ECOLOGICAL ASSESSMENT OF OWHIRO STREAM AND TRIBUTARY AT T&T LANDFILL

Prepared for T & T Landfills Limited

March 2017

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1 Introduction

T & T Landfills Ltd hold Consent WGN070260 [30627] for the discharge of contaminants from the landfill to an unnamed tributary of Owhiro Stream (see Appendix A). Conditions 6, 7 and 8 of the consent specify monitoring requirements, tolerance limits and trigger values at specified locations in the unnamed tributary and Owhiro Stream.

Condition 12 required the permit holder to commission an ecological survey of the landfill tributary upstream and downstream of the T&T Landfill and the Owhiro Stream upstream and downstream of the tributary confluence (completed in 2010).

Condition 13 requires that, should the tolerance limits and trigger values from routine and follow up samples be exceeded, the permit holder shall engage a suitably qualified independent ecologist to provide an assessment of the ecological effects of the discharges from the site.

As detailed in the monitoring report for the last quarter of 2016 and indicated below in Table 1-1, the requirement to conduct an ecological assessment was triggered during the last quarter on 2016 and the present report has been prepared in fulfilment of Condition 13.

Table 1-1: Results of additional monitoring at TTD post September 2016 quarterly monitoring (from Cameron, 2017)

Determinand	ANZECC (2000) 90% TV	27/09/2016	3/10/2016 (A1)	30/11/2016 (A2)	Mean of A1 and A2	Adaptive Management action required?
pH	n.s.	7.3	7.4	7.3	7.35	no
Electrical conductivity	n.s.	167.5	84.1	195.9	140	no
Alkalinity	n.s.	440	290	480	385	no
Total suspended solids	n.s.	25	15	29	22	no
COD	n.s.	56	14	81	47.5	no
Total Hardness	n.s.	780	300	830	565	no
Total ammoniacal N	1.430 (2.34)	6	1.6	7.1	4.35	**Yes**
Iron	n.s.	8.2	0.03	0.07	0.05	no
Manganese	2.5	3.2	1.52	4.2	2.86	**Yes**
Lead	0.0056	0.0032	0.00005	0.00005	0.00005	no
Copper	0.0018	0.0038	0.00025	0.0006	0.000425	no
Zinc	0.015	0.061	0.0029	0.0104	0.00665	no
Chromium	0.006	0.006	0.0005	0.0025	0.0015	no
Arsenic	0.042	0.0034	0.0005	0.0037	0.0021	no

* ANZECC (2000) Guidelines for Ecosystem Protection 90% default trigger value (Table 3.4.1); values in brackets are the guidelines values after adjustment to site specific factors (ie. pH = 7.6 and hardness = 50 g/m^3 $CaCO_3$.

2 Methodology

2.1 Monitoring locations

The monitoring locations selected for the ecological survey are those established for a baseline survey in 2010 and subsequently used for routine quarterly water quality monitoring (Table 2-1 and Figure 2-1).

Table 2-1: Monitoring locations

Code	Site Description	GPS Reference
TTE	Eastern tributary upstream of landfill	E2656943; N5986600
TTW	Western tributary upstream of landfill	E2656690; N5986684
TTD	Combined tributary 100m downstream of landfill	E2656972; N5985320
OSU	Owhiro Stream upstream of landfill tributary confluence	E2657198; N5985220
OSD	Owhiro Stream downstream of landfill tributary confluence	E2657107; N5985087

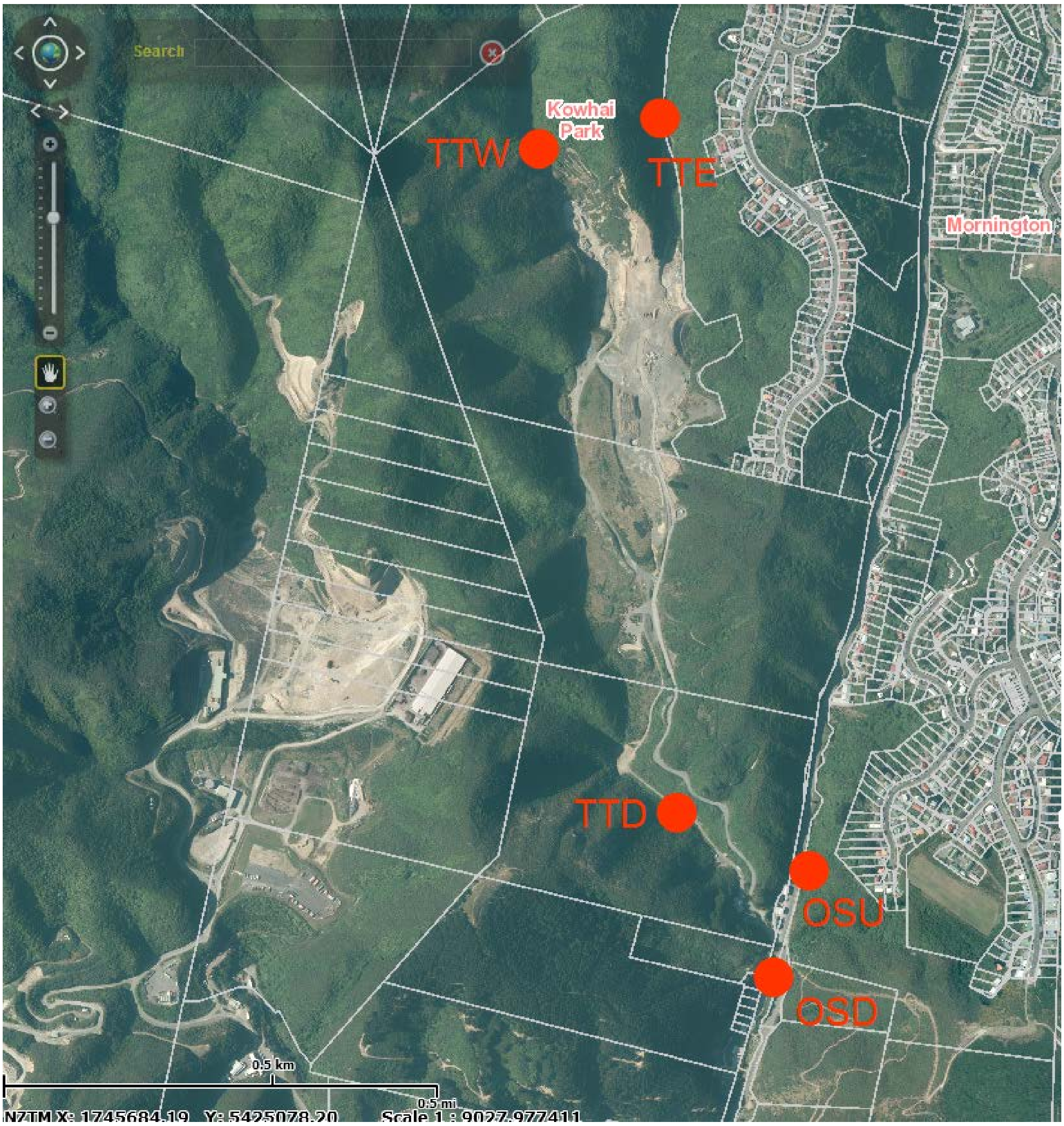
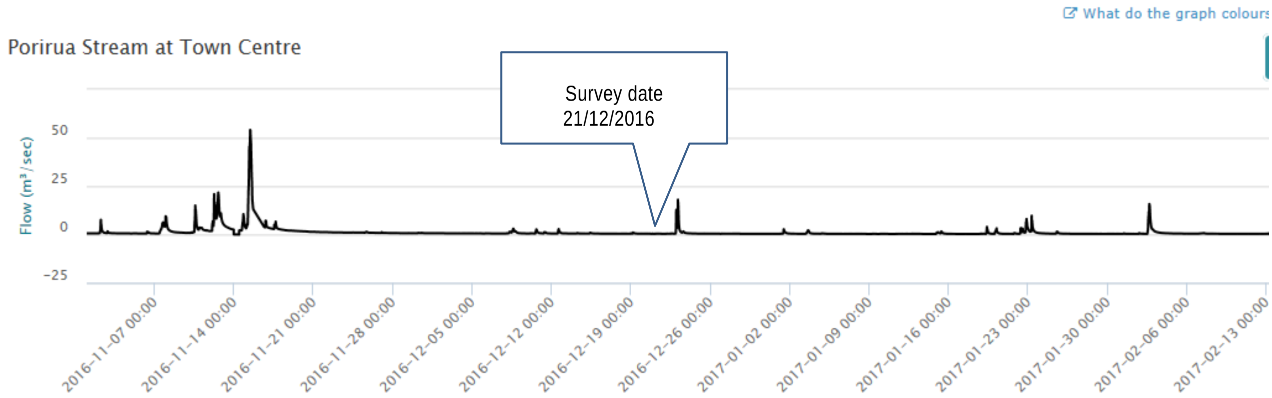


Figure 2-1: Location of T&T Landfill monitoring locations

2.2 Stream flows

As ongoing flow data is not available for Owhiro Stream the flow record for Porirua Stream has been used to give an indication of antecedent conditions. A major storm event occurred on 15th November 2016 which is known to have caused flooding, erosion and bed movement in the Owhiro Stream and its tributaries. The invertebrate survey was conducted nearly five weeks after the major flood event, and 10 days after a series of minor freshes (which peaked at approximately 3 times the mean flow for 2016).



2.3 Habitat quality survey

A habitat quality survey was conducted at each of the five stream sites listed in Table 2-1 on 21 December 2016 in order to provide a context for the ecological assessment. The survey included the following:

- In-situ measurements of water temperature, dissolved oxygen, pH and conductivity using a handheld YSI 566 multi-probe meter;
- A rapid habitat quality assessment using a protocol from Clapcott (2015);
- In-stream assessment of deposited sediment %cover using SAM2 from Clapcott *et al*, (2011); and
- An assessment of substrate compactness using a protocol from Harding *et al* (2009)

2.4 Macroinvertebrate survey

A macroinvertebrate community assessment was conducted on 21 December 2016 at each of the five stream sites. Quantitative macroinvertebrate Surber samples (0.1m^2) were collected from riffle habitat in general accordance with protocol C3-Hard Bottom, Quantitative (Stark *et al* 2001). As no riffle habitat was available at site TTD, samples were collected from runs and areas where water turbulence was increased by large rocks, logs, etc. The number of sample replicates varied between sites as follows:

- 3 replicates at each of TTE and TTW,
- 6 replicates at TTD, and
- 7 replicates at each of OSU and OSD.

Each sample was preserved in ethanol alcohol and transported to the Ryder Consulting Laboratory for processing by full count with subsampling option (Protocol P3: Stark et al, 2001). The results were summarised with a range of invertebrate community metrics including abundance, number of taxa, number of EPT taxa, MCI and QMCI (refer to Appendix B for details).

The significance of differences in invertebrate community metrics between sites upstream and downstream of the landfill (TTE+TTW compared with TTD), and sites upstream and downstream of the landfill tributary inflow to Owhiro Stream (OSU compared with OSD) were determined by equivalence tests of paired samples using Time Trends software version 5.00 (Jowett, Time Trends Version 5, 2015). Equivalence tests incorporate both testing of means (using a Student's t-test) and testing of meaningful change (i.e. interval testing of 'equivalence' and 'in-equivalence'). The method is described in detail by McBride (2014).

Patterns in macroinvertebrate community composition at the five sites were examined by non-metric multi-dimensional scaling (MDS) of macroinvertebrate abundance data. MDS ordination of macroinvertebrate abundance data maximises rank-order correlation between distance measures. Its purpose is to represent samples as points in two or three-dimensional space. Points that are close together represent samples that are very similar in community composition, and points that are far apart correspond to very different values of the variable set. MDS ordination was carried out in Primer version 6.1 (Primer-E Ltd, UK).

2.5 Periphyton

A visual assessment of periphyton % cover was conducted at each of the five stream sites. At each location a visual assessment was made at three points on six cross river transects. Periphyton cover was assessed for the following four categories:

- filamentous algae >2cm long;
- cyanobacteria mats >1mm thick;
- all mats >1mm thick; and
- “sludge” >1mm thick (including iron precipitate).

2.6 Water Quality

There is existing water quality data for the landfill tributary and Owhiro Stream based on quarterly monitoring over a period of seven years. This information was used to assist in the interpretation of benthic ecology data.

3 Existing State of Environment

3.1 Instream Habitat Quality

3.1.1 East Gully (TTE)

The east gully upstream of the landfill is narrow and steep-sided, supporting a regenerating mahoe forest. Urban development along the eastern, northern and western boundaries of the catchment is relatively close to the stream and it is likely that urban stormwater discharges have an intermittent effect on water quality and the flow regime. The gully is drained by a perennial first order stream flowing over a mobile gravel bed in a series of small pools (mostly less than 30cm deep), riffles and runs. The substrate is loose providing habitat in the interstitial spaces within the substrate. The streambed is clean, with light periphyton development and little fine sediment visible. The mahoe canopy provides nearly complete shade over the stream bed, except in the reach immediately upstream of the landfill where riparian vegetation has been removed for construction of an access track. .

The watercourse provides fair to good habitat for invertebrates and fish (see Tables 3-1 and 3-2), but its' ecological functions are potentially limited by low flows in summer, the landfill as a barrier to migrating fish, and urban stormwater runoff. A view of the east gully stream is provided in Figure 3-1

3.1.2 West Gully (TTW)

The west gully upstream of the landfill is similar in many respects to the east gully described above. The catchment has previously been cleared but now supports a regenerating mahoe forest which provides nearly complete shading over the stream. Although limited urban development has occurred along the northern catchment boundary the extent of urbanisation is less than in east gully and the great majority of the area above the landfill is relatively undisturbed.

A small first order perennial stream flows over a stony substrate in a series of small pools, runs and riffles. Periphyton development is light and there is no evidence of fine sediment deposition. The substrate appears larger, more stable and slightly more compacted than in the eastern gully. Overall the quality of stream habitat for invertebrates and fish is good, but its' ecological functions are potentially limited by low flows in summer and the landfill as a barrier to migrating fish. A view of the west gully stream is provided in Figure 3-2.

3.1.3 T&T Tributary Downstream (TTD)

The eastern and western tributaries flow under the landfill as separate branches but a single watercourse emerges from the toe of the landfill and flows into a wetland system which is currently under construction. This reach of the landfill tributary is relatively low gradient, with low to moderate water velocity and a narrow channel which is largely overgrown with rank grasses and emergent aquatic plants. In places the grasses are overshadowed by a riparian vegetation of mixed exotic and indigenous shrub and tree species. A view of the landfill tributary is provided in Figure 3-3.

