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Relationships between MCI, site altitude, and distance from source for Taranaki ring plain streams

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EXECUTIVE SUMMARY

The use of freshwater macroinvertebrate communities for reporting on river health is widespread worldwide and in New Zealand where the Macroinvertebrate Community Index and variants of it have been used in consent monitoring and State of the Environment monitoring for over 20 years.

Biotic indices, such as the MCI, are invaluable for reporting on the health of stream communities based upon macroinvertebrate sampling. However, water managers are interested not only in the present state of stream health, but also in how it has changed over time (*i.e.*, trends), or what it could or should be (*i.e.*, prediction).

Some sophisticated methods for predicting river health exist (*e.g.*, RIVPACS, AUSRIVAS), but simple models can also provide water managers with sufficient information to confirm that stream health meets expectations or to identify streams that may not be as healthy as they might be.

Stark (1985) defined a relationship whereby site altitude explained over 60% of the variance in MCI for Taranaki ring plain streams. This relationship was intended to provide an indication of the best stream condition that could be expected for a given altitude on the ring plain at that time.

In this report we explored relationships between MCI and three environmental variables (*viz*., site altitude, distance from coast, and distance from source) using macroinvertebrate data (1981 – 2006) from Taranaki Regional Council's extensive database in order to develop simple, yet robust, methods for predicting average stream health in Taranaki ring plain streams. We considered two categories of streams:

- Ring plain streams with source of flow within Egmont National Park (RPNP)
- Ring plain streams with source of flow on the upper ring plain outside the National park boundary (RPOP).

All RPNP streams are hard-bottomed (HB), but there are HB and soft-bottomed (SB) RPOP streams although insufficient data are available for most SB streams to enable predictive relationships to be developed.

We developed and evaluated the performance of six generic relationships for RPNP streams, three generic relationships for RPOP streams, and nine catchment-specific (Patea, Manganui, Waingongoro) relationships. Catchment-specific relationships explained 58-82% of the variance in MCI, with those between MCI and site altitude performing slightly better than MCI and distance from source. Catchment-specific relationships performed better than generic relationships because they did not include between-river variability.

Two generic relationships were recommended for predicting average MCI in RPNP and RPOP HB streams. These were:-

$$MCI = 84.427 + 0.102 * A \qquad (r^2 = 0.549) \qquad EQN6$$

and

$$MCI = 131.717 – 25.825 * \log_{10}(Ds) \qquad EQN10$$

Where A = site altitude (m above mean sea level) and D_s = distance from source (km).

Although these equations were developed from data collected from RPNP streams, they performed better when applied to RPOP streams than relationships developed using data from RPOP streams.

Comparison of maps of Taranaki overlaid with average MCI values in six stream/river health classes calculated from macroinvertebrate samples collected throughout the region (1980 to date) and average MCI values predicted from the MCI – site altitude regression equation revealed areas on the ring plain where observed stream health is better, worse, or equal to that which is predicted. This analysis suggested that approximately 65.3% of the area met or exceeded the stream health predicted by the MCI – altitude relationship, with the remaining 34.7% falling just one quality class below that predicted.

Given the intensity of land-use on the Taranaki ring plain, we believe that the existing state whereby streams in over 65% of the area meet or exceed the average predicted stream health (as indicated by the MCI) is a good result. Those areas where stream health falls one quality class below predicted, have considerable potential for improvement. Identification of areas of Taranaki where MCI values appear to be below average may provide the impetus for TRC to investigate why this might be the case, determine the likely cause(s), and consider whether there are practical and cost-effective steps that can be taken to improve stream health in those areas.

At this stage, insufficient data are available for SB streams on the ring plain and for most RPOP streams for generic or catchment-specific equations to be developed from predicting MCI from site altitude or distance from source. TRC might consider identifying sites down the length of RPOP and SB streams on the ring plain that could be sampled to enable such relationships to be developed in future.

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1 INTRODUCTION

The use of freshwater macroinvertebrate communities for reporting on river health is widespread in New Zealand and worldwide. In New Zealand, the Macroinvertebrate Community Index (or a variant of it) has been used in consent monitoring and State of the Environment monitoring (SEM) for over 20 years (Stark 1985, 1993, 1998, Stark & Fowles 2006; Stark & Maxted 2007).

Biotic indices, such as the MCI, are invaluable for reporting on the health of stream communities based upon macroinvertebrate sampling. However, water managers are interested not only in what the existing stream health is, but also in what it could be. Identifying streams that are degraded is the first step towards remediation, and knowing how good they could be can help define the objectives of remediation.

Some sophisticated methods for predicting river health exist. One of the first computerized predictive systems was developed in Great Britain, and since 1990 has been the principal tool used by government agencies for assessing the ecological quality of rivers throughout the United Kingdom. The River Invertebrate Prediction and Classification System (RIVPACS) develops statistical relationships between the fauna and the environmental characteristics of a large set of high quality reference sites that can then be used to predict the macroinvertebrate fauna to be expected at any site in the absence of pollution or other environmental stress (Clarke *et al.* 2003). Comparison of field macroinvertebrate data with predictions can assist in the determination of impairment.

The Canadian Benthic Assessment of Sediment (BEAST) (Reynoldson *et al.* 1995) and the Australian River Assessment Scheme (AUSRIVAS) (Simpson *et al.* 1997) are predictive models similar to RIVPACS. In 1999, Ministry for the Environment funded a trial of AUSRIVAS using data from the Waikato region (Coysh & Norris 1999) with a view to implementing AUSRIVAS in New Zealand. The trial may have raised more questions than it answered (Stark 1999) and changes within MfE meant that any momentum that existed for widespread introduction of such a predictive modeling system was lost. Since then, however, some progress has been made and RIVPACS-type predictive models for invertebrates in the Manawatu-Wanganui region (Joy & Death 2003) and fish assemblages for the Manawatu-Wanganui (Joy & Death 2002) and Wellington (Joy & Death 2004) regions have been developed. Unlike overseas implementations of RIVPACS – AUSRIVAS models, which predicted observed : expected ratios (O/E) of taxon richness and a biotic index, Joy & Death (2003) did not include O/E MCI, which would have been logical in order to apply such models in New Zealand in a similar manner to previous applications in overseas countries. Predictive models rely on an extensive, regionally relevant, up-to-date macroinvertebrate database from reference sites, with data from different seasons. Given the extensive biogeographic variability of New Zealand stream ecosystems, it is likely that different regional (and seasonal) models would be required for widespread implementation in New Zealand. This would be costly to establish and to maintain, and, in our view, is unlikely to deliver significant additional benefits for water management compared to the widespread use of the more traditional and easily understood MCI.

Taranaki Regional Council has a long history of macroinvertebrate biomonitoring beginning in the early 1980s. An extensive computerised macroinvertebrate database was established and now contains about 8,000 records. Although there have been some minor changes in sample processing over the years (*e.g.*, from presence-absence initially, to three, and then five, levels of relative abundance) there has been a high level of consistency in field methodology and general consistency with New Zealand's standard methods (Stark *et al.* 2001). In addition, throughout the period there has been a consistent level of taxonomy with macroinvertebrate identifications, so MCI values calculated from any data contained within the database should be comparable.

In this report, some simple relationships between environmental variables (*i.e.*, site altitude, distance from the coast, and distance from source) and MCI values are explored in order to provide simple, yet robust, methods for predicting stream health in Taranaki ring plain streams and rivers[1]. Data from two categories of streams are considered in this report:

- Ring plain streams with source of flow within Egmont National Park (RPNP)
- Ring plain streams with source of flow on the upper ring plain outside the National park boundary (RPOP).

Most streams on the ring plain can be categorized as either RPNP or RPOP. Streams with source of flow within the National park (RPNP) have a source of flow that is unlikely to be affected significantly by human or agricultural activities, whereas streams arising on the ring plain downstream of the National Park boundary (RPOP) may be affected by enrichment from human or agricultural sources. For this reason, these categories were considered separately when developing predictive relationships between MCI and selected environmental variables.

At the recent New Zealand Freshwater Sciences Society Conference in New Plymouth, Dr John Leathwick (NIWA, Hamilton) presented a paper that explained how expected values of MCI could be predicted by modeling the influences of land-use and physical environment overlaid on the GIS-based River Environment Classification (REC). His research confirmed that there is regional variation in maximum MCI values throughout New Zealand and enables MCI values that would be expected to occur given natural conditions to be predicted, for any stream reach in New Zealand, and then compared with observed values which may be affected by environmental and human impacts. The correspondence between Leathwick's complex model outputs for the Taranaki ring plain and the results of our simple MCI – altitude and distance from source relationships was striking.

[1] There are many streams, some rivers, and some creeks on the Taranaki ring plain. Rather than use the generic term 'waterways' or refer to them collectively as 'rivers, streams, and creeks' we use the term 'streams' in this report to refer to waterways that may have 'River', "Stream', or "Creek' in their proper names.

2 EXISTING MCI AND SITE ALTITUDE RELATIONSHIPS

2.1 Pristine Sites – Stark (1985)

Stark (1985) was first to define a relationship between site altitude and MCI for Taranaki ring plain streams. This relationship was based on combined summer and winter MCI values (which best represented the annual mean MCI) from a selection of 15 ringplain sites that were not affected by point source discharges and experienced minimal diffuse source enrichment. The relationship was intended to provide an indication of the best stream condition that could be expected for a given altitude on the ring plain at that time.

$$MCI = 116.054 + 0.048 * A \qquad r^2 = 0.609 \qquad \text{(EQN1)}$$

where A = site altitude (m above mean sea level).

This relationship indicated that over 60% of the variability in MCI for the subset of data from unperturbed sites may be explained in terms of the linear relationship with altitude. Site altitude was easily determined from topographical maps and was a surrogate for the length of river below the Egmont National Park boundary that flows through farmland to the coast. The further from the Park boundary (the source of pristine water quality), the greater the potential impact of organic enrichment from farming activities on stream health, which, in turn is reflected by MCI values. Stark (1985) noted that distance by river from the park boundary most likely would have been a more reliable physical variable to use (but it was difficult to estimate at that time).

Stark's (1985) relationship (EQN1) suggested that a pristine ring plain stream would have an MCI of 140 ±10 at the Park boundary (500 m above mean sea level) and 116 ±10 at the coast (0 m above mean sea level). EQN1 suggests that the best estimate of natural decrease in MCI with altitude down a ring plain stream is 4.8 MCI units per 100m altitude decrease.

The above relationship is based on MCI values calculated using the tolerance values of Stark (1985). An updated list of the "official" tolerance values is presented by Stark & Maxted (2007). Taranaki Regional Council, however, has modified some of the tolerance values, based on more data than was available to Stark (1985), to better reflect the pollution tolerances or habitat preferences of the taxa concerned and has also added values that were not included in the original list of scores (Appendix 1). All other relationships between MCI and site altitude or distance from coast or source presented in this report are determined from MCI values calculated using TRC's list of tolerance values (Appendix 1).

Re-calculation of Stark's (1985) MCI-altitude relationship using TRC's tolerance values (Appendix 1) produced the following relationship for ringplain sites relatively unaffected by enrichment:-

$$MCI = 111.919 + 0.040 * A \qquad r^2 = 0.624,\ p = 0.0005 \qquad \text{(EQN1A)}$$

where A = site altitude (m above mean sea level).

Over 62% of the variability in MCI was explained by this relationship with site altitude. This relationship indicates that MCI values of 132 ±10 at the Park boundary and 112 ±10 at the coast are the best that could reasonably be expected in ring plain streams subjected to diffuse source enrichment from agricultural activities and loss of riparian shading, and that the natural rate of change of MCI with altitude is 4.0 MCI units decrease per 100 m decrease in altitude. In catchments with point source discharges containing nutrients, or catchments with extensive areas of intensive pastoral farming on the ring plain, MCI values as high as these may not be achievable.

EQN1A is comparable with all of the equations presented subsequently because they all use TRC's version of the MCI.

2.2 TRC's (1999) MCI – site altitude relationship

Taranaki Regional Council (1999) defined a series of relationship between site altitude and MCI for different subsets of data from ring plain streams for the period 1980 to 1998.

2.2.1 All sites

The first relationship, using all data available (4007 samples), was not considered particularly useful for water management because it included data from lowland, non-ring plain, and highly impacted sites. This relationship is included here only for completeness:-

$$MCI = 68.49 + 0.114 * A \qquad r^2 = 0.361 \qquad \text{(EQN2)}$$

where A = site altitude (m above mean sea level).

This relationship indicated an MCI of 125 ±10 at the Park boundary and 68 ±10 near the coast. Only 36% of the variability in MCI was explained by this relationship with site altitude.

2.2.2 'Control' sites

A second relationship included data from 'control' sites (1625 site surveys throughout the region) after elimination of any sites that were established as impact sites from biomonitoring programmes (*i.e.*, downstream of monitored discharges etc.).

$$MCI = 72.52 + 0.121 * A \qquad r^2 = 0.504 \qquad \text{(EQN3)}$$

where A = site altitude (m above mean sea level).

