Water quality and land use trends in the Puwera catchment

2006-2011

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1. Introduction

Dairy farming is an important industry in New Zealand. However, like most intensive land uses, it impacts on water quality and aquatic ecosystems. The on-going intensification of existing dairy farms and the expansion into new regions have increased the importance of addressing impacts on aquatic environments (MfE 2011). The industry-backed 'Dairying and Clean Streams Accord (2003)' provides a statement of intent and framework for actions to promote sustainable dairy farming in New Zealand. It focuses on reducing the impacts of dairying on New Zealand streams, rivers, lakes, ground water and wetlands water quality.

To assess whether the Accord has been successful, Regional Councils were asked to nominate and monitor a dairy catchment within their region. This report summarises water quality data from Northland's representative catchment (Puwera Catchment) over the period 2006 to 2011. This report contributes to the national collection of environmental information to enable the benefits of implementing the Clean Streams Accord to be identified over time.

2. The Puwera catchment

The Puwera catchment is approximately eight kilometres south of Whangarei and covers a land area of about nine square kilometres ($9km^2$). The River Environment Classification (REC) describes the Puwera Stream as a warm, wet, lowland, hard sedimentary, pastoral stream order 3 (MfE 2010). The Puwera stream is a tributary of the Otaika Stream which flows into the Whangarei Harbour. It is a small stream, with highly variable, seasonally dependant flow ($0\text{-}282m^3s^{-1}$). The geology of the catchment is dominated by the Northland Allochthon (Onerahi Chaos) which is a complex mix of highly sheared and fractured mudstone, siltstone and limestone. The majority of soils are strongly leached and weathered, and range from imperfectly to poorly drained.

Rainfall in the Puwera catchment is 1634 mm per year and the topography is made up of flat land in the valley bottom and steep hill country to the side. Land use is predominantly pasture with dairy covering 70%, sheep and beef 25%, and other 5%. Lifestyle blocks are a recent addition to the catchment.

There are five dairy farms in the catchment, including one that ceased supplying in 2009, with a total of about 1400 milking cows with a stock density of 1.5 milking cows per hectare. In addition, there are four dry stock farms. It is estimated that less than 10% of the stream has stock exclusion and with the exception of a few small areas of willows, riparian canopy is absent. Although there is no specific knowledge of recreational use of the Puwera Stream, it is considered to be unlikely. The stream discharges into a mangrove area of Whangarei Harbour where contact recreation is unlikely but some shell fish gathering might occur.

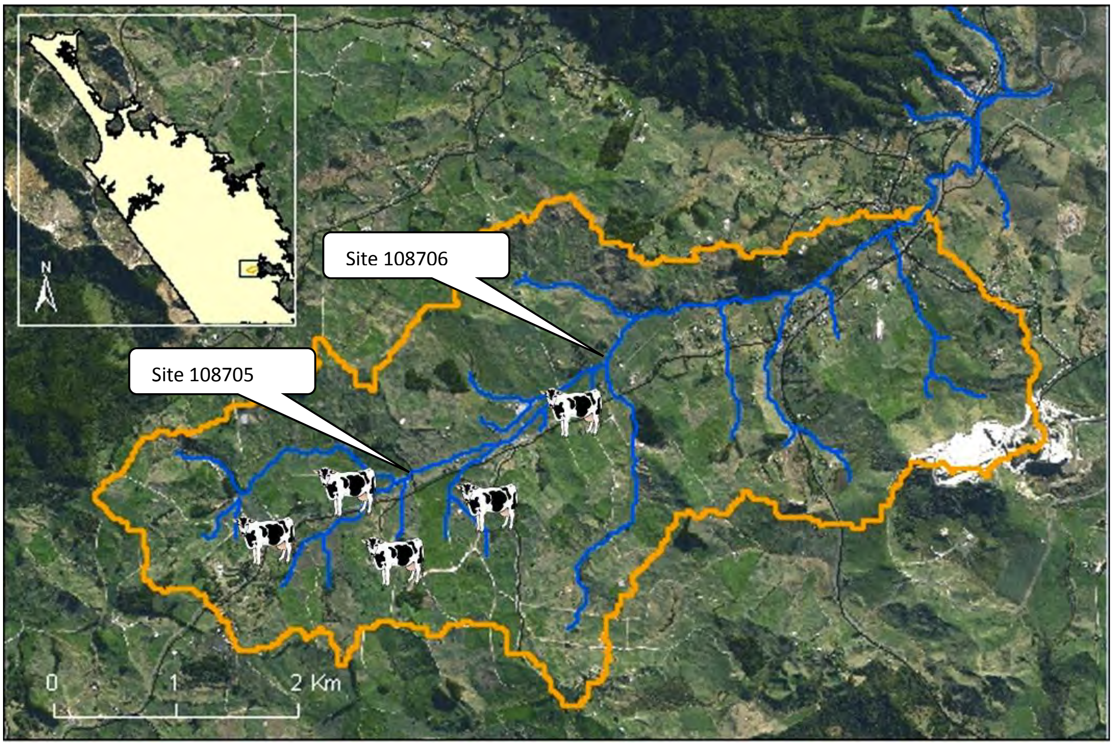


Figure 1: Puwera catchment outline (yellow). The stream network (blue) drains to the northeast with the cows representing dairy farm locations.

3. Changes in land use and farm practice

3.1 Historical land use

The Puwera River catchment was one of the earliest land development blocks in Northland. The Department of Lands and Survey (from which emerged Landcorp Farming Ltd) developed gumland from scrub and settled returned World War Two servicemen on dairy farms. The Northland Catchment Commission subsidised several soil conservation activities on farms within the catchment, in particular the control of gully erosion in acid sulphate shale rock that underlies the land. The shale rock is very acid with acid sulphates reducing the pH of water discharging from the gullies down to two or less. The mature, often podzolised soils overlying this rock have a strongly developed columnar subsoil structure. This material gullies rapidly, particularly when drains are constructed up valley bottoms on too steep a grade. Because of the low pH of the exposed material, it is very difficult to re-vegetate and so initial gully control often requires the construction of flumes, debris dams and other grade control structures. Once the gully bottom stops eroding the sides remain stable long enough to leach out the acid sulphates and allow other species to colonise the bare ground. Some of the small pine woodlots seen in the valley today occupy formerly eroding gully systems.

Some of these gullies can be five or more metres deep and extend several hundred metres down the hillsides. Large quantities of sediment are discharged, creating alluvial fans, infilling the floodplain and being channelled to the harbour. This gully erosion can often trigger of slumping in the folded and crushed allochthomous shale rock (B Cathcart, Pers Comm).

3.2 Present day land use

Present day land use includes a mixture of dairy and beef farming, lifestyle blocks, a quarry and a truck depot.

Since 2006, five dairy farms are present in the catchment including one that ceased supplying in 2009 and has only been used as a standoff area for the last three years. One farm ceased its activity in 2006 and was converted to a beef farm. Despite one farm ceasing supply, there has been no significant change in total cow numbers with an average of 1400 dairy cows in the catchment. There has also been no significant change in the total number of beef in the catchment. In addition, a few extra houses have been constructed on lifestyle blocks, but no change has been made to either the quarry site or the truck depot.

All dairy farms upgraded their effluent treatment systems within the last five years. They also have effluent land application systems which allow farmers to irrigate effluent onto paddocks when conditions are suitable, i.e. when the soil is not saturated with water which otherwise would result in land run-off and affect water quality. This practice allows the farmers to recycle nutrients and provides a cost effective and easily available fertiliser for the grass. Some of the farms may also use complementary fertilisers such as chicken manure mostly during the dry season, but this may also occur during the wetter season.

Only one farm out of the five has had non-compliance with regional rules and/or consent conditions relating to the discharge of untreated effluent to water.

Since 2006 it appears that few actions have been taken in this catchment to minimise the losses of pollutants to the stream. There is no record of any Environment Fund applications or works in the catchment. This does not include farms where farmers may have fenced on their own accord in which case it is not necessarily reported to the Council. It is estimated that stock is excluded from less than 10% of waterways.

There are several tributaries of the Puwera Stream where flow can cease altogether in summer months. This means the stream does not meet the Accord waterway criteria (i.e. size and flow) and therefore would not be included in Accord implementation works. This could have affected the extent to which landowners adopted the Accord and other best practice management actions over time. However, high flow variability is a feature of many Northland catchments. The Puwera catchment therefore (arguably) provides a typical and realistic picture of the relationship between water quality and dairying land use in the region. If future policy or accords are to be more successful in improving water quality, then they must cover ephemeral source areas as well as permanently flowing streams.

4. Methods

4.1 Monitoring Programme

A range of physicochemical and biological parameters, listed in

Table 1, were measured during the monitoring programme at two sites in the catchment:

- site 108705 located towards the head of the catchment at Keays Access Road,
- and site 108706 at the boundary of the most downstream dairy farm at Bennett's boundary (see Figure 1).

Macroinvertebrate identification was also carried out in January, July, and October 2006. Stream flow was measured monthly throughout the sampling period, i.e. July 2006 to December 2011 using pot gaugings at the downstream site 108706.

Table 1: Monitoring parameters

DETERMINANT		
Chemical	**Biological**	**Physical**
Turbidity **Total Suspended Solids** **Total Kjeldahl Nitrogen** **Nitrate and Nitrite Nitrogen** **Ammoniacal Nitrogen** **Total Phosphorous** **Dissolved Reactive Phosphorous** **pH** **Biochemical Oxygen Demand 5 day** **Dissolved Oxygen**	**E. Coli** **Faecal Coliforms** **Periphyton** **Chlorophyll a** **Quantitative Macroinvertebrate Community Index**	**Temperature** **Conductivity** **Stream Flow**

4.2 Guidelines used for compliance

Australian and New Zealand Environment and Conservation Council guidelines for fresh and marine water quality (often referred to as ANZECC guidelines (2000)) were used to assess water quality at the two sampling sites. The level of the indicator bacteria (Escherichia coli) have been used to assess water quality for recreational bathing and stock drinking water.

4.2.1 ANZECC guidelines (2000)

The results are compared to the ANZECC guidelines (2000) trigger values for the protection of aquatic ecosystems in New Zealand.

These guidelines provide default trigger values for total and dissolved nitrogen and phosphorus for assessing the risk of adverse effects in slightly disturbed ecosystems. These trigger values are based on the 80th percentile of a distribution of reference data as shown in Table 2 for lowland rivers.