A gravel bed substrate is exposed in places but extensive deposition of fine sediment is the dominant feature of this reach. In addition the streambed is heavily coated in an orange deposit and woolly flocculant mass associated with iron bacteria, probably *Leptothrix ochracea*. These bacteria derive the energy they need to live and multiply by oxidizing dissolved ferrous iron (or manganese). Iron bacteria colonize the transition zone where de-oxygenated water from an anaerobic environment flows into an aerobic environment. Groundwater containing dissolved organic material (DOM) may be de-oxygenated by microorganisms feeding on that DOM. Where concentrations of DOM exceed the concentration of dissolved oxygen required for complete oxidation, microbial populations with specialized enzymes can reduce insoluble ferric oxide in aquifer soils to soluble ferrous hydroxide and use the oxygen released by that change to oxidize some of the remaining organic material. When the de-oxygenated water reaches a source of oxygen, iron bacteria use that oxygen to convert the soluble ferrous iron back into an insoluble reddish precipitate of ferric iron. Organic material dissolved in water is often found to be the underlying cause of an iron bacteria population (Snoeyink, et al, 1980)

The adverse effects of dissolved iron are considered to be largely a result of bed smothering by iron-oxidizing bacteria. Vuori (1995) concluded that the combined direct and indirect effects of iron contamination can decrease the species diversity and abundance of periphyton, benthic invertebrates and fish. While ANZECC (2000) does not provide a trigger level for direct toxicity effects of iron, the US EPA (2009a) 'aquatic life criteria' includes a 'chronic' guideline value of 1.0 g/m^3 for iron.

3.1.4 Owhiro Stream above the landfill tributary confluence

The Brooklyn branch of Owhiro Stream drains the heavily urbanised suburb of Brooklyn and is extensively culverted upstream of this point; few of the contributing headwater tributaries flow in open channels. The progressive urbanisation of Brooklyn has resulted in the loss of much of the ecological value of the stream, although recent efforts to enhance these values (and aesthetic values) by riparian planting have improved conditions to some extent. Views of site OSU are provided in Figures 3-5 & 3-6.

Nevertheless the stream continues to be confined to an artificially narrow channel and receives rapid runoff from roads and other impervious surfaces, resulting in high water velocities and frequent bed disturbance during rainfall events. The invertebrate and fish habitat in this reach likely to be compromised by extensive urban development in the Brooklyn catchment.

3.1.5 Owhiro Stream below the landfill tributary confluence

The Brooklyn branch of Owhiro Stream downstream of the landfill tributary confluence is subject to the same pressures as the upper Brooklyn branch but also receives flow from the T&T Landfill catchment. At the time of the survey the Owhiro Stream bed downstream of the landfill tributary had elevated levels of deposited fine sediment, an extensive coating of the orange precipitate, and increased substrate compactness, all of which contribute to a substantially degraded habitat quality compared with site OSU (see Tables 3-1 and 3-2). View of site OSD are provided in Figures 3-7 and 3-8.

Table 3-1: Stream channel characteristics of tributary streams in the study area (MWH, 21/12/16)

Habitat Parameter	*Sampling Site*				
	TTE	*TTW*	*TTD*	*OSU*	*OSD*
Location	Upstream eastern tributary	Upstream western tributary	100m downstream of landfill	Owhiro Stream upstream of tributary	Owhiro Stream downstream of tributary
NZTM Ref					
Date/Time sampled	21/12/16 11:30am	21/12/16 12:05pm	21/12/16 10:30am	21/12/16 1:50pm	21/12/16 1:10am
% fine sediment cover[1]	<5	<5	71	<5	19
Dominant substrate	gravel/cobble	cobble	silt/gravel	cobble	cobble
Substrate compactness[2]	1	2	2	1	4
Water temperature (°C)[3]	12.6	12.5	14.3	16.8	15.4
Electrical conductivity (mS/cm)[3]	240	226	769	297	648
pH[3]	6.19	6.30	6.01	7.27	6.90
DO (%sat)[3]	91.7	93.1	85.7	96.6	87.2
DO (mg/L)[3]	9.82	9.99	8.75	9.38	8.70
Periphyton %cover:					
Filamentous >2cm long	<5	<5	<5	<5	<5
Cyanobacteria >1mm thick	<5	<5	<5	<5	<5
All mats >3mm thick	<5	<5	<5	<5	6
Sludge[4]	<5	<5	97	<5	90
Macrophytes %cover	<5	10	10	<5	10
Observations	Clean streambed and high water clarity	Clean streambed and high water clarity	Extensive orange precipitation on streambed; low water clarity	Clean streambed and high water clarity	Extensive orange precipitation on streambed; moderate water clarity

[1]Sediment Assessment Method 2 (Clapcott, et al., 2011)

[2]Substrate compactness is assessed on a 1 – 4 scale: 1= loose, easily moved substrate; 2 = mostly loose, little compaction; 3 = moderately packed; 4 = tightly packed substrate (Harding, et al., 2009).

[3]Measured in situ by hand-held YSI 566 multi-probe meter.

[4]Sludge includes the orange deposit and woolly flocculent mass associated with iron bacteria.

Table 3-2: Rapid habitat assessment results summary (using a protocol from Clapcott J., 2015)

Habitat parameter	*Sampling Site*				
	TTE	*TTW*	*TTD*	*OSU*	*OSD*
Deposited sediment	9	9	1	9	6
Invertebrate habitat diversity	5	5	2	7	5
Invertebrate habitat abundance	9	9	3	8	5
Fish cover diversity	2	4	4	7	7
Fish cover abundance	3	4	6	6	6
Hydraulic heterogeneity	5	5	3	7	6
Bank erosion	9	9	8	5	6
Bank vegetation	8	7	7	8	7
Riparian width	10	10	6	7	5
Riparian shade	9	9	7	8	5
Habitat quality score (of 100)	69	71	47	72	58

Figure 3-1: Site TTE, upstream of landfill

Figure 3-2: Site TTW, upstream of landfill

Figure 3-3: Site TTD, 100m downstream from toe of landfill

Figure 3-4: Wetland treatment system under construction at toe of landfill

Figure 3-5: Site OSU, Upstream of T&T tributary

Figure 3-6: Site OSU, Upstream of T&T tributary

Figure 3-7: Site OSD, downstream of T&T tributary

Figure 3-8: Site OSD, downstream of T&T tributary

3.2 Macroinvertebrate Communities

3.2.1 Community composition

A macroinvertebrate data report is included in Appendix B and a summary of invertebrate metric scores is given in Figure 3-3. A total of 57 invertebrate taxa were identified across the five sites included in the study. The benthic fauna on the western branch tributary upstream of landfill (site TTW) was dominated by the mayfly *Deleatidium*, the freshwater snail *Potamopyrgus* and Orthoclad midges, all of which were moderately abundant. The mean number of invertebrates from 3 sample replicates was 194, comprising 17 invertebrate taxa and 6 EPT[1] taxa. The MCI[2] and QMCI[3] indices indicate an invertebrate community of fair to good quality. While the invertebrate community is slightly to moderately degraded at TTW, it is of better quality than at all other sites in the study and serves as an upstream reference site.

The eastern branch tributary upstream of the landfill (site TTE), was dominated by Orthoclad midges while the amphipod *Paracalliope* and the snail *Potamopyrgus* were also common. Overall invertebrate abundance was lower than in the western branch (TTW), as was the number of taxa and the number of EPT taxa. The MCI and QMCI scores indicate an invertebrate community of fair/poor quality. Although in many respects the habitat quality at TTE is similar to TTW, its closer proximity to urban areas of Brooklyn and its higher degree of exposure to urban stormwater runoff probably account for the poorer quality and lower abundance of the macroinvertebrate community.

The tributary stream 100m downstream of the landfill (site TTD) has a lower gradient than the upstream sites, is affected by sediment deposition, ferric iron precipitation and the discharge of a range of contaminants from the landfill, and has a predominantly soft sediment substrate. These influences have resulted in a depauperate invertebrate fauna dominated by the snail *Potamopyrgus*. The community is characterised by a low abundance of invertebrates, a low number of taxa and a total absence of EPT taxa. The MCI and QMCI scores indicate a poor quality macroinvertebrate community which is significantly degraded compared to the upstream sites TTW and TTE.

The Owhiro Stream upstream of the tributary stream confluence (site OSU) is influenced by stormwater run-off from urban Brooklyn but is not affected by the T&T landfill. Sensitive invertebrate taxa were notably absent from the community at this location, which was dominated by Orthoclad midges and the blackfly larvae *Austrosimulium*, both of which were common or abundant, contributing to a moderately high total invertebrate abundance. An average of 13 taxa were identified from seven replicate samples but only two EPT taxa were recorded. The MCI and QMCI scores indicate a poor quality macroinvertebrate community, probably as a result of elevated dissolved copper and zinc sourced from urban runoff (see Section 3-3).

Table 3-3: Mean macroinvertebrate metric values from 3 to 7 replicates at five sites (21/12/2016)

metric	TTW (3 reps.)	TTE (3 reps)	TTD (6 reps)	OSU (7 reps)	OSD (7 reps)
Number of individuals	194	96	33	323	93
Number of taxa	17	12	8	13	10
Number of EPT taxa	6	3	0	2	0.4
%EPT taxa	35	21	0	14	3.9
%EPT individuals	38	5	0.3	1.6	0.6
MCI	104	85.7	61	77.9	67.3
QMCI	4.93	3.37	2.77	2.57	2.30
Dominant taxa	*Deleatidium*	Orthocladiinae	Potamorpyrgus	Orthocladiinae	Oligochaeta

[1] EPT refers to taxa in the Ephemeroptera, Plecoptera and Trichoptera groups, which are generally dominated by invertebrates that are indicative of higher quality conditions. In stony bed rivers these indexes usually increase with improved water quality and increased habitat diversity.

[2] MCI in the Macroinvertebrate Community Index (Stark 1993) which uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream.

[3] QMCI is a quantitative variant of the MCI (Stark 1985) which weights each taxa score depending on abundant of that taxa.

The Owhiro Stream downstream of the landfill tributary (site OSD) is influenced by runoff from urban Brooklyn as well as contaminants discharged from T & T Landfill. The invertebrate community at OSD was dominated by Oligochaete worms while Orthoclad midges and *Potamopyrgus* were also common. Overall invertebrate abundance was lower than at OSU. An average of 10 taxa were identified from seven replicate samples while EPT taxa were virtually absent. The MCI and QMCI scores indicate a poor quality macroinvertebrate community, probably reflecting the combined effects of elevated dissolved copper and zinc sourced from urban Brooklyn and elevated ammonia and suspended solids for the T & Landfill (see Section 5).

3.2.2 Upstream – downstream differences

Examination of seven invertebrate metrics by equivalence testing (Table 3-4) and boxplots (Figure 3-9) provides moderate or strong evidence for a practically important decrease in the quality or 'health' of the invertebrate community in the landfill tributary at site TTD compared with the upstream sites (TTW + TTE). Four mayfly taxa, 3 stonefly taxa and 4 caddis fly taxa that were represented upstream of the landfill were absent downstream of the landfill. These results indicate that the invertebrate community 100m downstream of the landfill is adversely affected by poor habitat quality and/or contaminants discharged from the landfill.

In order to determine whether these effects extend downstream as far as the Owhiro Stream, equivalence testing was also conducted on invertebrate metrics for Owhiro Stream site OSU upstream of the landfill tributary confluence and site OSD downstream of the confluence (OSD is approximately 510m downstream of the landfill). The results provide moderate or strong evidence for a decrease in some invertebrate metrics including total abundance, species richness, number of EPT taxa and %EPT taxa. However, the results for the biotic indexes MCI and QMCI are equivocal (Table 3-5).

The weight of evidence is that contaminants discharged from the T&T Landfill have adversely affected the invertebrate community in the landfill tributary and in Owhiro Stream immediately downstream of the landfill tributary confluence.

An MDS ordination of invertebrate abundance data (refer Figure 3-10) shows clear differences between all five sites including:

- A clear difference in invertebrate community composition between the two branches of the tributary upstream of the landfill;
- A strong difference in invertebrate community composition between tributary sites located upstream and downstream of the landfill; and
- A clear difference in invertebrate community composition between Owhiro Stream sites located upstream and downstream of the tributary inflow.

Table 3-4: Mean values and equivalence test results for T&T tributary sites TTE+TTW (upstream) and TTD (downstream) using a p-value <0.05 and equivalence test limits of ±20% (Time Trends software Version 5, Jowett, 2015)

Indices	N	Mean at TTE+TTW	Mean at TTD	Sum of paired diff.	t-test p-value	Equivalence test
Number of invertebrates	6	145	33	112	0.006	Strong evidence for a practically important decrease
Number of taxa	6	14.3	8.3	6.0	0.008	Mod. evidence for a practically important decrease
Number of EPT taxa	6	4.17	0.17	4.0	0.002	Strong evidence for a practically important decrease
% EPT taxa	6	27.7	1.33	26.3	0.000	Strong evidence for a practically important decrease
% EPT individuals	6	21.8	0.33	21.5	0.013	Strong evidence for a practically important decrease
MCI	6	95.0	61.3	33.7	0.000	Strong evidence for a practically important decrease
QMCI	6	4.15	2.767	0.91	0.005	Mod. evidence for a practically important decrease

Table 3-5: Mean values and equivalence test results for Owhiro Stream sites OSU (upstream) and OSD (downstream) using a p-value <0.05 and equivalence test limits of $\pm$20% (Time Trends software Version 5, Jowett, 2015)

Indices	N	Mean at OSU	Mean at OSD	Sum of paired diff.	t-test p-value	Equivalence test
Number of invertebrates	7	323.7	92.5	231.1	0.013	Strong evidence for a practically important decrease
Number of taxa	7	13.4	9.57	3.85	0.003	Mod. evidence for a practically important decrease
Number of EPT taxa	7	2.0	0.43	1.57	0.020	Strong evidence for a practically important decrease
% EPT taxa	7	14.1	3.86	10.29	0.007	Strong evidence for a practically important decrease
% EPT individuals	7	1.57	0.57	1.00	0.057	Weak – inconclusive, not enough data
MCI	7	77.9	67.3	10.57	0.003	Some evidence for a decrease, but trivial
QMCI	7	2.57	2.30	0.271	0.146	Weak – inconclusive, not enough data