This relationship indicated an MCI of 133 ±10 at the Park boundary and 73 ±10 near the coast. Just over 50% of the variability in MCI was explained by this relationship with site altitude.

2.2.3 ‘Control’ sites with Egmont National Park source of flow

Data from 792 ‘control’ site surveys from ring plain streams with source of flow within the Egmont National Park (RPNP) were used to calculate the following relationship.

$$MCI = 79.12 + 0.116 * A \qquad r^2 = 0.568 \qquad \text{(EQN4)}$$

where A = site altitude (m above mean sea level).

This relationship indicated an MCI of 137 ±10 at the Park boundary and 79 ±10 near the coast. Nearly 57% of the variability in MCI was explained by this relationship with site altitude.

This relationship was regarded as the most useful for MCI prediction on the Taranaki ring plain by Taranaki Regional Council (1999). It represented the existing biological condition of these streams and rivers and reflected the downstream decline in MCI scores with altitude as a consequence of cumulative impacts of ‘natural’ downstream changes in instream habitat, loss of shading, non-point source, and point-source discharges in a predominantly dairy agricultural region. The MCI near the Park boundary (137) was similar to that predicted from EQN1A (*i.e.*, Stark’s (1985) equation recalculated using TRC MCI values) (132), but the downstream decline (to the coast) was greater (58 *cf.* 20 units) reflecting the difference between average conditions and the best that could be expected (but not necessarily achieved).

2.2.4 ‘Control’ sites with source of flow below Egmont National Park

Data from 257 ‘control’ site surveys from ring plain streams with source of flow outside the National Park (RPOP) were included in this dataset.

$$MCI = 80.18 + 0.062 * A \qquad r^2 = 0.213 \qquad \text{(EQN5)}$$

where A = site altitude (m above mean sea level).

This relationship indicated an MCI of 111 ±10 just below the Park boundary and 80 ±10 near the coast. The predicted MCI near the coast was very similar to the MCI predicted from the relationship derived for RPNP sites, and the lower values predicted for the upper ring plain probably indicated that seepage streams have poorer quality habitat in their upper reaches than those with RPNP source of flow. Not surprisingly, because of the variety of different streams represented in this group and the comparatively low number (257) of them, only 21% of the variability in MCI was explained by this relationship with site altitude.

3 UPDATED MCI, ALTITUDE, AND DISTANCE RELATIONSHIPS

In this section of the report, data from TRC's macroinvertebrate database from June 1981 to July 2006 were used to develop updated relationships between MCI (using TRC's list of tolerance values – Appendix 1), site altitude, distance from the coast, and distance from source for streams and rivers on the Taranaki ring plain. Data from 'control' sites only are used. Data from 'impact' sites (*i.e.*, downstream of discharge points or potential impacts from consent monitoring programmes) are excluded because we wish to derive relationships that describe average stream condition.

Two classes of ring plain streams were considered – (1) those with source of flow within the National Park (RPNP), and (2) those with source of flow outside (of downstream of) the National park (RPOP).

3.1 'Control' sites with Egmont National Park source of flow

Data from 1640 site surveys undertaken between June 1981 and July 2006 at 'control' sites on the Taranaki ring plain with source of flow inside Egmont National Park were used for this analysis.

The updated linear regression for MCI vs Altitude (n = 1640) is:-

$$MCI = 84.427 + 0.102 * A \qquad r^2 = 0.549, p < 0.0001 \qquad \text{(EQN6)}$$

where A = site altitude (m above mean sea level).

This relationship indicates an MCI of 135 ±10 at the Park boundary (500 m above mea sea level) and 84 ±10 near the coast (Figure 1). This analysis updates EQN4 using more than twice the number of data values. The relationship is slightly weaker (explaining 55% of the variance in MCI cf. 57%), with a slightly lower slope indicating that the decline in MCI with decreasing altitude is slightly less. The 95% confidence limits, which are ±24 MCI units above and below the main regression line, suggest that the MCI at the coast should be between 60 and 109, and at the Park boundary 110 - 160. In statistical terms there is unlikely to be any significant difference between them (*i.e.*, EQN4 & EQN6) because both regression lines are within ±10 MCI units of each another.

With GIS systems it is now much easier to determine distance by river length than it was in 1985. However, plotting MCI against distance from coast for all RPNP 'control' sites reveals a discontinuity in the X-axis because the ring plain rivers that flow east from Mt Taranaki are much longer than most of those that flow north, west, or south towards the sea. Consequently, data from long rivers and streams (*i.e.*, Kahouri, Konini, Maketawa, Manganui, Mangatokiiti, Ngatoro, Patea, Piakau South, Te Popo, Waingongoro, and Waipuku) were excluded from this analysis. Exclusion of these longer rivers and streams produces a stronger relationship between MCI and distance from the coast for typical RPNP streams, all of which are less than 40 km long (Figure 2).

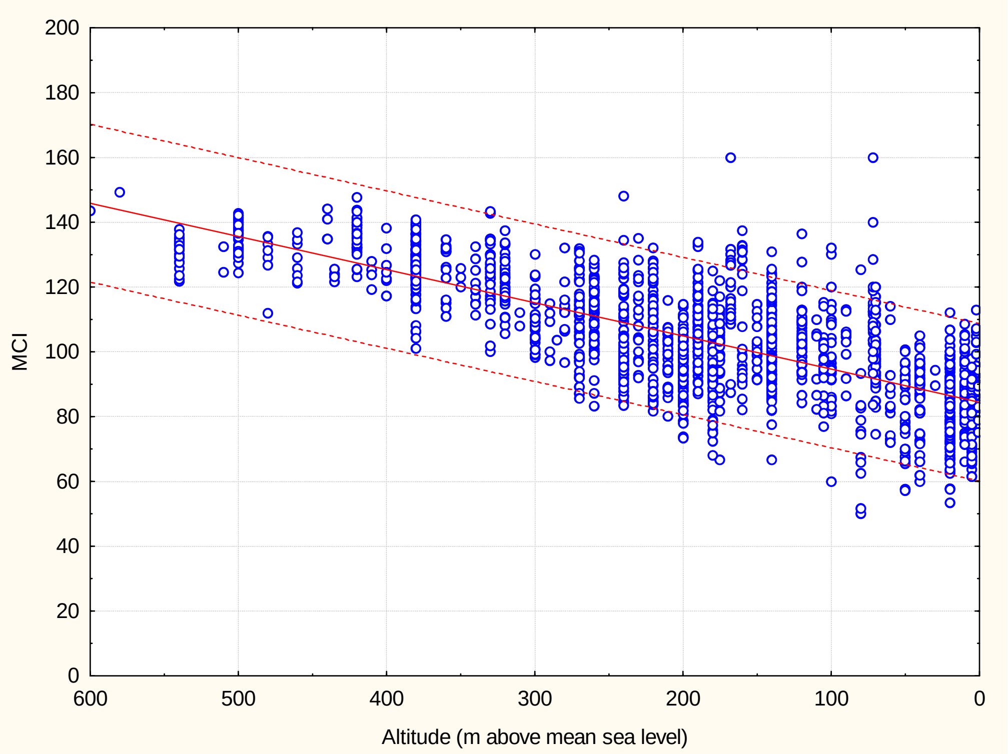

Figure 1 Linear relationship between MCI and site altitude (EQN6) from TRC surveys (N = 1640) between June 1981 and July 2006 for ‘control’ RPNP subregion sites. Dashed lines are 95% confidence limits about the prediction.

$$MCI = 86.855 + 1.152 * D_c \qquad r^2 = 0.312,\ p < 0.0001 \qquad \text{(EQN7)}$$

where D_c = distance from the coast (km).

Elimination of data from the above-named nine long rivers excluded 545 data points and improved the r^2 for the MCI vs D_c relationship from 0.060 to 0.312.

It should be emphasised that EQN7 should not be used to predict MCI values for locations on any of the long rivers that were excluded from this analysis. EQN7 should not be applied to rivers more than 40km in length.

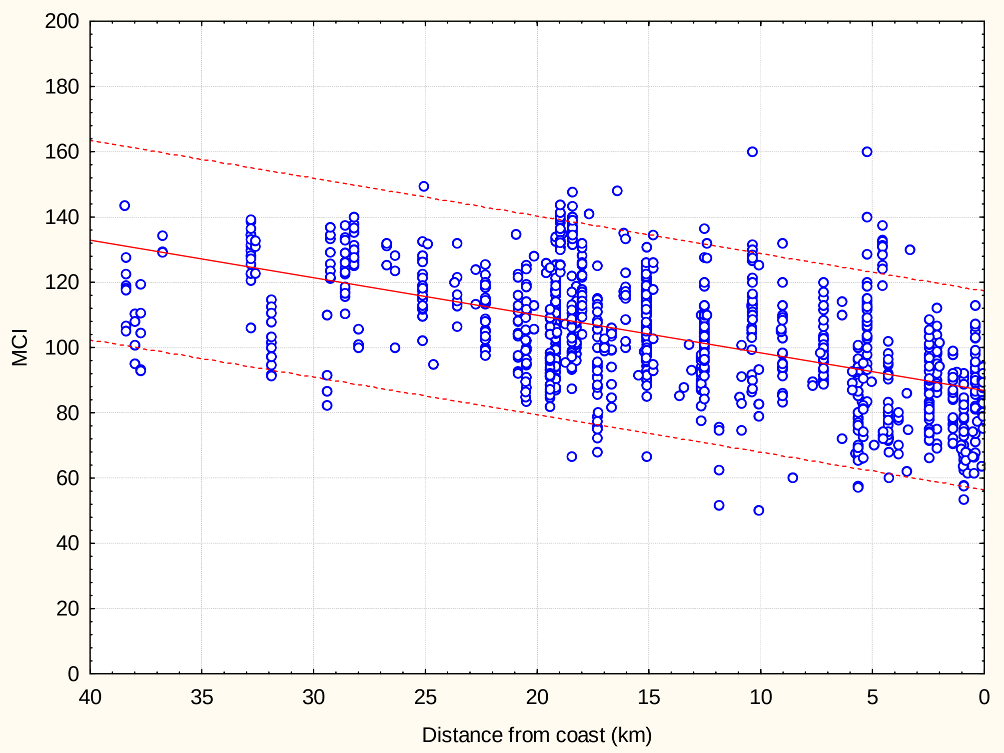

Figure 2 Linear relationship between MCI and distance from the coast (EQN7) from TRC surveys (N = 1095) between June 1981 and July 2006 for 'control' RPNP sites (excluding sites on long rivers). Dashed lines are 95% confidence limits about the prediction.

Distance from source of National Park streams is a better alternative variable to distance from the coast. The distance from the coast has been defined semi-arbitrarily (because it is easier to determine via GIS or from maps than the true physical source of each waterway) for the source of each ring plain stream (Table 1). These data, plus the existing distance from coast data, were used to determine the distances from source for each ring plain site (Appendix 2). The underlying assumption behind the MCI – distance from source relationship is that Mt Taranaki is a consistently high-quality source of water for ringplain streams, and the MCI should be high and decrease progressively with distance from source. Data from Table 1 were used to convert distance from coast values to distance from source for all monitoring sites on the rivers listed in Table 1. Data from rivers not listed in Table 1 and tributaries of these rivers (many un-named) were excluded from these analyses.

The resulting plot of MCI versus distance from source is presented as Figure 3. The linear regression (EQN8) is not a particularly good fit to these data (although better than EQN7), tending to under-estimate MCI both in the upper reaches of RPNP streams, and in the lower reaches of the longest rivers (*i.e.*, > 40 km) such as the Patea, Manganui, Maketawa, and other rivers draining the eastern side of the mountain.

$$MCI = 119.363 - 0.893 * D_s \qquad r^2 = 0.370,\ p < 0.0001 \qquad \text{(EQN8)}$$

where D_s = distance from the source (km).

Table 1 Site altitudes and distances from the coast for RPNP streams.

