

State of the Environment Monitoring

# River Water Quality Annual Report 2010

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# State of the Environment Monitoring: River Water Quality Annual Report 2010

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1 Executive summary

The Auckland Regional Council operates a long-term river water quality monitoring programme throughout the region. The objectives of this monitoring include State of the Environment reporting, identification of major environmental issues and the assessment of the efficacy of Council policy initiatives and strategies. This report documents any changes to the monitoring programme and provides a summary of the data collected during the 2010 calendar year.

Water quality is assessed monthly at 31 sites around the region using a combination of field based and laboratory tested parameters. The results are presented as box plots, which display the variation in the measured parameters at each of the sites, and in tables, which provide a statistical summary of each parameter at each of the sites.

The data was used to produce water quality indices, which allowed sites to be ranked and assigned a water quality class. This analysis allows the complex water quality data to be communicated in a simple form. The water quality indices indicated that during 2010 the best river water quality was in the West Hoe Stream, followed by Cascades Stream and Wairoa Tributary, all of which were classified as having excellent water quality. The worst water quality was observed in streams in and around the metropolitan urban area, of which the Otaki Creek site was the lowest ranked in 2010.

## <sup>2</sup> Introduction

## 2.1 Auckland's rivers

The Auckland region has an estimated 16500 km of permanently flowing rivers, which increases to 28240 km when intermittent and ephemeral rivers are included (Storey & Wadhwa, 2009). As no mainland location in the region is greater than 20 km from the coast, the catchment areas of each river are relatively small. This means that most of the rivers reach the sea before they merge with others to form large rivers. Consequently, most rivers are first and second order (Table 1), meaning they are relatively small, with most less than a few metres wide.

The relatively low elevation of the Auckland region and the underlying geology also have a profound influence on the nature of the rivers, usually resulting in slow flowing, low gradient rivers with soft substrate beds. Fast flowing, high gradient rivers with hard stony substrates are mostly restricted to catchments that drain the Waitakere or Hunua Ranges.

#### Table 1

Permanent rivers of the Auckland region stratified by stream order (Storey & Wadhwa, 2009).

| Stream order | Length (km) | % in order | Cumulative % |
|--------------|-------------|------------|--------------|
| 1            | 8753        | 52.7       | 52.7         |
| 2            | 4262        | 25.6       | 78.3         |
| 3            | 2121        | 12.7       | 91.0         |
| 4            | 1003        | 6.0        | 97.0         |
| 5            | 372         | 2.2        | 99.2         |
| 6            | 122         | 0.7        | 99.9         |
| 7            | 16          | 0.1        | 100          |

### 2.2 Water quality

The water quality (its physical and chemical characteristics) of a river partly determines how suitable it is for supporting animal and plant life and for use by humans.

At a given point in a river, water quality is a function of the temperature, amount of nutrients, oxygen, sediment and other pollutants in the water, and is dependent upon many factors of its catchment. In the absence of human influences, these factors include climate, topography, geology and soil type. Where there are human influences, the type of land cover and activities in the river's catchment can also strongly affect water quality.

The River Environment Classification (REC) (Snelder *et al.*, 2004) classified each river in New Zealand by the land cover in its catchment as this is known to affect the quality and quantity of water, the types of ecological habitats and flow patterns in the river. The classification used is based on the following land cover types;

- Native forest (including natural alpine environments)
- Exotic forest
- Rural (includes all non-forested rural land)
- Urban

The majority (63%) of rivers within the Auckland region drain non-forested rural catchments (pastoral farming, horticulture and rural residential), followed by native forest catchments (21%), with exotic forest and urban catchments accounting for 8% each (Table 2).

The catchment land cover of rivers within the Auckland region is quite different from New Zealand as a whole (Table 2). These differences reflect the high population density in Auckland and the environmental pressures associated with this high population.

#### Table 2

| Land cover                  | % of rivers |             |  |  |  |  |
|-----------------------------|-------------|-------------|--|--|--|--|
|                             | Auckland    | New Zealand |  |  |  |  |
| Rural                       | 63          | 43          |  |  |  |  |
| Native forest (inc. alpine) | 21          | 51          |  |  |  |  |
| Exotic forest               | 8           | 5           |  |  |  |  |
| Urban                       | 8           | 1           |  |  |  |  |

Catchment land cover for rivers in Auckland and New Zealand.

## 2.3 Auckland Council monitoring programme

The overall aim of the Auckland Council's freshwater State of the Environment monitoring programmes is to describe the quantity and quality of the region's freshwater resources, and to assess the effects of environmental stressors upon them. To meet this aim, the Council's freshwater monitoring is carried out under two concurrent work streams. The **quantity** work stream measures the volume of the region's freshwater resources. The **quality** work stream measures the condition of the region's freshwater resource using a combination of physical, chemical and biological measures.

The Auckland Council operates two river quality monitoring programmes, of which the Water Quality Programme is one. The Water Quality Programme monitors the physical, chemical and microbiological properties of rivers at 31 sites. This monitoring provides information on the temperature, amounts of nutrients, oxygen, sediment and other pollutants in the sampled rivers. The results enable us to assess the life-supporting capacity of the river (how suitable it is for supporting plant and animal life) and its suitability for human use.

The River Water Quality Programme initially commenced with 8 sites in 1977-78 and ran until 1981; it was re-started with 17 sites in 1986 and has been running continuously ever since. The programme has evolved during its duration and the current 31 site network has been operating since January 2009. Each of the 31 sites is sampled monthly.

The monitoring programme is regionally representative. This means that it monitors all sizes and types of rivers, and also covers the range of different catchment land cover types found across the region. This allows us to extrapolate the results to infer the likely water quality of rivers that we do not sample.

## 2.4 Programme objectives

The information generated by the River Water Quality Programme, in conjunction with the Council's other monitoring programmes, is used to meet the following objectives;

- Satisfy the obligations for state of the environment monitoring as required by section 35 of the Resource Management Act (1991).
- Contribute to community outcome monitoring required by the Local Government Act (2002).
- · Help inform the efficiency and efficacy of policy initiatives and strategies.
- Assist with the identification of large scale or cumulative impacts of contaminants and disturbance associated with varying land uses.
- Provide baseline, regionally representative data from which impacts of individual activities can be measured through compliance monitoring.
- Provide baseline, regionally representative data to support preparation of environmental effects assessments required through the resource consent process.
- Address queries from the public and promote awareness of freshwater issues.

A key issue is to manage the effects of development on our natural environment. This includes balancing the needs for sustainable environmental management with the community's social, economic and cultural well being.

Specific objectives include managing and minimising the adverse effects of present and future urban and rural development, growth and intensification across the region. Water quality provides information on the condition of the region's streams and feedback on management actions. Such information is necessary to confirm that Council's management strategies are effective in sustaining stream functions and uses.

## 2.5 Report scope

This report provides a tabular and graphical summary of the data collected from the 31 sites in the River Water Quality Programme during the 2010 calendar year. Furthermore, the 2010 water quality data is used to produce an index for each site, which allows the complex water quality data to be communicated in a simple form.

This is the 21<sup>st</sup> annual report since the inception of the monitoring programme, and the sixth time since 2000 that the river water quality data has been reported separately from the marine and lake data. In addition, a comprehensive state and trends analysis of the water quality data was carried out in 2007 (see Scarsbrook, 2007).

All reports can be obtained from the publications area of the Auckland Council website (www.aucklandcouncil.govt.nz/publications).

## 3 Methods

## 3.1 Sample sites

The current River Water Quality Programme operates with a network of 31 sites (Table 3). The number of sites sampled each year has varied due to logistical considerations and programme objectives, and the current network has been operating since January 2009. The location of the 31 sites is displayed on page 13 (Figure 1).

### 3.2 Monitoring network design

The sampling network began with 8 sites in 1977-78 with the objective of providing longterm data on water quality in the Auckland region (ARC, 1982). The current network was designed to provide broad geographical coverage and to cover the four major land cover classes (native forest, exotic forest, rural and urban) that exist in the Auckland region (ARC, 2008).

### 3.3 Programme changes

The programme was last reviewed in 2008 and subsequent changes were described in the 2009 Annual Report (Neale, 2010).

Following a screening level assessment in 2009, heavy metal testing was extended to an additional nine sites in September 2010. As a result, heavy metal testing is now undertaken at 21 of the 31 sites in the programme.

There were no site changes in 2010.

## 3.4 Sampling methodology

For the 29 sites monitored by Auckland Council, all sample collection is carried out by Council staff. Up to 21 water quality parameters are routinely monitored in the programme (Table 4). Six parameters are determined in the field; the remainder are determined by laboratory tests.

Quality control measures are undertaken in accordance with Auckland Council's internal standards which meet ISO 9001:2000. This covers procedures for the collection, transport and storage of samples, methods for data verification and quality assurance to ensure consistency across the monitoring programmes.

Laboratory samples are analysed under contract by Watercare Laboratory Services Ltd, an IANZ accredited laboratory. Analytical methods follow the "Standard Methods for the Examination of Water and Wastewater" 21st Edition (APHA, 2005).

Sites sampled in 2010 in the River Water Quality Programme, together with their location details, catchment land cover and record start date.

| Site name                          | NZTM X  | NZTM Y  | Land cover    | Start date |
|------------------------------------|---------|---------|---------------|------------|
| Cascades Stream                    | 1735628 | 5916378 | Native forest | 1978       |
| Hoteo River (NIWA operated)        | 1735254 | 5972546 | Rural         | 1986       |
| Kaukapakapa River                  | 1735833 | 5944978 | Rural         | 2009       |
| Kumeu River                        | 1739252 | 5928781 | Rural         | 1993       |
| Lucas Creek                        | 1751468 | 5934510 | Urban         | 1993       |
| Mahurangi River (Forestry HQ)      | 1747750 | 5965035 | Exotic forest | 1993       |
| Mahurangi River (Water Supply)     | 1748864 | 5970457 | Rural         | 1993       |
| Makarau River                      | 1736150 | 5953126 | Rural         | 2009       |
| Matakana River                     | 1753500 | 5976481 | Rural         | 1986       |
| Ngakaroa Stream                    | 1775164 | 5881624 | Rural         | 1993       |
| Oakley Creek                       | 1751963 | 5917636 | Urban         | 1994       |
| Okura Creek                        | 1751405 | 5938716 | Rural         | 2003       |
| Omaru Creek                        | 1766268 | 5916749 | Urban         | 1985       |
| Opanuku Stream                     | 1742086 | 5915581 | Rural         | 1978       |
| Otaki Creek                        | 1764306 | 5907216 | Urban         | 1985       |
| Otara Creek (East Tamaki)          | 1767422 | 5907535 | Urban         | 1986       |
| Otara Creek (Kennell Hill)         | 1768335 | 5908376 | Urban         | 1992       |
| Oteha Stream                       | 1751325 | 5933519 | Urban         | 1986       |
| Pakuranga Creek (Botany Rd)        | 1769973 | 5913013 | Urban         | 1985       |
| Pakuranga Creek (Greenmount Drive) | 1769473 | 5910813 | Urban         | 1985       |
| Papakura Stream                    | 1771240 | 5900290 | Rural         | 1993       |
| Puhinui Stream                     | 1766440 | 5904295 | Urban         | 1994       |
| Rangitopuni River (NIWA operated)  | 1744450 | 5932301 | Rural         | 1986       |
| Riverhead Forest Stream            | 1737125 | 5933216 | Exotic forest | 2009       |
| Vaughan Stream                     | 1755414 | 5938729 | Rural         | 2001       |
| Wairoa River                       | 1782682 | 5901720 | Rural         | 1978       |
| Wairoa Tributary                   | 1784426 | 5898982 | Native forest | 2009       |
| Waitangi River                     | 1754343 | 5878534 | Rural         | 2009       |
| Waiwera River                      | 1748628 | 5953665 | Rural         | 1986       |
| West Hoe Stream                    | 1748314 | 5950610 | Native forest | 2002       |
| Whangamaire Stream                 | 1763578 | 5884625 | Rural         | 2009       |

The distribution of the 31 sampling sites used in the Auckland Council River Water Quality Programme.



For the two NRWQN sites, sample collection is carried out by NIWA field teams. The NRWQN sites are monitored for the same parameters listed in Table 4, with the exception of salinity, suspended solids and heavy metals. Temperature and dissolved oxygen are determined in the field, the remainder are determined by laboratory tests at NIWA's water quality laboratory in Hamilton. Further information can be obtained from https://secure.niwa.co.nz/wqis/index.do.

## 3.5 Data processing and analysis

All field and laboratory data generated by Council are stored in the Council's water quality archiving database (HYDSTRA). The data from the two sites operated by NIWA was extracted from the NIWA's web-based Water Quality Information System. The 2010 data was collated and used to produce;

- Box plots which display the variation in the measured parameters at each of the sites. These were produce in the software package Sigmaplot using the default percentile functions. The boxes represent the inter-quartile range (25<sup>th</sup> to 75<sup>th</sup> percentile) and the whiskers represent the 5<sup>th</sup> and 95<sup>th</sup> percentiles. The median is shown as a line in each box.
- Summary tables which provide a statistical summary of each parameter at each site. These were produced using the summary statistics function in Excel.
- Water Quality Indices which were produced using the data for seven water quality parameters to allow a water quality class to be assigned to each site. These were produced using a Excel workbook produced by the Canadian Council of Ministers of the Environment (2001). The application of this method to the Council's water quality data is described in Appendix 1.