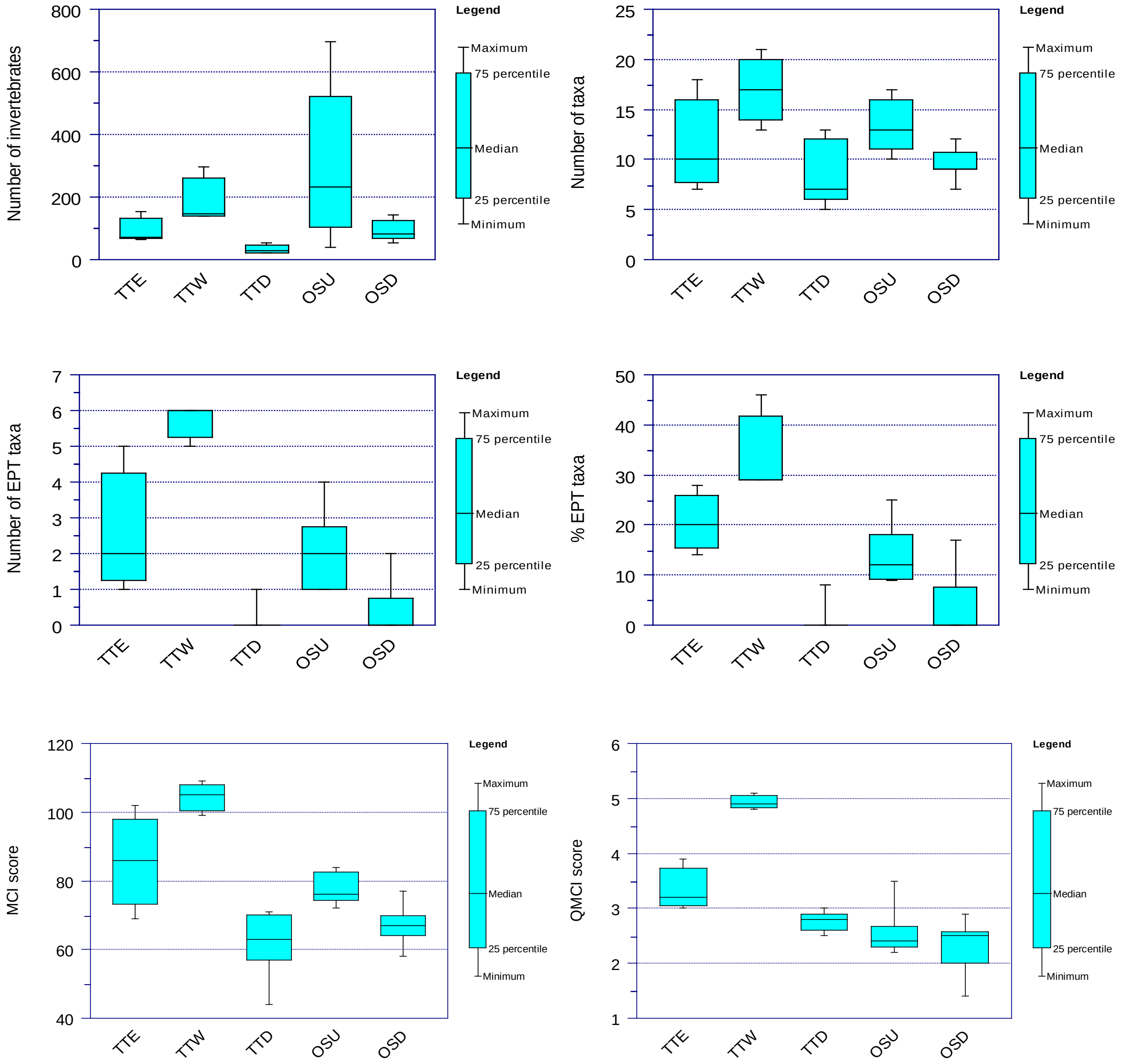


Figure 3-9: Box plots of invertebrate metrics for three sites on the T&T tributary and two sites on Owhiro Stream

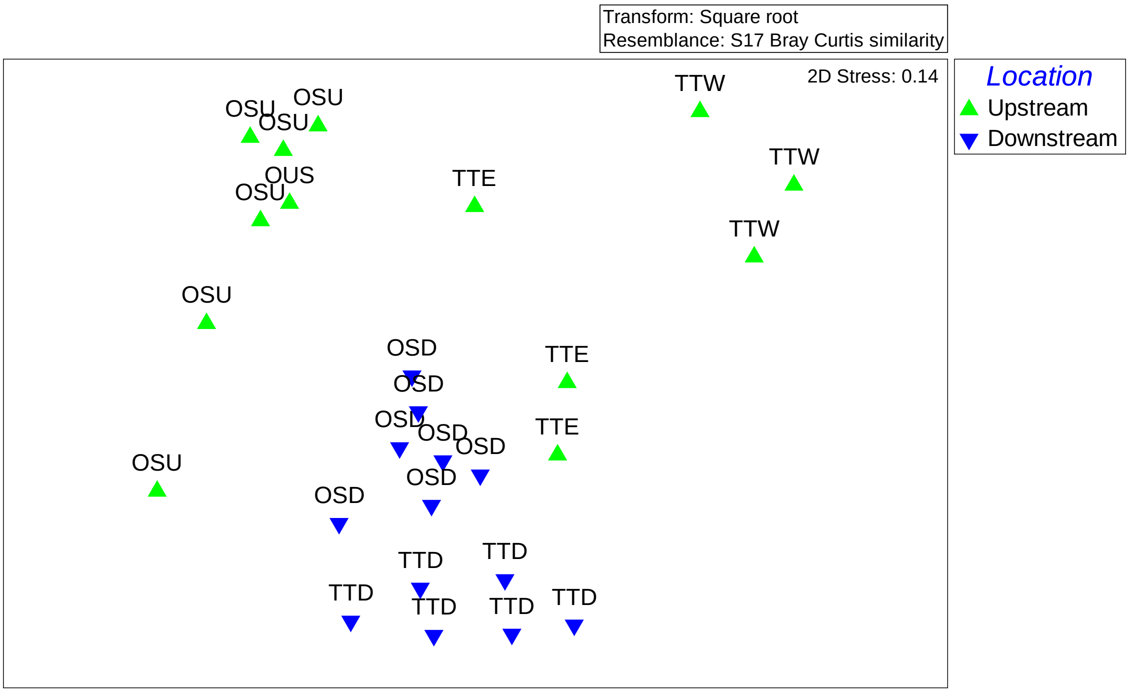


Figure 3-10: Plot from an MDS Ordination (stress = 0.14) for invertebrate communities sampled at sites TTW, TTE, TTD, OSU and OSD on 21/12/2016. Location = upstream and downstream of T&T Landfill

3.2.3 Temporal differences

A baseline survey of the stream ecology conducted in 2010 pursuant to Condition 12 of Consent WGN070260[26124] included a semi-quantitative survey of the macroinvertebrate community at the same five sites use in the present study (Cameron, 2010). The 2010 survey was based on 3 replicate kicknet samples, a less robust method than used in the present study (7 replicate Surber samples), but nevertheless valid a comparison can be made between the two surveys provided those differences are taken into account. The results show that:

- Metric scores are lower in 2016 than in 2010 at all sites. The reason for differences at upstream sites TTW and TTW is not clear, but may be related to a major flood event that occurred approximately 5 weeks prior to the 2016 survey.
- Adverse effects in the tributary below the landfill appear to have been more pronounced in 2010 than in 2016, and
- Adverse effects in Owhiro Stream were similar, but slightly more pronounced in 2016 than in 2010.

Table 3-6: Comparison of invertebrate metric scores from surveys conducted in 2010 and 2016.

Metric	TTW		TTE		TTD		OSU		OSD	
	2010	2016	2010	2016	2010	2016	2010	2016	2010	2016
Number of taxa	23	17	17	12	8	8	18	13	16	10
Number of EPT taxa	13	6	7	3	0.3	0	3	2	3	0.4
%EPT taxa	60	35	44	21	4	0	25	14	21	3.9
MCI	132	104	114	85.7	87	61	84	77.9	77	67.3
QMCI	6.85	4.93	5.93	3.37	2.39	2.77	3.12	2.57	2.50	2.30
Dominant taxa	Deleatidium	Deleatidium	Orthopsyche	Orthocladiinae	Potamoprgus	Potamoprgus	Orthocladiinae	Orthocladiinae	Orthocladiinae	Oligochaeta

Overall, the macroinvertebrate community metrics do not show a greater level of adverse effects in 2016 compared with 2010. However, as described in Section 3.3, other factors including water quality and iron precipitation on the streambed have deteriorated over that period.

3.3 Water Quality

Although the western tributary receives some urban runoff from the Waterhouse Drive area, the great majority of the catchment is in scrubland and regenerating bush. The eastern tributary has a higher proportion of urban development in its catchment, receiving urban stormwater runoff from Ashton Fitchett Drive, Karepa Street and Mitchell Streets, but also including substantial areas of scrubland and regenerating bush. The results of water quality monitoring from 2011 to 2016, as summarised in Table 3-7 (and summarised by box plots in Appendix C), show relatively high water quality in both tributaries upstream of the landfill, with low contaminant levels and consistent compliance with ANZECC trigger values (TVs). The water quality results presented here do not explain the differences observed in macroinvertebrate composition between the two branches (see Section 4). Those differences may due to short term spikes in water quality associated with stormwater runoff events which are not represented in the water quality monitoring results. Alternatively, they may be due to other physical differences between the two sites (e.g., flow regime or habitat quality).

The two tributaries converge under the T & T landfill and emerge as a single watercourse. The monitoring results for site TTD show that concentrations of some contaminants increase in the tributary during passage under the landfill. Downstream increases are recorded for electrical conductivity (EC), alkalinity, water hardness, dissolved calcium, dissolved magnesium, chemical oxygen demand (COD), total suspended solids (TSS), ammonia nitrogen, total arsenic, total copper, total and dissolved iron, total and dissolved manganese, total lead, dissolved zinc and total zinc.

Many of these water quality changes are relatively small and do not cause an exceedance of ANZECC 90% TVs. Nevertheless, the data for TTD show an increasing trend in the period 2010 to 2016 for a number of contaminants including EC, alkalinity, hardness, calcium, magnesium, ammonia, iron and manganese, which are possibly associated with the gradual development of the landfill over that period (see Figures 3-11 & 3-12, and Appendix C). By contrast total copper, total lead and total zinc (Figures 3-14 and 3-15) show a decreasing trend at TTD over that period. Metal fractions that show no measurable increase during passage under the landfill include dissolved arsenic, dissolved copper, dissolved chromium, total chromium and dissolved lead.

The contaminants of most concern at TTD are iron, manganese and ammonia, all of which have significantly exceeded TVs. High levels of iron (Figure 3-12) have, in combination with elevated levels of dissolved organic matter (DOM), resulted in ferric iron precipitation covering streambed substrates in the reach below the landfill, extending downstream beyond site OSD. A review of quarterly reports indicates that the extent of streambed affected by iron bacteria has gradually increased between 2011 and 2016. Similarly, TSS has gradually increased at TTD (Figure C15 in Appendix C) and this at least partially driven by increased iron bacteria growths. It is noted that iron precipitation may have direct or indirect effects on stream biota but also has an adverse effect on water clarity, TSS, and the visual appearance of the streambed.

Elevated concentrations of ammonia occurred at site TTD for periods in 2012/13 and 2016/17 at concentrations that are potentially toxic to some stream organisms (Figure 5-11). Both events appear to have been triggered by intensive rainfall leading to flooding and ponding of water upstream of the landfill. The precise mechanism leading to increased ammonia concentrations is not clear but may be related to an accumulation of decaying vegetation in ponded water, associated with the flood events.

The inflow of the landfill tributary to Owhiro Stream has resulted elevated concentration of iron, manganese and ammonia in Owhiro Stream from time to time and has caused significant iron precipitation in Owhiro Stream at site OSD (Figure 3-8). It is noted however that elevated levels of dissolved copper and zinc in Owhiro Stream at OSU and OSD are primarily sourced from urban Brooklyn (see Figures 5-5 and 5-11).

Table 3-7: Summary statistics for quarterly water quality monitoring results from January 2011 to December 2016 (values above guideline trigger values are shaded red)

Parameter	Unit	n sample	TTE		TTW		TTD		OSU		OSD		ANZECC 90%
			Median	95%ile	Median	95%ile	Median	95%ile	Median	95%ile	Median	95%ile	
pH	pH	19	7.5	7.9	7.7	7.96	7.3	7.5	7.6	7.8	7.8	8.06	6-9
Alkalinity (as $CaCO_3$)	g/m³	19	49	59.2	48	59.7	260	462	51	65	200	412	NA
Hardness (as $CaCO_3$)	g/m³	19	57	73	55	71	260	808	63	73	210	717	NA
Electrical conductivity	mS/m	19	32.1	35.7	30.4	33.9	73.2	183	34.7	51.7	63.3	201	NA
Dissolved calcium	g/m³	19	13.3	16.2	12.1	16.7	81	265	14.3	16.5	65	235	NA
Dissolved magnesium	g/m³	19	6.3	8.03	5.9	7.1	14.2	36.9	6.6	7.7	12.1	32.9	NA
TSS	g/m³	19	<3	14.9	<3	18	15	36	<3	3	6	27.6	NA
COD	g/m³	19	<6	12	<6	10	14	70	<6	10	11	63.7	NA
Total ammonia-N	g/m³	19	<0.01	0.012	<0.01	0.01	1.02	6.61	<0.01	2.5	0.28	5.76	1.43 (2.34)
Arsenic (Total)	g/m³	20	<0.002	<0.002	<0.002	<0.002	0.003	0.008	<0.002	<0.002	<0.002	0.006	NA
Arsenic (dissolved)	g/m³	10	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.042
Copper (Total)	g/m³	25	<0.002	0.002	<0.002	0.008	<0.002	0.005	0.002	0.004	<0.002	0.012	NA
Copper (Dissolved)	g/m³	10	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.004	<0.002	<0.002	0.0018 (0.0028)
Chromium (total)	g/m³	20	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	0.004	NA
Chromium (Dissolved)	g/m³	10	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.006
Iron (Total)	g/m³	25	0.032	0.172	0.030	0.176	5.800	15.7	0.033	0.282	2.00	10.10	NA
Iron (Dissolved)	g/m³	10	0.030	0.168	0.010	0.011	0.025	1.910	0.015	0.004	0.025	0.980	1.00*
Manganese (Total)	g/m³	25	0.004	0.010	0.003	0.014	1.400	4.35	0.003	0.005	0.690	6.930	NA
Manganese (Diss.)	g/m³	10	0.003	5.400	<0.002	0.006	1.37	4.20	0.003	0.006	0.66	2.700	2.5
Lead (Total)	g/m³	25	<0.002	<0.002	<0.002	<0.002	0.006	0.005	<0.002	0.003	<0.002	0.003	NA
Lead (Dissolved)	g/m³	10	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0056 (0.011)
Zinc (Total)	g/m³	25	0.005	0.020	<0.002	0.007	0.018	0.088	0.016	0.024	0.009	0.042	NA
Zinc (Dissolved)	g/m³	10	0.004	0.006	<0.002	0.005	0.007	0.037	0.020	0.032	0.008	0.028	0.015 (0.027)