Stream Code	Stream name	Altitude at 'source'	Distance measured from	Distance from Coast
CLD	Cold Stream	410	Park Boundary	20.88
KAI	Kaiauaia Stream	420	Downstream from Park Boundary	28.51
KHH	Kaihihi Stream	460	Bush edge	18.44
KHI	Kahouri Stream	558	Park Boundary	148.66
KNN	Konini Stream	560	Park Boundary	149.09
KPA	Kapoaiaia Stream	400	Park Boundary	26.14
KPK	Kaupokonui Stream	494	Park Boundary	31.48
KPN	Kapuni Stream	508	Park Boundary	36.05
KRI	Kiri Stream	420	Carrington Rd	17.43
KTK	Katikara Stream	420	Carrington Rd	18.45
MGE	Mangorei Stream	500	Park Boundary	31.95
MGN	Manganui River	536	Park Boundary	65.62
MGW	Mangawarawara Stream	500	Park Boundary	31.08
MHM	Mangahume Stream	380	Park Boundary	20.87
MKW	Maketawa Stream	440	Edge of main bush line	47.44
MMN	Momona Stream	450	Carrington Rd	17.51
MTI	Mangatokiti Stream	540	Park Boundary	51.72
MTK	Mangatoki Stream	535	Park Boundary	51.81
NGN	Ngatoronui Stream	460	Park Boundary	49.45
NGT	Ngatoro Stream	460	Edge of bush line	49.29
OAN	Oaonui Stream	374	Park Boundary	23.26
OEO	Oeo Stream	440	Park Boundary	25.74
OKR	Oakura River	420	Carrington Rd	18.87
OTK	Otakeho Stream	458	Park Boundary	26.67
PAT	Patea River	556	Park Boundary	148.98
PIK	Piakau Stream (Waitara)	470	Park Boundary	47.47
PKS	Piakau South Stream (Patea)	540	Downstream from Park Boundary	148.81
PNH	Punehu Stream	420	Park Boundary	22.34
STY	Hangatahua (Stony) River	390	Park Boundary	17.68
THN	Te Henui Stream	476	Edge of bush line	24.30
TMR	Timaru Stream	370	Edge of bush line	18.14
TPP	Te Popo Stream	550	Park Boundary	67.97
WAA	Waiaua River	370	Park Boundary	20.70
WGA	Waiongana Stream	450	Park Boundary	35.54
WGG	Waingongoro River	560	Park Boundary	66.95
WKH	Waiwhakaiho River	450	Park Boundary	29.06
WMK	Waimoku Stream	100	Edge of Lucy Gully bush line	4.08
WPK	Waipuku Stream	530	Park Boundary	57.94
WRA	Wairau Stream	100	Bush line	3.39
WRE	Teikaparua (Warea) River	390	Park Boundary	24.31
WWN	Waiweranui Stream	390	Park Boundary	19.98

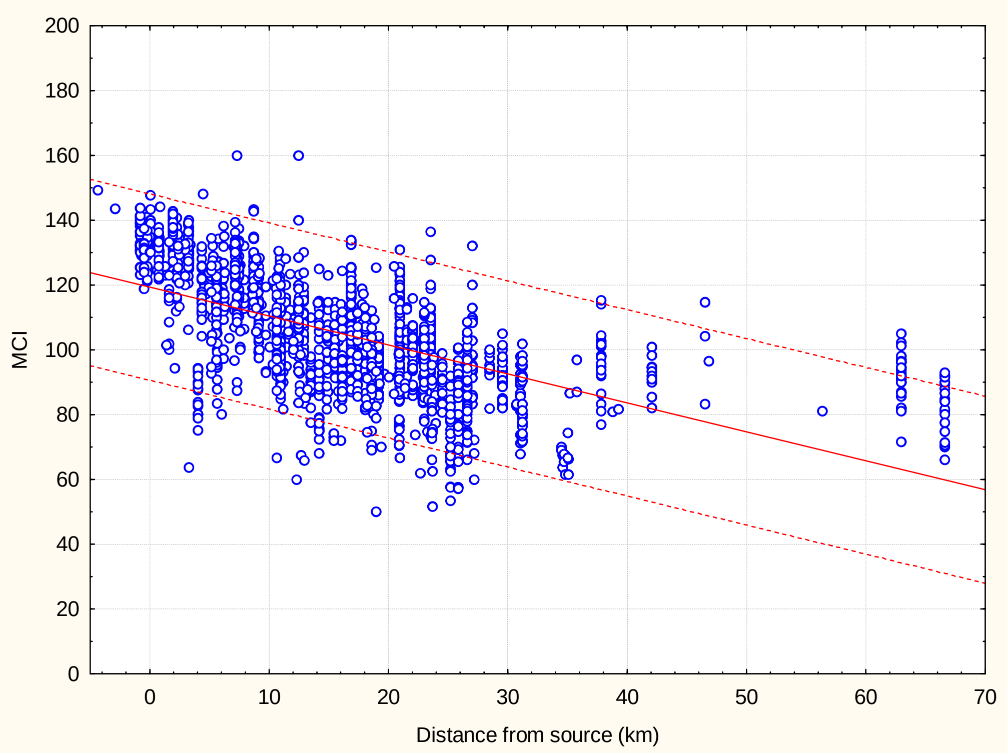

Figure 3 Linear relationship between MCI and distance from source (EQN8) from TRC surveys (N = 1628) between June 1981 and July 2006 for 'control' RPNP subregion sites. Dashed lines are 95% confidence limits about the prediction.

As noted above, a linear regression is not a particularly good fit to these data. Examination of Figure 3 indicates that a better linear fit may be obtained for sites of 35 km or less from the source (N = 1535), which is more typical of the length of streams on the ringplain. Indeed, that is the case (Figure 4):-

$$MCI = 127.255 - 1.503 * D_s \qquad r^2 = 0.506,\ p < 0.0001 \qquad \text{(EQN9)}$$

where D_s = distance from the source (km).

A linear relationship describes the relationship between MCI and site altitude (Figure 1, EQN6), and the relationship between MCI and distance from source for the first 35km of river length (Figure 4, EQN9) very well. However, beyond 35km from source a linear regression is not a good fit. Since altitude decreases logarithmically with distance down the ring plain towards the coast, it follows that a logarithmic relationship between MCI and distance from source (Figure 5, EQN10) may provide better predictions of MCI, particularly for sites further than 35km from the source of pristine water quality (which, in most cases is the Egmont National Park boundary).

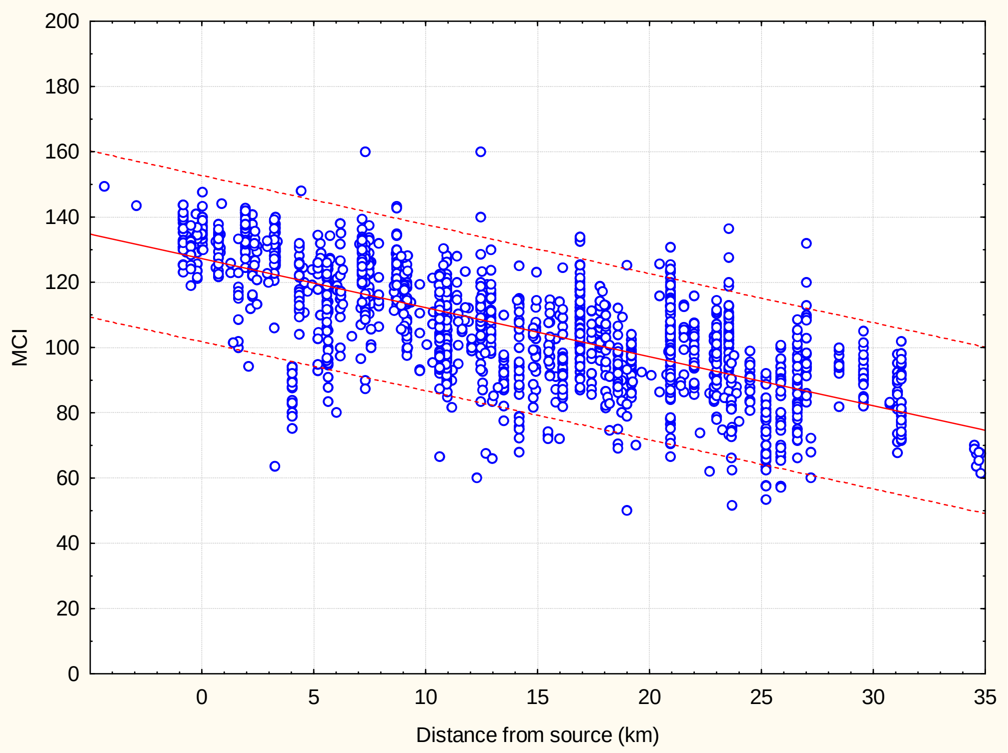

Figure 4 Linear relationship between MCI and distance from source (EQN9) from TRC surveys (N = 1535) between June 1981 and July 2006 for 'control' RPNP subregion sites where sites more than 35 km from source are excluded. Dashed lines are 95% confidence limits about the prediction.

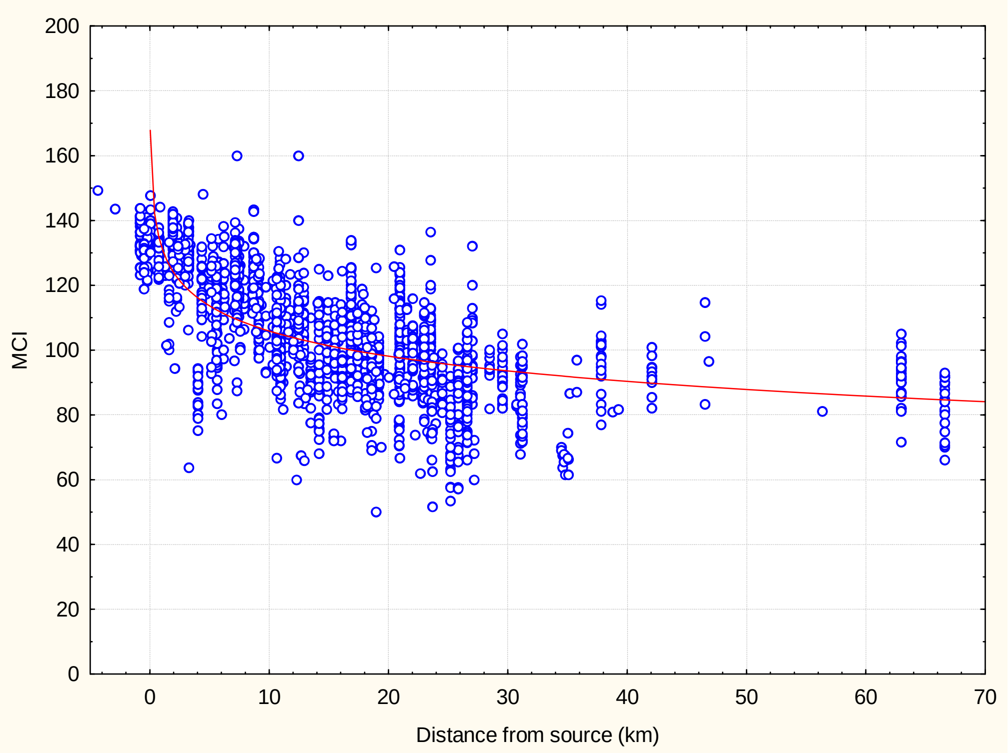

Figure 5 Logarithmic relationship between MCI and distance from source (EQN10) from TRC surveys (N = 1642) between June 1981 and July 2006 for 'control' RPNP subregion sites.

$$MCI = 131.717 – 25.825 * \log_{10}(D_s) \qquad \text{(EQN10)}$$

where D_s = distance from the source (km).

It is not possible to place 95% confidence limits about the prediction on the logarithmic regression (Figure 5).

An alternative to the logarithmic regression would be to apply two linear regressions. The first for the first 35km of distance from source (*i.e.*, Figure 4, EQN9) and the second for sites 35 – 70 km from source. This latter regression, which is based on only 93 data values, (EQN11) is only just statistically significant so is not especially strong:-

$$MCI = 98.592 – 0167 * D_s \qquad r^2 = 0.042, p = 0.0494 \qquad \text{(EQN11)}$$

where D_s = distance from the source between 35 km and 70 km.

EQN11 suggested that average MCI values at 'control' sites on RPNP streams should be between 93 (at 35km) and 87 (at 70 km). The logarithmic regression (EQN10) provides very similar predictions (*i.e.*, 92 and 84 respectively).

3.1.1 How well do these predictive relationships work?

In this section of the report the predictive relationships are compared with site mean MCI values for RPNP sites within selected catchments to provide examples of the use of these relationships and to assess how well they match observed data.

Stark's (1985) original linear relationship with site altitude (EQN1 and the variant of it using TRC's MCI values: EQN1A) was intended to indicate the best possible state that a ring plain stream could achieve, while recognizing that MCI values decrease downstream in streams due to 'natural' change in instream habitat, loss of riparian cover, and increasing enrichment from diffuse and point sources. Unlike Stark's (1985) original MCI- Altitude equation, the relationships derived in this report between MCI (TRC version) and site altitude (EQN6) and distance from source (EQN9) are based upon data that reflect the average existing situation. This means that some streams (or stream reaches) will have higher MCI values than predicted by these relationships, whereas other streams will not. These latter streams may warrant consideration for remedial action.

3.1.1.1 Kapuni Stream

The area of the Kapuni catchment upstream of SH45 is 41 km^2 with 80% of this land use being farming on exotic grasses.

Figure 6 compares mean MCI values recorded from the Kapuni Stream (1981 to 2008) with predictions based on linear relationships between MCI and site altitude (EQN1A & EQN6) and a logarithmic relationship between MCI and distance from source (EQN10).

