness, Calcium and Magnesium

There is a consistent increase in water hardness, calcium and magnesium concentrations at downstream sites on the T&T Tributary (TTD) and Owhiro Stream (OSD) (Figure 7 and Figure 8). Whilst not indicators of effects in themselves, these increases do indicate a profound change in chemistry in both the unnamed tributary and the Owhiro Stream. It is also notable that "peaks" in hardness, calcium and magnesium appeared during the same periods as the peaks in TSS, ammoniacal nitrogen, iron and manganese noted above.

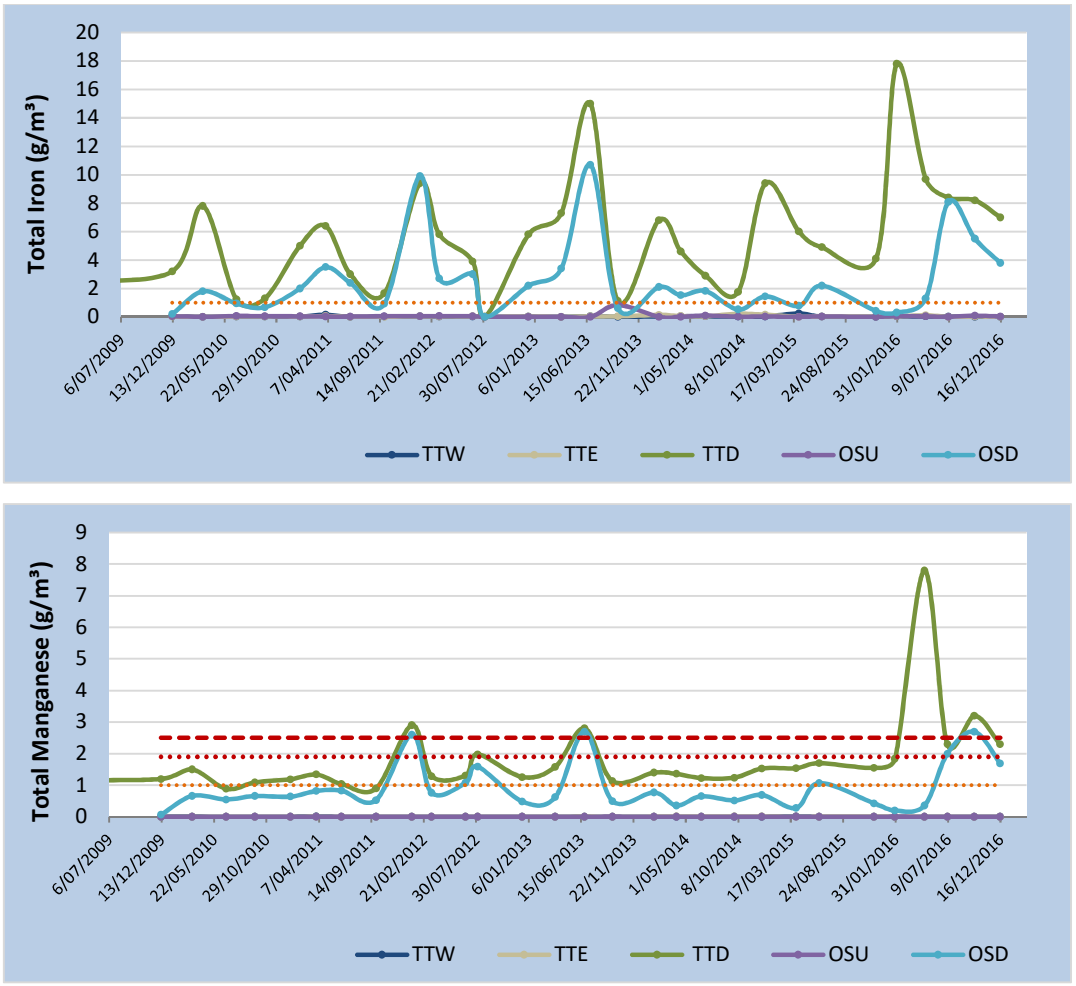


Figure 6: Total Iron (upper) and Total Manganese (middle) concentrations over time and Mean Iron and Manganese concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream. Red lines indicate ANZECC (2000) trigger values for the 90% (dashed) and 95% (dotted) species protection level. Orange lines represent the NIWA recommended guideline to prevent bed-smothering by iron/manganese floc.

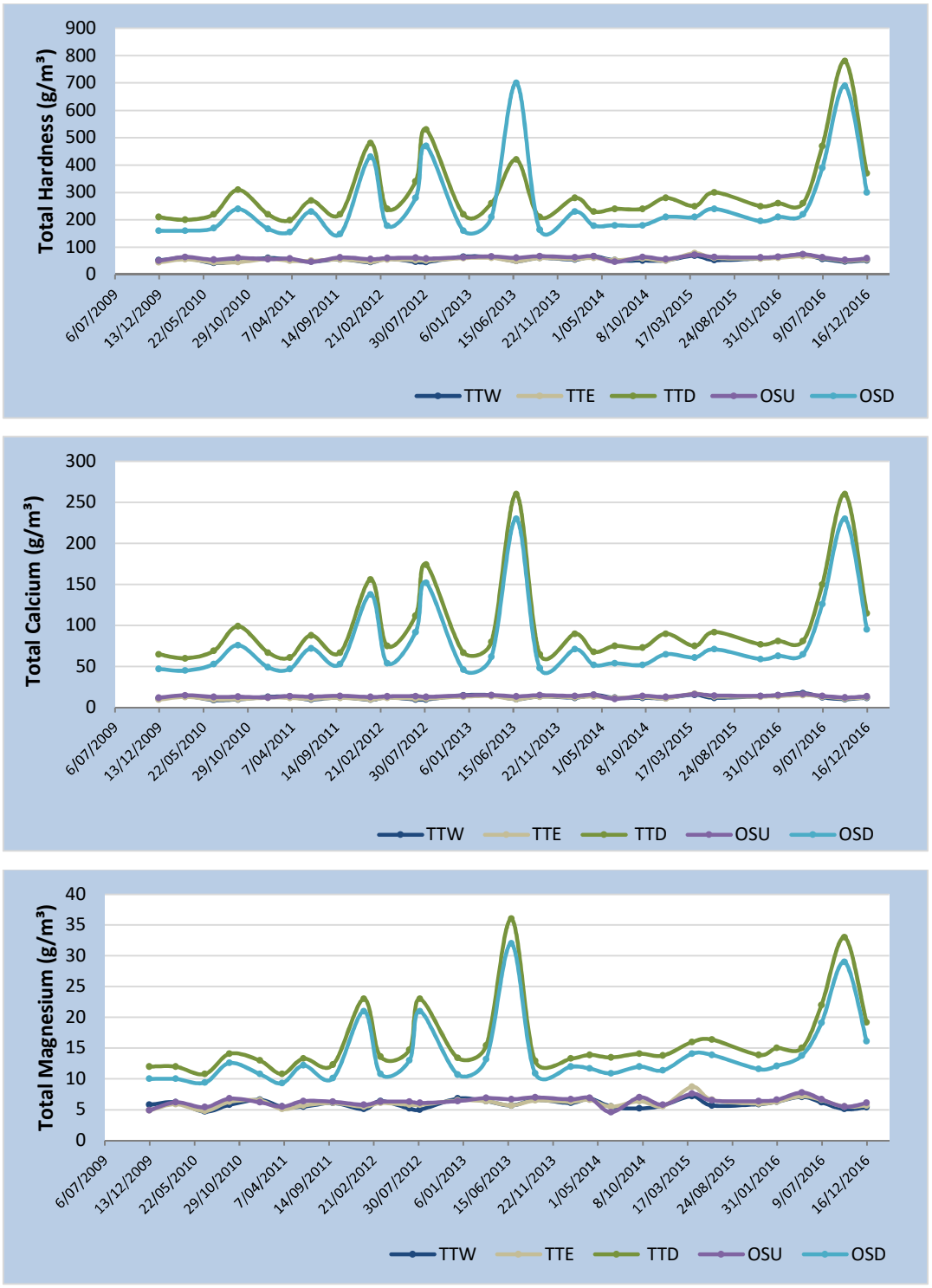
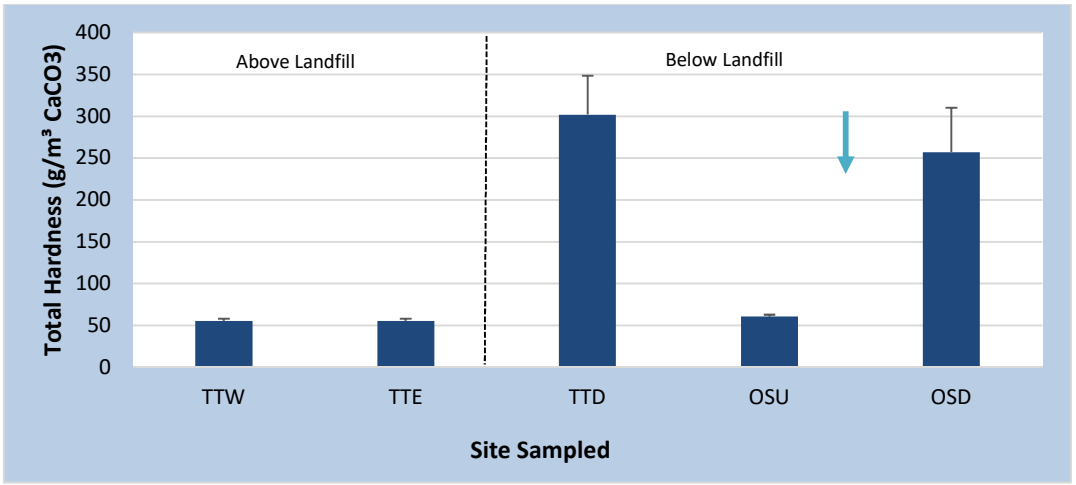
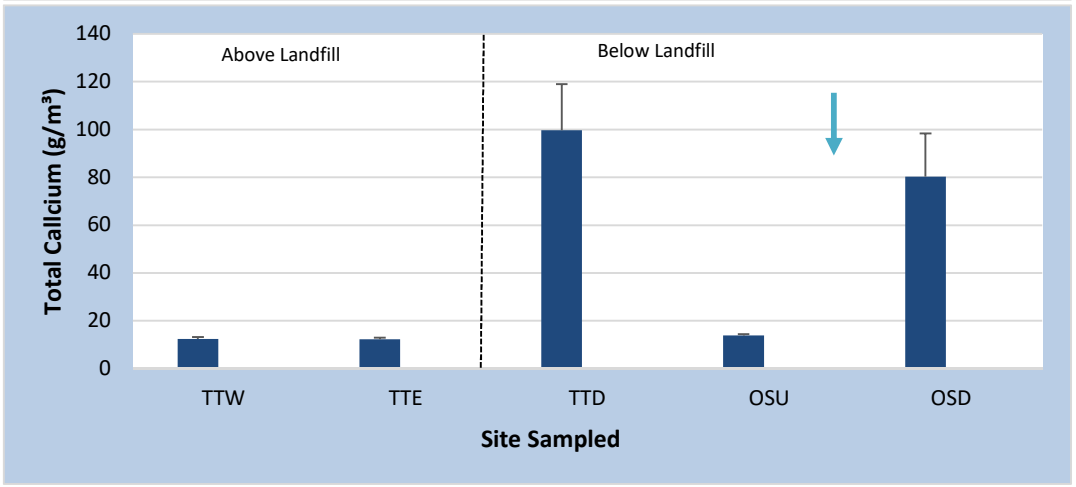


Figure 7: Total Hardness (upper) and Total Calcium (middle) and Magnesium (lower) concentrations over time in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH.





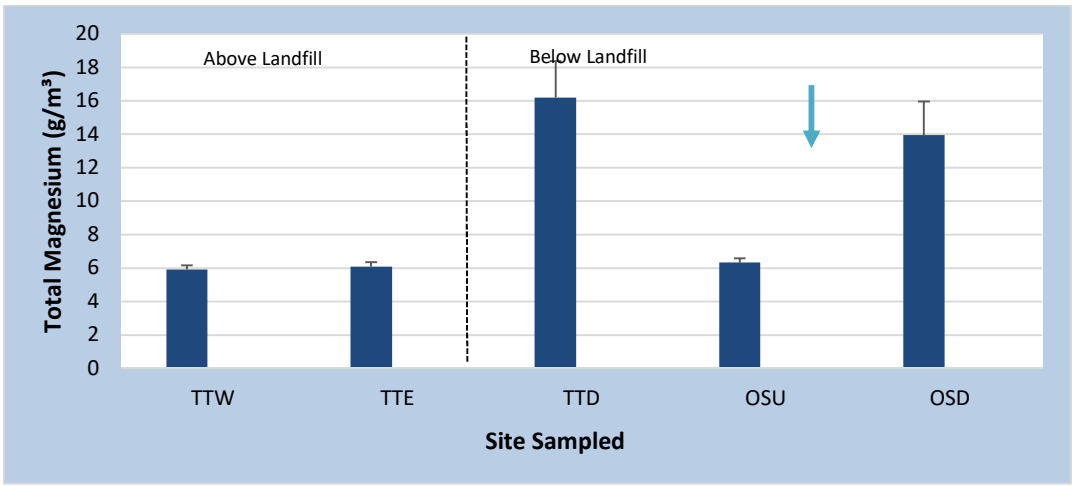


Figure 8: Mean Total Hardness (upper) and Mean Total Calcium (middle) and Magnesium (lower) concentrations in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

4.1.5. Other Metals

Zinc: In the T&T Tributary, upstream concentrations are generally low in the West Branch (TTW), but moderately elevated in the East Branch (TTE). There is however a general increase downstream of the landfill, to concentrations well in excess of the ANZECC trigger values at both the 95% and the 90% protection levels.

In the Owhiro Stream, zinc concentrations are generally well in excess of the ANZECC trigger values upstream of the discharge (OSU), and generally comparable (or lower) downstream (OSD). However, concentration "peaks" (10 to 20 times the 90% trigger value) occurred downstream of the discharge both in the tributary and the Owhiro Stream in January and August 2012, June 2013 and October2016 (Figure 9).

The upstream zinc concentrations in the eastern branch of the tributary and the Owhiro Stream are possibly associated with stormwater discharges from urban areas.