*USEPA (2009) chronic 'aquatic life criteria'

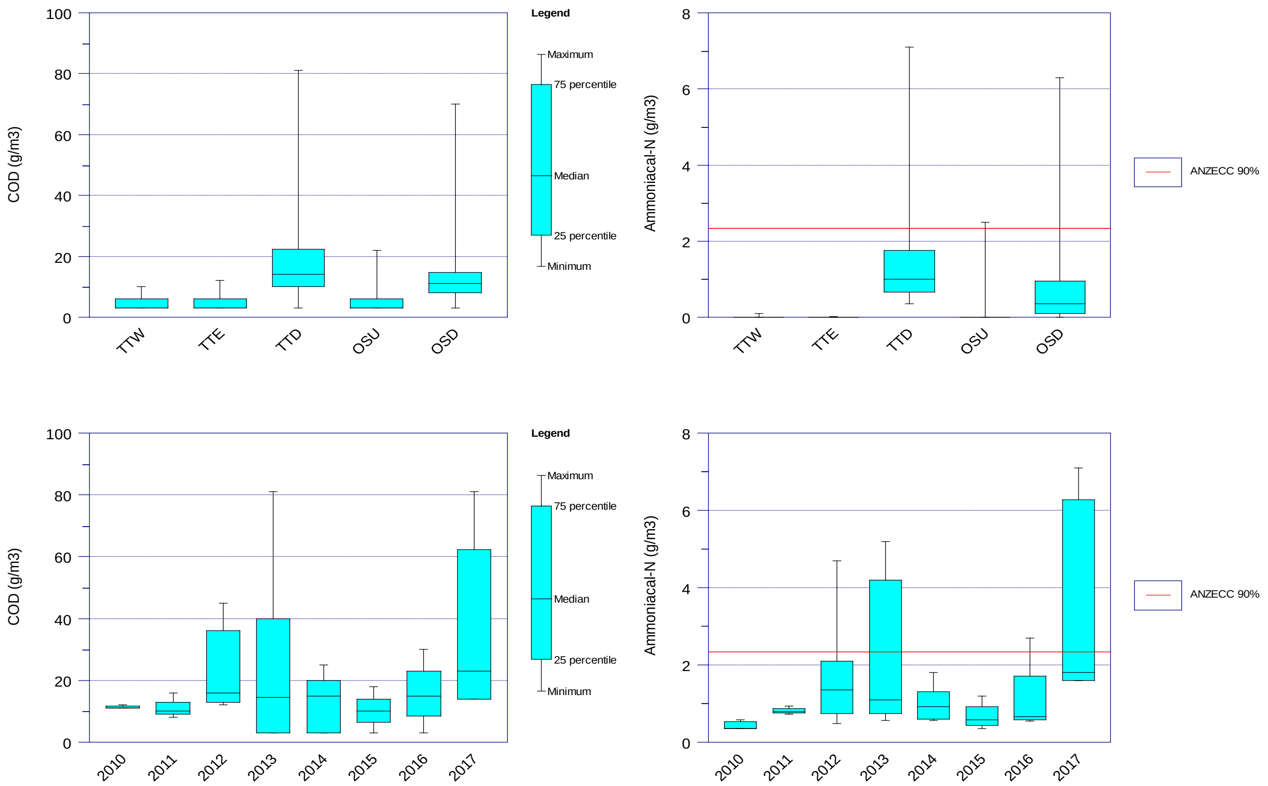


Figure 3-11: Summary of COD and ammonia results by site (above) and by year at TTD (below)

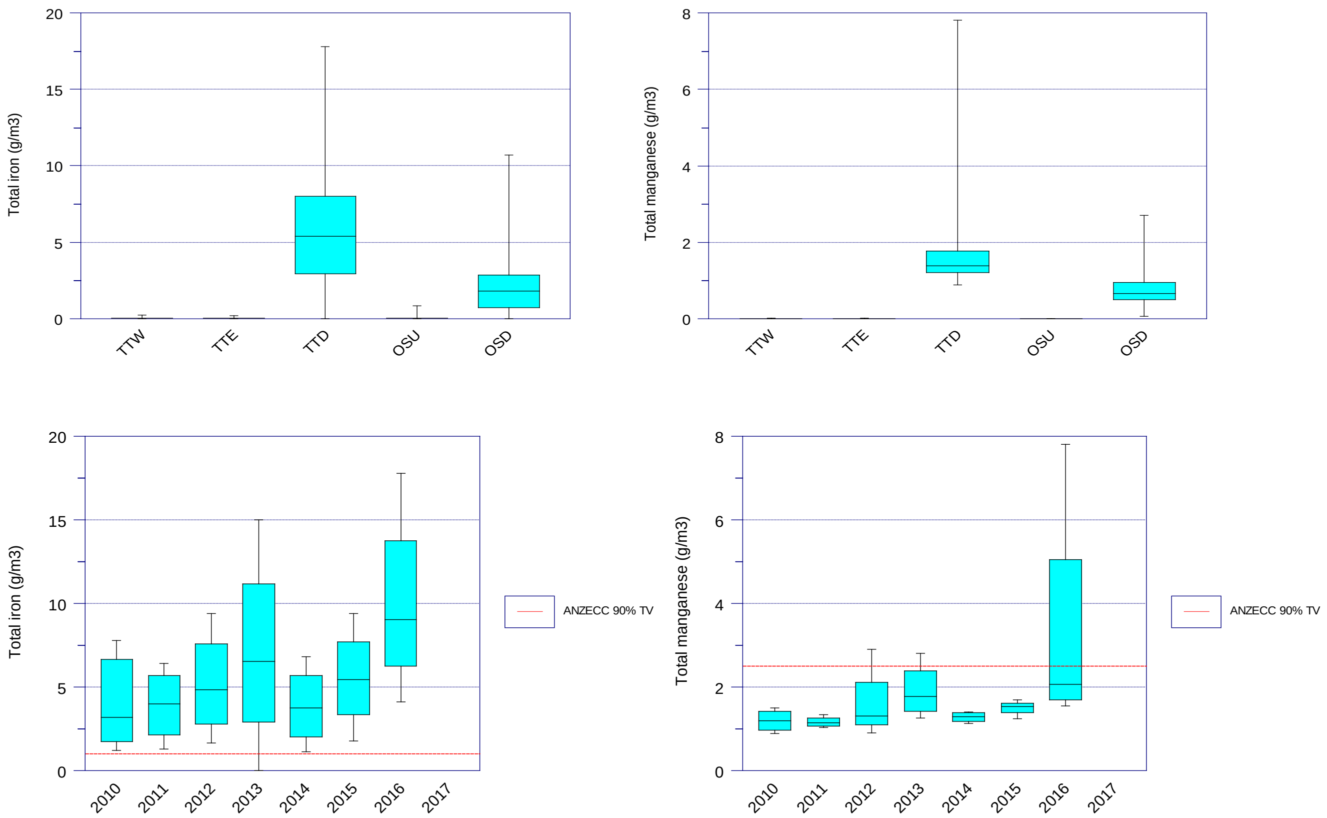


Figure 3-12: Summary of total iron and manganese by site (above) and by year at site TTD (below)

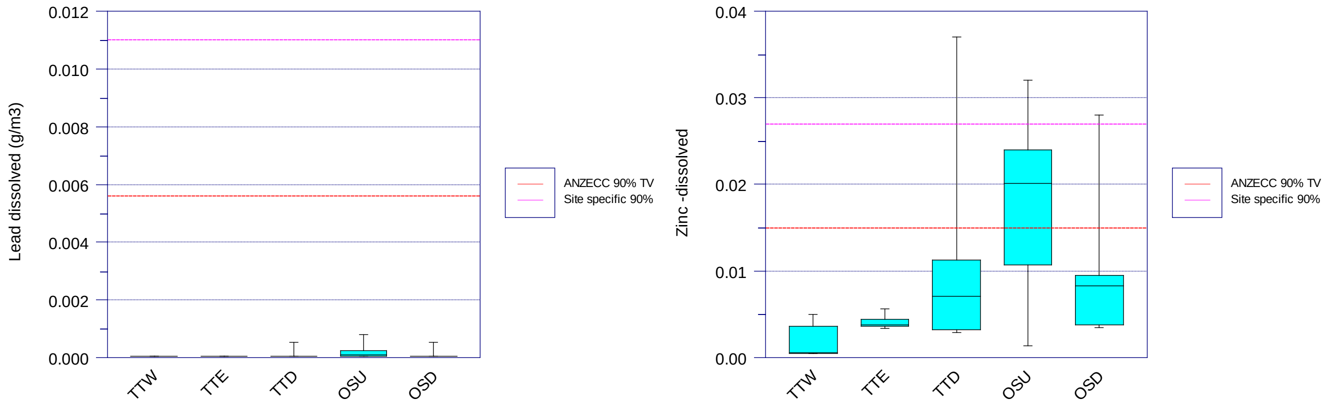


Figure 3-13: Dissolved lead and zinc by site compared with TVs (2010 - 2016)

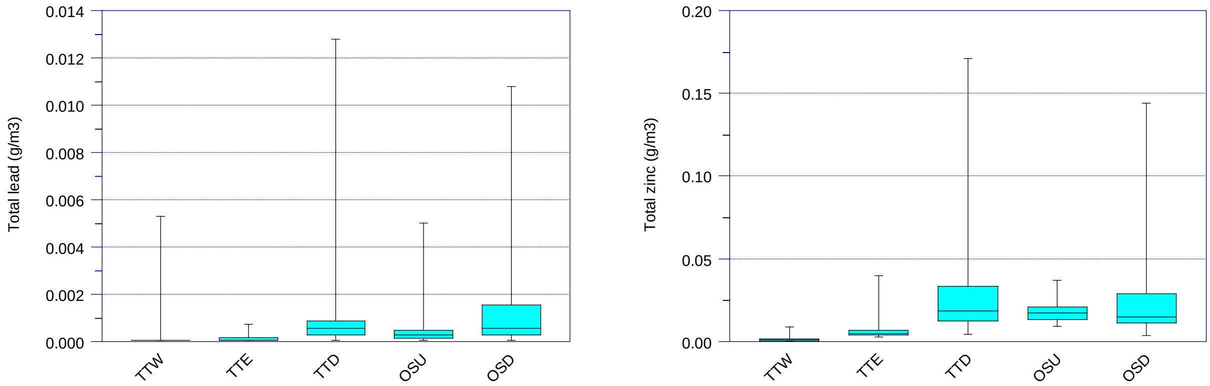


Figure 3-14: Total lead and zinc by site (2010 – 2016)

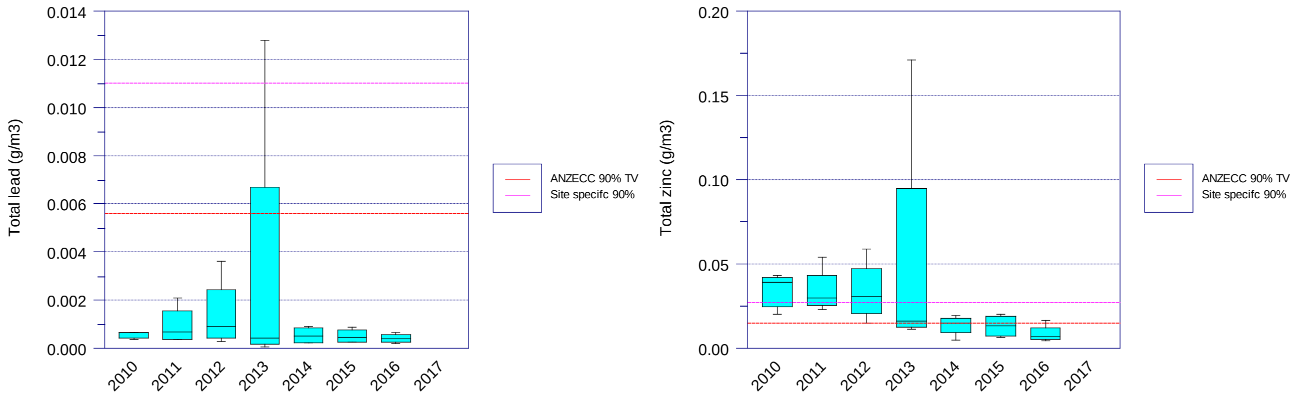


Figure 3-15: Total lead and zinc by year at site TTD

4 Assessment of Environmental Effects

Routine quarterly water quality monitoring in the tributary downstream of the landfill at site TTD over the period January 2011 to December 2016 has shown an increasing trend for stream concentrations of some contaminants but especially of ammonia, iron and manganese. The long term increasing trend for ammonia is punctuated by spikes during 2012/13 and in the last quarter of 2016 which appear to be related to periods of exceptionally heavy rainfall resulting in flooding and ponding at the upstream edge of the landfill, and an accumulation of decaying vegetation in the ponded water seeping into and under the landfill.

Increased concentrations of dissolved iron, dissolved manganese and dissolved organic material have been accompanied by a proliferation of iron bacteria in the tributary downstream of the landfill and the associated development of a highly visible orange woolly flocculant mass, precipitation of ferric iron on streambed substrates, and an associated increase in TSS as well as reduced water clarity. At the time of the December 2016 ecology survey the landfill was causing a conspicuous change in water clarity and colour in both the unnamed tributary and in Owhiro Stream (see Figures 3-1 to 3-8). The TSS results summarised in Table 3-7 and Appendix C show that this effect has occurred over a sustained period and was most pronounced during the 2016 monitoring year. In our assessment these results indicate a “significant change in visual clarity” in both watercourses downstream of the landfill, which is contrary to condition 11 of the consent and section 107(1)(d) of the RMA.

In light of recorded ammonia concentrations above the 90% protection TV for sustained periods and the smothering of benthic habitats by iron bacteria and ferric iron precipitation, some adverse consequences for macroinvertebrate and periphyton communities were anticipated. This assessment provides strong evidence for a decrease in macroinvertebrate community health in the tributary stream downstream of the landfill compared to upstream sites, as indicated by decreases in both invertebrate abundance and diversity, and marked reductions in MCI and QMCI scores.

There is evidence that some of the effects identified in the landfill tributary extend downstream into Owhiro Stream, at least as far as the reach immediately downstream of the confluence, which is a distance of over 500m. These include a decrease in total abundance, species richness, number of EPT taxa and %EPT taxa. However differences in MCI and QMCI score are not significant at the Owhiro Stream sites.

The weight of evidence is that contaminants discharged from the landfill have had a significant adverse effect on the invertebrate community of the landfill tributary, and a lesser but still measurable effect on the invertebrate community of Owhiro Stream immediately downstream of the confluence.

Whether the adverse effects on macroinvertebrate communities amount to a “significant adverse effect on aquatic life” in terms of condition 11 of the consent and section 107(1)(g) of the RMA, would depend on a number of factors including:

(a) The magnitude of the effect,
(b) The frequency/duration of the effect, and
(c) The extent of the effect on life in the stream.