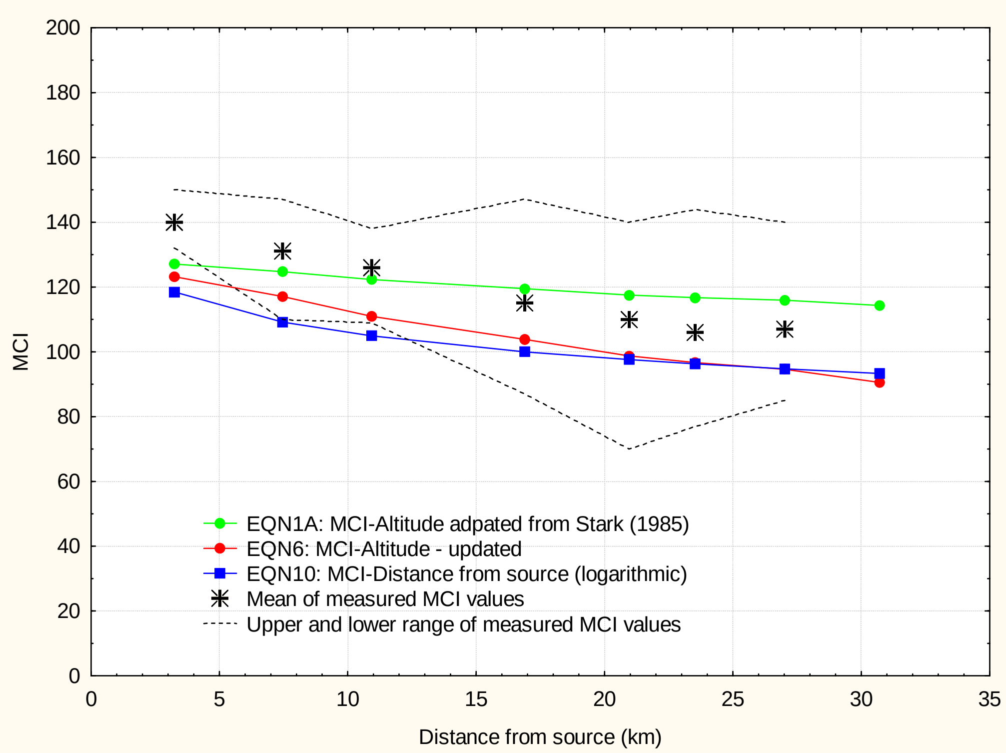

Figure 6 Comparison of measured site mean MCI values and predictions for the Kapuni Stream from Opunake Road to SH45.

Stark's (1985) MCI-Altitude relationship (EQN1A) predicts measured mean MCI values very well at Eltham Road and Site 9 (11-17 km from source), but under-estimates MCI at Opunake Road and Upper Palmer Road. From 17km downstream from the source to the coast measured MCI values undershoot the predictions (Figure 6).

The linear MCI-Altitude relationship (EQN6) and the logarithmic MCI-distance from source relationship (EQN10) provide quite similar predictions (Figure 6). Predictions from the former tend to be slightly higher in the upper to middle regions of the ring plain, but almost identical further downstream. Measured mean MCI values for the Kapuni Stream are higher than both of these relationships predict, suggesting that the Kapuni Stream is in better health than the average ring plain stream. This result is not surprising, given that the Kapuni catchment is comparatively narrow, has few tributaries of any significance (minimising the influence of enrichment via run-off from farmland), and consent conditions on the stormwater discharges from the petrochemical industries that are effective at minimising their environmental impact on the stream.

All three equations predict MCI values that are within the range of MCI values recorded at monitoring sites in the Kapuni catchment, with the exception of the upper-most monitoring site (Opunake Road), where MCI values higher than those predicted (by EQN6 & EQN10) have consistently been recorded (Figure 6).

3.1.1.2 Patea River

The Patea River is the longest river with a source within Egmont National Park. The catchment area upstream of the Skinner Road recorder site (which is 19.2 km from the Park boundary) is 87.5 km^2 and comprises 90% farming on exotic grasses.

Figure 7 shows a comparison between predicted MCI and site mean MCI values for the Patea River between Barclay Road and Raupuha Road. Beyond Raupuha Road the Patea River in influenced by eastern hill-country tributaries such as the Mangaehu River and the Makuri Stream. Downstream of Cardiff Road (which is approximately 6.2 km from the Park boundary), river health declines at a greater rate than Stark's (1985) best possible equation (EQN1A) predicts. EQN6, representing the average ring plain stream, fits actual mean MCI values well until downstream of Stratford (ca. 10km), where treated sewage from Stratford's municipal oxidation pond system enters the river and almost certainly contributes to the observed decrease in river health. The logarithmic EQN10 under-estimates MCI values from Stratford upstream but is a good predictor of mean MCI values further downstream.

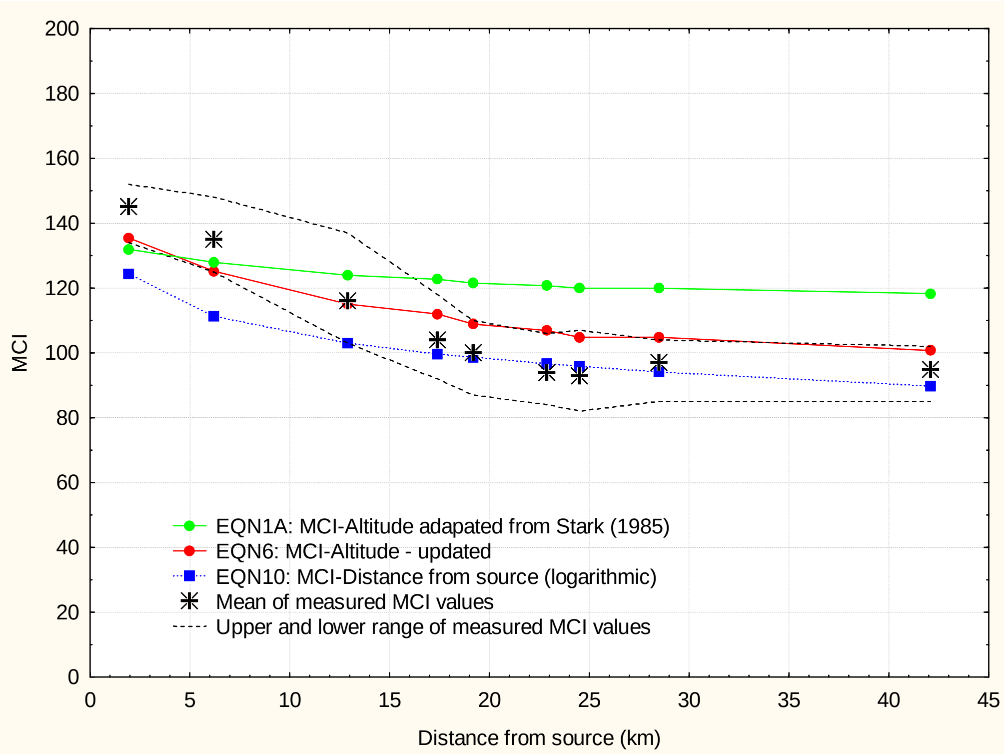

Figure 7 Comparison of measured site mean MCI values and predictions for the Patea River from Barclay Road to Raupuha Road

3.1.1.3 Waingongoro River

The Waingongoro River at approximately 70 km in length is the longest river confined entirely to the ring plain. Most of the large (for a ring plain stream) catchment area (98% of 200 km^2)

is farming on exotic grasses. As Stark (1985; Figure 6), and subsequent state of the environment data (Stark & Fowles 2006, TRC 2007) have shown, MCI values decrease towards the coast with the greatest decrease occurring near Eltham (between 10 and 20 km from the source) with only a very gradual decrease further downstream (Figure 8).

Once again, EQN1A and EQN6 predict MCI values in the river well for the first 10 km downstream of the National Park (Figure 8). Further downstream and in the lower reaches of the river, EQN6 and EQN10 (especially) provide accurate MCI predictions.

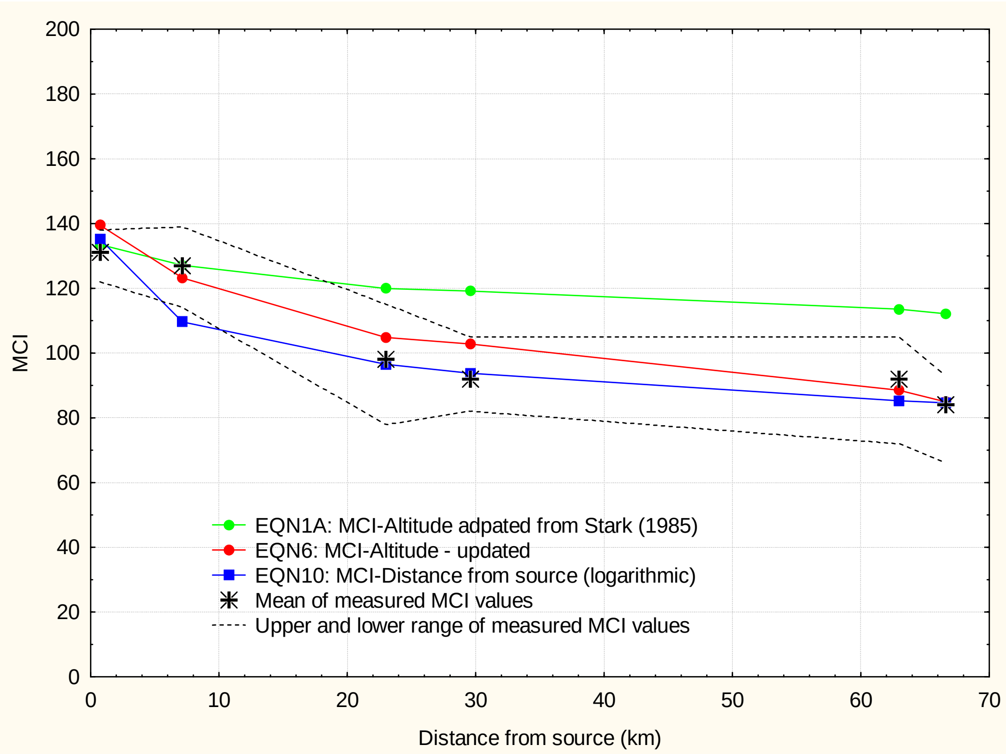

Figure 8 Comparison of measured site mean MCI values and predictions for the Waingongoro River from near the National Park Boundary to Ohawe Beach.

3.1.1.4 Stony River

By contrast, the Stony River is one of the shortest ring plain streams with a catchment area of 47 km^2 above the recorder site at Okato. The catchment is very narrow (250m to 1100 m) below the Park Boundary, so the flow is dominated by high-quality water from the north-western slopes of Mt Taranaki, and the southern and south-eastern slopes of the Pouakai range. Approximately 10% of the low flow is from the Akukawakawa Swamp. Farming on exotic grasses occupies only 12% of the catchment and does not seem to have a major influence on river health. Since 1985 the Stony River has been protected under a Local Conservation Order, however severe and frequent high natural erosion rates in the headwaters have caused extensive sedimentation and scouring in the river downstream.

Mean measured MCI values in the Stony catchment fall very close to the original MCI-Altitude equation of Stark (1985) (EQN1A), although the logarithmic MCI-Distance from source EQN10 is also a reasonable predictor of stream health for this river (Figure 9). Based on MCI values, the Stony would regarded as a better than average ring plain river when not affected by such erosion events.

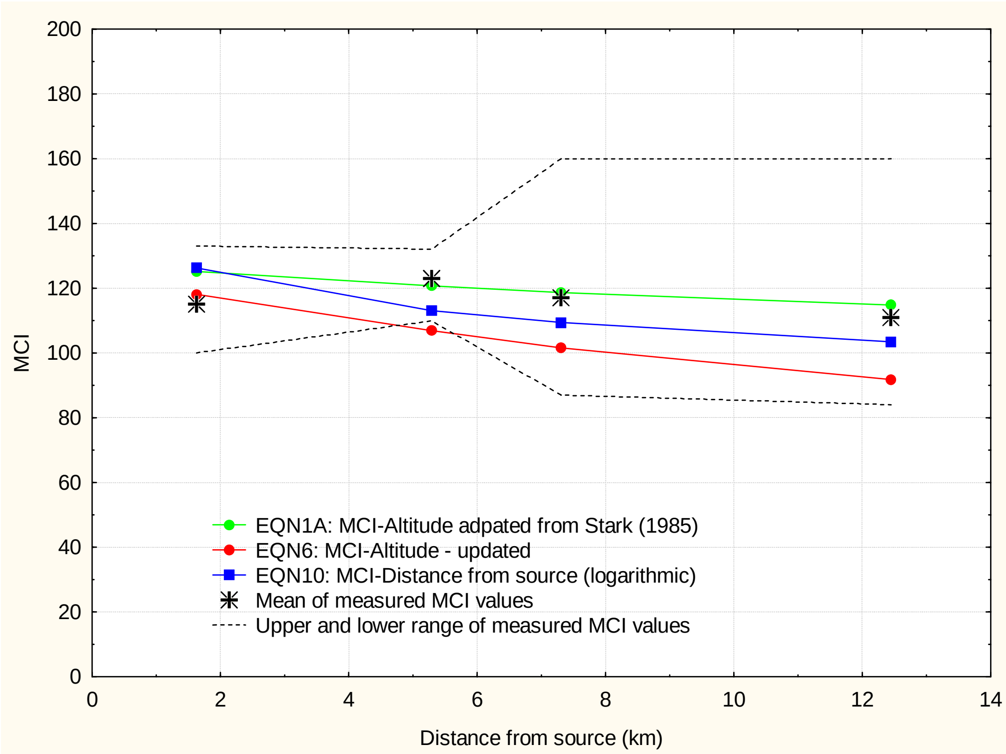

Figure 9 Comparison of measured site mean MCI values and predictions for the Stony River from near the National Park Boundary to SH45.