For the purposes of this report, results that were reported as below the limit of detection were replaced by a value of half the limit of detection value (Chapman, 1996). For example, a value reported as less than a 1 mg  $\Gamma^1$  limit of detection would be included in the data analysis as 0.5 mg  $\Gamma^1$ .

Parameters tested in 2010 in the River Water Quality Programme (laboratory test methods refer to those tests carried out by Watercare Services Ltd under contract).

| Parameter                   | Code     | Units                | Method                  |
|-----------------------------|----------|----------------------|-------------------------|
| Dissolved oxygen            | DO (sat) | % sat                | Portable YSI 556 meter  |
| Dissolved oxygen            | DO (ppm) | ppm                  | Portable YSI 556 meter  |
| Temperature                 | Temp     | °C                   | Portable YSI 556 meter  |
| Conductivity                | Cond     | mS cm <sup>-1</sup>  | Portable YSI 556 meter  |
| Salinity                    | Salinity | ppt                  | Portable YSI 556 meter  |
| рН                          | рН       | pH units             | Portable YSI 556 meter  |
| Suspended solids            | TSS      | mg l⁻¹               | APHA (2005) 2540 D      |
| Turbidity                   | Turb     | NTU                  | APHA (2005) 2130 B      |
| Ammoniacal nitrogen         | Ammonia  | mg N I <sup>-1</sup> | APHA (2005) 4500-NH3 G  |
| Total oxidised nitrogen     | TON      | mg N I <sup>-1</sup> | APHA (2005) 4500-NO3 F  |
| Kjedhahl nitrogen           | KN       | mg N I <sup>-1</sup> | By calculation          |
| Total nitrogen              | TN       | mg N I⁻¹             | APHA (2005) 4500-N C    |
| Soluble reactive phosphorus | SRP      | mg P l⁻¹             | APHA (2005) 4500-P F    |
| Total phosphorus            | TP       | mg P l⁻¹             | APHA (2005) 4500-P B, F |
| Soluble copper              | Cu sol   | µg l⁻¹               | USEPA 200.8             |
| Total copper                | Cu tot   | µg l⁻¹               | USEPA 200.8             |
| Soluble zinc                | Zn sol   | µg l⁻¹               | USEPA 200.8             |
| Total zinc                  | Zn tot   | μg l <sup>-1</sup>   | USEPA 200.8             |
| Soluble lead                | Pb sol   | µg l⁻¹               | USEPA 200.8             |
| Total Lead                  | Pb tot   | μg l⁻¹               | USEPA 200.8             |
| Eschericia coli             | E. coli  | cfu/100ml            | APHA (2005) 9213 F      |

## ₄ Results

The data from the 2010 calendar year are presented as;

- box plots which display the variation in the measured parameters at each of the sites (Section 4.1).
- tables which provide a statistical summary of each parameter at each site (Section 4.2)
- water quality indices produced using the data for seven water quality parameters allowing a water quality class to be assigned to each site (Section 4.3)

The results listed below should be used with discretion for the following reasons;

- Heavy metals
  - Heavy metals were monitored routinely at the 12 sites in the network that are affected by urban land use. In September 2010, this testing was extended to an additional nine sites (making 4 samples in 2010). The results are presented in the summary tables (minimum and maximum) for these nine sites, but have been omitted from the box plots because the calculation of meaningful percentiles is not possible with only four data points.
- Soluble lead
  - Soluble lead levels were typically very low in 2010 and hence the majority of tests returned results below the limit of detection. This resulted in many sites having a minimum, maximum, median and mean of 0.025 µg l<sup>-1</sup> with a standard error of zero. This analysis is of limited value; the only real finding at these sites is that soluble lead is always below 0.05 µg l<sup>-1</sup>.
- pH
- The Council experienced performance issues with one it's field meters during 2010. The issues were restricted to the pH sensor on the probe, which returned numerous erroneous results. To eliminate the effects of this performance issue, the pH data from any run on which issues were identified was removed prior to analysis. Hence, for many sites there are only eight results from 2010.

## 4.1 Box plots

#### Figure 3

Box plots showing the variation in dissolved oxygen % saturation (upper plot) and ppm (lower plot)) at the 31 sites using data collected during the 2010 calendar year.



Box plots showing the variation in temperature (upper plot) and conductivity (lower plot) at the 31 sites using data collected during the 2010 calendar year. Note the axis break and scale change on the y-axis of the conductivity plot.



Box plots showing the variation in salinity (upper plot) and pH (lower plot) at the 31 sites using data collected during the 2010calendar year. Note the axis break and scale change on the y-axis of the salinity plot.



Box plots showing the variation in suspended sediment (upper plot) and turbidity (lower plot) at the 31 sites using data collected during the 2010 calendar year. Note the axis break and scale change on the y-axis of both plots.



Box plots showing the variation in ammoniacal nitrogen (upper plot) and total oxidised nitrogen (lower plot) at the 31 sites using data collected during the 2010 calendar year. Note the axis break and scale change on the y-axis of both plots.



Box plots showing the variation in Kjeldhal nitrogen (upper plot) and total nitrogen (lower plot) at the 31 sites using data collected during the 2010 calendar year. Note the axis break and scale change on the y-axis of both plots.



Box plots showing the variation in soluble reactive phosphorus (upper plot) and total phosphorus (lower plot) at the 31 sites using data collected during the 2010 calendar year. Note the axis break and scale change on the y-axis of both plots.



Box plots showing the variation in soluble copper (upper plot) and total copper (lower plot) at the 12 sites where it is monitored, using data collected during the 2010 calendar year.



Box plots showing the variation in soluble zinc (upper plot) and total zinc (lower plot) at the 12 sites where it is monitored, using data collected during the 2010 calendar year. Note the axis break and scale change on the y-axis of both plots.



Box plots showing the variation in soluble lead (upper plot) and total lead (lower plot) at the 12 sites where it is monitored, using data collected during the 2010 calendar year.



Box plots showing the variation in *Escherichia coli* at the 31 sites using data collected during the 2010 calendar year. The upper plot has y-axis which covers the full range of the data; the lower plot y-axis is limited to 40000 to provide greater resolution for sites with lower *Escherichia coli* levels. Note the axis break and scale change on the y-axis of the upper plot.



## 4.2 Summary tables

#### Table 6

Dissolved oxygen (% saturation)

| Site                               | Count | Minimum | Maximum | Median | Mean  | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|-------|-------------------|
| Cascades Stream                    | 12    | 99.1    | 112.3   | 104.1  | 104.7 | 1.20              |
| Hoteo River (NIWA operated)        | 12    | 86.2    | 94.0    | 91.0   | 90.9  | 0.76              |
| Kaukapakapa River                  | 12    | 54.1    | 92.7    | 77.8   | 76.1  | 4.06              |
| Kumeu River                        | 12    | 11.3    | 92.1    | 78.2   | 71.6  | 6.67              |
| Lucas Creek                        | 12    | 59.8    | 103.8   | 83.2   | 83.2  | 4.20              |
| Mahurangi River (Forestry HQ)      | 12    | 93.8    | 116.8   | 100.6  | 102.4 | 1.98              |
| Mahurangi River (Water Supply)     | 12    | 80.0    | 106.3   | 97.1   | 95.0  | 2.42              |
| Makarau River                      | 12    | 85.8    | 112.1   | 99.8   | 100.3 | 2.04              |
| Matakana River                     | 12    | 74.7    | 101.8   | 92.8   | 92.0  | 1.99              |
| Ngakaroa Stream                    | 12    | 50.8    | 102.7   | 94.4   | 87.4  | 4.93              |
| Oakley Creek                       | 12    | 85.4    | 107.6   | 94.5   | 94.2  | 2.16              |
| Okura Creek                        | 12    | 16.9    | 107.5   | 81.2   | 73.5  | 9.39              |
| Omaru Creek                        | 12    | 12.3    | 103.4   | 91.3   | 82.5  | 6.88              |
| Opanuku Stream                     | 12    | 87.0    | 114.0   | 99.5   | 100.9 | 2.11              |
| Otaki Creek                        | 12    | 26.2    | 260.0   | 90.7   | 97.8  | 16.13             |
| Otara Creek (East Tamaki)          | 12    | 98.6    | 148.1   | 110.4  | 113.1 | 3.78              |
| Otara Creek (Kennell Hill)         | 12    | 42.0    | 106.6   | 82.2   | 81.6  | 5.28              |
| Oteha Stream                       | 12    | 42.2    | 99.8    | 70.5   | 71.5  | 6.00              |
| Pakuranga Creek (Botany Rd)        | 12    | 108.7   | 174.4   | 140.4  | 140.9 | 5.28              |
| Pakuranga Creek (Greenmount Drive) | 12    | 53.1    | 92.7    | 76.2   | 76.8  | 3.56              |
| Papakura Stream                    | 12    | 69.1    | 97.8    | 90.6   | 88.0  | 2.16              |
| Puhinui Stream                     | 12    | 70.0    | 151.0   | 106.5  | 109.5 | 6.32              |
| Rangitopuni River (NIWA operated)  | 12    | 36.9    | 92.9    | 57.3   | 65.7  | 6.95              |
| Riverhead Forest Stream            | 12    | 48.1    | 89.7    | 84.0   | 78.2  | 3.44              |
| Vaughan Stream                     | 12    | 17.3    | 97.0    | 73.1   | 68.8  | 6.26              |
| Wairoa River                       | 12    | 86.0    | 108.8   | 97.9   | 97.2  | 1.79              |
| Wairoa Tributary                   | 12    | 97.6    | 118.3   | 102.4  | 103.9 | 1.63              |
| Waitangi River                     | 12    | 32.1    | 102.5   | 83.6   | 72.6  | 7.59              |
| Waiwera River                      | 12    | 75.4    | 103.9   | 94.3   | 92.0  | 2.15              |
| West Hoe Stream                    | 12    | 83.9    | 107.2   | 93.4   | 93.6  | 1.53              |
| Whangamaire Stream                 | 12    | 59.3    | 110.7   | 88.9   | 88.0  | 5.19              |

Dissolved oxygen (ppm)

| Site                               | Count | Minimum | Maximum | Median | Mean | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|------|-------------------|
| Cascades Stream                    | 12    | 10.0    | 12.2    | 10.9   | 11.0 | 0.18              |
| Hoteo River (NIWA operated)        | 12    | 7.6     | 11.1    | 9.1    | 9.2  | 0.31              |
| Kaukapakapa River                  | 12    | 5.1     | 10.0    | 7.6    | 7.7  | 0.52              |
| Kumeu River                        | 12    | 1.1     | 9.7     | 7.8    | 7.3  | 0.73              |
| Lucas Creek                        | 12    | 5.6     | 11.0    | 8.7    | 8.5  | 0.56              |
| Mahurangi River (Forestry HQ)      | 12    | 9.1     | 12.3    | 10.6   | 10.4 | 0.27              |
| Mahurangi River (Water Supply)     | 12    | 7.2     | 11.0    | 9.3    | 9.4  | 0.39              |
| Makarau River                      | 12    | 8.3     | 11.7    | 10.3   | 10.1 | 0.30              |
| Matakana River                     | 12    | 7.2     | 10.7    | 9.6    | 9.2  | 0.32              |
| Ngakaroa Stream                    | 12    | 4.8     | 10.8    | 9.8    | 9.0  | 0.58              |
| Oakley Creek                       | 12    | 8.0     | 11.1    | 9.5    | 9.4  | 0.32              |
| Okura Creek                        | 12    | 1.6     | 11.7    | 8.5    | 7.8  | 1.06              |
| Omaru Creek                        | 12    | 1.0     | 10.4    | 8.4    | 8.1  | 0.70              |
| Opanuku Stream                     | 12    | 8.4     | 12.2    | 10.7   | 10.5 | 0.34              |
| Otaki Creek                        | 12    | 2.1     | 21.3    | 8.9    | 9.0  | 1.31              |
| Otara Creek (East Tamaki)          | 12    | 9.1     | 13.0    | 11.0   | 11.0 | 0.29              |
| Otara Creek (Kennell Hill)         | 12    | 3.9     | 11.8    | 7.7    | 8.2  | 0.70              |
| Oteha Stream                       | 12    | 3.9     | 10.7    | 7.0    | 7.3  | 0.69              |
| Pakuranga Creek (Botany Rd)        | 12    | 10.9    | 14.4    | 12.5   | 12.7 | 0.30              |
| Pakuranga Creek (Greenmount Drive) | 12    | 4.7     | 9.7     | 7.4    | 7.4  | 0.46              |
| Papakura Stream                    | 12    | 6.8     | 10.1    | 9.3    | 8.9  | 0.33              |
| Puhinui Stream                     | 12    | 6.6     | 14.3    | 10.7   | 10.4 | 0.57              |
| Rangitopuni River (NIWA operated)  | 12    | 3.6     | 11.3    | 5.9    | 7.0  | 0.90              |
| Riverhead Forest Stream            | 12    | 4.8     | 10.0    | 9.0    | 8.3  | 0.47              |
| Vaughan Stream                     | 11    | 3.8     | 10.1    | 7.6    | 7.4  | 0.58              |
| Wairoa River                       | 12    | 8.3     | 11.3    | 10.2   | 9.8  | 0.30              |
| Wairoa Tributary                   | 12    | 10.1    | 13.0    | 11.1   | 11.2 | 0.22              |
| Waitangi River                     | 12    | 3.0     | 10.2    | 8.4    | 7.3  | 0.83              |
| Waiwera River                      | 12    | 7.1     | 10.8    | 9.4    | 9.2  | 0.35              |
| West Hoe Stream                    | 12    | 8.3     | 11.7    | 9.9    | 9.8  | 0.27              |
| Whangamaire Stream                 | 12    | 5.6     | 11.4    | 9.5    | 9.1  | 0.62              |