Table 2: Trigger values for New Zealand lowland rivers (ANZECC 2000)

Parameter	Trigger values for lowland rivers
Dissolved oxygen (% Saturation)	98 - 105
Water clarity (m)	> 0.6
Turbidity (NTU)	< 5.6
Dissolved reactive phosphorus (mg/L)	< 0.01
Total phosphorus (mg/L)	< 0.033
Nitrate, nitrite nitrogen (mg/L)	<0.444
Ammoniacal nitrogen (mg/L)	< 0.021
Total nitrogen (mg/L)	< 0.614
pH	7.2 – 7.8

Arguably, both the macroinvertebrate and ANZECC guidelines could be considered environmentally conservative for highly modified dairy catchments. However, in the absence of more appropriate reference data for these modified systems, both guidelines still provide useful context for the data in this report.

4.2.2 Escherichia coli – bacteria

The levels of the bacteria Escherichia coli (E. coli) are used as indicator for the presence of pathogen causing bacteria, which can be a health risk for humans and stock. The levels of E. coli can be compared to the microbiological water quality guidelines for recreational users to determine whether the water is safe for recreational use. The Ministry for the Environment (MfE) guideline preconize that levels of E. coli should remain below 550 E. coli/100mL of sample (MfE 2003).

Additionally, while ANZECC guidelines do not directly mention E. coli trigger levels, it is stated that: “Drinking water for livestock should contain less than 100 E. coli/100mL of sample (median value)”.

4.3 Trend Analysis

Trend analysis was carried out using the Time Trends™ software to analyse trends and equivalence in water quality data developed by the National Institute of Water and Atmospheric research (NIWA). Results are presented in Section 5. Results for faecal coliforms and total Kjeldahl nitrogen are presented in Appendix A.

Trend analysis involves a flow adjustment of the raw data for each variable at each site, followed by trend analysis accounting for any seasonal pattern. This form of analysis has been adopted throughout New Zealand as good practice for water quality trend analysis (NIWA 2007).

Flow adjustment is necessary because most water quality variables are subject to either dilution (decreasing concentration with increasing flow) or land run-off (increasing concentration with increasing flow). Flow adjustment was performed using LOWESS (LOcally WEighted Scatterplot Smoothing), within the Time Trends™ software, with a 30% span. Every data-point in the record was then adjusted depending on the flow value.

The non-parametric trend analysis was then applied to the whole data set for each parameter at each site which takes into account the seasonal variability in the data.

This analysis is based on two key measures:

- The seasonal Kendall slope estimator (SKSE) which measures the magnitude of the trend, and
- The associated seasonal Kendall trend test which determines whether the trend is statistically significant.

Statistically significant trends were determined using a p-value <0.05 or <0.01. If a p-value is less than 0.05 (or 0.01), then there is a less than 5% (or 1%) chance of finding a trend when there is not one. In the data presented below p-value are highlighted if the value is less than 0.05 (statistically significant) or less than 0.01 (statistically very significant).

The slope of the trend Seasonal Kendall Sen Slope Estimator (SKSE) is expressed in units of change per year. A positive SKSE indicates a positive (increasing) trend, and a negative SKSE indicates a negative (decreasing) trend. The SKSE allows comparisons in the slope between parameters and sites and is used in the tables below.

It is important to note that the terms 'significant' and 'very significant' as used in this report primarily refer to the certainty of a trend rather than to the magnitude of that trend or to its potential ecological consequences.

Because of the high flow variability of the waterways in the Puwera catchment – especially upstream of the Puwera stream where site 108705 is located – trend analysis was carried out only for the downstream site 108706 in order to exclude periods when the upstream site 108705 had limited or no flow.

5. Trends in water quality and ecosystem health

5.1 Nitrogen

Nitrogen is needed by aquatic plants for growth and occurs naturally in water bodies. Man-made sources of nitrogen include fertiliser runoff, urine from farm animals, and treated wastewater discharges. If nitrogen enters rivers it can result in pollution which can lead to extensive algal growths, which then impact on the aquatic ecosystem. The recommended guideline value for the protection of aquatic ecosystems is that nitrate and nitrite nitrogen (NNN) concentration should remain below 0.444mg/L, and ammoniacal nitrogen (NH_4) below 0.021mg/L (ANZECC 2000).

Nitrogen in the rivers and streams of the Puwera catchment was measured in the form of: Nitrate (NO_3^-), Nitrite (NO_2^-), and Total Kjeldahl Nitrogen (TKN) which consists of organic nitrogen, ammonia (NH_3) and ammonium (NH_4^+). The following results are presented using the sum of nitrate and nitrite nitrogen (NNN) in Table 3, Figure 2 and Figure 3; and ammoniacal nitrogen (NH_4) in Table 5, Figure 4 and Figure 5. Note that for laboratory analysis purposes, Total Kjeldahl Nitrogen (TKN) is a test performed that is made up of both organic nitrogen and ammonia with results in Appendix A.

While both sites had reasonable compliance rates for NNN, especially in 2010-11, levels of NH_4 were frequently above recommended guidelines. Nitrogen concentrations were higher in spring which coincides with calving and increased rainfall. The proportionally higher concentration from the upstream site (108705) may be due to the ephemeral nature of the stream with less flow to dilute contaminants.

Nitrate and nitrite nitrogen (NNN)

Table 3: Median NNN concentration, range and percent compliance with ANZECC guidelines

Nitrate, Nitrite, Nitrogen (mg/L)												
YEAR	**2006**		**2007**		**2008**		**2009**		**2010**		**2011**	
SITE	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**
Samp.sz	**13**	**13**	**19**	**19**	**8**	**8**	**12**	**12**	**8**	**8**	**11**	**11**
Med	**0.411**	**0.348**	**0.260**	**0.128**	**0.304**	**0.165**	**0.259**	**0.162**	**0.144**	**0.046**	**0.110**	**0.196**
Max	**1.440**	**0.651**	**1.162**	**0.946**	**0.832**	**0.621**	**0.560**	**0.590**	**0.250**	**0.280**	**0.300**	**1.000**
Min	**0.072**	**0.017**	**0.001**	**0.001**	**0.005**	**0.037**	**0.018**	**0.033**	**0.006**	**0.001**	**0.001**	**0.008**
Within g-lines	**7**	**9**	**15**	**16**	**6**	**7**	**8**	**11**	**8**	**8**	**11**	**10**
% com-pliance	**53.8**	**69.2**	**100**	**84.2**	**75**	**87.5**	**66.7**	**91.7**	**100**	**100**	**100**	**90.9**

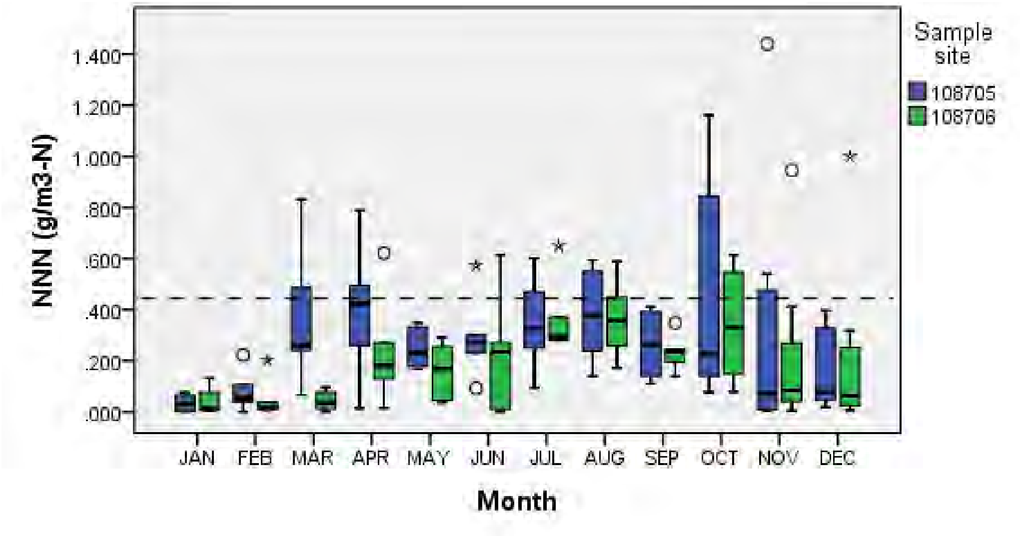


Figure 2: Seasonal boxplot of nitrate and nitrite nitrogen. Dashed line = ANZECC guideline

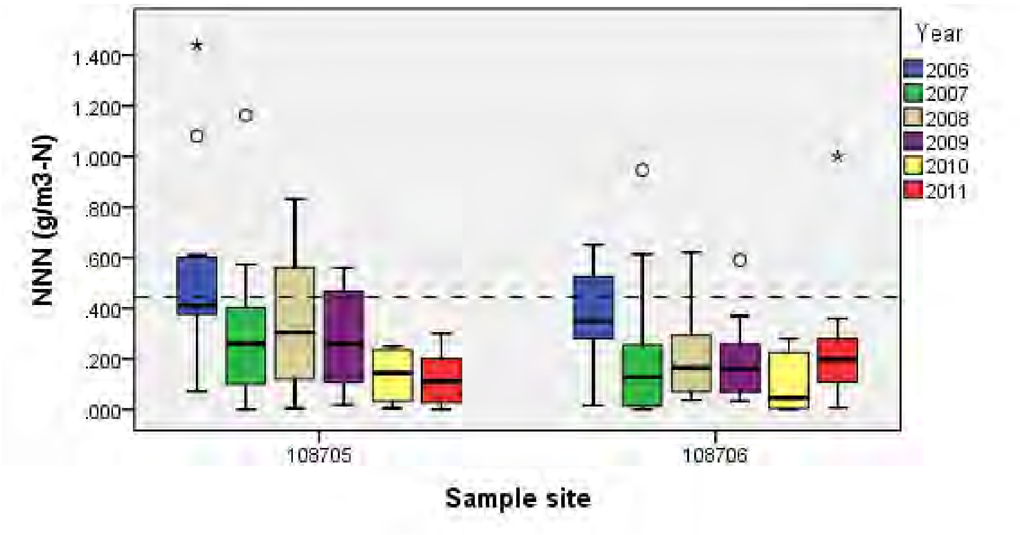


Figure 3: Annual boxplot of nitrate and nitrite nitrogen. Dashed line = ANZECC guideline

Trend analysis showed no significant trend at site 108706 for NNN with a p-value of 0.64 as shown in Table 4 below.