3.1.2 General comments

The four examples above suggest that Stark's (1985) original MCI-Altitude relationship modified to use TRC's MCI tolerance values (EQN1A) may provide an excellent prediction of MCI values for RPNP streams within 5 – 12 km of the National Park boundary (and the entire length of the Stony River – when it was not affected by sedimentation and scouring). In each of these examples, mean MCI values for these upper ring plain sites have equaled or exceeded those predicted by EQN1A. This is understandable because water quality in this zone is likely to be dominated by pristine water from the mountain. Further downstream, natural changes in instream habitat compounded by farmland runoff, the entry of tributaries draining farmland, and a reduction in riparian vegetation may lead to increasing enrichment and a departure from the ideal (as represented by EQN1A).

Further downstream the updated MCI-Altitude relationship (EQN6) and/or the logarithmic MCI-Distance from source relationship (EQN10) provided more accurate estimates of site mean MCI values. All three predictive relationships (*i.e.*, EQN1A, EQN6, & EQN10) provided estimates of MCI that are within the range of measured values (Figures 6-9).

Equations 1A, 6, and 10 could be used in combination (as in Figures 6-9) to indicate how observed MCI values measure up against the various predictions. However, this was not the original intention – these equations were plotted together on these figures to show how each one of them matched observed MCI values, and how any one of them could be used to determine whether observed values met expectations. Which one of these equations should be used is a decision for the water managers. If the desired stream condition is near-pristine (which is likely to be an unrealistic target for most ring plain streams given the catchment development that has already occurred), then EQN1A might be appropriate. However, either EQN6 (if altitude data are available) or EQN10 (distance from source) is likely to provide a more realistic target for stream improvement. In our view, observed MCI values in most streams on the Taranaki ring plain should meet or exceed the values predicted by EQN6 or EQN10 if best management practices are employed to deal with diffuse- and point-source enrichment from agricultural, industrial, and urban activities, if riparian margins of streams are intact and healthy, and if direct stock access to waterways is prevented.

3.2 'Control' sites with source of flow outside Egmont National Park (RPOP)

Rivers that arise on the upper ring plain below the National park boundary do not have a source of pristine water flow that can be defined easily (as for RPNP streams). Sources can include springs and seepages, some of which may be pristine in quality but others could already be contaminated by runoff or farming activities. Consequently, it is not practical to define relationships between MCI and distance from source for RPOP streams.
Whereas all RPNP sites are hard-bottomed, there are hard-bottomed (HB) (N = 426) and soft-bottomed (SB) (N = 62) RPOP 'control' sites on the ring plain.

The linear regression equation for MCI vs Altitude (N = 426) for HB ring plain streams (Figure 10) with source of flow outside the National Park (RPOP) is:-

$$MCI = 85.564 + 0.037 * A \qquad r^2 = 0.109,\ p < 0.0001 \qquad \text{(EQN12)}$$

where A = site altitude (m above mean sea level).

Although the MCI – Altitude regression for HB streams is statistically significant ($p < 0.0001$), only 11% of the variability in MCI is explained. The slope also is very flat – an increase of only 3.7 MCI units for every 100 metres of altitude corresponding to an MCI of 86 at the coast and 100 at 400m altitude (Figure 10).

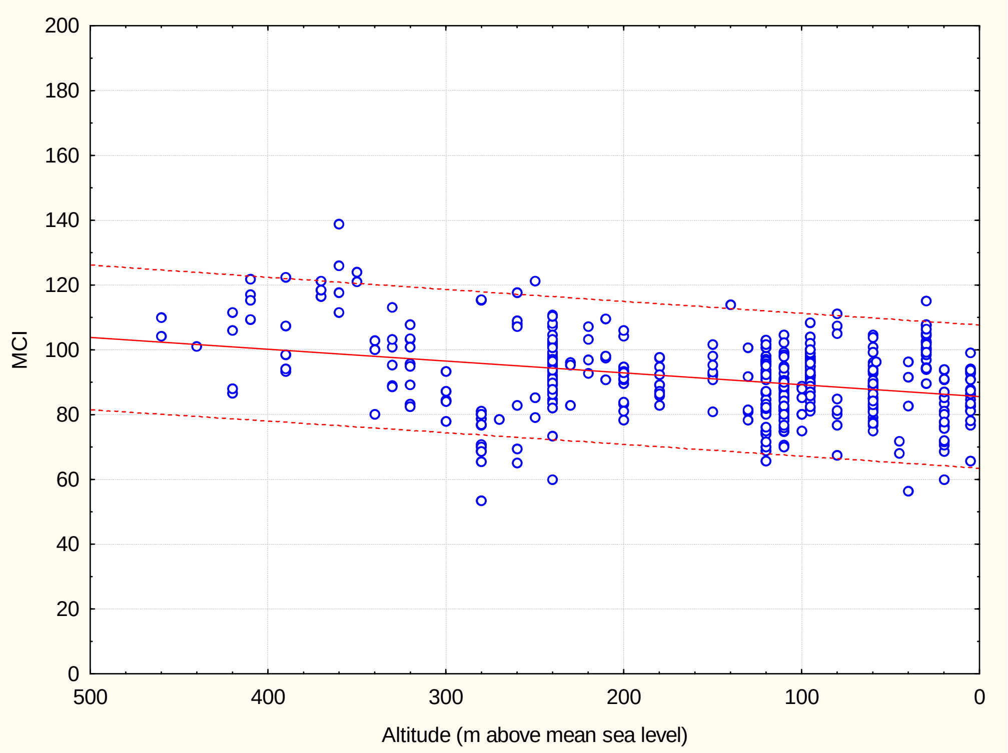

Figure 10 Linear relationship between MCI and site altitude (EQN12) from TRC surveys (N = 426) between June 1981 and July 2006 for HB 'control' RPOP subregion sites. Dashed lines are 95% confidence limits about the prediction.

The linear regression equation for MCI vs Altitude (n = 62) for SB ring plain streams (Figure 11) with source of flow outside the National Park (RPOP) is:-

$$MCI = 71.702 + 0.081 * A \qquad r^2 = 0.243,\ p = 0.00005 \qquad \text{(EQN13)}$$

where A = site altitude (m above mean sea level).

Note that even though the above relationship was developed for SB streams, it uses MCI values calculated with TRC's (HB) tolerance values, not the MCI-sb tolerance values (Appendix 1).

Data for SB RPOP streams are relatively sparse (N = 62) and restricted to an altitudinal range of 100to 325 m above mean sea level on the ring plain. A little over 24% of the variance in MCI is explained by site altitude. Most of these data are from surveys conducted in close proximity upstream and downstream of point source discharges.

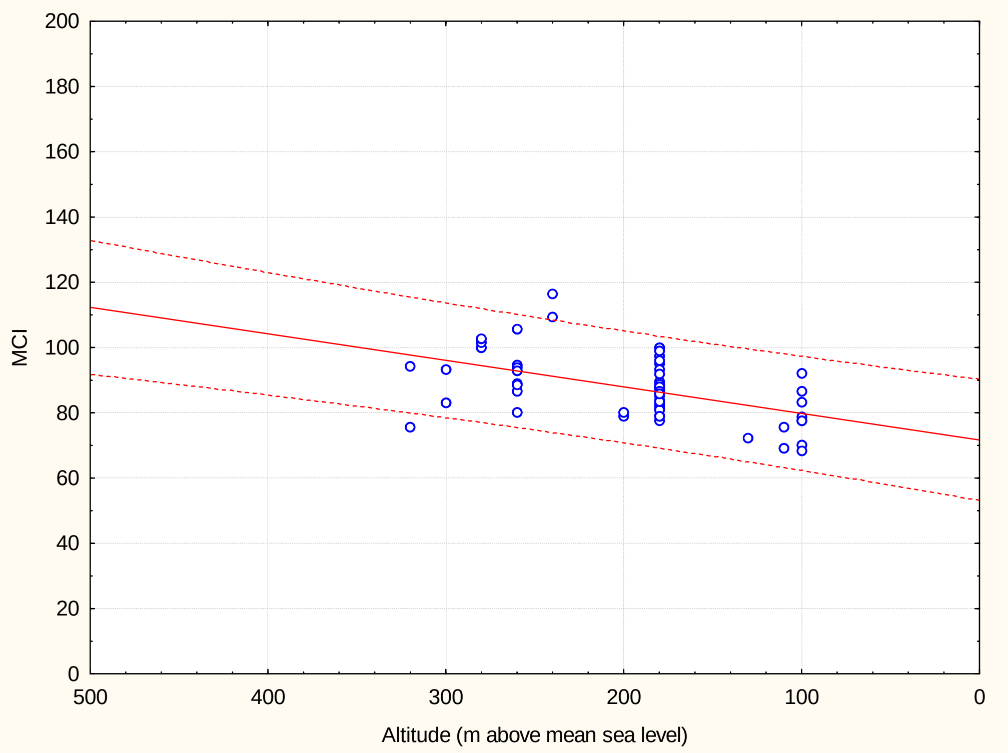

Figure 11 Linear relationship between MCI and site altitude (EQN13) from TRC surveys (N = 62) between June 1981 and July 2006 for SB 'control' RPOP subregion sites. Dashed lines are 95% confidence limits about the prediction.

The linear regression equation for MCI vs Altitude (n = 488) for all 'control' sites (*i.e.*, SB + HB) on ring plain streams (Figure 11) with source of flow outside the National Park (RPOP) is:-

$$MCI = 84.970 + 0.036 * A \qquad r^2 = 0.102, p < 0.0001 \qquad \text{(EQN14)}$$

where A = site altitude (m above mean sea level).

Not surprisingly, this relationship is very similar to that for HB RPOP streams (because 87% of the data are from HB streams and only 13% from SB RPOP streams).

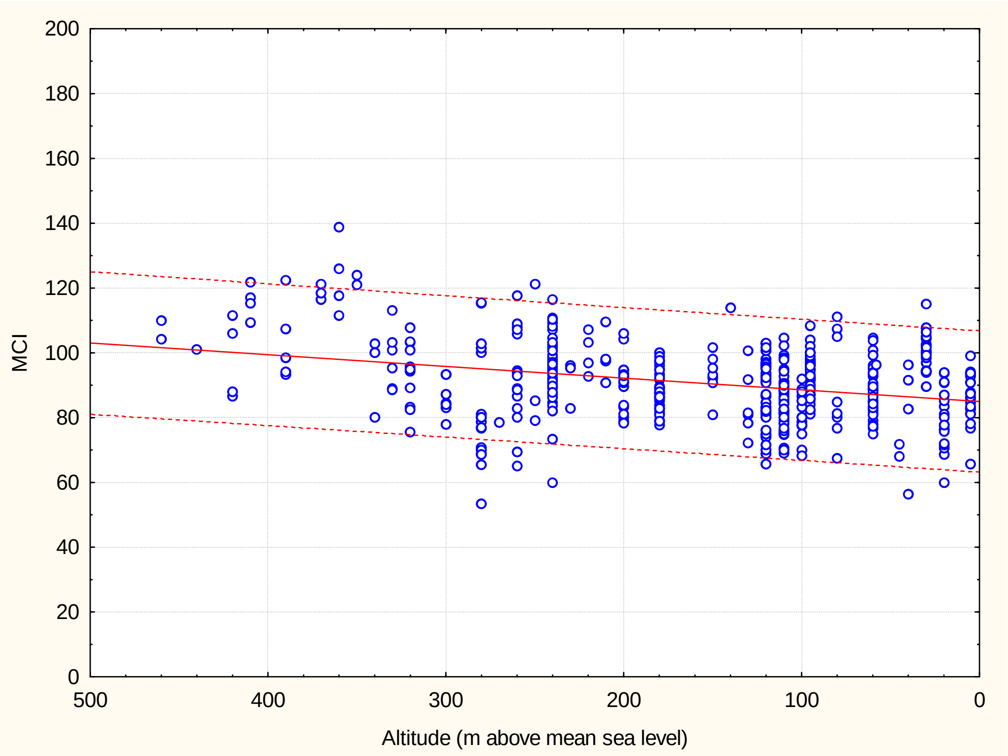

Figure 12 Linear relationship between MCI and site altitude (EQN14) from TRC surveys (N = 488) between June 1981 and July 2006 for SB and HB 'control' RPOP subregion sites. Dashed lines are 95% confidence limits about the prediction.