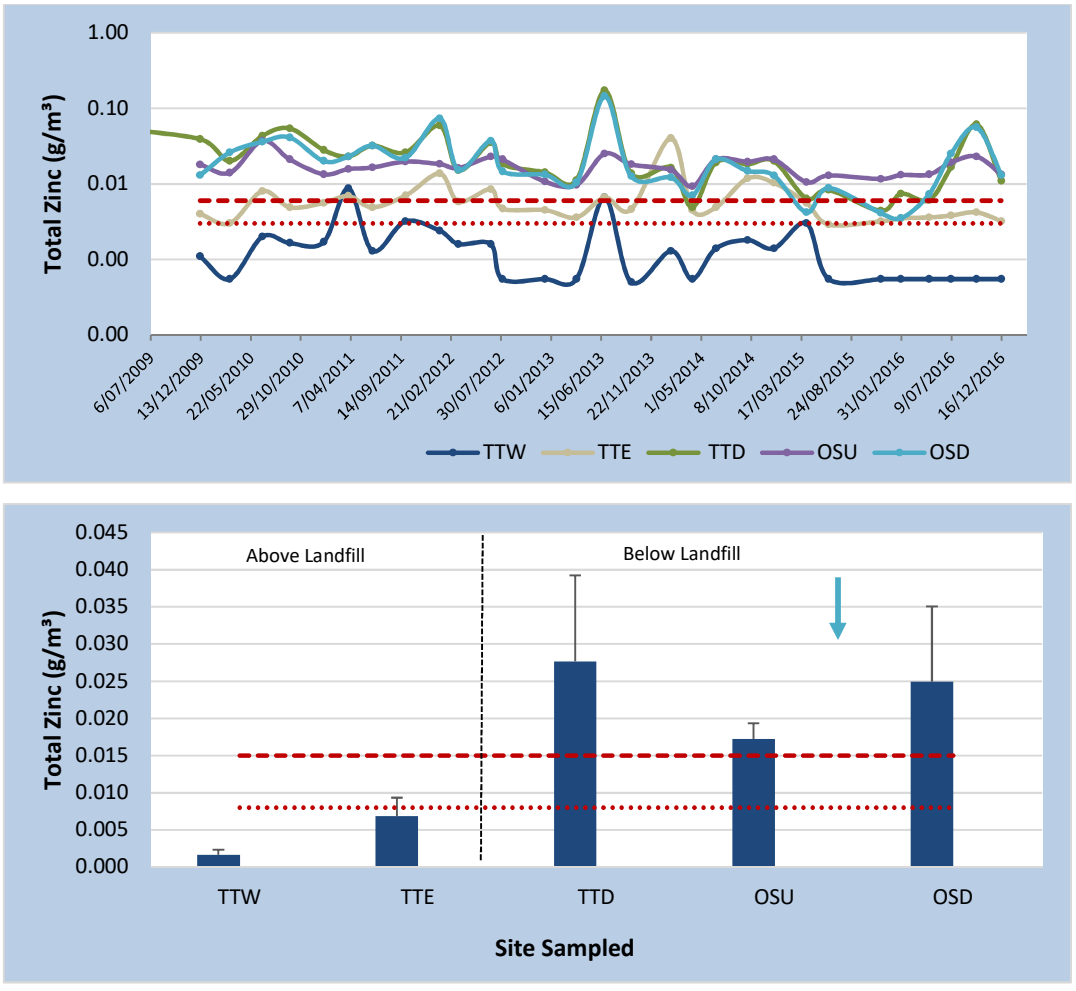


Figure 9: Total Zinc concentrations over time (upper) and Mean Total Zinc concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. Red lines indicate ANZECC (2000) trigger values for the 90% (dashed) and 95% (dotted) species protection level. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

Chromium: There is a general increase in Chromium concentrations between sites upstream and downstream on the Owhiro Stream and T&T Landfill Tributary. While concentrations are generally below guideline levels, peaks in 2012, 2013 and 2016 exceeded the 95% protection level ANZECC trigger values (Figure 10).

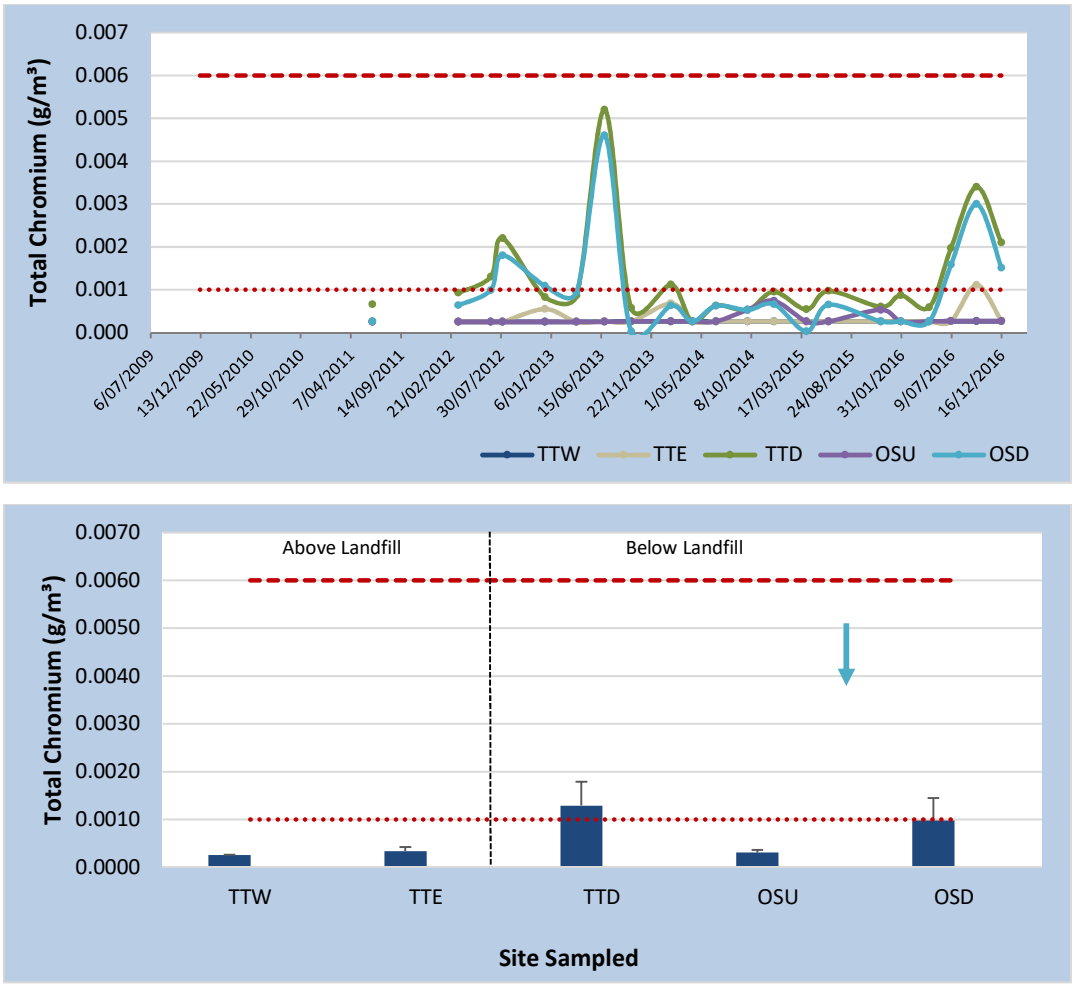


Figure 10: Total Chromium concentrations over time (upper) and Mean Total Chromium concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. Red lines indicate ANZECC (2000) trigger values for the 90% (dashed) and 95% (dotted) species protection level. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

Arsenic: While there is a general increase between upstream and downstream, concentrations remain below ANZECC guideline levels at all sites (Figure 11).

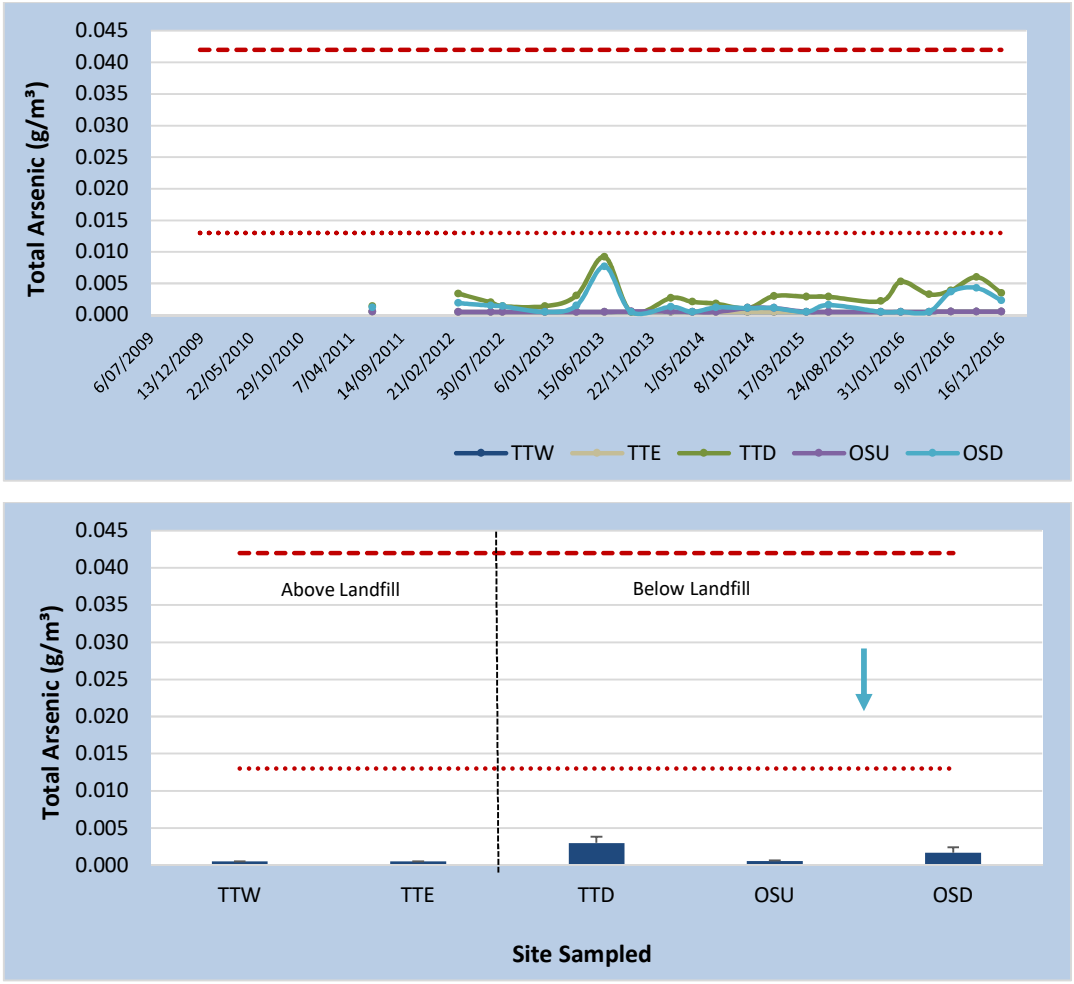


Figure 11: Total Arsenic concentrations over time (upper) and Mean Total Arsenic concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. Red lines indicate ANZECC (2000) trigger values for the 90% (dashed) and 95% (dotted) species protection level. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

Copper. The Owhiro Stream upstream of the landfill has generally elevated concentrations of copper, probably associated with urban stormwater discharges. Copper concentrations appear to generally reduce downstream of the tributary confluence, apart from two peaks in 2013 and 2016, when the downstream concentrations largely exceeded all trigger values. There was generally no clear discernible pattern in the tributary, apart for the aforementioned peaks in 2013 and 2016 (Figure 12).

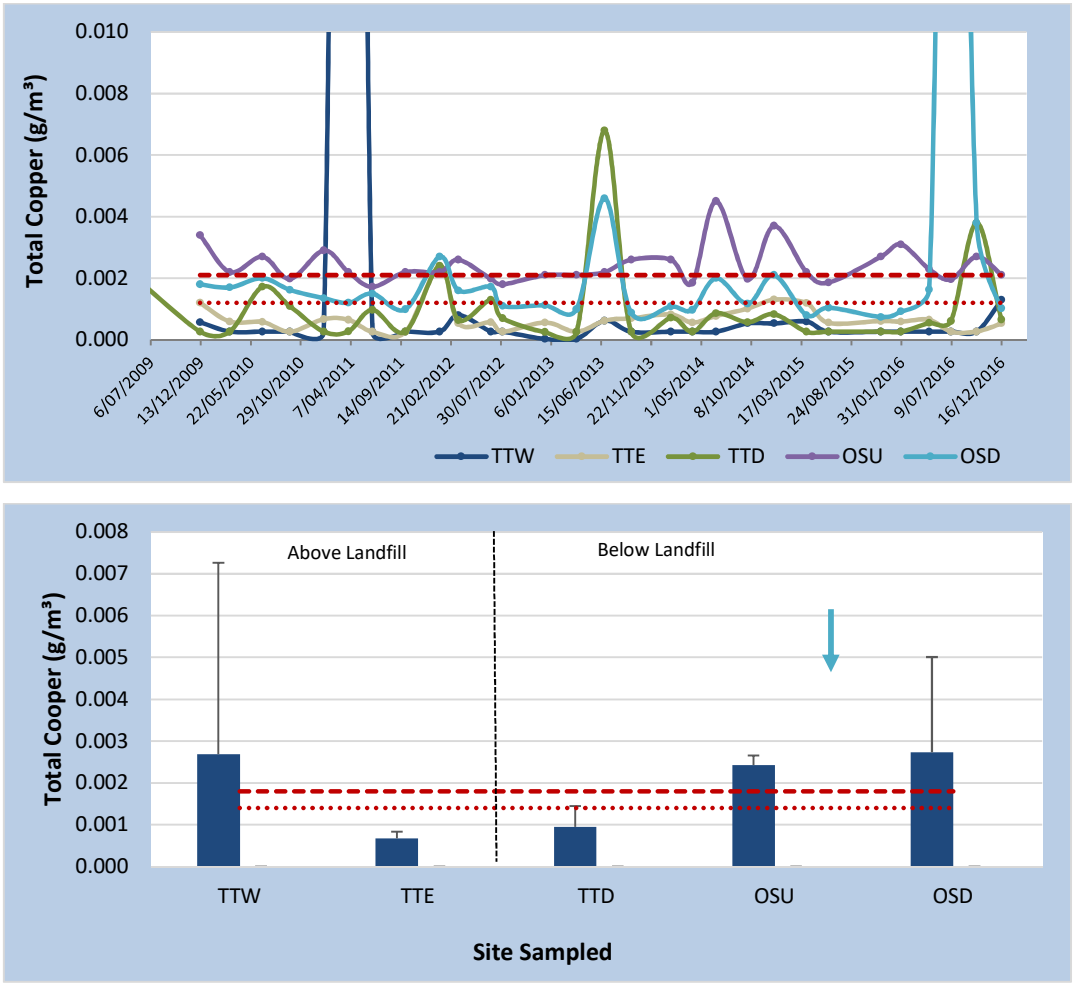


Figure 12: Total Copper concentrations over time (upper) and Mean Total Copper concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. Red lines indicate ANZECC (2000) trigger values for the 90% (dashed) and 95% (dotted) species protection level. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

Lead: No discernible general patterns were observed in lead concentrations apart from the peaks in 2012, 2013 and 2016, where downstream concentrations in the T&T Tributary (TTD) and Owhiro Stream (OSD) exceeded 95% ANZECC trigger values (and the 90% trigger value in June 2013) (Figure 13).