Table 4: Seasonal Kendall trend test results for NNN at site 108706

NNN	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	0.01	-6	112.67	-0.5	0.64	-0.01	-0.03	0.01

Ammoniacal nitrogen (NH_4)

Table 5: Median NH_4 concentration, range and percent compliance with ANZECC guidelines

	Ammoniacal nitrogen (mg/L)											
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	19	19	8	8	12	12	8	8	11	11
Med	0.180	0.100	0.050	0.020	0.050	0.070	0.115	0.046	0.029	0.032	0.022	0.094
Max	1.820	0.380	22.900	1.100	1.400	0.500	9.270	0.320	0.290	0.360	0.131	0.503
Min	0.010	0.010	0.005	0.005	0.005	0.010	0.005	0.010	0.005	0.005	0.005	0.005
Within g-lines	2	3	4	11	4	2	2	3	3	1	4	2
% compliance	15.4	23.1	21.1	57.9	50	25	16.7	25	37.5	12.5	36.4	18.2

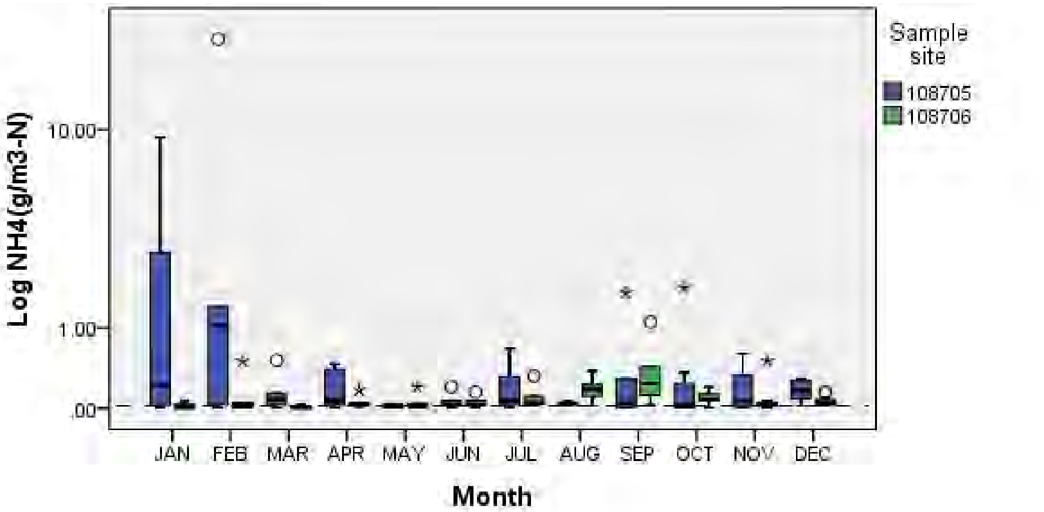
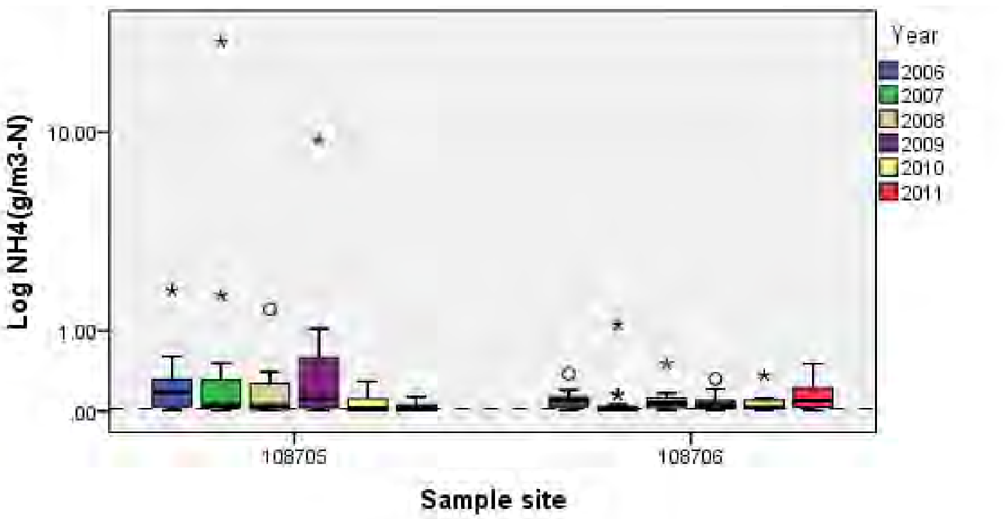


Figure 4: Seasonal boxplot of ammoniacal nitrogen. Dashed line = ANZECC guideline



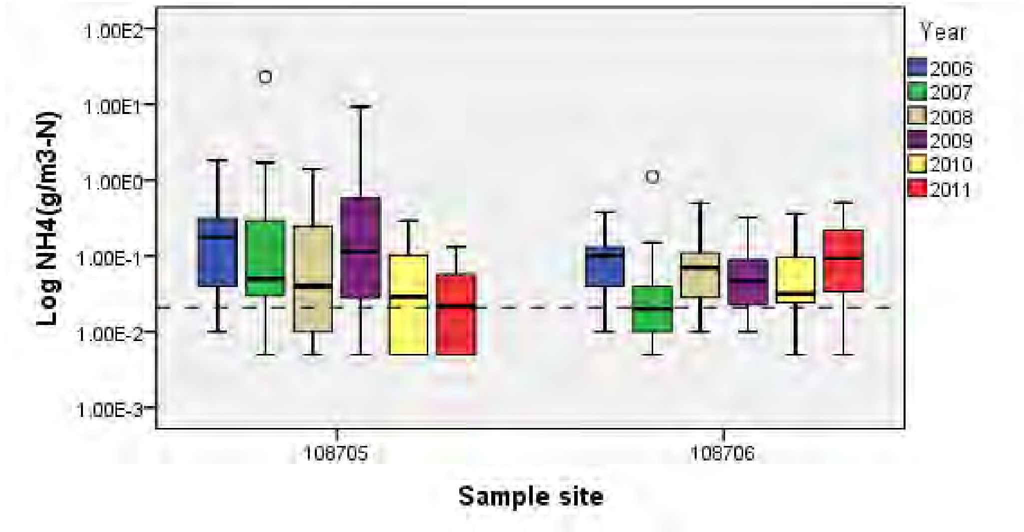


Figure 5: Annual boxplot of ammoniacal nitrogen. Figures 5A and 5B have different logged scales. Dashed line = ANZECC guideline.

Trend analysis showed no significant trend at site 108706 for NH_4 with a p-value of 0.78 as shown in Table 6 below.

Table 6: Seasonal Kendall trend test results for NH_4 at site 108706

NH4	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	0	4	112.67	0.28	0.78	0	0	0.01

5.2 Phosphorus

Like nitrogen, phosphorus is required by plants and algae for growth and occurs naturally in water bodies. Man-made sources include fertiliser runoff, wastewater discharges and runoff after land clearance. If phosphorus enters waterways it can result in pollution which can lead to extensive algal growth which can impact the aquatic ecosystem. The recommended guideline for protection of aquatic ecosystems is that total phosphorus (TP) should remain below 0.033mg/L (ANZECC 2000).

Overall, streams within the Puwera catchment had very poor rates of compliance with guidelines. Results are presented in Table 7, Figure 6 and Figure 7 below. The poor TP compliance rate was partly due to Northland's phosphorus rich sandstone and mudstone catchment geology which provides a high background level of phosphorus to streams naturally. For example, only two of Northland's monitored rivers (Waipapa River and Waipapa Stream) had 100% compliance with the total phosphorus guideline in the 2009-2010 financial year (NRC 2011).

Like nitrogen, TP was higher in spring which coincides with calving and increased rainfall. The proportionally higher concentration from the upstream site (108705) was probably due to the ephemeral nature of the stream with less flow to dilute contaminants.

Total phosphorus (TP)

Table 7: Median TP concentration, range and percent compliance with ANZECC guidelines

Total phosphorus (mg/L)												
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	19	19	8	8	12	12	8	8	11	11
Med	0.166	0.110	0.364	0.110	0.156	0.083	0.239	0.160	0.163	0.113	0.065	0.066
Max	0.949	0.209	10.100	0.290	0.580	0.253	4.570	0.867	0.88	1.320	0.340	0.210
Min	0.076	0.058	0.088	0.038	0.052	0.060	0.044	0.067	0.033	0.019	0.018	0.051
Within g-lines	0	0	0	0	0	0	0	0	0	2	1	0
% compliance	0	0	0	0	0	0	0	0	0	25	9.1	0

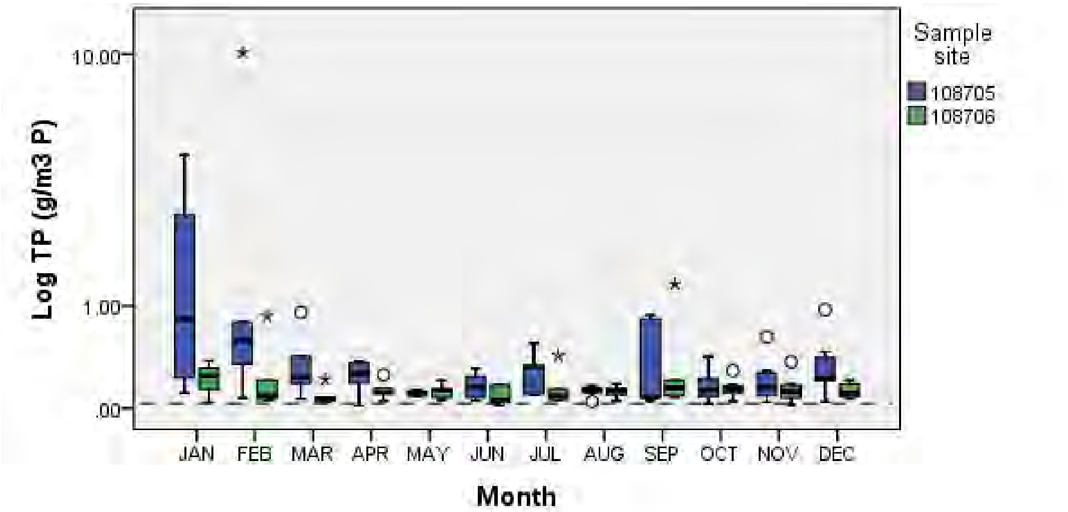


Figure 6: Seasonal boxplot of total phosphorus. Dashed line = ANZECC guideline

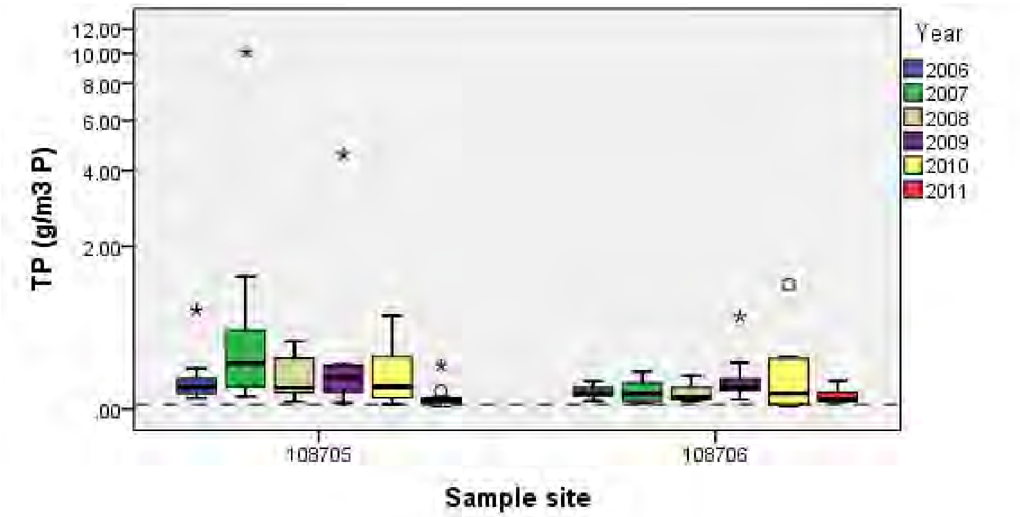


Figure 7: Annual boxplot of total phosphorus. Dashed line = ANZECC guideline

Trend analysis showed no significant trend at site 108706 for TP with a p-value of 0.18 as shown in Table 8 below.