3.2.1 How well do these predictive relationships work?

In this section of the report the predictive relationships are compared with site mean MCI values for RPOP sites within selected catchments. Comparatively few RPOP streams have been sampled frequently at a number of sites along their lengths to facilitate useful comparisons between measured MCI value and predictions from EQN12, EQN13, or EQN14. Two exceptions are the Huatoki Stream (State of the Environment Monitoring Programme) and the Inaha Stream (Consent Compliance Monitoring Programme). There are no SB RPOP streams that have been sampled at several points along an altitudinal gradient.

3.2.1.1 Huatoki Stream

The Huatoki Stream arises on the upper ring plain a short distance upstream of Upper Frankley Road below the northern flanks of the Pouakai Range. It flows through farmland, a sizeable domain on the outskirts of New Plymouth and discharges to the sea via culverts under the main streets of central New Plymouth city.

The Huatoki Stream is hard-bottomed, so Figure 13 shows mean measured MCI values (which are limited in number at some sites) versus predictions from EQN12 and EQN14. There is no real difference between the two equations for predicting MCI for RPOP streams based on data from HB streams (EQN12) or HB+SB streams (EQN14). The fit to measured data is reasonable in the lower reaches. The elevated (versus predicted) mean MCI value at 30m altitude is from the site in the Huatoki Domain where significantly improved riparian conditions (cf. farmland) are responsible for some improvement in stream health (see Scarsbrook & Halliday 1999, Collier, Fowles, & Hogg 2000). Both equations under-estimate MCI values in the upper reaches of the Huatoki Stream, almost certainly because it arises in close proximity to native forest on the Pouakai Range with limited influence from farming activities. In this respect the upper Huatoki Stream (at Frankley Road (280 m altitude)) is much more like a RPNP stream - EQN6 predicts an MCI of 113 *cf.* measured 115. This is shown by the red line on Figure 13.

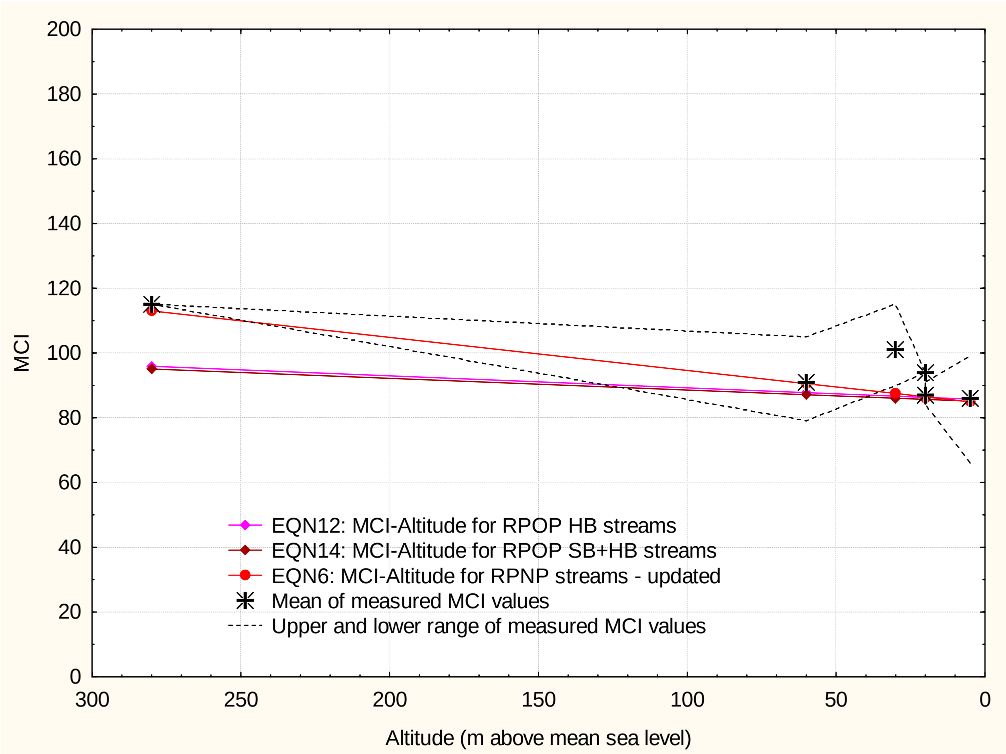

Figure 13 Comparison of measured site mean MCI values and predictions for the Huatoki Stream between Upper Frankley Road downstream to Molesworth St.

3.2.1.2 Inaha Stream

The Inaha Stream is primarily a hard-bottomed stream with source of flow on the upper ring plain on the southern side of the mountain. The predictive relationships (EQN12 & EQN14) between MCI and Altitude developed for HB and HB+SB RPOP streams (which are virtually identical), do not fit the measured MCI values very well (Figure 14). By contrast, the MCI-Altitude relationship developed for RPNP streams (EQN6) fits the observed data very well with the impact of the Taranaki By-Products discharge evident (low MCI value of 83 at 110 m altitude) (Figure 14).

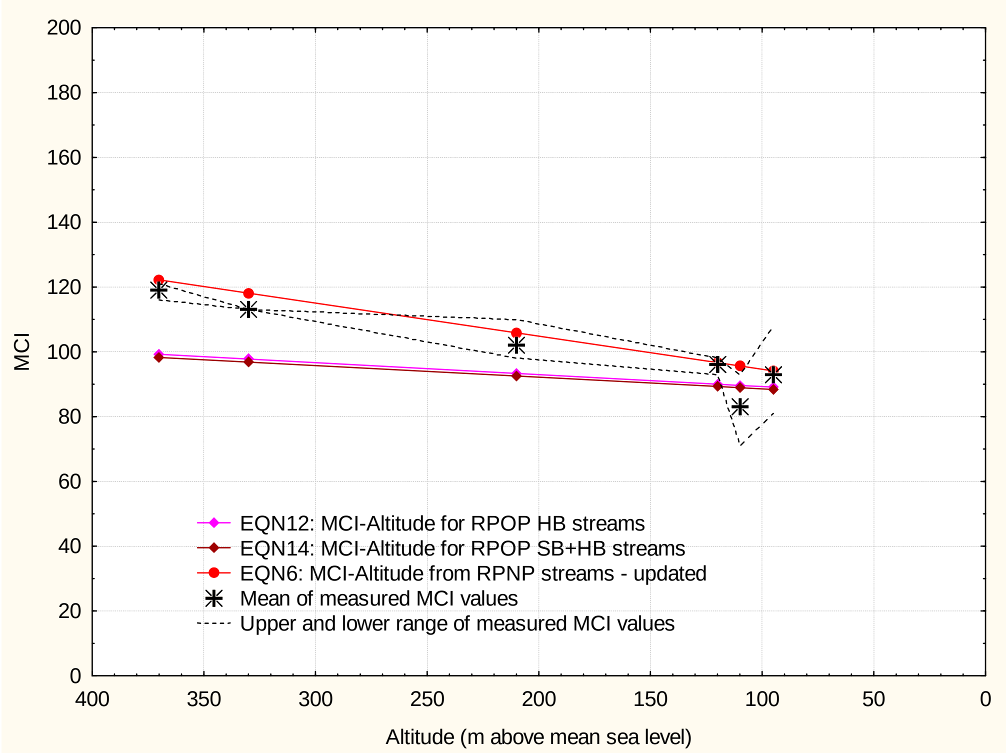

Figure 14 Comparison of measured site mean MCI values and predictions for the Inaha Stream 500m downstream of Palmer Road and downstream of Kohiti Road.

3.2.2 General comments

There are insufficient data from SB RPOP streams to derive relationships between MCI and site altitude. The relationship between MCI and site altitude for all RPOP streams (*i.e.*, HB & SB) is almost identical to that for RPOP HB streams alone (because there are few data from RPOP SB streams). The only RPOP streams for which sufficient data have been collected longitudinally are the Huatoki and Inaha Streams. As the graphs above show (Figures 13 & 14) the MCI-Altitude relationship that describes the average condition of RPNP streams is a better fit to observed data in these two RPOP streams.

Until more data – and preferably longitudinal series down the lengths of specific RPOP streams – are available, the use of predictive equations specifically derived for RPOP streams (*i.e.*, EQN12, EQN13, or EQN14) is not recommended. EQN6 should be used instead.

3.2.3 Relationship between site altitude and distance from source

Site altitude can be determined relatively easily and quickly from a map or on-site using a hand-held GPS. Determination of distance from source is more time-consuming – a desktop exercise using a computerized GIS system. However, for ring plain streams less than 35 km in length, there is a good relationship between the two, so an acceptable estimate of distance from source can be made using EQN15 if site altitude is known.

$$D_s = 24.382 - 0.048 * A \qquad r^2 = 0.531 \; p < 0.0001 \qquad \text{(EQN15)}$$

where D_s = distance from source (km), and A = site altitude (m above mean sea level).

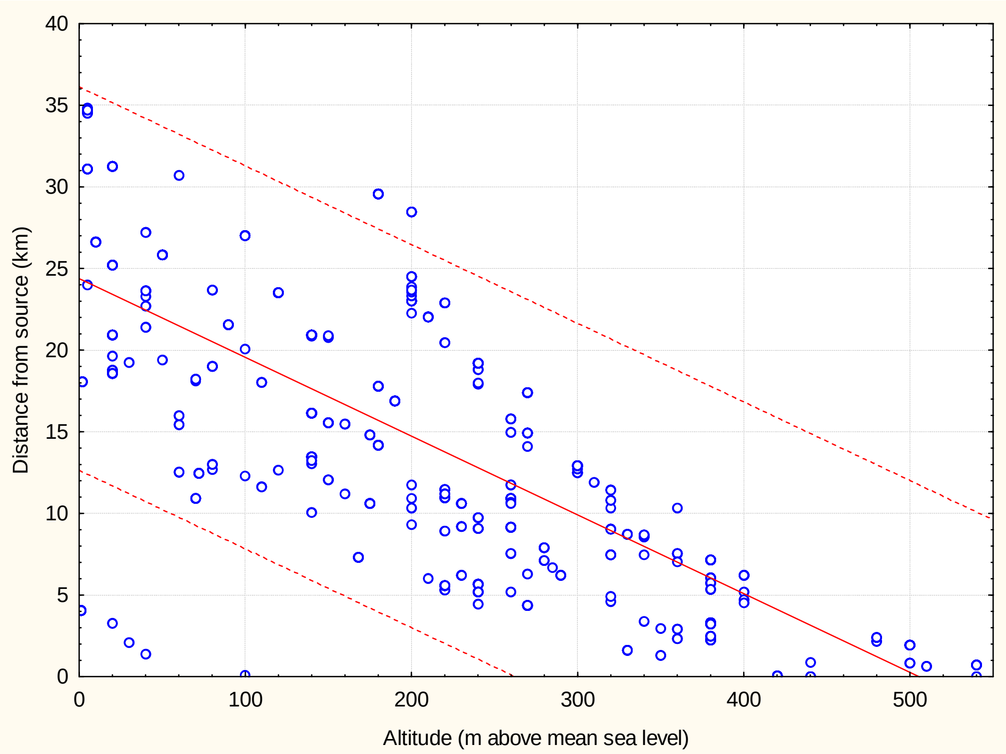

Figure 15 Relationship between site altitude and distance from source (EQN15) for 'control' sites on ring plain RPNP streams less than 35 km in length. Dashed lines are 95% confidence limits about the prediction.

The relationship shown in Figure 15 should not be used on streams of 35 km or more in length.

3.3 Specific relationships for atypically long ring plain streams

The relationships between site altitude and distance from source derived previously are for typical ring plain streams and should be applied with caution (or not at all) to the lower reaches of atypically long ring plain streams with source for flow more than 40 km from the coast. Notable examples include the Patea (and tributaries), the Manganui, and the Waingongoro Rivers (Table 1). For these rivers, or indeed any river with sufficient data, river-specific relationships between MCI and site altitude or distance from source can be derived. River-specific relationships are likely to be stronger (*i.e.*, higher r^2values) than those derived for groups of rivers because river-specific relationships do not include variability in MCI values (for a given distance from source or site altitude) due to differences between rivers. Both the river-specific and generic relationships do, however, include temporal variability in MCI (*i.e.*, due to sampling monitoring sites on different days, in different seasons, or in different years).

Note that extrapolation of any of the MCI-Altitude or MCI-Distance from source relationships beyond the range of data on which they are based is unwise, and may produce spurious results.

3.3.1 Patea River

The linear regression equation for MCI vs Altitude (n = 167) for the Patea River (Figure 16) is:-

$$MCI = 61.557 + 0.153 * A \qquad r^2 = 0.822, p < 0.0001 \qquad \text{(EQN16)}$$

where A = site altitude (m above mean sea level).

Altitude explains over 82% of the variance in MCI for the Patea River (at altitudes between 150 and 500 m above mean sea level). This is the best-performing relationship of this type that has been derived to date.