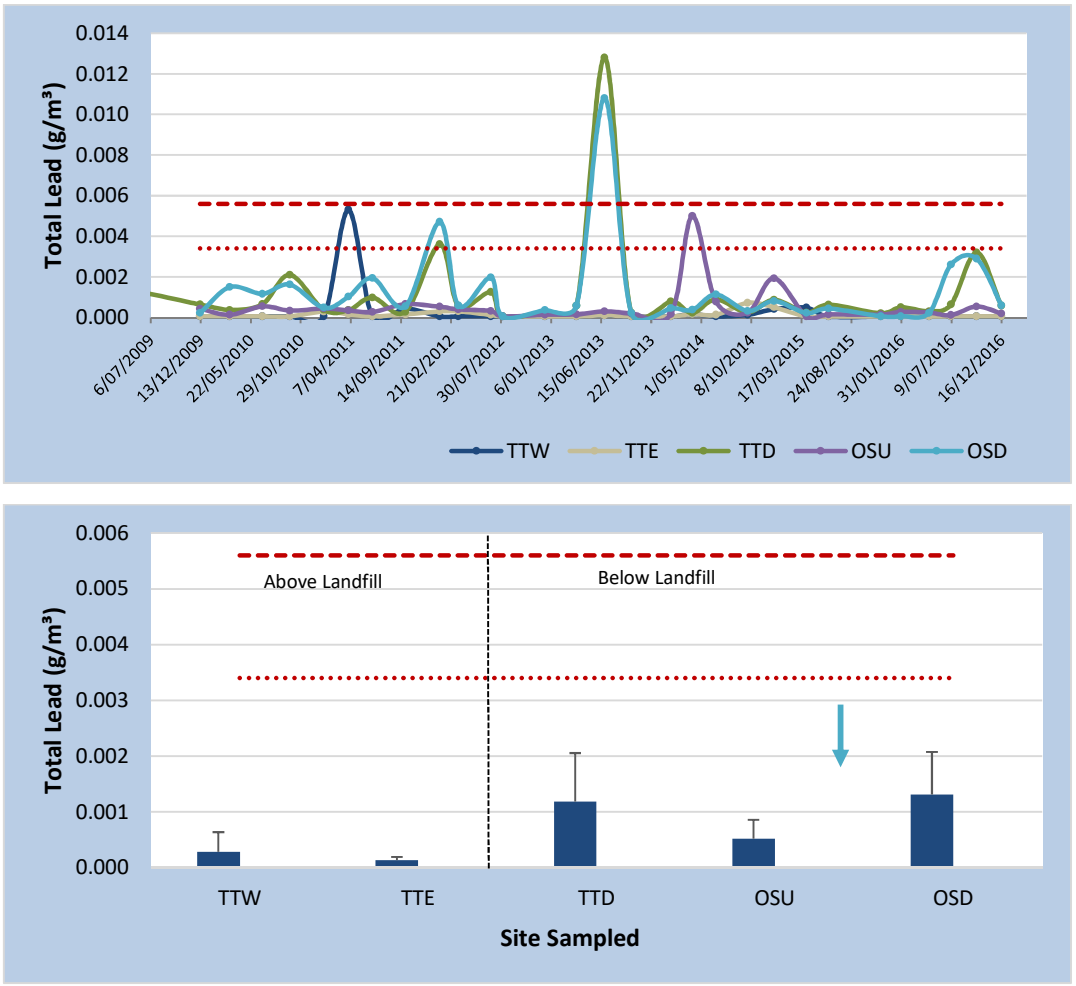


Figure 13: Total Lead concentrations over time (upper) and Mean Total Lead concentrations (lower) in the Unnamed Tributary upstream (East branch: TTE and West Branch: TTW) and downstream (TTD) and in the Owhiro Stream upstream (OSU) and downstream (OSD) of the T&T Landfill. Based on quarterly data (2009-2016) provided by MWH. Red lines indicate ANZECC (2000) trigger values for the 90% (dashed) and 95% (dotted) species protection level. The Blue arrow indicates the confluence of the Tributary from the T&T Landfill site (TTD) with the Owhiro Stream.

4.2. 2010 macroinvertebrate survey

The results of a survey of macroinvertebrate communities undertaken in 2010 by MWH showed large reductions in all indices of macroinvertebrate health in the T&T Tributary, providing strong evidence of significant adverse effects. It was notable that the sensitive EPT taxa were dominant upstream, but nearly absent downstream of the landfill.

In the Owhiro Stream, all indicators showed a reduction in community health. There was an approximately 20% reduction in QMCI (from 3.12 to 2.50), a threshold used in several regional plans as a threshold for significant adverse effects. Effects were less marked in the Owhiro Stream than in the tributary, probably because of already somewhat degraded macroinvertebrate communities upstream of the tributary confluence (possibly associated with the stormwater discharges from the Brooklyn area).

4.3. 2012 NIWA report

In 2012, a report was prepared by Dr Chris Hickey, NIWA, providing an assessment of environmental effects of the T&T discharge at the time. This report has particular relevance in the current context, as it appears to have been prepared in response to a similar event to that which occurred in November 2016, specifically the damming of one of the tributaries entering the fill area and the consequential ponding over an extended period of time, with associated anoxic conditions and release of ammonia, iron and manganese. As such the 2012 NIWA report should not be considered as representative of the ongoing/background effects of the T&T landfill; rather it should be taken as describing an event similar to that of November 2016.

The 2012 NIWA report notes prolonged and marked exceedance of the iron guideline in the tributary and the Owhiro Stream downstream of the Landfill, indicating that floc precipitation was probably significant at that site. It also notes ammonia spikes exceeding the chronic toxicity guideline on two occasions in the tributary and the Owhiro Stream.

The report recommends that, in the short term, improvements be made to the drainage from the West gully and any other intermittently dammed side streams. In the long-term, the report recommends the installation of the proposed stormwater reticulation system and the downstream wetland system, stating that the open channel diversions will maintain aeration and avoid the high iron concentrations and ammoniacal-N spikes.

5. Effects of the November 2016 event on Water Quality

Water quality monitoring undertaken by GWRC staff following reports of foam and discolouration in the Owhiro Stream, was carried out on 22nd November 2016, 28th November 2016, 6th December 2016, 14th December 2016 and 18th January 2017. Results are discussed in the following sections. Table 5 summarises the main conclusions.

5.1. Water Quality Monitoring: 22nd November 2016:

Sampling undertaken by GWRC on the morning of 22nd November 2016 was the first round of sampling following reports of foam and discolouration in the Owhiro Stream. Samples were collected from 6 sites starting from the Stilling Basin at the T&T Landfill site and moving downstream to the Owhiro Stream (Figure 14). Results are shown in Figure 15.

All parameters measured, except pH, were noticeably low in the Owhiro Stream upstream of its confluence with the Tributary which flows from the Landfill (T&T Tributary) but increased considerably downstream of the confluence; whilst pH decreased. There was a major increase in TSS concentration in the Owhiro Stream (from 2.5 to 61 mg/L), indicative of a significant reduction in water clarity. Concentrations of the three metals

tested for (iron, manganese and zinc) exceeded relevant guidelines. Ammoniacal nitrogen was not tested in any of the samples collected that day.

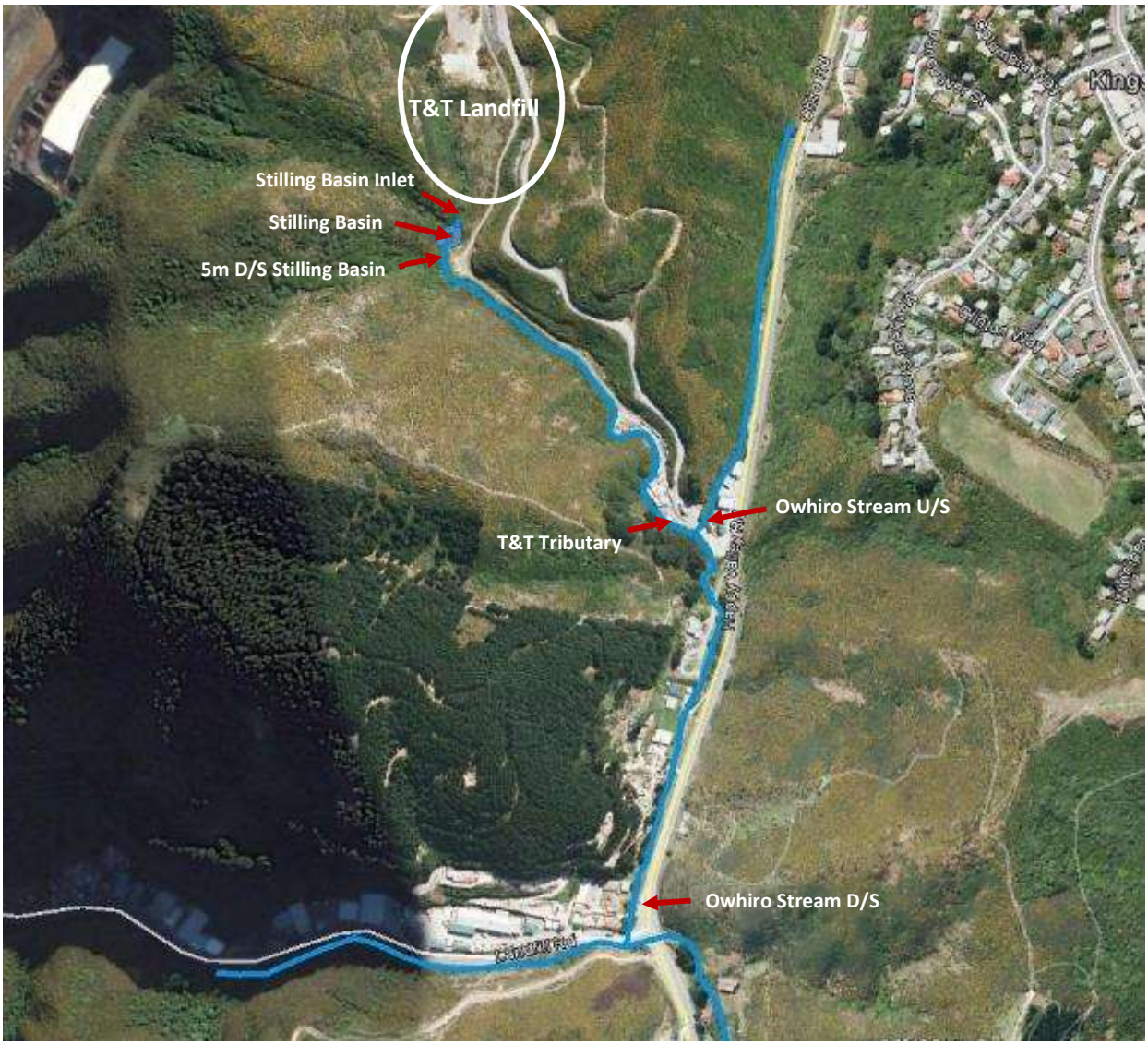


Figure 14: Sites monitored for water quality on 22nd November 2016 (red arrows).

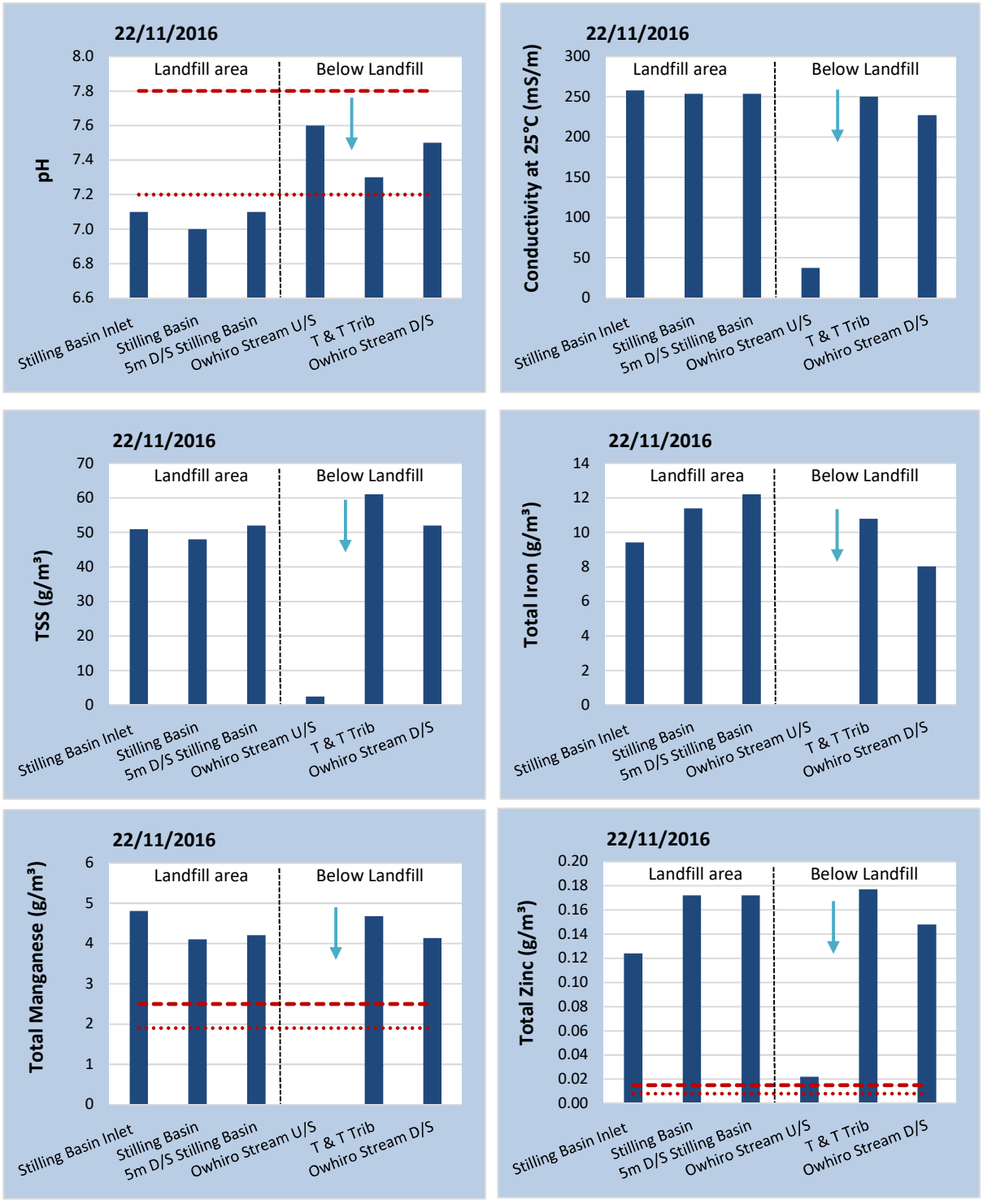


Figure 15: Results of monitoring undertaken on 22nd November 2016. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluence of the Tributary from the T&T Landfill site with the Owhiro Stream.

5.1. Water Quality Monitoring: 28th November 2016:

A second round of samples was collected on 28th November 2016 at slightly different sites from those monitored the previous week but still moving downstream from the Stilling Basin to the Owhiro Stream (Figure 16). Results are shown in Figure 17.

Samples collected showed concentrations for most parameters were similar to those measured on the previous week at the Stilling Basin and in the T&T Tributary, but decreasing with increasing distance downstream from the T&T Landfill.

Figure 16: Sites monitored for water quality on 28th November 2016 (red arrows).

