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Prepared by:
Brett Stansfield (Environmental Impact Assessments Ltd)
Wiea van der Zwan (Kessels Ecology)

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Peer reviewed by:
Dr. Jennifer Price and
Gerry Kessels

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Approved for release by:
Grant Blackie

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Waikato Regional Council

Review of Catchment Environmental Monitoring Programme and Clean Streams Monitoring Programme:

Benefits of Riparian Restoration in Selected Catchments of the Waikato Region

ENVIRONMENTAL IMPACT ASSESSMENTS LTD
SUSTAINABLE WATER SOLUTIONS

Kessels Ecology
SURVEY, ASSESSMENT AND RESTORATION

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Prepared by: Brett Stansfield (Environmental Impact Assessments Ltd) and Wiea van der Zwan

Reviewed by: Dr. Jennifer Price and Gerry Kessels

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www.kessels-ecology.co.nz

Executive Summary

Background

In March 2014 the River Catchment Services Group of the Waikato Regional Council requested that a summary report be provided that reviewed and assessed the existing monitoring information surrounding riparian restoration projects within the Waikato Region. Monitoring information was to be derived from five sources, namely:

- Catchment Environmental Monitoring Programme (CEMP);
- Clean Streams Monitoring Programme (CSMP);
- Regional Rivers Water Quality Monitoring Programme (RWQMP);
- Regional Ecological Monitoring of Streams Programme (REMS); and
- Suspended Sediment Yields Monitoring Programme (SSYMP).

The work request sought a review and assessment of monitoring information primarily through the CEMP and CSMP including an assessment and commentary on trends over time and across catchments. Where applicable, findings from regional data monitoring would be included to assist the recognition and interpretation of monitoring trends. A full analysis of all data was not required; however, data analysis for the CSMP and CEMP has been provided as an update to existing information and to assess trends.

In addition to assessing the existing information, the work request sought an assessment of the suitability of the CEMP and CSMP data collected for achieving the objective of measuring the effects of soil conservation and riparian measures. An assessment of the overall success or limitations of the types of monitoring was required, particularly with respect to establishing trends at all sites.

Trends shown by CEMP and CSMP data

The CSMP has been particularly effective at demonstrating improvements in water temperature and macroinvertebrate communities resulting from the restoration of the stream sites while the CEMP has demonstrated less improvement for these variables at the restored reaches. The difference in success of the programmes is likely to be due to the fact that the CSMP has focused on smaller stream catchments, most of which are less than 1000 ha and have a smaller stream order (1-2) compared to the sites of the CEMP, which mostly have catchments greater than 3000 ha and are of a higher stream order (3-5).

The CEMP programme could be more effective in demonstrating improvements if smaller catchments of lower stream order were targeted for soil conservation work. Monitoring in large catchments is unlikely to demonstrate any beneficial effects unless the entire catchments are subjected to soil conservation improvements.

Small first and second order streams are likely to demonstrate ecological improvements sooner than larger stream catchments because they have narrow stream channels which take less time to develop adequate shading to reduce downstream water temperatures. The shading also causes the stream to widen and develop a more natural meandering course which provides for a diverse assemblage of habitat types.

While the individual reaches monitored by the CEMP programme do show improvements to stream shading, streambank stability and riparian condition, this does not provide an adequate assessment of these variables at the catchment scale because the reported assessments have only focused on selected transects of the catchment. The CEMP programme is in effect a stream reach environmental monitoring programme and would be more effective if smaller catchments were targeted to measure the success of the soil conservation work. This is not to say that the CEMP restoration measures have had no effect. The CEMP restoration measures may have had other biodiversity benefits that are more difficult to measure and have not been monitored as yet, such as improvement of plant diversity, increasing habitat for terrestrial invertebrates and other indigenous fauna, and enhancing habitat connectivity.

Other monitoring programmes

Other monitoring programmes, such as the RWQMP and SSYMP, have provided supporting information as to why some biological responses may be occurring at selected sites. For example, the Pokaiwhenua River of the CEMP shows a statistically significant downward trend of MCI values over time. This decline in ecosystem health is supported by pressure indicators of the RWQMP, which shows increasing turbidity, declining water clarity and increasing total nitrogen concentrations over time. The same site is showing decreasing concentrations of total phosphorus and total ammonia. This would suggest that the former trends could be contributing to the decline in ecosystem health, however the latter trends may not be.

The Pokaiwhenua River site of the REMS programme has shown no change in MCI since monitoring commenced. This result is different to the findings of the CEMP programme; however, these differing results could be driven by substrate differences at the sites.

With the exception of the Toenepi Stream, most restoration sites of the REMS programme have shown no significant change in ecosystem health. The Toenepi Stream is a restoration site of the REMS programme that is showing a statistically and ecologically significant increase in MCI values indicating an improvement of aquatic ecosystem health. This small catchment has been the subject of an ongoing research programme into the effects of best practice farming and riparian restoration on stream water quality and ecology. It is likely that these best practices being employed by land owners of this catchment are benefiting stream health.

Conclusions

The CSMP and CEMP have identified a number of emerging trends, some of which have statistical and / or ecological significance with respect to the instream ecological success of the restoration programmes investigated. The CSMP has shown more consistent beneficial trends—of decreasing water temperature and improving macroinvertebrate communities—than the CEMP programme. This is likely to be due to the fact that smaller stream catchments are targeted in the CSMP for which beneficial results will take less time.

The CEMP programme has largely been driven by measuring effectiveness of soil conservation works for which benefits in riparian shading, streambank stability and riparian condition have been demonstrated at the selected transects. However the transect results do not provide a representative catchment wide context to the terrestrial variables that are monitored.

Recommendations

The performance of both monitoring programmes could be enhanced by measuring more biological and physical parameters (or 'variables'), which are discussed in this document. Periphyton and aquatic macrophyte cover are being measured but are not reported. Reporting of these variables in future publications is recommended. Monitoring of other variables is also recommended, such as stream bed particle size, frequency of meso-habitats, organic matter abundance, longitudinal profile variability, residual pool depth, settled sediment, water clarity, faecal coliforms, fish and terrestrial plant biodiversity. Many of these variables can be monitored at little extra cost.

It is strongly recommend that the Waikato Regional Council undertakes a stock take of its riparian restoration efforts for two variables, namely length of stream restored (as a percentage of all streams in the catchment) and mean riparian buffer width. Understanding how much riparian restoration is needed to result in ecological success is vital information for Council and should be an important component of its monitoring programmes.

It is also recommended that detailed methods of the CSMP are documented in a Waikato Regional Council technical report as this has not yet been completed and is a requirement of Council's ISO certification.

It is recommended that the CEMP programme drop monitoring of its current catchments and move to smaller catchments of similar size to the CSMP programme if it wishes to demonstrate beneficial effects of its soil conservation works. Targeting smaller stream catchments for the CEMP programme would improve the ability to demonstrate improvements of soil conservation work at the catchment scale. Greater focus should be given to terrestrial biodiversity variables in measuring overall success of the CEMP programme.

If any sites are to be added to the CSMP or CEMP it is recommended that they be monitored for three years prior to any restoration efforts are made. This helps establish the baseline stream condition prior to restoration works.

1 Introduction

This report provides an overview of two monitoring programmes, the Catchment Environmental Monitoring Programme (CEMP) and the Clean Streams Monitoring Programme (CSMP), that are specifically targeted to assess the benefits of riparian retirement and restoration on soil conservation and in stream water quality and ecology of selected stream catchments within the Waikato Region.

To support the findings of these Waikato Regional Council riparian restoration programmes, three additional programmes are also discussed in this document: the Regional Rivers Water Quality Monitoring Programme (RWQMP), Regional Ecological Monitoring of Streams Programme (REMS) and Suspended Sediment Yields Monitoring Programme (SSYMP).

All results are discussed in the context of Waikato Regional Council's Water Management Zones.

Temporal trend analysis of water temperature and macroinvertebrate community health in this report has focused only on sites of each monitoring programme that have greater or equal to 8 years' worth of monitoring data as it takes many years data to have statistical confidence in the emerging trends of water quality and ecology. Most of the trends reported for the CEMP and CSMP in this report should therefore be treated as preliminary as the data sets are still quite small, with fewer than 11 years of data.

The five monitoring programmes have been running for differing lengths of time, and have different sites and variables measured because they have different purposes. However, collectively these programmes have the capacity to support findings for each other. For example, the CEMP programme could show an improving aquatic macroinvertebrate fauna that could be supported by findings of the water quality monitoring programme which could show a temporal downward trend of suspended sediments. Alternatively, lower sediment yield sites analysed in the SSYMP could reflect stream catchments in which conservation planting and fencing is occurring in the CSMP.

Table 1 overleaf provides a general summary of each monitoring programme. Note that only those sites that meet the >7 year criterion are formally analysed in this document, but data for the other sites is also displayed. This criterion is less applicable to the suspended sediment yields regime as what is more important in this programme is the sediment / flow rating relationship.

Table 1. Details of relevant Waikato Regional Council's monitoring programmes discussed in this report.

Monitoring Programme	Record Length	Number of Sites	Variables Monitored	Purpose
Catchment Environment (CEMP)	Dependent on sites but generally 7-9 years	8: 6 restoration sites and 2 reference sites (5 restoration sites have over 7 years of data and are analysed in this report)	Riparian vegetation, % fenced, stream bank stability, stream morphology summer diurnal water temperature, suspended sediment yield, MCI	Demonstrate the long term benefits of soil conservation.
Clean Streams (CSMP)	Dependent on sites but generally 8-10 years	9 locations which each include an upstream and downstream site. (6 sites have over 7 years of data and are analysed in this report)	Summer diurnal water temperature, MCI, stream morphology	Measure ecological changes occurring as a result of implemented stream enhancement initiatives (fencing and planting)
River Water Quality (RWQMP)	Site dependent but generally between 10 to 33 years	104 (8 are relevant for this report)	17 water quality variables of which 3 are most relevant to catchment soil conservation (turbidity, suspended sediments, water clarity) and 1 is of relevance to riparian shading (water temperature)	To determine spatial and temporal trends in river water quality throughout the Waikato Region.
River Ecological (REMS)	Site dependent but generally between 8 to 18 years	60 randomly selected 51 long term analysis 24 reference (8 long term sites are relevant for this report; 6 are restoration sites)	MCI, EPT richness, %EPT, MCI, QMCI, ASPM, flow and water quality measured at selected sites	Identify temporal trends, provide a robust estimate of ecological state
Suspended Sediment Yields (SSYMP)	Site dependent but generally between 8 to 20 years	23 (3 are relevant for this report)	Sediment concentration and flow	Identify and quantify sediment sources, manage effects measure trends and effectiveness of mitigation measures.

1.1 Monitoring Sites

The REMS and RWQMP have the greatest number of sampling sites (135 and 104 respectively) followed by the suspended sediment yields regime (23 sites) followed by the CSMP (9 locations) and CEMP (8 sites). Because this report focuses on the benefits of soil conservation and river management works, the sites discussed in this report include all of those from the CSMP and CEMP with more than 7 years of data, as well as sites of the REMS, RWQMP and SSYMP monitoring programmes that either fall within the CSMP and CEMP river catchments or are restoration sites contained within the REMS monitoring programme.

Figure 1 shows a general overview of site locations for the various monitoring programmes used for this report. Note these are only general locations, for further information about upstream/downstream and reference site locations of the CEMP and CSMP programmes see Appendix I. A more detailed summary including data on monitoring parameters and frequency is included in the Excel spreadsheet accompanying this report.

Photos and site descriptions of the CEMP and CSMP monitoring programmes are provided in the Results section.

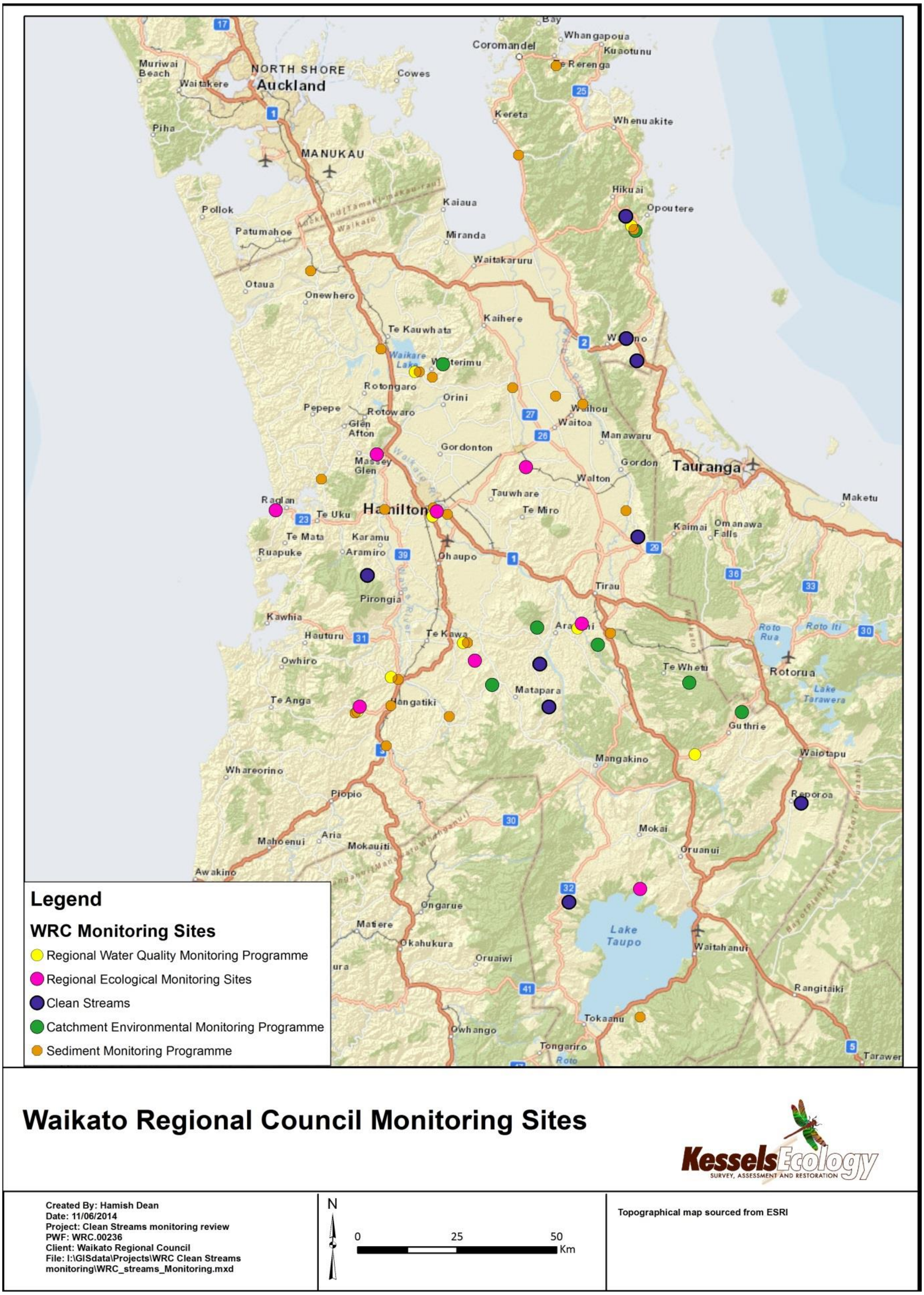

Figure 1. Monitoring sites of Waikato Regional Council monitoring programmes that are discussed in this report. Note: For CEMP and CSMP, only sites with >7 years of data are discussed.

1.2 Expected Changes to Stream Ecology

There are a number of important morphological changes that occur to a stream following riparian fencing and restoration that create changes to in stream water quality and ecology. To begin with, stock can no longer access the stream banks, so tall rank grasses can develop which can provide additional shading and stream bank protection, however as the riparian canopy (created by riparian plants) develops, these grasses and weeds become shaded out. This results in bare ground appearing which makes the stream more prone to erosion from storm events. With each storm event, the stream loses bank material into the channel as the stream widens and possibly meanders to create a more natural flow path. The stream bed substrate can change towards more fine material being present in the stream bed matrix. Pool depths can become shallower owing to the infilling of fine sediments created by deposition from storm events. If the stream is spring fed, then the hydrology of the stream (predominantly stable flows) may constrain how much sediment gets flushed from the system with subsequent high flow events.

Stream water temperatures can rise as the stream becomes wider and more solar radiation is able to reach the stream bed. However, as the canopy develops further and provides greater shading capacity, water temperatures are likely to become cooler and less variable than when the stream margins were grazed. This is because the micro climate created by the overhanging vegetation effectively insulates the stream from cold and hot temperature extremes. As the canopy develops, an understory of plants more adapted to low light conditions will grow, providing greater stream bank stability to the entire system. As the stream channel widens, it will finally reach an equilibrium width at which most flood events no longer reach bank capacity which enables the stream margins to stabilise over time.

Parkyn et al. (2010) stress that changes to stream health resulting from riparian fencing and restoration will not necessarily result in linear improvements over time. Furthermore it is expected that as the riparian vegetation shades the tall rank grasses and weeds that hold the stream bank together, some variables will initially show a decline in quality (channel width, stream bed substrate, stream bank stability, dissolved oxygen, gross primary productivity, ecosystem respiration, organic matter processing). Other variables may show an improvement followed by a decline followed by an improvement in condition (water clarity, residual pool depth, riparian rubbish, water temperature).

There are many reasons for these changes; however, the main driver is the development of the riparian canopy discussed earlier.

It should therefore be noted that any decline in stream water quality or ecology should not be viewed as an indication that a restoration project is failing, rather it is an indication that the effects of the riparian retirement are in the early stages and general improvement in the variables are expected to occur later on.

Parkyn et al. (2010) point out that to judge whether a stream has been enhanced towards a predetermined end point, depends upon measurements from the stream prior to impairment and some measure of reference conditions at a comparable undisturbed site. The authors stress the importance of gathering as much information as possible about the current and prior land use (e.g. upstream stocking densities, stream crossings, access for stock watering, condition of fencing, presence of rubbish, forest harvesting) for both the stream reach and up and downstream of the project site. This helps determine current and historical constraints to restoration potential. The authors also note that it is important to monitor the restoration reaches preferably three years prior to restoration to establish a pre restoration baseline from which future comparisons can be made.

1.3 Report Content

This report is divided into six sections, namely:

1. Introduction - outlining the current monitoring programmes, site locations and purpose;
2. Methods - an overview of the methods used for each monitoring programme;

3. Results - an overview of the findings of each monitoring programme grouped by Waikato Regional Council's management zones (Taupo, Upper Waikato, Central Waikato, Lower Waikato, Waipa and West Coast, Waihou/Piako and Coromandel). This includes findings generated from analysis of the Clean Streams Monitoring Programme, not previously undertaken;
4. Discussion - an interpretation of the results to date as well as a critique of the CSM and CEM monitoring programmes and how they could be improved to reach their primary objectives;
5. Recommendations; and
6. Conclusion.

2 Methodology

This section of the report provides an overview of the methods for the five monitoring programmes along with details of statistical methods used in this report. More in depth details of the CEMP methods can be found in Grant, Kotze & Hill (2009), RWQMP programme methods in Vant (2013), REMS programme methods in Collier & Hamer (2012) and SSYMP methods in Hoyle et al. (2011). Methods of the CSMP have not yet been formally documented. While the RWQM and REMS programmes sample for a broader spectrum of variables than the CEMP and CSMP, this report only describes variables that have relevance to soil conservation and river works effects.

2.1 Catchment Environmental Monitoring Programme

The CEMP monitors six priority catchments (Matahuru, Mangare, Pokaiwhenua, Tahunaatara, Mangatutu and Wharekawa). The Mangare Stream is used as a control site for some of the CSMP sites so has been reported with sites of that programme.

At each monitoring site, soil conservation measurements of stream bank stability, riparian characteristics and photo points are undertaken. Each year these soil conservation measures are reported using bar charts to demonstrate changes to riparian vegetation, fencing and erosion. Measurements of mean stream channel width, wetted width, stream depth and water velocity are also undertaken each year. For most sites stream depth measurements are often not possible to measure because high flows make them unsafe to gauge.

Water temperature is also measured upstream and downstream of the riparian restoration stream length to determine whether the shading provided by the riparian planting is affecting stream water temperature. The difference between the mean maximum downstream and upstream water temperature is reported each year using data generated from temperature loggers in the summer months of January to March.

All sites except the Matahuru Catchment are monitored for aquatic macroinvertebrates by taking between 5 to 10 kick net samples and compositing these into one sample. Samples are taken from riffle habitat. This provides for a statistically detectable difference precision of between 3.42 and 4.84 MCI units for each site (Stark 1998). For each site aquatic macroinvertebrates are sampled at the downstream site and these are compared to a reference site using time series line plots. All sampling sites of the CEMP except Matahuru have a hard bottomed substrate.

Selected catchments (Matahuru, Mangatutu, Wharekawa) are also sampled for suspended sediments both during base flow and storm events using loggers. This latter monitoring forms part of the SSYMP (discussed later). Each year these sites are reported for specific sediment yield, average sediment yield, % of sediment in gauged flow and % error in yield estimate.

Three sites are used as reference comparison sites of the CEMP. The reference sites reported are the Otautora Stream (a reference site for the Mangatutu Stream), the Mangare Stream (a reference site for some CSMP and CEMP sites) and the Mokaihaha Stream (a reference for the Pokaitu River and Pokaiwhenua River).

To make the results of the CEMP directly comparable to the CSMP I have subjected the water temperature and macroinvertebrate community index data to statistical testing using the Mann Kendall Trend Test and Sen Slope Estimator. This is a more appropriate statistical technique to use than what has previously been reported by the CEMP as the testing can accommodate non-normally distributed data sets. As with previous Waikato Regional Council methods, I have calculated a mean maximum seasonal water temperature for each year then subjected this data to the statistical testing. In terms of assessing statistical significance a p value of <0.05 criterion has been used. The p value is the probability of having data at least as variable as the data analysed if the null hypothesis is true. The probability of making a Type I error is therefore less than 5%.

In terms of declaring ecological significance I have followed those criteria recommended by Vant (2013) for which a change in water temperature of greater than 1% per annum is considered ecologically significant. I have also adopted the criteria recommended by Collier & Hamer (2012) for which an overall change of 15% or greater in MCI and the trend slope exceeding 1% per annum over the time period is considered ecologically significant.

2.2 Clean Streams Monitoring Programme

The CSMP has nine monitoring sites of which six (Waimata, Boom, Otupotu, Te Pahu, Waiomou and Waitete streams) have been subject to temporal trend analysis of water temperature and macroinvertebrate community health owing to their sample size being large enough ($n > 7$). There are no reference sites monitored in the CSMP however where possible, comparisons have been made with reference sites of the CEMP.

The CSMP comprises water temperature monitoring, macroinvertebrate sampling, habitat scoring and snapshot turbidity monitoring.

Water temperature and macroinvertebrate monitoring is undertaken very much the same way as the CEMP, however no reporting has previously been undertaken for these variables by Waikato Regional Council. Unlike the CEMP, the CSMP includes macroinvertebrate sampling from both soft bottomed (Waimata, Waiomou & Wils) and hard bottom streams (Te Pahu, Waitete) while a further two streams have been reported as both (Boom, Otupotu). These last two sites could have regular sediment loadings to specific reaches that could result in this changing substrate assessment.

The habitat scoring and macroinvertebrate data generated from the sampling is used to provide an overall assessment of stream condition.

Measurements of mean stream channel width, wetted width, stream depth and water velocity are also undertaken each year. For most sites stream depth measurements are often not possible to measure owing to time constraints or high flows making them unsafe to gauge.

Water samples for turbidity and suspended sediment analysis are taken downstream and upstream of the planted/fenced reach of stream to determine if water clarity changes through the reach. These samples are taken when the temperature loggers are retrieved toward the end of summer.

2.3 Regional Water Quality Monitoring Programme

The RWQMP began in 1980 and is likely to be Waikato Regional Council's most comprehensive rivers state of the environment monitoring programme. Of the 104 sites, there are eight that are in close proximity to the CEMP and CSMP sites. Of the 17 water quality variables measured by the RWQMP, 3 are most relevant to soil catchment conservation namely turbidity, water clarity and suspended sediments. These variables are monitored on a monthly basis and the data is collated and analysed for spatial and temporal trends. Flow is also estimated from either manual gaugings, telemetered sites or correlations with sites nearby. This flow data enables the Council to flow adjust the raw data to determine whether a trend in a water quality variable was due to flow.

2.4 Regional Ecological Monitoring of Streams Programme

The REMS programme has 135 sites of which six have been identified as either restored or planned to be restored. In addition to this there are a further two sites that are in close proximity to the CEMP sites. Collectively the results for these eight sites have been compared to those of the CEMP and CSMP programmes as they have greatest relevance to these programmes.

The REMS programme is a comprehensive state of the environment monitoring programme that includes both fixed and randomised sampling components. Details of the survey design can be found in Collier & Hamer (2012). Briefly, the programme includes 60 randomly selected sites which are rotated on a regular basis, 51 long term analysis sites, and 24 long term reference sites.

At each site between five to seven replicate kick net samples are taken from riffle areas of stony bottom streams or sweep nets from woody or macrophyte run habitat of soft bottomed streams. This provides for a statistical detectable difference precision of between 4.09 and 4.84 MCI units for each hard bottom site (Stark 1998). Effects of sample replication on detectable difference of the SBMCI have not been previously researched. The distinction between stream types in the protocols is based on whether reaches have surficial cover by sand/silt or pumice which is greater than or equal to 50% (soft- bottomed) or less than 50% (hard-bottomed) of bed area.

Sites are monitored for a host of variables including five biotic metrics; EPT richness, % EPT abundance, MCI, QMCI and the average score per metric which is an aggregation of the two EPT metrics and MCI benchmarked to reference condition in a particular year.

In addition to the macroinvertebrate sampling, the REMS has a habitat sampling protocol (Collier & Kelly 2005) which comprises a cover sheet of basic watershed and in stream habitat characteristics which are categorised according to a tick box method. The types of habitat and percentages sampled are recorded in this form. This is followed by a habitat assessment questionnaire comprising 10 questions of riparian vegetation zone width, vegetative protection, stream bank stability, mesohabitat frequency (run riffles, pools), channel stability, sediment deposition, velocity and depth regimes, abundance and diversity of stable in stream habitat and periphyton growth. For each question a score of between 1 and 20 is assigned depending on the condition of the stream being examined.

2.5 Suspended Sediment Yields Monitoring Programme

The suspended sediment yields monitoring programme comprises sediment and flow monitoring of 23 catchments to determine the relationships between mean annual sediment yield and event sediment yield in terms of catchment characteristics, including rainfall, runoff, slope land use and lithology.

Nine sites are monitored using auto samplers while the remaining 14 are manually sampled for suspended sediment concentration and flow. Of the 23 sites, monitored, 4 are of relevance to the CEMP (Mangatutu Stream at Walker Rd Bridge, Matahuru Stream at Myers, Matahuru at Waiterimu Rd and Wharekawa at Adams Farm Bridge) and one has relevance to the REMS programme (Mangatutu at Lethbridge Rd). Reporting for this monitoring programme is approximately once every 5 years.

3 Results

3.1 Clean Streams Monitoring Programme

Nine Clean Streams locations have been analysed in this report, which are illustrated in Figure 2 below. A brief description of each site follows, along with a description of trends over time. Detailed results of statistical analyses are provided in Appendix II.

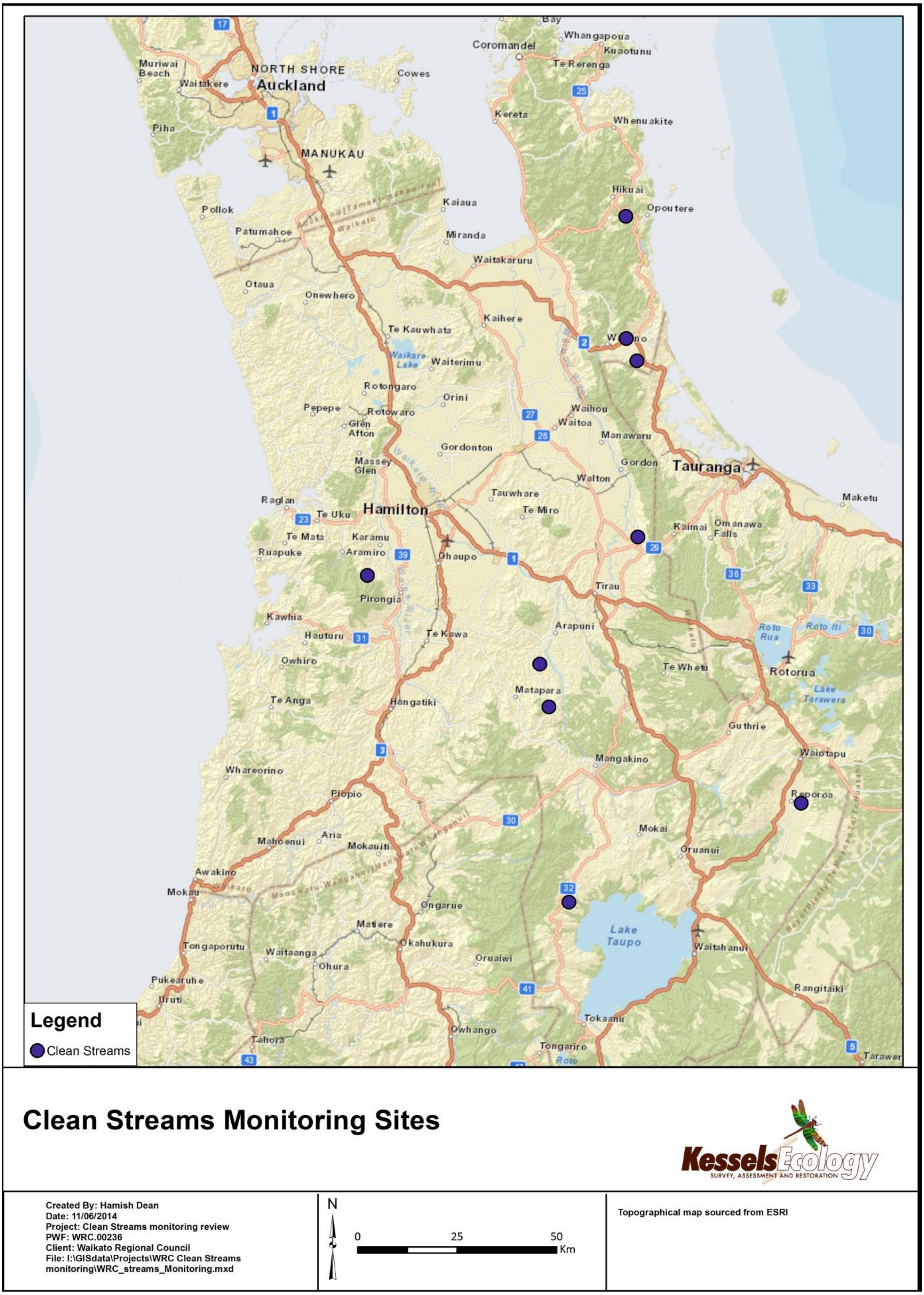

Figure 2. Clean Streams Monitoring Programme sites discussed in this report.