Temperature (°C)

| Site                               | Count | Minimum | Maximum | Median | Mean | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|------|-------------------|
| Cascades Stream                    | 12    | 10.6    | 17.6    | 12.7   | 13.1 | 0.64              |
| Hoteo River (NIWA operated)        | 12    | 8.4     | 23.2    | 15.5   | 15.5 | 1.29              |
| Kaukapakapa River                  | 12    | 11.7    | 20.6    | 13.8   | 15.2 | 0.91              |
| Kumeu River                        | 12    | 12.1    | 20.5    | 13.7   | 15.0 | 0.88              |
| Lucas Creek                        | 12    | 11.4    | 19.8    | 14.2   | 15.0 | 0.90              |
| Mahurangi River (Forestry HQ)      | 12    | 10.5    | 19.3    | 13.4   | 14.9 | 0.99              |
| Mahurangi River (Water Supply)     | 12    | 11.5    | 20.8    | 15.0   | 16.1 | 1.01              |
| Makarau River                      | 12    | 11.2    | 20.6    | 14.0   | 15.3 | 0.95              |
| Matakana River                     | 12    | 11.4    | 20.4    | 14.5   | 15.6 | 0.95              |
| Ngakaroa Stream                    | 12    | 9.8     | 18.5    | 14.2   | 14.5 | 0.87              |
| Oakley Creek                       | 12    | 12.5    | 19.2    | 15.2   | 15.7 | 0.60              |
| Okura Creek                        | 12    | 10.4    | 18.2    | 12.7   | 13.6 | 0.78              |
| Omaru Creek                        | 12    | 10.5    | 23.5    | 16.5   | 17.1 | 1.16              |
| Opanuku Stream                     | 12    | 10.5    | 18.8    | 12.8   | 13.8 | 0.86              |
| Otaki Creek                        | 12    | 13.6    | 23.5    | 18.1   | 18.4 | 1.04              |
| Otara Creek (East Tamaki)          | 12    | 12.2    | 21.7    | 16.7   | 16.6 | 0.95              |
| Otara Creek (Kennell Hill)         | 12    | 7.4     | 22.1    | 15.9   | 15.9 | 1.30              |
| Oteha Stream                       | 12    | 12.1    | 20.6    | 14.3   | 15.3 | 0.82              |
| Pakuranga Creek (Botany Rd)        | 12    | 13.6    | 28.7    | 21.0   | 20.5 | 1.50              |
| Pakuranga Creek (Greenmount Drive) | 12    | 13.2    | 21.4    | 17.4   | 17.3 | 0.86              |
| Papakura Stream                    | 12    | 10.9    | 19.9    | 14.2   | 15.3 | 0.95              |
| Puhinui Stream                     | 12    | 12.6    | 23.6    | 17.2   | 17.6 | 1.12              |
| Rangitopuni River (NIWA operated)  | 12    | 7.1     | 21.6    | 14.6   | 14.5 | 1.20              |
| Riverhead Forest Stream            | 12    | 10.2    | 19.2    | 12.1   | 13.3 | 0.87              |
| Vaughan Stream                     | 11    | 11.0    | 20.9    | 14.0   | 15.9 | 1.11              |
| Wairoa River                       | 12    | 10.3    | 20.1    | 13.8   | 15.2 | 1.03              |
| Wairoa Tributary                   | 12    | 8.7     | 15.5    | 11.8   | 12.1 | 0.64              |
| Waitangi River                     | 12    | 11.1    | 20.4    | 15.0   | 15.7 | 0.93              |
| Waiwera River                      | 12    | 11.3    | 20.8    | 13.9   | 15.7 | 1.06              |
| West Hoe Stream                    | 12    | 10.8    | 17.2    | 12.6   | 13.2 | 0.65              |
| Whangamaire Stream                 | 12    | 10.3    | 18.8    | 14.1   | 14.5 | 0.82              |

Conductivity (Millisiemens/cm @ 25°C)

| Site                               | Count | Minimum | Maximum | Median | Mean | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|------|-------------------|
| Cascades Stream                    | 12    | 0.09    | 0.19    | 0.17   | 0.16 | 0.010             |
| Hoteo River (NIWA operated)        | 12    | 0.16    | 0.25    | 0.20   | 0.20 | 0.009             |
| Kaukapakapa River                  | 12    | 0.15    | 0.26    | 0.22   | 0.21 | 0.011             |
| Kumeu River                        | 12    | 0.13    | 0.22    | 0.17   | 0.18 | 0.008             |
| Lucas Creek                        | 12    | 0.16    | 0.29    | 0.22   | 0.23 | 0.012             |
| Mahurangi River (Forestry HQ)      | 12    | 0.14    | 0.20    | 0.18   | 0.17 | 0.006             |
| Mahurangi River (Water Supply)     | 12    | 0.14    | 0.25    | 0.19   | 0.19 | 0.010             |
| Makarau River                      | 12    | 0.15    | 0.24    | 0.19   | 0.19 | 0.009             |
| Matakana River                     | 12    | 0.14    | 0.24    | 0.19   | 0.19 | 0.010             |
| Ngakaroa Stream                    | 12    | 0.14    | 0.26    | 0.17   | 0.18 | 0.011             |
| Oakley Creek                       | 12    | 0.19    | 2.02    | 0.26   | 0.51 | 0.182             |
| Okura Creek                        | 12    | 0.19    | 0.46    | 0.27   | 0.28 | 0.023             |
| Omaru Creek                        | 12    | 0.20    | 0.38    | 0.27   | 0.28 | 0.017             |
| Opanuku Stream                     | 12    | 0.09    | 0.16    | 0.14   | 0.13 | 0.007             |
| Otaki Creek                        | 12    | 0.20    | 19.88   | 0.59   | 4.28 | 1.966             |
| Otara Creek (East Tamaki)          | 12    | 0.12    | 0.20    | 0.19   | 0.18 | 0.008             |
| Otara Creek (Kennell Hill)         | 12    | 0.17    | 0.30    | 0.24   | 0.24 | 0.012             |
| Oteha Stream                       | 12    | 0.16    | 0.32    | 0.19   | 0.21 | 0.015             |
| Pakuranga Creek (Botany Rd)        | 12    | 0.21    | 0.31    | 0.27   | 0.27 | 0.009             |
| Pakuranga Creek (Greenmount Drive) | 12    | 0.22    | 0.64    | 0.46   | 0.46 | 0.040             |
| Papakura Stream                    | 12    | 0.18    | 0.25    | 0.21   | 0.21 | 0.007             |
| Puhinui Stream                     | 11    | 0.17    | 0.25    | 0.23   | 0.22 | 0.008             |
| Rangitopuni River (NIWA operated)  | 12    | 0.20    | 0.27    | 0.23   | 0.23 | 0.008             |
| Riverhead Forest Stream            | 12    | 0.17    | 0.29    | 0.24   | 0.24 | 0.010             |
| Vaughan Stream                     | 12    | 0.19    | 13.77   | 0.30   | 2.12 | 1.257             |
| Wairoa River                       | 12    | 0.09    | 0.15    | 0.12   | 0.12 | 0.005             |
| Wairoa Tributary                   | 12    | 0.08    | 0.15    | 0.12   | 0.12 | 0.005             |
| Waitangi River                     | 12    | 0.16    | 0.25    | 0.21   | 0.21 | 0.006             |
| Waiwera River                      | 12    | 0.16    | 0.24    | 0.20   | 0.20 | 0.007             |
| West Hoe Stream                    | 12    | 0.13    | 0.21    | 0.19   | 0.18 | 0.008             |
| Whangamaire Stream                 | 12    | 0.21    | 0.36    | 0.32   | 0.31 | 0.013             |

Salinty (ppt)

| Site                               | Count     | Minimum                   | Maximum | Median | Mean | Standard<br>error |  |
|------------------------------------|-----------|---------------------------|---------|--------|------|-------------------|--|
| Cascades Stream                    | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Hoteo River (NIWA operated)        | Not measu | Not measured at this site |         |        |      |                   |  |
| Kaukapakapa River                  | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Kumeu River                        | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Lucas Creek                        | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Mahurangi River (Forestry HQ)      | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Mahurangi River (Water Supply)     | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Makarau River                      | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Matakana River                     | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Ngakaroa Stream                    | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Oakley Creek                       | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Okura Creek                        | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Omaru Creek                        | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Opanuku Stream                     | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Otaki Creek                        | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Otara Creek (East Tamaki)          | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Otara Creek (Kennell Hill)         | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Oteha Stream                       | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Pakuranga Creek (Botany Rd)        | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Pakuranga Creek (Greenmount Drive) | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Papakura Stream                    | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Puhinui Stream                     | 12        | 0.04                      | 0.09    | 0.08   | 0.07 | 0.005             |  |
| Rangitopuni River (NIWA operated)  | Not measu | red at this site          | 9       |        |      |                   |  |
| Riverhead Forest Stream            | 12        | 0.08                      | 0.14    | 0.12   | 0.12 | 0.005             |  |
| Vaughan Stream                     | 12        | 0.09                      | 7.98    | 0.14   | 0.82 | 0.652             |  |
| Wairoa River                       | 12        | 0.01                      | 0.07    | 0.06   | 0.05 | 0.004             |  |
| Wairoa Tributary                   | 12        | 0.01                      | 0.06    | 0.06   | 0.05 | 0.004             |  |
| Waitangi River                     | 12        | 0.01                      | 0.11    | 0.10   | 0.09 | 0.008             |  |
| Waiwera River                      | 12        | 0.07                      | 0.12    | 0.09   | 0.09 | 0.004             |  |
| West Hoe Stream                    | 12        | 0.06                      | 0.10    | 0.09   | 0.08 | 0.004             |  |
| Whangamaire Stream                 | 12        | 0.01                      | 0.16    | 0.15   | 0.13 | 0.012             |  |

pH (pH units)

| Site                               | Count | Minimum | Maximum | Median | Mean | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|------|-------------------|
| Cascades Stream                    | 8     | 6.5     | 7.9     | 7.1    | 7.2  | 0.17              |
| Hoteo River (NIWA operated)        | 12    | 7.1     | 7.9     | 7.6    | 7.5  | 0.09              |
| Kaukapakapa River                  | 8     | 6.1     | 7.3     | 6.9    | 6.8  | 0.15              |
| Kumeu River                        | 8     | 6.2     | 7.5     | 6.7    | 6.7  | 0.16              |
| Lucas Creek                        | 9     | 6.8     | 7.8     | 7.2    | 7.2  | 0.09              |
| Mahurangi River (Forestry HQ)      | 8     | 6.3     | 7.6     | 6.9    | 7.0  | 0.17              |
| Mahurangi River (Water Supply)     | 8     | 6.6     | 7.6     | 7.1    | 7.2  | 0.13              |
| Makarau River                      | 8     | 6.7     | 7.7     | 7.2    | 7.2  | 0.14              |
| Matakana River                     | 8     | 6.0     | 7.7     | 7.1    | 7.0  | 0.19              |
| Ngakaroa Stream                    | 8     | 6.4     | 7.2     | 6.9    | 6.9  | 0.08              |
| Oakley Creek                       | 8     | 6.6     | 7.5     | 7.3    | 7.2  | 0.11              |
| Okura Creek                        | 9     | 6.7     | 7.8     | 7.0    | 7.1  | 0.10              |
| Omaru Creek                        | 8     | 7.2     | 8.4     | 7.5    | 7.6  | 0.13              |
| Opanuku Stream                     | 8     | 6.5     | 7.8     | 7.4    | 7.3  | 0.15              |
| Otaki Creek                        | 8     | 6.1     | 7.9     | 7.1    | 7.1  | 0.18              |
| Otara Creek (East Tamaki)          | 8     | 5.7     | 8.6     | 6.7    | 7.0  | 0.38              |
| Otara Creek (Kennell Hill)         | 8     | 6.1     | 8.0     | 6.9    | 6.9  | 0.22              |
| Oteha Stream                       | 9     | 6.9     | 7.7     | 7.0    | 7.1  | 0.08              |
| Pakuranga Creek (Botany Rd)        | 8     | 7.2     | 8.7     | 7.5    | 7.8  | 0.23              |
| Pakuranga Creek (Greenmount Drive) | 8     | 6.5     | 8.3     | 7.1    | 7.2  | 0.21              |
| Papakura Stream                    | 8     | 6.1     | 7.4     | 7.0    | 6.8  | 0.18              |
| Puhinui Stream                     | 8     | 6.6     | 7.6     | 7.1    | 7.1  | 0.13              |
| Rangitopuni River (NIWA operated)  | 12    | 7.0     | 7.3     | 7.1    | 7.1  | 0.02              |
| Riverhead Forest Stream            | 8     | 5.7     | 7.3     | 6.2    | 6.3  | 0.22              |
| Vaughan Stream                     | 9     | 6.3     | 7.8     | 7.0    | 6.9  | 0.17              |
| Wairoa River                       | 8     | 6.5     | 7.4     | 7.1    | 7.0  | 0.11              |
| Wairoa Tributary                   | 8     | 6.6     | 7.8     | 7.3    | 7.3  | 0.14              |
| Waitangi River                     | 8     | 6.6     | 7.0     | 6.8    | 6.8  | 0.04              |
| Waiwera River                      | 8     | 6.7     | 7.4     | 7.1    | 7.0  | 0.09              |
| West Hoe Stream                    | 8     | 6.5     | 7.7     | 7.0    | 7.0  | 0.13              |
| Whangamaire Stream                 | 8     | 6.8     | 7.4     | 7.0    | 7.0  | 0.07              |