The magnitude of the effect in the unnamed tributary is at the higher end of the scale as all metrics show marked decreases, including the loss of important taxa downstream of the landfill, although it is not clear to what extent these changes are caused by discharges from the landfill versus reduced habitat quality. The magnitude of the effect on Owhiro Stream is less pronounced with neither MCI nor QMCI showing a significant difference, indicating that significant effects probably do not extend downstream much beyond the confluence. The duration of the effect (up to 6 months, recurring on an occasional basis) has in recent years amounted to a substantial proportion of the time. Nevertheless, because the effect on macroinvertebrate communities is localised and mostly limited to the unnamed tributary, it probably does not amount to a significant adverse effect on aquatic life of Owhiro Stream. It is noted that sensitive EPT taxa are absent from Owhiro Stream *upstream* of the landfill tributary because of the influence of urban Brooklyn and that the absence of pollution sensitive taxa probably explains the relatively muted response to contaminants discharged from the landfill.

The overall conclusion is that while discharges from the landfill have not had a significant adverse effect on the aquatic life of Owhiro Stream, they have caused a significant change in the colour and/or visual clarity of the stream, and the magnitude of that effect has increased since the baseline survey was conducted in 2010. In our assessment that effect does require mitigation, as discussed in the following section.

5 Recommended mitigation

It is recommended that some urgency be given the proposed diversion of streams around the landfill, including the minor side gullies and the two main branches of the landfill tributary. In our view this approach is likely to be the most effective method of avoiding or mitigating the adverse effects described in this report. Diversion of stream and local stormwater around the landfill will greatly reduce leachate volumes, and will enable the remaining leachate to be more effectively treated by the wetland which is currently under construction.

References

Cameron, D. (2010). *Baseline Survey of the Aquatic Ecology in an unnamed tributary of Owhiro Stream.* Report prepared by MWH for T&T Landfill Ltd.

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Harding, Clapcott, Quinn, Hayes, Joy, Storey, . . . Boothroyd. (2009). *Stream Habitat Assesment Protocols for wadeable rivers and streams in New Zealand.*

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Appendices

Appendix A Resource Consent

Conditions to Resource Consent WGN070260 [30627]

1[1]. The location, design, implementation and operation of the discharge shall be in general accordance with the application, associated documents and further information lodged with Wellington Regional Council on:

- 14 June 2007 (consent application)
- 14 June 2007 (plans, including final stormwater discharge plan E04-1000-FL)
- 21 June 2007 (microalgae investigation report)
- 6 September 2007 (second microalgae investigation report)
- 7 September 2007 (executive summary)
- 4 June 2008 (Wellington City Council application)
- 27 February 2009 (Further information)
- 18 August 2010 (change of conditions application); and
- 14 June 2011 (Further information)

Where there may be contradictions or inconsistencies between the application and further information provided by the applicant, the most recent information applies. In addition, where there may be inconsistencies between information provided by the applicant and conditions of consent, the conditions apply.

Note: Any change from the location, design concepts and parameters implemented and/or operation may require a change in consent conditions pursuant to Section 127 of the Resource Management Act 1991.

2. The permit holder shall provide a copy of this permit and any documents referred to in this permit to each operator or contractor undertaking works authorised by this permit before that operator or contractor starts any works.

Note: It is recommended that the contractor(s) undertaking the works be verbally briefed on the conditions of this and all other associated permits prior to the works being undertaken.

3. The permit holder shall ensure that a copy of this permit and all other permits granted under the Wellington Regional Council resource consent suite WGN070260 is kept within the site office, and presented to any Wellington Regional Council officer on request.

4. The permit holder shall keep a permanent record of any complaints received alleging adverse effects from the permit holder's operations. The complaints record shall contain the following where practicable:

- The name and address of the complainant, if supplied
- Identification of the nature of the complaint
- Date and time of the complaint and alleged event
- Weather conditions at the time of the alleged event
- Results of the permit holder's investigations; and
- Any mitigation measures adopted.

The complaints record shall be made available to the Wellington Regional Council on request.

Site Operations and Maintenance Condition

5. The permit holder shall, at all times, operate, maintain, supervise and control all processes and equipment on site to ensure compliance with all conditions of this permit and the Operations Management Plan required by condition 6 of permit WGN070260 [26122].

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[1] Condition changed under section 127 of the Act, granted 28/07/11

Monitoring of Discharge

6. Within six months of the grant of this permit, the permit holder shall engage a suitably qualified person to prepare and submit a **Discharge Management Plan (DMP)** for approval, to the Manager, Environmental Regulation, Wellington Regional Council.

The purpose of the DMP is to establish and implement a more scientifically robust quantification at representative locations of the effects of the discharge coming from the landfill, and the effects of the discharge to the downstream unnamed tributaries of Owhiro Stream.

The DMP shall include, but not be limited to, the following:

- The provision of maps and monitoring locations (GPS locations or NZMS 260 grid references) that provide for an upstream control sample from both the eastern (TTE) and western arm (TTW) tributaries, downstream of the discharge point (TTD/TTG) and the main trunk of Owhiro Stream (upstream and downstream of the confluence of the landfill tributary with the main trunk of Owhiro Stream); and
- A monitoring methodology for surface and ground water quality sampling, including, but not limited to:
  - The technique used to recover the contaminants from the samples
  - The location and area the sampling will be undertaken over; and
  - A comparison with relevant tolerance limits (including method of calculation) and guidelines (e.g. surface water quality values against the ANZECC 2000 90% ecosystem protection values for freshwater quality) and the upstream control samples for the protection and maintenance of ecosystem services within the Owhiro Stream

Note: The DMP is to be included in the OMP alongside the other required plans under condition 6 of permit WGN070260 [26122].

7[2]. At a minimum, the groundwater contaminants at the location TTG (as total recoveries) to be sampled in March, June, October and December of each year shall include, but not be limited to:

• pH	
• Conductivity	µS/m
• Chloride	g/m^3
• Ammoniacal Nitrogen	g/m^3
• Nitrate Nitrogen	g/m^3
• Iron	mg/m^3
• Manganese	mg/m^3
• Lead	mg/m^3
• Copper	mg/m^3
• Zinc	mg/m^3
• Chromium	µg/L
• arsenic	µg/L

At a minimum, the **surface water** contaminants at the locations TTW, TTE, TTD and the two new locations on the main branch of the Owhiro Stream (as total recoveries) to be sampled in March, June, October and December of each year shall include, but not be limited to:

• pH	
• Conductivity	µS/m
• Alkalinity	g/m^3
• Total suspended solids	g/m^3
• COD	
• Total Hardness	g/m^3
• Ammoniacal Nitrogen	g/m^3
• Iron	mg/m^3
• Manganese	mg/m^3

[2] Condition changed under section 127 of the Act, granted 28/07/11

- Lead mg/m³
- Copper mg/m³
- Zinc mg/m³
- Chromium µg/L
- Arsenic µg/L

All sampling techniques employed in respect of the conditions of this permit shall be to the satisfaction of the Manager, Environmental Regulation, Wellington Regional Council. All analyses shall be performed by an International Accreditation New Zealand (IANZ) registered laboratory or otherwise as specifically approved by the Manager, Environmental Regulation, Wellington Regional Council.

8[3]. The quality of the surface water discharge as sampled under condition 7 of this permit shall be compared with the following tolerance range, determined from *total recoveries*:

Contaminant and unit		**Lower tolerance range**	**Upper tolerance range**
pH		-0.4	0.4
Conductivity	µS/m		72.4
Alkalinity	g/m³		226
Total suspended solids	g/m³		
COD	g/m³		21
Total Hardness	g/m³		
Ammoniacal Nitrogen	g/m³		0.346
Total Iron	mg/m³		2748
Total Manganese	mg/m³		1461
Total Lead	mg/m³		5.9
Total Copper	mg/m³		4.0
Total Zinc	mg/m³		130
Total Arsenic	µg/L		13.0
Total Chromium	µg/L		1.0

The limits for Total Suspended Solids and Total Hardness shall be calculated once the number of samples reaches 10. The same calculations to determine the upper and lower tolerance limits shall be applied as is detailed in the DMP in condition 6 of this permit.

Should the tolerance limit for any parameter be exceeded, and where that parameter also exceeds the latest ANZECC Guidelines for Ecosystem Protection (90%) trigger levels, the permit holder shall, within one month of the receipt of the laboratory report:

- Undertake a second sample and analyse this for the exceeded parameter, and
- Undertake a third sample within one month of the second sample being taken, and analyse this for the exceeded parameter
- In these instances, the *dissolved metal* fraction, rather than the total metal fraction shall be tested for
- If the average of these two samples continues to exceed the relevant tolerance limits and the latest ANZECC Guidelines for Ecosystem Protection (90%) trigger levels, the permit holder shall implement the **adaptive management** conditions as required by conditions 13 and 14 of this permit.

9. The permit holder shall ensure that a person suitably qualified to the satisfaction of the Manager, Environmental Regulation, Wellington Regional Council prepares and submits a report by 30 June of each year detailing the items as required by conditions 6 and 7 and the approved DMP.

The report shall include, but not be limited to:

- The results and comparisons of the contaminants sampled for with the relevant limits approved under the DMP and condition 8 of this permit

[3] Condition changed under section 127 of the Act, granted 28/07/11

- A comparison of the concentration of contaminants of the latest year of sampling with the base line ecology survey results as required by condition 12 of this permit to determine whether there may have been a degradation in the quality of the aquatic ecosystem as a result of the discharge
- Any other relevant information; and
- Any recommendations for approval to the Manager, Environmental Regulation, Wellington Regional Council, to remedy or mitigate any significant adverse effects that have occurred, or to avoid foreseen significant adverse effects as a result of the discharge of contaminants from the landfill area to the tributaries of Owhiro Stream. Examples of these could be:

  Changes to the management or site acceptance protocols;
  - Methods to remedy adverse effects that may have been transported into the Owhiro Stream catchment; and
  - Mitigation measures to offset or minimise the significant adverse effects.

Note 1: For the purposes of this condition, 'significant adverse effects' are those effects which are determined to be significant in the professional opinion of the engaged independent expert.

Note 2: Annual reports can be bundled and submitted as one large report, providing that the relevant sections are clearly defined within the one document.

10. Should any recommendations arise from the report produced under condition 9 of this permit, the permit holder shall undertake to provide for the recommendations in a manner and timeframe that meets the satisfaction of the Manager, Environmental Regulation, Wellington Regional Council.

Note: These activities may require further resource consents.

Mixing zones

11. The discharges shall not give rise to any of the following effects after reasonable mixing:

- The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials
- Any conspicuous change in colour or visual clarity
- Any emission of objectionable odour
- The rendering of fresh water unsuitable for consumption by farm animals
- Any significant adverse effects on aquatic life; or
- Any visible deposition of iron oxide or other heavy metals

For the purposes of this condition and permit, the discharges shall be reasonably mixed at 100 metres downstream of the discharge point from the stilling basin within the unnamed tributary of Owhiro Stream.

Should any of these effects occur, the permit holder shall commission an updated DMP exploring the relevant treatment methodologies as required by condition 6 of this permit.

Baseline Ecological Survey Condition

12. During the period 1 December 2009 to 30 April 2010 inclusive, and following at least a two week period without a significant flood event (defined as 3x median stream flow) the permit holder shall have an appropriately experienced and qualified freshwater ecologist that meets the satisfaction of the Manager, Environmental Regulation, Wellington Regional Council carry out a semi-quantitative ecological survey of the landfill tributary upstream and downstream of the landfill discharge and the Owhiro Stream upstream and downstream of the confluence of the landfill tributary.

The survey shall comprise as a minimum:

- A macroinvertebrate survey following protocols C1 and P2 from the Ministry for the Environment's report on protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001) involving the collection of a 3 replicate samples (a minimum of 5 kicknet samples per replicate) within riffle habitat at each site, fixed count of macroinvertebrate taxa to the taxonomic resolution specified for use of the MCI and enumeration of the results as taxa richness, MCI, SQMCI, number of EPT taxa, %EPT taxa and %EPT individuals

- Macroinvertebrate surveys should also be accompanied by visual assessment of periphyton cover and substrate characteristics. Survey sites should share similar habitat characteristics in terms of substrate, flow and depth; and
- A full fish survey including electrofishing and spotlighting within the unnamed tributaries of the Owhiro Stream downstream of the landfill, and within the western and eastern arms of the tributaries upstream of the landfill

Note: The results of the Baseline Ecological Survey are to be included in the OMP alongside the other required plans under condition 6 of permit WGN070260 [26122].

Adaptive Management Conditions

13[4]. Should the tolerance limits, the latest ANZECC Guidelines for the protection of aquatic ecosystems (90%) trigger levels and additional sampling show an increase in the level of any one contaminant as described in condition 8 of this permit, the permit holder shall engage a suitably qualified, independent ecologist to provide an assessment of the ecological effects of the discharges from the site.

The qualifications of and methods employed by the ecologist or other suitably qualified person (in the case of recommendations on the practicable treatment of the discharged contaminants) shall meet the satisfaction of the Manager, Environmental Regulation, Wellington Regional Council.

The ecologist or other suitably qualified person shall provide specific assessment recommendation and implementation of the following:

- A monitoring methodology for *macroinvertebrate* sampling, including, but not limited to:
  - The techniques that will be used to carry out the surveys;
  - The location and area the sampling will be undertaken over;
  - The analysis methodology used to record and present the data; and
  - Other physical habitat quantifications used to assess the local ecosystem.
- An assessment of the potential effects of the discharge of contaminants to the unnamed tributary of Owhiro Stream;
- A recommendation of the number of sampling events that need to be undertaken (along with timeframes) to adequately gauge the effects of the discharges from the site;
- An assessment, once the invertebrate sampling has been undertaken, whether the existing treatment methodology for the discharge to the unnamed tributary of Owhiro Stream is the best practicable option for the treatment of the contaminants arising from either the historical or current land use of the area (i.e. both the fill placed by the permit holder, and the fill that existed on site prior to the operator's activities at the site) to feed back into the DMP as approved under condition 6 of this permit; and
- Provide recommendations on methods that could be used to further treat the discharge to ensure they remain within the tolerance limits specified in condition 8 of this permit.
- In the case of the limits for Total Chromium and /or Total Arsenic being exceeded, provide a recommendation as to whether or not the consent holder should cease the disposal of processed timber (both treated and untreated) to the landfill.

Note: Some recommended viable adaptive management measures could include the installation of a treatment wetland, sand filter system or enlargement of the stilling basin.

Note: The consent holder may store treated timber on site in the event arsenic and/or chromium tolerance limits are exceeded; however, all in-ground disposal must cease until informed otherwise.