Table 8: Seasonal Kendall trend test results for TP at site 108706

TP	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	0	-15	107.67	-1.4	0.18	-0.02	-0.02	-0.01

Dissolved reactive phosphorus (DRP)

Similarly to TP, DRP concentration was proportionally higher at the upstream site (108705); again probably due to the ephemeral nature of the stream with less flow to dilute contaminants. Results for DRP are presented in Table 9, Figure 8 and Figure 9 below.

Table 9: Median DRP concentration, range and percent compliance with ANZECC guidelines

Dissolved reactive phosphorus (mg/L)												
YEAR	**2006**		**2007**		**2008**		**2009**		**2010**		**2011**	
SITE	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**
Samp.sz	**13**	**13**	**19**	**19**	**8**	**8**	**12**	**12**	**8**	**8**	**11**	**11**
Med	**0.082**	**0.043**	**0.124**	**0.056**	**0.130**	**0.071**	**0.125**	**0.071**	**0.048**	**0.029**	**0.018**	**0.023**
Max	**0.194**	**0.091**	**5.120**	**0.149**	**0.300**	**0.163**	**2.305**	**0.240**	**0.230**	**0.520**	**0.104**	**0.112**
Min	**0.025**	**0.007**	**0.040**	**0.010**	**0.043**	**0.026**	**0.032**	**0.015**	**0.010**	**0.002**	**0.003**	**0.013**
Within g-lines	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**3**	**0**
% com-pliance	**0**	**7.7**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**25**	**27.3**	**0**

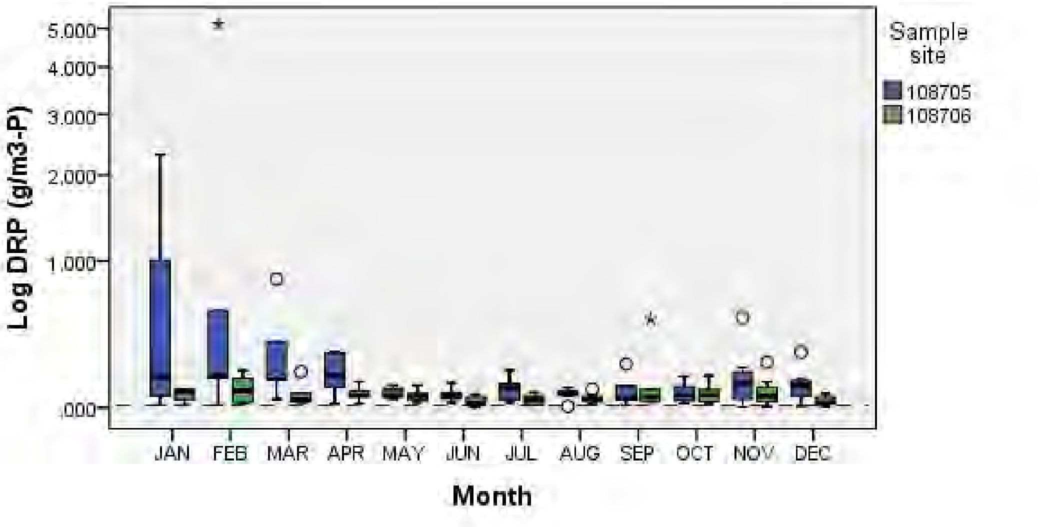


Figure 8: Seasonal boxplot of dissolved reactive phosphorus. Dashed line = ANZECC guideline

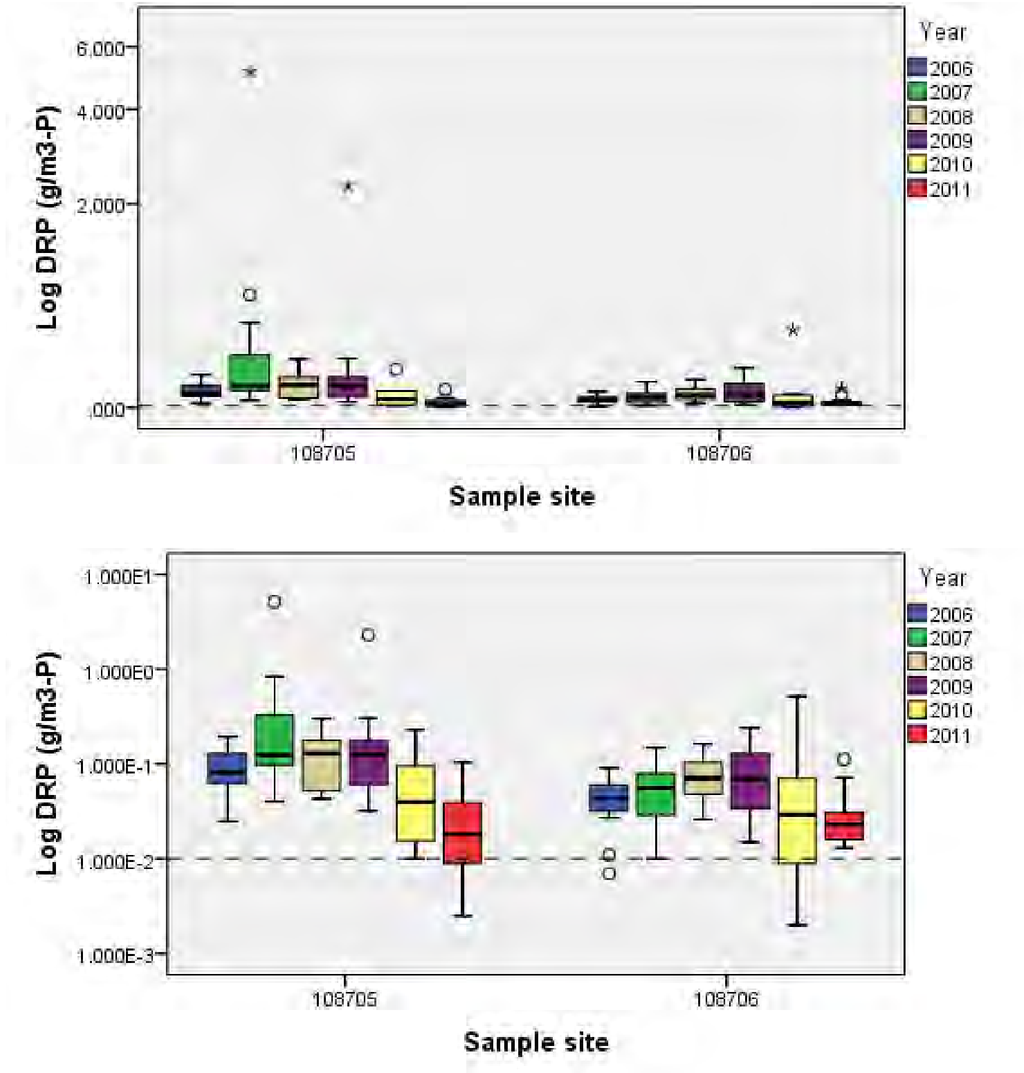


Figure 9: Annual boxplot of dissolved reactive phosphorus. Figures 9A and 9B have different logged scales. Dashed line = ANZECC guideline.

Trend analysis showed no significant trend at site 108706 for DRP with a p-value of 0.07 as shown in Table 10 below.

Table 10: Seasonal Kendall trend test results for DRP at site 108706

DRP	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	0	-20	112.67	-1.8	0.07	-0.01	-0.01	0

5.3 Escherichia coli – bacteria

Low levels of bacteria can be present in freshwater bodies as a result of natural processes such as plant decay. However, land-use practices and human activity can increase the levels of bacteria in freshwater bodies. The bacteria Escherichia coli (E. coli) is used to indicate faecal pollution and scientific studies have shown that where E. coli is present, we can assume there are pathogens in the water (MfE 2002).

Water that has been contaminated by human or animal faeces may contain a range of disease causing micro-organisms such as viruses, bacteria, and protozoa. These organisms may pose a health hazard when the water is used for recreational activities.

The bathing guideline value is 550 E. coli/100mL of sample (MfE, MoH 2003). If concentrations of E. coli are greater, it may pose health risks for people swimming in the water. While the ANZECC guidelines do not directly mention E. coli trigger levels, section 9.3.3.2 states that: "Drinking water for livestock should contain less than 100 thermo tolerant coliforms/100 mL of sample (median value)."

Bacteria levels appeared to be improving since monitoring began with compliance rates in 2006 increasing from 53.8% to 81.8% in 2011 for site 108705; and from 38.5% in 2006 to 90.9% in 2011 for site 108706 as shown in Table 11. However, E. coli levels were still regularly above the recommended level for stock drinking water as shown in Table 12. Results are represented in Figure 10 and Figure 11.