The LOWESS fit on Figure 16 shows a discontinuity in the trend of decreasing MCI with altitude around Stratford (altitude 300m)

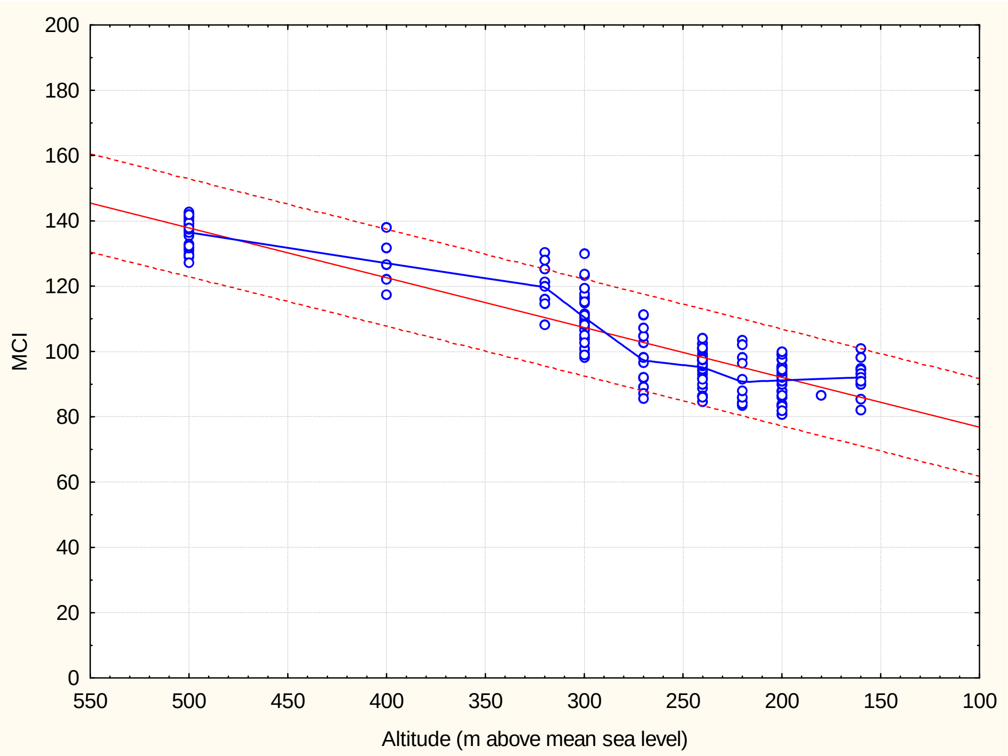

Figure 16 Linear relationship between MCI and site altitude (EQN16) from TRC surveys (N = 167) between June 1981 and July 2006 for the Patea River. Dashed lines are 95% confidence limits about the prediction. The blue lines is a LOWESS fit (tension = 0.4).

The linear and logarithmic relationships between MCI and distance from source for the Patea River (Figure 17) are:-

$$MCI = 130.230 - 1.411 * D_s \qquad r^2 = 0.654,\ p < 0.0001 \qquad \text{(EQN17)}$$

$$MCI = 149.788 - 39.451 * \log_{10}(D_s) \qquad \text{(EQN18)}$$

where D_s = distance from the source (km).

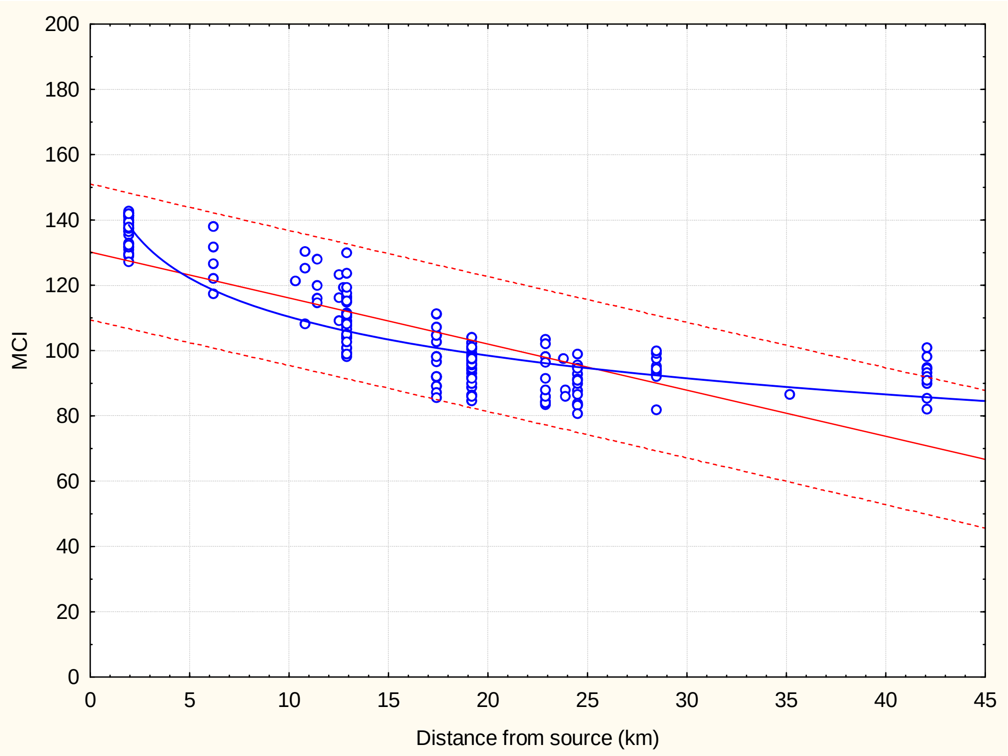

Figure 17 Linear relationship between MCI and distance from source (EQN17) from TRC surveys (N = 167) between June 1981 and July 2006 for the Patea River. Dashed lines are 95% confidence limits about the prediction. The blue line is a logarithmic fit (EQN18).

The linear regression (EQN17) tends to underestimate MCI values within 10 km of the source of the Patea River and also between 30 km and 45 km from the source. The logarithmic regression (EQN18) performs a little better within 5 km of the source and beyond 30 km (Figure 17)

3.3.2 Manganui River

The linear regression equation for MCI vs Altitude (n = 101) for the Manganui River (Figure 18) is:-

$$MCI = 79.791 + 0.121 * A \qquad r^2 = 0.643,\ p < 0.0001 \qquad \text{(EQN19)}$$

where A = site altitude (m above mean sea level).

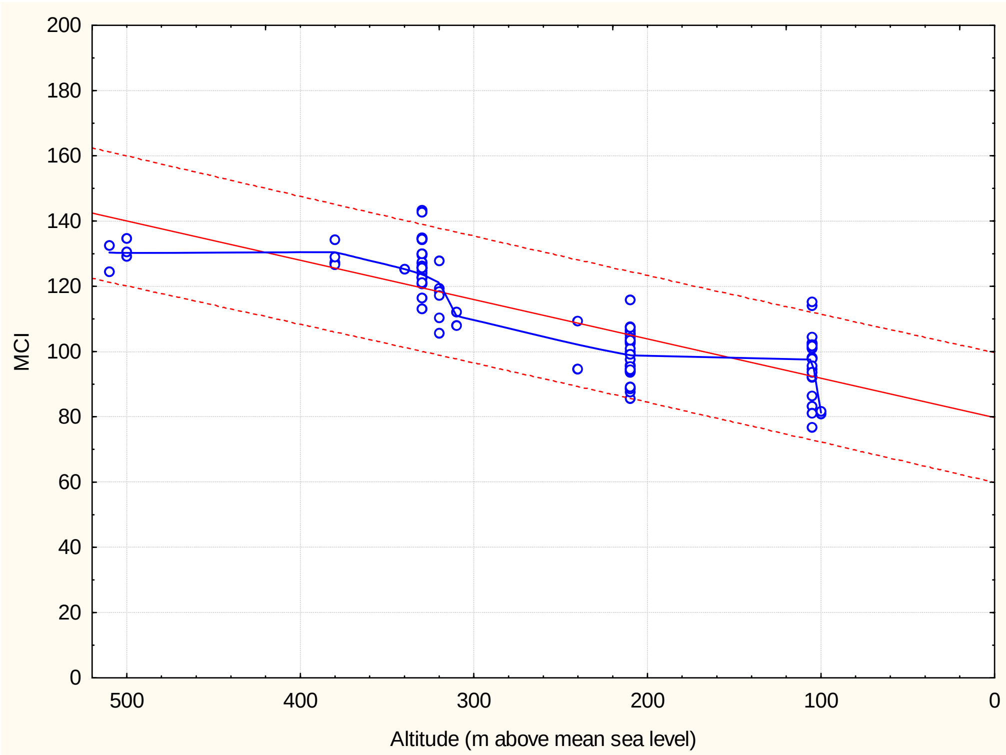

Figure 18 Linear relationship between MCI and site altitude (EQN19) from TRC surveys (N = 101) between June 1981 and July 2006 for the Manganui River. Dashed lines are 95% confidence limits about the prediction. The blue line is a LOWESS fit (tension = 0.4).

The linear and logarithmic relationships between MCI and distance from source for the Manganui River are (Figure 19):-

$$MCI = 130.165 - 1.053 * D_s \qquad r^2 = 0.626,\ p < 0.0001 \qquad \text{(EQN20)}$$

$$MCI = 144.844 - 30.279 * \log_{10}(D_s) \qquad \text{(EQN21)}$$

where D_s = distance from the source (km).

Visual inspection of Figure 19 suggests that these relationships fit observed data equally well.

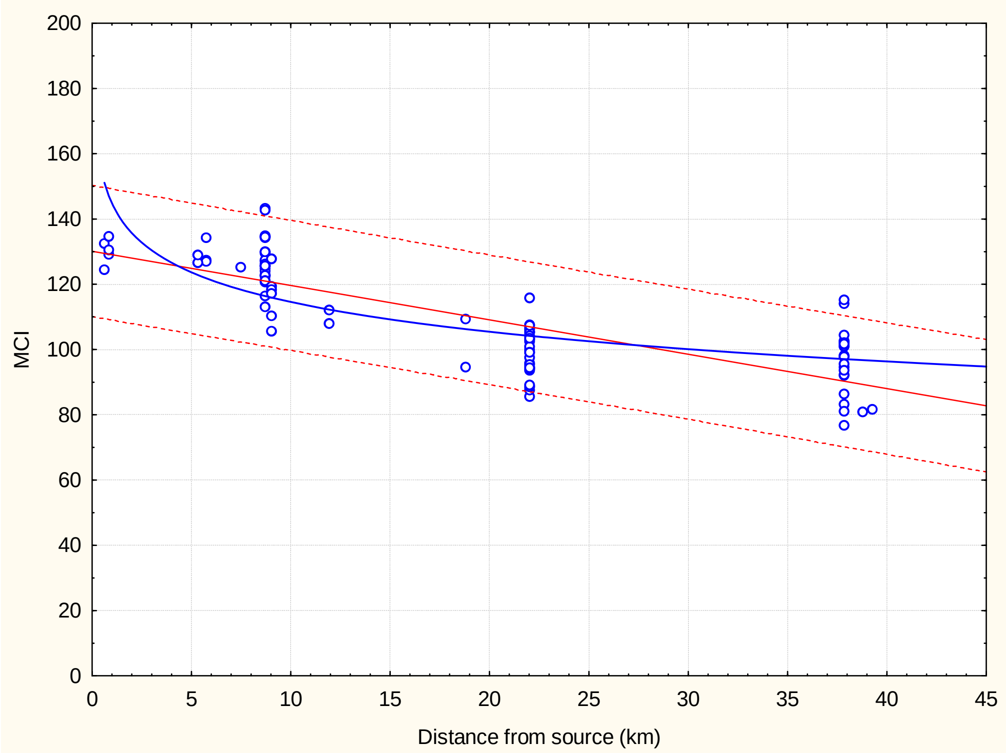

Figure 19 Linear relationship between MCI and distance from source (EQN20) from TRC surveys (N = 101) between June 1981 and July 2006 for the Manganui River. Dashed lines are 95% confidence limits about the prediction. The blue line is a logarithmic fit (EQN21).

3.3.3 Waingongoro River

The linear regression equation for MCI vs Altitude (n = 182) for the Waingongoro River (Figure 20) is:-

$$MCI = 82.222 + 0.094 * A \qquad r^2 = 0.736, p < 0.0001 \qquad \text{(EQN22)}$$

where A = site altitude (m above mean sea level).

Altitude explains nearly 74% of the variance in MCI for the Waingongoro River, but note the dip in the LOWESS smooth fit at around 200m altitude (Eltham) where the two major industrial and municipal waste discharges occur. The LOWESS fit line also suggests that river health recovers somewhat further downstream (Figure 20).

EQN22 is analogous to the generic MCI-Altitude relationship (EQN6) and is a stronger relationship (r^2 = 0.736 vs r^2 = 0.549) because it does not encompass variability due to differences between rivers. Both relationships encompass temporal variability in MCI values for each monitoring site included in the data.