14. The recommendations approved from the report prepared under the DMP and ecological assessment undertaken under conditions 6, 12 and 13 of this permit shall be undertaken by the permit holder to the satisfaction of the Manager, Environmental Regulation, Wellington Regional Council and within timeframes specified by the manager, Environmental Regulation, Wellington Regional Council.

Note: Further resource consents may be required to undertake the works recommended.

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[4] Condition changed under section 127 of the Act, granted 28/07/11

Long term Management Conditions

15. The permit holder shall, no less than **twelve** months prior to the expiry or surrender of this permit for the closure of the landfill, make application(s) for such consent(s) as are required for the future management of the site.

    This requirement shall also be complied with should filling activities at the site cease for a continuous twelve month period.

16. The permit holder shall continue to sample and provide monitoring results as required by conditions 6, 7, 8 and 9 until the expiry of this permit.

Water quality management - wetland creation

17[5]. The permit holder shall lodge application(s) for such consent(s) as are required for the creation of a wetland area at the location as shown on drawing numbers S02-0752-41 Rev.A and S02-0752-42 Rev.A, submitted as evidence at the change of conditions application hearing on 7 July 2011. The application must be lodged with and accepted by the Wellington Regional Council by **31 October 2011**.

The application(s) for such consent(s) shall provide information on, but not be limited to:

Design

- The wetland shall be designed in accordance with NIWA's '*New Zealand Constructed Wetland Planting Guidelines, 2006*'.
- Evidence to show how the wetland will improve the water quality of the discharges from the landfill.
- Details of how the proposed wetland will treat the following list of contaminants:
  - Ammoniacal Nitrogen
  - Iron
  - Manganese
  - Lead
  - Copper
  - Zinc
  - Chromium
  - Arsenic

Construction

- A 'step by step' construction methodology and timeline for the creation of the wetland
- Details of the amount of earthworks required to increase the size of the stilling basin (volumes of cut and fill)
- How any unsuitable material from the stream bed will be removed from the site and disposed of
- Erosion and sediment control measures to be implemented prior to works starting
- Erosion and sediment control measures to be used during construction to ensure sedimentation effects on the unnamed tributary of Owhiro Stream will be mitigated while works are occurring;, and
- Identifying person(s) who will be responsible for managing each part of the construction operation (including sediment control).

Planting

- Details of pre-planting site preparation;
- A to scale design plan(s) clearly showing:
  - The location and extent where planting will be undertaken around the stilling basin; and
  - The browse resistant native wetland plants species (sedges and rushes etc) that are proposed to be planted to aid in the treatment of the landfill's discharge, the size of the plants and the density of planting.
- A Monitoring and Maintenance Plan which shall be undertaken for the first 12 months upon completion of the planting, including, but not be limited to, the following:
  - Details of how plants will be irrigated during their establishment;

[5] Condition changed under section 127 of the Act, granted 28/07/11

- Details of how the site will be maintained and how often, including the ongoing replacement of plants that do not survive and eradication of evasive weeds from the planting site to ensure adequate growth (e.g. weeding, spraying, mulching); and
  - Details of how plants will be protected from animal pests (e.g. goats).
- A list of the key responsibilities and identification of the suitably experienced persons responsible for implementing the wetland planting.

Note 1: The intent of the wetland area is to improve water quality downstream of the landfill. The wetland is expected to help treat the heavy metals and other contaminants that will percolate through and discharge from the landfill.

Note 2: The wetland area shall be made a large as possible.

Note 3: The construction of the wetland shall be completed within two years of the grant of the resource consent(s) required from the Wellington Regional Council, or within a different timeframe on assessment of the consent application.

Note 4: The approved RMP as required under condition 9 of WGN070260 [26129] and ongoing ecological assessment as required under various conditions of WGN070260 [26124] may provide information that is helpful to the development of the wetland.

Review Conditions

18. The Wellington Regional Council may review any or all conditions of this permit by giving notice of its intention to do so, pursuant to section 128 of the Resource Management Act 1991 at any time within the life of the landfill for any of the following purposes:

- To deal with any adverse effects on the environment which may arise from the exercise of this permit, and which it is appropriate to deal with at a later stage;
- To review the adequacy of any plan prepared for this permit and/or the monitoring requirements so as to incorporate into the permit any modification to any plan or monitoring which may be necessary to deal with any adverse effects on the environment arising from the management or operation of the landfill and recycling centre;
- To impose limits on the discharge of contaminants in light of the results obtained from previous monitoring; or
- To enable consistency with any relevant Regional Plans or any National Environmental Standards.

Note: Following review, conditions or restrictions on the use of the site may be set by the Council if deemed necessary.

19. Wellington Regional Council shall be entitled to recover from the permit holder the costs of the conduct of any review, calculated in accordance with and limited to the council's scale of charges in force and application at the time, pursuant to section 36 of the Resource Management Act 1991.

Appendix B Macroinvertebrate survey results

Z0096704

Summary of Freshwater Macroinvertebrate Sample Processing & Results

December 2016

Z0096704

Summary of Freshwater Macroinvertebrate Sample Processing & Results

December 2016

prepared for MWH New Zealand Limited by Ryder Consulting Limited

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Table of Contents

1. Introduction

Preserved benthic macroinvertebrate samples were provided to Ryder Consulting by MWH New Zealand Limited. MWH New Zealand Limited staff collected these samples in December 2016. Ryder Consulting was engaged to process the samples, and report the results of taxonomic composition.

2. Laboratory Analysis

2.1 Processing

Samples were passed through a 500 μm sieve to remove fine material. Contents of the sieve were then placed in a white tray and macroinvertebrates were counted and identified by eye and under a dissecting microscope (10-40x) using criteria from Winterbourn *et al.* (2006).

2.2 Data summaries and metric calculations

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of invertebrates: The total number of individuals from all taxa groups per sample. Invertebrate abundance gives an indication of benthic production.

Number of taxa: A measurement of the number of taxa present.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, percentage of the total number of taxa comprising EPT taxa (% EPT taxa), and percentage of the total abundance comprising EPT taxa (% EPT individuals): These insect groups are generally dominated by invertebrates that are indicative of higher quality conditions. In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index (MCI) (Stark 1993): The MCI uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g., worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g., most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national standards (Table 1). For example, a low site score (e.g., 40) represents 'poor' conditions and a high score (e.g., 140) represents 'excellent' conditions.

$$MCI = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

Quantitative Macroinvertebrate Community Index (QMCI) (Stark 1985): The QMCI uses the same approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Site scores range between 0 and 10. As for MCI, QMCI scores can be interpreted in the context of national standards (Table 1).

$$QMCI = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

Where S = the total number of taxa in the sample, n_i is the number of invertebrates in the ith taxa, a_i is the score for the *i*th taxa, and N is the total number of invertebrates in the entire sample.

Table 1 *Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).*

Quality Class A	Quality Class B	MCI	QMCI
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

3. Results

3.1 Macroinvertebrate results

The macroinvertebrate results are included below and have also been forwarded to MWH New Zealand Limited in electronic form (Excel spreadsheet).

		TTE			TTW			TTD					
TAXON	**MCI score**	**a**	**b**	**c**	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**
ACARINA	5			3	1					1	1	2	1
CNIDARIA													
Hydra species	3												
COLEOPTERA													
Elmidae	6		1		3								
COLLEMBOLA	6	1			6		1			1	4	1	5
CRUSTACEA													
Copepoda	5										1		
Isopoda	5			1									
Ostracoda	3						2	1		3	7	7	1
Paracalliope fluviatilis	5	15	8	56									
Talitridae	5	1		3					1			1	
DIPTERA													
Aphrophila species	5												
Austrosimulium species	3				15								
Chironomus species	1				1	1							
Corynoneura scutellata	2				3								
Empididae	3												
Ephydridae	4												
Eriopterini	9				1		1						
Hexatomini	5											1	
Limonia species	6												
Maoridiamesa species	3												
Mischoderus species	4												
Molophilus species	5			1									
Muscidae	3										1		
Orthocladiinae	2	32	25	54	27	34	16	1		2	3	2	2
Paralimnophila skusei	6				2								
Podonominae	8			1									
Polypedilum species	3			2	19	11	12		1		1	2	
Psychodidae	1	5	3	7	3		1	4	1	5	9	10	2
Stratiomyidae	5											3	
Tanyderidae	4			1									
Tanypodinae	5				29	20	10						
Tanytarsini	3				21	9	8						
EPHEMEROPTERA													
Acanthophlebia species	7					1	2						
Ameletopsis perscitus	10					1							
Deleatidium species	8	2		3	58	43	33						
Zephlebia species	7				13	2	9						
HEMIPTERA													
Microvelia macgregori	5										1		
MEGALOPTERA													
Archichauliodes diversus	7				2	1	1						
MOLLUSCA													
Physa / Physella species	3												
Potamopyrgus antipodarum	4	11	19	5	71	13	12	13	17	5	10	16	1
Sphaeriidae	3								1		1		
NEMATODA	3			1									
NEMERTEA	3												
ODONATA													
Xanthocnemis zealandica	5										2		
OLIGOCHAETA	1	1	7	4			1	5	12	4	6	7	10
PLATYHELMINTHES	3	2					11						
PLECOPTERA													
Acroperla species	5												
Spaniocerca species	8	1		6									
Stenoperla species	10				2		3						
Zelandobius species	5		2		18	9	16						
Zelandoperla species	10												
TRICHOPTERA													
Hydrobiosella species	9				1	2							
Hydrobiosidae early instar	5												
Hydroptilidae	2												
Orthopsyche species	9			2									
Paroxyethira hendersoni	2											1	
Polyplectropus species	8			1	1								
Psilochorema species	8			2									
Number of invertebrates		71	65	153	297	147	139	24	33	21	47	53	22
Number of taxa		10	7	18	21	13	17	5	6	7	13	12	7
Number of EPT taxa		2	1	5	6	6	5	0	0	0	0	1	0
% EPT taxa		20	14	28	29	46	29	0	0	0	0	8	0
% EPT individuals		4	3	9	31	39	45	0	0	0	0	2	0
MCI score		86	69	102	105	109	99	44	57	63	71	70	63
QMCI score		3.2	3.0	3.9	4.8	4.9	5.1	2.8	2.8	2.5	3.0	2.9	2.6

		OSU							OSD						
TAXON	**MCI score**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**a**	**b**	**c**	**d**	**e**	**f**	**g**
ACARINA	5			3	2	1	1			2					
CNIDARIA															
Hydra species	3	1	1												
COLEOPTERA															
Elmidae	6														
COLLEMBOLA	6	3	15	17	15	5	7	29	1		4	3	2	1	2
CRUSTACEA															
Copepoda	5									1					
Isopoda	5	2		1	1										
Ostracoda	3							1				1			
Paracalliope fluviatilis	5														
Talitridae	5			1									1		
DIPTERA															
Aphrophila species	5	2		10	4		1	18							
Austrosimulium species	3	32	18	59	50			56							1
Chironomus species	1														
Corynoneura scutellata	2														
Empididae	3					1									
Ephydridae	4				1								1		
Eriopterini	9														
Hexatomini	5														
Limonia species	6													1	
Maoridiamesa species	3				2	1		5							
Mischoderus species	4												1		
Molophilus species	5					1		2	1						
Muscidae	3			1		1	1				3				
Orthocladiinae	2	136	165	538	433	12	53	322	6	11	37	12	12	8	19
Paralimnophila skusei	6														
Podonominae	8										1	1			
Polypedilum species	3	2	1	9	7		1	18		1	2	2	3	2	5
Psychodidae	1			7	3		1	5	3	2	6	2	1	1	4
Stratiomyidae	5														
Tanyderidae	4														
Tanypodinae	5														
Tanytarsini	3														
EPHEMEROPTERA															
Acanthophlebia species	7														
Ameletopsis perscitus	10														
Deleatidium species	8									1					
Zephlebia species	7	1													
HEMIPTERA															
Microvelia macgregori	5													1	
MEGALOPTERA															
Archichauliodes diversus	7														
MOLLUSCA															
Physa / Physella species	3			1		3	1							2	
Potamopyrgus antipodarum	4	1	1	4	1	9		14	3	31	61	24	17	17	28
Sphaeriidae	3									1					
NEMATODA	3	1	1	7	3	4	1	9	1		1	3			1
NEMERTEA	3										2	1			1
ODONATA															
Xanthocnemis zealandica	5														
OLIGOCHAETA	1	19	24	33	5		1	6	57	32	24	38	30	22	77
PLATYHELMINTHES	3	2	1	1						1	1				
PLECOPTERA															
Acroperla species	5				1	1		2							
Spaniocerca species	8			3	1			4							
Stenoperla species	10														
Zelandobius species	5														
Zelandoperla species	10											2			
TRICHOPTERA															
Hydrobiosella species	9														
Hydrobiosidae early instar	5							2							
Hydroptilidae	2	1										1			
Orthopsyche species	9		4	2	2		1	3							
Paroxyethira hendersoni	2														
Polyplectropus species	8														
Psilochorema species	8														
Number of invertebrates		203	231	697	531	39	69	496	72	83	142	90	68	55	138
Number of taxa		13	10	17	16	11	11	16	7	10	11	12	9	9	9
Number of EPT taxa		2	1	2	3	1	1	4	0	1	0	2	0	0	0
% EPT taxa		15	10	12	19	9	9	25	0	10	0	17	0	0	0
% EPT individuals		1	2	1	1	3	1	2	0	1	0	3	0	0	0
MCI score		72	74	81	84	76	75	83	63	70	67	77	67	69	58
QMCI score		2.2	2.4	2.3	2.3	3.5	2.6	2.7	1.4	2.6	2.9	2.5	2.3	2.5	1.9

4. References

Boothroyd, I.G. and Stark, J.D. 2000. Use of invertebrates in monitoring. Chapter 14 in Collier, K.J. and Winterbourn, M.J. eds. New Zealand stream invertebrates: ecology and implications for management. New Zealand Limnological Society, Christchurch. Pp. 344-373.

Stark, J.D. 1985. A macroinvertebrate community index of water quality for stony streams. Water and Soil Miscellaneous Publication 87. National Water and Soil Conservation Authority, Wellington.

Stark, J.D. 1993. Performance of the Macroinvertebrate Community Index: effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. *New Zealand Journal of Marine and Freshwater Research.* **27**: 463-478.

Stark, J.D. and Maxted, J.R. 2007. A biotic index for New Zealand's soft-bottomed streams. *New Zealand Journal of Marine and Freshwater Research*. **41**: 43-61.