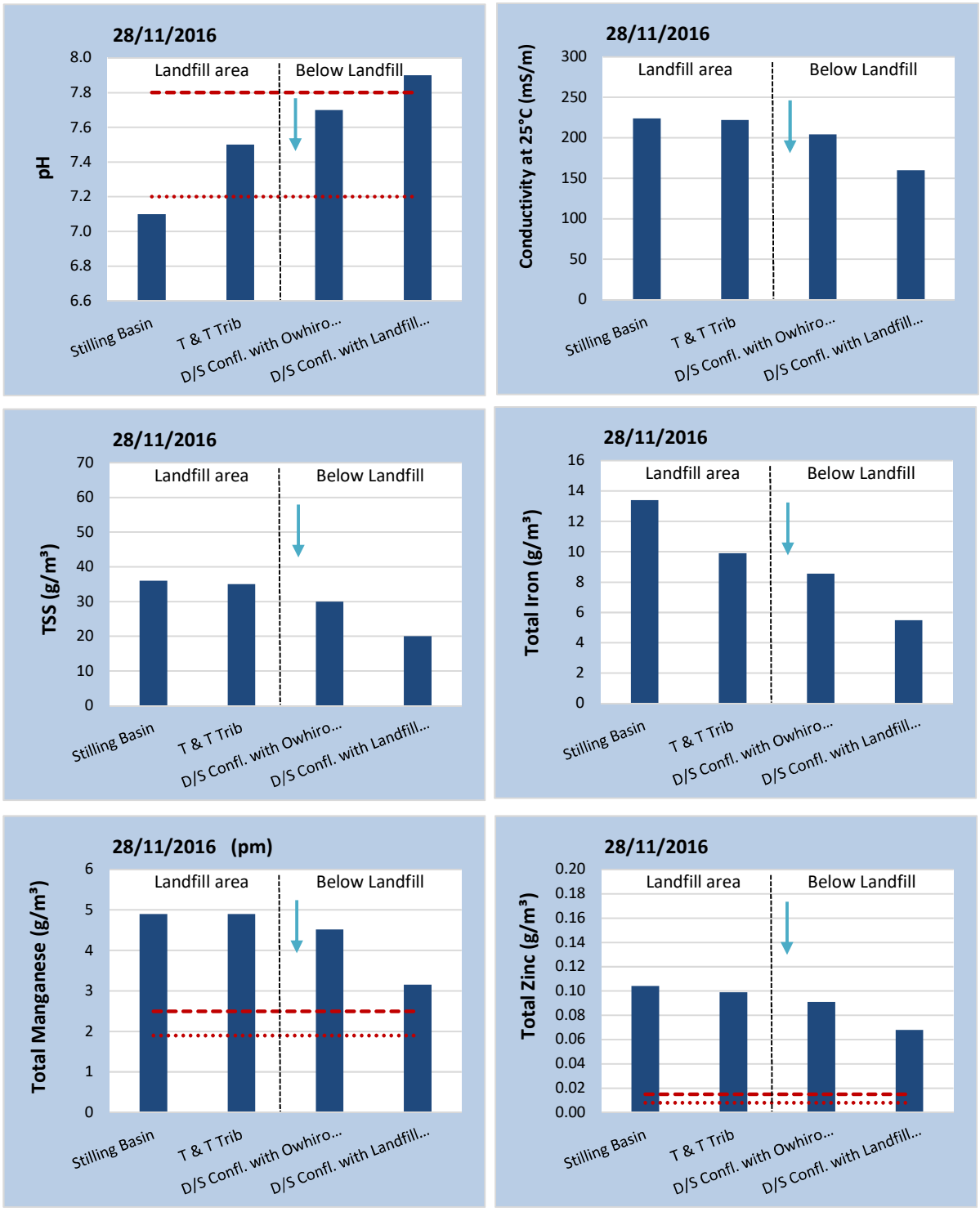


Figure 17: Results of monitoring undertaken on 28th November 2016. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluence of the Tributary from the T&T Landfill site with the Owhiro Stream.

5.2. Water quality Monitoring: 6th December 2016:

Water quality samples were collected again on 6th December 2016 from 6 sites (Figure 19). Results from the two Owhiro Stream sites immediately upstream and downstream of the T&T Tributary confluence appear inconsistent with results obtained at other sites on the same day and at the same sites on other sampling occasions. It appears likely that labels for these two sites were mixed up at the time of sampling. Data from these two sites were excluded from analysis.

Results indicate elevated concentrations of ammoniacal nitrogen both in the Tributary and in the lower Owhiro Stream (at the mouth), well in excess of the NPSFM (2014) National Bottom Line. Iron exceeded the 1 mg/L NIWA guideline to avoid the formation of iron/manganese deposits at all sites (Figure 20).

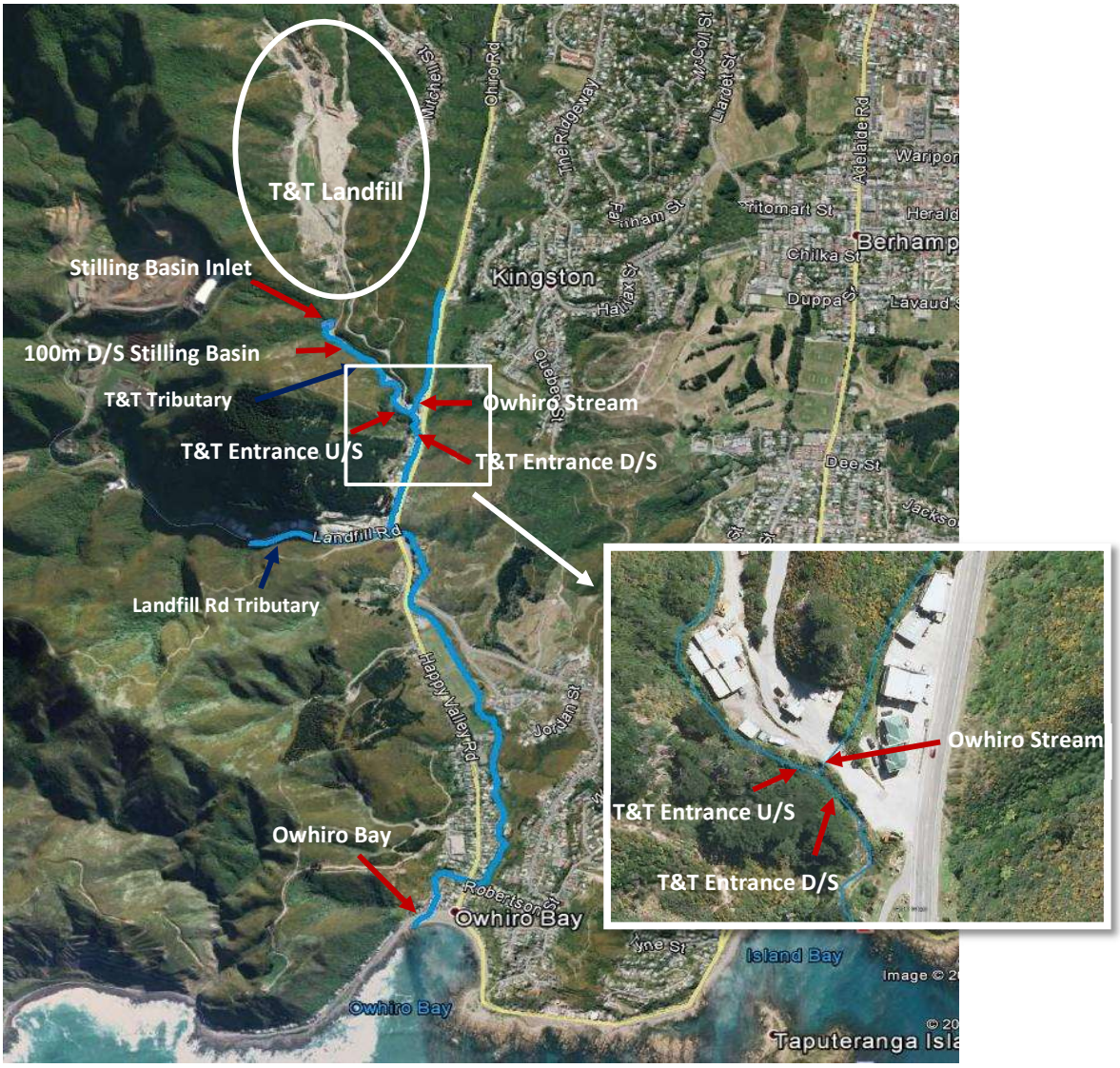


Figure 18: Sites monitored for water quality on 6th December 2016 (red arrows).

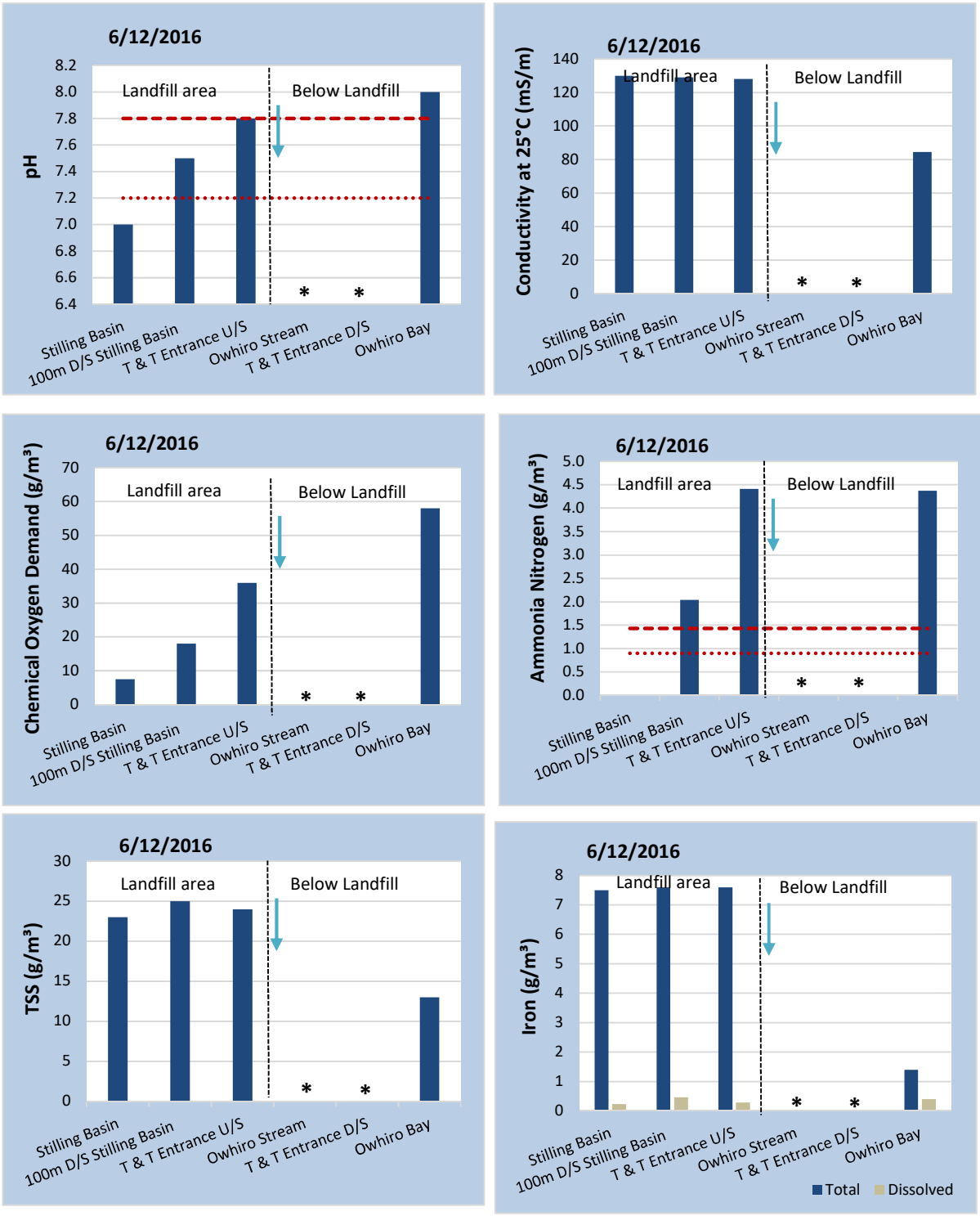


Figure 20: Results of monitoring undertaken on 6th December 2016. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluences of the Tributary from the T&T Landfill site with the Owhiro Stream. Asterisks indicate data excluded from analysis.

5.3. Water Quality Monitoring: 14th December 2016:

A fourth round of water quality sampling was undertaken on 14th December 2016, this time at 12 sites (Figure 21), some of which were in similar locations to those from previous sampling rounds. Results are shown in Figure 22 to Figure 24.

Samples were collected at three sites within the ponding area (Mitchell St Dam, Pool and Gully), three sites within the Stilling Basin area or immediately downstream of it (Stilling Basin and T&T Entrance U/S -which is the T&T Landfill Tributary before it reaches the Owhiro Stream). The Owhiro Stream itself was sampled upstream (Owhiro Stream) and downstream (T&T Entrance D/S) of the T&T Landfill Tributary confluence. Further downstream, the Owhiro Stream was sampled upstream (330 Owhiro Rd) and downstream (Landfill Road D/S) of the point where the Landfill Road Tributary (from the Southern Landfill area) joins it. The Landfill Rd Tributary was also sampled (Landfill Rd U/S). Lastly, the Owhiro Stream was sampled upstream of its mouth to Owhiro Bay (Owhiro Bay).

Results indicate significant increases in concentrations of Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), ammoniacal nitrogen, iron and manganese in the Owhiro Stream between upstream and downstream of the T&T Tributary. The increase in TSS concentration from below detection limit upstream to 19 mg/L downstream indicates a significant adverse effect on water clarity. The high COD concentration in the Owhiro Stream downstream of the T&T tributary confluence indicates a strong organic content. The ammoniacal nitrogen concentration, corrected for pH, was just below the NPSFM (2014) National Bottom Line. Iron and manganese concentrations were well above the NIWA guideline to avoid the formation of iron/manganese floc.

It is interesting to note that the ammoniacal-nitrogen concentrations in the Mitchell Street samples (Dam, Pool and Gully) were below detection limit (0.005 mg/L), but were much higher (2-3 mg/L) where the water exits the landfill (Stilling basin, T&T Tributary). This tends to indicate that the source of the ammoniacal nitrogen seems to be from decomposition of organic matter within the landfill area, rather than in the ponding area as might have been suggested.

The Landfill Road Tributary did not appear to be a source of any of the contaminants of concern on this sampling occasion.

5.4. Water Quality Monitoring: 18th January 2017:

A final round of water quality sampling was undertaken on 18th January 2017, at 10 of the 12 sites sampled on 14th December 2016 (Refer Figure 21). Results are shown in Figure 25 and Figure 26.

Parameters measured on 18th January 2017 show similar patterns to those measured previously, although concentrations were generally lower. Manganese and Iron concentrations in the Owhiro Stream downstream of the T&T Tributary, and in the Tributary itself, still exceeded the NIWA guideline to avoid the formation of iron/manganese floc, but by a smaller margin than in December 2016. Ammoniacal nitrogen concentrations increased in the Owhiro Stream downstream of the landfill, but remained below toxicity thresholds.

With respect to metals (lead, copper, zinc, arsenic and chromium), laboratory detection limits were higher than those used in previous sampling rounds, leading to most results being below detection limit. The

detection limits used on this occasion were higher than the ANZECC trigger values for both 95% and 90% protection levels, making the interpretation of the results impossible.