3.1.1 Coromandel Management Zone

3.1.1.1 Boom Stream

The Boom Stream sampling site is located within the Coromandel Water Management Zone. Boom Stream at this site has a river environment classification (REC) of warm wet, low elevation volcanic acidic pastoral low order (1st) high gradient (WW/L/VA/P/LO/HG). The site is located 12.28 km from the sea and has a catchment area of 116.4 ha.

The stream has an approximate channel width of 2.7 m, a wetted width of 1.8 m, a mean depth of 0.2 m and the substrate is a mixture of hard (gravels and cobbles) and soft bottom (sand and silts) substrates. The stream has a regular occurrence of riffle habitat and less regular occurrence of run and pool habitat owing to the shallowness of the stream.

Riparian fencing and restoration commenced in 2004 and is still continuing today. The estimated continuous retired stream length has not been physically measured before.

Riparian plants within the retired zone are predominantly indigenous with a canopy height of between 1 and 4 m with an understory of predominantly indigenous seedlings and saplings.

Figure 3. Retired reach of Boom Stream in 2004 and 2013

3.1.1.2 Stream Morphology

Figure 4 shows that the average stream channel width and wetted width have increased markedly since March 2005. Scouring and slumping of the stream banks may have caused temporary reductions in width. However the overall trend is for a widening of Boom Stream's channel and wetted width.

Monitoring of water depth has been erratic for all sites in the CSMP, however Figure 5 shows that overall there has been a decline in average stream depth since March 2004.

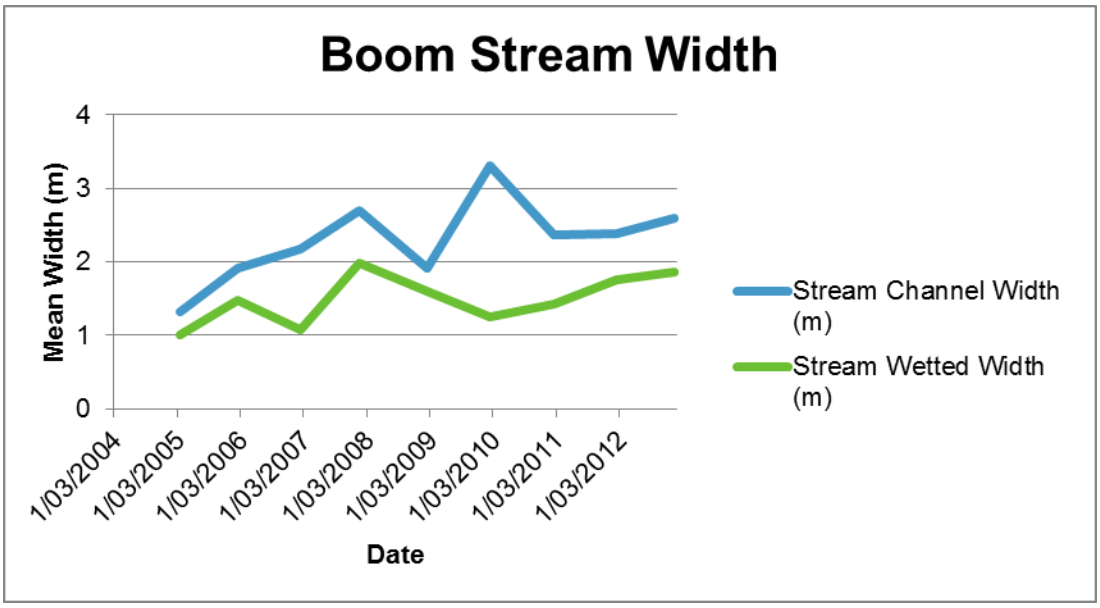

Figure 4. Changes to average stream width since riparian restoration

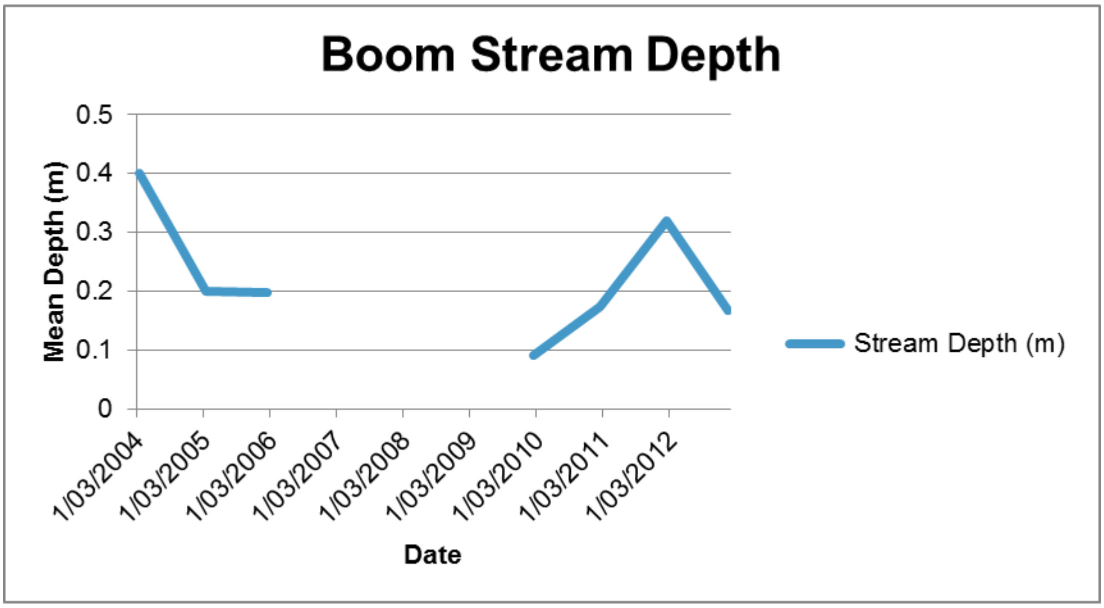

Figure 5. Average water depth of Boom Stream.

3.1.1.3 Water Temperature

In 2004 the mean maximum water temperature (from diurnal monitoring from January 1 to March 31) was approximately 1.25 °C warmer at the downstream site when compared to the same temperature indicator measured upstream of the restoration area. Monitoring undertaken in the summer of 2013 shows that this temperature difference has declined to approximately 1 °C. It is possible that the stream shading provided by the riparian plants has enabled the stream to maintain cooler water temperatures at the downstream site. Figure 6 shows the declining temperature differential between the downstream and upstream monitoring sites. This trend is not statistically or ecologically significant at present.

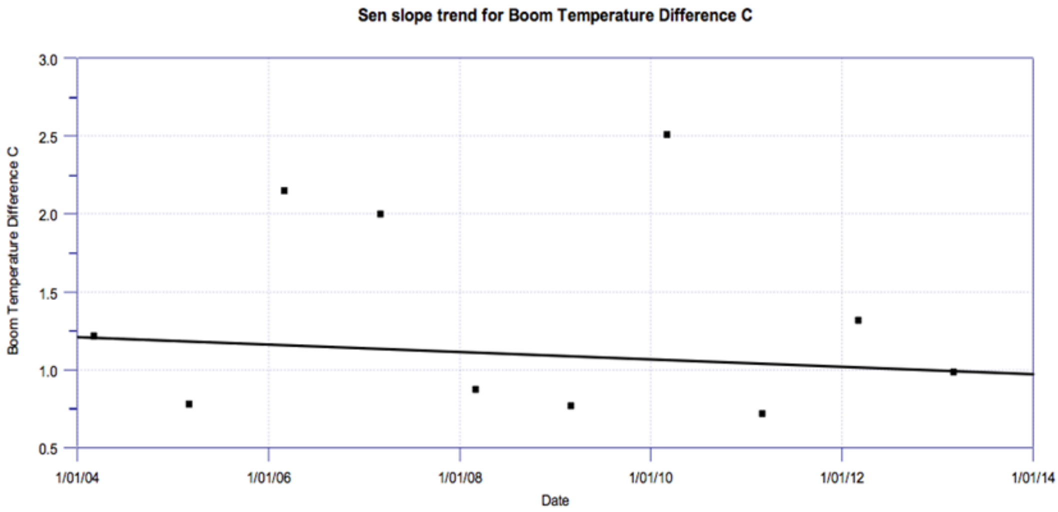

Figure 6. Mean maximum water temperature difference between downstream and upstream monitoring sites of Boom Stream.

3.1.1.4 Macroinvertebrate Community Index

In 2004 the macroinvertebrate community index value measured at the downstream site was approximately 95. While there has been some variability in MCI values generated since this time, there has been an overall improvement. The median MCI value for the complete data set is 105 which is representative of mild organic enrichment. Figure 7 shows a time series plot of MCI values since 2004. While the overall trend is not yet statistically or ecologically significant, it is likely that it will become so if the trend continues into the future.

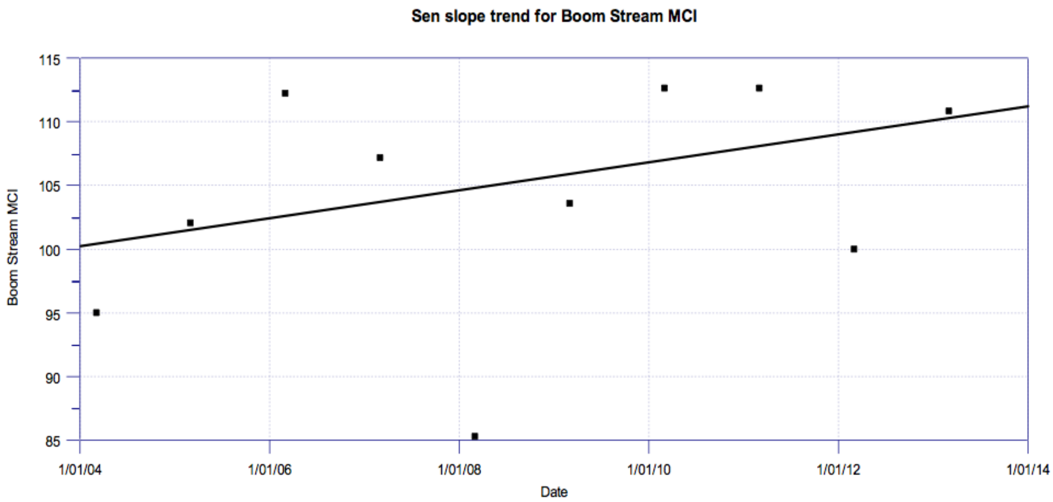

Figure 7. MCI time series plot for Boom Stream

3.1.2 Hauraki Management Zone

3.1.2.1 Waitete Stream

Figure 8. Retired reach of Waitete Stream in 2005 and 2013

The Waitete Stream is located within the Hauraki Water Management Zone. The stream has a REC classification of warm extremely wet, low elevation, volcanic acidic, pastoral low order (2nd order) medium gradient stream (WX/L/VA/P/LO/MG). The site is located 72.7 km from the sea and has a catchment area of 631.6 ha.

The stream has an approximate channel width of 6 m, a wetted width of 4 m, a mean depth of 0.38 m and the substrate comprises a mixture of hard substrates (gravels and cobbles). The stream has a regular occurrence of run and riffle habitat with occasional pools.

Riparian fencing and restoration commenced in 2005 and is still continuing today. The estimated continuous stream length that has been fenced and planted has not been physically measured as yet.

Riparian plants within the retired zone are predominantly indigenous with a canopy height of between 3 and 5 m.

3.1.2.2 Stream Morphology

Figure 9 shows that Waitete Stream channel and wetted width has increased since March 2005. Bank slumping may have given rise to the channel narrowing in February 2008 and February 2011, however the overall trend is for stream widening. Figure 10 shows that measurements of stream depth have been erratic since 2005. Generally the stream depth is slightly shallower (0.42 dropping to 0.37 m) than when monitoring first commenced.

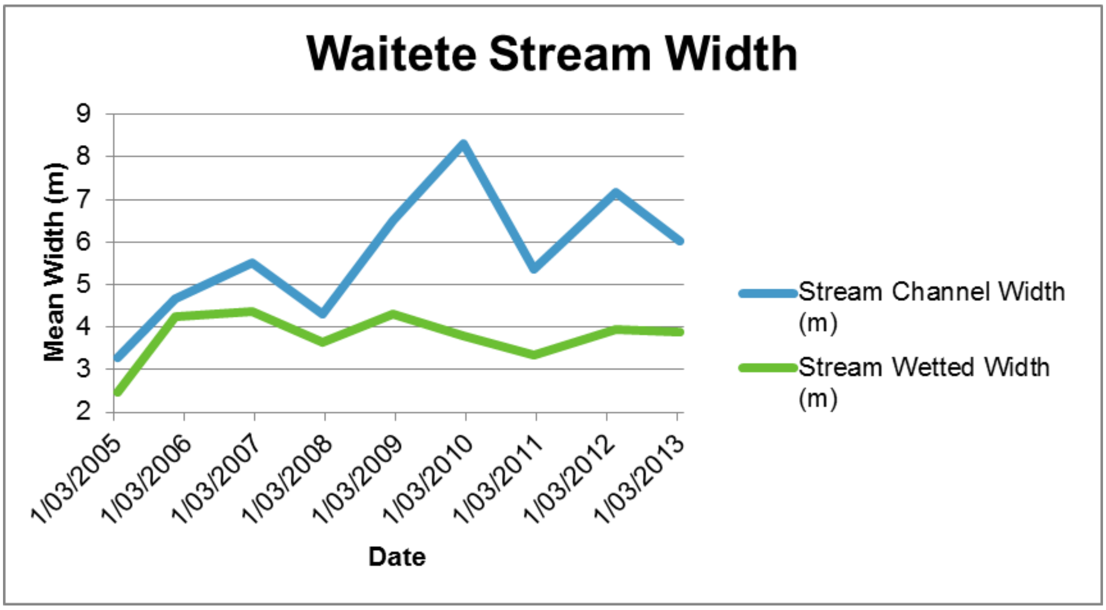

Figure 9. Mean channel and wetted width of Waitete Stream since 2005

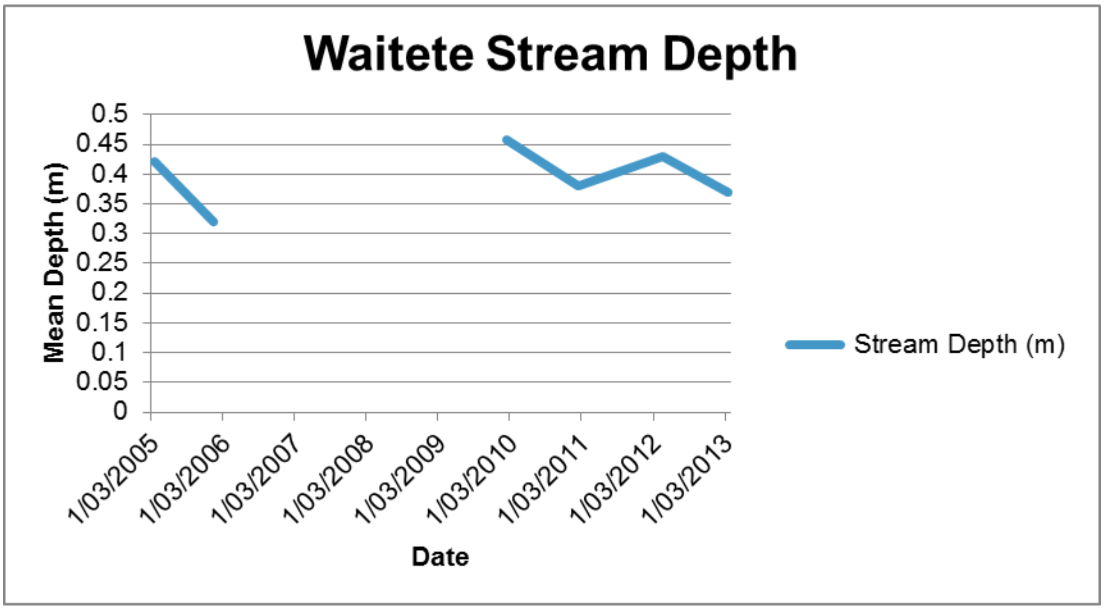

Figure 10. Mean stream depth since 2005

3.1.2.3 Water Temperature

In 2005 the mean maximum daily water temperature (from diurnal monitoring from January 1 to March 31) was approximately 4.2 °C warmer at the downstream site when compared to upstream of the restoration area. Monitoring undertaken in the summer of 2012 shows that this temperature difference has declined to approximately 3.2 °C. It is possible that the stream shading provided by the developing riparian plants has enabled the stream to maintain cooler water temperatures at the downstream site.

Figure 11 shows the declining temperature differential between the downstream and upstream monitoring sites. While this trend is close to statistical significance ($p = 0.054$) it is not yet ecologically significant. If the trend continues it is likely that it will attain statistical and ecological significance in the future.

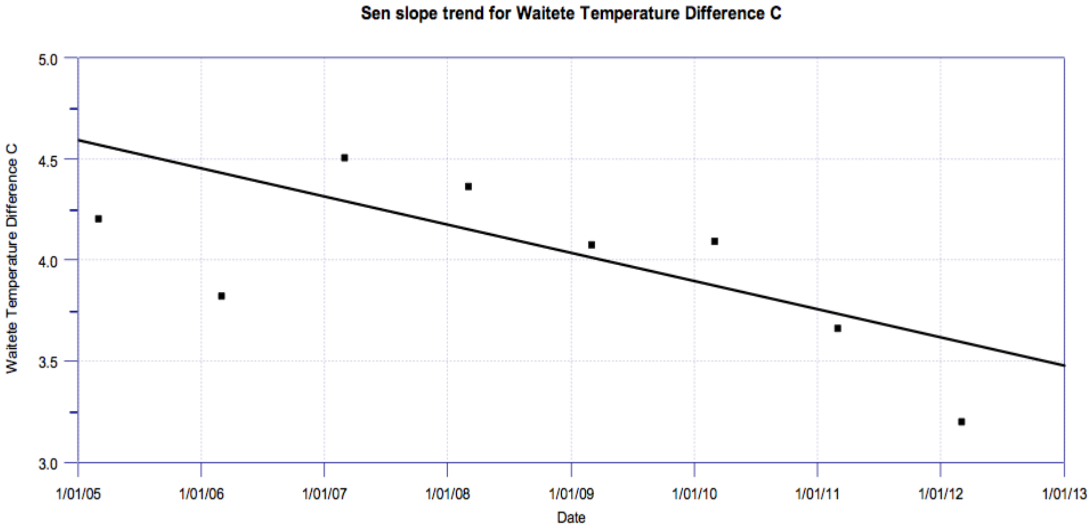

Figure 11. Mean daily maximum water temperature difference between downstream and upstream monitoring sites of the Waitete Stream.

3.1.2.4 Macroinvertebrate Community Index

In 2005 the macroinvertebrate community index value measured at the downstream site was approximately 85. While there has been some variability in MCI values generated since this time, there has been an overall improvement in ecosystem health since this time. The median MCI value for the complete data set is 86 which is representative of moderate organic enrichment.

Figure 12 shows an increasing trend in MCI values over time indicating an improvement in aquatic ecosystem health. The overall change in MCI is approximately 15 units. This trend is both statistically ($p = 0.03$) and ecologically significant using criteria specified by Collier (2013) who suggested that a MCI change of >15% and if the trend exceeded 1% per annum then it was ecologically significant. In this case the change over time represents an 18.7% improvement in MCI and the slope of the trend is 1.76% per annum. It is likely that the improvement in MCI could also be due to other contributing factors besides water temperature, such as habitat enhancement.

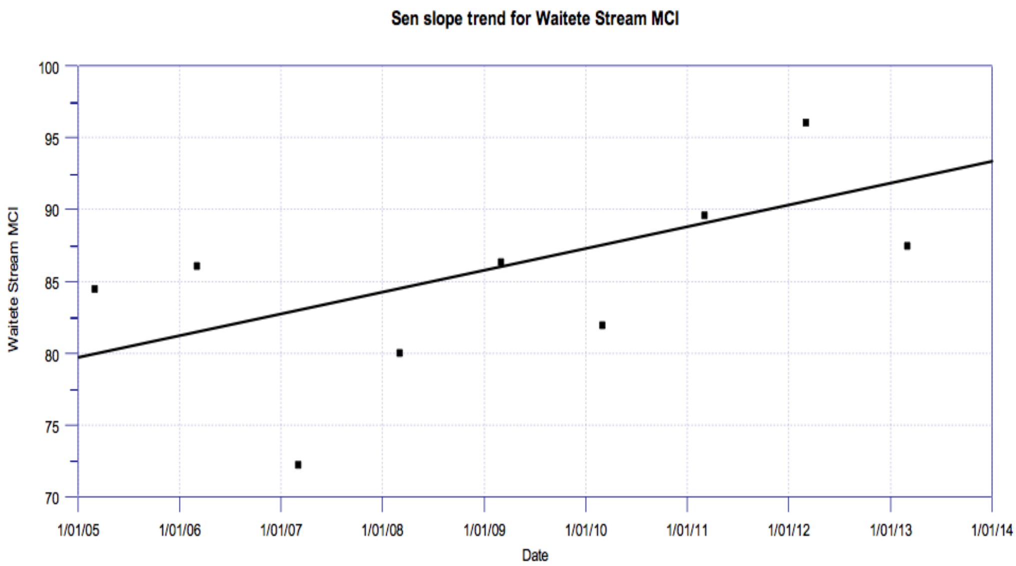

Figure 12. MCI time series plot for the Waitete Stream

3.1.2.5 Waimata Stream

The Waimata Stream is located within the Hauraki Water Management Zone. The stream has a REC classification of warm, extremely wet, low elevation, volcanic acidic, pastoral medium order (3rd order) low gradient stream (WX/L/VA/P/MO/LG). The site is located 78.1 km from the sea and has a catchment area of 1,109.7 ha.

The stream has an approximate channel width of 2.6 m, a wetted width of 1.0 m, a mean depth of 0.2 m and the substrate comprises a mixture of soft substrates (sands and silts). The stream channel provides predominantly stable flowing run habitat with no riffles or pools. Riparian fencing and restoration commenced in 2005 and is still continuing today. The estimated continuous stream length that has been retired has not been physically measured as yet. Riparian plants within the retired zone are predominantly indigenous, with a canopy height of between 1 to 3 m, and an understory of largely indigenous saplings and seedlings.


Figure 13. Retired reach of the Waimata Stream in 2005 and 2013

3.1.2.6 Changes to Stream Morphology

Figure 14 shows that stream width was not measured until January 2006. Bank slumping may have occurred in February 2008 to give rise to the narrowing of the channel however the overall trend is for Waimata Streams channel and wetted width to widen.

Figure 15 shows that mean stream depth has declined significantly since February 2003.

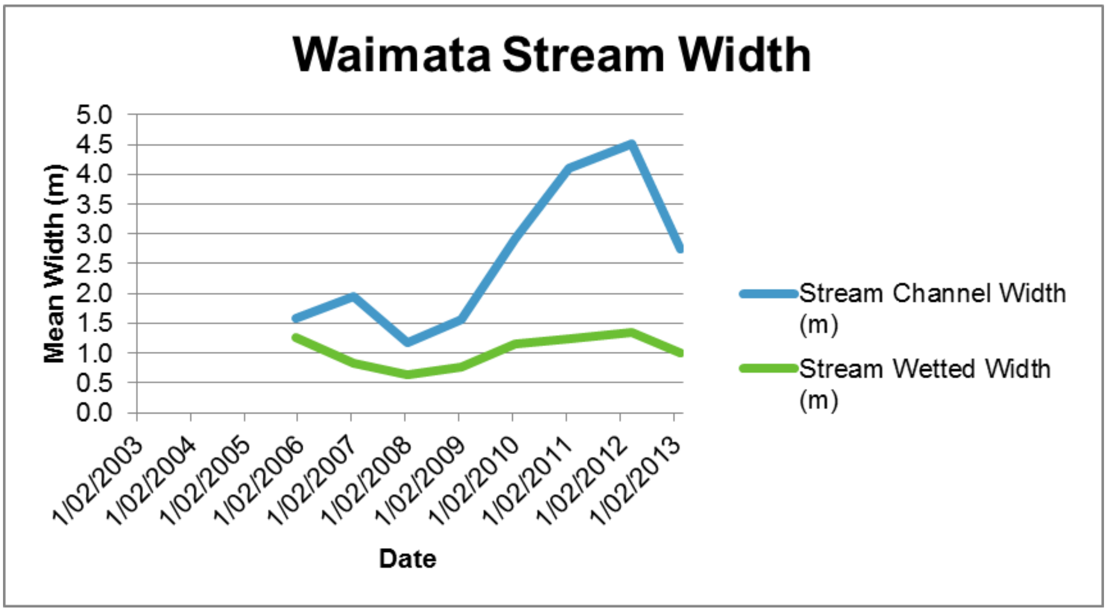

Figure 14. Changes to mean stream width since 2006

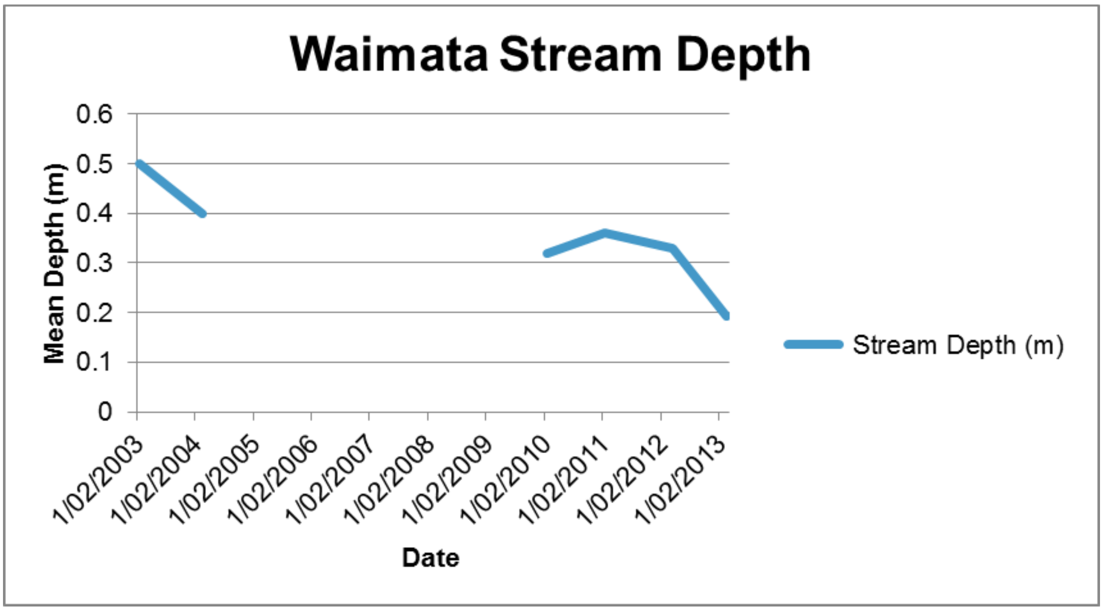

Figure 15. Changes to mean stream depth since 2006

3.1.2.7 Water Temperature

In 2004 the mean maximum daily water temperature (from diurnal monitoring from January 1 to March 31) was approximately 2 °C warmer at the downstream site when compared to the same temperature indicator measured upstream of the restoration area. Monitoring undertaken in the summer of 2012 shows that this temperature difference has declined to approximately 1.6 °C. It is possible that the stream shading provided by the developing riparian plants has enabled the stream to maintain cooler water temperatures at the downstream site. The reason for the -2 °C temperature difference measured in March 2003 is unclear. This data point looks to be an outlier when compared to the remaining data points. Figure 16 shows a fairly flat line travelling through the data series. This trend line is not considered statistically or ecologically significant. There is a lot of variability in the data series.

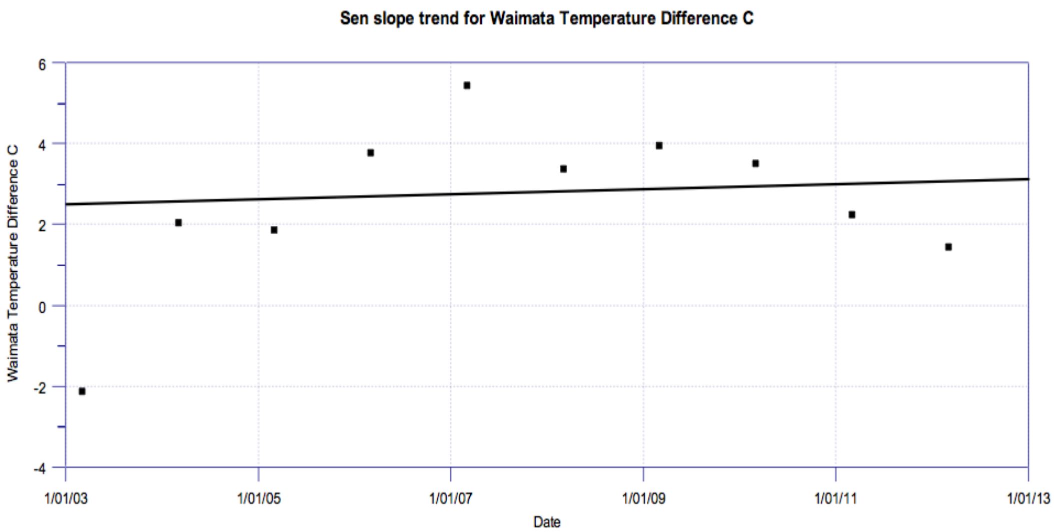

Figure 16. Mean daily maximum water temperature difference between downstream and upstream monitoring sites of the Waimata Stream.