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Appendix C Box plots of quarterly water quality data

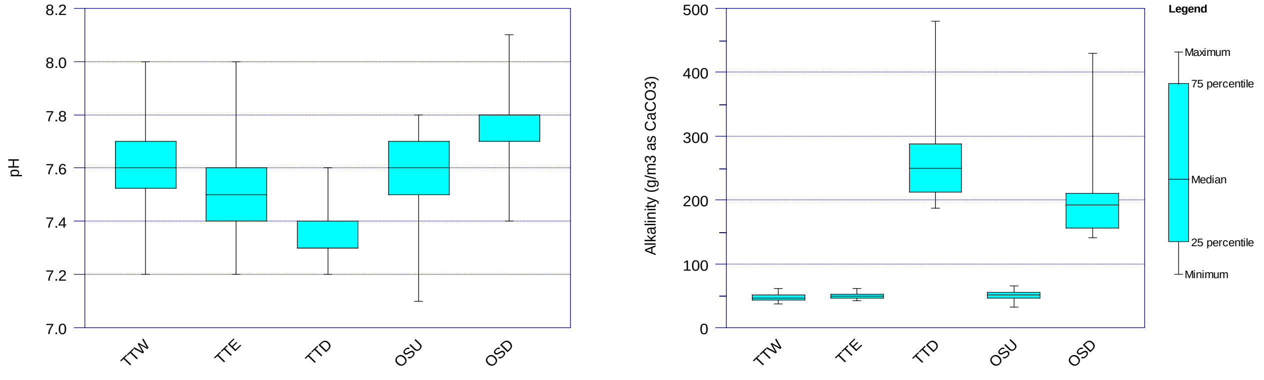

Figure C-1: Summary of pH and alkalinity by site (above) and by year at site TTD (below)

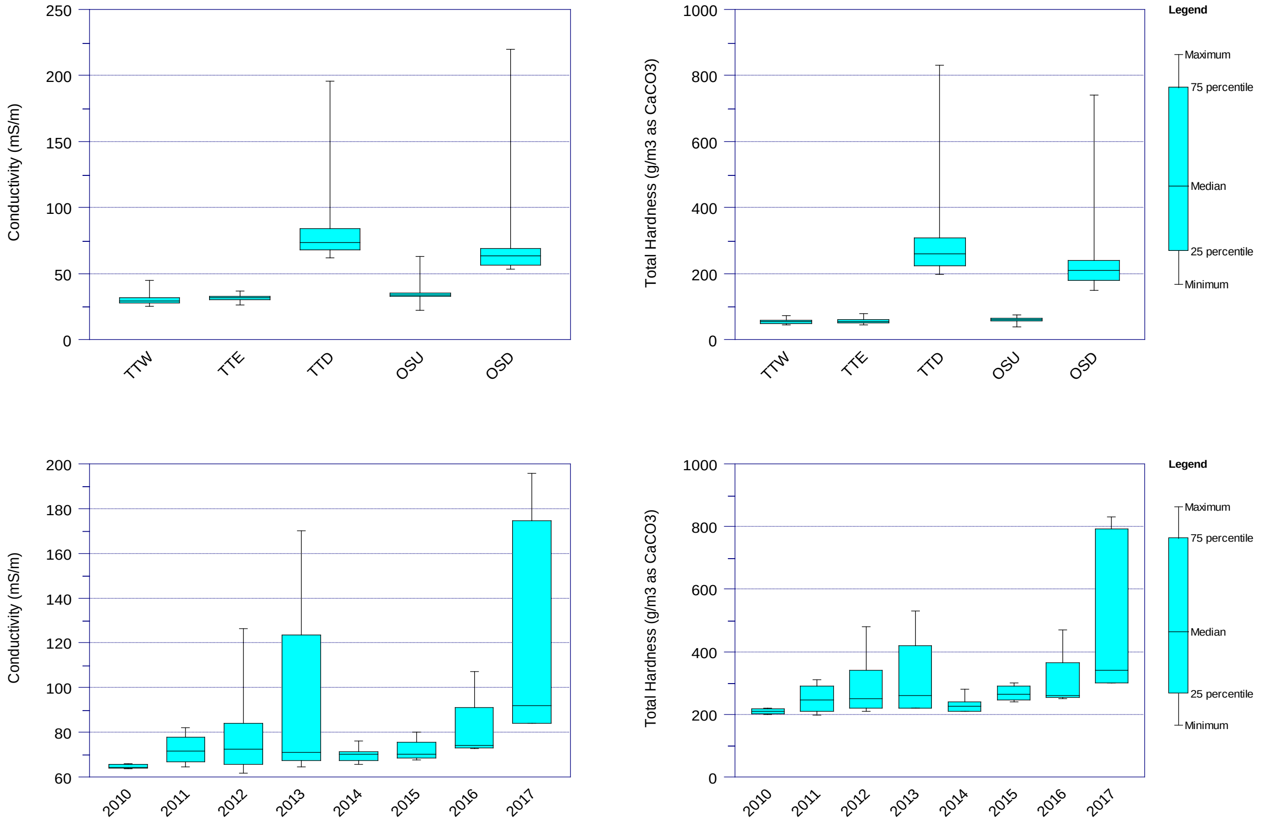

Figure C-2: Summary of conductivity hardness by site (above) and by year at TTD (below)

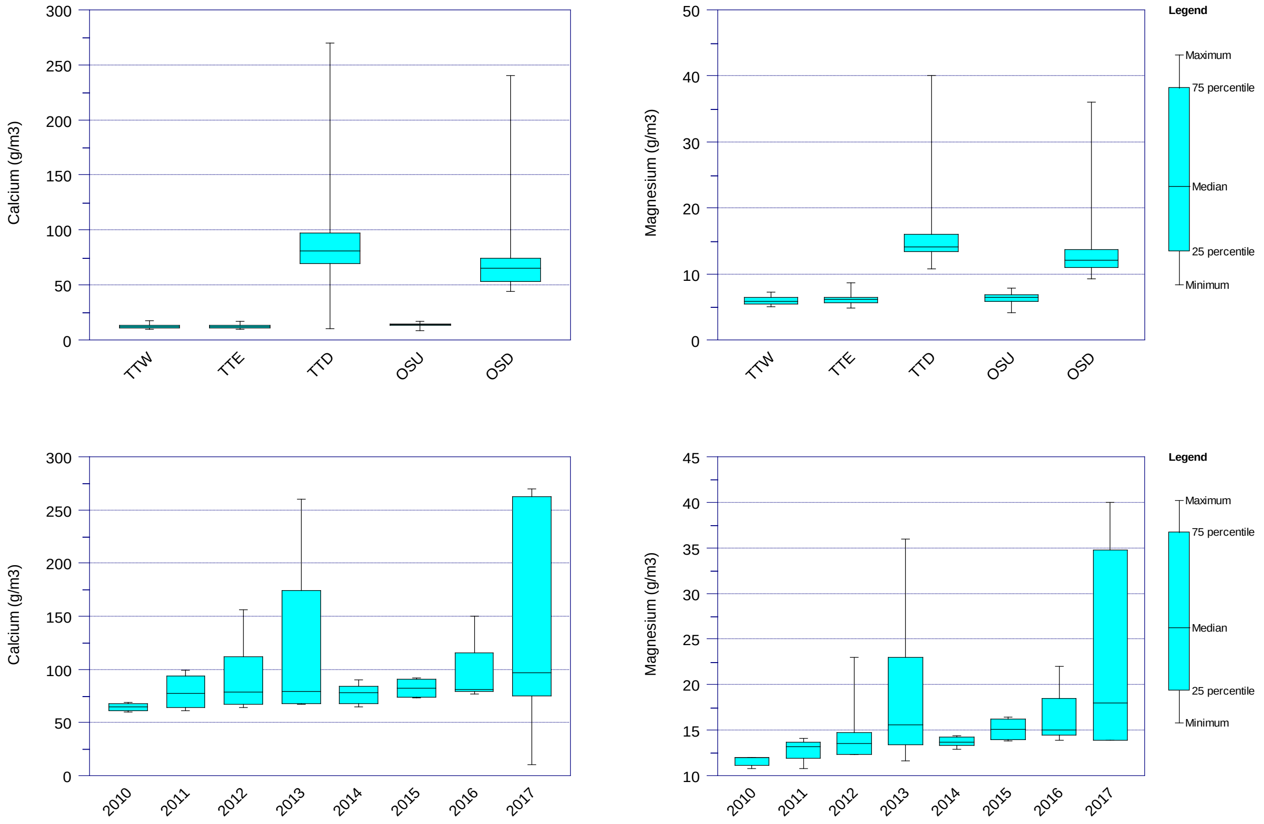

Figure C-3: Summary of calcium and magnesium by site (above) and by year at TTD (below)

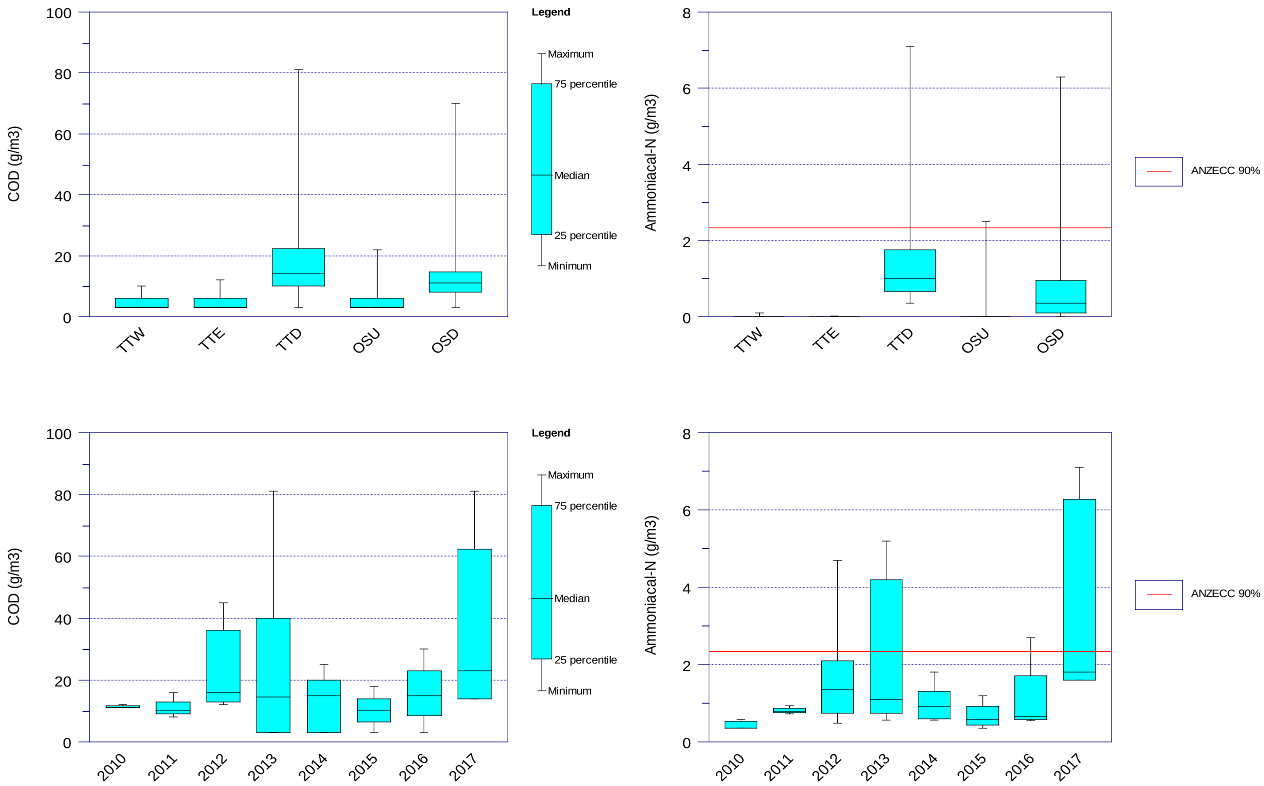

Figure C-4: Summary of COD and ammonia results by site (above) and by year at TTD (below)

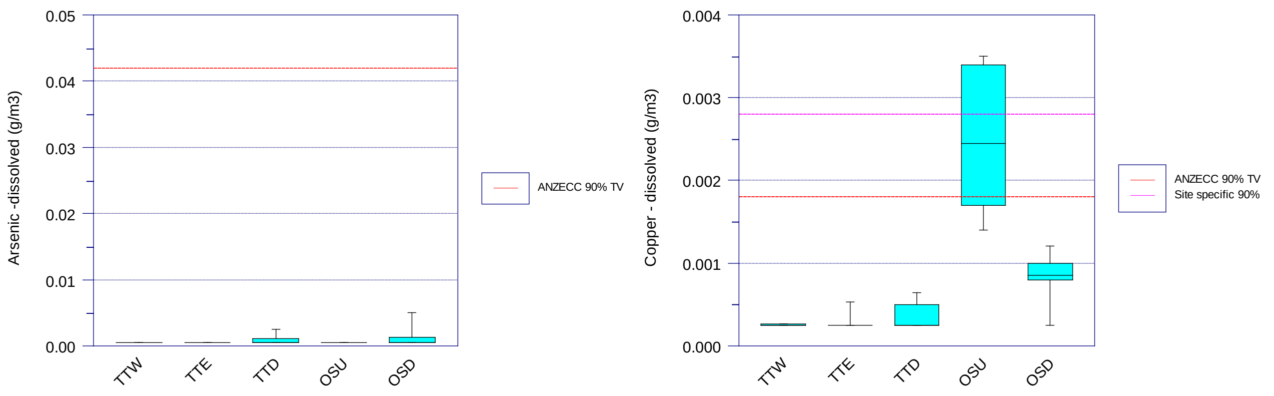

Figure C-5: Dissolved arsenic and copper by site (2010 – 2016) compared with TVs

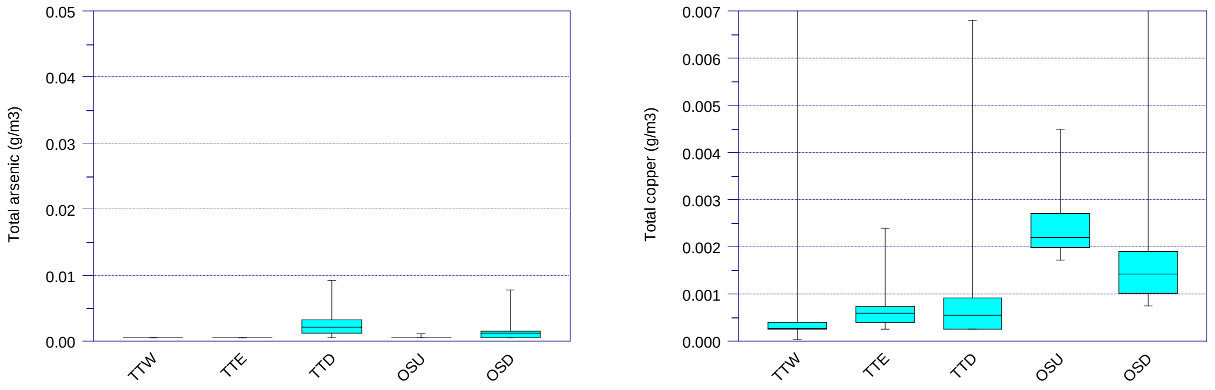

Figure C-6: Total arsenic and copper by site (2010 to 2016)