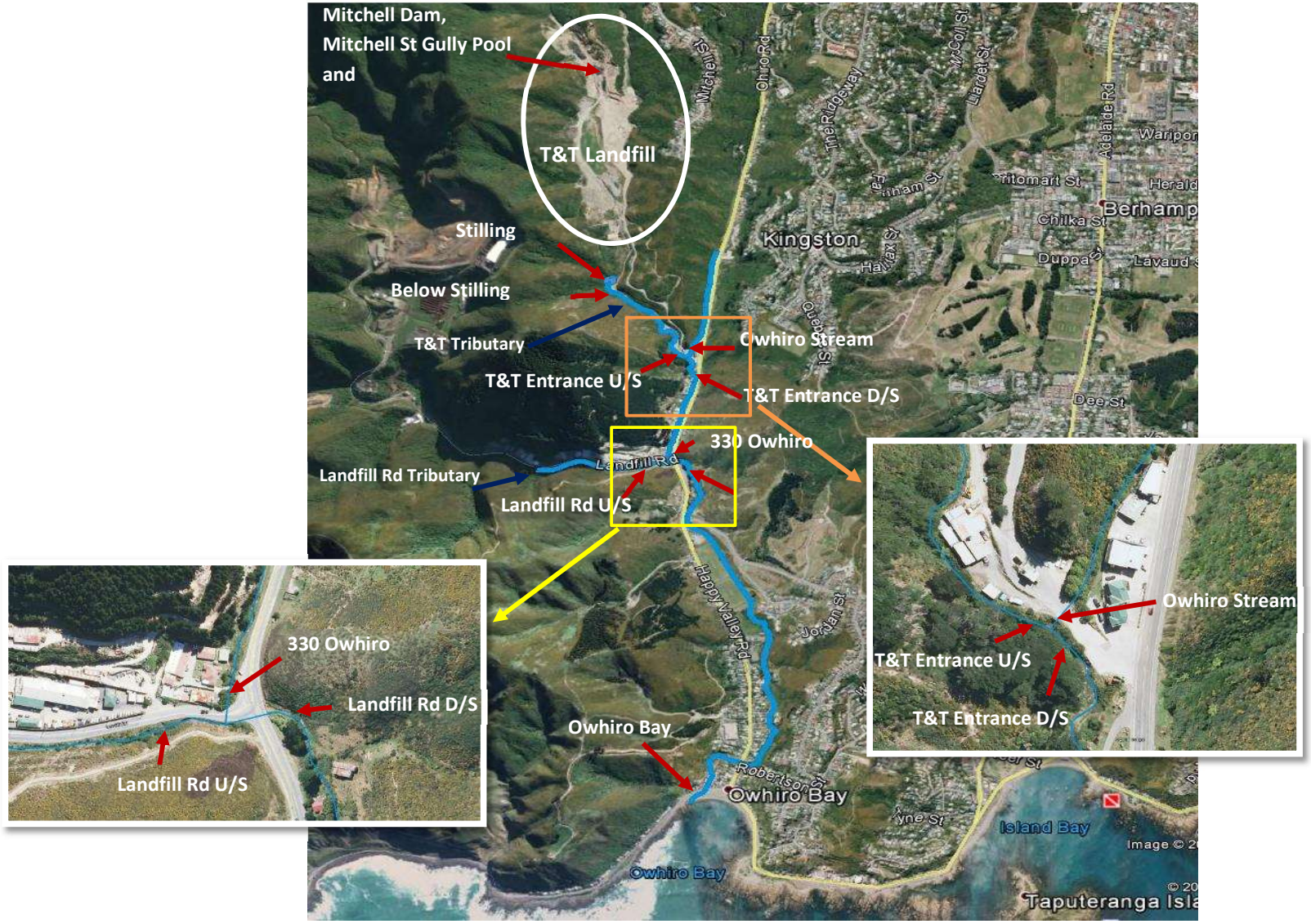


Figure 21: Sites monitored for water quality on 14th December 2016 and 18th January 2017(red arrows).

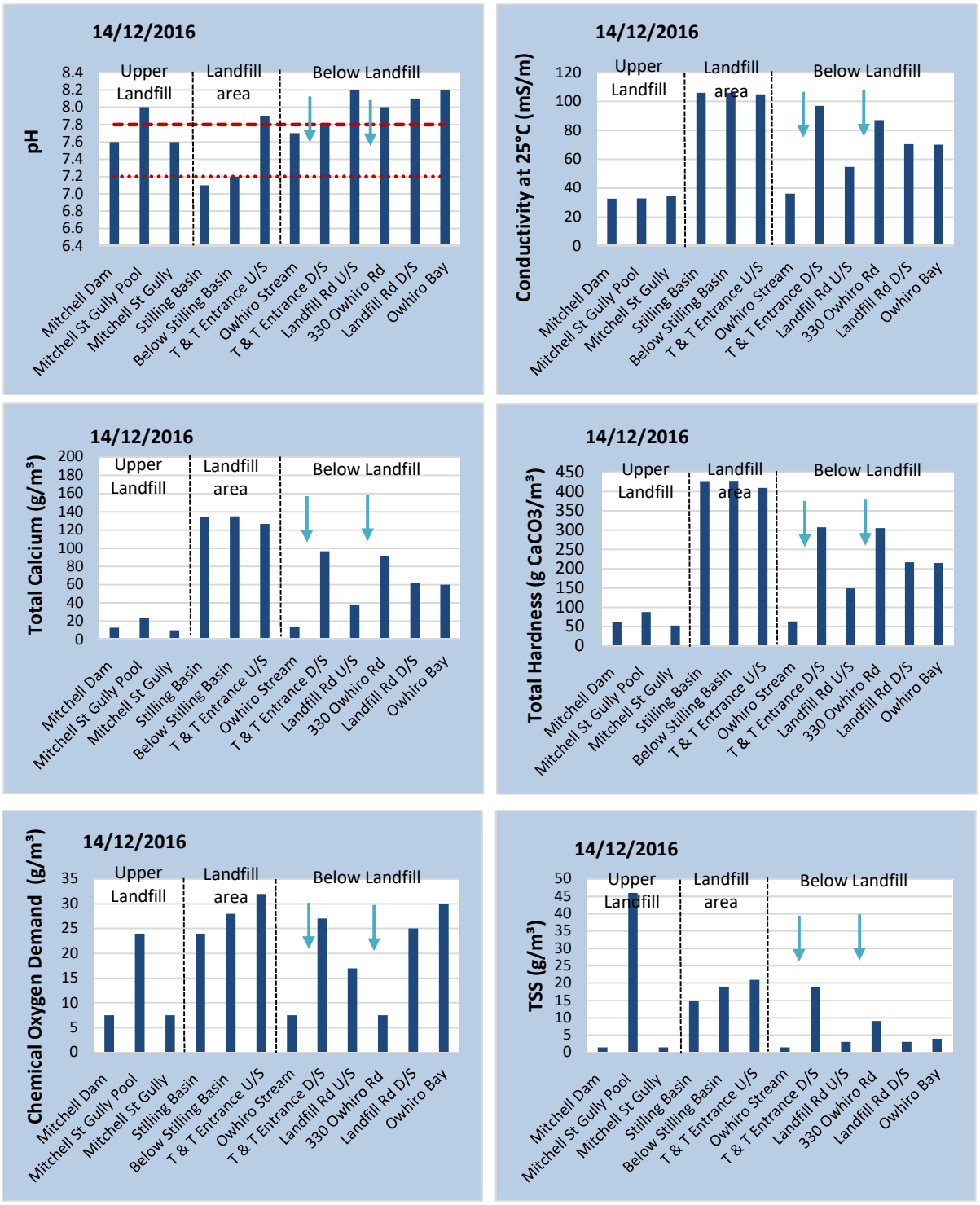


Figure 22: Results of monitoring undertaken on 14th December 2016. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluences of the Tributary from the T&T Landfill site and the Tributary from Landfill Rd with the Owhiro Stream.

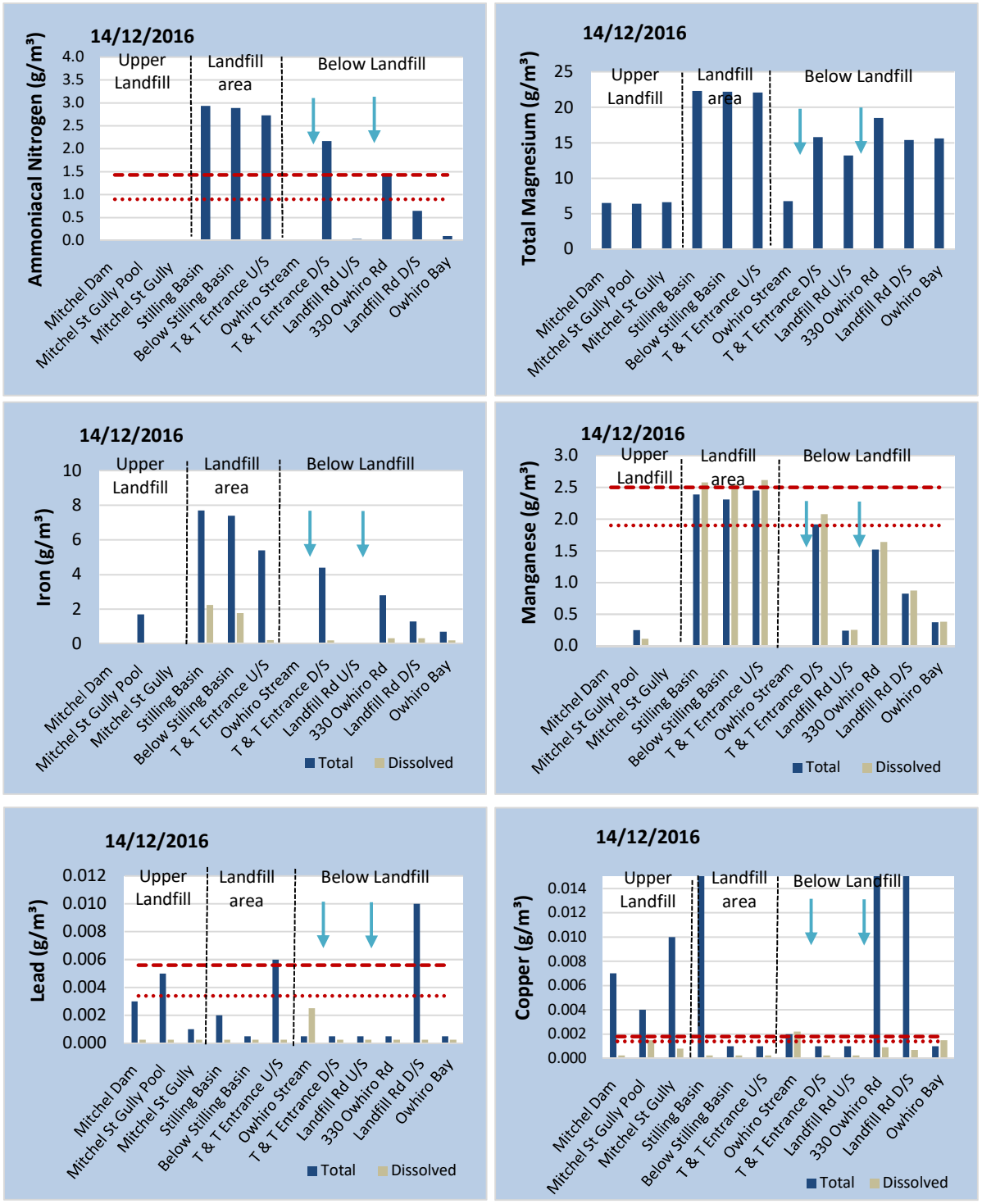


Figure 23: Results of monitoring undertaken on 14th December 2016. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluences of the Tributary from the T&T Landfill site and the Tributary from Landfill Rd with the Owhiro Stream.

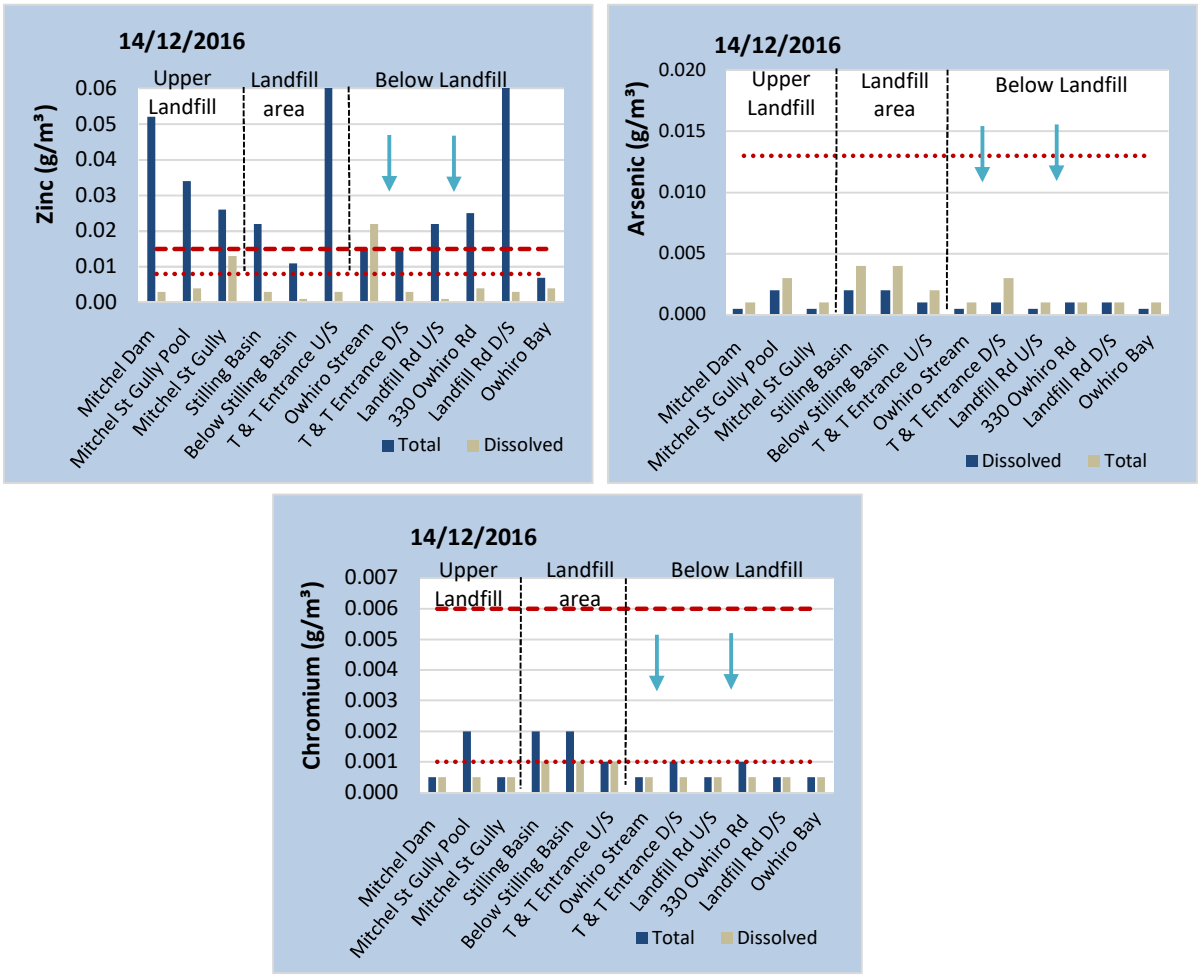


Figure 24: Results of monitoring undertaken on 14th December 2016. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluences of the Tributary from the T&T Landfill site and the Tributary from Landfill Rd with the Owhiro Stream.