3.1.2.8 Macroinvertebrate Community Index

In 2003 the macroinvertebrate community index value measured at the downstream site was approximately 79. While there has been some variability in MCI values generated since this time, there has been an overall improvement in ecosystem health since this time. The median MCI value for the complete data set is 85 which is representative of moderate organic enrichment. Figure 17 shows an increasing trend of MCI values since 2003 however this trend is not statistically or ecologically significant.

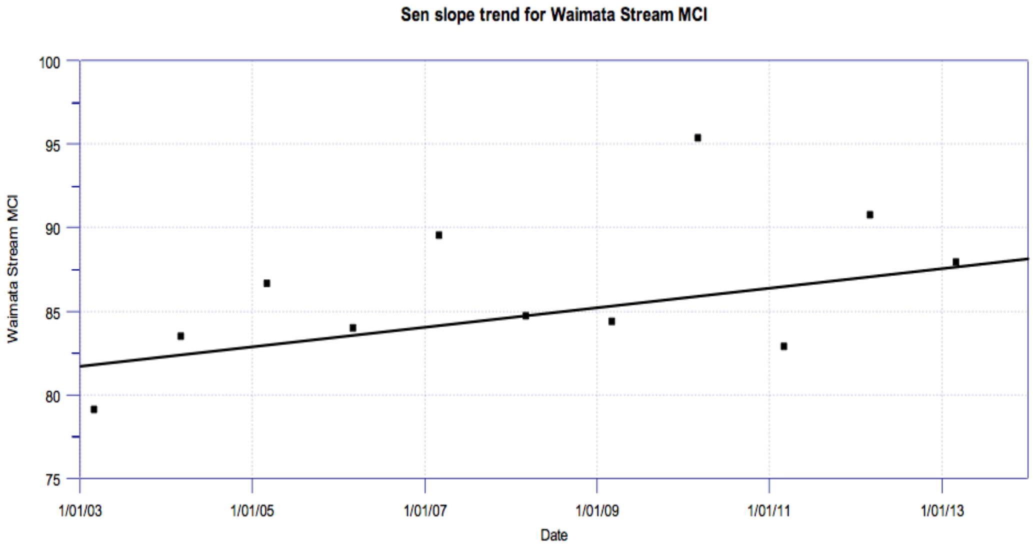

Figure 17. MCI Time series plot for the Waimata Stream

3.1.2.9 Waiomou Stream

Figure 18. Representative reach of the Waiomou Stream in 2005 and 2013

The Waiomou Stream is located within the Hauraki Water Management Zone. The stream has a REC classification of warm wet, low elevation, volcanic acidic, pastoral medium order (3rd order) low gradient stream (WW/L/VA/P/MO/LG). The site is located 128.8 km from the sea and has a catchment area of 210.8 ha.

The stream has an approximate channel width of 4 m, a wetted width of 1.4 m, a mean depth of 0.26 m and the substrate comprises a mixture of soft substrates (sands and silts). The stream provides predominantly run and pool habitat with an infrequent occurrence of riffles.

Riparian fencing and restoration commenced in 2005 and is still continuing today. The estimated continuous restored stream length has not been physically measured before.

3.1.2.10 Changes to Stream Morphology

Figure 19 shows that mean channel width of the Waiomou Stream has increased since 2005. Stream bank slumping may have given rise to the narrowing evident in February 2009 and January 2012 however the overall trend is for a widening of Waiomou Stream's channel. Figure 19 also shows that the wetted width of the Waiomou Stream has increased slightly since 2005.

Figure 20 shows that mean stream depth has been erratically monitored since 2005. Overall the mean depth in January 2013 (0.23 m) is very similar to the mean depth monitored in March 2005 (0.26 m).

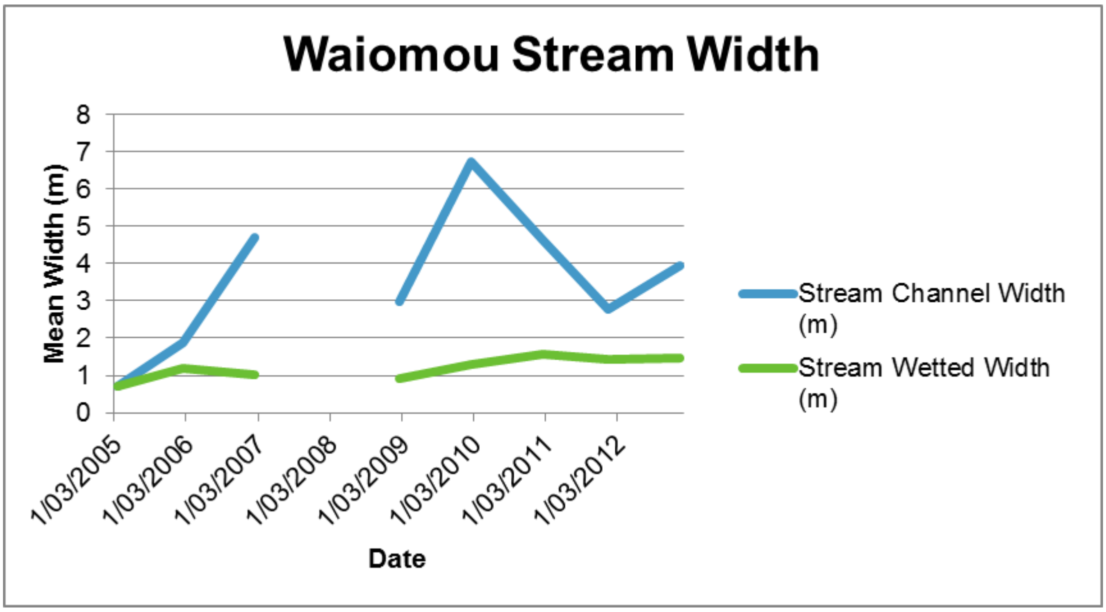

Figure 19. Changes to mean channel and wetted width since 2005

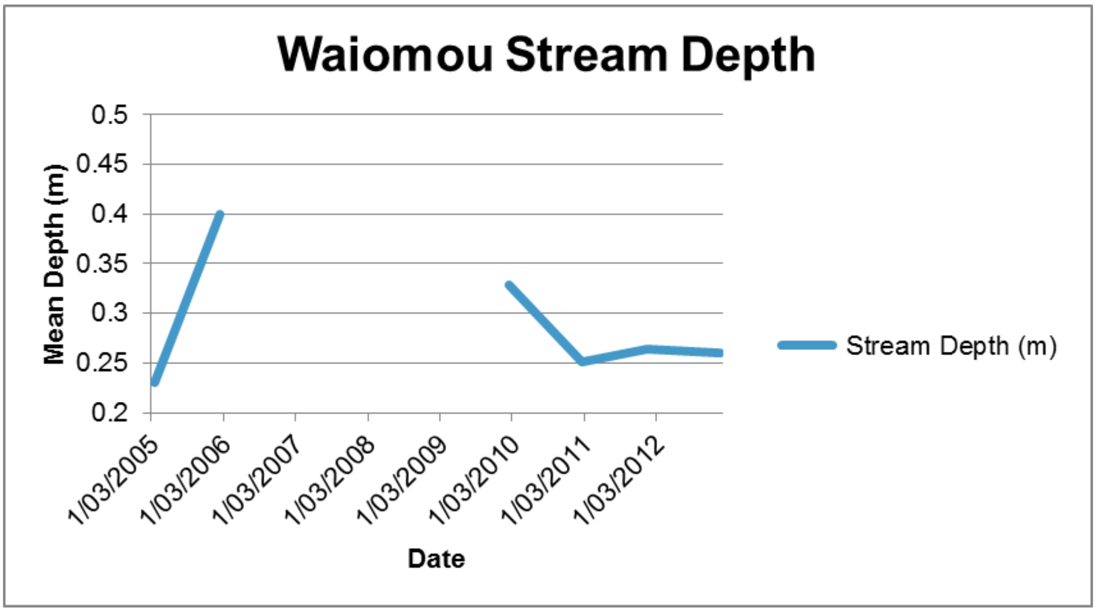

Figure 20. Changes to mean stream depth since 2005

3.1.2.11 Water Temperature

In 2004 the mean maximum daily water temperature (from diurnal monitoring from January 1 to March 31) was approximately 5.2 °C warmer at the downstream site when compared to the same temperature indicator measured upstream of the restoration area. Monitoring undertaken in the summer of 2012 shows that this temperature difference has declined to approximately 2.0 °C. It is possible that the stream shading provided by the developing riparian plants has enabled the stream to maintain cooler water temperatures at the downstream site.

Figure 21 shows a declining temperature differential between the downstream and upstream monitoring sites. This trend is statistically significant (p = 0.01) and is also environmentally significant. The slope of the trend equates to a temperature decline 12.6% per annum as an expression of the median.

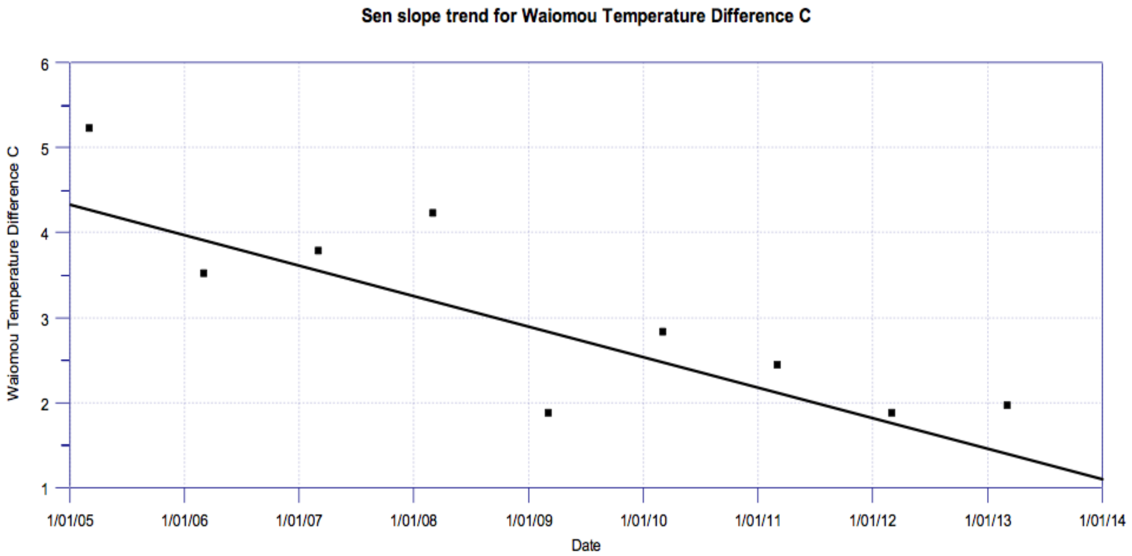

Figure 21. Mean daily maximum water temperature difference between downstream and upstream monitoring sites of the Waiomou Stream

3.1.2.12 Macroinvertebrate Community Index

In 2005 the macroinvertebrate community index value measured at the downstream site was approximately 82. While there has been some variability in MCI values generated since this time, there has been no discernible trend in ecosystem health since this time. The median MCI value for the complete data set is 83 which is representative of moderate organic enrichment.

Figure 22 shows a slight downward trend in MCI, however this trend is not considered statistically or ecologically significant.

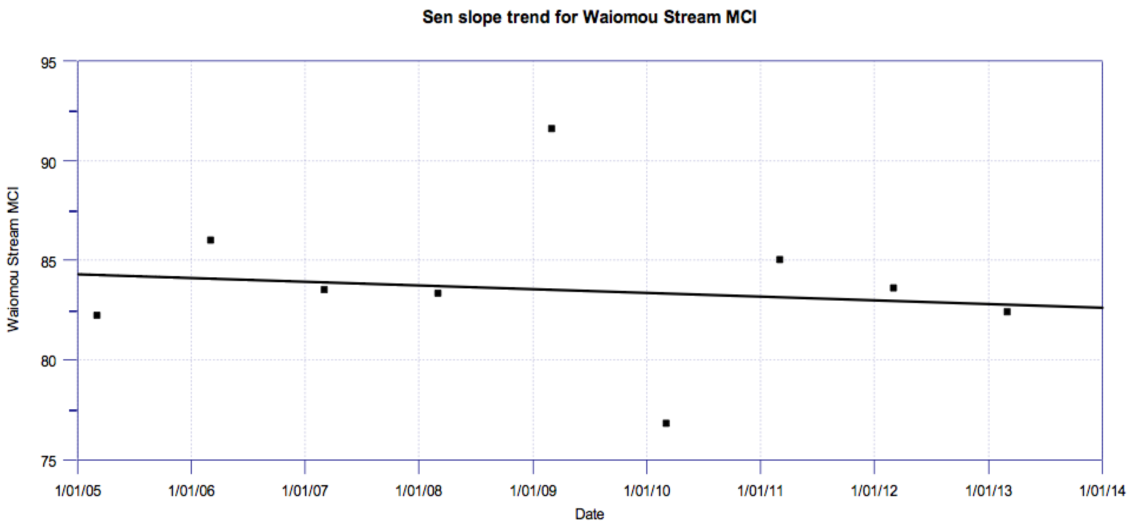

Figure 22. MCI Time Series Plot for Waiomou Stream

3.1.3 Waipa Management Zone

3.1.3.1 Te Pahu Stream

The Te Pahu Stream is located within the Waipa Water Management Zone. The stream has a REC classification of warm wet, low elevation, volcanic acidic, pastoral low order (2nd order) high gradient stream (WW/L/VA/P/LO/HG). The site is located 151.6 km from the sea and has a catchment area of 218.8 ha.

The stream has an approximate channel width of 4.3 m, a wetted width of 2.7 m, a mean depth of 0.3 m and the substrate comprises a mixture of hard substrates (gravels and cobbles). The stream provides a regular occurrence of run, riffle and pool habitat.

Riparian fencing and restoration commenced in 2003 and is still continuing today. The estimated continuous stream length has not been physically measured before.

Riparian plants within the retired zone are predominantly indigenous with a canopy height of between 3 to 5 m. Ground cover within these reaches are predominantly indigenous seedlings and saplings.

Figure 23. Retired reach of the Te Pahu Stream in 2003 and 2013

3.1.3.2 Changes to Stream Morphology

Figure 24 shows that mean channel width of Te Pahu Stream has increased since 2005. Stream bank slumping may have been responsible for the narrowing occurring during the time series however the overall trend is for Te Pahu Stream's channel to widen.

Figure 24 also shows that the stream wetted width of Te Pahu stream has declined since March 2005. Stream bank slumping and hydrological conditions would have contributed to the see sawing pattern of the time series trend. Overall the mean wetted width has declined form 2.9 m in 2005 to 2.7 m in 2013.

Figure 25 shows that stream depth has declined from 0.4 m in February 2003 to approximately 0.3m March 2013.

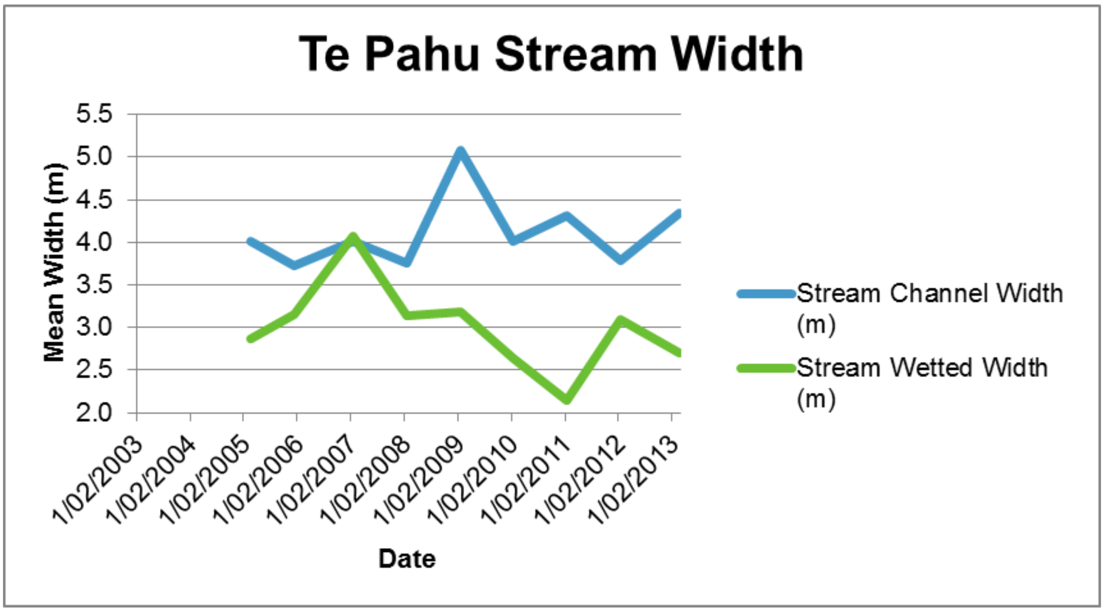

Figure 24. Changes to mean channel and wetted width since 2005

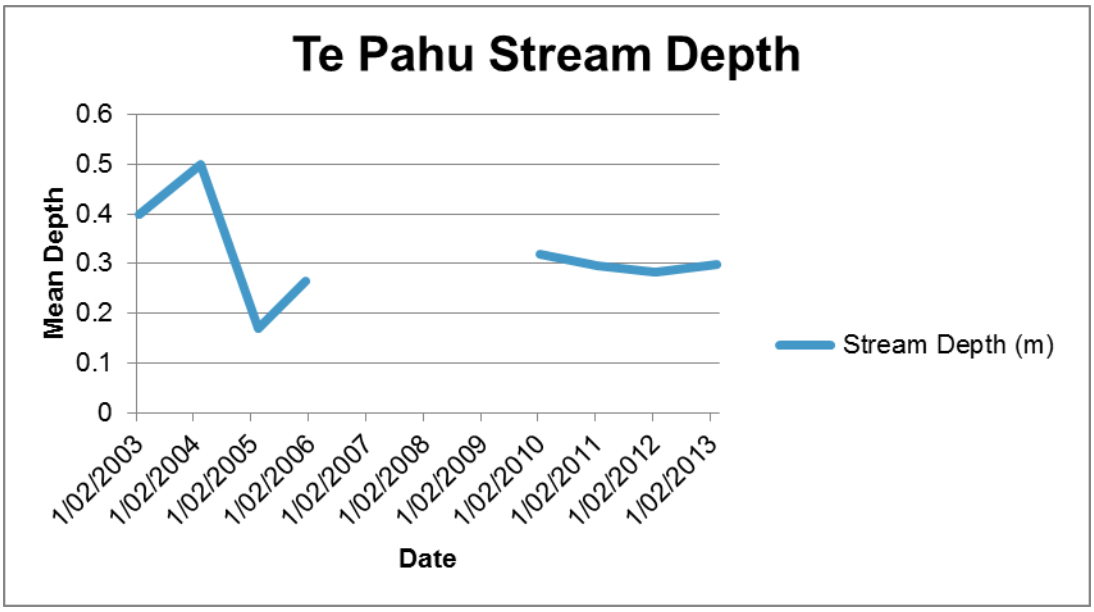

Figure 25. Changes to mean stream depth since 2003

3.1.3.3 Water Temperature

In 2003 the mean maximum daily water temperature (from diurnal monitoring from January 1 to March 31) was approximately 4.1 °C warmer at the downstream site when compared to the same temperature indicator measured upstream of the restoration area. Monitoring undertaken in the summer of 2012 shows that this temperature difference has declined to approximately 2.5 °C. It is possible that the stream shading provided by the developing riparian plants has enabled the stream to maintain cooler water temperatures at the downstream site.

Figure 26 shows a declining temperature differential over the successive years. This trend is statistically significant and environmentally significant. The slope of the trend equates to a temperature decline of 5.8% per annum as an expression of the median.

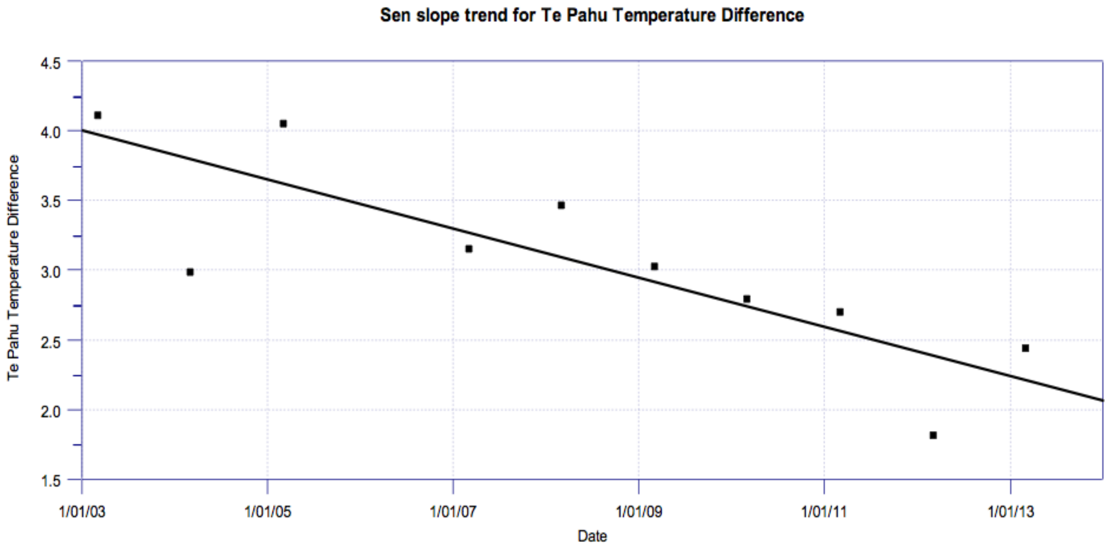

Figure 26. Mean daily maximum water temperature difference between downstream and upstream monitoring sites

3.1.3.4 Macroinvertebrate Community Index

In 2003 the macroinvertebrate community index value measured at the Te Pahu downstream site was approximately 130. While there has been some variability in MCI values generated since this time, there has been a slight downward trend in ecosystem health since this time. The median MCI value for the complete data set is 126 which is representative of excellent habitat and water quality. Figure 27 shows a slight downward trend in MCI values since monitoring commenced. This trend is not statistically or environmentally significant.

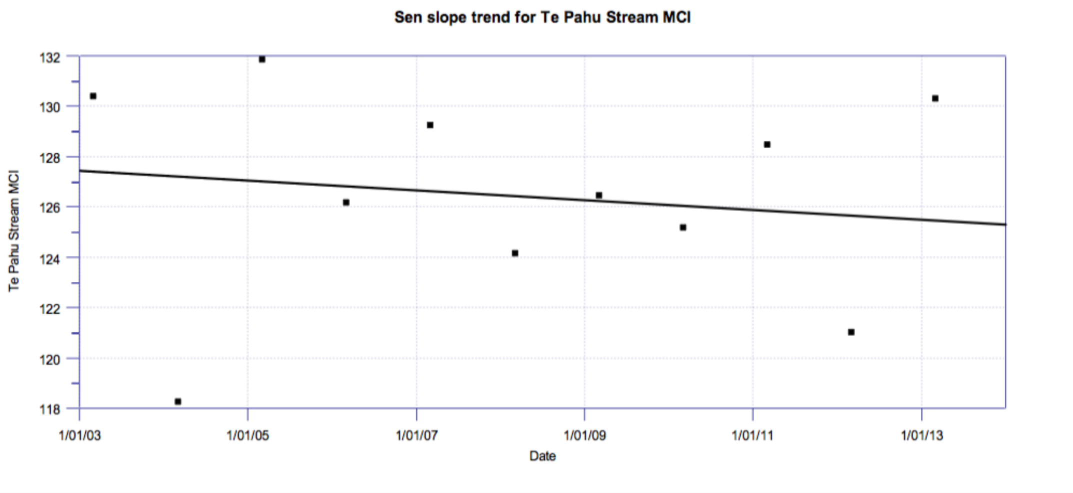

Figure 27. MCI Time Series Plot for Te Pahu Stream

3.1.4 Upper Waikato Zone

3.1.4.1 Mangare Stream

The Mangare Stream is located within the Upper Waikato Water Management Zone and although it is a site of the CEMP (discussed later), it acts as a control site for the Makomako Stream of the CSMP, so is best discussed here. The stream has a REC classification of cool wet, hill, volcanic acidic, pastoral low order (4th order) low gradient stream (CW/H/VA/P/LO/LG). The site is located 189.4 km from the sea and has a catchment area of 3422 ha.

The stream has an approximate channel width of 7 m, a wetted width of 4 m, a mean depth of 0.3 m and the substrate comprises a mixture of hard and soft substrates (gravels, cobbles, sands silts, wood). The stream provides a regular occurrence of run, riffle and pool habitat.

Riparian fencing and restoration commenced in 2006 and is still continuing today. The estimated continuous stream length that has been restored has not been physically measured before.

Riparian plants within the retired zone are a mix of indigenous and exotic species with a canopy height of between 1 and 3 m with an understory of tall rank grasses and weeds.

Figure 28. Retired reach of the Mangare Stream in 2004 and 2013.

3.1.4.2 Changes to Stream Morphology

Figure 29 shows that the stream channel width of the Mangare Stream has narrowed and then widened. Overall the stream channel width has widened by 3.4 m since 2006. Figure 29 also shows that the mean wetted width of the Mangare stream has widened slightly (0.1 m) since 2006.

Figure 30 shows that monitoring of stream channel depth has been erratic. Overall the stream depth has decreased from 0.4 m measured in February 2006 to 0.28 m measured in February 2013.

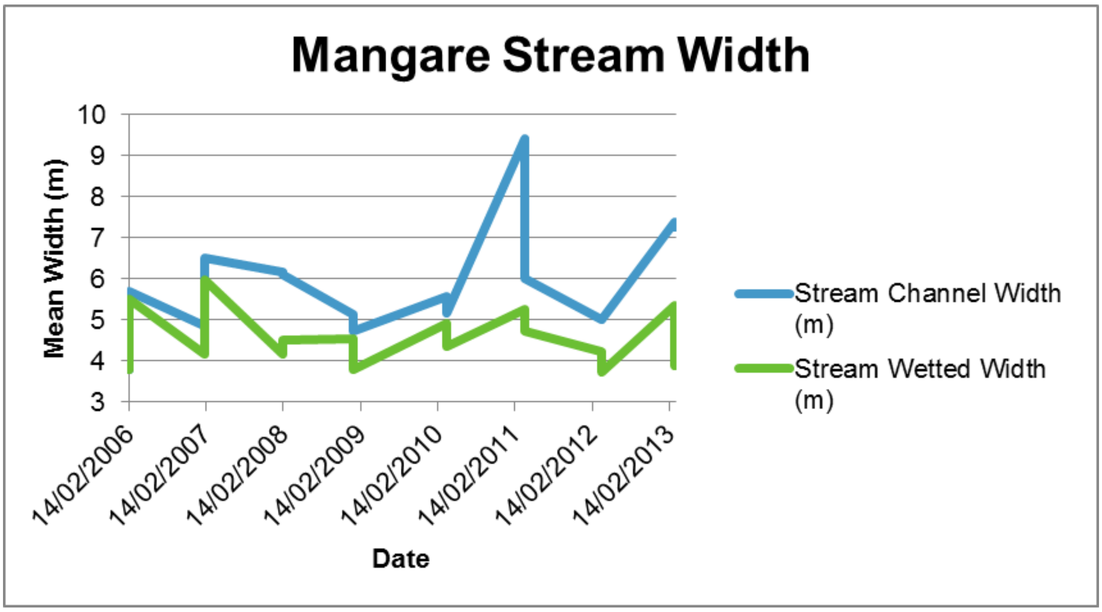

Figure 29. Changes to mean channel and wetted width since 2006

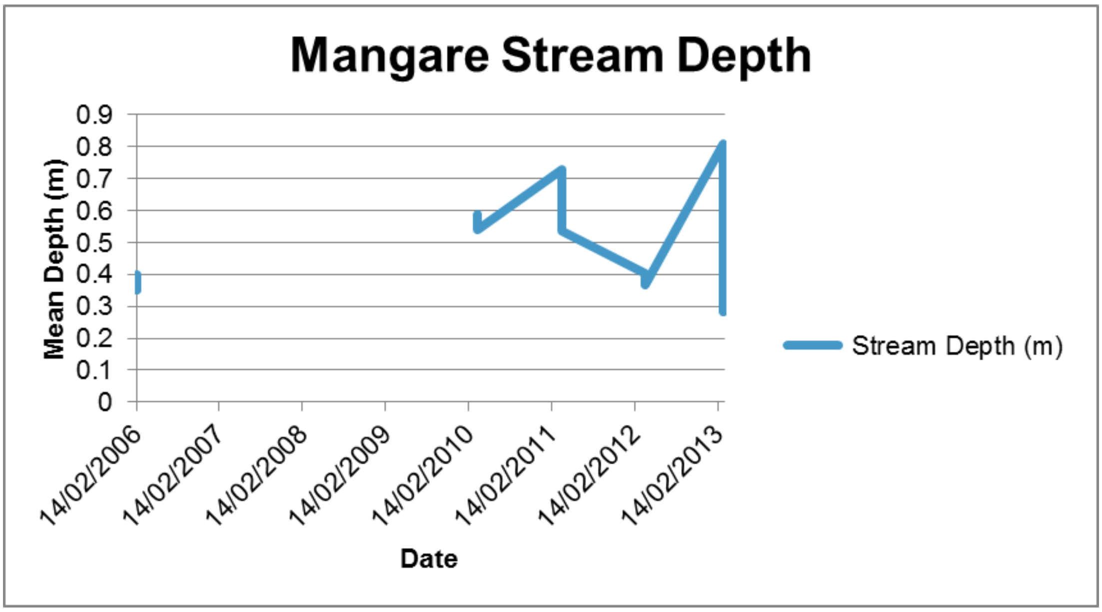

Figure 30. Changes to mean stream depth since 2006

3.1.4.3 Water Temperature and Macroinvertebrate Community Index

Because the Mangare Stream has been monitored since 2006, the data set is quite small (n = 7) therefore the site has not been statistically analysed for time series trends of water temperature or macroinvertebrate community health. The following charts illustrate the general trends for these variables.

The Mangare Stream has a median MCI of 96 indicating a macroinvertebrate community characteristic of moderate organic enrichment. Figure 31 shows that MCI values have improved slightly since monitoring commenced in 2006.

Figure 32 shows a declining temperature differential over the successive years from approximately -0.2 °C in 2006 to -1.2 °C in 2012.