Suspended sediment (mg l<sup>-1</sup>)

| Site                               | Count     | Minimum                   | Maximum | Median | Mean | Standard<br>error |  |
|------------------------------------|-----------|---------------------------|---------|--------|------|-------------------|--|
| Cascades Stream                    | 12        | 0.4                       | 6.0     | 1.9    | 2.2  | 0.51              |  |
| Hoteo River (NIWA operated)        | not measu | not measured at this site |         |        |      |                   |  |
| Kaukapakapa River                  | 12        | 12 5.2 93.0 8.5 18.7      |         |        |      |                   |  |
| Kumeu River                        | 12        | 2.4                       | 40.0    | 6.8    | 12.6 | 3.78              |  |
| Lucas Creek                        | 12        | 2.0                       | 18.0    | 4.8    | 6.2  | 1.26              |  |
| Mahurangi River (Forestry HQ)      | 12        | 0.8                       | 15.0    | 3.1    | 5.2  | 1.35              |  |
| Mahurangi River (Water Supply)     | 12        | 0.8                       | 19.0    | 2.2    | 4.8  | 1.55              |  |
| Makarau River                      | 12        | 2.6                       | 210.0   | 4.9    | 29.4 | 17.65             |  |
| Matakana River                     | 12        | 1.0                       | 33.0    | 2.4    | 6.5  | 2.65              |  |
| Ngakaroa Stream                    | 12        | 0.2                       | 15.0    | 2.4    | 3.7  | 1.17              |  |
| Oakley Creek                       | 12        | 0.8                       | 27.0    | 3.5    | 5.4  | 2.01              |  |
| Okura Creek                        | 12        | 2.7                       | 14.0    | 7.4    | 8.2  | 1.01              |  |
| Omaru Creek                        | 12        | 2.3                       | 13.0    | 4.3    | 5.7  | 0.99              |  |
| Opanuku Stream                     | 12        | 1.0                       | 46.0    | 3.0    | 7.5  | 3.63              |  |
| Otaki Creek                        | 12        | 2.0                       | 69.0    | 6.5    | 15.3 | 5.82              |  |
| Otara Creek (East Tamaki)          | 12        | 0.4                       | 33.0    | 3.7    | 6.1  | 2.52              |  |
| Otara Creek (Kennell Hill)         | 12        | 3.2                       | 21.0    | 6.5    | 7.2  | 1.49              |  |
| Oteha Stream                       | 12        | 1.7                       | 15.0    | 2.8    | 5.0  | 1.36              |  |
| Pakuranga Creek (Botany Rd)        | 12        | 2.3                       | 34.0    | 4.8    | 6.9  | 2.50              |  |
| Pakuranga Creek (Greenmount Drive) | 12        | 2.2                       | 14.0    | 3.9    | 4.8  | 0.92              |  |
| Papakura Stream                    | 12        | 0.8                       | 8.4     | 2.9    | 3.5  | 0.65              |  |
| Puhinui Stream                     | 12        | 2.0                       | 28.0    | 6.6    | 8.5  | 2.19              |  |
| Rangitopuni River (NIWA operated)  | not measu | red at this site          | )       |        |      |                   |  |
| Riverhead Forest Stream            | 12        | 0.8                       | 22.0    | 4.4    | 5.6  | 1.59              |  |
| Vaughan Stream                     | 12        | 0.8                       | 29.0    | 8.2    | 8.9  | 2.01              |  |
| Wairoa River                       | 12        | 3.0                       | 16.0    | 5.7    | 6.6  | 0.98              |  |
| Wairoa Tributary                   | 12        | 0.4                       | 19.0    | 2.5    | 3.9  | 1.42              |  |
| Waitangi River                     | 12        | 0.5                       | 93.0    | 2.0    | 10.0 | 7.57              |  |
| Waiwera River                      | 12        | 2.7                       | 100.0   | 5.6    | 16.9 | 8.00              |  |
| West Hoe Stream                    | 12        | 1.0                       | 36.0    | 3.7    | 7.0  | 2.84              |  |
| Whangamaire Stream                 | 12        | 1.1                       | 29.0    | 1.9    | 4.3  | 2.26              |  |

Turbidity (NTU)

| Site                               | Count | Minimum | Maximum | Median | Mean | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|------|-------------------|
| Cascades Stream                    | 12    | 1.3     | 45.0    | 3.3    | 9.7  | 3.72              |
| Hoteo River (NIWA operated)        | 12    | 3.7     | 20.5    | 6.2    | 8.0  | 1.47              |
| Kaukapakapa River                  | 12    | 6.9     | 55.7    | 10.8   | 15.8 | 4.01              |
| Kumeu River                        | 12    | 5.6     | 41.2    | 11.4   | 16.0 | 3.26              |
| Lucas Creek                        | 12    | 4.3     | 43.0    | 6.3    | 12.4 | 3.41              |
| Mahurangi River (Forestry HQ)      | 12    | 3.1     | 17.9    | 5.9    | 8.5  | 1.54              |
| Mahurangi River (Water Supply)     | 12    | 0.9     | 22.8    | 5.5    | 6.8  | 1.88              |
| Makarau River                      | 12    | 3.9     | 142.0   | 7.4    | 24.5 | 11.73             |
| Matakana River                     | 12    | 1.1     | 24.9    | 4.1    | 9.0  | 2.54              |
| Ngakaroa Stream                    | 12    | 0.9     | 9.2     | 1.9    | 3.3  | 0.77              |
| Oakley Creek                       | 12    | 1.2     | 19.1    | 3.2    | 4.9  | 1.35              |
| Okura Creek                        | 12    | 5.4     | 26.3    | 16.2   | 15.2 | 1.86              |
| Omaru Creek                        | 12    | 3.3     | 15.7    | 4.7    | 7.0  | 1.36              |
| Opanuku Stream                     | 12    | 2.1     | 46.6    | 7.7    | 11.1 | 3.66              |
| Otaki Creek                        | 12    | 4.4     | 26.5    | 11.3   | 13.2 | 2.18              |
| Otara Creek (East Tamaki)          | 12    | 2.0     | 23.7    | 5.7    | 6.6  | 1.66              |
| Otara Creek (Kennell Hill)         | 12    | 4.4     | 22.1    | 7.7    | 9.3  | 1.54              |
| Oteha Stream                       | 12    | 2.0     | 36.2    | 3.4    | 9.8  | 3.22              |
| Pakuranga Creek (Botany Rd)        | 12    | 5.7     | 25.0    | 7.2    | 8.7  | 1.52              |
| Pakuranga Creek (Greenmount Drive) | 12    | 2.8     | 77.9    | 5.5    | 11.8 | 6.04              |
| Papakura Stream                    | 12    | 1.1     | 14.0    | 3.7    | 5.0  | 1.16              |
| Puhinui Stream                     | 12    | 2.4     | 24.1    | 5.8    | 7.7  | 1.73              |
| Rangitopuni River (NIWA operated)  | 12    | 2.3     | 12.5    | 4.7    | 5.5  | 0.89              |
| Riverhead Forest Stream            | 12    | 4.7     | 38.0    | 10.6   | 14.9 | 2.94              |
| Vaughan Stream                     | 12    | 5.5     | 23.1    | 10.2   | 12.3 | 1.54              |
| Wairoa River                       | 12    | 3.1     | 19.6    | 7.2    | 7.9  | 1.27              |
| Wairoa Tributary                   | 12    | 3.5     | 32.9    | 5.3    | 7.5  | 2.33              |
| Waitangi River                     | 12    | 0.4     | 78.9    | 3.3    | 9.5  | 6.35              |
| Waiwera River                      | 12    | 4.5     | 82.2    | 8.3    | 18.0 | 6.34              |
| West Hoe Stream                    | 12    | 5.2     | 21.7    | 9.0    | 10.4 | 1.38              |
| Whangamaire Stream                 | 12    | 0.5     | 25.3    | 1.8    | 3.9  | 2.00              |

Ammoniacal Nitrogen (mg N I<sup>-1</sup>)

| Site                               | Count | Minimum | Maximum | Median | Mean  | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|-------|-------------------|
| Cascades Stream                    | 12    | 0.003   | 0.036   | 0.006  | 0.008 | 0.0027            |
| Hoteo River (NIWA operated)        | 12    | 0.002   | 0.029   | 0.009  | 0.012 | 0.0028            |
| Kaukapakapa River                  | 12    | 0.003   | 0.112   | 0.032  | 0.039 | 0.0083            |
| Kumeu River                        | 12    | 0.012   | 0.105   | 0.028  | 0.036 | 0.0072            |
| Lucas Creek                        | 12    | 0.010   | 0.132   | 0.029  | 0.036 | 0.0090            |
| Mahurangi River (Forestry HQ)      | 12    | 0.009   | 0.123   | 0.023  | 0.033 | 0.0086            |
| Mahurangi River (Water Supply)     | 12    | 0.005   | 0.040   | 0.018  | 0.020 | 0.0031            |
| Makarau River                      | 12    | 0.003   | 0.079   | 0.019  | 0.023 | 0.0062            |
| Matakana River                     | 12    | 0.003   | 0.040   | 0.017  | 0.017 | 0.0031            |
| Ngakaroa Stream                    | 12    | 0.003   | 0.070   | 0.016  | 0.022 | 0.0051            |
| Oakley Creek                       | 12    | 0.003   | 0.091   | 0.023  | 0.029 | 0.0066            |
| Okura Creek                        | 12    | 0.020   | 2.750   | 0.048  | 0.328 | 0.2251            |
| Omaru Creek                        | 12    | 0.013   | 7.300   | 0.029  | 0.643 | 0.6052            |
| Opanuku Stream                     | 12    | 0.005   | 0.054   | 0.015  | 0.018 | 0.0037            |
| Otaki Creek                        | 12    | 0.025   | 12.700  | 0.104  | 1.223 | 1.0455            |
| Otara Creek (East Tamaki)          | 12    | 0.006   | 0.073   | 0.022  | 0.025 | 0.0052            |
| Otara Creek (Kennell Hill)         | 12    | 0.011   | 0.112   | 0.031  | 0.043 | 0.0100            |
| Oteha Stream                       | 12    | 0.023   | 0.054   | 0.037  | 0.038 | 0.0030            |
| Pakuranga Creek (Botany Rd)        | 12    | 0.013   | 0.648   | 0.032  | 0.093 | 0.0516            |
| Pakuranga Creek (Greenmount Drive) | 12    | 0.034   | 0.343   | 0.283  | 0.238 | 0.0330            |
| Papakura Stream                    | 12    | 0.017   | 0.261   | 0.037  | 0.067 | 0.0203            |
| Puhinui Stream                     | 12    | 0.003   | 0.171   | 0.022  | 0.042 | 0.0135            |
| Rangitopuni River (NIWA operated)  | 12    | 0.013   | 0.036   | 0.019  | 0.022 | 0.0024            |
| Riverhead Forest Stream            | 12    | 0.003   | 0.041   | 0.015  | 0.017 | 0.0032            |
| Vaughan Stream                     | 12    | 0.013   | 0.114   | 0.024  | 0.041 | 0.0097            |
| Wairoa River                       | 12    | 0.003   | 0.045   | 0.015  | 0.017 | 0.0031            |
| Wairoa Tributary                   | 12    | 0.003   | 0.034   | 0.009  | 0.010 | 0.0025            |
| Waitangi River                     | 12    | 0.003   | 0.111   | 0.013  | 0.027 | 0.0091            |
| Waiwera River                      | 12    | 0.003   | 0.056   | 0.018  | 0.022 | 0.0044            |
| West Hoe Stream                    | 12    | 0.003   | 0.021   | 0.013  | 0.012 | 0.0018            |
| Whangamaire Stream                 | 12    | 0.011   | 0.140   | 0.021  | 0.031 | 0.0102            |