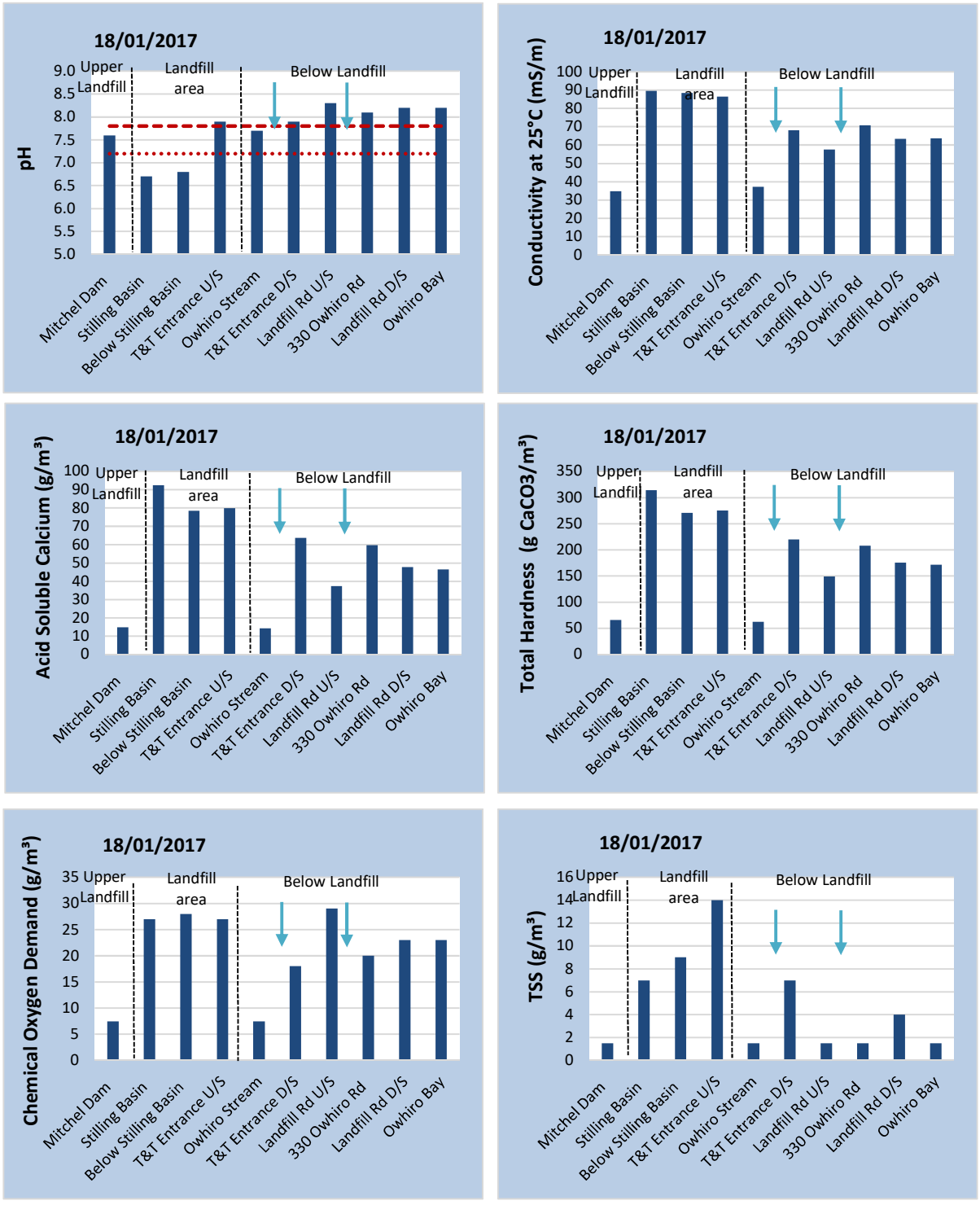


Figure 25: Results of monitoring undertaken on 18th January 2017 in relation to reports of foam and discolouration in the Owhiro Stream. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluences of the Tributary from the T&T Landfill site and the Tributary from Landfill Rd with the Owhiro Stream.

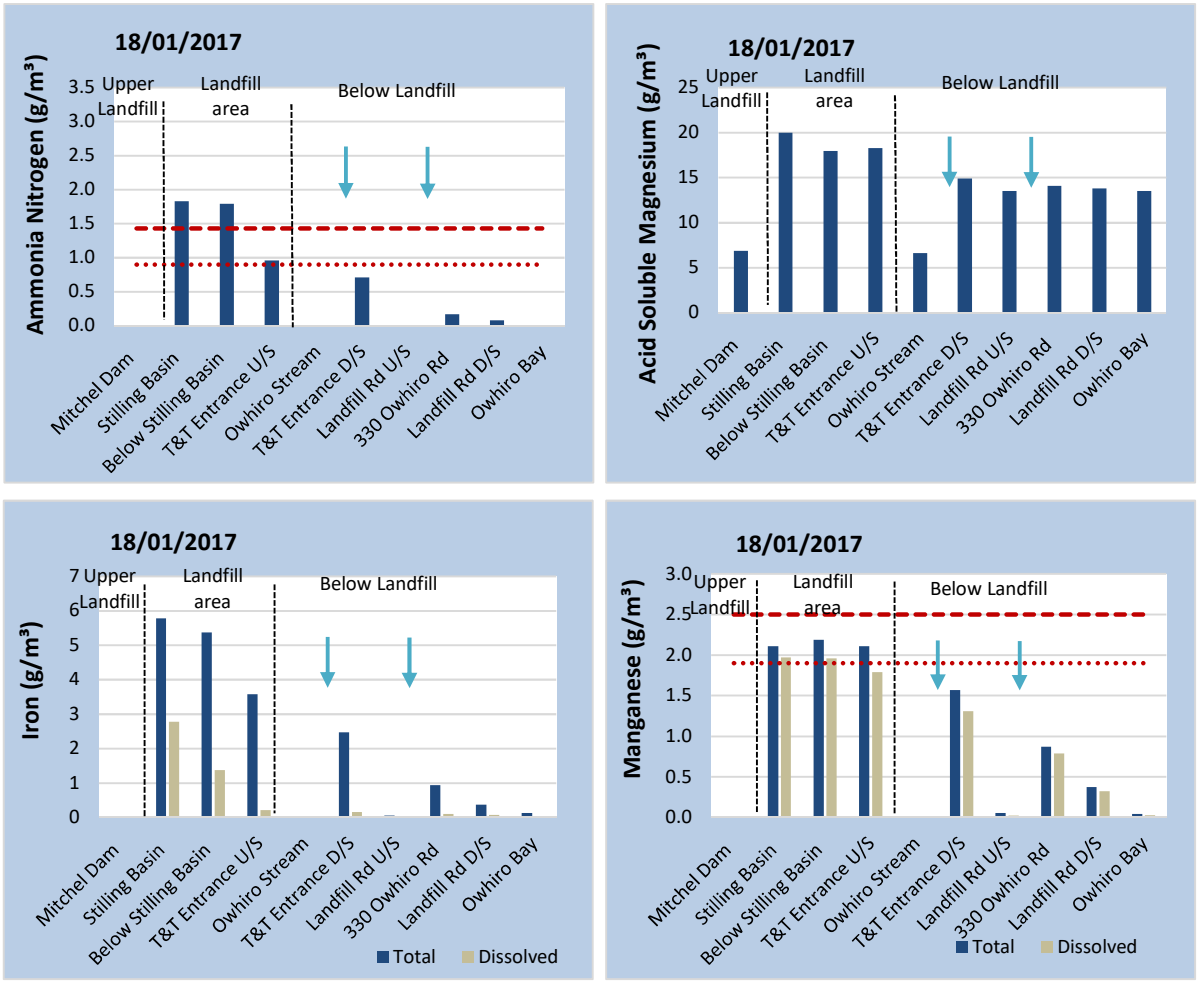


Figure 26: Results of monitoring undertaken on 18th January 2017 in relation to reports of foam and discolouration in the Owhiro Stream. Red lines indicate ANZECC (2000) trigger values. Blue arrows indicate the confluences of the Tributary from the T&T Landfill site and the Tributary from Landfill Rd with the Owhiro Stream.

Table 5: Summary of effects of the T&T discharge following the November 2016 event.

Date	Contaminant / indicator	Effect from the discharge?	Effects above "ongoing/background" effect?
22 November	Water clarity	Yes significant effects in the Owhiro Stream (TSS concentration below detection limit upstream and 60mg/L downstream)	Yes
	Iron (Fe) and Manganese (Mn)	Yes significant effects in both the Tributary and Owhiro Stream [Fe+Mn] was c. 12-15 times the 1 mg/L NIWA guideline Mn exceeded toxicity threshold	Yes Median concentrations: c. 1 mg/L for Mn and 2.6 mg/L for Fe)
	Zinc (Zn)	Yes significant risk of effects in both the Tributary and Owhiro Stream [Zn] 0.150 to 0.180 mg/L, i.e. 20-30 times toxicity thresholds	Yes (median concentration: 0.015 mg/L)
28 November	Water clarity	Likely (no upstream sample, but effect likely assuming upstream concentrations remained the same as previously)	Yes (likely)
	Iron (Fe) and Manganese (Mn)	Yes significant effects in both the Tributary and Owhiro Stream [Fe+Mn] was c. 12times the 1 mg/L NIWA guideline Mn exceeded toxicity threshold	Yes Median concentrations: c. 1 mg/L for Mn and 2.6 mg/L for Fe)
	Zinc (Zn)	Yes significant risk of effects in both the Tributary and Owhiro Stream [Zn] 0.090 to 0.100 mg/, i.e. 15 times toxicity thresholds	Yes (median [Zn]: 0.015 mg/L)
6 December	Water clarity / TSS	Yes significant effects in the Owhiro Stream (TSS concentration below detection limit upstream and 13 mg/L downstream)	Yes Median [TSS] = 7.0 mg/L
	Iron (Fe) and Manganese (Mn)	Yes significant effects in both the Tributary and Owhiro Stream [Fe] was c. 3.5 to 7 times the 1 mg/L NIWA guideline Mn not analysed	Yes Median concentrations: c. 1 mg/L for Mn and 2.6 mg/L for Fe)
	Ammoniacal-N	Yes, significant risk of toxic effects, potential for acute effects Above NPSFM National Bottom Line in lower Owhiro Stream	Yes Median [TNH4-N]: 0.17 mg/L
	Zinc (Zn)	Yes [Zn] was 2.5 times the 90% trigger value and 5 times the 95% TV	No Downstream concentrations similar to long-term median
	As, Cr, Pb and Cu	No, concentrations generally below toxicity thresholds	No
14 December	Water clarity / TSS	Yes significant effects in the Owhiro Stream (TSS concentration below detection limit upstream and 19 mg/L downstream)	Yes Median [TSS] = 7.0 mg/L
	Iron (Fe) and Manganese (Mn)	Yes significant effects in both the Tributary and Owhiro Stream [Fe+Mn] was c. 6 times the 1 mg/L NIWA guideline Mn exceeded toxicity threshold in tributary but not Owhiro Stream	Yes Median concentrations: c. 1 mg/L for Mn and 2.6 mg/L for Fe)
	Ammoniacal-N	Yes, risk of chronic effects, but not acute Just below NPSFM National Bottom Line	Yes Median [TNH4-N]: 0.17 mg/L
	Zinc (Zn)	No. Total Zn concentrations exceeded TV, but not dissolved concentrations	No Downstream concentrations similar to long-term median
	As, Cr, Pb and Cu	No, concentrations generally below toxicity thresholds	No

Date	Contaminant / indicator	Effect from the discharge?	Effects above "ongoing/background" effect?
18 January	Water clarity / TSS	Yes effects in the Owhiro Stream, but localised (TSS concentration below the 3 mg/L detection limit upstream and 7 mg/L downstream, but return to low concentrations further downstream)	No Median [TSS] = 7.0 mg/L
	Iron (Fe) and Manganese (Mn)	Yes effects in both the Tributary and Owhiro Stream, but lesser than previously [Fe+Mn] was c. 3 times the 1 mg/L NIWA guideline Mn did not exceed toxicity threshold	No Median concentrations: c. 1 mg/L for Mn and 2.6 mg/L for Fe)
	Ammoniacal-N	No, concentration increased, but remained below toxicity thresholds	No
	Zinc (Zn)	No. Total Zn concentrations exceeded trigger values, but dissolved concentrations did not	No Downstream concentrations similar to long-term median
	As, Cr, Pb and Cu	No, concentrations generally below toxicity thresholds	No

6. Effects on river ecology

6.1. Macroinvertebrate Communities

6.1.1. December 2016 MWH macroinvertebrate survey

In December 2016 MWH undertook a macroinvertebrate survey, at approximately the same locations as in 2010 (and at the same locations as the quarterly water quality monitoring sites, as shown in Figure 2). This survey was triggered under Condition 13, which requires an ecological survey to be undertaken if tolerance limits and trigger values from routine and follow-up monitoring are exceeded. Results of the 2016 survey were similar to those of 2010, and showed large reductions in all indices of macroinvertebrate health in the T&T Tributary, providing strong evidence of significant adverse effects. It was notable that the sensitive EPT taxa were dominant upstream, but nearly absent downstream of the landfill. Invertebrate densities were also reduced in a major way (77% reduction).

In the Owhiro Stream, all indicators showed a reduction in community health, although effects were less marked than in the Tributary, possibly in part because of already somewhat degraded macroinvertebrate communities upstream of the tributary confluence. There was a major reduction in the number of macroinvertebrates (macroinvertebrate density (72% reduction).

6.1.2. December 2016 Aquanet/GWRC macroinvertebrate survey

On 22nd December 2016, staff from GWRC and Aquanet Consulting Ltd undertook a separate ecological survey. The focus of this survey was to assess the effects of the discharge from the T&T landfill on the whole length of the Owhiro Stream. Sampling was carried out at four sites spread along the Owhiro Stream, from above the T&T Tributary to above the stream mouth (Figure 28). Results are discussed below.

The chironomid Orthocladiinae dominated macroinvertebrate communities at all sites except downstream of the T&T Landfill where the freshwater snail *Potamopyrgus* sp. and oligochaetes were dominant (Figure 29).

Macroinvertebrate communities indices were generally indicative of poor water quality at all sites in the Owhiro Stream. Number of individuals, Number of Taxa and %EPT Taxa decreased significantly at the site downstream of the T&T Landfill but increased again further down in the Owhiro Stream, other biotic indices did not differ significantly between sites (Figure 30). There was a major reduction in the macroinvertebrate density (number of individuals) downstream of the T&T discharge (from 655 to 129, an 80% reduction). All indices, apart from the number of taxa show a gradual recovery along the length of the Owhiro Stream, with levels at the most downstream site (Owhiro Bay) comparable to upstream of the discharge.

Of note was that the snails found at the site upstream of the T&T Landfill and down at Owhiro Bay looked normal in shape and colour while those downstream of the T&T Landfill were an orangey colour and presented abnormally-shaped shells, possibly a result of the deposition of iron/manganese floc (Plate 2).

The decrease in macroinvertebrate density, number and % of EPT taxa and the notable change in shape and colour of the molluscs present downstream of the landfill indicate that discharge from the T&T Landfill site was having significant adverse effects on instream communities up to at least 22nd December 2016.