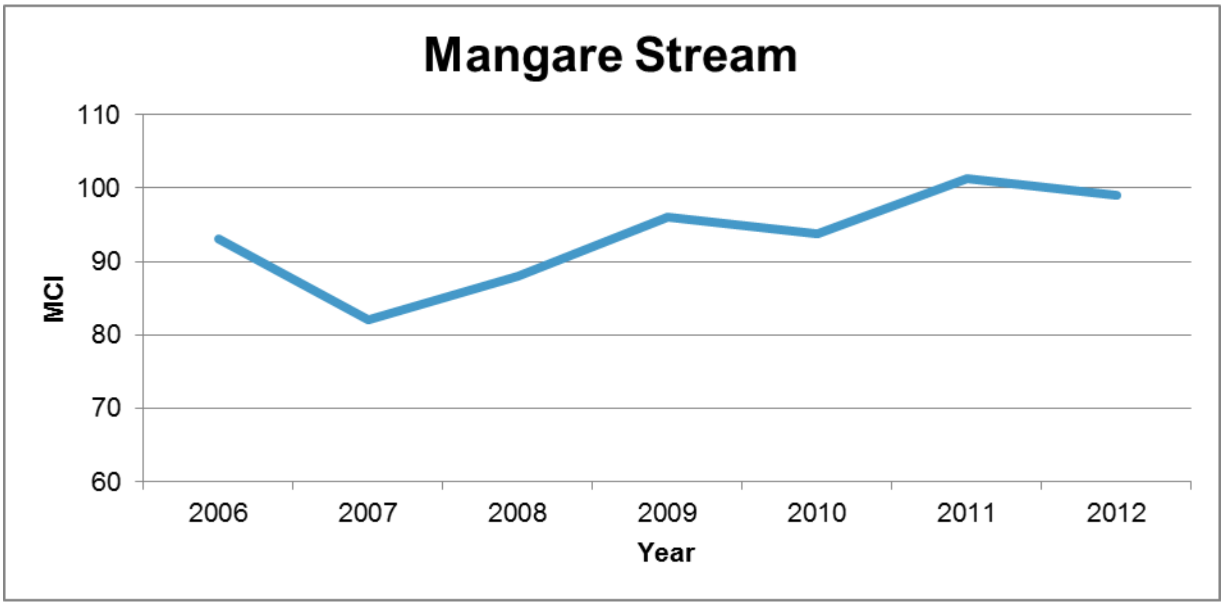

Figure 31. Time series plot of Macroinvertebrate Community Index at Mangare Stream

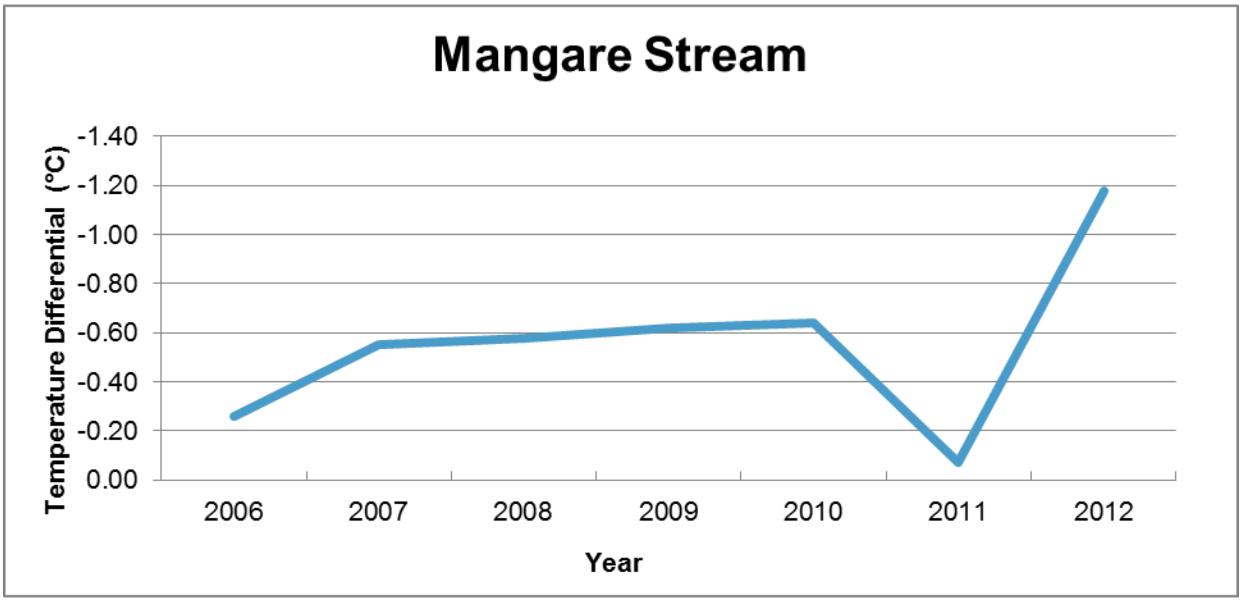

Figure 32. Mean daily maximum water temperature difference between downstream and upstream monitoring sites

Because the Mangare Stream is part of the CEMP programme, a number of riparian characteristics are monitored. Figures 33 to 35 show that more woody vegetation is present, and fencing and streambank stability has improved at the monitored transects. Overall the riparian condition of the Mangare Stream transects have improved since restoration works first commenced in 2003 (graphics taken from Littler et al. 2012).

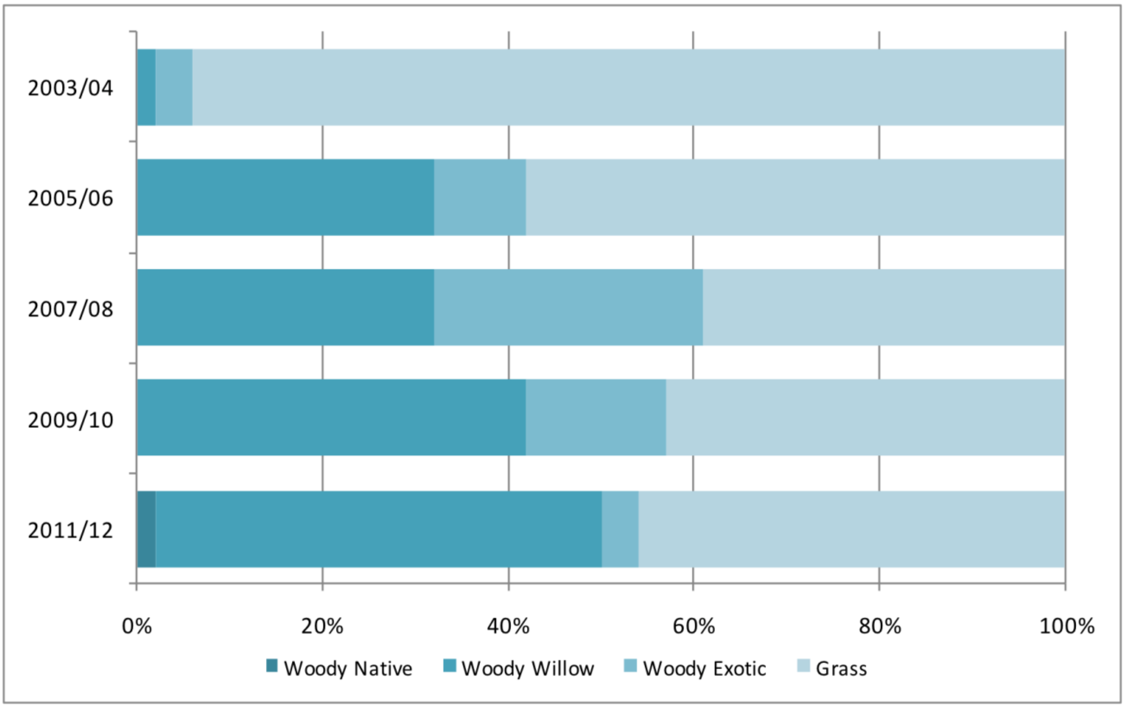

Figure 33. Vegetational changes of selected transects of the Mangare Stream since 2003

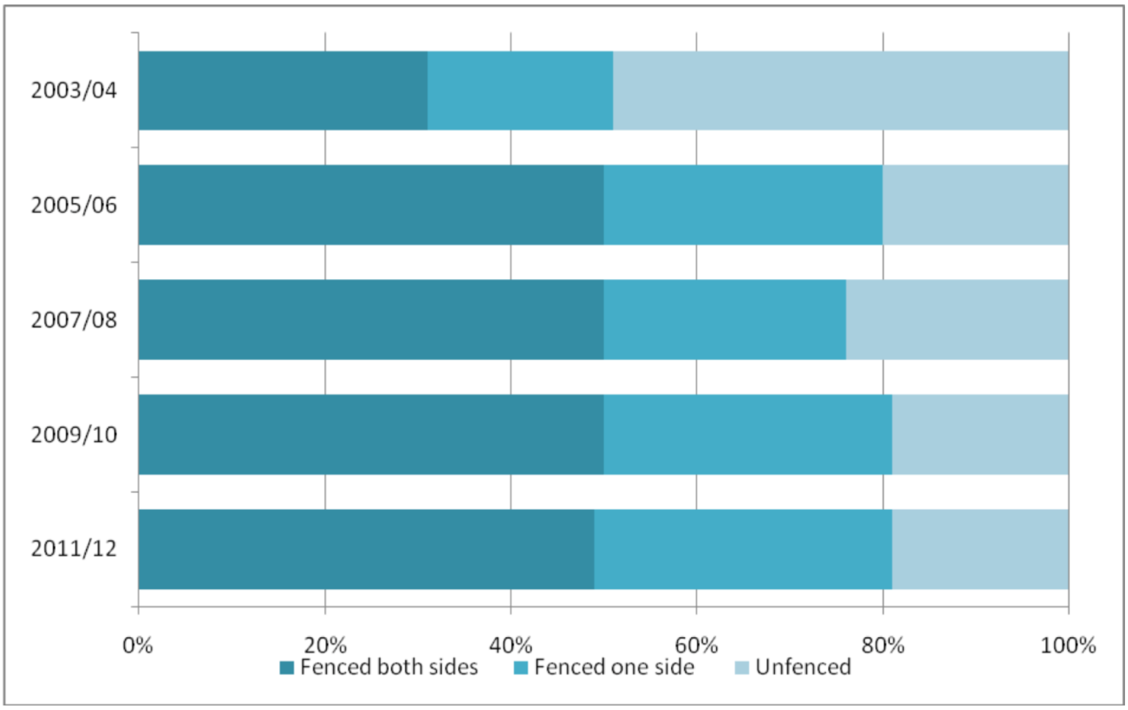

Figure 34. Improvements to fencing at selected transects since 2003

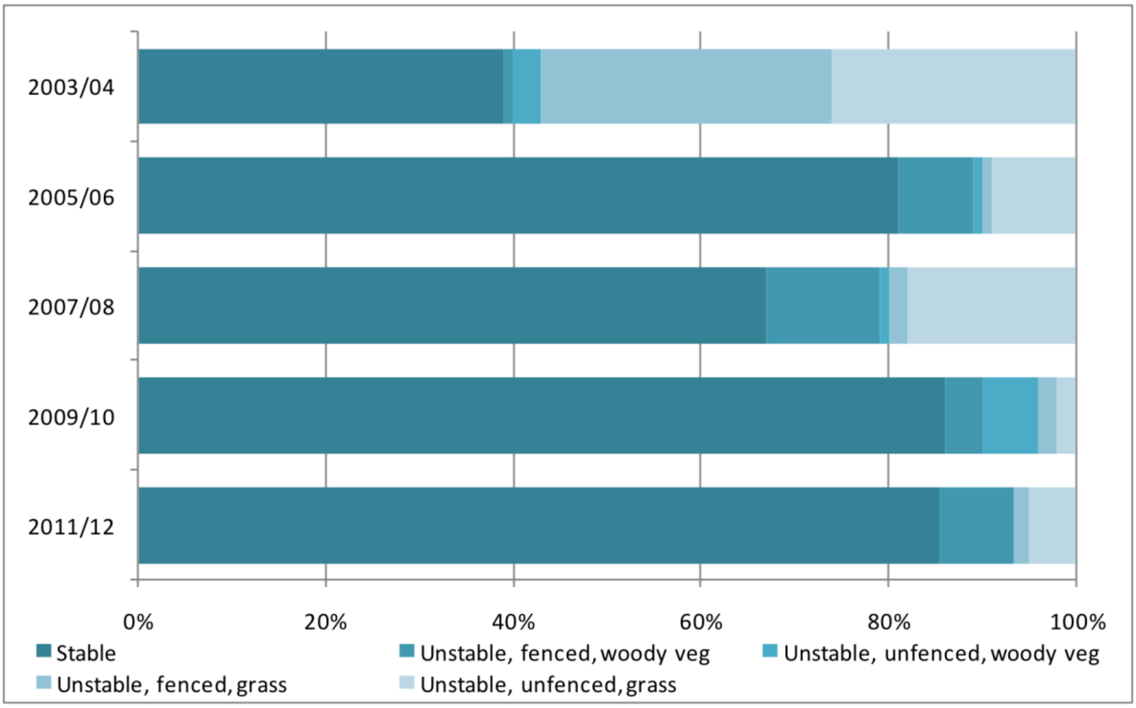

Figure 35. Improvements to streambank stability at selected transects since 2003

3.1.4.4 Makomako Stream

The Makomako Stream is located within the Upper Waikato Water Management Zone and has actively been monitored since 2007. The stream has a REC classification of cool wet, hill, volcanic acidic, pastoral low order (2nd order) low gradient stream (CW/H/VA/P/LO/LG). The site is located 202.3 km from the sea and has a catchment area of 223 ha.

The stream has an approximate channel width of 3 m, a wetted width of 1.6 m, a mean depth of 0.25 m and the substrate comprises a mixture of hard and soft substrates (gravels, cobbles, sands silts, wood). The stream provides predominantly run and riffle habitat with occasional pools.

Riparian fencing and restoration commenced in 2007 and is still continuing today. The estimated continuous retired stream length has not been physically measured before.

Riparian plants within the retired zone are a mix of indigenous and exotic species with a canopy height of between 1 and 3 metres with an understory of tall rank grasses and weeds.

Figure 36. Retired reach of the Mangare Stream in 2004 and 2013.

3.1.4.5 Changes to Stream Morphology

Figure 37 shows that the stream channel width of the Makomako Stream has narrowed by almost 1 m since 2007. Figure 35 also shows that the mean wetted width of the Makomako stream has widened slightly (0.5m) since 2007.

Figure 38 shows that monitoring of stream channel depth has been erratic. Overall the Makomako Stream depth has increased from 0.2 m measured in February 2010 to 0.25 m measured in February 2013.

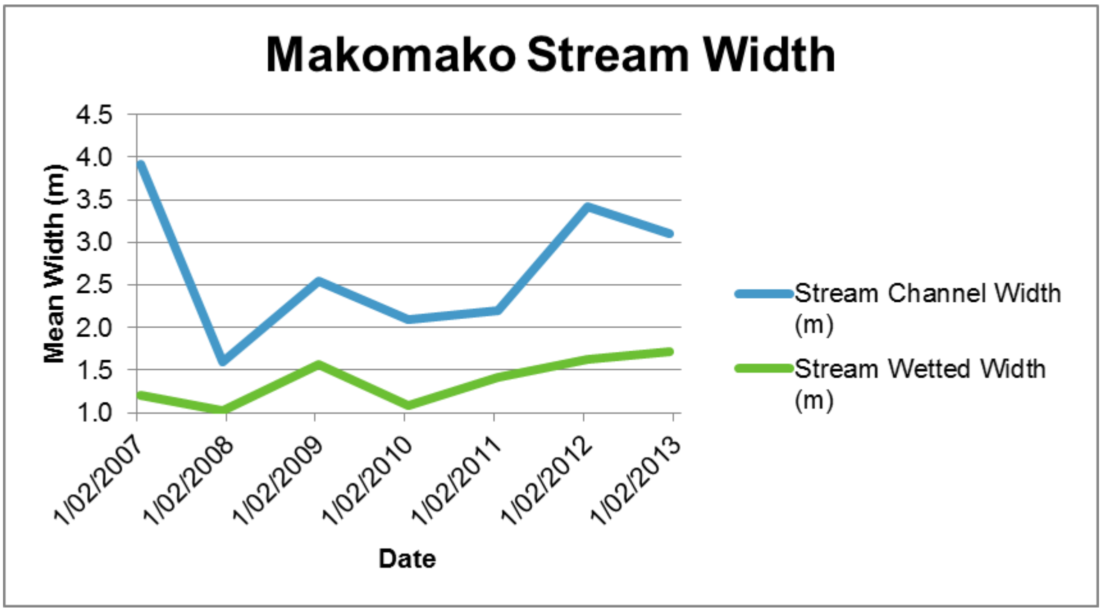

Figure 37. Changes to mean channel and wetted width since 2007

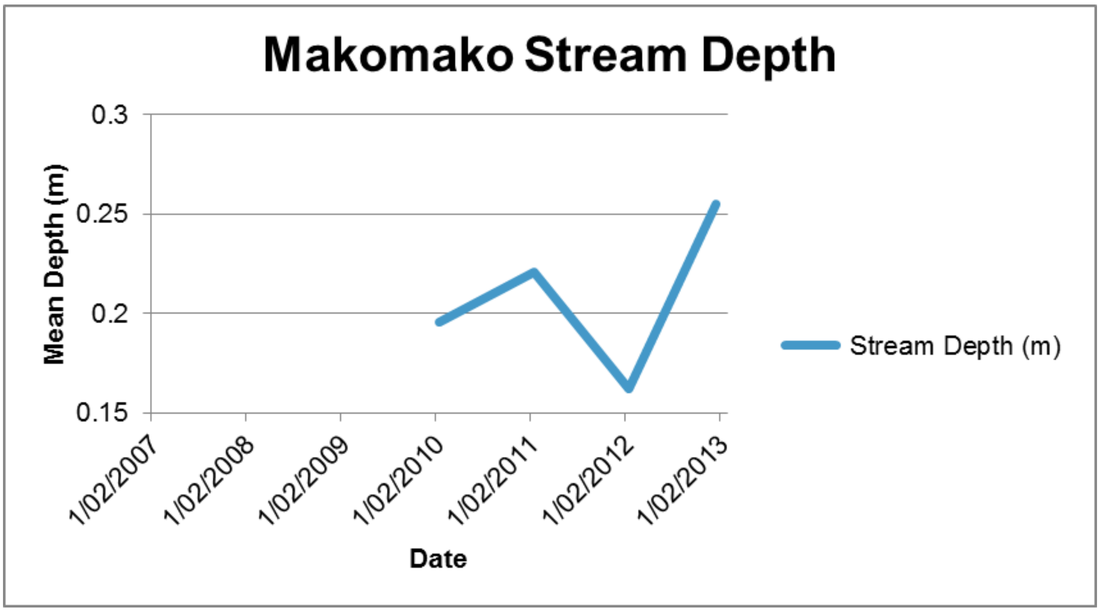

Figure 38. Changes to mean stream depth since 2006

3.1.4.6 Water Temperature and Macroinvertebrate Community Index

Because the Makomako Stream has been monitored since 2007, the data set is quite small (n = 7) therefore the site has not been statistically analysed for time series trends of water temperature or macroinvertebrate community health. The following time series plots show the general trends for these two variables.

The Makomako Stream has a median MCI value of 115 indicating a macroinvertebrate community characteristic of mild pollution. Figure 39 shows no discernible trend for the 2007 to 2012 period.

Figure 40 shows a lot of variability in the temperature differential between upstream and downstream sites since monitoring began. No determinate trend is evident.

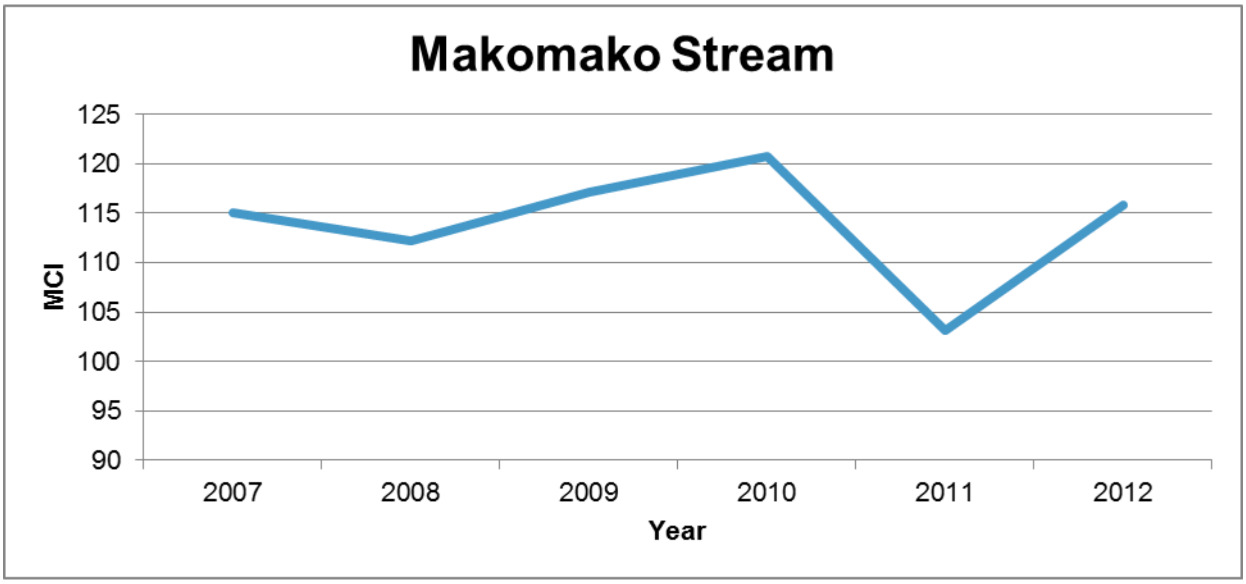

Figure 39. Time series plot of Macroinvertebrate Community Index at Makomako Stream

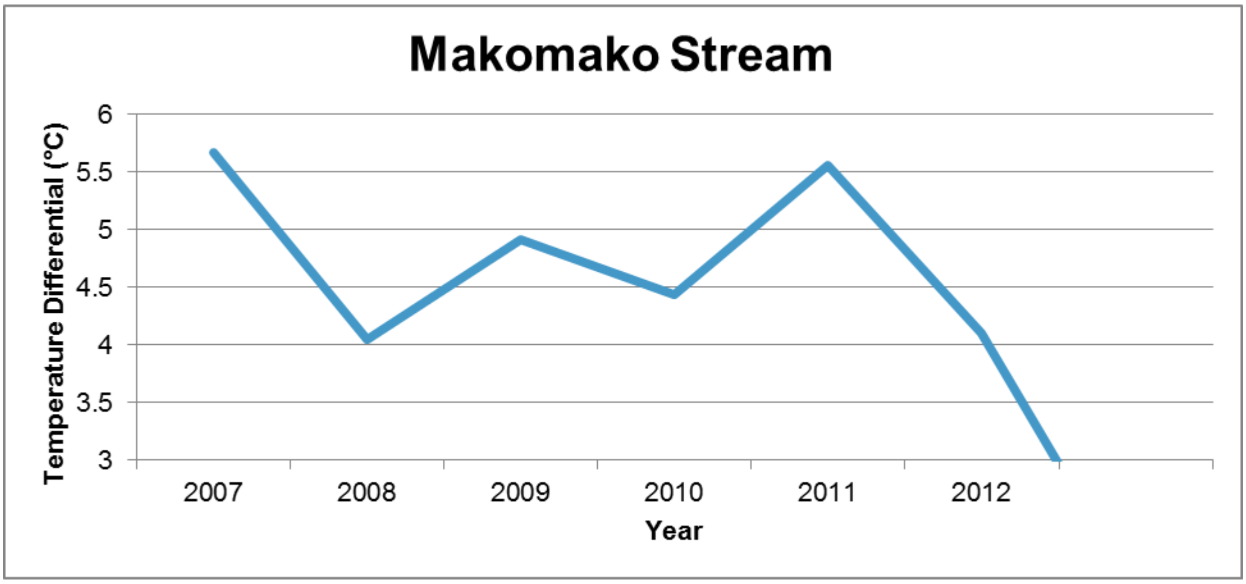

Figure 40. Mean daily maximum water temperature difference between downstream and upstream monitoring sites

3.1.4.7 Wharekaunga Tributary

The Wharekaunga Tributary is located within the Upper Waikato Water Management Zone and has actively been monitored since 2007. The stream has a REC classification of cool wet, hill, volcanic acidic, pastoral low order (2nd order) low gradient stream (CW/H/VA/P/LO/LG). The site is located 300.5 km from the sea and has a catchment area of 204 ha.

The stream has an approximate channel width of 7 m, a wetted width of 4 m, a mean depth of 0.3 m and the substrate comprises a mixture of hard and soft substrates (gravels, cobbles, sands silts, wood). The stream is predominantly run and riffle habitat with occasional pools.

Riparian fencing and restoration commenced in 2007 and is still continuing today. The estimated continuous stream length that has not been physically measured as yet.

Riparian plants within the retired zone are a mix of indigenous and exotic species with a canopy height of between 1 and 3 metres with an understory of tall rank grasses and weeds.

Figure 41. Retired reach of the Wharekaunga Tributary in 2003 and 2013

3.1.4.8 Changes to Stream Morphology

Figure 42 shows that the stream channel width and wetted width of the Wharekaunga Tributary has widened since 2007. Channel width has increased by approximately 0.6m while wetted width has increased by 0.2 m.

Figure 43 shows that monitoring of stream channel depth has been erratic. Overall the Wharekaunga Tributary depth has increased from 0.37 m measured in February 2010 to 0.46 m measured in February 2013.

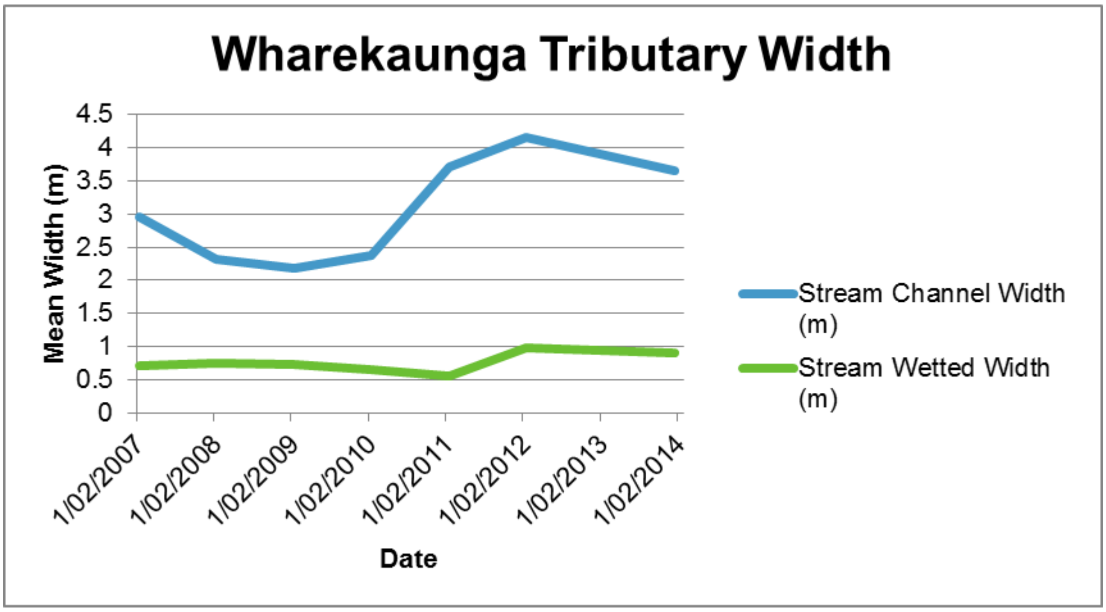

Figure 42. Changes to mean channel and wetted width since 2007

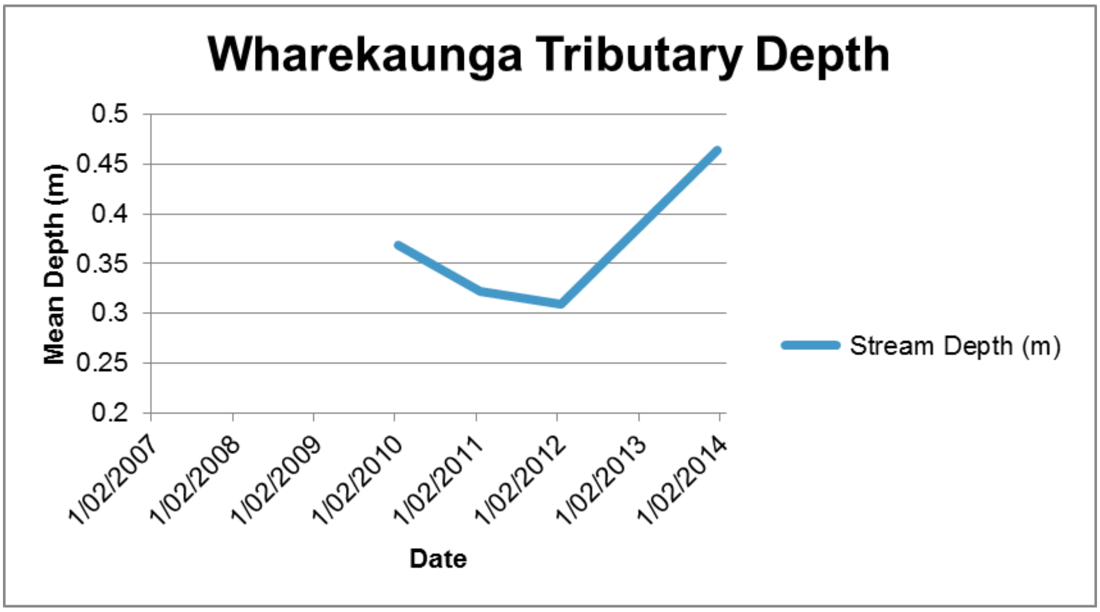

Figure 43. Changes to mean stream depth since 2007

3.1.4.9 Water Temperature and Macroinvertebrate Community Index

Because the Wharekaunga Tributary has been monitored since 2007, the data set is quite small (n = 6) therefore the site has not been statistically analysed for time series trends of water temperature or macroinvertebrate community health. The following time series plots show the emerging trends for these two variables.

The Wharekaunga Stream has a median MCI value of 86 which is characteristic moderately enriched water. Figure 44 shows no discernible trend in MCI values since monitoring commenced.