Table 11: Median E. coli concentration, range and percent compliance with MfE guidelines

E. coli (MPN[1]/100mL) - Bathing guideline												
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	19	19	8	8	12	12	8	8	11	11
Med	461	605	393	512	199	313	140	374	260	485	109	145
Max	1986	2098	24192	15531	2046	1296	4106	6867	41060	54750	3076	1376
Min	41	54	5	86	31	110	20	63	109	52	20	41
Within g-lines	7	5	12	10	5	6	10	9	5	5	9	10
% com-pliance	53.8	38.5	63.2	52.6	62.5	75	83.3	75	62.5	62.5	81.8	90.9

Table 12: Median E. coli concentration, range and percent compliance with ANZECC guidelines

E. coli (MPN/100mL) – Stock drinking water guideline												
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	19	19	8	8	12	12	8	8	11	11
Med	461	605	393	512	199	313	140	374	260	485	109	145
Max	1986	2098	24192	15531	2046	1296	4106	6867	41060	54750	3076	1376
Min	41	54	5	86	31	110	20	63	109	52	20	41
Within g-lines	2	1	4	2	1	0	3	1	0	1	5	2
% com-pliance	15.4	7.7	21.1	10.5	12.5	0	25	8.3	0	12.5	45.5	18.2

[1] MPN: Most Probable Number of E. coli per 100mL of sample.

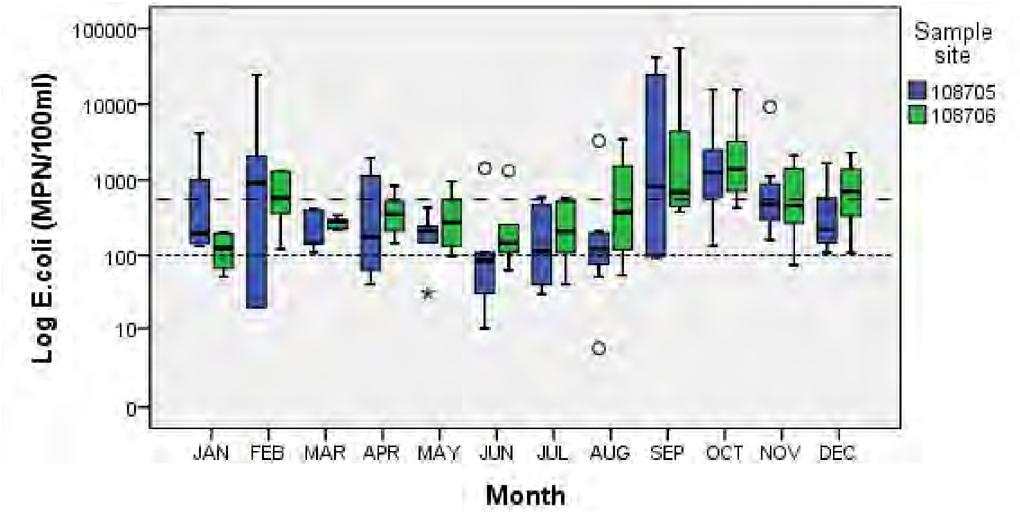


Figure 10: Seasonal boxplot of E. coli. Dashed lines = ANZECC guideline (long dash) and MfE guideline (short dash)

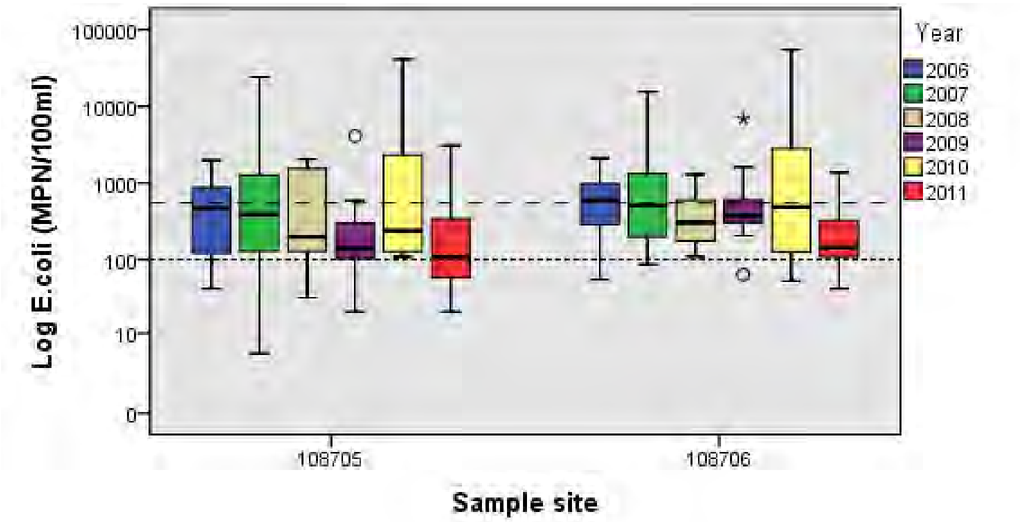


Figure 11: Annual boxplot of E. coli. Dashed line = ANZECC guideline (long dash) and MfE guideline (short dash)

Trend analysis showed a very significant trend at site 108706 for E. coli with a p-value of 0.01. E. coli concentration showed a meaningful decreasing trend with a slope value of -126.89 units of change per year as shown in Table 13 below. This means that levels of E. coli were decreasing during the sampling period, i.e. nutrient enrichment of the stream was declining.

Table 13: Seasonal Kendall trend test results for E. coli at site 108706

ECOLI	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	-157.09	-28	112.67	-2.5	0.01	-126.89	-172.64	-56.63

5.4 Suspended sediment and turbidity

Water turbidity measures how clear the water is. Turbidity quantifies the degree to which light travelling through water is scattered by the suspended particles present - the greater the amount of suspended material, the greater the light scattering and the higher the turbidity. The light-scattering particles can be both organic (e.g. algae and other plant or animal debris) or inorganic (e.g. fine silts or clays). Turbid water can compromise the river's suitability for swimming and also impact on river ecosystems by reducing visibility for predators, e.g. wading birds or fish, and by reducing the light available for aquatic plants.

Turbid water usually indicates that there are high amounts of sediment in the water. Sediments range in size from fine clays, silt and sand particles up to gravels. In a water quality context the fine clays and silts are of greatest concern. These sediments settle to the stream bed and can smother important habitat or irritate the gills of invertebrates and fish. Sediment in the water column is usually referred to as suspended sediment (SS), and measured as a concentration in mg/L.

Sediment may also carry other pollutants into water bodies. Nutrients and toxic chemicals such as heavy metals can attach to sediment and get carried into surface waters where they can settle with the sediment, or detach and become soluble in the water column. Rain washes silt and other soil particles off all surfaces, but particularly those where the vegetative cover has been disturbed. Consequently, soil erosion and activities such as earthworks, vegetation clearance, and cultivation can result in sediment movement into surface water, particularly after heavy rainfall. Stock trampling in the bed of a stream or trampling the margins and banks can also release large amounts of sediment into the water.

The turbidity guideline value for ecosystem protection is that turbidity should remain below 5.6 NTU[2] (ANZECC 2000). There are no ANZECC guidelines for SS. Both sites on the Puwera Stream frequently had turbidity levels above recommended guidelines. Peaks in SS mirrored peaks in turbidity suggesting the majority of particles were inorganic. Winter and spring typically had higher levels although the summer months also had peaks – which might have been related to summer storms. Compliance rates varied between 15% and 75% throughout the record as shown in Table 14 and represented in Figure 12 and Figure 13.

Turbidity (TURB)

Table 14: Median turbidity concentration, range and percent compliance with ANZECC guidelines

Turbidity (NTU)												
YEAR	**2006**		**2007**		**2008**		**2009**		**2010**		**2011**	
SITE	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**
Samp.sz	13	13	19	19	8	8	12	12	8	8	11	11
Med	6.2	8.4	6.2	6.9	3.85	5.35	4.4	7.35	6.9	8.25	4.25	6.45
Max	20	13.8	79	26	20.5	12	47	21	200	200	14.8	17.9
Min	2.4	4.9	0.7	1	1	2.2	2.2	4.4	1	3.5	1	2.8
Within g-lines	6	2	9	8	6	4	7	5	3	3	5	3
% com-pliance	46.2	15.4	47.4	42.1	75	50	58.3	41.7	37.5	37.5	45.5	27.3

[2] NTU: Nephelometric Turbidity Units

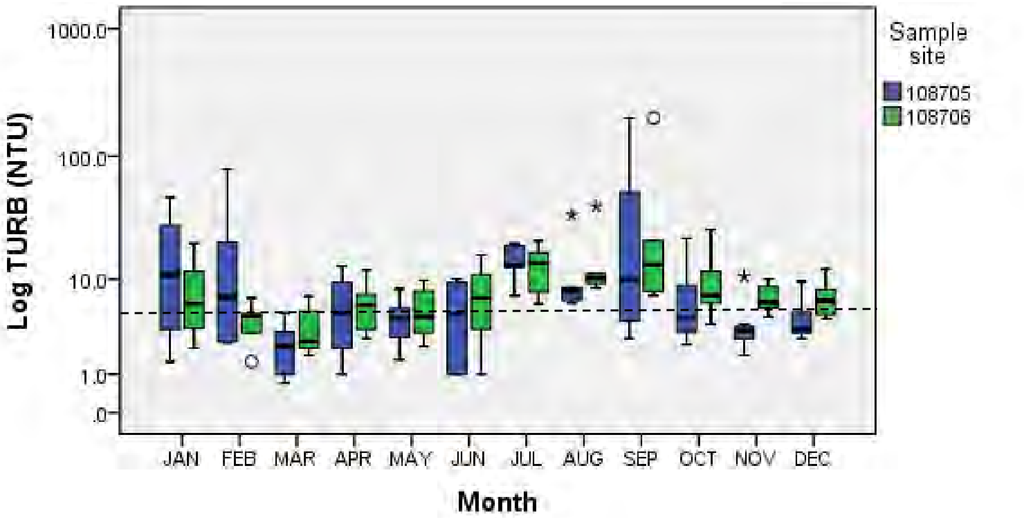


Figure 12: Seasonal boxplot of turbidity. Dashed lines = ANZECC guideline

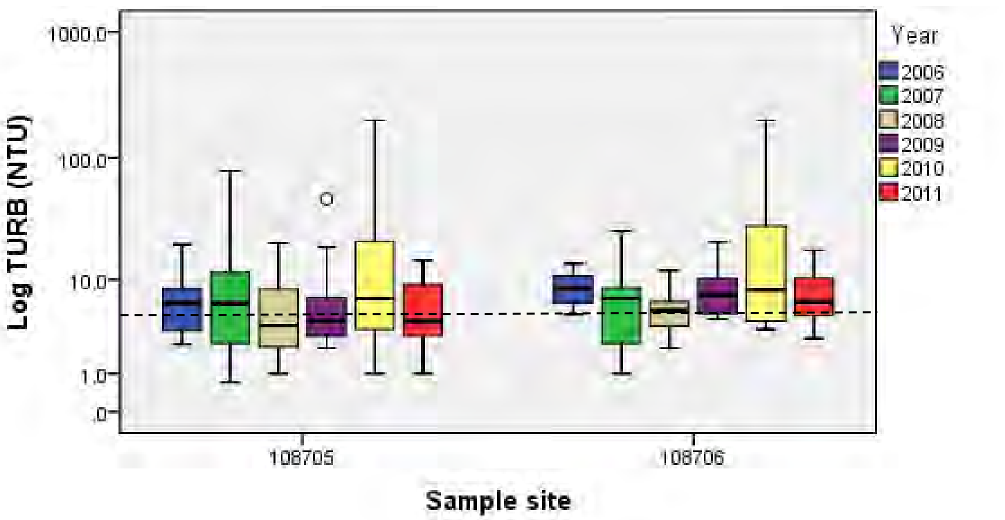


Figure 13: Annual boxplot of turbidity. Dashed line = ANZECC guideline

Trend analysis showed no significant trend at site 108706 for TURB with a p-value of 0.31 as shown in Table 15 below.