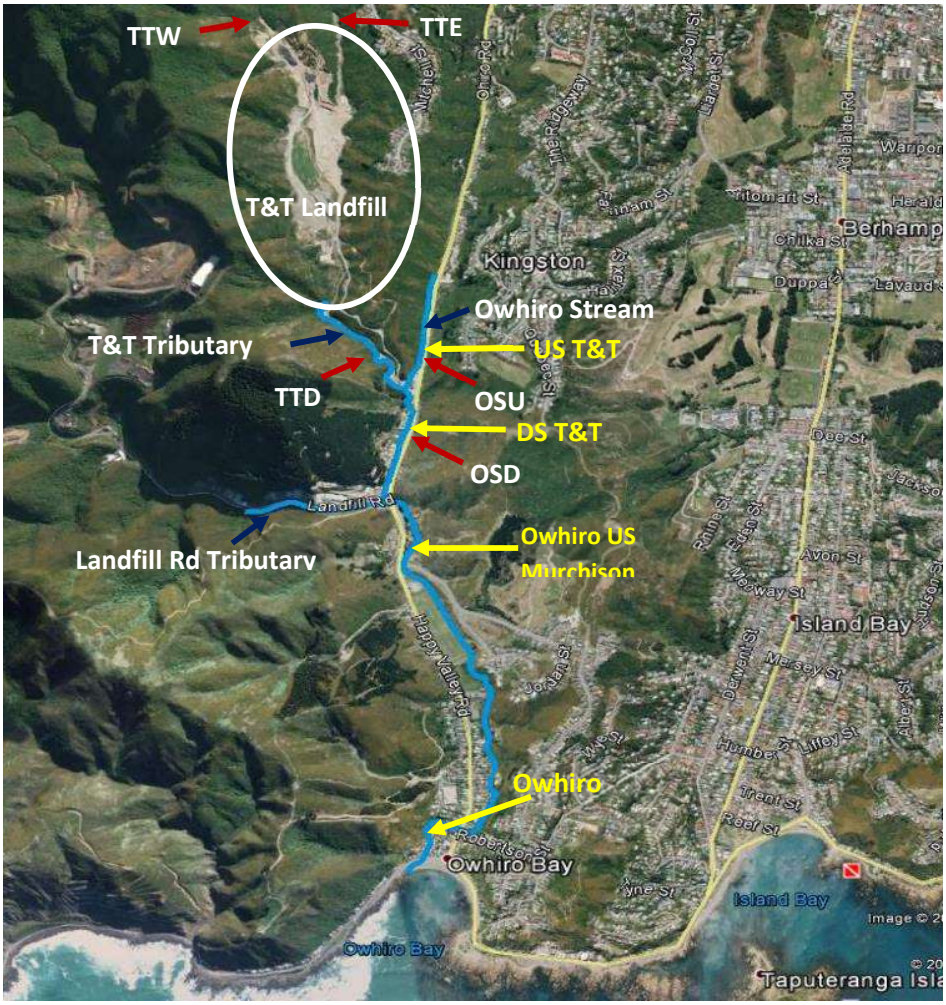


Figure 27: Map showing locations of ecological survey undertaken on 21st December 2016 (red arrows) by MWH and on 22nd December 2016 (yellow arrows), by Aquanet Consulting Ltd.

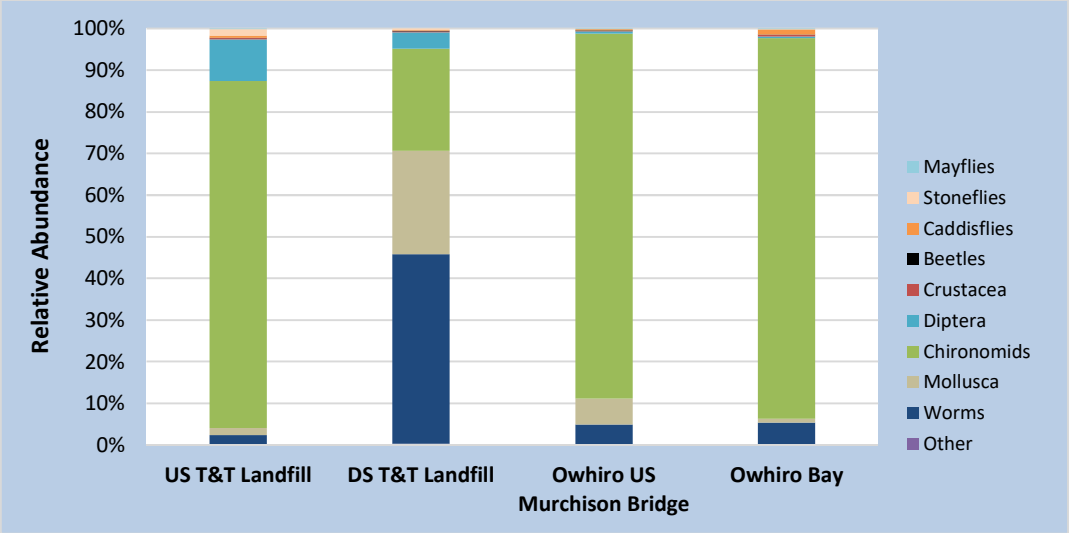


Figure 28: Relative abundance of the main taxonomic groups for sites sampled upstream and downstream of the T&T Landfill site and on the Owhiro Stream, 22 December 2017.

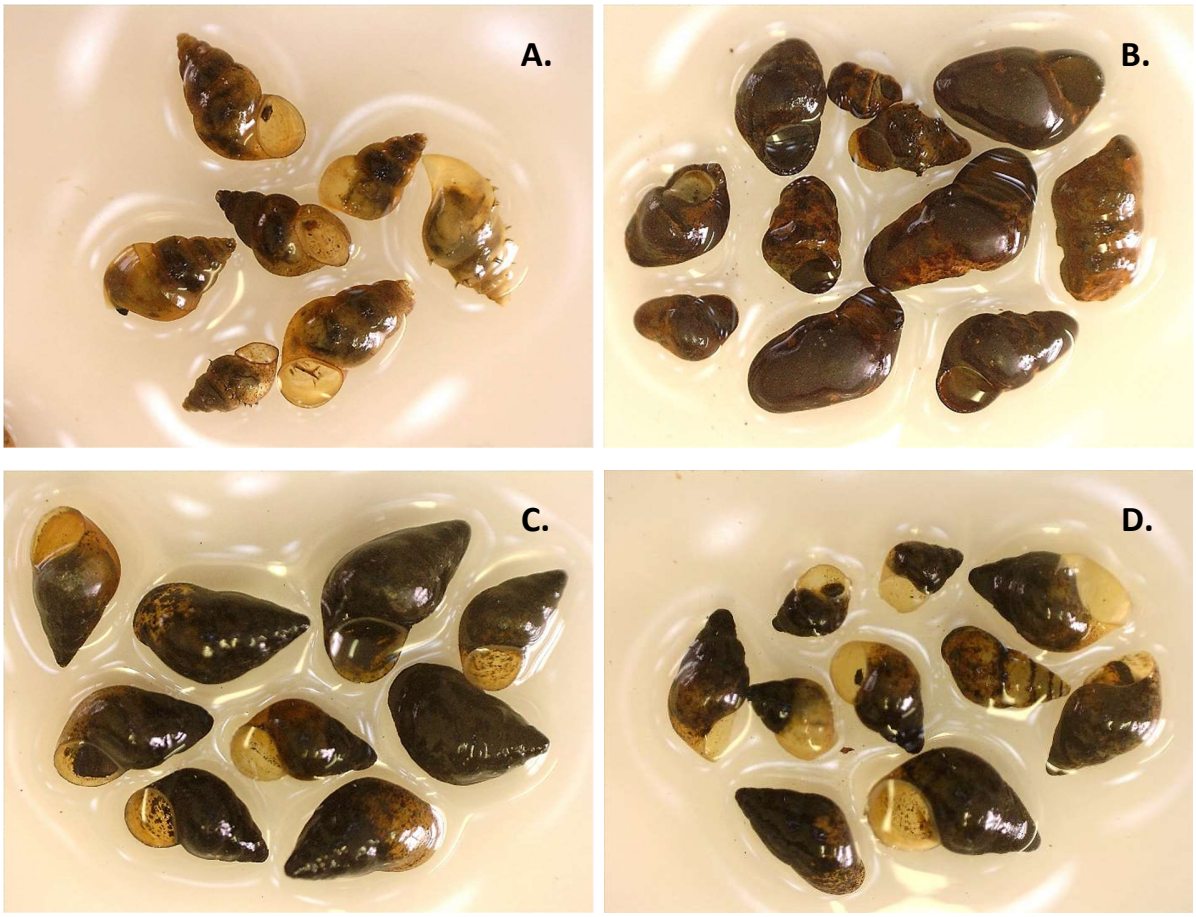


Plate 2: Examples of snails (*Potamopyrgus* sp.) collected from A. Upstream of T&T landfill, B. Downstream T&T Landfill, C. Owhiro Stream upstream Murchison Bridge and D. Owhiro Stream at Owhiro bay, 22nd December 2016.

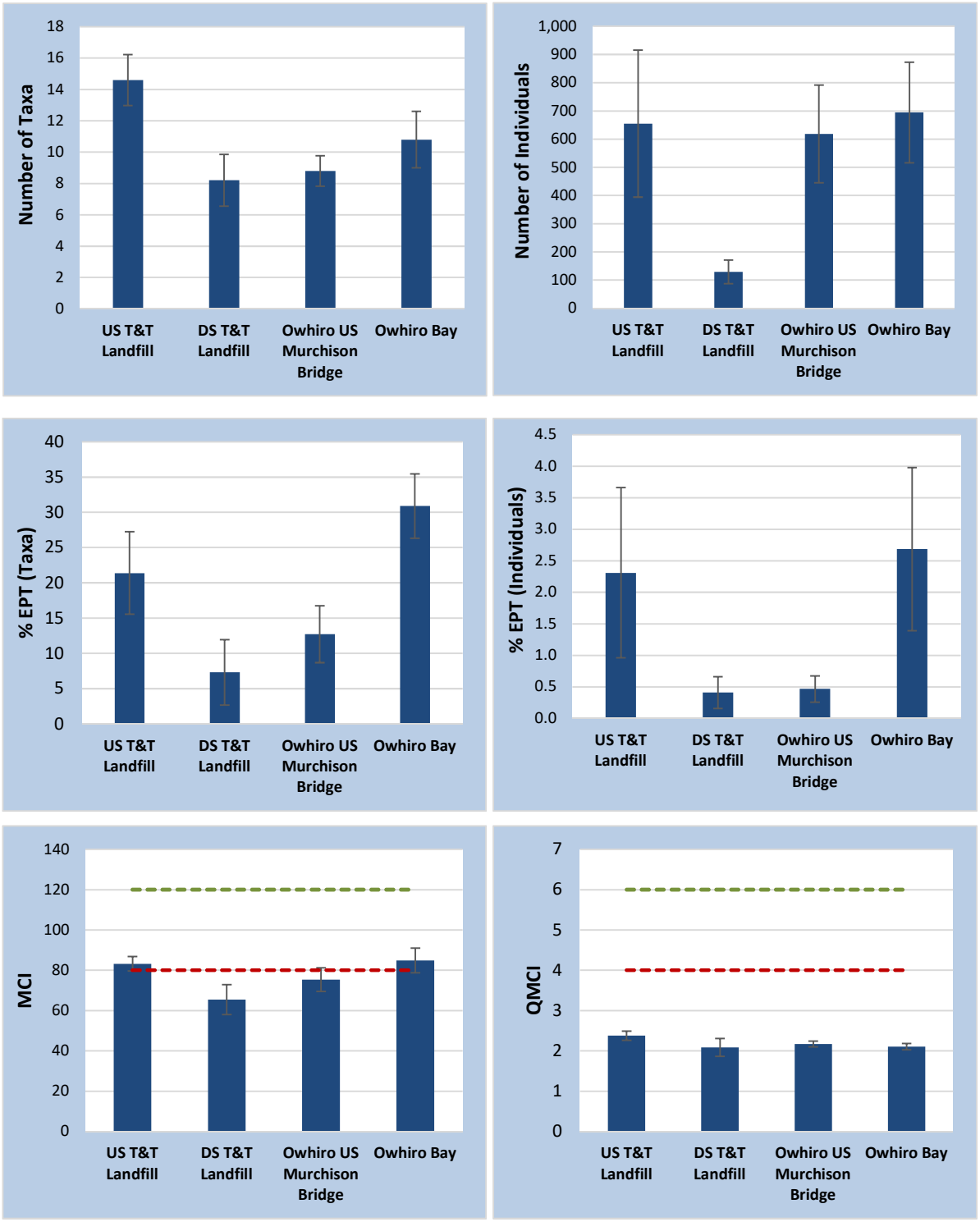


Figure 29: Mean Number of Taxa (upper left), Number of Individuals (upper right), % EPT Taxa (mid left), % EPT Individuals (mid right), MCI (lower left) and QMCI (lower right) for sites sampled upstream and downstream of the T&T Landfill site and on the Owhiro Stream, 22 December 2017.

6.2. Periphyton Communities

Periphyton communities visually assessed on 22nd December at the same four sites where macroinvertebrate monitoring was undertaken showed most substrates in both the T&T Tributary and the Owhiro Stream to be dominated by a film with some sediment also present (Figure 31). Long green filamentous algae were present at both sites on the Owhiro but well below the MfE guidelines of 30% cover.

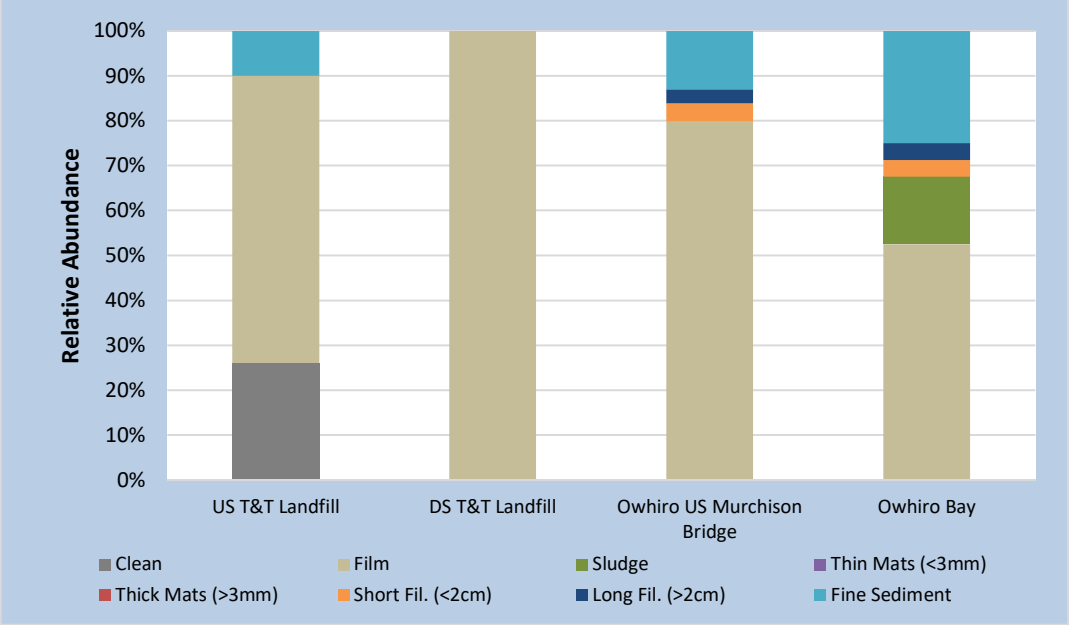


Figure 30: Periphyton communities visually assessed at sites sampled upstream and downstream of the T&T Landfill site and on the Owhiro Stream, 22 December 2017.