Total oxidised Nitrogen (mg N I<sup>-1</sup>)

| Site                               | Count | Minimum | Maximum | Median | Mean   | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|--------|-------------------|
| Cascades Stream                    | 12    | 0.004   | 0.024   | 0.013  | 0.013  | 0.0020            |
| Hoteo River (NIWA operated)        | 12    | 0.001   | 0.589   | 0.072  | 0.194  | 0.0663            |
| Kaukapakapa River                  | 12    | 0.009   | 0.966   | 0.104  | 0.196  | 0.0766            |
| Kumeu River                        | 12    | 0.025   | 0.591   | 0.147  | 0.209  | 0.0453            |
| Lucas Creek                        | 12    | 0.010   | 0.771   | 0.078  | 0.174  | 0.0643            |
| Mahurangi River (Forestry HQ)      | 12    | 0.014   | 0.484   | 0.060  | 0.125  | 0.0443            |
| Mahurangi River (Water Supply)     | 12    | 0.003   | 0.170   | 0.041  | 0.059  | 0.0164            |
| Makarau River                      | 12    | 0.007   | 0.921   | 0.070  | 0.180  | 0.0770            |
| Matakana River                     | 12    | 0.003   | 0.261   | 0.031  | 0.071  | 0.0266            |
| Ngakaroa Stream                    | 12    | 1.770   | 8.010   | 2.890  | 3.402  | 0.4741            |
| Oakley Creek                       | 12    | 0.941   | 2.690   | 1.395  | 1.541  | 0.1411            |
| Okura Creek                        | 12    | 0.098   | 12.600  | 0.437  | 2.272  | 1.1944            |
| Omaru Creek                        | 12    | 0.004   | 1.610   | 0.563  | 0.684  | 0.1581            |
| Opanuku Stream                     | 12    | 0.016   | 0.171   | 0.056  | 0.063  | 0.0142            |
| Otaki Creek                        | 12    | 0.011   | 2.480   | 0.992  | 1.040  | 0.2176            |
| Otara Creek (East Tamaki)          | 12    | 0.274   | 1.880   | 0.701  | 0.876  | 0.1708            |
| Otara Creek (Kennell Hill)         | 12    | 0.025   | 0.781   | 0.368  | 0.363  | 0.0843            |
| Oteha Stream                       | 12    | 0.096   | 0.953   | 0.212  | 0.341  | 0.0782            |
| Pakuranga Creek (Botany Rd)        | 12    | 0.307   | 1.320   | 0.884  | 0.836  | 0.1122            |
| Pakuranga Creek (Greenmount Drive) | 12    | 0.162   | 1.030   | 0.497  | 0.546  | 0.0657            |
| Papakura Stream                    | 12    | 0.024   | 2.010   | 0.225  | 0.547  | 0.1944            |
| Puhinui Stream                     | 12    | 0.006   | 1.511   | 0.327  | 0.474  | 0.1381            |
| Rangitopuni River (NIWA operated)  | 12    | 0.001   | 0.348   | 0.071  | 0.135  | 0.0399            |
| Riverhead Forest Stream            | 12    | 0.008   | 0.367   | 0.042  | 0.068  | 0.0276            |
| Vaughan Stream                     | 12    | 0.008   | 0.281   | 0.058  | 0.110  | 0.0312            |
| Wairoa River                       | 12    | 0.018   | 1.190   | 0.119  | 0.403  | 0.1351            |
| Wairoa Tributary                   | 12    | 0.006   | 0.060   | 0.042  | 0.040  | 0.0043            |
| Waitangi River                     | 12    | 0.024   | 3.390   | 1.920  | 1.621  | 0.3983            |
| Waiwera River                      | 12    | 0.003   | 0.794   | 0.057  | 0.132  | 0.0636            |
| West Hoe Stream                    | 12    | 0.003   | 0.061   | 0.010  | 0.013  | 0.0045            |
| Whangamaire Stream                 | 12    | 2.350   | 16.020  | 13.450 | 12.644 | 1.1377            |

Kjeldhal Nitrogen by calculation (mg N  $l^{-1}$ )

| Site                               | Count | Minimum | Maximum | Median | Mean | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|------|-------------------|
| Cascades Stream                    | 12    | 0.01    | 0.72    | 0.13   | 0.18 | 0.059             |
| Hoteo River (NIWA operated)        | 12    | 0.19    | 0.56    | 0.28   | 0.30 | 0.029             |
| Kaukapakapa River                  | 12    | 0.33    | 1.06    | 0.47   | 0.59 | 0.083             |
| Kumeu River                        | 12    | 0.19    | 1.26    | 0.49   | 0.62 | 0.099             |
| Lucas Creek                        | 12    | 0.10    | 0.66    | 0.36   | 0.34 | 0.043             |
| Mahurangi River (Forestry HQ)      | 12    | 0.04    | 0.50    | 0.18   | 0.23 | 0.044             |
| Mahurangi River (Water Supply)     | 12    | 0.12    | 1.05    | 0.24   | 0.32 | 0.073             |
| Makarau River                      | 12    | 0.13    | 1.82    | 0.26   | 0.45 | 0.133             |
| Matakana River                     | 12    | 0.12    | 0.49    | 0.25   | 0.28 | 0.033             |
| Ngakaroa Stream                    | 12    | 0.18    | 1.68    | 0.87   | 0.92 | 0.149             |
| Oakley Creek                       | 12    | 0.22    | 1.37    | 0.36   | 0.44 | 0.087             |
| Okura Creek                        | 12    | 0.30    | 6.40    | 0.43   | 1.35 | 0.562             |
| Omaru Creek                        | 12    | 0.19    | 113.00  | 0.31   | 9.72 | 9.389             |
| Opanuku Stream                     | 12    | 0.06    | 0.95    | 0.28   | 0.35 | 0.073             |
| Otaki Creek                        | 12    | 0.19    | 14.99   | 0.53   | 2.12 | 1.210             |
| Otara Creek (East Tamaki)          | 12    | 0.15    | 0.65    | 0.33   | 0.35 | 0.048             |
| Otara Creek (Kennell Hill)         | 12    | 0.34    | 0.67    | 0.44   | 0.48 | 0.029             |
| Oteha Stream                       | 12    | 0.21    | 0.65    | 0.37   | 0.40 | 0.039             |
| Pakuranga Creek (Botany Rd)        | 12    | 0.24    | 1.23    | 0.50   | 0.54 | 0.076             |
| Pakuranga Creek (Greenmount Drive) | 12    | 0.36    | 0.78    | 0.62   | 0.57 | 0.045             |
| Papakura Stream                    | 12    | 0.38    | 1.14    | 0.55   | 0.61 | 0.066             |
| Puhinui Stream                     | 12    | 0.23    | 1.18    | 0.42   | 0.54 | 0.079             |
| Rangitopuni River (NIWA operated)  | 12    | 0.32    | 0.59    | 0.42   | 0.42 | 0.022             |
| Riverhead Forest Stream            | 12    | 0.09    | 0.48    | 0.26   | 0.29 | 0.034             |
| Vaughan Stream                     | 12    | 0.27    | 1.49    | 0.77   | 0.76 | 0.107             |
| Wairoa River                       | 12    | 0.16    | 0.71    | 0.24   | 0.30 | 0.043             |
| Wairoa Tributary                   | 12    | 0.01    | 0.29    | 0.09   | 0.10 | 0.022             |
| Waitangi River                     | 12    | 0.21    | 1.37    | 0.27   | 0.48 | 0.113             |
| Waiwera River                      | 12    | 0.19    | 0.96    | 0.27   | 0.37 | 0.066             |
| West Hoe Stream                    | 12    | 0.02    | 0.29    | 0.12   | 0.13 | 0.025             |
| Whangamaire Stream                 | 12    | 0.90    | 5.80    | 2.35   | 2.79 | 0.464             |

Total Nitrogen (mg N I<sup>-1</sup>)

| Site                               | Count | Minimum | Maximum | Median | Mean  | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|-------|-------------------|
| Cascades Stream                    | 12    | 0.01    | 0.74    | 0.14   | 0.19  | 0.061             |
| Hoteo River (NIWA operated)        | 12    | 0.24    | 0.95    | 0.38   | 0.49  | 0.070             |
| Kaukapakapa River                  | 12    | 0.38    | 2.00    | 0.57   | 0.79  | 0.142             |
| Kumeu River                        | 12    | 0.45    | 1.60    | 0.60   | 0.83  | 0.113             |
| Lucas Creek                        | 12    | 0.24    | 1.20    | 0.53   | 0.52  | 0.075             |
| Mahurangi River (Forestry HQ)      | 12    | 0.10    | 0.62    | 0.32   | 0.35  | 0.053             |
| Mahurangi River (Water Supply)     | 12    | 0.15    | 1.10    | 0.26   | 0.38  | 0.077             |
| Makarau River                      | 12    | 0.25    | 1.90    | 0.32   | 0.63  | 0.156             |
| Matakana River                     | 12    | 0.14    | 0.65    | 0.28   | 0.36  | 0.046             |
| Ngakaroa Stream                    | 12    | 2.60    | 9.10    | 4.11   | 4.32  | 0.515             |
| Oakley Creek                       | 12    | 1.40    | 3.20    | 1.80   | 1.98  | 0.174             |
| Okura Creek                        | 12    | 0.44    | 19.00   | 1.05   | 3.62  | 1.609             |
| Omaru Creek                        | 12    | 0.34    | 113.00  | 1.23   | 10.40 | 9.328             |
| Opanuku Stream                     | 12    | 0.12    | 0.97    | 0.39   | 0.41  | 0.071             |
| Otaki Creek                        | 12    | 0.92    | 15.00   | 1.85   | 3.16  | 1.104             |
| Otara Creek (East Tamaki)          | 12    | 0.57    | 2.20    | 1.01   | 1.22  | 0.150             |
| Otara Creek (Kennell Hill)         | 12    | 0.42    | 1.40    | 0.90   | 0.84  | 0.087             |
| Oteha Stream                       | 12    | 0.39    | 1.60    | 0.65   | 0.74  | 0.102             |
| Pakuranga Creek (Botany Rd)        | 12    | 0.69    | 2.40    | 1.45   | 1.37  | 0.150             |
| Pakuranga Creek (Greenmount Drive) | 12    | 0.52    | 1.50    | 1.15   | 1.12  | 0.076             |
| Papakura Stream                    | 12    | 0.42    | 2.90    | 0.81   | 1.16  | 0.239             |
| Puhinui Stream                     | 12    | 0.25    | 2.30    | 0.84   | 1.01  | 0.182             |
| Rangitopuni River (NIWA operated)  | 12    | 0.32    | 0.88    | 0.49   | 0.55  | 0.047             |
| Riverhead Forest Stream            | 12    | 0.12    | 0.78    | 0.30   | 0.35  | 0.052             |
| Vaughan Stream                     | 12    | 0.28    | 1.70    | 0.95   | 0.87  | 0.122             |
| Wairoa River                       | 12    | 0.25    | 1.90    | 0.40   | 0.70  | 0.166             |
| Wairoa Tributary                   | 12    | 0.05    | 0.33    | 0.15   | 0.14  | 0.021             |
| Waitangi River                     | 12    | 0.25    | 3.90    | 2.16   | 2.10  | 0.449             |
| Waiwera River                      | 12    | 0.24    | 1.10    | 0.36   | 0.50  | 0.085             |
| West Hoe Stream                    | 12    | 0.01    | 0.29    | 0.14   | 0.15  | 0.026             |
| Whangamaire Stream                 | 12    | 8.00    | 20.00   | 16.50  | 15.43 | 0.991             |

Soluble reactive Phosphorus (mg P  $I^{-1}$ )

| Site                               | Count | Minimum | Maximum | Median | Mean  | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|-------|-------------------|
| Cascades Stream                    | 12    | 0.011   | 0.029   | 0.018  | 0.017 | 0.0015            |
| Hoteo River (NIWA operated)        | 12    | 0.007   | 0.021   | 0.012  | 0.013 | 0.0014            |
| Kaukapakapa River                  | 12    | 0.017   | 0.059   | 0.027  | 0.029 | 0.0035            |
| Kumeu River                        | 12    | 0.008   | 0.043   | 0.016  | 0.020 | 0.0030            |
| Lucas Creek                        | 12    | 0.007   | 0.061   | 0.014  | 0.018 | 0.0042            |
| Mahurangi River (Forestry HQ)      | 12    | 0.003   | 0.020   | 0.007  | 0.008 | 0.0015            |
| Mahurangi River (Water Supply)     | 12    | 0.003   | 0.014   | 0.010  | 0.009 | 0.0011            |
| Makarau River                      | 12    | 0.007   | 0.025   | 0.011  | 0.012 | 0.0014            |
| Matakana River                     | 12    | 0.003   | 0.020   | 0.014  | 0.013 | 0.0015            |
| Ngakaroa Stream                    | 12    | 0.003   | 0.014   | 0.006  | 0.006 | 0.0010            |
| Oakley Creek                       | 12    | 0.013   | 0.036   | 0.026  | 0.026 | 0.0018            |
| Okura Creek                        | 12    | 0.007   | 1.251   | 0.032  | 0.294 | 0.1363            |
| Omaru Creek                        | 12    | 0.015   | 0.527   | 0.022  | 0.064 | 0.0422            |
| Opanuku Stream                     | 12    | 0.003   | 0.016   | 0.012  | 0.011 | 0.0012            |
| Otaki Creek                        | 12    | 0.003   | 0.737   | 0.018  | 0.077 | 0.0601            |
| Otara Creek (East Tamaki)          | 12    | 0.007   | 0.020   | 0.014  | 0.013 | 0.0014            |
| Otara Creek (Kennell Hill)         | 12    | 0.007   | 0.023   | 0.017  | 0.016 | 0.0014            |
| Oteha Stream                       | 12    | 0.003   | 0.029   | 0.013  | 0.013 | 0.0020            |
| Pakuranga Creek (Botany Rd)        | 12    | 0.008   | 0.026   | 0.018  | 0.018 | 0.0015            |
| Pakuranga Creek (Greenmount Drive) | 12    | 0.009   | 0.043   | 0.030  | 0.029 | 0.0030            |
| Papakura Stream                    | 12    | 0.018   | 0.064   | 0.040  | 0.041 | 0.0043            |
| Puhinui Stream                     | 12    | 0.009   | 0.043   | 0.019  | 0.021 | 0.0026            |
| Rangitopuni River (NIWA operated)  | 12    | 0.009   | 0.033   | 0.016  | 0.017 | 0.0020            |
| Riverhead Forest Stream            | 12    | 0.003   | 0.026   | 0.005  | 0.007 | 0.0020            |
| Vaughan Stream                     | 12    | 0.009   | 0.026   | 0.016  | 0.016 | 0.0014            |
| Wairoa River                       | 12    | 0.009   | 0.029   | 0.015  | 0.016 | 0.0019            |
| Wairoa Tributary                   | 12    | 0.021   | 0.041   | 0.034  | 0.032 | 0.0021            |
| Waitangi River                     | 12    | 0.003   | 0.015   | 0.009  | 0.009 | 0.0009            |
| Waiwera River                      | 12    | 0.009   | 0.018   | 0.014  | 0.013 | 0.0009            |
| West Hoe Stream                    | 12    | 0.003   | 0.014   | 0.006  | 0.007 | 0.0011            |
| Whangamaire Stream                 | 12    | 0.006   | 0.014   | 0.007  | 0.008 | 0.0008            |