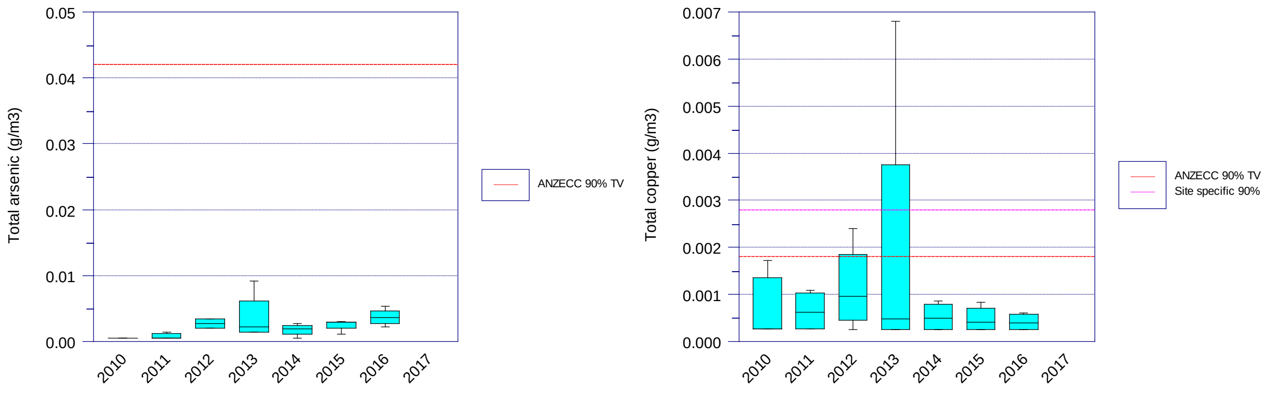

Figure C-7: Total arsenic and copper by year at site TTD

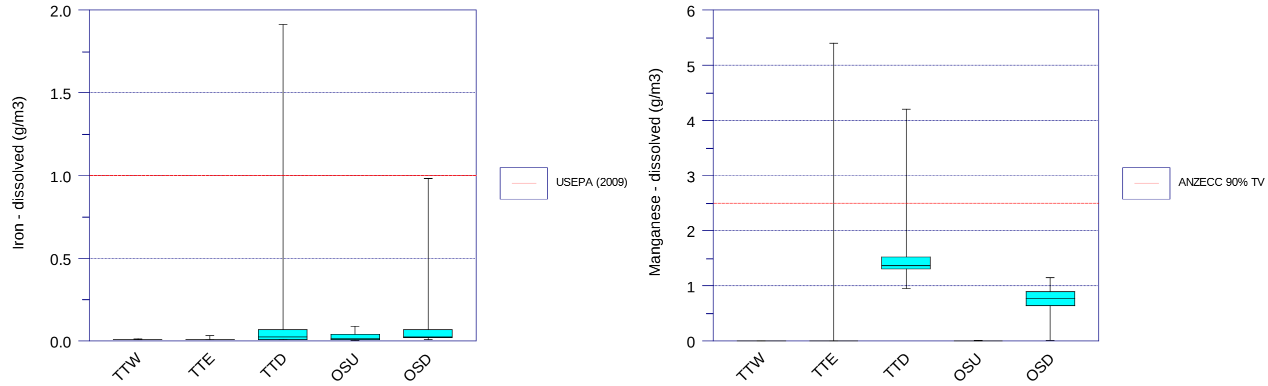

Figure C-8: Dissolved iron and manganese by site (2010 – 2016) compared with TVs

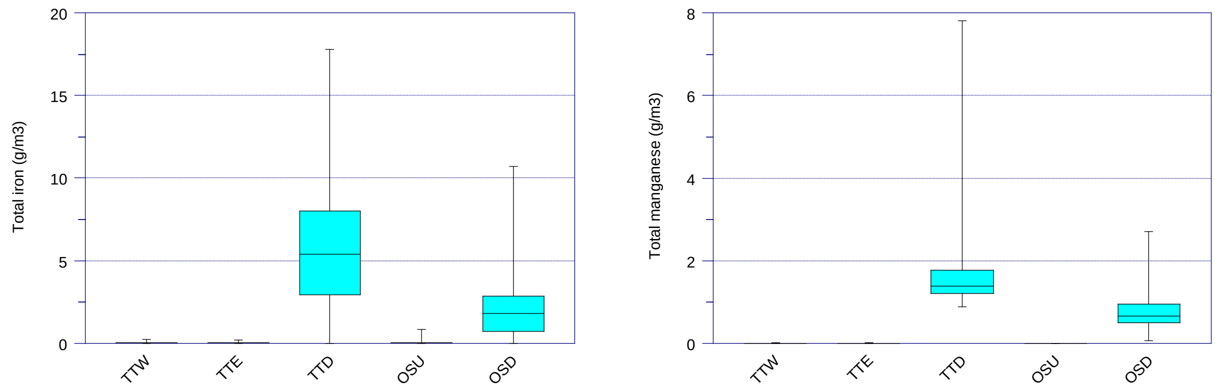

Figure C-9: Total iron and manganese by site (2010 – 2016)

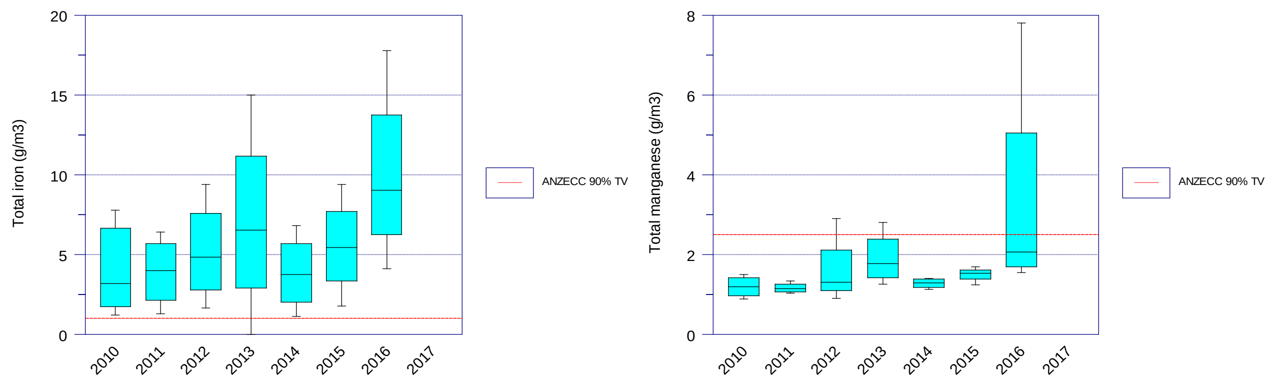

Figure C-10: Total iron and manganese by year at site TTD

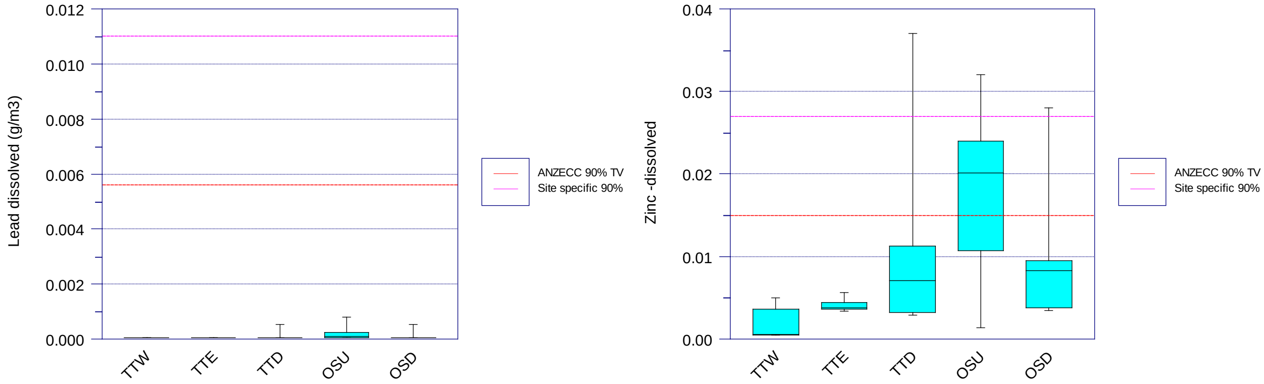

Figure C-11: Dissolved lead and zinc by site compared with TVs (2010 - 2016)

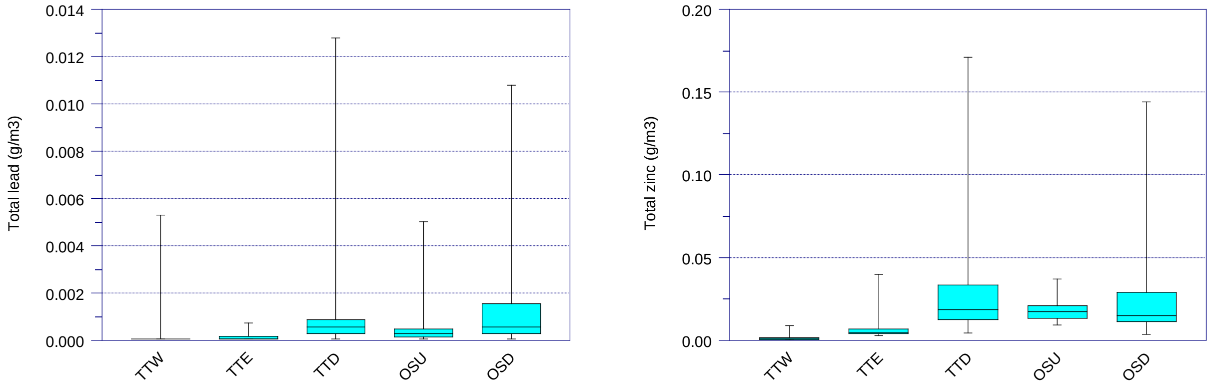

Figure C-12: Total lead and zinc by site (2010 – 2016)

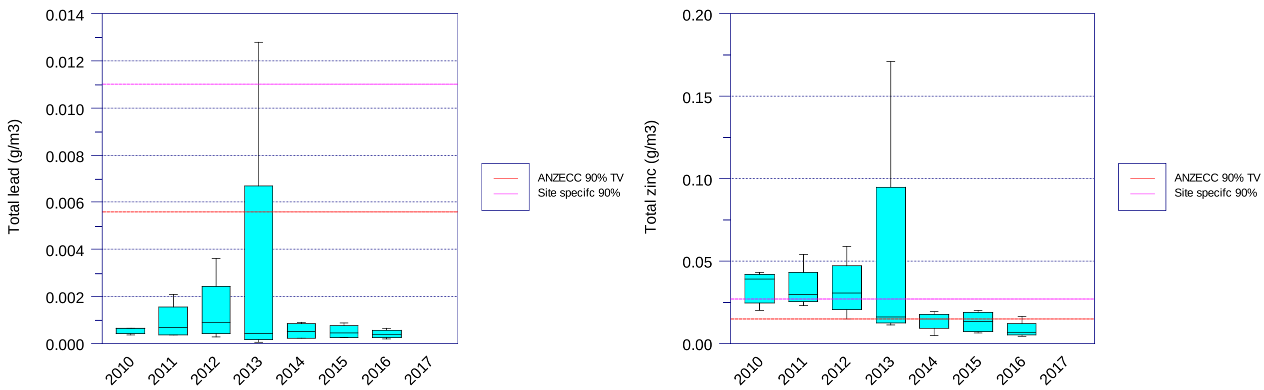

Figure C-13: Total lead and zinc by year at site TTD

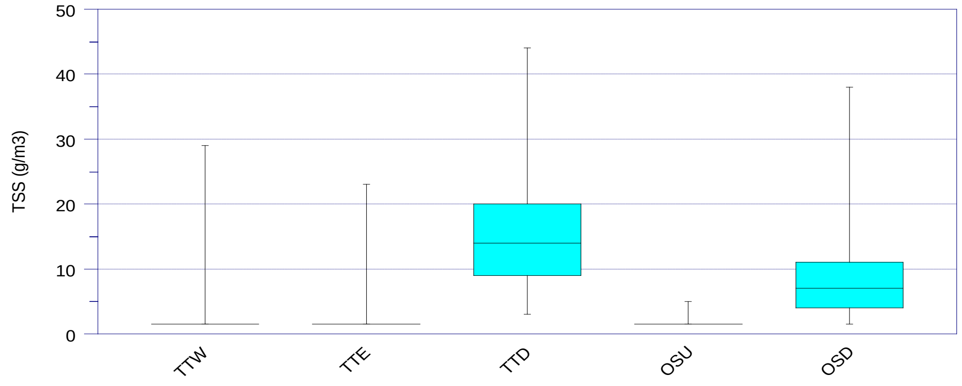

Figure C-14: Total suspended solids by site (2010 to 2016)

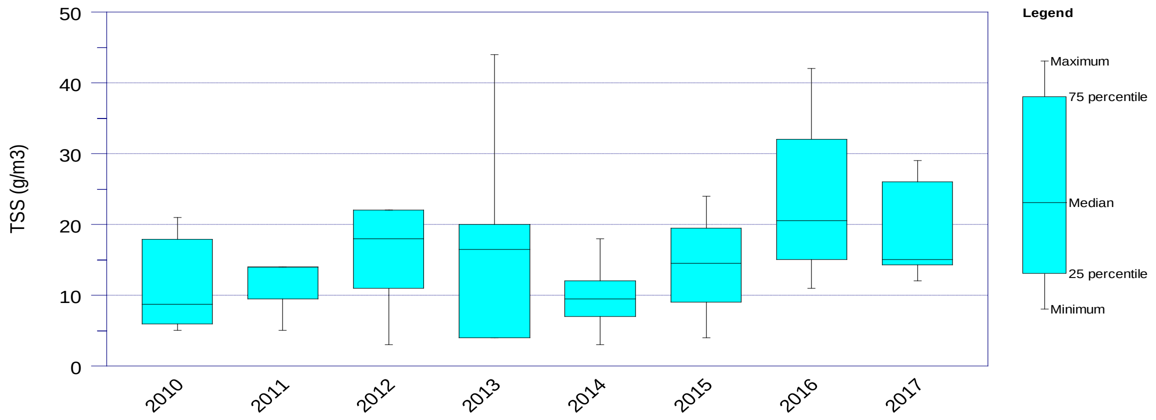

Figure C-15: Total suspended solids results by year at site TTD

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