7. Summary –Effects from November 2016 Event

An assessment of the main effects of the T&T discharge in the weeks following the November 2016 event is summarised below.

7.1. Effects on water clarity and colour

The unusually dark and foamy appearance of the Owhiro Stream following the November 2016 event prompted a number of complaints and it is our understanding that subsequent investigations by GWRC officers traced the source of the conspicuous changes in water clarity and colour in the Owhiro Stream to the confluence with the Unnamed Tributary, and then to the T&T Landfill.

Water samples taken during these investigations provide strong evidence of significant changes in water clarity in the Owhiro Stream between upstream and downstream on 22nd November 2016 (from below the 5mg/L detection limit upstream to 52 mg/L downstream), on 6 December (from below the 5mg/L detection limit upstream to 13 mg/L downstream), and on 14 December 2016 (from below the 3 mg/L detection limit

upstream to 9 mg/L downstream). The data indicates that the effects reduced over the period of time covered by the samples and there was no strong evidence of an effect on TSS concentrations in the Owhiro Stream on 18th January 2017.

Visual observations made by Dr Olivier Ausseil during the period 15th November 2016 to end of January 2017 corroborate the above. Water clarity in the lower Owhiro Stream was very low (c. <10cm) and water colour was unusually dark, with the presence of foam until approximately 3rd December 2016. Stream flow appeared higher than expected during that period. Visual water clarity in the lower Owhiro Stream gradually improved after 3rd December. However, conspicuous reductions in water clarity in the Owhiro Stream downstream of the T&T Tributary were still observed on 19th December (T&T site visit with Mr James Snowdon) and 22nd December (ecological survey with Dr Mark Heath, Freshwater Scientist at GWRC) (Plate 3). On 22ndDecember, a gradual recovery in water clarity along the length of the stream down to the mouth, although not to upstream levels, was noted (Plate 4).

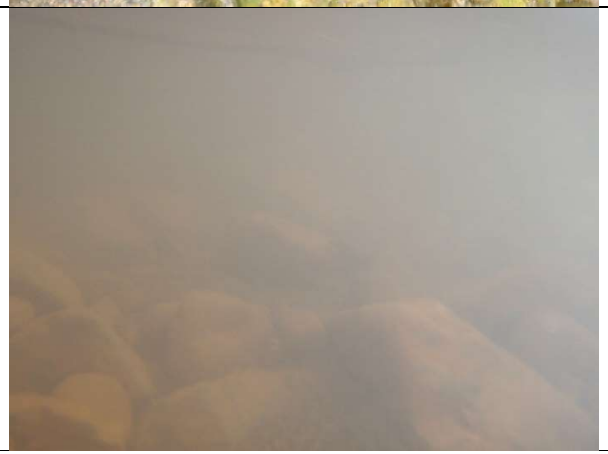
Site	Above water view	Under water view
Owhiro Stream upstream of T&T Landfill Tributary		
Owhiro Stream dowsntream of T&T Tributary confluence		

Plate 3: Above and under water views of the Owhiro Stream upstream and downstream of the confluence with the T&T Tributary on 22nd December 2016. (Photographs Olivier Ausseil).

Site	Above water view	Under water view
Owhiro Stream upstream of Murchison Bridge		
Owhiro Stream at Owhiro Bay		

Plate 4: Above and under water views of the middle (Murchison Bridge) and lower (Owhiro Bay) Owhiro Stream on 22nd December 2016. (Photographs Olivier Ausseil).

7.2. Deposition of sediment and iron/manganese precipitate

Concentrations of manganese and iron were elevated downstream of the discharge on all sampling events, and well in excess of the NIWA 1 mg/L for iron + manganese to avoid the formation of iron/manganese floc. On 19th and 22nd December, thick orange-coloured floc was observed in the T&T Tributary and the Owhiro Stream downstream of the tributary confluence, covering all surfaces of the stream beds (Plate 5). The orange floc was also present further downstream to the stream mouth, although in gradually diminishing abundance. The orange floc was easily disturbed and re-suspended when wading across the stream (Plate 6).

Plate 5: View of the confluence of the Owhiro Stream (upstream at the bottom of the photograph) and the T&T Tributary (coming from the top right of photograph), showing orange-coloured iron/manganese deposit on the bottom of the tributary and the Owhiro Stream downstream of the confluence.

Plate 6: View of re-suspended iron/manganese floc following gentle stirring of the stream bed in the Owhiro Stream downstream of the T&T Tributary and upstream of Murchison Street Bridge.

7.3. Ammonia

Water samples taken in December 2016 showed consistently elevated ammoniacal nitrogen concentrations in the T&T Landfill Tributary and the Owhiro Stream downstream of the T&T Landfill. On 6 December[1] ammoniacal nitrogen concentrations exceeded ANZECC trigger values and NPSFM national bottom line for maximum concentration in the Tributary and the lower Owhiro Stream at Owhiro Bay. Concentrations in the lower Owhiro Stream were 4.4 mg/L, twice the NPSFM national bottom line (at which concentrations "start approaching acute impact level (i.e. risk of death) for sensitive species").

Ammoniacal nitrogen concentrations in the tributary and the Owhiro Stream appear to decrease gradually in December and January, and met toxicity guidelines on 18th January 2017.

Concentrations of ammoniacal nitrogen in November and December were sufficiently elevated to cause accelerated algae growth in the stream, and potentially in the near-shore environment of Owhiro Bay.

8. Conclusions and recommendations

8.1. Ongoing/background effects

Long-term monitoring data indicates that the T &T Landfill causes a number of significant adverse changes in water quality and ecology on a consistent basis. In particular, it causes consistent degradation of water clarity, deposition of iron/manganese precipitate and increases in the concentrations of ammoniacal nitrogen and a number of metals in the T&T Tributary and the Owhiro Stream. Clear "spikes" in contaminant concentrations were measured in January and August 2012, June 2013 and October2016. The ecological data available (2010) indicates significant adverse effects on macroinvertebrate communities of both the tributaries and the Owhiro Stream itself.

In 2012, a report prepared by NIWA described an event similar to that of November 2016 (the damming of a side tributary) with similar consequences, i.e. prolonged exceedances of the iron guideline and increased ammoniacal-nitrogen concentrations. The report recommended improvements to the drainage system, diversion of the tributaries around the landfill and treatment by way of a wetland.

8.2. Effects of the November 2016 event

The November 2016 event resulted in significant effects on water clarity and colour in both the tributary and the Owhiro Stream, largely exceeding RMA S107(1)(d) narrative standard[2]. The effects on water clarity and colour during and following the November 2016 event were greater than the "ongoing" effects seen in quarterly monitoring data and are considered major, due to their intensity (very low water clarity< 0.1m), duration (several weeks) and spatial extent (the whole of the Owhiro Stream downstream of the discharge).

[1] Samples taken on 28 November were not analysed for ammoniacal nitrogen

[2] Relative to a discharge causing a conspicuous change in water clarity or colour after reasonable mixing.

The November 2016 event was also associated with a clear "spike" in concentrations of ammoniacal nitrogen and a number of metals, including iron, manganese, zinc and copper. Ammoniacal-nitrogen concentrations in the T&T Tributary and the Owhiro Stream exceeded the NPSFM National Bottom Line at times and are likely to have caused both chronic and acute toxic effects on aquatic life.

Iron and manganese from the tributary stream exiting the landfill caused the deposition of large amounts of orange/brown precipitate in the tributary and along the length of the Owhiro Stream down to the mouth, although in decreasing amounts going downstream. By 18th January 2017, effects appeared to have reduced back to the "ongoing" level of effects.

Significant adverse effects on macroinvertebrate communities occurred in both the T&T Tributary and the Owhiro Stream itself, with a 70 to 80% reduction in the overall number of macroinvertebrates, a near-disappearance of pollution sensitive species and the presence of abnormally coloured and formed freshwater snails downstream of the discharge. A gradual recovery was observed along the length of the Owhiro Stream, with macroinvertebrate communities recovering to levels comparable to upstream of the discharge at the most downstream site sampled, just above the stream mouth to Owhiro Bay.

8.3. Recommendations

The T&T Landfill appears to be causing significant adverse effects on water clarity and colour and on aquatic life on an ongoing basis. However, the intensity and scale of effects appears to vary in time, with a number of clear spikes in the concentrations of contaminants measured in January and August 2012, June 2013 and October2016.

The November 2016 event led to greater effects than the normal ongoing/background effects. However it does not appear to have been a unique event, similar conditions having been reported in 2012. It is also possible that the June 2013 and October 2016 spikes in contaminants were the result of similar events.

On the basis of the above conclusions, we can only recommend that some urgency be given to implementing mitigation measures, including:

- diversion of the tributaries around the landfill to reduce as much as practicable the amount of water circulating under and through the fill area. We understand that surface diversion channel are being considered. We recommend that their design incorporates input from a water quality scientist/ecologist to ensure that the diversion channels do not prevent fish passage and do not lead to other effects (for example, some shading should be provided to avoid significant increases in temperature);
- capture and treatment of the remainder of the leachate at the toe of the landfill. We understand that a wetland treatment is being considered. Like with all wetland treatment systems, adequate design of the wetland will be critical to treatment efficiency, particularly given the physical constraints of the site (only a very small wetland will be able to be constructed). We also note that wetland treatment is not generally considered efficient for removal of ammoniacal nitrogen, and additional treatment may be required if elevated ammoniacal nitrogen are recorded again in the future.

With regards to ongoing monitoring, we make the following recommendations:

- It appears that events similar to that of November 2016 have already occurred in the past following heavy rainfall, leading to “spikes” in contaminant concentrations being discharged to the Owhiro Stream. The frequency of the current water quality monitoring regime (every three months) means that short- to medium-term spikes may not be identified. It would seem appropriate to undertake systematic water quality sampling in the 2-4 week period following heavy rainfall. Site inspections may also help identify any water ponding areas;
- It is also recommended that further monitoring of macroinvertebrate communities be undertaken in the Tributary and along the length of the Owhiro Stream, to provide a measure of recovery after the November 2016 event, noting however that a significant rainfall in early April appears to be causing a new event similar to that of November 2016 at the time of finalising this report.
- There does not appear to be any data on the presence or abundance of organic micro-contaminants in the Owhiro Stream. Given the unknown nature of the waste underlying the T&T clean fill operation, some analyses of SVOC/VOCs in sediment at various points down the catchment would be useful to provide some base information on the presence of these contaminants in the catchment.

REFERENCES

Hickey C. (2012). Review of water quality issues in relation to an ammoniacal-nitrogen spike at T & T Landfills. *Memorandum Dated 18 December 2012. Ref TAT 13201.*

Cameron, D. (2017). Ecological Assessment of Owhiro Stream and tributary at T&T Landfill. *Prepared for T & T Landfills Limited. March 2017*

Rosenberg, D. M., and V. H. Resh, editors. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall, New York.

Scarsbrook M. R. and McBride G. B. (2007). Best practice guidelines for the statistical analysis of freshwater quality data. *Prepared for the Ministry for the Environment by the National Institute for Water and Atmospheric Research (NIWA). NIWA client report: HAM2007-088.*

Stark, J. D. 1985. A macroinvertebrate community index of water quality for stony streams. Water & Soil Miscellaneous Publication 87, Ministry of Works and Development, Wellington.

Stark, J.D., Boothroyd, I.K.G., Harding, J.S. and Scarsbrook, M.R. 2001. Protocols for sampling wadeable streams. Ministry for the Environment.

Winterbourn, M. J. 1999. The use of Macroinvertebrates in Water Management. Ministry for the Environment, Wellington.

APPENDICES

Appendix A:

Mean density of macroinvertebrates collected in 5 Surber samples (0.1m^2) at sites sampled upstream and downstream of the T&T Landfill site and on the Owhiro Stream, 22nd December 2017.

T&T Landfill / Owhiro Stream (22/12/2016)	MCI score	US T&T	DS T&T	Owhiro US Murchison Bridge	Owhiro Bay
Mayflies					
Deleatidium sp.	8	0.8	0	0.6	0.8
Stoneflies					
Acroperla sp.	5	3.2	0.4	0	0
Spaniocerca sp.	8	7	0	0	0.6
Caddisflies					
Aoteapsyche sp.	*4*	0	0	1.4	6.8
Hydrobiosidae early instar	*5*	0.4	0	0	0
Hydrobiosis	*5*	0	0	0	0.8
Orthopsyche sp.	*9*	2.6	0.2	0.6	0.4
Oeconesidae	*9*	0.2	0	0	0
Polyplectropus sp.	*8*	0	0	0	0.6
Psilochorema sp.	*8*	0	0	0	0.2
Coleoptera					
Dytiscidae	5	0.4	0	0	0
Elmidae	*6*	0	0.2	0.4	0.6
Hydraenidae	8	0.2	0	0	0
Hydrophilidae	5	0.2	0	0.2	0.2
Crustacea					
Amphipoda	5	1.8	0.4	0.8	2.6
Isopoda	5	0	0	0.4	0
Diptera					
Aphrophila sp.	*5*	11.2	0.6	1.4	1.4
Austrosimulium sp.	*3*	50.8	0.2	0.2	0
Ephydridae	4	0	0.2	0.2	0
Eriopterini	9	0	0.4	0	0
Mischoderus sp.	4	0.2	0	0	0
Molophilus sp.	5	0.8	0	0	0
Muscidae	3	1.2	0.4	0.2	0.2
Paralimnophila skusei	6	0	0.4	0	0.2
Psychodidae	1	1.4	2.6	1.2	0.4
Sciomyzidae	3	0	0.2	0	0
Chironomids					
Chironomus	1	0	0	0	0.8
Orthocladiinae	2	539.8	31.4	533.2	626.2
Maoridiamesa sp.	3	4.8	0.2	8.4	8
Tanytarsini	3	0.6	0.2	0.4	0
Mollusca					
Gyraulus	*3*	0	0.2	0	0
Physa	*3*	1.6	0	0.2	0
Potamopyrgus sp.	*4*	10	32	38	5.8
Sphaeriidae	*3*	0	0	0.2	0
Worms					
OLIGOCHAETA	1	14.4	58.4	30.2	36

T&T Landfill / Owhiro Stream (22/12/2016)	MCI score	US T&T	DS T&T	Owhiro US Murchison Bridge	Owhiro Bay
PLATYHELMINTHES	3	0.4	0.4	0	0
Other					
Procordulia	6	0	0.2	0	0
NEMERTEA	3	0.6	0	0	0
Hygraula	4	0	0.2	0	0.2
MEGALOPTERA Archichauliodes diversus	7	0	0	0.2	1.2
Number of Taxa		**14.6**	**8.2**	**8.8**	**11**
Number of Individuals		***655***	***129***	***618***	***694***
% EPT Taxa		***21***	***7***	***13***	***31***
% EPT Individuals		***2***	***0.4***	***0.5***	***3***
MCI		***83***	***65***	***75***	***85***
QMCI		***2.38***	***2.09***	***2.17***	***2.11***