Figure 45 shows that the temperature difference between up and downstream sites has declined since monitoring commenced. It is likely that increased shading provided by the restoration works has enabled the downstream reach to attain cooler water temperatures more representative of the upstream reach.

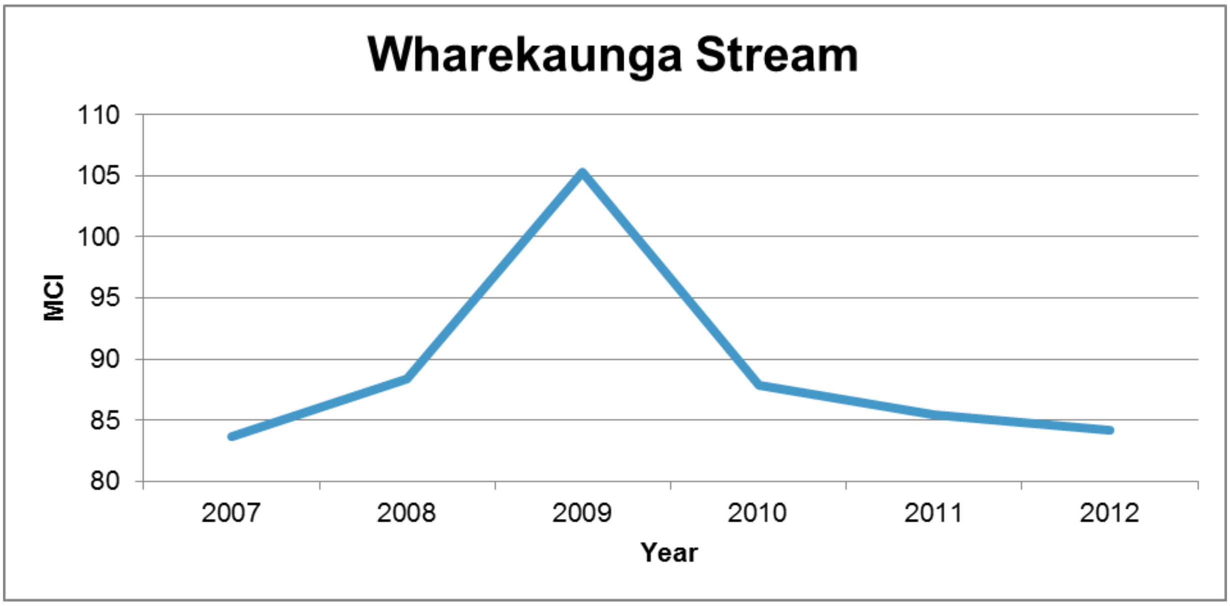

Figure 44. Time series plot of macroinvertebrate community index since 2007

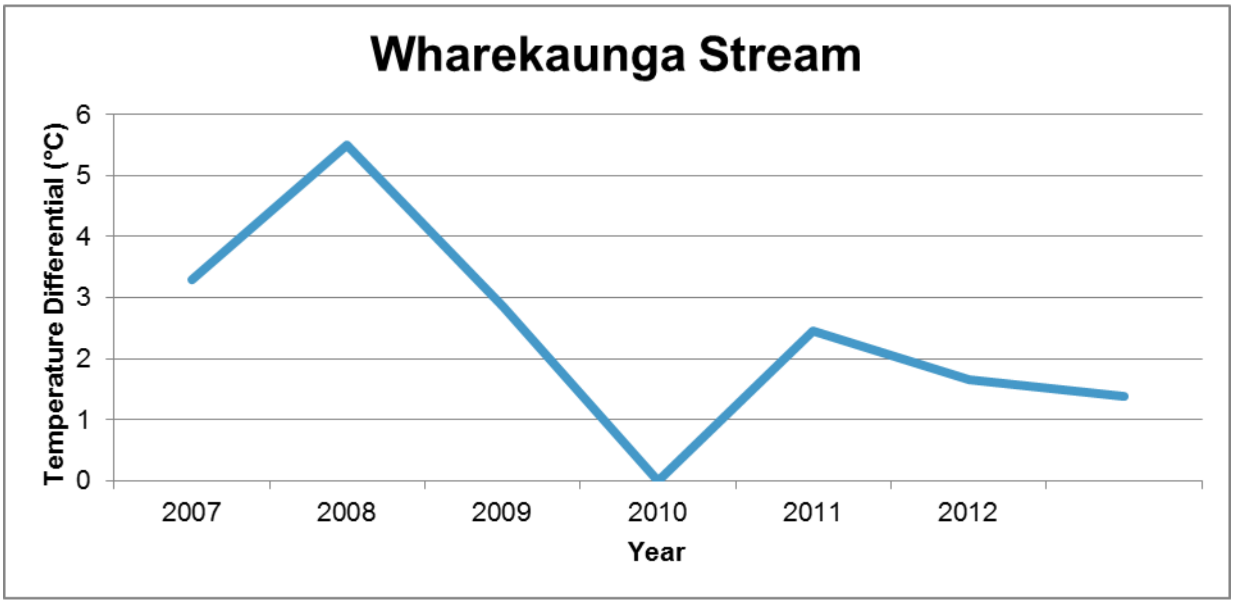

Figure 45. Mean daily maximum water temperature difference between downstream and upstream monitoring sites

3.1.5 Taupo Management Zone

3.1.5.1 Otupotu Stream

The Otupotu Stream is located within the Taupo Water Management Zone. The stream has a REC classification of cool wet, hill, volcanic acidic, pastoral low order (2nd order) low gradient stream (CW/H/VA/P/LO/LG). The site is located 375.6 km from the sea and has a catchment area of 747.4 ha.

The stream has an approximate channel width of 2.5 m, a wetted width of 0.4 m, a mean depth of 0.1 m and the substrate comprises a mixture of hard and soft substrates (gravels, cobbles, sands silts, wood). The stream is predominantly run and riffle habitat with an occasional occurrence of pools.

Riparian fencing and restoration commenced in 2004 and is still continuing today. The estimated continuous retired stream length has not been physically measured as yet.

Riparian plants within the retired zone are a mix of indigenous and exotic species with a canopy height of between 1 and 3 m with an understory of tall rank grasses and weeds.

Figure 46. Retired reach of the Otupotu Stream in 2004 and 2013.

3.1.5.2 Changes to Stream Morphology

Figure 47 shows that the stream channel width of the Otupotu Stream has narrowed and then widened. Overall the stream channel width has widened by 0.5 m since 2007.

Figure 47 also shows that mean stream wetted width of the Otupotu Stream has decreased since 2007. The wetted width widened in 2008 however since this time the stream has decreased in channel width.

Figure 48 shows that monitoring of stream channel depth has been erratic. Overall the stream depth has decreased from 0.2 m measured in March 2004 to 0.1 m measured in February 2013.

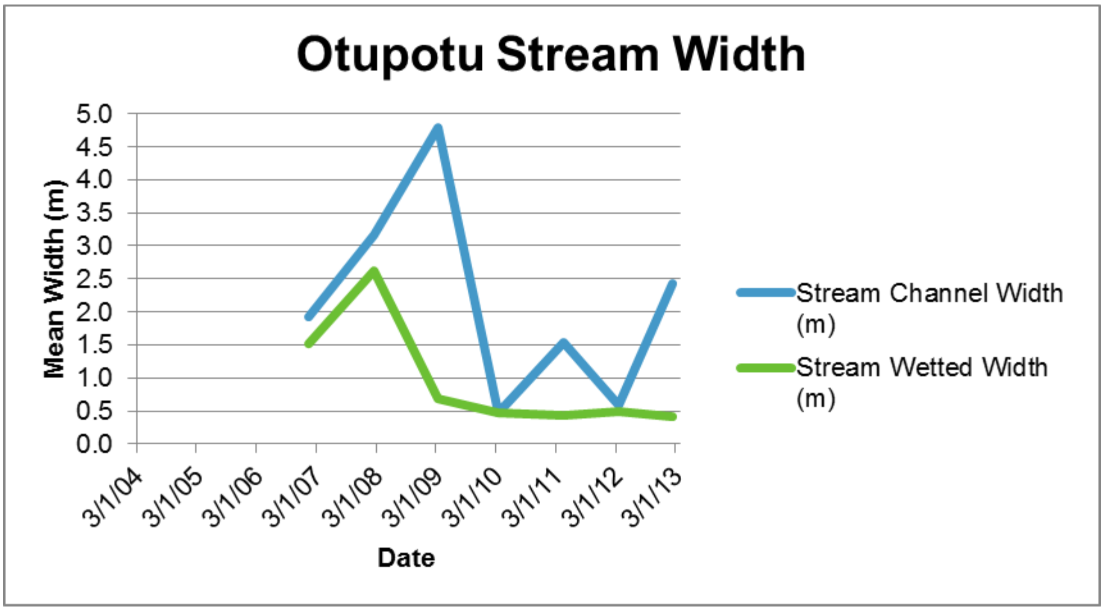

Figure 47. Changes to stream channel and wetted width since 2007

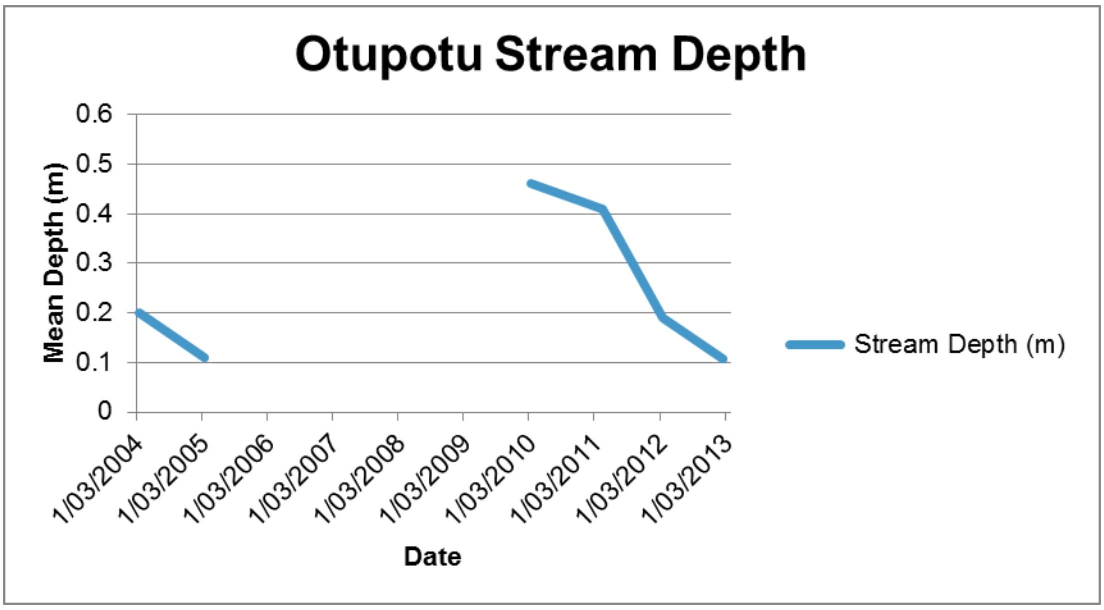

Figure 48. Changes to mean stream channel depth since 2004

3.1.5.3 Water Temperature

In 2004 the mean maximum daily water temperature (from diurnal monitoring from January 1 to March 31) was approximately 4.9 °C warmer at the downstream site when compared to the same temperature indicator measured upstream of the restoration area. Monitoring undertaken in the summer of 2013 shows that this temperature difference has declined to approximately -0.8 °C. It is possible that the stream shading provided by the developing riparian plants has enabled the stream to maintain cooler water temperatures at the downstream site.

Figure 49 shows a declining temperature differential over the successive years. This trend is nearing statistical significance ($p = 0.07$) and is environmentally significant. The slope of the trend equates to a temperature differential decline of 18.6% per annum as an expression of the median.

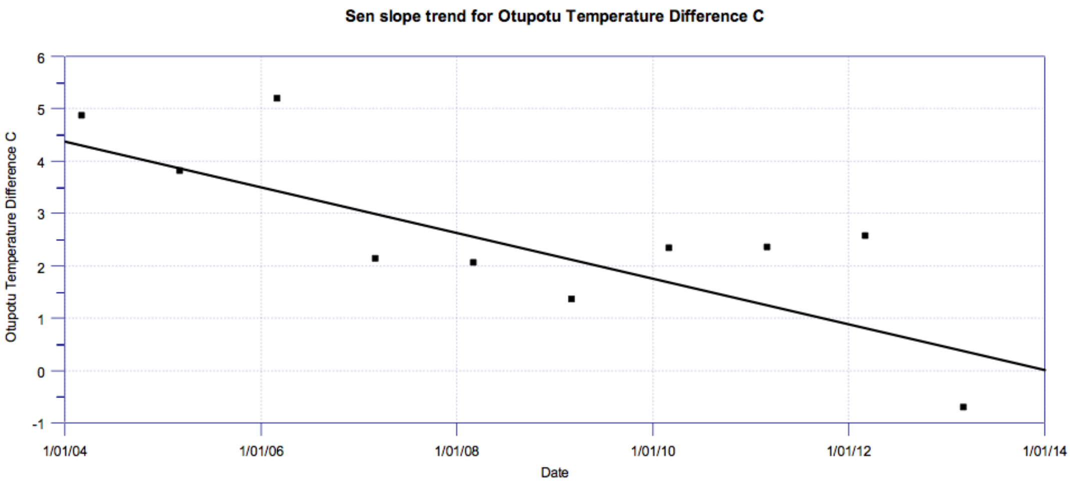

Figure 49. Mean daily maximum water temperature difference between downstream and upstream monitoring sites of the Otupotu Stream

3.1.5.4 Macroinvertebrate Community Index

In 2004 the macroinvertebrate community index value measured at the downstream site was approximately 69. While there has been some variability in MCI values generated since this time, there has been a discernible upward trend in ecosystem health since this time. The median MCI value for the complete data set is 92.3 which is representative of moderate organic enrichment.

Figure 50 shows a strong upward trend of MCI values since 2004. This trend is near statistical significance ($p = 0.054$) and is environmentally significant. Collier (2013) suggested that if a MCI change of >15% and if the trend exceeded 1% per annum then it was ecologically significant. In this case the change over time represents a 33% improvement in MCI and the slope of the trend as an expression of the median value is 3.3% per annum.

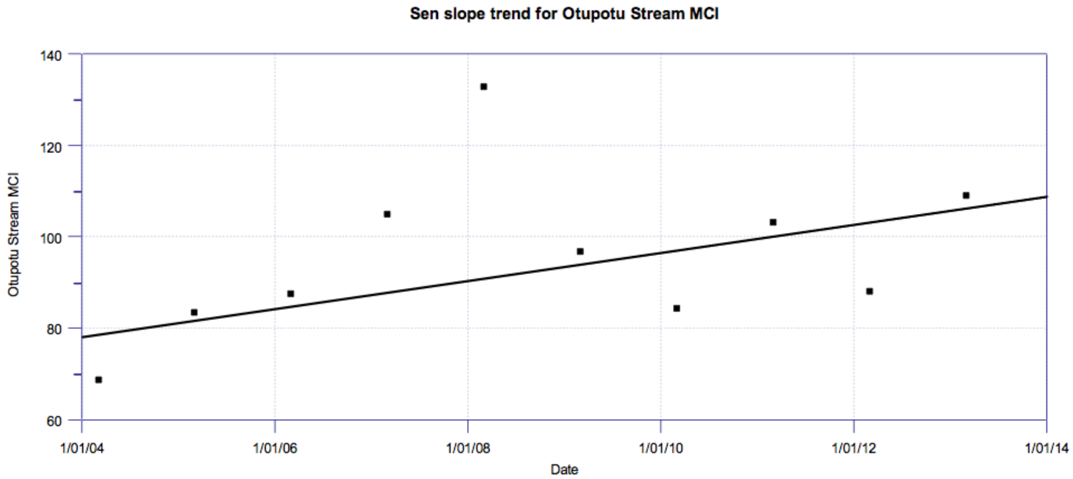

Figure 50. MCI Time Series Plot for the Otupotu Stream

3.2 Clean Streams Monitoring Programme Summary

The following table illustrates a summary of results for the CEMP sites previously discussed. Table 2 shows that most stream sites have a catchment area of <1000 ha and have a fairly low stream order (1st or 2nd). Table 2 also shows that most sites have shown an increase in channel width (CW) and just over half of the sites have also shown an increase in wetted width. Most sites have become shallower and most sites have shown a decline in downstream water temperatures with three sites showing that these trends are both environmentally and statistically significant. Most sites have also shown an improvement in MCI value with one site showing statistical and ecological significance while a further site has shown ecological significance and is close to statistical significance ($p = 0.054$).

Table 2. Clean Streams Monitoring Programme: summary of trends

Stream	Order	Catchment area (ha)	Change To Stream Width	Change To Stream Depth	Water Temperature	Ecosystem Health
Boom	1	116	CW & WW increase	Shallower	Decline	Increase MCI
Waitete	2	636	CW & WW increase	Shallower	Decline	**Increase MCI**
Waimata	3	1110	CW increase WW decline	Shallower	No Change	Increase MCI
Waiomou	3	210	CW & WW increase	Shallower	**Decline**	No Change
Te Pahu	2	208	CW increase WW decline	Shallower	**Decline**	No Change
Mangare Stream			CW & WW increase	Shallower	Insufficient data	Insufficient Data
Makomako Stream			CW & WW decrease	Deeper	Insufficient data	Insufficient Data
Wharekaunga Tributary			CW & WW increase	Deeper	Insufficient data	Insufficient Data
Otupotu	2	747	CW increase WW decline	Shallower	**Decline**	***Increase MCI***

Key: **Bold type** = statistically and ecologically significant trend
Bold and italic = ecologically significant

3.3 Catchment Environmental Monitoring Programme

There are seven CEMP sites analysed in this report which are illustrated in the map below (Figure 39). Of these seven sites, five are restoration sites and two are reference sites.

Figure 51. Catchment Environmental Monitoring Programme sites discussed in this report.

A brief description of each site follows while a commentary of the water temperature and macroinvertebrate monitoring results is provided in Appendix III.

3.3.1 Coromandel Management Zone

3.3.1.1 Wharekawa River

Figure 52. Representative reach of the Wharekawa River in 2007 (left) and 2009 (right) (taken from Grant et al. 2010)

The Wharekawa River is located within the Coromandel Water Management Zone. The river has a REC classification of warm wet, low elevation, volcanic acidic, indigenous forest high order (5th order) low gradient river (WW/L/VA/IF/HO/LG). The site is located 7.5 km from the sea and has a catchment area of 4695.4 ha.

The river has an approximate channel width of 13 m, a wetted width of 10.4 m, a mean depth of 0.5 m and the substrate comprises a mixture of hard substrates (gravels and cobbles). The river provides a regular occurrence of run, riffle and pool habitat.

3.3.1.2 Riparian Characteristics

Riparian fencing and restoration commenced in 2005 and is still continuing today. The estimated continuous stream length restored has not been physically measured before.

Riparian plants within the retired zone are predominantly exotic with a canopy height of between 5 to 10 m with an understory of tall rank grasses and weeds.

No riparian characteristics data was collected in the 2011/12 reporting period and the previous report (Littler et al. 2011) presented the data differently (pie charts as opposed to bar charts) from which temporal changes of riparian condition cannot be determined.

3.3.2 Waipa Management Zone

3.3.2.1 Otautora Stream

Figure 53. Representative reach of the Otautora Stream Reference site in 2013

The Otautora Stream is located within the Waipa Water Management Zone and was selected as a reference comparison stream for the catchment environmental monitoring programme. The stream has a REC classification of cool wet, hill fed, volcanic acidic, indigenous forest low order (1st order) high gradient stream (CW/H/VA/IF/LO/HG). The site is located 213 km from the sea and has a catchment area of 26.4 ha.

The stream has an approximate channel width of 3.5 m, a wetted width of 2.1 m, a mean depth of 0.2 m and the substrate comprises a mixture of hard substrates (gravels and cobbles). The stream is predominantly run and riffle habitat with an occasional occurrence of pools.

The Otautora Stream has been monitored as a reference comparison site for all sites within the Waipa Water Management Zone. Therefore it has not been subject to any riparian retirement or fencing.

Riparian plants within the retired zone are predominantly indigenous with a canopy height of between 5 to 20 m with an understory of indigenous saplings and seedlings.

There is no transect information on riparian condition of this site as it is a reference site.

3.3.2.2 Mangatutu Stream

Figure 54. Representative headwater reach of the Mangatutu Stream in 2005 (left) and 2009 (right) (taken from Grant et al. 2010)

The Mangatutu Stream is located within the Waipa Water Management Zone. The stream has a REC classification of warm wet, low elevation, volcanic acidic, pastoral low order (2nd order) low gradient stream (WW/L/VA/P/LO/LG). The site is located 213 km from the sea and has a catchment area of 506.5 ha.

The Mangatutu Stream has an approximate mean channel width of 13.5 m, a wetted width of 8.5 m and a mean depth of 0.4 m. and the substrate comprises a mixture of hard substrates (gravels and cobbles). The stream is predominantly run and pool habitat with an occasional occurrence of riffles.

3.3.2.3 Riparian Characteristics

Riparian fencing and restoration commenced in 2005 and is still continuing today. The estimated continuous stream length that has been restored has not been physically measured before.

Riparian plants within the retired zone are predominantly exotic with no canopy, the vegetation is predominantly tall rank grasses and weeds.

No riparian characteristics data was collected in the 2011/12 period and the previous report (Littler et al. 2011) presented the data differently (pie charts as opposed to bar charts) from which temporal changes of riparian condition cannot be determined.

3.3.3 Lower Waikato Management Zone

3.3.3.1 Matahuru Stream

The Matahuru Stream is located within the Lower Waikato Water Management Zone. The stream has a REC classification of warm wet, low elevation, hard sedimentary, pastoral medium order (4th order) low gradient stream (WW/L/HS/P/MO/LG). The site is located 88.9 km from the sea and has a catchment area of 5974.9 ha.

No stream morphology measurements have been made of the Matahuru Stream. This is largely because the stream is quite steep sided and deep, therefore it poses difficulties with measuring channel width, wetted width and stream depth safely. The stream is predominantly run habitat with no riffles or pools evident.

Figure 55. Representative reach of the Matahuru Stream in 2004 (left) and 2012 (right) (taken from Littler et al. 2012)

3.3.3.2 Riparian Characteristics

Riparian fencing and restoration commenced in 2004 and is still continuing today. The estimated continuous retired stream length has not been physically measured before.

Riparian plants within the retired zone are predominantly exotic with a canopy height of between 3 to 10 m with an understory of tall rank grasses and weeds.

Figures 56 to 58 show that more woody vegetation is present, and fencing and streambank stability has improved at the monitored transects. Overall the riparian condition of the Matahuru Stream transects have improved since restoration works first commenced in 2003 (graphics taken from Littler et al. 2012)

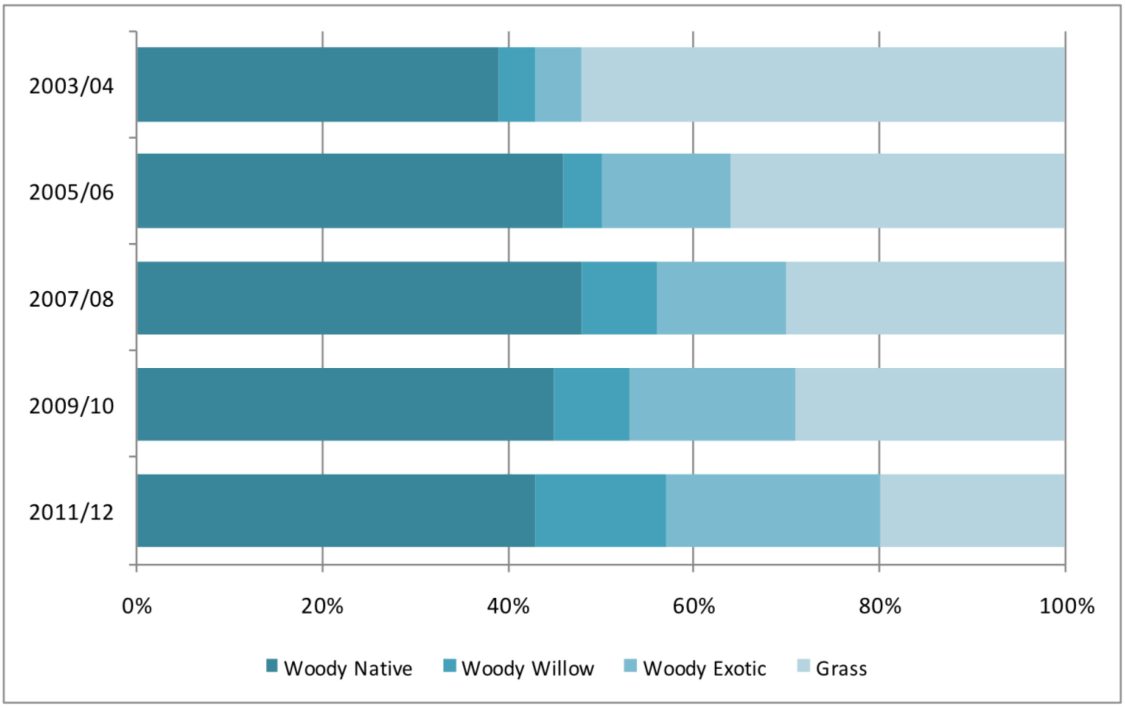

Figure 56. Vegetational changes at the Matahuru Stream transects since 2003

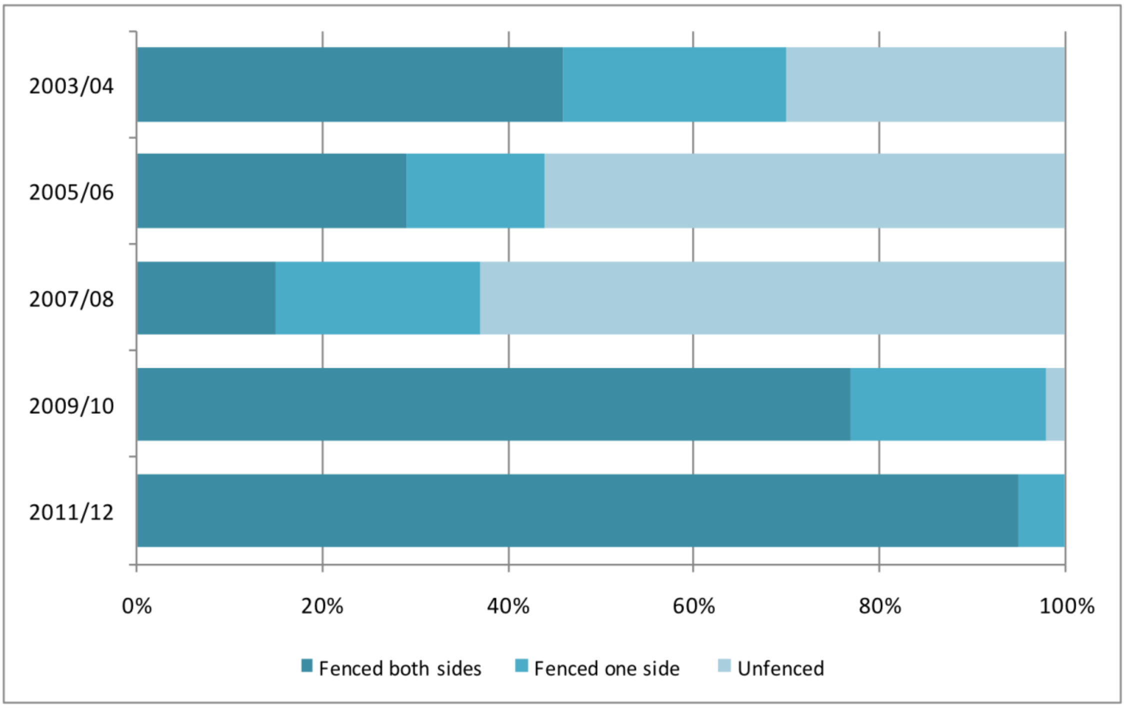

Figure 57. Improvements to fencing at selected transects of the Matahuru Stream

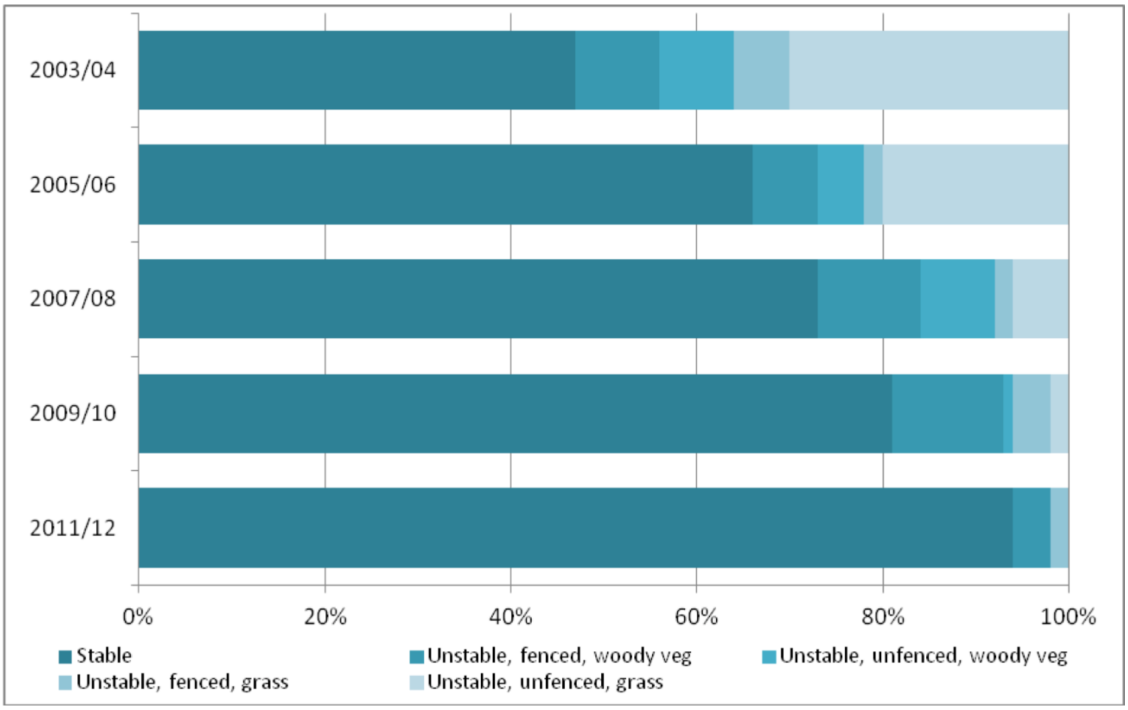

Figure 58. Improvements to streambank stability of selected transects of the Matahuru Stream

3.3.4 Upper Waikato Management Zone

3.3.4.1 Pokaiwhenua River

Figure 59. Representative reach of the Pokaiwhenua River in 2004(left) and 2012 (right) (taken from Littler et al. 2012)

The Pokaiwhenua River located within the Upper Waikato Water Management Zone. The stream has a REC classification of cool wet, low elevation, volcanic acidic, pastoral high order (5th order) low gradient river (CW/L/VA/P/HO/LG). The site is located188.1 km from the sea and has a catchment area of 33,775.2 ha.