Table 15: Seasonal Kendall trend test results for TURB at site 108706

TURB	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	-0.13	-11	97.67	-1	0.31	-0.24	-0.53	0.34

Suspended sediment (SS)

Table 16: Median suspended sediment concentration and range

Suspended sediment (mg/L)												
YEAR	**2006**		**2007**		**2008**		**2009**		**2010**		**2011**	
SITE	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**
Samp.sz	**13**	**13**	**19**	**19**	**8**	**8**	**12**	**12**	**8**	**8**	**11**	**11**
Med	**4**	**5**	**3**	**3**	**2.5**	**3**	**1.5**	**3**	**5**	**10.5**	**4**	**4**
Max	**8**	**71**	**105**	**20**	**24**	**7**	**46**	**11**	**215**	**224**	**8**	**10**
Min	**1**	**3**	**0.5**	**1**	**1**	**2**	**0.5**	**1**	**0.5**	**2**	**0.5**	**2**

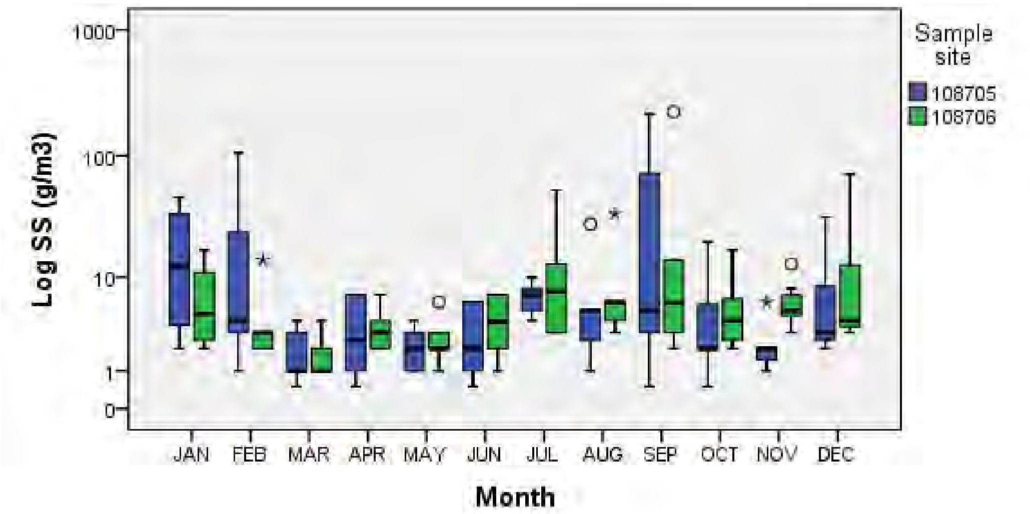


Figure 14: Seasonal boxplot of suspended sediment.

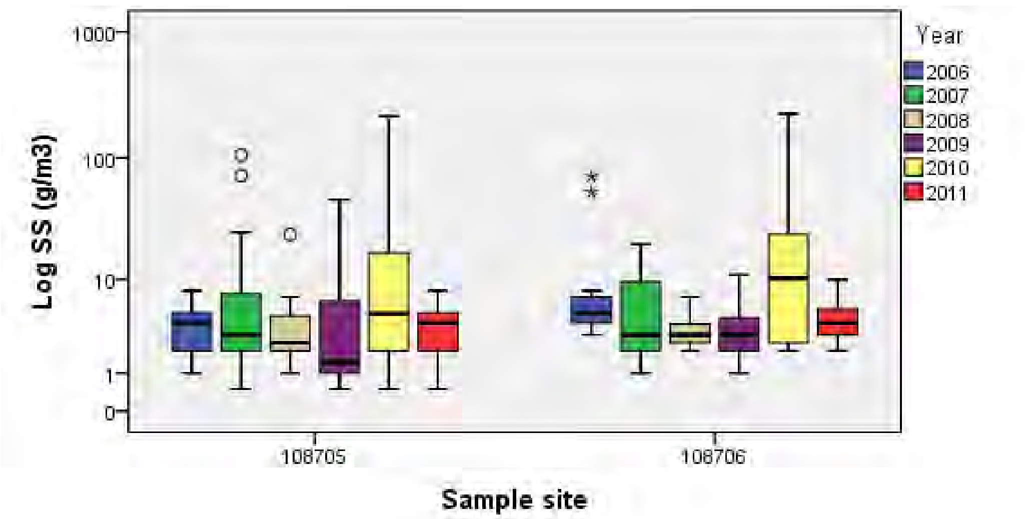


Figure 15: Annual boxplot of suspended sediment.

Trend analysis showed no significant trend at site 108706 for SS with a p-value of 0.78 as shown in Table 17 below.

Table 17: Seasonal Kendall trend test results for SS at site 108706

SS	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	-0.25	-4	112.67	-0.3	0.78	0	-0.49	0.47

5.5 Dissolved oxygen

Dissolved oxygen (DO) measures the amount of oxygen that is dissolved in water and is an indicator of the health of freshwater ecosystems. Oxygen saturation is important in rivers and streams to sustain animals living in water such as fish, invertebrates and other aquatic life that requires DO to breathe. When dissolved oxygen levels are depleted, aquatic animals can become stressed and die. Oxygen depletion is commonly caused by organic pollutants breaking down in waterways via anaerobic bacterial reaction, elevated water temperatures or night-time respiration by dense algal blooms in nutrient-rich waters.

Conversely, too much oxygen in the water (super-saturation) can also be detrimental to aquatic biota. Super-saturation oxygen conditions during the day are usually followed by low oxygen (anoxic) levels at night. Oxygen in water has a natural diurnal pattern that is driven by plant photosynthesis and respiration. Photosynthesis is driven by sunlight and produces free oxygen during the production phase (day), which increases DO during the day. During the respiration phase (night) of photosynthesis, algal, microbial, and plant respiration consumes free oxygen, which causes a decrease in DO and releases carbon dioxide during the night.

Because visits to surface-water quality stations typically took place between 8 am and 2 pm, these variations were generally not observed unless continuous monitoring was in place. To avoid the detrimental effects of either too much or too little DO the ANZECC guideline has an upper and lower limit of 105% and 98% of DO.

The Puwera Stream had a very poor compliance rate for DO levels, only reaching about 18% of compliance for site 108705 and 9% for site 108706 as a maximum as shown in Table 18. However, these results and their interpretation are complicated by a number of interacting factors. These include the time of the day when samples were collected with a majority collected in the morning when the photosynthesis cycle had only just begun. This would skew the results lower overall. Other variables influencing DO levels are the amount of shade and temperature of the stream. Warmer temperatures can influence plant growth and therefore increase DO levels through photosynthesis, or conversely decrease them when organic matter is decomposing. Another important factor is the amount of flow within a stream with greater flow generating higher DO levels through increased aeration and turbulence. This explains the seasonal variation in DO levels observed at the sample sites, and in particular at the upstream site (108705) which was only intermittently flowing. In general there are higher values in winter which correlates with increased flow and thus aeration of the water column.

Results for DO levels are presented in Table 18 and represented in Figure 16 and Figure 17 below.

Table 18: Median dissolved oxygen concentration, range and percent compliance with ANZECC guidelines

Dissolved oxygen (%)												
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	19	19	8	8	12	12	8	8	11	11
Med	73	84	58.5	70.1	55.8	61.9	57.2	83.2	85.2	89.9	79.6	83.9
Max	90.7	89	95.2	111.2	78.1	83.5	94.3	99.2	94.1	99.2	103.9	105
Min	24.9	59.2	0.5	33.5	4.8	20	2.1	40.1	8.8	31.5	59.5	71.3
Within g-lines	0	0	0	0	0	0	0	1	0	1	2	1
% com-pliance	0	0	0	0	0	0	0	8.3	0	12.5	18.2	9