Total Phosphorus (mg P l<sup>-1</sup>)

| Site                               | Count | Minimum | Maximum | Median | Mean  | Standard<br>error |
|------------------------------------|-------|---------|---------|--------|-------|-------------------|
| Cascades Stream                    | 12    | 0.017   | 0.063   | 0.030  | 0.031 | 0.0038            |
| Hoteo River (NIWA operated)        | 12    | 0.027   | 0.072   | 0.042  | 0.046 | 0.0042            |
| Kaukapakapa River                  | 12    | 0.054   | 0.154   | 0.072  | 0.079 | 0.0081            |
| Kumeu River                        | 12    | 0.028   | 0.091   | 0.063  | 0.061 | 0.0057            |
| Lucas Creek                        | 12    | 0.029   | 0.109   | 0.037  | 0.045 | 0.0067            |
| Mahurangi River (Forestry HQ)      | 12    | 0.011   | 0.031   | 0.018  | 0.019 | 0.0018            |
| Mahurangi River (Water Supply)     | 12    | 0.010   | 0.056   | 0.032  | 0.034 | 0.0040            |
| Makarau River                      | 12    | 0.016   | 0.181   | 0.037  | 0.052 | 0.0134            |
| Matakana River                     | 12    | 0.018   | 0.077   | 0.032  | 0.037 | 0.0052            |
| Ngakaroa Stream                    | 12    | 0.006   | 0.045   | 0.015  | 0.019 | 0.0033            |
| Oakley Creek                       | 12    | 0.037   | 0.107   | 0.049  | 0.053 | 0.0055            |
| Okura Creek                        | 12    | 0.027   | 1.289   | 0.070  | 0.333 | 0.1382            |
| Omaru Creek                        | 12    | 0.033   | 1.563   | 0.067  | 0.190 | 0.1249            |
| Opanuku Stream                     | 12    | 0.012   | 0.062   | 0.025  | 0.029 | 0.0038            |
| Otaki Creek                        | 12    | 0.042   | 1.818   | 0.082  | 0.271 | 0.1461            |
| Otara Creek (East Tamaki)          | 12    | 0.020   | 0.114   | 0.035  | 0.041 | 0.0073            |
| Otara Creek (Kennell Hill)         | 12    | 0.042   | 0.080   | 0.055  | 0.058 | 0.0036            |
| Oteha Stream                       | 12    | 0.024   | 0.065   | 0.038  | 0.040 | 0.0032            |
| Pakuranga Creek (Botany Rd)        | 12    | 0.035   | 0.108   | 0.070  | 0.069 | 0.0066            |
| Pakuranga Creek (Greenmount Drive) | 12    | 0.052   | 0.130   | 0.089  | 0.091 | 0.0067            |
| Papakura Stream                    | 12    | 0.045   | 0.115   | 0.078  | 0.076 | 0.0052            |
| Puhinui Stream                     | 12    | 0.026   | 0.106   | 0.057  | 0.060 | 0.0077            |
| Rangitopuni River (NIWA operated)  | 12    | 0.032   | 0.167   | 0.054  | 0.068 | 0.0111            |
| Riverhead Forest Stream            | 12    | 0.012   | 0.041   | 0.019  | 0.023 | 0.0024            |
| Vaughan Stream                     | 12    | 0.032   | 0.124   | 0.053  | 0.058 | 0.0069            |
| Wairoa River                       | 12    | 0.019   | 0.096   | 0.043  | 0.044 | 0.0054            |
| Wairoa Tributary                   | 12    | 0.021   | 0.061   | 0.043  | 0.043 | 0.0029            |
| Waitangi River                     | 12    | 0.009   | 0.269   | 0.024  | 0.042 | 0.0208            |
| Waiwera River                      | 12    | 0.017   | 0.110   | 0.039  | 0.044 | 0.0069            |
| West Hoe Stream                    | 12    | 0.006   | 0.025   | 0.016  | 0.016 | 0.0017            |
| Whangamaire Stream                 | 12    | 0.013   | 0.143   | 0.018  | 0.030 | 0.0104            |

Soluble Copper (µg  $I^{-1}$ )

| Site                               | Count                     | Minimum          | Maximum | Median | Mean | Standard<br>error |  |  |
|------------------------------------|---------------------------|------------------|---------|--------|------|-------------------|--|--|
| Cascades Stream                    | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Hoteo River (NIWA operated)        | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Kaukapakapa River                  | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Kumeu River                        | 4                         | 0.97             | 1.90    | 1.10   | 1.27 | 0.218             |  |  |
| Lucas Creek                        | 12                        | 0.48             | 3.10    | 1.08   | 1.39 | 0.235             |  |  |
| Mahurangi River (Forestry HQ)      | 4                         | 0.24             | 0.45    | 0.36   | 0.35 | 0.057             |  |  |
| Mahurangi River (Water Supply)     | 4                         | 0.42             | 0.77    | 0.64   | 0.62 | 0.076             |  |  |
| Makarau River                      | 4                         | 0.48             | 1.00    | 0.57   | 0.65 | 0.118             |  |  |
| Matakana River                     | 4                         | 0.45             | 1.10    | 0.69   | 0.73 | 0.146             |  |  |
| Ngakaroa Stream                    | Not measured at this site |                  |         |        |      |                   |  |  |
| Oakley Creek                       | 12                        | 0.49             | 2.80    | 1.25   | 1.44 | 0.214             |  |  |
| Okura Creek                        | 12                        | 0.86             | 4.70    | 1.15   | 1.57 | 0.310             |  |  |
| Omaru Creek                        | 12                        | 0.91             | 3.80    | 2.05   | 2.03 | 0.218             |  |  |
| Opanuku Stream                     | Not measured at this site |                  |         |        |      |                   |  |  |
| Otaki Creek                        | 12                        | 0.43             | 3.10    | 1.20   | 1.50 | 0.257             |  |  |
| Otara Creek (East Tamaki)          | 12                        | 0.74             | 2.60    | 1.15   | 1.34 | 0.147             |  |  |
| Otara Creek (Kennell Hill)         | 12                        | 0.60             | 1.80    | 1.10   | 1.10 | 0.103             |  |  |
| Oteha Stream                       | 12                        | 1.10             | 3.40    | 1.65   | 1.91 | 0.213             |  |  |
| Pakuranga Creek (Botany Rd)        | 12                        | 0.90             | 2.60    | 1.55   | 1.50 | 0.136             |  |  |
| Pakuranga Creek (Greenmount Drive) | 11                        | 1.00             | 2.20    | 1.30   | 1.55 | 0.130             |  |  |
| Papakura Stream                    | 4                         | 0.58             | 1.20    | 0.91   | 0.90 | 0.132             |  |  |
| Puhinui Stream                     | 12                        | 0.78             | 2.90    | 1.60   | 1.62 | 0.174             |  |  |
| Rangitopuni River (NIWA operated)  | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Riverhead Forest Stream            | 4                         | 0.48             | 0.55    | 0.48   | 0.50 | 0.018             |  |  |
| Vaughan Stream                     | 12                        | 0.20             | 3.00    | 0.68   | 1.00 | 0.242             |  |  |
| Wairoa River                       | 4                         | 0.36             | 0.66    | 0.54   | 0.52 | 0.063             |  |  |
| Wairoa Tributary                   | Not measu                 | red at this site | e       |        |      |                   |  |  |
| Waitangi River                     | Not measu                 | red at this site | e       |        |      |                   |  |  |
| Waiwera River                      | 4                         | 0.47             | 0.97    | 0.73   | 0.73 | 0.139             |  |  |
| West Hoe Stream                    | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Whangamaire Stream                 | Not measu                 | red at this site | Э       |        |      |                   |  |  |

Total Copper (µg l<sup>-1</sup>)

| Site                               | Count                     | Minimum          | Maximum | Median | Mean | Standard<br>error |  |  |
|------------------------------------|---------------------------|------------------|---------|--------|------|-------------------|--|--|
| Cascades Stream                    | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Hoteo River (NIWA operated)        | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Kaukapakapa River                  | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Kumeu River                        | 4                         | 1.30             | 3.20    | 1.40   | 1.83 | 0.459             |  |  |
| Lucas Creek                        | 12                        | 0.85             | 4.90    | 1.25   | 1.94 | 0.379             |  |  |
| Mahurangi River (Forestry HQ)      | 4                         | 0.41             | 0.75    | 0.42   | 0.50 | 0.083             |  |  |
| Mahurangi River (Water Supply)     | 4                         | 0.62             | 1.00    | 0.78   | 0.80 | 0.094             |  |  |
| Makarau River                      | 4                         | 0.72             | 3.50    | 0.81   | 1.46 | 0.682             |  |  |
| Matakana River                     | 4                         | 0.78             | 1.30    | 0.93   | 0.99 | 0.111             |  |  |
| Ngakaroa Stream                    | Not measured at this site |                  |         |        |      |                   |  |  |
| Oakley Creek                       | 12                        | 0.90             | 5.80    | 2.10   | 2.44 | 0.381             |  |  |
| Okura Creek                        | 12                        | 1.00             | 6.50    | 1.85   | 2.19 | 0.423             |  |  |
| Omaru Creek                        | 12                        | 2.50             | 6.40    | 3.30   | 3.70 | 0.393             |  |  |
| Opanuku Stream                     | Not measured at this site |                  |         |        |      |                   |  |  |
| Otaki Creek                        | 12                        | 2.00             | 7.00    | 3.50   | 3.55 | 0.408             |  |  |
| Otara Creek (East Tamaki)          | 12                        | 1.10             | 5.80    | 1.65   | 2.01 | 0.364             |  |  |
| Otara Creek (Kennell Hill)         | 12                        | 1.10             | 3.60    | 1.40   | 1.73 | 0.216             |  |  |
| Oteha Stream                       | 12                        | 1.00             | 4.80    | 2.20   | 2.61 | 0.374             |  |  |
| Pakuranga Creek (Botany Rd)        | 12                        | 1.50             | 4.40    | 2.50   | 2.68 | 0.242             |  |  |
| Pakuranga Creek (Greenmount Drive) | 11                        | 1.70             | 4.20    | 1.90   | 2.37 | 0.236             |  |  |
| Papakura Stream                    | 4                         | 0.91             | 1.80    | 1.07   | 1.21 | 0.207             |  |  |
| Puhinui Stream                     | 12                        | 1.20             | 5.20    | 2.05   | 2.44 | 0.323             |  |  |
| Rangitopuni River (NIWA operated)  | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Riverhead Forest Stream            | 4                         | 0.53             | 0.80    | 0.57   | 0.62 | 0.063             |  |  |
| Vaughan Stream                     | 12                        | 0.40             | 3.60    | 1.65   | 1.74 | 0.339             |  |  |
| Wairoa River                       | 4                         | 0.53             | 0.85    | 0.74   | 0.71 | 0.068             |  |  |
| Wairoa Tributary                   | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Waitangi River                     | Not measu                 | red at this site | Э       |        |      |                   |  |  |
| Waiwera River                      | 4                         | 0.79             | 2.10    | 0.85   | 1.15 | 0.319             |  |  |
| West Hoe Stream                    | Not measu                 | red at this site | e       |        |      |                   |  |  |
| Whangamaire Stream                 | Not measu                 | red at this site | Э       |        |      |                   |  |  |