At the upstream site the river has an approximate channel width of 16 m, a wetted width of 10 m, and a mean depth of 1m. At the downstream site the river has an approximate channel width of 13 m, a wetted width of 12 m and a mean depth of 1 m. The substrate of the river comprises a mixture of hard substrates (gravels and cobbles). The river is predominantly run and pool habitat with occasional riffles.

3.3.4.2 Riparian Characteristics

Riparian fencing and restoration commenced in 2004 and is still continuing today. The estimated continuous retired stream length has not been physically measured before.

Riparian plants within the retired zone are predominantly exotic with a canopy height of between 5 to 10 m with an understory of tall rank grasses and weeds.

Figures 60 to 62 show that more woody vegetation is present, and fencing and streambank stability has improved at the monitored transects. Overall the riparian condition of the Pokaiwhenua Stream transects have improved since restoration works first commenced in 2003 (graphics taken from Littler et al. 2012)

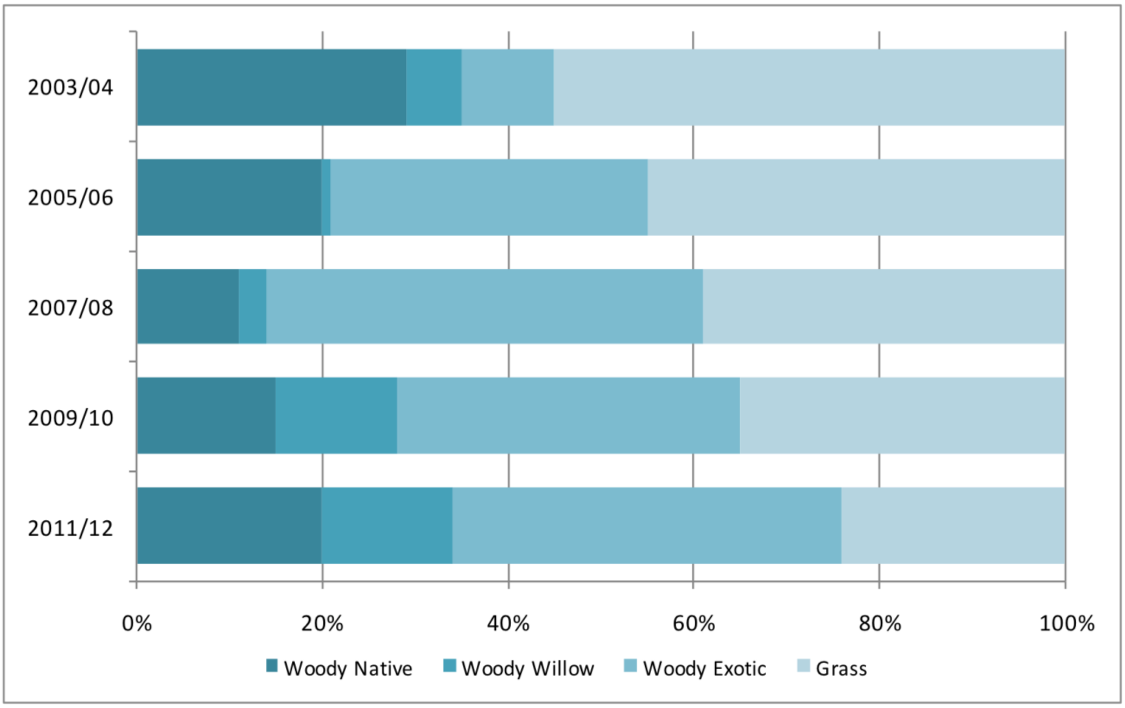

Figure 60. Vegetational changes at selected transects of the Pokaiwhenua River

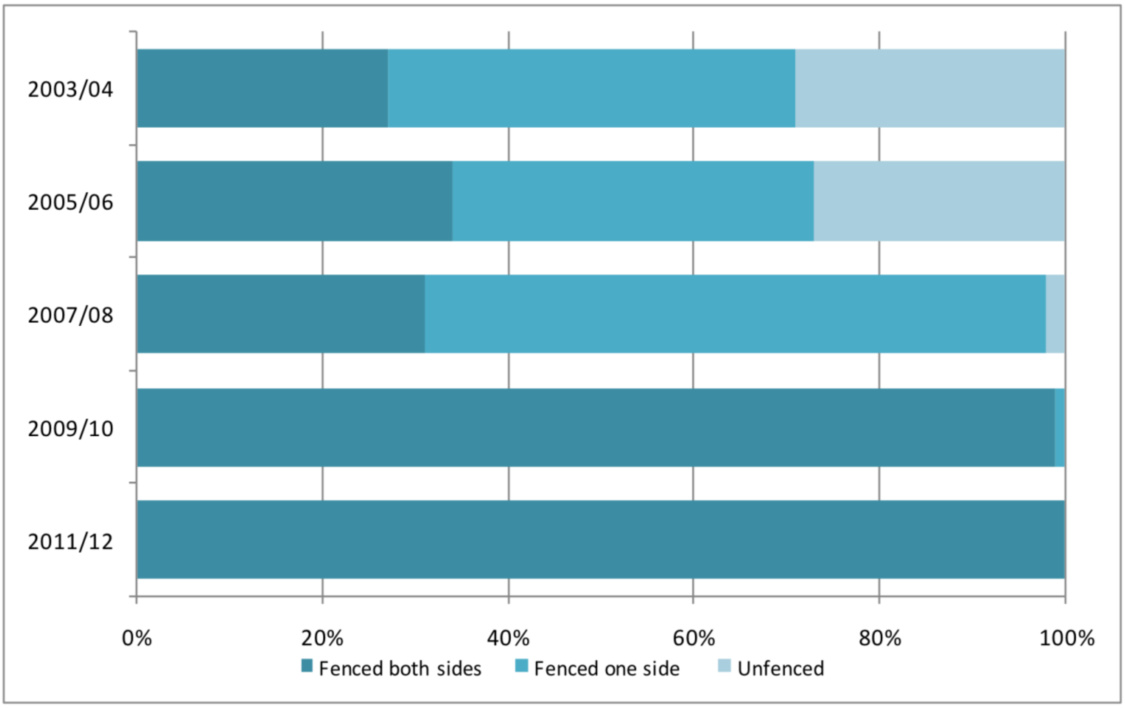

Figure 61. Improvements to fencing at selected transects of the Pokaiwhenua River

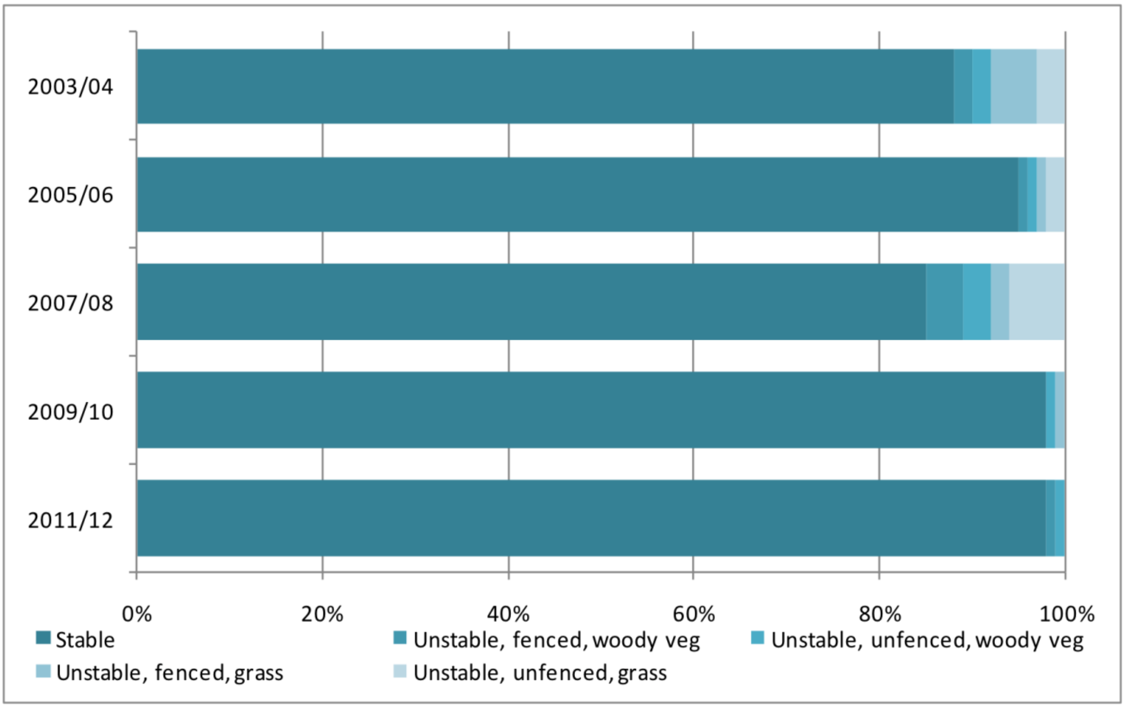

Figure 62. Improvements to streambank stability at selected transects of the Pokaiwhenua River

3.3.4.2 Mokaihaha Stream

Figure 63. Representative reach of the Mokaihaha Stream

The Mokaihaha Stream is located within the Upper Waikato Water Management Zone and was selected as a reference comparison site for the catchment environmental monitoring programme.

The stream has a REC classification of cool wet, hill, volcanic acidic, indigenous forest, medium order (3rd order) medium gradient stream (CW/H/VA/IF/MO/MG). The site is located 220.1 km from the sea and has a catchment area of 742.2 ha.

The river has an approximate channel width of 6.5 m, a wetted width of 4 m, a mean depth of 0.2 m and the substrate comprises a mixture of hard substrates (gravels and cobbles). The stream is predominantly run and riffle habitat with an occasional occurrence of pools.

Riparian plants within the catchment are predominantly indigenous with a canopy height of between 10 to 20 m and an understory of indigenous seedlings and saplings.

Because the Mokaihaha Stream is a control site, it is not monitored for riparian characteristics.

3.3.4.3 Pokaitu Stream

Figure 64. Representative reach of the Pokaitu Stream in 2004 and 2009 (taken form Grant et al. 2010)

The Pokaitu Stream is located within the Upper Waikato Water Management Zone. The stream has a REC classification of cool wet, hill, volcanic acidic, pastoral, medium order (4th order) low gradient stream (CW/H/VA/P/MO/LG). The site is located 285.6 km from the sea and has a catchment area of 3037.2 ha.

The river has an approximate channel width of 8 m, a wetted width of 6 m, a mean depth of 0.6 m and the substrate comprises a mixture of soft substrates (sands and silts). The river is predominantly run and pool habitat with an occasional occurrence of riffles.

3.3.4.4 Riparian Characteristics

Riparian fencing and restoration commenced in 2004 and is still continuing today. The estimated continuous retired stream length has not been physically measured before.

Riparian plants within the retired zone are predominantly exotic with a canopy height of between 5 to 10 m with an understory of tall rank grasses and weeds.

Riparian characteristics data is not collected for the Pokaitu Stream (Littler et al. 2012), the reason for this is not explained.

3.3.5 Catchment Environmental Monitoring Programme Summary

Table 3 shows that with the exception of the Otautora Reference site and the Mangatutu site, the monitoring sites are from large catchments (>3000 ha) of high stream order (3 to 5). There is no consistent pattern of stream width, depth changes or temperature changes (see Appendix III for commentary). Some sites have shown changes to MCI however only one of these (Mokaihaha) is a statistically and ecologically significant trend which is a reference site.

Table 3. Catchment Environmental Monitoring Programme: summary of trends

Stream	Order	Catchment area (ha)	Change To Stream Width	Change To Stream Depth	Water Temperature	Ecosystem Health
Wharekawa	5	4695	No change	Increase	No data	Increase MCI
Otautora (Ref)	1	26	No change	Increase	No data	Decrease MCI
Mangatutu	2	505	No data	No data	No change	Decrease MCI
Matahuru	4	5974	No data	No data	Increase	No data
Pokaiwhenua	5	33775	No data	No data	Decrease	*Decrease MCI*
Mokaihaha (Ref)	3	742	Decrease	ID	No data	**Decrease MCI**
Pokaitu	4	3037	Increase	Shallower	Increase	Decrease MCI

Key: **Bold type** = statistically and ecologically significant trend

Italic = statistically significant

3.4 Regional Ecological Monitoring of Streams Programme

Collier & Hamer (2012) identified six long-term monitoring sites that are restoration/management sites within the REMS programme (Toenepi, Waitoki, Whangamata, Mangakotukotu, Waitomo, Wainui). In addition to this there two further long-term sites that have relevance to the CEMP (Pokaiwhenua and Mangatutu).

Most of these sites have shown no trends that are statistically or ecologically significant with the exception of the Toenepi Stream restoration site (increasing MCI, statistical and ecological significance), the Wainui Stream (decreasing MCI, statistical significance only) and the Pokaiwhenua Stream (no MCI trends, however increasing ASPM statistical and ecological significance) (Collier & Hamer 2012).

3.5 Regional Water Quality Monitoring Programme

Vant (2013) identified a number of water quality trends occurring within the Waikato Region. Of particular relevance to the CEMP are those identified for the Wharekawa River (increasing turbidity and total nitrogen), the Matahuru Stream (increasing turbidity and declining water clarity), the Pokaiwhenua River (increasing turbidity, declining water clarity, increasing total nitrogen, declining ammonia and total phosphorus), the Mangatutu Stream (increasing turbidity, declining water clarity, increasing total nitrogen and declining ammonia), and the Waitomo Stream (declining ammonia).

3.6 Suspended Sediment Yields Monitoring Programme

Hoyle, Hicks and Roulston (2011) have estimated suspended sediments loads from 23 sites throughout the Waikato Region. Of particular relevance are the results for the Mangatutu Stream, Matahuru Stream and Wharekawa River sites which are all showing increasing trends of residuals over time. The authors noted that yields were lower from forested catchments compared with catchments in pasture or horticulture. The variation in yield across the Waikato region was due mainly to catchment rainfall, mean slope and land cover.

4 Discussion

4.1 Comparison of the Clean Streams Monitoring Programme and Catchment Environmental Monitoring Programme

The Clean Streams Monitoring Programme (CSMP) has been more effective at demonstrating improvements in water temperature and ecosystem health compared to the Catchment Environmental Monitoring Programme (CEMP). The prime reason for this is that the CSMP has investigated smaller stream catchments (most are less than 1000 ha) compared to the CEMP for which most catchments are >3000 ha.

In most cases the CSMP sites show that the streams are widening and becoming shallower. This is an expected trajectory for streams that are subject to riparian retirement as the canopy trees will start to shade out pasture grasses and weeds which then leaves bare ground which is subject to stream bank slumping as the river develops a wider and more natural stream course.

Most sites of the CSMP with sufficient data for trend analysis have also shown a general decrease in water temperature (5/6) and an improvement to macroinvertebrate community index (MCI) values (4/6). For some sites these changes are both statistically and ecologically significant. It is likely that the increased shading provided by the retired riparian margins has helped maintain cool water temperatures for these ecosystems.

Conversely, the CEMP sites have been difficult to monitor for changes to stream morphology (owing to their size) and the temperature and MCI data do not show any consistent trend pattern. With the exception of the Mokaihaha Stream reference site, which shows a statistically and ecologically significant decline in ecosystem health, and the Pokaiwhenua River which shows a statistically significant decline in MCI, the sites show no significant trends. The decline in MCI values at the Mokaihaha Stream needs to be investigated further as this is not expected for a reference site.

While three sites (Mangare Stream, Pokaiwhenua River and Matahuru Stream) have shown improving temporal trends in riparian condition (vegetation, fencing and streambank stability), the remaining sites of the CEMP have not been analysed in the same manner, as reporting prior to the 2011/12 year displayed these variables as pie charts.

The improvements in riparian condition displayed by the CEMP programme are only specific to the selected transects that have been monitored, therefore conclusions cannot be applied to a catchment wide context.

The results of the CSMP clearly demonstrate that the restoration works implemented by Waikato Regional Council have resulted in significant ecological improvements to macroinvertebrate community health and water temperature.

The results of the CEMP however only demonstrate that improvements to riparian condition have occurred at the selected transects.

4.2 Other Monitoring Programmes

4.2.1 Pokaiwhenua River

Some trends of the CEMP are supported by other monitoring programmes. For example the Pokaiwhenua River shows a statistically significant downward trend of MCI values over time, this decline in ecosystem health is supported by pressure indicators of the Regional Water Quality Monitoring Programme (RWQMP) which shows increasing turbidity, declining water clarity and increasing total nitrogen concentrations over time. The same site is showing decreasing concentrations of total phosphorus and total ammonia. This would suggest that these latter trends may not be contributing to the decline in ecosystem health, however the former trends could be.

The REMS programme has shown no statistically or ecologically significant trend in MCI at the Pokaiwhenua site, however the programme has shown that the average score per metric has increased over time. The reason for this trend could be driven by the substrate being more dominated by bedrock at the REMS site but may warrant further investigation.

4.2.2 Matahuru Stream

No stream morphology or in stream ecology measurements have been made of the Matahuru Stream of the CEMP. This is because the stream is steep sided, deep and non-wadeable making it impractical to make such measurements. Supporting monitoring programmes indicate that this stream is under increasing pressure from suspended sediment loadings.

The RWQMP shows increasing suspended sediment concentrations and declining water clarity in the Matahuru Stream. Furthermore the Suspended Sediment Yields Monitoring Programme (SSYMP) indicates that suspended sediment yields are increasing for this stream catchment.

A good way to measure the ecological response of the Matahuru Stream to the pressures it is receiving would be to measure ecosystem respiration and metabolism using the methods proposed by Young et al. (2008).

4.2.3 Wharekawa River

The Wharekawa River is also subject to increasing pressures as evidenced by the RWQMP which shows increasing turbidity and total nitrogen concentrations and the SSYMP which shows increasing suspended sediment yields over time. While the MCI currently shows a slight improvement for this river, this trend is not statistically or ecologically significant. Measurements of ecosystem respiration and metabolism are also warranted for this river as they are likely to help determine what the current pressures on the river are having on ecosystem health.

4.3 Study Limitations

It is likely that any benefits of riparian retirement for the CEMP sites will take longer to appear than the CSMP or may not eventuate. This is because larger river systems take a longer time to develop a more natural stream channel and attain adequate shading to cool a wider stream width. Furthermore little benefit may be demonstrated if upstream tributaries have not been restored also. Monitoring smaller catchments for the CEMP is likely to deliver more consistent results that demonstrate improvements to stream health as a result of the soil conservation works.

It should be noted here that the data sets analysed for the CSMP and CEMP are small so some caution should be used in the interpretation of results. Further monitoring of these sites is likely to demonstrate more significant trends as the data sets become larger and greater statistical confidence can be placed on the results.

5 Recommendations

5.1 Further Monitoring

There are a number of indicators that could be monitored and reported for both the CSMP and CEMP to enhance their overall performance of monitoring the ecological success of stream restoration as described in this section. Overviews of current and recommended monitoring indicators for the CSMP and CEMP are provided in Tables 4 and 5.

Note that variables recommended in tables below can easily be monitored at little extra cost and effort and are recommended for future monitoring. While some of these bold type variables may be monitored as part of Waikato Regional Council's ecological assessment habitat protocols (Collier & Kelly 2005, Collier et al. 2006) the data generated from those field sheets are largely categorical and too generic to obtain emerging trends in habitat quality at a fine scale. This report recommends using methods specified in the restoration indicator toolkit published by Parkyn et al. 2010.

Table 4. Variables to monitor to improve determination of ecological success of riparian retirement, Clean Streams Monitoring Program. Aim: to establish a measure of the ecological changes occurring as a result of implemented stream enhancement initiatives (fencing and planting). Variables in bold font can easily be monitored at little extra cost and effort and are recommended for future monitoring. Variables in italic font could also be monitored but may not be necessary for the CSMP.

Value	Indicator	Monitored
Natural Habitat	**Shade of water surface**	
Natural Habitat	Water and channel width	Yes
Natural Habitat	**Stream bed particle size**	
Natural Habitat	**Mesohabitats**	
Natural Habitat	**Bank erosion and condition**	
Natural Habitat	**Organic matter abundance**	
Natural Habitat	**Longitudinal profile variability**	
Natural Habitat	**Residual pool depth**	
Natural Habitat	**Periphyton**	Yes but not reported
Natural Habitat	**Macrophyte cover and clogginess**	Yes but not reported
Natural Habitat	Water temperature	Yes
Natural Habitat	**Water clarity**	
Natural Habitat	**Settled sediment**	
Water Quality	**Faecal indicators**	
Water Quality	*Nutrients*	
Water Quality	*Dissolved oxygen*	
Ecosystem Function	*Ecosystem metabolism*	
Ecosystem Function	*Organic matter processing*	
Ecosystem Function	**Leaf litter retention**	
Aquatic Biodiversity	**In-stream macrophytes**	Yes but not reported
Aquatic Biodiversity	Benthic macroinvertebrates	Yes
Aquatic Biodiversity	**Fish**	
Natural Habitat and Terrestrial Biodiversity	**Terrestrial plant biodiversity and survival of plantings**	

Table 5. Variables to monitor to improve determination of ecological success of riparian retirement, Catchment Environment Monitoring Program. Aim: to demonstrate the long term benefits of soil conservation. Variables in bold font can easily be monitored at little extra cost and effort and are recommended for future monitoring. Variables in italic font could also be monitored but may not be necessary for the CEMP.

Value	Indicator	Monitored
Natural Habitat	**Shade of water surface**	Yes
Natural Habitat	Water and channel width	Yes
Natural Habitat	**Stream bed particle size**	
Natural Habitat	**Mesohabitats**	
Natural Habitat	Bank erosion and condition	Yes
Natural Habitat	**Organic matter abundance**	
Natural Habitat	**Longitudinal profile variability**	
Natural Habitat	**Residual pool depth**	
Natural Habitat	**Periphyton**	Yes but not reported
Natural Habitat	**Macrophyte cover and clogginess**	Yes but not reported
Natural Habitat / Water Quality	Water temperature	Yes
Natural Habitat / Water Quality	**Water clarity**	
Natural Habitat	**Settled sediment**	
Water Quality	**Faecal indicators**	
Water Quality	**Nutrients**	
Water Quality / Ecosystem Function	**Dissolved oxygen**	
Ecosystem Function	**Ecosystem metabolism**	
Ecosystem Function	**Organic matter processing**	
Ecosystem Function	**Leaf litter retention**	
Aquatic Biodiversity	**In-stream macrophytes**	Yes but not reported
Aquatic Biodiversity	Benthic macroinvertebrates	Yes
Aquatic Biodiversity	**Fish**	
Natural Habitat and Terrestrial Biodiversity	**Terrestrial plant biodiversity and survival of plantings**	

5.1.1 Stream bed particle size

Stream bed particle size is a strong driver of biological communities in streams. A more diverse range of particle sizes is likely to house a more diverse stream macroinvertebrate community (Death 2000). Fine sediments (sand and silt) are generally considered unsuitable for the majority of sensitive macroinvertebrates (mayflies, stoneflies and caddis flies), favouring less sensitive macroinvertebrates (worms, molluscs, midges). Most indigenous fish are benthic in habit, using the stream bed for shelter, foraging and nesting, and thus benefit form large particles (cobbles and boulders). Loss of large particles or increases in fine sediment can cause a decrease in indigenous fish abundance and diversity (Richardson & Jowett 2002) due to degradation of their habitat. It is likely that as a stream becomes restored a greater diversity of substrates and stable habitat (wood) will develop which will house a more diverse aquatic community of plants and animals.

5.1.2 Frequency of mesohabitats

Run, riffle, pool, rapids and backwaters are hydraulic habitats within a stream reach which have differing mean water velocities and depths. Stream biota have differing hydraulic habitat preferences and species often benefit from a mix of different habitats for different activities e.g. feeding, resting, spawning (Jowett et al. 2008, Jowett & Richardson 1994, Jowett et al. 1991). Increased meso-habitat diversity can result in greater biodiversity of the in stream biota.

5.1.3 Organic matter abundance

Organic matter (leaves, twigs, wood) on the stream bed provides an important food source for stream life. Leaf packs and wood also provide important habitat for fish and invertebrates.

5.1.4 Longitudinal profile variability

This measurement provides a quantitative measure of changes in the variability of depth along a restored reach as a simple indicator of habitat variability.

5.1.5 Residual pool depth

This is the difference between the maximum water depth of a pool and the water depth at the riffle crest immediately downstream of the pool. Residual pool depth estimates the maximum depth of water that would remain in the pool when the stream ceases to flow which provides important refugia for invertebrates and fish during extreme low flow periods. Residual pool depth can also provide an indication of pool infilling due to increased sediment deposition.

5.1.6 Periphyton cover

As a stream becomes increasingly shaded it is likely that nuisance periphyton growths will become light limited and their proportion of stream bed cover will become less. This is likely to benefit the aquatic fauna of the stream.

5.1.7 Macrophyte cover and clogginess

Many soft bottomed streams are clogged by extensive aquatic macrophyte growth. This creates areas of anoxia within the stream which is caused by respiration of the plant and the impedance of flow giving little aeration to the water column. As a stream becomes increasingly shaded by riparian restoration it is likely that nuisance aquatic macrophyte growths will become light limited. This will enable the stream to flow more freely and areas of anoxia will disappear. In general exotic species of macrophyte are likely to create more problems in soft bottomed streams than indigenous species. Therefore recording the relative cover of each macrophyte adds further useful information towards measuring the ecological success of a stream restoration project.

Note the current methods deployed by Waikato Regional Council for ecological assessments for periphyton and plant cover are the same as those specified by the restoration indicator toolkit (Parkyn et al. 2010). However the data generated from these assessments of the CEMP, CSMP and REMS programmes have not been reported before. The data for these variables need to be reported in future publications as emerging trends are likely to demonstrate ecological changes to the respective stream ecosystems.

5.1.8 Settled sediment

Settled sediment in a stream may rise during the initial stages of a stream developing a more natural water course; however, over time it is expected that settled sediment on the substrate will become less. A detailed methodology on assessing settled sediment is provided by Clapcott et al. (2011) of which Method 1 is most applicable.

Many of the variables mentioned above are measured as part of Waikato Regional Council's ecological assessment habitat protocols (Collier & Kelly 2005); however, these habitat assessment protocols were largely derived for state of the environment monitoring purposes. The data generated from the field sheets of some habitat components are mostly categorical and more generic than the information needed for measuring the ecological success of stream restoration. Therefore emerging trends will be more difficult to determine from such assessments as opposed to the methods which are detailed in the restoration indicator toolkit specified by Parkyn et al. (2010).

5.1.9 Water clarity

Water clarity measures the depth of light penetration available for aquatic plants to grow as well as estimating the distance at which aquatic animals may sight prey. It is expected that as a stream is restored, its water clarity will improve during both base and peak flow events.

5.1.10 Faecal indicator bacteria

This is a particularly important variable to measure for the CSMP for which the goal is to protect the streams from surrounding land use practices. *Escherichia coli* is a species of indicator bacteria common to the faeces of mammals. Fencing stock from water ways and planting riparian buffers is likely to result in a reduction in *E. coli* concentrations in a stream.

5.1.11 Fish

Fish are an important indicator of overall ecosystem health and function. As a stream becomes restored it is likely that a greater diversity of habitat types will become available which would enhance fish diversity and abundance. Removing fish migration barriers is an important component of stream restoration that would also enhance the fishery value of a stream. As a first step the Waikato Regional Council should monitor fish of their restoration and reference sites to determine the diversity of fish there. Diversity and abundance of indigenous fish are important indicators to measure ecological success of a stream restoration project.

5.1.12 Terrestrial plant biodiversity

The successful establishment of riparian vegetation is vital for stream restoration as most indicator measures rely on or are influenced by the development of shade and other attributes (e.g. provision of microclimate, food and habitat resources) that is sourced from tall, woody vegetation. While the CEMP records the relative percentage of indigenous and non-indigenous woody vegetation, the CSMP does not. In addition to this both programmes need to undertake Recce plot surveys (Hurst & Allen 2007) to determine the overall improvements of terrestrial biodiversity to the restored reaches.

5.1.13 Ecosystem respiration and metabolism

A good way to measure the ecological response of the Matahuru Stream and Wharekawa River to the pressures they are receiving is through measuring ecosystem respiration and metabolism using the methods proposed by Young et al. (2008).

5.2 Quantifying restoration efforts

It is strongly recommend that the Waikato Regional Council undertakes a stock take of its riparian restoration efforts for two variables, namely length of stream restored and mean riparian buffer width. Understanding how much riparian restoration is needed to result in ecological success is vital information for Council and should be an important component of its monitoring programmes. The CEMP has gone some way in assessing broad vegetation amounts, degree of fencing and areas of erosion, however this data has been generated using fixed transects and does not provide the data in a catchment wide context. Initially a desk top GIS project could go some way to defining how much stream length has riparian vegetation cover, however it would require field validation to determine whether the shaded regions of a map are fenced and whether that vegetation is indigenous or exotic. A desktop study of the land cover data base may also help quantify whether any land use changes may have influenced results of current monitoring programmes.

5.3 Reporting

It is recommended that detailed methods of the CSMP are documented in a Waikato Regional Council technical report as this has not yet been completed. It is also recommended that any future CEMP reports incorporate data previously reported as bar charts to allow comparison over time at all sites.

6 Conclusions

The Clean Streams Monitoring Programme has identified a number of emerging trends, some of which have statistical and / or ecological significance with respect to the ecological success of this restoration programme.

Conversely, the Catchment Environmental Monitoring Programme has been less successful in determining its prime objective of determining improvements of soil conservation. This stems largely from the survey design of this monitoring programme which has focused on larger catchments and only analysed selected transects for changes in riparian condition.