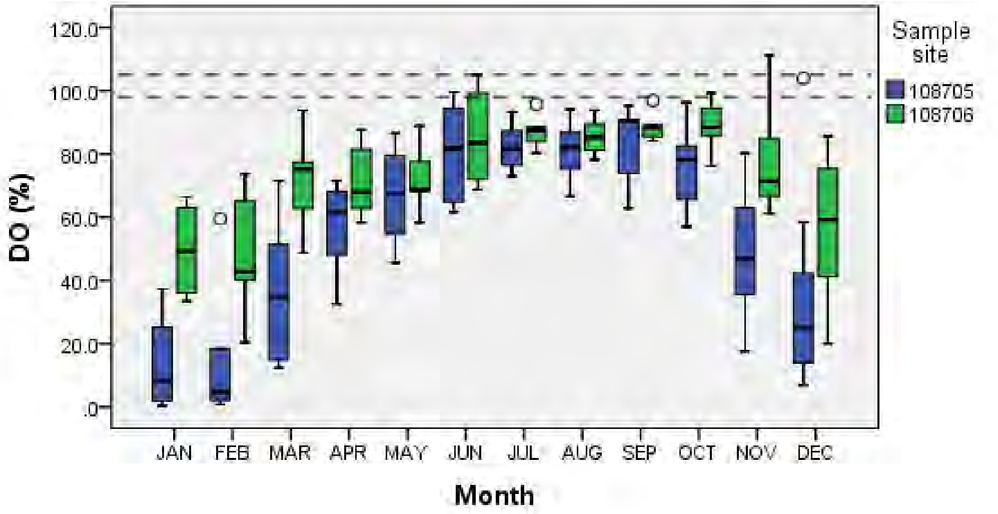


Figure 16: Seasonal boxplot of dissolved oxygen. Dashed lines = ANZECC guideline

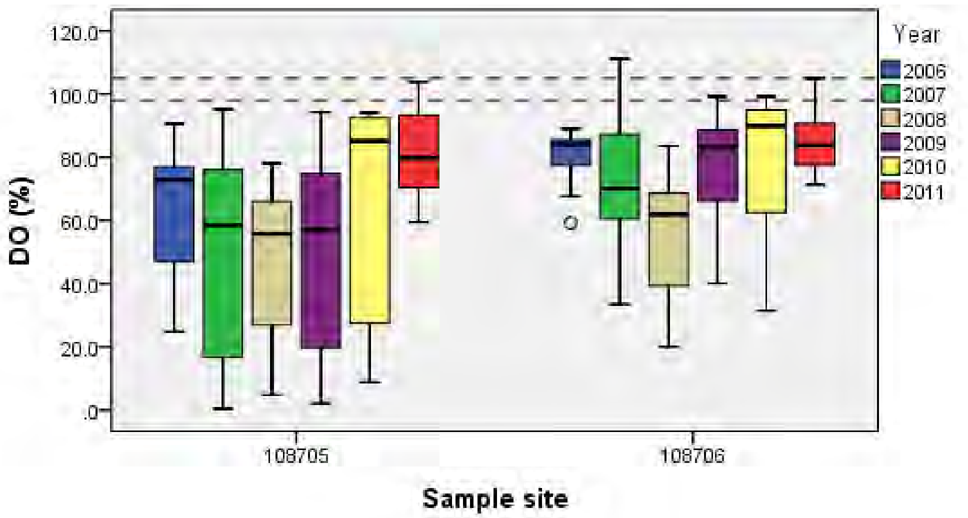


Figure 17: Annual boxplot of dissolved oxygen. Dashed lines = ANZECC guideline

Trend analysis showed no significant trend at site 108706 for DO with a p-value of 0.11 as shown in Table 19 below.

Table 19: Seasonal Kendall trend test results for DO at site 108706

DO%	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	1.43	18	112.67	1.6	0.11	1.67	1.16	2.53

5.6 pH

The acidity or alkalinity of water is measured using the pH scale. The scale goes from 0 to 14 to indicate the degree of acidity or alkalinity of water – 0 is very strong acid and 14 is very strong alkaline. Pure water is neutral with a pH of 7 which represents the mid point of the pH scale. As an example, vinegar has a pH of 3 and lemon juice has a pH of 2, making them both acidic. Organisms in Northland streams are generally comfortable living in water with a pH comprised between 6.5 and 9 beyond which they would move away or die. The recommended guideline for lowland streams is that pH should range between 7.2 and 7.8 (ANZECC 2000). Overall the pH of the Puwera stream was slightly acid although all pH readings were within the comfortable range for Northlands freshwater organisms.

Compliance rate with ANZECC guideline did not get above 45% for site 108705 and 23% for site 108706 as shown in Table 20 below.

Table 20: Median pH, range and percent compliance with ANZECC guidelines

	pH											
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	18	18	8	8	12	12	8	8	11	11
Med	7.0	7.0	7.1	7.0	7.1	7.1	7.1	7.0	7.0	6.9	7.1	6.9
Max	7.3	7.5	7.4	7.4	7.3	7.1	7.2	7.1	7.4	7.4	7.3	7.5
Min	6.6	6.7	6.7	6.7	6.9	6.8	6.9	6.9	6.4	6.3	6.2	6.2
Within g-lines	3	3	7	4	2	0	4	0	1	1	5	1
% compliance	23.1	23.1	38.9	22.2	25	0	33.3	0	12.5	12.5	45.5	9.1

Trend analysis showed a significant trend at site 108706 for pH with a p-value of 0.05. The trend was meaningful and decreasing with a slope value of -0.03 units of change per year as shown in Table 21 below. This means that water pH has been decreasing during the sampling period, i.e. the stream was becoming increasingly acidic.

Table 21: Seasonal Kendall trend test results for pH at site 108706

PH	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	-0.01	-21	107.67	-1.9	0.05	-0.03	-0.04	0

5.7 Water temperature and conductivity

Water temperature is controlled by several factors such as channel shading and riparian vegetation, seasonal and annual climates, daily temperatures and sunlight hours, stream flow, river depth and width. Shallow slow moving exposed streams tend to have much higher temperatures than deeper, shaded and fast moving streams. Water temperature is not only important for recreation, it also affects both the surface appearance of rivers and more importantly, the aquatic life they support.

Conductivity measures the ability of water to conduct an electrical current. It increases with increasing amount and mobility of ions. These ions, which come from the breakdown of compounds, conduct electricity because they are negatively or positively charged when dissolved in water. Therefore conductivity is an indirect measure of the presence and levels of dissolved solids such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution.

Depending on the type of geological substrate where the stream or river is flowing through will greatly affect the conductivity. For example, if acidic water flows over rocks containing calcite (CaCO3), such as calcareous shale, calcium (Ca2+) and carbonate (CO_3^{2-}) ions will dissolve into the water. Therefore conductivity will increase. On the other hand substrates such as quartz (SiO2) are very resistant and do not dissolve easily when water flows over them. Therefore conductivity of waters draining areas where the geology only consists of quartz or other resistant rocks will be low, unless other factors are involved.

High quality distilled water has a conductivity of about 0.0055mS[3]/m, typical drinking water is in the range of 5-50mS/m while sea water about 5000mS/m.

There are no guidelines for either water temperature or conductivity. Results presented in Table 22 and Table 24 were therefore compared to results for other monitoring programs around Northland and throughout New Zealand.

Water temperature (TEMP)

Table 22: Median temperature and range

Temperature (°C)												
YEAR	**2006**		**2007**		**2008**		**2009**		**2010**		**2011**	
SITE	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**
Samp.sz	13	13	19	19	8	8	12	12	8	8	11	11
Med	13.6	13.4	15.8	16.0	16.9	17.2	15.0	15.2	14.6	15.0	14.6	14.7
Max	16.2	17.1	19.8	20.6	18.2	18.4	19.4	20.3	21.0	22.1	21.4	21.3
Min	8.8	8.9	9.6	10.2	12.3	12.2	10.0	10.1	8.5	8.6	10.8	10.7

Trend analysis showed no significant trend at site 108706 for temperature with a p-value of 1.00 as shown in Table 23 below.

Table 23: Seasonal Kendall trend test results for temperature at site 108706

TEMP	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow	-0.4	0	112.67	0	1.00	-0.04	-0.24	0.15

[3] mS: milliSiemens per metre is the unit used to measure conductivity

adjusted								

Conductivity (COND)

Table 24: Median conductivity and range

Conductivity (mS/m)												
YEAR	**2006**		**2007**		**2008**		**2009**		**2010**		**2011**	
SITE	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**	**8705**	**8706**
Samp.sz	**13**	**13**	**19**	**19**	**8**	**8**	**12**	**12**	**8**	**8**	**11**	**11**
Med	**37.5**	**27.5**	**37.1**	**28.5**	**35.1**	**28.2**	**36.6**	**27.2**	**39.3**	**30.5**	**35.8**	**27.8**
Max	**61.4**	**50.0**	**115.4**	**45.6**	**41.7**	**34.8**	**75.4**	**48.0**	**62.8**	**41.1**	**40.5**	**34.1**
Min	**32.7**	**11.1**	**26.5**	**24.9**	**21.4**	**24.0**	**31.8**	**25.0**	**20.3**	**19.0**	**30.6**	**25.3**

Trend analysis showed no significant trend at site 108706 for COND with a p-value of 0.30 as shown in Table 25 below.

Table 25: Seasonal Kendall trend test results for conductivity at site 108706

COND	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	-0.24	12	112.67	1.04	0.30	0.17	0.04	0.41

5.8 Macroinvertebrates

Freshwater macroinvertebrates are aquatic animals such as insects or molluscs that have no backbone or spinal column and can be found in both lakes and rivers. Sampling both the types of macroinvertebrate taxa, i.e. groups of similar individuals present in a waterway, as well as the number in each taxon provides an indication of the overall river health and water quality.

Two common measures of macroinvertebrates are:

- the Macroinvertebrate Community Index (MCI), and
- the percentage of the total abundance comprising Ephemeroptera, Plecoptera, and Trichoptera taxa (%EPT).

The MCI looks at the whole macroinvertebrate population structure and provides a score that indicates general water quality. Generally, an MCI score lower than 80 indicates poor water quality and a score greater than 119 indicates excellent water quality as shown in

Table 26 on the following page.

Some macroinvertebrates are particularly sensitive to pollution and therefore are good indicators of potential water quality degradation caused by human activity. In particular, the contribution to the total abundance of macroinvertebrates belonging to the sensitive Ephemeroptera, Plecoptera and Trichoptera groups (mayflies, stoneflies and caddisflies) form a measurement called %EPT (MfE 2009). Low %EPT, i.e. below 25% indicates a river under pollution stress, while high %EPT, i.e. above 50% indicates good water quality – the higher the score, the better water quality.

Table 26: Macroinvertebrate community index and %EPT scoring system

MCI Score	%EPT	Water quality grade
>119		Excellent
100-119	>50	Good
80-99		Fair
<80	<25	Poor

The MCI scores at both sites are presented in Table 27 below. All the scores fell within the fair water quality grade. However %EPT scores for both sites fell within a poor water quality grade. As the sampling was only done at the start of the monitoring period in 2006, this method could not be used to assess any changes in MCI or %EPT scores and thus water quality over time.

Table 27: MCI and %EPT results for site 108705 and 108706

	108705		108706	
Sampling season 2006	**MCI**	**%EPT**	**MCI**	**%EPT**
January	83.2	8	84.2	10.5
July	84.3	13	84.2	21.1
October	88.9	22	77.5	12.5

6. Synthesis of land use and water quality data

As previously mentioned, no action has been undertaken in the Puwera catchment before, during or after the monitoring period (between 2006 and 2011). The only action that is likely to have influenced water quality would have been the upgrade of effluent treatment systems in each dairy farm which should prevent discharges of untreated effluent to water.

Trend analysis at the downstream site 108706 showed that meaningful trends were observed for some of the water quality parameters as shown in Table 28. Very significant trends were observed for E. coli and faecal coliform concentrations, and a significant trend was observed for pH. Positive trends, i.e. trends improving water quality, were the meaningful decrease of E. coli and faecal coliforms. A decrease in E. coli and faecal coliforms is a good first step for improving water quality and in some instances can be aligned with a decrease in nutrient levels. However, on this occasion the slight decrease in nutrient levels was not statistically significant.