Soluble Zinc ( $\mu g l^{-1}$ )

| Site                               | Count                     | Minimum          | Maximum | Median | Mean   | Standard<br>error |  |  |
|------------------------------------|---------------------------|------------------|---------|--------|--------|-------------------|--|--|
| Cascades Stream                    | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Hoteo River (NIWA operated)        | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Kaukapakapa River                  | Not measu                 | red at this site | Э       |        |        |                   |  |  |
| Kumeu River                        | 4                         | 2.10             | 8.20    | 3.30   | 4.23   | 1.427             |  |  |
| Lucas Creek                        | 12                        | 1.00             | 7.40    | 2.40   | 3.23   | 0.659             |  |  |
| Mahurangi River (Forestry HQ)      | 4                         | 0.15             | 1.70    | 0.27   | 0.60   | 0.372             |  |  |
| Mahurangi River (Water Supply)     | 4                         | 0.93             | 2.30    | 1.60   | 1.61   | 0.324             |  |  |
| Makarau River                      | 4                         | 0.15             | 1.10    | 0.49   | 0.56   | 0.241             |  |  |
| Matakana River                     | 4                         | 0.15             | 1.40    | 0.70   | 0.74   | 0.304             |  |  |
| Ngakaroa Stream                    | Not measured at this site |                  |         |        |        |                   |  |  |
| Oakley Creek                       | 12                        | 4.20             | 33.00   | 7.75   | 13.72  | 3.077             |  |  |
| Okura Creek                        | 12                        | 1.80             | 12.00   | 4.40   | 5.23   | 0.897             |  |  |
| Omaru Creek                        | 12                        | 9.00             | 280.00  | 93.50  | 104.25 | 23.257            |  |  |
| Opanuku Stream                     | Not measured at this site |                  |         |        |        |                   |  |  |
| Otaki Creek                        | 12                        | 2.40             | 69.00   | 34.00  | 33.01  | 5.890             |  |  |
| Otara Creek (East Tamaki)          | 12                        | 3.90             | 83.00   | 17.50  | 21.58  | 6.112             |  |  |
| Otara Creek (Kennell Hill)         | 12                        | 3.10             | 29.00   | 7.10   | 9.10   | 2.112             |  |  |
| Oteha Stream                       | 12                        | 6.90             | 66.00   | 20.00  | 29.08  | 5.352             |  |  |
| Pakuranga Creek (Botany Rd)        | 12                        | 4.70             | 46.00   | 11.50  | 14.00  | 3.079             |  |  |
| Pakuranga Creek (Greenmount Drive) | 12                        | 5.60             | 21.00   | 11.00  | 11.69  | 1.408             |  |  |
| Papakura Stream                    | 4                         | 1.50             | 13.00   | 3.15   | 5.20   | 2.671             |  |  |
| Puhinui Stream                     | 12                        | 5.40             | 81.00   | 16.50  | 23.70  | 6.726             |  |  |
| Rangitopuni River (NIWA operated)  | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Riverhead Forest Stream            | 4                         | 4.00             | 23.00   | 10.65  | 12.08  | 4.344             |  |  |
| Vaughan Stream                     | 12                        | 0.87             | 21.00   | 3.70   | 5.14   | 1.625             |  |  |
| Wairoa River                       | 4                         | 0.39             | 1.50    | 1.08   | 1.01   | 0.235             |  |  |
| Wairoa Tributary                   | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Waitangi River                     | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Waiwera River                      | 4                         | 0.55             | 1.30    | 0.64   | 0.78   | 0.177             |  |  |
| West Hoe Stream                    | Not measu                 | red at this site | Э       |        |        |                   |  |  |
| Whangamaire Stream                 | Not measu                 | red at this site | 9       |        |        |                   |  |  |

Total Zinc (µg l<sup>-1</sup>)

| Site                               | Count                     | Minimum          | Maximum | Median | Mean   | Standard<br>error |  |  |
|------------------------------------|---------------------------|------------------|---------|--------|--------|-------------------|--|--|
| Cascades Stream                    | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Hoteo River (NIWA operated)        | Not measu                 | red at this site | )       |        |        |                   |  |  |
| Kaukapakapa River                  | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Kumeu River                        | 4                         | 3.30             | 13.00   | 4.10   | 6.13   | 2.312             |  |  |
| Lucas Creek                        | 12                        | 1.80             | 12.00   | 4.35   | 5.68   | 1.142             |  |  |
| Mahurangi River (Forestry HQ)      | 4                         | 0.15             | 1.10    | 0.50   | 0.56   | 0.206             |  |  |
| Mahurangi River (Water Supply)     | 4                         | 0.98             | 3.70    | 2.15   | 2.25   | 0.561             |  |  |
| Makarau River                      | 4                         | 0.76             | 7.00    | 1.19   | 2.54   | 1.494             |  |  |
| Matakana River                     | 4                         | 0.48             | 2.30    | 1.35   | 1.37   | 0.434             |  |  |
| Ngakaroa Stream                    | Not measured at this site |                  |         |        |        |                   |  |  |
| Oakley Creek                       | 12                        | 8.00             | 64.00   | 18.00  | 23.23  | 4.973             |  |  |
| Okura Creek                        | 12                        | 3.30             | 19.00   | 7.15   | 8.73   | 1.480             |  |  |
| Omaru Creek                        | 12                        | 30.00            | 400.00  | 115.00 | 149.67 | 29.944            |  |  |
| Opanuku Stream                     | Not measured at this site |                  |         |        |        |                   |  |  |
| Otaki Creek                        | 12                        | 26.00            | 87.00   | 52.00  | 53.67  | 5.501             |  |  |
| Otara Creek (East Tamaki)          | 12                        | 7.80             | 110.00  | 22.50  | 31.40  | 8.189             |  |  |
| Otara Creek (Kennell Hill)         | 12                        | 6.80             | 48.00   | 11.50  | 15.27  | 3.316             |  |  |
| Oteha Stream                       | 12                        | 10.00            | 86.00   | 31.50  | 39.58  | 7.222             |  |  |
| Pakuranga Creek (Botany Rd)        | 12                        | 12.00            | 69.00   | 22.50  | 27.42  | 4.598             |  |  |
| Pakuranga Creek (Greenmount Drive) | 12                        | 11.00            | 37.00   | 19.50  | 20.67  | 2.372             |  |  |
| Papakura Stream                    | 4                         | 2.80             | 18.00   | 4.80   | 7.60   | 3.539             |  |  |
| Puhinui Stream                     | 12                        | 9.50             | 99.00   | 26.00  | 34.96  | 7.957             |  |  |
| Rangitopuni River (NIWA operated)  | Not measu                 | red at this site | 9       |        |        |                   |  |  |
| Riverhead Forest Stream            | 4                         | 5.70             | 25.00   | 13.25  | 14.30  | 4.626             |  |  |
| Vaughan Stream                     | 12                        | 1.60             | 25.00   | 6.00   | 8.98   | 2.195             |  |  |
| Wairoa River                       | 4                         | 1.10             | 1.90    | 1.70   | 1.60   | 0.191             |  |  |
| Wairoa Tributary                   | Not measu                 | red at this site | )       |        |        |                   |  |  |
| Waitangi River                     | Not measu                 | red at this site | )       |        |        |                   |  |  |
| Waiwera River                      | 4                         | 1.10             | 4.10    | 1.75   | 2.18   | 0.668             |  |  |
| West Hoe Stream                    | Not measu                 | red at this site | )       | •      | •      | •                 |  |  |
| Whangamaire Stream                 | Not measu                 | red at this site | 9       |        |        |                   |  |  |

Soluble Lead ( $\mu g l^{-1}$ )

| Site                               | Count                     | Minimum          | Maximum | Median | Mean | Standard<br>error |  |  |
|------------------------------------|---------------------------|------------------|---------|--------|------|-------------------|--|--|
| Cascades Stream                    | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Hoteo River (NIWA operated)        | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Kaukapakapa River                  | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Kumeu River                        | 4                         | 0.11             | 0.26    | 0.14   | 0.16 | 0.035             |  |  |
| Lucas Creek                        | 12                        | 0.03             | 0.14    | 0.07   | 0.06 | 0.012             |  |  |
| Mahurangi River (Forestry HQ)      | 4                         | 0.03             | 0.03    | 0.03   | 0.03 | 0.000             |  |  |
| Mahurangi River (Water Supply)     | 4                         | 0.03             | 0.06    | 0.03   | 0.03 | 0.009             |  |  |
| Makarau River                      | 4                         | 0.03             | 0.03    | 0.03   | 0.03 | 0.000             |  |  |
| Matakana River                     | 4                         | 0.03             | 0.31    | 0.03   | 0.10 | 0.071             |  |  |
| Ngakaroa Stream                    | Not measured at this site |                  |         |        |      |                   |  |  |
| Oakley Creek                       | 12                        | 0.06             | 0.37    | 0.19   | 0.20 | 0.027             |  |  |
| Okura Creek                        | 12                        | 0.03             | 0.69    | 0.11   | 0.16 | 0.052             |  |  |
| Omaru Creek                        | 12                        | 0.03             | 0.32    | 0.19   | 0.17 | 0.028             |  |  |
| Opanuku Stream                     | Not measured at this site |                  |         |        |      |                   |  |  |
| Otaki Creek                        | 12                        | 0.03             | 0.45    | 0.14   | 0.15 | 0.037             |  |  |
| Otara Creek (East Tamaki)          | 12                        | 0.05             | 0.30    | 0.11   | 0.14 | 0.023             |  |  |
| Otara Creek (Kennell Hill)         | 12                        | 0.03             | 0.17    | 0.07   | 0.07 | 0.010             |  |  |
| Oteha Stream                       | 12                        | 0.03             | 0.18    | 0.10   | 0.10 | 0.015             |  |  |
| Pakuranga Creek (Botany Rd)        | 12                        | 0.03             | 0.19    | 0.09   | 0.10 | 0.015             |  |  |
| Pakuranga Creek (Greenmount Drive) | 12                        | 0.03             | 0.07    | 0.03   | 0.03 | 0.004             |  |  |
| Papakura Stream                    | 4                         | 0.07             | 0.14    | 0.11   | 0.11 | 0.017             |  |  |
| Puhinui Stream                     | 12                        | 0.11             | 0.31    | 0.16   | 0.18 | 0.020             |  |  |
| Rangitopuni River (NIWA operated)  | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Riverhead Forest Stream            | 4                         | 0.03             | 0.03    | 0.03   | 0.03 | 0.000             |  |  |
| Vaughan Stream                     | 12                        | 0.03             | 0.64    | 0.06   | 0.12 | 0.052             |  |  |
| Wairoa River                       | 4                         | 0.03             | 0.09    | 0.08   | 0.07 | 0.014             |  |  |
| Wairoa Tributary                   | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Waitangi River                     | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Waiwera River                      | 4                         | 0.03             | 0.03    | 0.03   | 0.03 | 0.000             |  |  |
| West Hoe Stream                    | Not measu                 | red at this site | 9       |        |      |                   |  |  |
| Whangamaire Stream                 | Not measu                 | red at this site | 9       |        |      |                   |  |  |

Total Lead ( $\mu g l^{-1}$ )

| Site                               | Count                       | Minimum                   | Maximum | Median | Mean | Standard<br>error |  |
|------------------------------------|-----------------------------|---------------------------|---------|--------|------|-------------------|--|
| Cascades Stream                    | Not measured at this site   |                           |         |        |      |                   |  |
| Hoteo River (NIWA operated)        | Not measured at this site   |                           |         |        |      |                   |  |
| Kaukapakapa River                  | Not measu                   | Not measured at this site |         |        |      |                   |  |
| Kumeu River                        | 4                           | 0.23                      | 0.89    | 0.47   | 0.51 | 0.140             |  |
| Lucas Creek                        | 12                          | 0.10                      | 0.61    | 0.17   | 0.27 | 0.054             |  |
| Mahurangi River (Forestry HQ)      | 4                           | 0.03                      | 0.09    | 0.03   | 0.04 | 0.016             |  |
| Mahurangi River (Water Supply)     | 4                           | 0.05                      | 0.16    | 0.09   | 0.10 | 0.024             |  |
| Makarau River                      | 4                           | 0.07                      | 0.91    | 0.09   | 0.29 | 0.207             |  |
| Matakana River                     | 4                           | 0.05                      | 0.93    | 0.13   | 0.31 | 0.209             |  |
| Ngakaroa Stream                    | Not measu                   | Not measured at this site |         |        |      |                   |  |
| Oakley Creek                       | 12                          | 0.55                      | 4.20    | 0.84   | 1.35 | 0.362             |  |
| Okura Creek                        | 12                          | 0.18                      | 2.70    | 0.34   | 0.56 | 0.205             |  |
| Omaru Creek                        | 12                          | 0.24                      | 1.70    | 0.74   | 0.87 | 0.158             |  |
| Opanuku Stream                     | Not measu                   | Not measured at this site |         |        |      |                   |  |
| Otaki Creek                        | 12                          | 0.53                      | 5.00    | 1.65   | 2.00 | 0.373             |  |
| Otara Creek (East Tamaki)          | 12                          | 0.22                      | 4.30    | 0.45   | 0.75 | 0.325             |  |
| Otara Creek (Kennell Hill)         | 12                          | 0.18                      | 2.00    | 0.30   | 0.44 | 0.144             |  |
| Oteha Stream                       | 12                          | 0.09                      | 0.79    | 0.23   | 0.36 | 0.079             |  |
| Pakuranga Creek (Botany Rd)        | 12                          | 0.24                      | 5.20    | 0.45   | 0.84 | 0.399             |  |
| Pakuranga Creek (Greenmount Drive) | 12                          | 0.09                      | 0.76    | 0.22   | 0.27 | 0.056             |  |
| Papakura Stream                    | 4                           | 0.17                      | 0.34    | 0.25   | 0.25 | 0.035             |  |
| Puhinui Stream                     | 12                          | 0.36                      | 1.80    | 0.58   | 0.73 | 0.129             |  |
| Rangitopuni River (NIWA operated)  | Not measured at this site   |                           |         |        |      |                   |  |
| Riverhead Forest Stream            | 4                           | 0.06                      | 0.12    | 0.08   | 0.08 | 0.014             |  |
| Vaughan Stream                     | 12                          | 0.08                      | 1.80    | 0.25   | 0.47 | 0.170             |  |
| Wairoa River                       | 4                           | 0.15                      | 0.24    | 0.18   | 0.19 | 0.022             |  |
| Wairoa Tributary                   | Not measured at this site   |                           |         |        |      |                   |  |
| Waitangi River                     | Not measured at this site   |                           |         |        |      |                   |  |
| Waiwera River                      | 4 0.10 0.41 0.12 0.19 0.075 |                           |         |        |      | 0.075             |  |
| West Hoe Stream                    | Not measured at this site   |                           |         |        |      |                   |  |
| Whangamaire Stream                 | Not measured at this site   |                           |         |        |      |                   |  |