The CSMP has generally monitored smaller stream catchments than the CEMP, therefore emerging trends have been quicker to appear. The CEMP has focused on larger stream or river catchments for which ecological benefits may take longer to emerge. Furthermore, the larger stream sites may show little change if upstream smaller order tributaries have not been restored to the same extent. It is difficult to tell how much stream length has been restored as this is a variable that has not been measured for either programme. It is recommended that the CEMP programme should focus on smaller stream catchments if it is to deliver consistent results that demonstrate improvements to stream health at the catchment scale.

As mentioned previously, the results of this report should be treated with caution as the data sets analysed are still very small. Ongoing collection of monitoring data will allow more robust conclusions to be drawn.

If any sites are to be added to the CSMP or CEMP it is recommended that they be monitored for three years before any restoration efforts are made. This helps establish the baseline stream condition prior to restoration works.

7 Acknowledgements

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Appendix I
General Monitoring Site Locations

Table A1. Monitoring site locations, sorted by monitoring programme. Key: * Used in report; † Reference site; [i] Long Term REMS Site. Note: all sites are listed for CEMP and CSMP, but only relevant sites are listed for other programmes.

Project	Located Number	Stream/Location name	Stream/River name	Management Zone	NZTM - EASTING	NZTM - NORTHING
Clean Streams*	1164_5	Waimata	Stony Stream	Hauraki	1851911	5851085
Clean Streams*	56_7	Boom	Tramway Gully Stream	Coromandel	1849927	5888672
Clean Streams*	1873_1	Otupotu	Otaipihu	Taupo	1835682	5714801
Clean Streams*	1009_3	Te Pahu	Te Pahu Stream Tributary	Waipa	1785016	5796710
Clean Streams*	1174_19	Waiomou	Omahine Stream	Hauraki	1853014	5807375
Clean Streams*	1243_6	Waitete	Stony Stream	Hauraki	1850052	5857839
Clean Streams*	355.7	Makomako	Mangare Stream Tributary	Upper Waikato	1831432	5764748
Clean Streams*	934.6	Tahunaatara tributary	Pokaitu Stream	Upper Waikato	1868339	5752795
Clean Streams*	1311.6		Wharekaunga Tributary	Upper Waikato	1894031	5739920
CEMP*		Pokaiwhenua Catchment	Pokaiwhenua Stream	Upper Waikato	1802788	5851201
CEMP*†	555_2	Mokaihaha Reference		Upper Waikato	1864718	5770433
CEMP*		Tahunaatara Catchment	Pokaitu Stream	Upper Waikato	1877975	5762982
CEMP*		Mangatutu Catchment	Mangatutu Stream	Waipa	1815149	5769884
CEMP*†	1888_4	Otautora Reference		Waipa	1826491	5784415
CEMP*		Matahuru Catchment	Matahuru Stream	Lower Waikato	1802788	5851201
CEMP*		Wharekawa	Wharekawa River	Coromandel	1851199	5885040
CEMP* (also CSMP)		Mangare Catchment	Mangare Stream	Upper Waikato		
REMS*[i]	1043_1	Toenepi		Hauraki	1824850	5823912
REMS*	1252_3/1252_1	Waitoki		Hauraki	1787335	5827153
REMS*[i]	398_1	Mangakotukutuku		Upper/Mid Waikato	1802460	5812673
REMS*	786_2	Pokaiwhenua		Upper/Mid Waikato	1838916	5784216
REMS*	1253_9	Waitomo Stream		Waipa	1783079	5763172
REMS*	476_1	Mangatutu		Waipa	1812017	5774875
REMS*	1172_6	Wainui (Raglan)		West Coast	1761922	5813014
REMS*[i]	1300_2	Whangamata		Upper/Mid Waikato	1853536	5717011
RWQMP*	1253-5	Waitomo Stream		Waipa	1792015	5771848
RWQMP*	1253-7	Waitomo Stream		Waipa	1783624	5763236
RWQMP*	1312-3	Wharekawa River		Coromandel	1852450	5886287
RWQMP*	398-1	Mangakotukutuku Stream		Upper/Mid Waikato	1802460	5812673
RWQMP*	476-7	Mangatutu Stream (Waike)		Waipa	1810109	5780575
RWQMP*	516-5	Matahuru Stream		Lower Waikato	1798000	5849274
RWQMP*	786-2	Pokaiwhenua Stream		Upper/Mid Waikato	1838866	5784259
RWQMP*	934-1	Tahunaatara Stream		Upper Waikato	1868374	5752236
SSYMP*		Mangatutu Stream		Waipa	1810109	5780575
SSYMP*		Matahuru		Lower Waikato	1798000	5849274
SSYMP*		Wharekawa		Coromandel	1851964	5885309

Appendix II
Statistical Outputs for Time Series Trends

Time Trends 16/04/14

File: E:\clean streams trend data.xlsx: Worksheet: Temp

Mann-Kendall test for Boom Temperature Difference C

Period analysed 9 years and 1 months for calendar years 2004 to 2013

10 observations from 1/03/04 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	1.100	-5.0	125.0	-0.358	0.36	-0.024	-0.162	0.104

Mann-Kendall test for Otupotu Temperature Difference C

Period analysed 9 years and 1 months for calendar years 2004 to 2013

10 observations from 1/03/04 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	2.340	-17.0	125.0	-1.43	0.07	-0.436	-0.702	0.039

Mann-Kendall test for Te Pahu Temperature Difference

Period analysed 10 years and 1 months for calendar years 2003 to 2013

10 observations from 1/03/03 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	3.005	-33.0	125.0	-2.86	0.001	-0.176	-0.253	-0.115

Mann-Kendall test for Waimata Temperature Difference C

Period analysed 9 years and 1 months for calendar years 2003 to 2012

10 observations from 1/03/03 to 1/03/12 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	2.789	5.0	125.0	0.35	0.36	0.063	-0.384	0.574

Mann-Kendall test for Waiomou Temperature Difference C

Period analysed 8 years and 1 months for calendar years 2005 to 2013

9 observations from 1/03/05 to 1/03/13 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	2.833	-22.00	92.0	-2.18	0.01	-0.358	-0.539	-0.216

Mann-Kendall test for Waitete Temperature Difference C

Period analysed 7 years and 1 months for calendar years 2005 to 2012

8 observations from 1/03/05 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	4.082	-14.0	65.3	-1.60	0.054	-0.140	-0.279	0.003

Mann-Kendall test for Boom Stream MCI

Period analysed 9 years and 1 months for calendar years 2004 to 2013

10 observations from 1/03/04 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	105.357	11.0	125.0	0.89	0.19	1.100	-0.809	2.828

Mann-Kendall test for Otupotu Stream MCI

Period analysed 9 years and 1 months for calendar years 2004 to 2013

10 observations from 1/03/04 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	92.333	19.0	125.0	1.61	0.054	3.071	-0.274	5.378

Mann-Kendall test for Te Pahu Stream MCI

Period analysed 10 years and 1 months for calendar years 2003 to 2013

11 observations from 1/03/03 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	126.429	-5.0	165.0	-0.31	0.75	-0.194	-1.245	0.971

Mann-Kendall test for Waimata Stream MCI

Period analysed 10 years and 1 months for calendar years 2003 to 2013

11 observations from 1/03/03 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	84.706	21.0	165.0	1.55	0.11	0.586	-0.098	1.642

Mann-Kendall test for Waiomou Stream MCI

Period analysed 8 years and 1 months for calendar years 2005 to 2013

9 observations from 1/03/05 to 1/03/13 with 0 ties

Sample size less than 11 and small sample size probablities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	83.529	-2.0	92.0	-0.10	0.46	-0.187	-1.329	0.546

Mann-Kendall test for Waitete Stream MCI

Period analysed 8 years and 1 months for calendar years 2005 to 2013

9 observations from 1/03/05 to 1/03/13 with 0 ties

Sample size less than 11 and small sample size probabilities were used

File: E:\cemp temp trends.xlsx: Worksheet: Sheet1

Mann-Kendall test for Matahuru Stream Temperature difference

Period analysed 8 years and 1 months for calendar years 2004 to 2012

9 observations from 1/03/04 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	-0.9	22.0	92.0	2.18	0.012	0.060	0.023	0.086

Mann-Kendall test for Pokaiwhenua StreamTemperature difference

Period analysed 8 years and 1 months for calendar years 2004 to 2012

9 observations from 1/03/04 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	-0.330	-10.000	92.000	-0.93	0.17	-0.037	-0.138	0.031

Mann-Kendall test for Pokaitu Stream Temperature difference

Period analysed 8 years and 1 months for calendar years 2004 to 2012

9 observations from 1/03/04 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	-0.380	10.000	92.000	0.938	0.179	0.051	-0.028	0.089

Mann-Kendall test for Mangatutu Mid/Upstream Temperature difference

Period analysed 7 years and 1 months for calendar years 2005 to 2012

8 observations from 1/03/05 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	1.075	6.000	65.333	0.619	0.274	0.042	-0.206	0.150

Mann-Kendall test for Mangatutu Mid/Downstream Temperature difference

Period analysed 7 years and 1 months for calendar years 2005 to 2012

8 observations from 1/03/05 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	-0.540	2.000	65.333	0.12	0.45	0.036	-0.429	0.373

Mann-Kendall test for Pokaiwhenua upstream MCI

Period analysed 9 years and 1 months for calendar years 2004 to 2013

10 observations from 1/03/04 to 1/03/13 with 2 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	112.600	10.000	121.333	0.81	0.21	0.333	-0.334	1.881

Mann-Kendall test for Pokaiwhenua downstream MCI

Period analysed 9 years and 1 months for calendar years 2004 to 2013

10 observations from 1/03/04 to 1/03/13 with 0 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	105.5	-21.0	125.0	-1.78	0.036	-1.600	-2.911	-0.072

Mann-Kendall test for Reference site - Mokaihaha Stream MCI

Period analysed 7 years and 1 months for calendar years 2005 to 2012

8 observations from 1/03/05 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	134.450	-14.000	65.333	-1.60	0.054	-1.425	-3.001	0.862

Mann-Kendall test for Mangatutu downstream MCI

Period analysed 8 years and 1 months for calendar years 2005 to 2013

9 observations from 1/03/05 to 1/03/13 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	106.9	-14.0	92.0	-1.35	0.09	-1.190	-2.394	0.242

Mann-Kendall test for Otautora Stream MCI

Period analysed 7 years and 1 months for calendar years 2005 to 2012

8 observations from 1/03/05 to 1/03/12 with 1 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	139.5	-15.0	64.3	-1.74	0.042	-1.500	-4.003	-0.101

Mann-Kendall test for Pokaitu downstream MCI

Period analysed 9 years and 1 months for calendar years 2004 to 2013

10 observations from 1/03/04 to 1/03/13 with 1 ties

Sample size greater than 10 and normal approximation used to determine P value

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	116.5	-4.0	124.0	-0.26	0.39	-1.000	-3.220	1.265

Mann-Kendall test for Mokaihaha Stream MCI

Period analysed 7 years and 1 months for calendar years 2005 to 2012

8 observations from 1/03/05 to 1/03/12 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	133.0	-20.0	65.3	-2.35	0.007	-2.759	-3.794	-1.333

Mann-Kendall test for Mangare upstream MCI

Period analysed 7 years and 1 months for calendar years 2006 to 2013

8 observations from 1/03/06 to 1/03/13 with 1 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	105.15	9.0	64.3	0.99	0.16	1.983	-1.102	4.516

Mann-Kendall test for Mangare downstream Mci

Period analysed 7 years and 1 months for calendar years 2006 to 2013

8 observations from 1/03/06 to 1/03/13 with 0 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	93.35	16.0	65.3	1.85	0.031	1.291	0.233	3.733

Mann-Kendall test for Reference site Otautora Stream MCI

Period analysed 6 years and 1 months for calendar years 2006 to 2012

7 observations from 1/03/06 to 1/03/12 with 2 ties

Sample size less than 11 and small sample size probabilities were used

	Median value	Kendall statistic	Varianc e	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	139.0	-9.0	42.3	-1.23	0.11	-0.920	-4.275	0.852

Mann-Kendall test for Wharekawa MCI

Period analysed 7 years and 1 months for calendar years 2005 to 2012

8 observations from 1/03/05 to 1/03/12 with 1 ties

Sample size less than 11 and small sample size probabilities were used

Appendix III
Commentary of Results of the Catchment Environmental Monitoring Programme

COROMANDEL MANAGEMENT ZONE

WHAREKAWA RIVER

CHANGES TO STREAM MORPHOLOGY

Figure 1 shows that the mean channel and wetted width of the Wharekawa River has varied a lot since March 2005.

Overall the channel and wetted widths have not changed significantly since monitoring commenced. Figure 2 shows that river depth has also been very dynamic in the Wharekawa River. It is likely that most of the changes in stream morphology of this river system have been driven by the prevailing hydrology as opposed to any influences of riparian retirement.

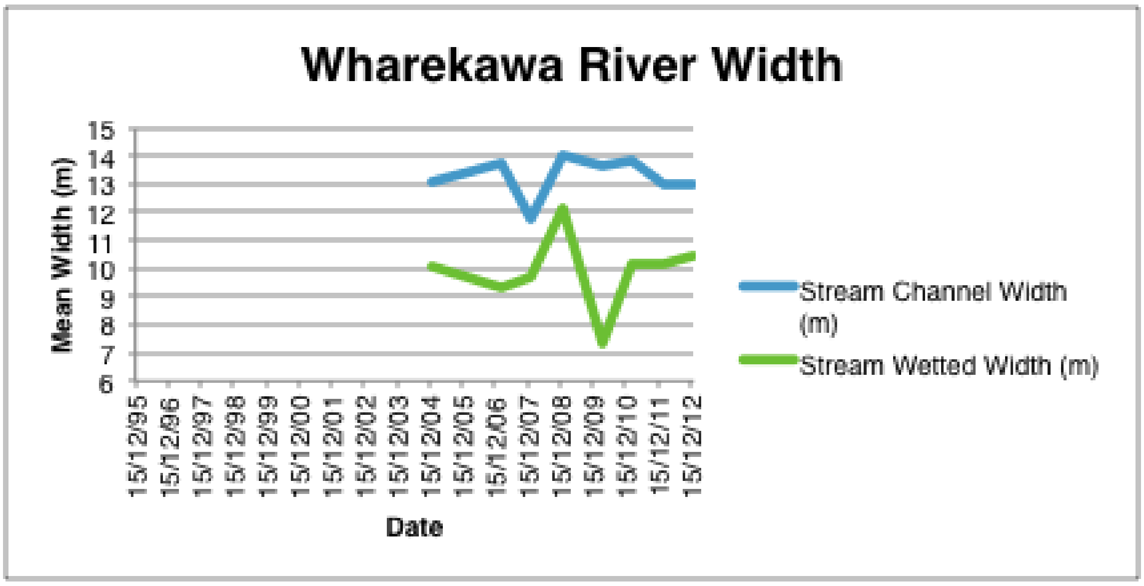


Figure 1. Changes to mean channel and wetted width since 2003

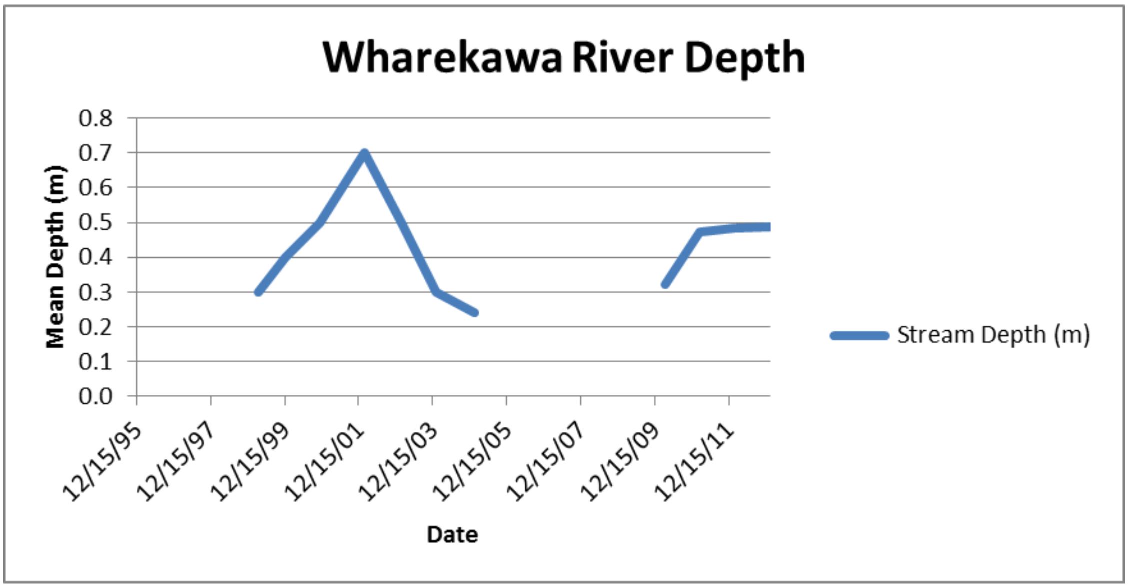


Figure 2. Changes to river depth since 2005

WATER TEMPERATURE

There is currently insufficient water temperature data to analyse for the Wharekawa River as the sample size is too small to have statistical confidence in the results. Littler et al. (2012) showed that unlike the macroinvertebrate community data, the temperature data was not collated until a year later.

MACROINVERTEBRATE COMMUNITY INDEX

In 2005 the macroinvertebrate community index value measured at the downstream site was approximately 95. There has been a lot of variability in MCI values generated since this time and there is a slight upward trend illustrated in the time series plot. The median MCI value for the complete data set is 94.1 which is representative of moderate organic enrichment. Figure 3 shows a slight upward trend of MCI values since 2005, however this trend is not considered statistically or ecologically significant.

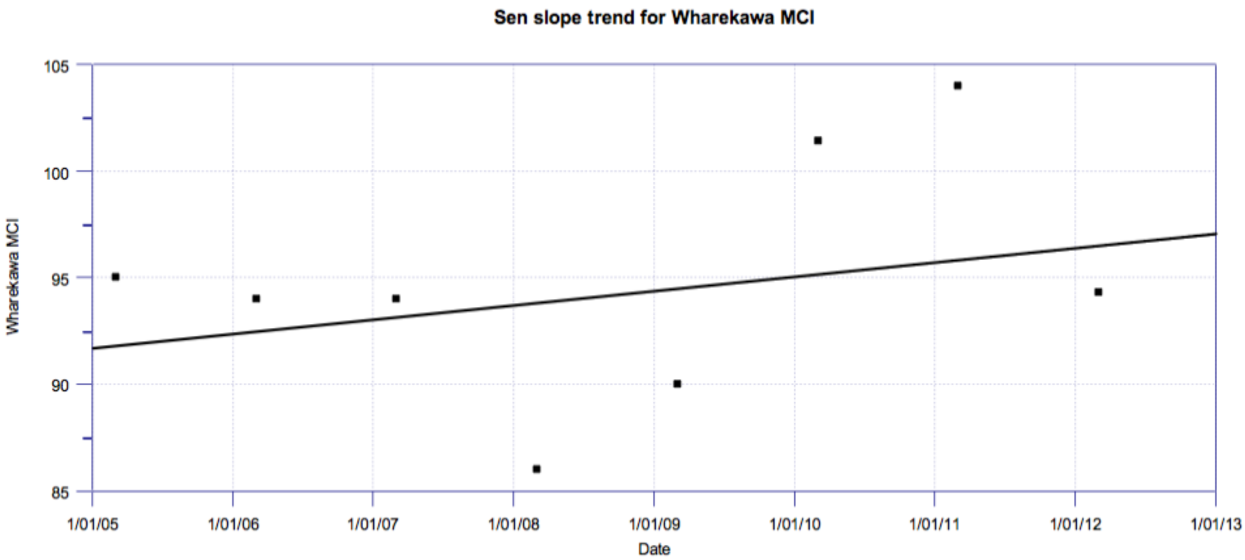


Figure 3. MCI Time Series Plot

WAIPA MANAGEMENT ZONE

OTAUTORA STREAM

CHANGES TO STREAM MORPHOLOGY

Figure 4 shows that the channel and wetted width of the Otautora stream is quite dynamic. Overall the channel width has decreased slightly from 3.7 m in 2005 to 3.5 m in 2012. Overall the wetted width has decreased from 3.6 m in 2005 to 2.1 m in 2013. Figure 5 shows that mean stream depth measurements have been erratic since 2004. Overall the mean stream depth has increased slightly from 0.15 m in 2005 to 0.21 m in 2013. As the Otautora Stream is a reference site, it is likely that any changes to stream morphology have been driven by preceding hydrological conditions as opposed to any management of the riparian zone of the stream.

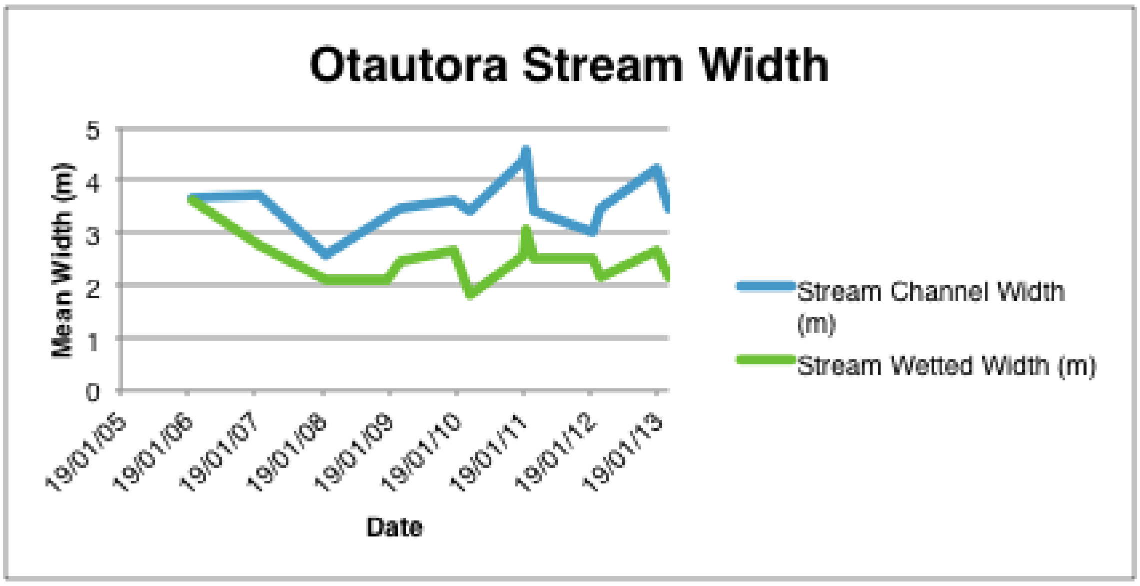


Figure 4. Changes to stream channel width since 2005

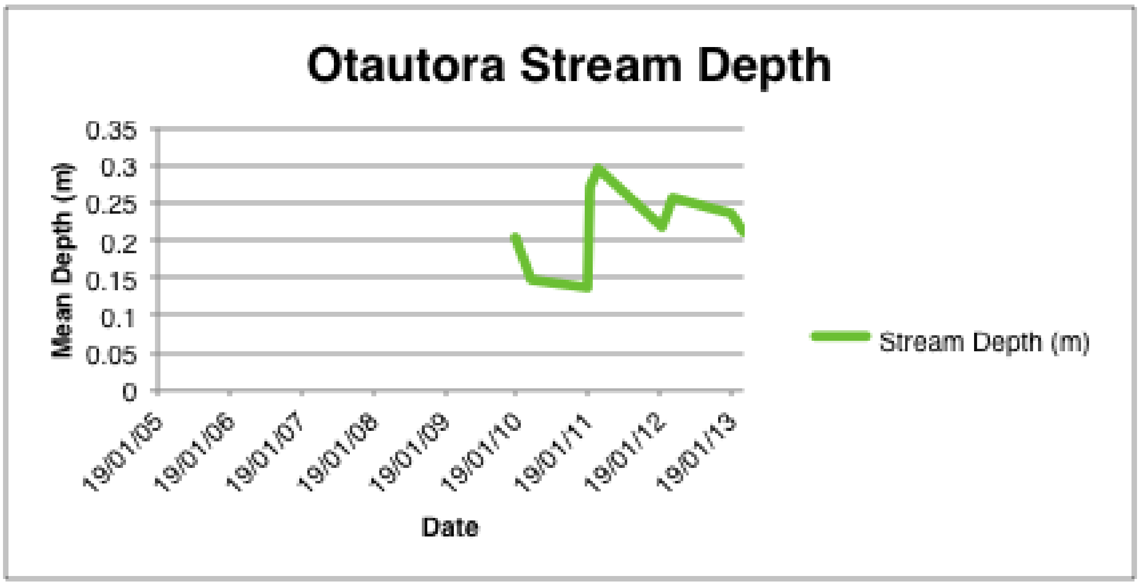


Figure 5. Changes to stream depth since 2004

WATER TEMPERATURE

Water temperature is not monitored in the Otautora Stream.

MACROINVERTEBRATE COMMUNITY INDEX

The MCI value measured in the summer of 2005/6 was approximately 145. Since this time MCI values have declined slightly. The median value for the data set is 139.5 which indicates excellent water and habitat quality. Figure 6 shows a declining trend in MCI values since monitoring commenced however there is a lot of variability around the trend. While the trend line is statistically significant ($p = 0.04$), it is not ecologically significant.

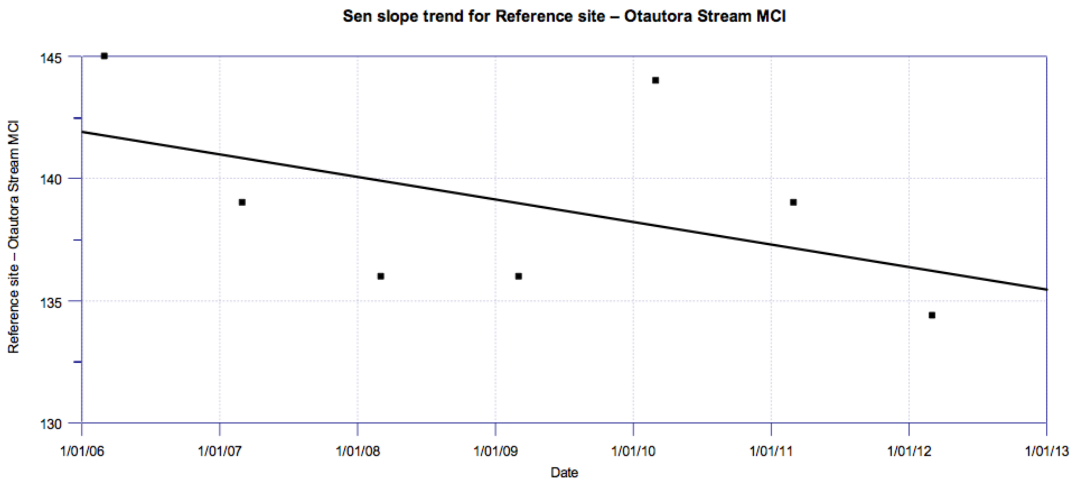


Figure 6. MCI Time Series Plot

MANGATUTU STREAM

CHANGES TO STREAM MORPHOLOGY

Measurements of stream channel width, wetted width and depth have only been regularly monitored since 2009. Therefore the data set is very small and little can be said about the changes to stream morphology at this stage.

WATER TEMPERATURE

Water temperature of the Mangatutu Stream has been monitored at three locations (downstream, midstream and upstream) since the summer of 2005. Figure 7 shows no discernible trend in water temperature differential between the up and downstream monitoring sites since monitoring commenced in 2005. The trend is not statistically or ecologically significant.

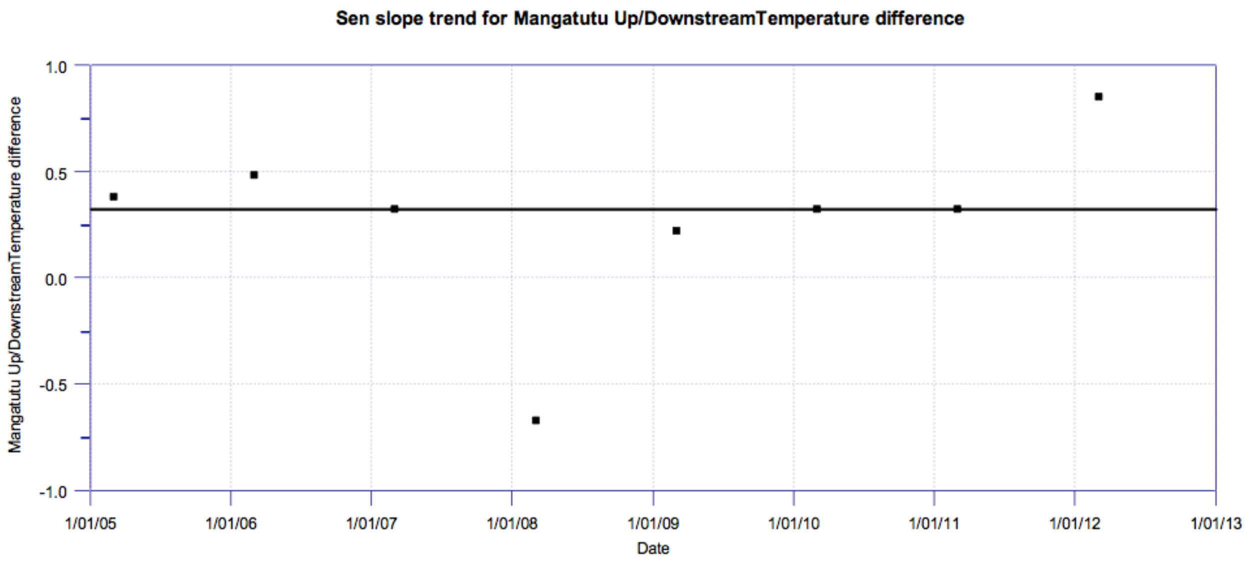


Figure 7. Mean daily maximum water temperature difference between downstream and upstream monitoring sites.

MACROINVERTEBRATE COMMUNITY INDEX

In 2005 the macroinvertebrate community index value measured at the downstream site was approximately 114. There has been a lot of variability in MCI values generated since this time and there is a downward trend illustrated in the time series plot. The median MCI value for the complete data set is 106.9 which is representative of mild organic enrichment.

Figure 8 shows a downward trend of MCI values since monitoring commenced in 2005 however this trend is not statistically or ecologically significant.