These positive trends could be associated with upgrades of effluent treatment systems on dairy farms that occurred in the previous years. Besides, it is important to note that levels of E. coli and faecal coliform were lower in the last year of sampling which also coincides with the highest compliance rate in the entire period.

The negative trend, i.e. reducing water quality, was the meaningful decrease in pH. Considering that pH in the Puwera stream was already low, this trend showed that the situation did not improve and the water was becoming increasingly acidic. This could be related to various factors such as heavy rainfall washing down soils that have inherent geological characteristics that would affect water pH as mentioned in section 3.1.

A plausible factor that could explain a decreasing pH could then be an increase in soil erosion, releasing fragments of acidic soils washed down into the stream. Other factors such as stream flow would also have an important influence. Farming activities may also affect pH when large amounts of acidic fertiliser (e.g. chicken manure) are spread onto paddocks which could potentially reduce the pH of the stream through run-off. However, it is not possible at this stage to identify with certitude a source or main factor having an effect on pH in the Puwera catchment.

Table 28: Summary of seasonal Kendall trend test results with significant trends for site 108706

Determinant	108706	
	p	SKSE
Ammoniacal nitrogen (NH_4)	0.78	0
Biochemical oxygen demand 5 day (BOD5)	0.05	-0.06
Chlorophyll a (CHLA)	0.78	0
Conductivity (COND)	0.3	0.17
Dissolved oxygen (DO)	0.11	1.67
Dissolved reactive phosphorus (DRP)	0.07	-0.01
Escherichia coli (E. coli)	0.01	-126.89
Faecal coliform (FC)	0.00	-127.6
Nitrate & nitrite nitrogen (NNN)	0.64	-0.01
pH	0.05	-0.03
Suspended sediment (SS)	0.78	0
Temperature (TEMP)	1	-0.04
Total Kjeldahl nitrogen (TKN)	0.18	-0.04
Total nitrogen (TN)	0	0
Total phosphorus (TP)	0.18	-0.02
Turbidity (TURB)	0.31	-0.24

7. Summary and recommendations

Following the analysis of the results of the water quality monitoring in the Puwera catchment and before drawing any conclusion, it is important to note that:

- the Puwera catchment is subject to high flow variability which means that much of the main-stem stream is not perceived as an Accord waterway, and therefore has not been subject to Accord actions
- the highly variable flow of the Puwera Stream may have consequences for establishing a baseline of water quality and drawing comparisons in non-continuous data over time

Following the monitoring of water quality in the Puwera catchment recommendations can be drawn for possible further investigation and area of improvement:

- keep monitoring Puwera stream at site 108706 to assess the changes in water quality and either confirm or not the positive trend for E. coli and faecal coliform concentration and the negative trend for pH
- investigate further the potential sources of the decreasing pH of the stream including geological characteristics, flow variability, or land use change
- in order to have a better understanding of the nutrient cycle in the catchment, it would be useful to implement additional monitoring programmes including more sampling sites on a longer period of time considering that the upstream flow can be limited

- if future policy or accords are to be more successful in improving water quality, then they must cover ephemeral source areas as well as permanently flowing streams

Recommendations for land management actions could include:

- if long-term monitoring is retained in the catchment, more detailed information on land-use change will be required
- farm management plans
- implementing a total stock exclusion from waterways by fencing all waterways in the catchment
- plant riparian buffers along streams to trap nutrients and prevent further nutrient wash down to the Harbour
- minimise soil erosion by implementing erosion control programmes
- construct wetlands/sediment traps at each stream within the catchment as it would not be possible to implement further downstream towards Whangarei Harbour

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Abbreviations

%EPT: % Ephemera, Plecoptera and Trichoptera

ANZECC: Australian and New Zealand Environment and Conservation Council

BOD5: Biochemical Oxygen Demand on 5 days

CHLA: Chlorophyll a

COND: Conductivity

DO: Dissolved oxygen

DRP: Dissolved Reactive Phosphorus

E. coli: Escherichia coli

FC: Faecal coliform

MfE: Ministry for the Environment

MCI: Macroinvertebrate Community Index

MoH: Ministry of Health

NH4: Ammonium nitrogen

NIWA: National Institute for water and Atmospheric Research

NNN: Nitrate and nitrite nitrogen

NRC: Northland Regional Council

REC: River Environment Classification

SKSE: Seasonal Kendall Slope Estimator

SS: Suspended sediment

TEMP: Temperature

TKN: Total Kjeldahl Nitrogen

TN: Total nitrogen

TP: Total phosphorus

TURB: Turbidity

Appendices

A. Results for faecal coliforms and total Kjeldahl nitrogen

Faecal coliform is closely related to E. coli as it includes all types of faecal coliforms, including E. coli. The ANZECC guidelines specify for stock drinking a faecal coliform limit of 100 CFU/100mL. Compliance rates were not high for both sites with better results for the upstream site (108705) as shown in Table 29. Results are represented in Figure 18 and Figure 19.

Table 29: Median faecal coliform, range and percent compliance with ANZECC guidelines

Faecal coliforms (CFU/100mL)												
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	19	19	6	6	12	12	8	8	11	11
Med	320	470	480	400	190	205	175	310	375	420	80	150
Max	1840	1330	36400	13200	1200	600	3200	4600	45000	49000	1600	1400
Min	100	60	10	110	5	90	40	70	80	90	40	40
Within g-lines	1	2	4	0	3	1	3	1	3	1	6	3
% compliance	7.7	15.4	21.1	0	50	17	25	8	37.5	12.5	54.5	27.3

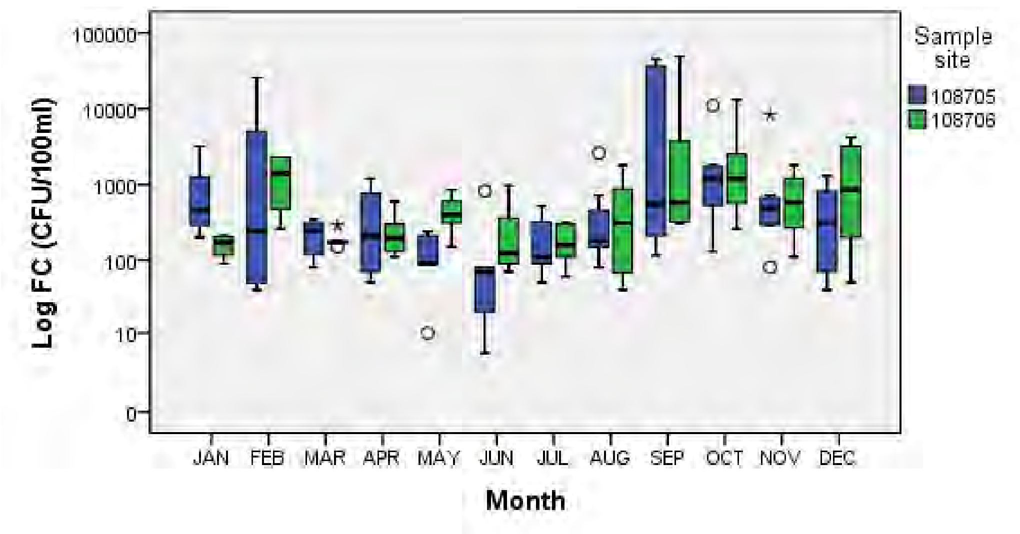

Figure 18: Seasonal boxplot of faecal coliform.

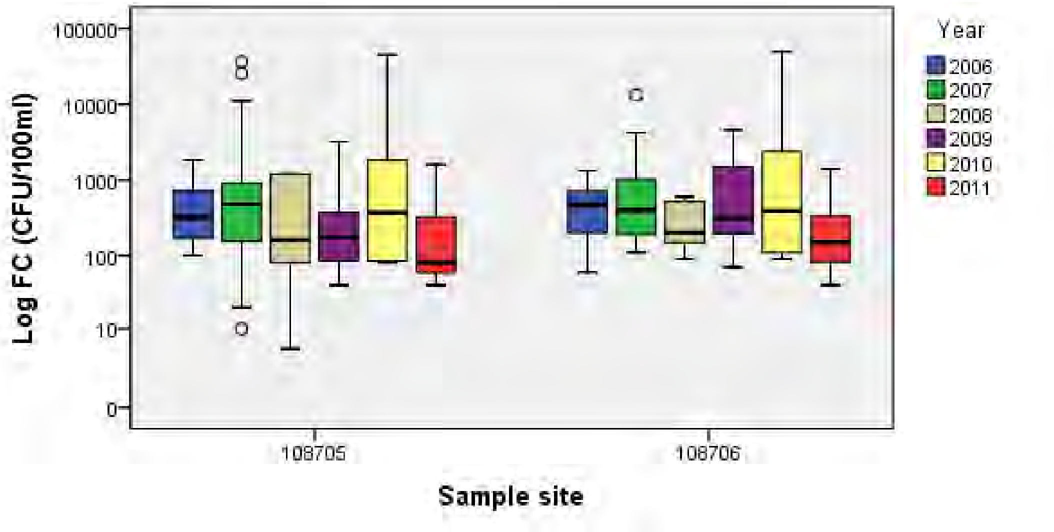

Figure 19: Annual boxplot of faecal coliform.

Trend analysis showed a very significant trend at site 108706 for faecal coliform with a p-value below 0.01. The trend was meaningful and decreasing with a slope value of -127.6 units of change per year as shown in Table 30 below. This means that faecal coliform levels were decreasing during the sampling period.

Table 30: Seasonal Kendall trend test results for faecal coliform at site 108706

FC	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Flow adjusted	-128.16	-32	103.67	-3	0.00	-127.6	-157.1	-46.57

There is no guideline for Total Kjeldahl nitrogen in ANZECC guidelines. Results are presented in Table 31 below.

Table 31: Median total Kjeldahl nitrogen and range

Total Kjeldahl Nitrogen (mg/L)												
YEAR	2006		2007		2008		2009		2010		2011	
SITE	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706	8705	8706
Samp.sz	13	13	18	18	8	8	12	12	8	8	11	11
Med	0.8	0.8	0.75	0.65	0.85	0.7	0.91	0.71	0.55	0.6	0.55	0.66
Max	2.7	1.1	34.0	1.5	3.5	1.4	12.9	0.93	2.1	2.5	0.87	1.0
Min	0.4	0.4	0.4	0.4	0.44	0.44	0.37	0.45	0.33	0.31	0.4	0.16