Escherichia coli (cfu/100ml)

| Site                               | Count | Minimum | Maximum  | Median | Mean   | Standard<br>error |
|------------------------------------|-------|---------|----------|--------|--------|-------------------|
| Cascades Stream                    | 12    | 1       | 860      | 32     | 118    | 69                |
| Hoteo River (NIWA operated)        | 12    | 9       | 770      | 136    | 202    | 58                |
| Kaukapakapa River                  | 12    | 153     | 3900     | 460    | 981    | 317               |
| Kumeu River                        | 12    | 198     | 4100     | 440    | 1386   | 451               |
| Lucas Creek                        | 12    | 90      | 2100     | 270    | 477    | 165               |
| Mahurangi River (Forestry HQ)      | 12    | 63      | 5600     | 735    | 1331   | 452               |
| Mahurangi River (Water Supply)     | 12    | 54      | 3100     | 257    | 650    | 281               |
| Makarau River                      | 12    | 190     | 9800     | 615    | 1942   | 838               |
| Matakana River                     | 12    | 63      | 4100     | 395    | 924    | 383               |
| Ngakaroa Stream                    | 12    | 72      | 680      | 295    | 319    | 50                |
| Oakley Creek                       | 12    | 340     | 4500     | 985    | 1495   | 412               |
| Okura Creek                        | 12    | 27      | 3400     | 435    | 793    | 297               |
| Omaru Creek                        | 12    | 108     | 664000   | 590    | 56166  | 55258             |
| Opanuku Stream                     | 12    | 210     | 2600     | 565    | 718    | 185               |
| Otaki Creek                        | 12    | 540     | 11500000 | 3300   | 965084 | 957724            |
| Otara Creek (East Tamaki)          | 12    | 270     | 6000     | 775    | 2038   | 586               |
| Otara Creek (Kennell Hill)         | 12    | 290     | 45000    | 875    | 6002   | 3669              |
| Oteha Stream                       | 12    | 45      | 1400     | 240    | 348    | 107               |
| Pakuranga Creek (Botany Rd)        | 12    | 230     | 26000    | 1900   | 4792   | 2052              |
| Pakuranga Creek (Greenmount Drive) | 12    | 189     | 4000     | 525    | 955    | 327               |
| Papakura Stream                    | 12    | 290     | 30000    | 925    | 3499   | 2418              |
| Puhinui Stream                     | 12    | 108     | 54000    | 320    | 4808   | 4472              |
| Rangitopuni River (NIWA operated)  | 12    | 11      | 980      | 185    | 271    | 76                |
| Riverhead Forest Stream            | 12    | 27      | 760      | 280    | 295    | 69                |
| Vaughan Stream                     | 12    | 144     | 14000    | 615    | 2068   | 1124              |
| Wairoa River                       | 12    | 108     | 990      | 550    | 549    | 81                |
| Wairoa Tributary                   | 12    | 10      | 710      | 115    | 200    | 56                |
| Waitangi River                     | 12    | 153     | 7500     | 410    | 1009   | 592               |
| Waiwera River                      | 12    | 210     | 7900     | 500    | 1668   | 718               |
| West Hoe Stream                    | 12    | 5       | 200      | 32     | 48     | 16                |
| Whangamaire Stream                 | 12    | 220     | 12000    | 390    | 1336   | 970               |

## 4.3 Water Quality Indices and classes

Using the methodology described in Appendix 1, water quality indices and classes were generated for each of the 31 sites (Table 27).

The West Hoe Stream had the best water quality in 2010. The West Hoe Stream, Wairoa Tributary, Cascades Stream, Opanuku Stream and Mahurangi River (Water Supply) were the only sites classified as having excellent water quality. All of these sites except Mahurangi also had excellent water quality in 2009.

The Otaki Creek had the worst water quality of the monitoring sites in 2010, with exceedances of the target levels common and often of high magnitudes.

There are 16 sites that had the same water quality class in 2010 as in 2009 (Neale, 2009), with 15 sites showing a change in class. Of the 15 sites, five sites recorded an improvement in class whereas 10 sites recorded a decline in class. However, of these 15 sites, only four sites changed by more than one class. Mahurangi River (Water Supply) moved from fair in 2009 to excellent in 2010; the Kumeu River and the two Otara Creek sites moved from good to poor. Such large changes in water quality class are unusual and these sites should be monitored closely to determine the nature of these water quality changes.

The WQI has now been used since 2007 for reporting the results of the water quality programme. This has allowed the use of the mean WQI from 2007, 2008 and 2009 as a reference point to assess the 2010 results. This comparison identified how the WQI for a particular site in 2010 deviated from the three-year average for that site (final column in Table 27).

Whilst most sites were within +/- 10 units of the three-year average for that site, there were 10 sites that showed a deviation of greater than 10 units. This likely represents the variable nature of water quality data. The two largest deviations from the 3-year site average in 2010 was observed at the Mahurangi River (Water Supply) site, where the 2010 WQI (91.6) was 22.3 points higher than the three year mean (69.3), and the Kumeu River site, where the 2010 WQI (40.8) was 21.6 points lower than the three year mean (62.4).

Table 27 indicates that, in general, urban sites were typically ranked lower in 2010. To allow the relationship between catchment land cover and water quality to be described in more detail, the mean indices were calculated for all sites within each of the four land use types used in the monitoring programme (Table 28). The native forest sites had the best water quality indices in 2010, with the urban sites having the worst water quality indices, but the same quality class as rural sites (fair). The sites with rural and exotic forest catchments typically had water quality indices intermediate between native forest and urban sites, with the exotic forest site classified as having good water quality and rural sites as having fair water quality.

Site based water quality indices and classes based on 2010 data. Deviation is based on the difference between 2010 WQI and the mean 2007, 2008 and 2009 WQI (comparisons are not possible for the sites added in 2009 (new sites)).

|    | Site                    | Scope | Frequency | Magnitude | 2010 WQI | 2010 class | Deviation |
|----|-------------------------|-------|-----------|-----------|----------|------------|-----------|
| 1  | West Hoe Stream         | 0.0   | 0.0       | 0.0       | 100.0    | Excellent  | +5.5      |
| 2  | Wairoa Tributary        | 14.3  | 1.3       | 0.2       | 91.7     | Excellent  | New site  |
| 3  | Cascades Stream         | 14.3  | 1.3       | 0.7       | 91.7     | Excellent  | 0         |
| 4  | Opanuku Stream          | 14.3  | 1.3       | 0.8       | 91.7     | Excellent  | 0         |
| 5  | Mahurangi River (WS)    | 14.3  | 2.5       | 0.1       | 91.6     | Excellent  | +22.3     |
| 6  | Mahurangi River (FHQ)   | 28.6  | 2.5       | 1.0       | 83.4     | Good       | +11.0     |
| 7  | Hoteo River             | 28.6  | 6.0       | 0.3       | 83.1     | Good       | +14.1     |
| 8  | Ngakaroa Stream         | 28.6  | 17.5      | 26.4      | 75.4     | Good       | +9.1      |
| 9  | Wairoa River            | 42.9  | 6.3       | 1.2       | 75.0     | Good       | +14.7     |
| 10 | Waiwera Stream          | 42.9  | 6.3       | 3.3       | 74.9     | Good       | +2.8      |
| 11 | Riverhead Forest Stream | 42.9  | 9.0       | 1.4       | 74.7     | Good       | New site  |
| 12 | Rangitopuni River       | 42.9  | 13.1      | 7.4       | 73.8     | Good       | +8.3      |
| 13 | Oakley Creek            | 42.9  | 17.5      | 8.2       | 72.9     | Good       | +14.1     |
| 14 | Matakana River          | 57.1  | 6.3       | 0.2       | 66.8     | Fair       | -8.0      |
| 15 | Lucas Creek             | 57.1  | 7.4       | 2.9       | 66.7     | Fair       | +3.9      |
| 16 | Oteha Stream            | 57.1  | 12.3      | 3.8       | 66.2     | Fair       | +9.4      |
| 17 | Makarau River           | 71.4  | 10.0      | 9.0       | 58.0     | Fair       | New site  |
| 18 | Papakura Stream         | 71.4  | 22.5      | 9.7       | 56.4     | Fair       | +1.0      |
| 19 | Puhinui Stream          | 71.4  | 23.8      | 6.2       | 56.4     | Fair       | +3.3      |
| 20 | Whangamaire Stream      | 57.1  | 21.0      | 62.2      | 49.8     | Poor       | +5.1      |
| 21 | Okura Creek             | 57.1  | 24.7      | 61.1      | 49.6     | Poor       | -7.4      |
| 22 | Otara Creek (KH)        | 85.7  | 18.8      | 3.3       | 49.3     | Poor       | -8.1      |
| 23 | Otara Creek (ET)        | 85.7  | 18.8      | 3.7       | 49.3     | Poor       | -11.9     |
| 24 | Vaughan Stream          | 85.7  | 20.0      | 7.9       | 49.0     | Poor       | -8.7      |
| 25 | Waitangi Stream         | 85.7  | 20.0      | 19.7      | 47.9     | Poor       | New site  |
| 26 | Pakuranga Creek (BR)    | 85.7  | 42.5      | 17.4      | 43.9     | Poor       | -5.1      |
| 27 | Kumeu River             | 100.0 | 20.0      | 10.0      | 40.8     | Poor       | -21.6     |
| 28 | Kaukapakapa River       | 100.0 | 25.0      | 6.5       | 40.4     | Poor       | New site  |
| 29 | Pakuranga Creek (GD)    | 100.0 | 37.5      | 31.3      | 35.8     | Poor       | -16.5     |
| 30 | Omaru Creek             | 85.7  | 23.8      | 73.1      | 33.5     | Poor       | -14.5     |
| 31 | Otaki Creek             | 85.7  | 46.3      | 76.2      | 28.6     | Poor       | -17.4     |

Mean water quality index scores and water quality class for all sites within a catchment land cover type

| Land Cover (number of sites) | Scope | Frequency | Magnitude | Water quality index | Water quality class |
|------------------------------|-------|-----------|-----------|---------------------|---------------------|
| Native forest (3)            | 9.5   | 0.8       | 0.3       | 94.5                | Excellent           |
| Exotic forest (2)            | 35.7  | 5.7       | 1.2       | 79.1                | Good                |
| Rural (13)                   | 56.3  | 13.9      | 14.1      | 64.0                | Fair                |
| Urban (11)                   | 75.7  | 24.9      | 22.6      | 50.2                | Fair                |

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The data from the Rangitopuni River and Hoteo River sites are used under licence from NIWA.

# 6 Appendix 1

The communication of water quality data is often hampered by the volume of results and the complexity of the information. In this report, a water quality index developed by the Canadian Council of Ministers for the Environment (CCME) (2001) was applied to the river water quality data collected by the Auckland Council to enable improved understanding and communication of the work.

The CCME approach uses water quality results to produce four water quality indices, and these indices can be used to assign a water quality class to each monitoring site. The four indices are;

- Scope This represents the percentage of parameters that failed to meet the objective at least once during the time period under consideration (the lower this index, the better).
- Frequency This represents the percentage of all individual tests that failed to meet the objective during the time period under consideration (the lower this index, the better).
- Magnitude This represents the amount by which failed tests exceeded the objective (the lower this index, the better). This is based on the collective amount by which individual tests are out of compliance with the objectives and is scaled to be between 1 and 100. This is the most complex part of the index derivation and the reader is referred to CCME (2001) for full details.
- WQI This represents an overall water quality index based on a combination of the three indices described above. It is calculated thus;

WQI = 100 - [{ $\sqrt{(\text{Scope}^2 + \text{Frequency}^2 + \text{Magnitude}^2)}} \div 1.732]$ 

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality.

The WQI index is used by Auckland Council to assign a water quality class to each site using the following ranges;

- Greater than 90 = excellent water quality
- Between 70 and 90 = good water quality
- Between 50 and 70 = fair water quality
- Lower than 50 poor water quality

The above indices are calculated for each site based on seven water quality parameters (Table 29). The objectives against which the Auckland Council water quality data are tested are derived from the range observed at the three Auckland Council reference sites (Cascades Stream, Wairoa Tributary and West Hoe Stream) over the five years preceding this report (2005 to 2009). This represents a change from the 2007 and 2008

reports. It was considered thresholds based on the fixed period (2002 to 2006) used in the 2007 and 2008 reports, whilst providing consistency, would not capture natural variation in water quality, nor account for improvements in the measurement of parameters (for example, improved meter performance or improvements in detection limits).

The ranges at these reference sites were used as this represents the best achievable water quality in the Auckland region. Therefore, the index represents the deviation from "natural" conditions in the Auckland region, rather than indicating whether the water quality is suitable for a particular purpose.

#### Table 29

The seven water quality parameters, and their objectives, used to produce the water quality indices in this report. The objectives are based on the 98th percentile of the data from reference sites in the programme collected between 2005 and 2009.

| Parameter                       | Objective (acceptable if)           |
|---------------------------------|-------------------------------------|
| Dissolved oxygen (% saturation) | Between 75 and 120%                 |
| pH                              | Between 6.4 and 8.1                 |
| Turbidity                       | Less than 29 NTU                    |
| Ammoniacal nitrogen             | Less than 0.07 mg N $I^{-1}$        |
| Temperature                     | Less than 20 °C                     |
| Total phosphorus                | Less than 0.07 mg P I <sup>-1</sup> |
| Total nitrogen                  | Less than 1.3 mg N l <sup>-1</sup>  |

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