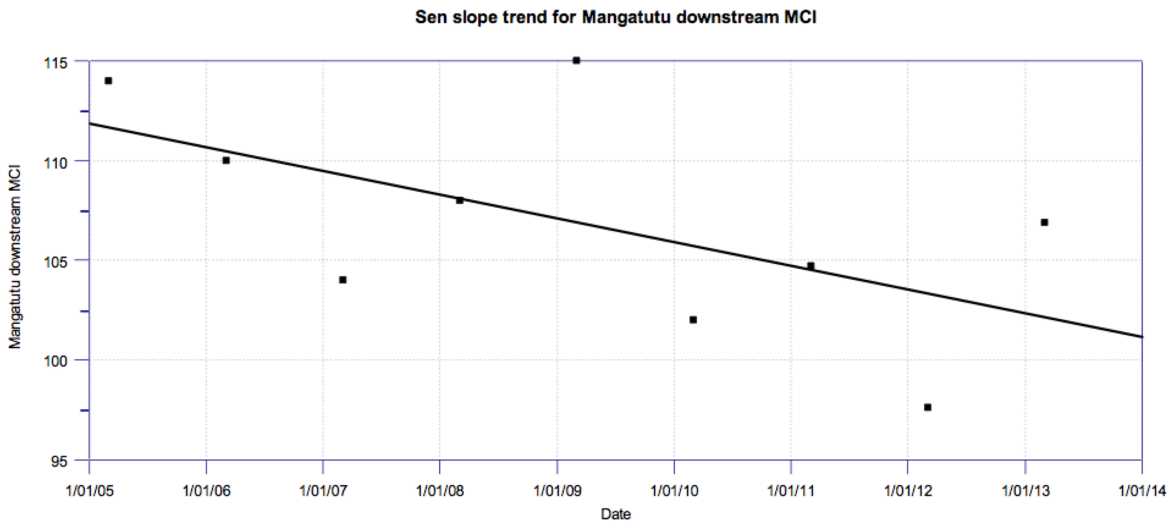


Figure 8. MCI Time Series Plot

LOWER WAIKATO MANAGEMENT ZONE

MATAHURU STREAM

No stream morphology measurements have been made of the Matahuru Stream. This is largely because the stream is quite steep sided and deep, therefore it poses difficulties with measuring channel width, wetted width and stream depth safely.

WATER TEMPERATURE

In the summer of 2004/05 the downstream water temperature was approximately 1.7 °C cooler at the downstream site. Since this time the temperature differential between the up and downstream sites has become smaller. Figure 9 shows that the stream water temperature downstream has warmed over the years of monitoring to become more like the upstream water temperature. This trend is both statistically (p=0.012) and environmentally significant (increase 6.6% / annum).

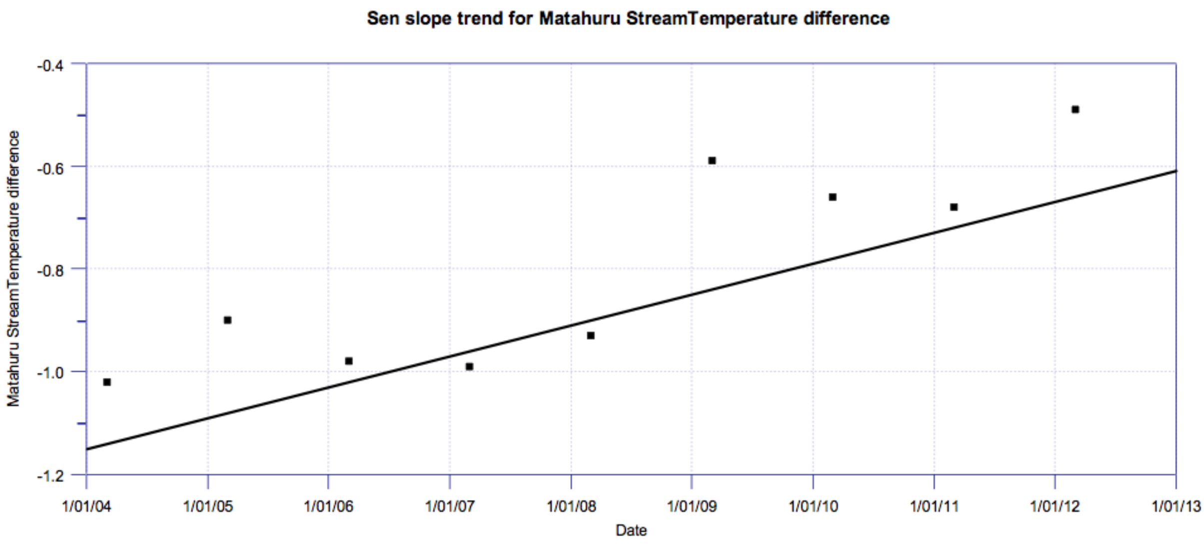


Figure 9. Mean daily maximum water temperature difference between downstream and upstream monitoring sites.

MACROINVERTEBRATE COMMUNITY INDEX

The Matahuru Stream is not monitored for aquatic macroinvertebrates.

UPPER WAIKATO MANAGEMENT ZONE

POKAIWHENUA RIVER

CHANGES TO STREAM MORPHOLOGY

The Pokaiwhenua Stream has only been monitored for stream morphology on a regular basis since 2010 therefore the data set is currently too small to make any conclusions about the changes to overall stream morphology.

WATER TEMPERATURE

In the summer of 2004/05 the downstream water temperature was approximately 0.2 ° C cooler at the upstream site. Downstream water temperatures have remained cooler at the downstream site however in more recent years the temperature difference has become less. Figure 10 shows that downstream water temperatures of the Pokaiwhenua progressively became cooler than the upstream site from 2004/05 through to 2009/10 however since this time the temperature difference has become less.

There is a lot of scatter about the trend line particularly from 2008 to 2010. The trend is not statistically or ecologically significant.

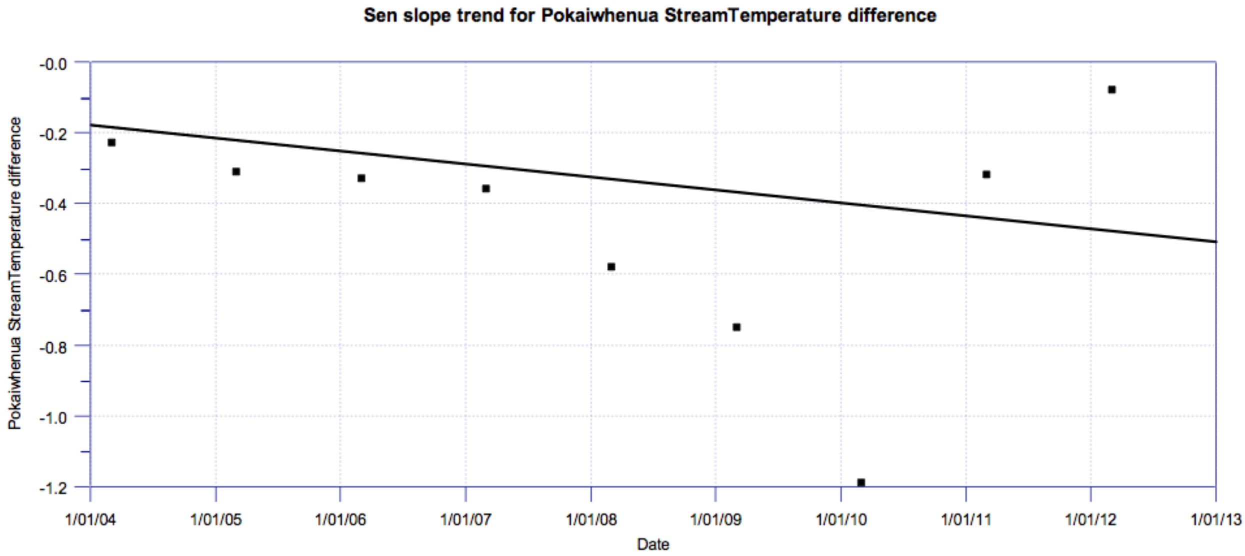
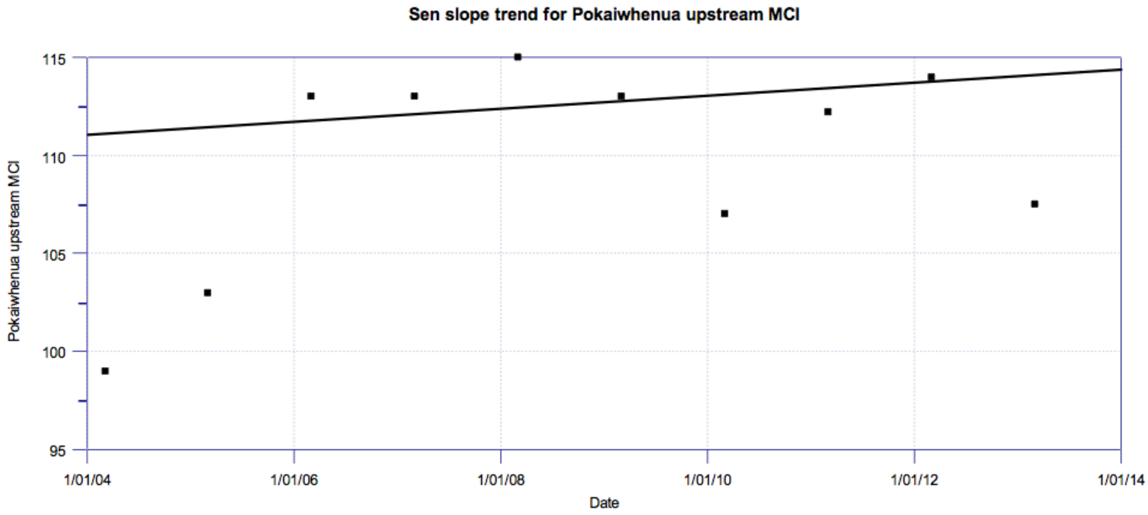


Figure 10. Mean daily maximum water temperature difference between downstream and upstream monitoring sites.

MACROINVERTEBRATE COMMUNITY INDEX

Macroinvertebrates are monitored upstream and downstream of the restored reach of the Pokaiwhenua Stream. The median MCI value for the upstream data set is 112.6 while the median MCI value for the downstream site is 105.5. Both sites are representative of mild organic enrichment. Figure 11 shows a slight upward trend for the MCI values of the upstream site while the downstream site shows a discernible downward trend. The upstream site trend is not considered statistically or ecologically significant while the downstream site trend is statistically significant (p= 0.03) but not considered ecologically significant.



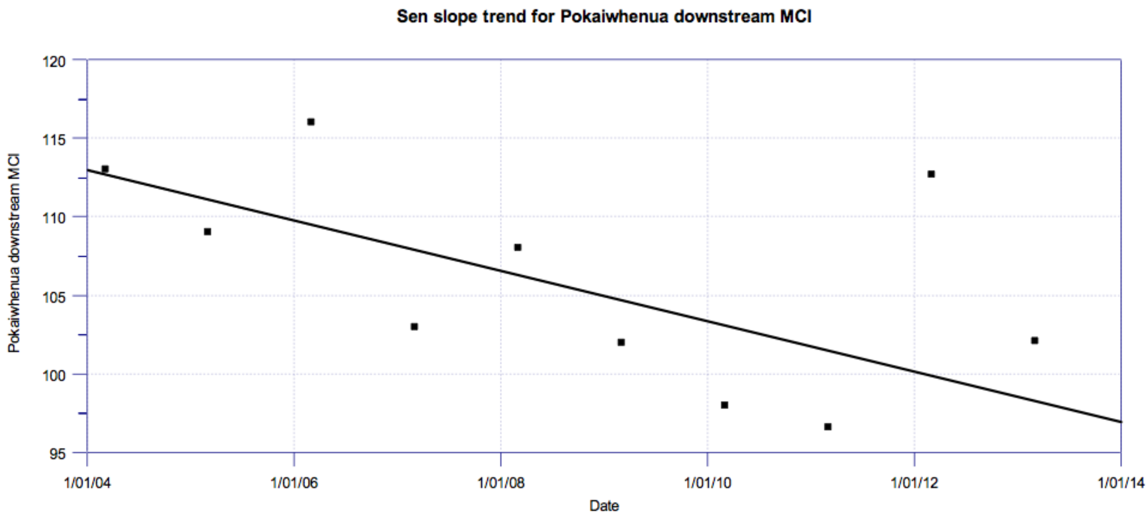


Figure 11. MCI Time Series Plots for Pokaiwhenua Upstream and Downstream Sites.

MOKAIHAHA STREAM - REFERENCE

CHANGES TO STREAM MORPHOLOGY

Figure 12 shows that the Mokaihaha Stream has quite a dynamic channel and wetted width. Overall the channel width has decreased from 7.2 m in February 2005 to 6.4 m in 2013 while the stream wetted width has decreased from 5.5 m in February 2005 to 4.0 m in February 2013

Figure 13 shows that monitoring of stream depth has been erratic since 2005. Overall the stream depth of the Mokaihaha Stream has increased from 0.17m in 2005 to 0.22 m in 2013.

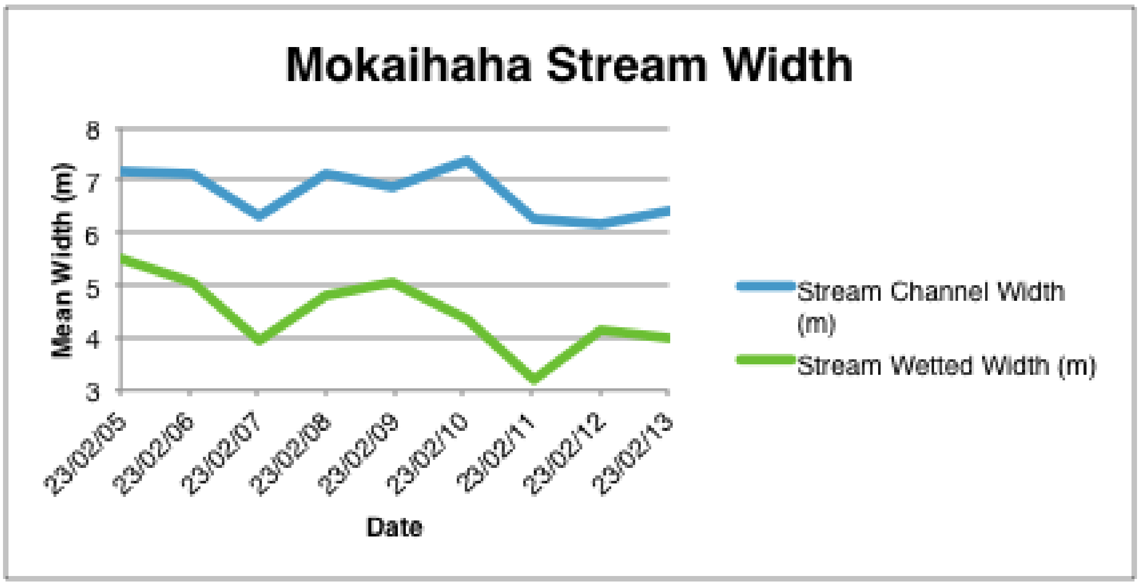


Figure 12. Changes to mean stream channel width since 2005

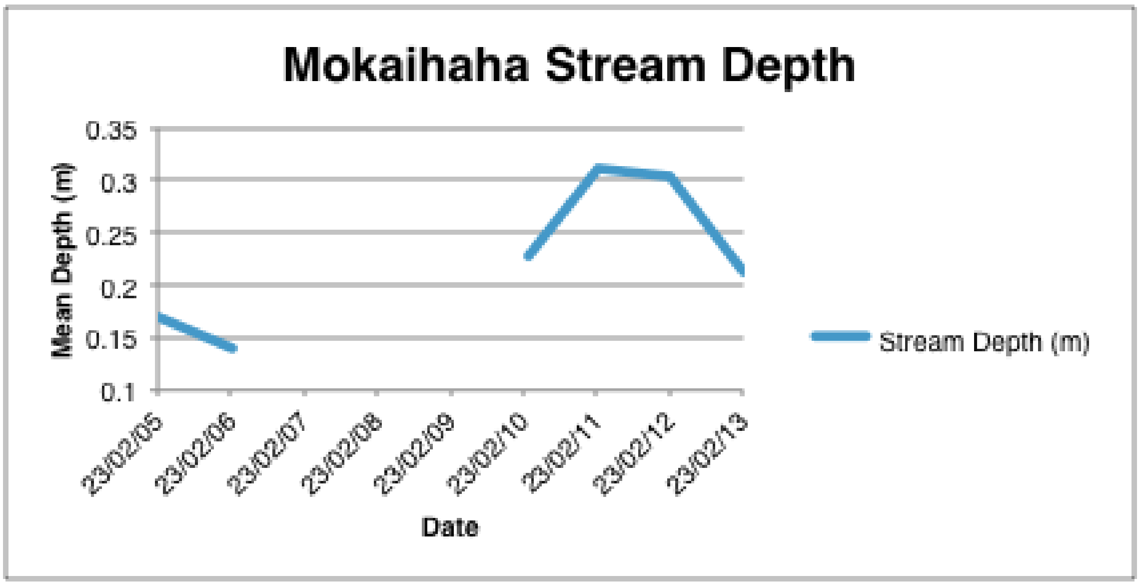


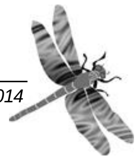
Figure 13. Changes to stream depth since 2005

WATER TEMPERATURE

The Mokaihaha Stream is not monitored for stream water temperature.

MACROINVERTEBRATE COMMUNITY INDEX

The Mokaihaha Stream has a median MCI value of 133 which is representative of excellent stream water quality and habitat. The site has been monitored as a reference stream for comparison with other streams that may have restoration works occurring. Figure 14 shows a discernible downward trend in MCI values since 2005/06. The reason for this downward trend is unclear. The trend is considered both statistically (p=0.007) and ecologically significant (overall change = 15.8%, rate of change = 2.07% /annum as an expression of the median).



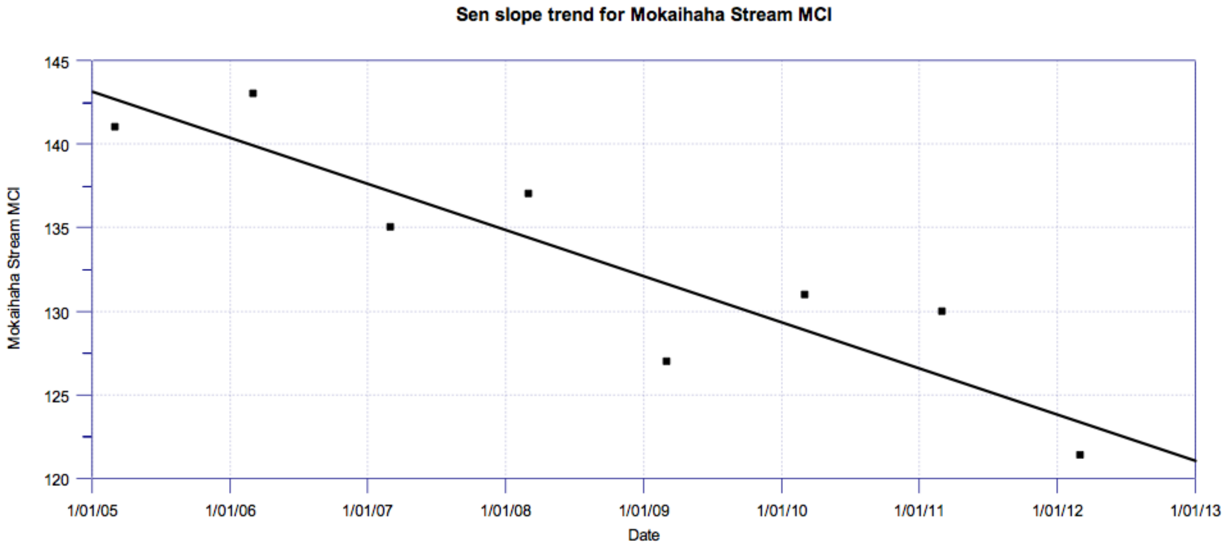


Figure 14. Time series MCI plot.

POKAITU STREAM

CHANGES TO STREAM MORPHOLOGY

Figure 15 shows that the Pokaitu Stream channel and wetted width has progressively widened over time. The overall mean channel width has increased from 4.4 m in 2005 to 8.2 m in 2013 while the wetted width has increased from 4.4 m in 2005 to 6.3 m in 2013.
Figure 16 shows that the mean stream depth of the Pokaitu Stream has been quite dynamic, however the overall change has been from 0.8 m in 2004 to 0.58 m in 2013.

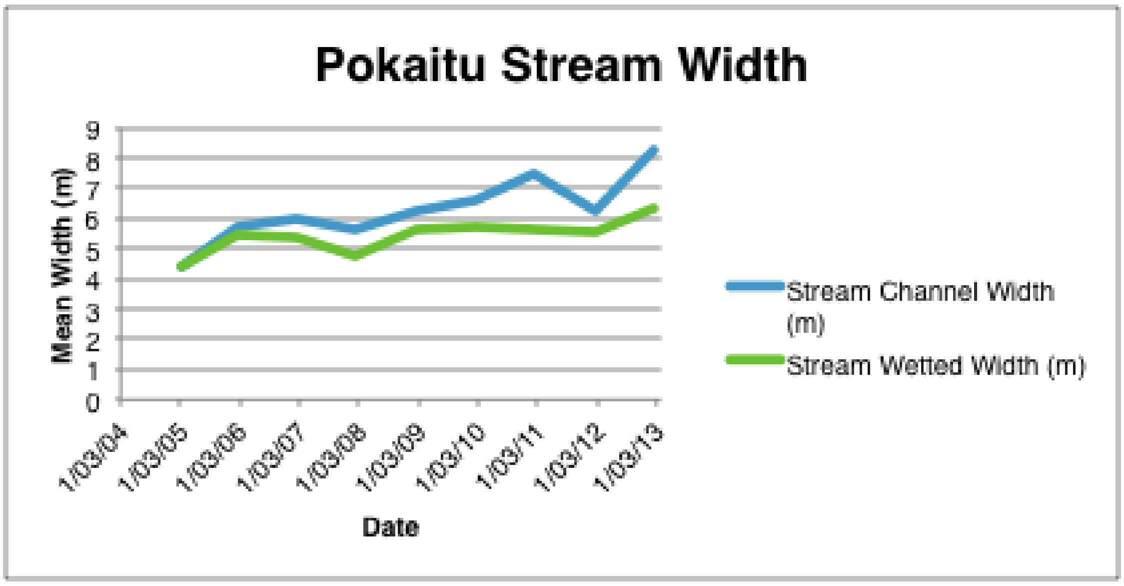


Figure 15. Changes to mean stream channel width since 2005

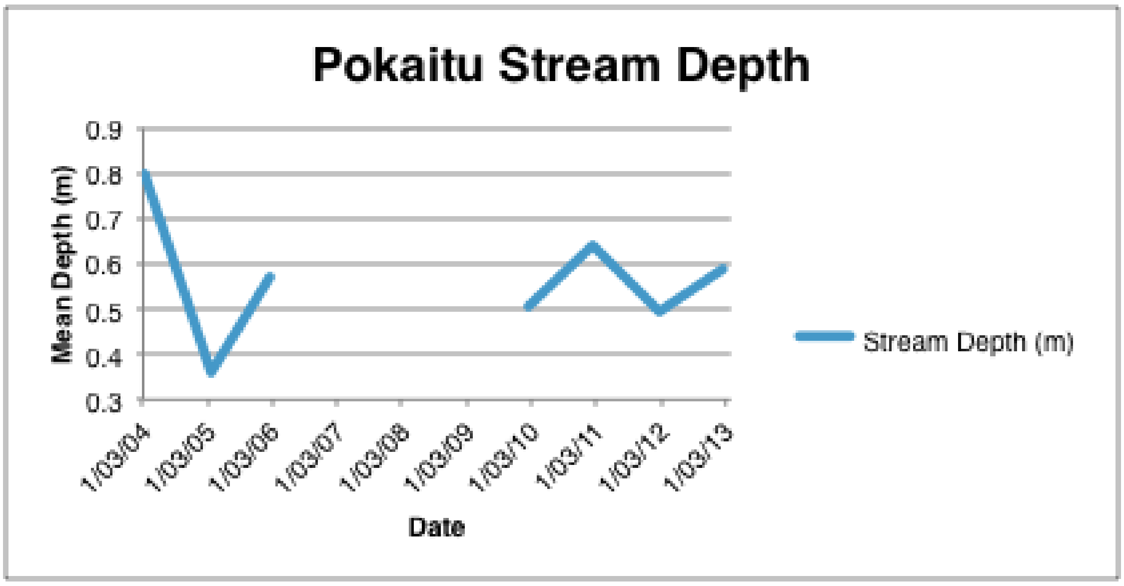


Figure 16. Changes to stream depth since 2003

WATER TEMPERATURE

In 2004 downstream water temperatures of the Pokaitu Stream were 0.6 °C cooler than the upstream reach. The temperature difference declined to 0.1 °C by 2010/11 however in the summer of 2011/12 the temperature difference was close to 0.7 °C. Figure 17 shows an upward trend indicated a decreasing water temperature difference between the upstream and downstream sites of the Pokaitu Stream, however there is a lot of scatter surrounding this trend line. The trend is not statistically or ecologically significant.

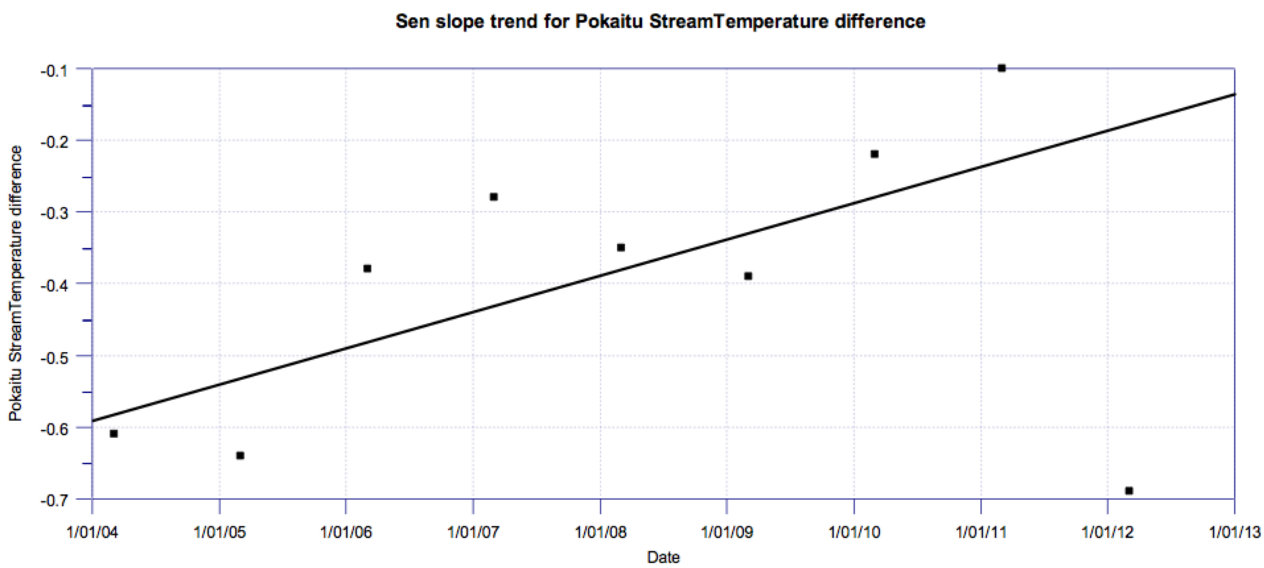


Figure 17. Mean daily maximum water temperature difference between downstream and upstream monitoring sites.

MACROINVERTEBRATE COMMUNITY INDEX

The Pokaitu Stream has a median MCI value of 116.5 which is representative of mild organic enrichment. Figure 18 shows a downward trend of MCI values since monitoring commenced in 2004. There is a reasonable amount of scatter around the trend line. The overall trend is not statistically or ecologically significant.

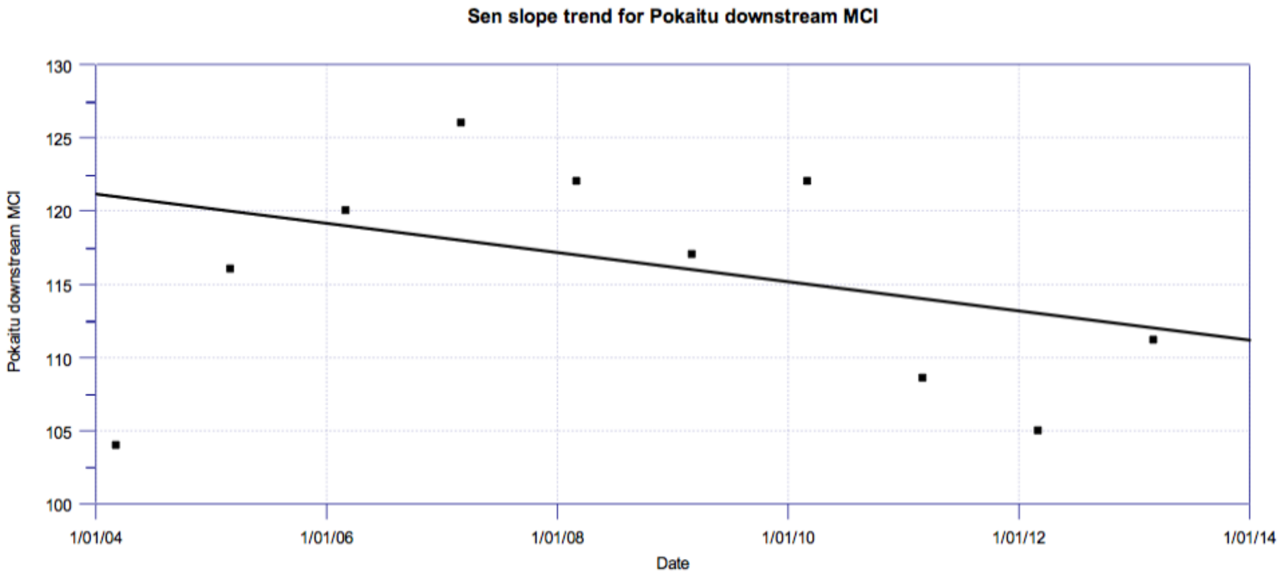


Figure 18. MCI Time series plot