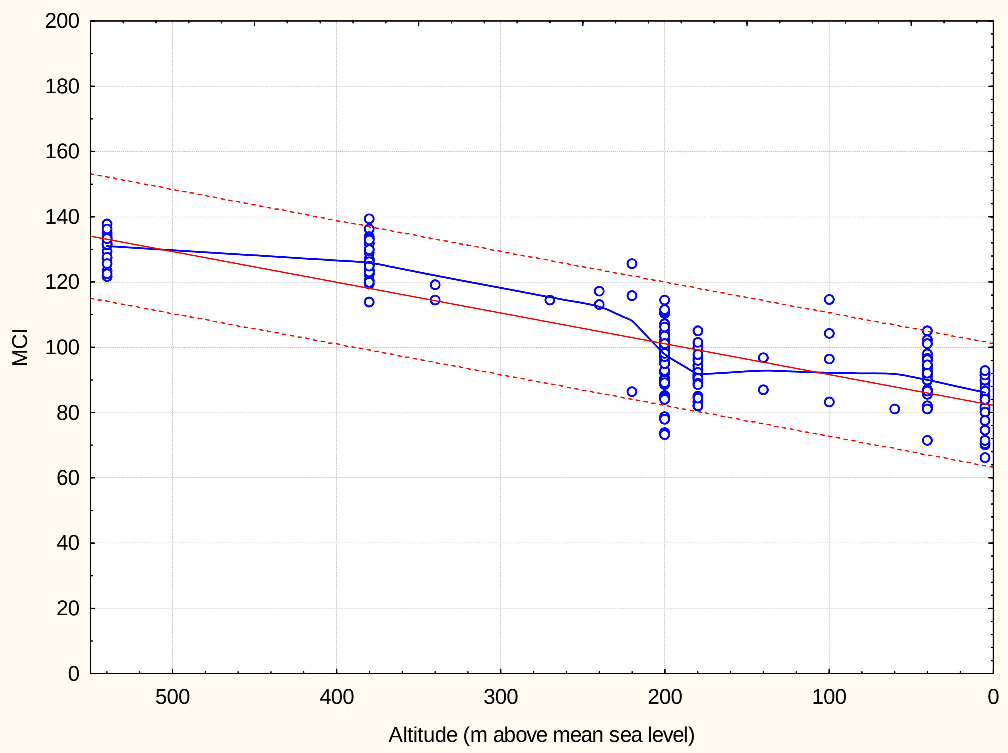

Figure 20 Linear relationship between MCI and site altitude (EQN22) from TRC surveys (N = 182) between June 1981 and July 2006 for the Waingongoro River. Dashed lines are 95% confidence limits about the prediction. The blue line is a LOWESS fit (tension = 0.4).

The linear and logarithmic relationships between MCI and distance from source for the Waingongoro River are (Figure 21):-

$$MCI = 121.342 - 0.609 * D_s \qquad r^2 = 0.578, p < 0.0001 \qquad \text{(EQN23)}$$

$$MCI = 133.684 - 24.974 * \log_{10}(D_s) \qquad \text{(EQN24)}$$

where D_s = distance from the source (km).

The linear EQN23 above is analogous to the generic EQN8 with the expected improvement in the strength of the relationship ($r^2 = 0.578$ vs $r^2 = 0.370$).

For the Waingongoro River both the linear (EQN23) and the logarithmic (EQN24) MCI – distance from source relationships do a reasonable job of matching observed MCI values (Figure 21).

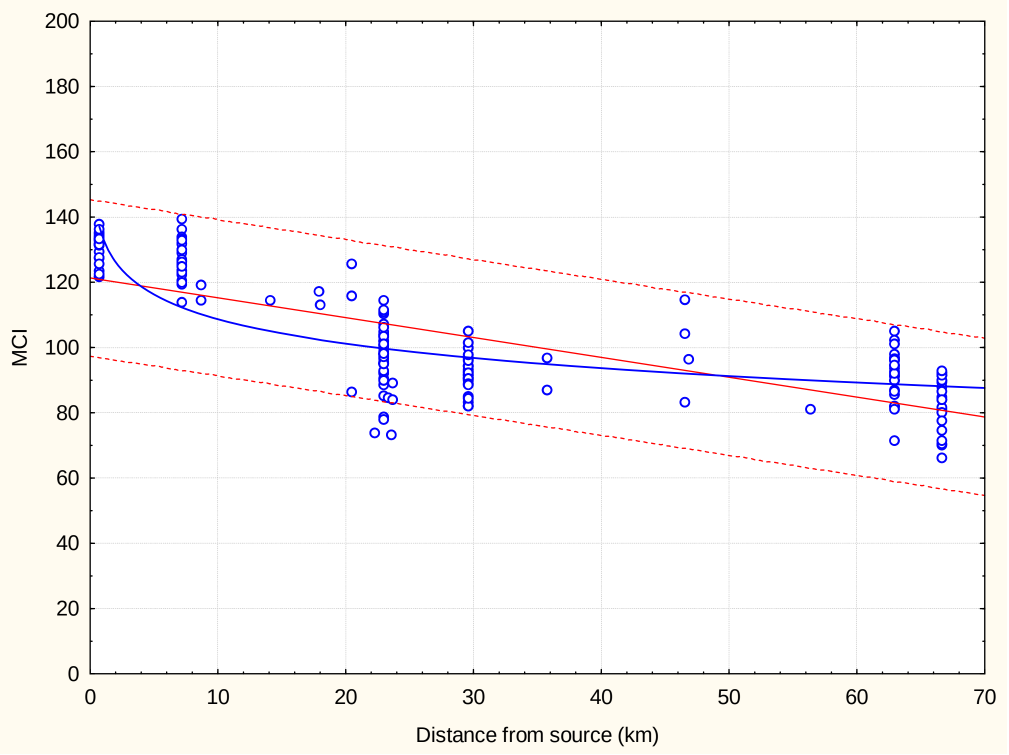

Figure 21 Linear relationship between MCI and distance from source (EQN23) from TRC surveys (N = 182) between June 1981 and July 2006 for the Waingongoro River. Dashed lines are 95% confidence limits about the prediction. The blue line is a logarithmic fit (EQN24).

4 DISCUSSION

Relationships between MCI and site altitude or distance from the National Park boundary are invaluable tools for water managers, and can assist in determining what expected stream/river health might be. Once established, expected stream health can be determined from such relationships as a desktop exercise for any site on any ring plain river. This can then be confirmed by field sampling, and any differences can be interpreted by an experienced stream ecologist in the light of knowledge of land-use, the integrity and character of riparian margins, existence of point source or non-point source discharges, and other physico-chemical data including information on water quality or the flow regime. Furthermore, MCI vs altitude relationships can be developed either as targets for stream improvement (Stark (1985) or for describing the normal condition of streams (which also provides a target for improvement of those streams (or localised reaches) that are below average in quality).

In this report, relationships between MCI and altitude have been updated using data from 1981 to 2006. Furthermore, relationships have been determined between MCI and distance from coast and distance from source, defined semi-arbitrarily, as the distance from the Egmont National Park boundary (in most cases). In all cases, the updated relationships focus on average stream condition.

Table 2 summaries relationships between MCI, site altitude, and distance (either from the coast or the source) that have been derived variously by Stark (1985), TRC (1999) or in this report.

4.1 Ring plain streams with National Park source of flow (RPNP)

Stark (1985) found that site altitude could be used to predict stream health on the Taranaki ring plain. The relationship he developed (EQN1) for unperturbed sites predicted the best possible MCI value for a given altitude, and was intended to provide a target for stream improvement, while acknowledging also for some streams that achieving this target may be unrealistic. Since Stark's (1985) MCI-Altitude relationship was for MCI values calculated using the original tolerance values, a variant of that equation has been derived using TRC's version of the MCI (EQN1A). Even though both of these relationships have been derived from a very limited data set (combined winter and summer data collected in 1981-82 from 15 "unperturbed" sites on the ring plain), it still is a good predictor of observed MCI values for RPNP streams within 10-12 km of the National Park (and the entire Stony River – see Figure 9).

Stark's (1985) relationship between MCI and altitude (EQN1) and the variant developed for TRC's MCI (EQN1A) explain over 60% of the variance in MCI – better than any of the generic relationships derived subsequently by TRC (1999) or in this report – and bettered only by river-specific relationships (*e.g.*, EQN16 – EQN24, Table 2). This is because Stark (1985) deliberately reduced the variance by selecting only the best quality ring plain sites over a range of altitudes, and the river-specific relationships avoid the variability that occurs between different rivers.

Table 2 Summary of relationships between MCI, site altitude (A) and distance from coast (D_c) or distance from source (D_s) for Taranaki ring plain streams. Only data from 'control' sites collected between June 1981 and Jul 2006 have been used. Shaded rows are the only ones that are recommended for use.

EQN No.	Equation	r^2	p	Application	Restrictions	Source	Rate of change
1	MCI = 116.054 + 0.048 * A	0.609	0.001	RPNP streams	Uses original MCI tolerance values	Stark (1985)	+4.8 MCI units /100m A
1A	MCI = 119.919 + 0.040 * A	0.624	0.0005	RPNP streams	EQN1 recalculated using TRC MCI values	This report	+4.0 MCI units /100m A
2	MCI = 68.49 + 0.114 * A	0.361	π	All sites in TRC database 1980 π 1998		TRC (1999)	+11.4 MCI units /100m A
3	MCI = 72.52 + 0.121 * A	0.504	π	'Control' sites only		TRC (1999)	+12.1 MCI units /100m A
4	MCI = 79.12 + 0.116 * A	0.568	π	RPNP 'control' sites		TRC (1999)	+11.6 MCI units /100m A
5	MCI = 80.18 + 0.062 * A	0.213	π	RPOP 'control' sites		TRC (1999)	+6.2 MCI units /100m A
6	MCI = 84.427 + 0.102 * A	0.549	*	RPNP 'control' sites (updates EQN4)		This report	+10.2 MCI units /100m A
7	MCI = 86.855 + 1.152 * D_c	0.312	*	RPNP 'control' sites	Only for rivers < 40 km long	This report	+1.152 MCI units /km D_c
8	MCI = 119.363 – 0.893 * D_s	0.370	*	RPNP 'control' sites	Only for rivers < 70 km long	This report	π0.893 MCI units /km D_s
9	MCI = 127.255 – 1.503 * D_s	0.506	*	RPNP 'control' sites	Only for rivers < 35 km long	This report	π1.503 MCI units /km D_s
10	MCI = 131.717 – 25.825 * $\log_{10}(D_s)$	π	π	RPNP 'control' sites	Only for rivers < 70 km long	This report	
11	MCI = 98.592 – 0.167 * D_s	0.042	0.0494	RPNP 'control' sites	Only for sites 35 π 70 km from source	This report	π0.167 MCI units /km D_s
12	MCI = 85.564 + 0.037 * A	0.109	*	RPOP HB 'control' sites		This report	+3.7 MCI units /100m A
13	MCI = 71.702 + 0.081 * A	0.243	*	RPOP SB 'control' sites		This report	+8.1 MCI units /100m A
14	MCI = 84.970 + 0.036 * A	0.102	*	RPOP SB+HB 'control' sites		This report	+3.6 MCI units /100m A
15	D_s = 24.382 – 0.048 * A	0.531	*	Relationship between A and D_s	Only for rivers < 35 km long	This report	
16	MCI = 61.557 + 0.153 * A	0.822	*	Patea River	Only for sites above 150 m altitude	This report	+15.3 MCI units /100m A
17	MCI = 130.230 π 1.411 * D_s	0.645	*	Patea River	0 π 45 km from source	This report	π1.411 MCI units /km D_s
18	MCI = 149.788 π 39.451 * $\log_{10}(D_s)$	π	π	Patea River	0 π 45 km from source	This report	
19	MCI = 79.791 + 0.121 * A	0.643	*	Manganui River		This report	+12.1 MCI units /100m A
20	MCI = 130.165 π 1.053 * D_s	0.626	*	Manganui River	0 π 40 km from source	This report	π1.053 MCI units /km D_s
21	MCI = 144.844 π 30.279 * $\log_{10}(D_s)$	π	π	Manganui River	0 π 40 km from source	This report	
22	MCI = 82.222 + 0.094 * A	0.736	*	Waingongoro River		This report	+9.4 MCI units /100m A
23	MCI = 121.342 π 0.609 * D_s	0.578	*	Waingongoro River	0 π 70 km from source	This report	π0.609 MCI units /km D_s
24	MCI = 133.684 π 24.974 * $\log_{10}(D_s)$	π	π	Waingongoro River	0 π 70 km from source	This report	

EQN1A best fits observed MCI data for narrow catchments that have limited scope for enrichment from diffuse or point sources (such as the Kapuni – see Figure 6). In catchments of larger area or with more intensive land-use, EQN1A is likely to over-estimate MCI values at distances more than 10-12 km from source perhaps by as much as 20%. While EQN1A undoubtedly provides a target MCI for stream improvement for most ring plain streams, it is uncertain whether it could realistically be achieved in large or very intensively modified catchments by adoption of water management initiatives such as riparian planting, stream shading, preventing stock access direct to waterways, and 'control' of point-source or diffuse-source nutrient enrichment. Further research would be required to determine whether stream improvement of this magnitude could be achieved while continuing to permit intensive agricultural, industrial, and urban activities within the catchments. We have no doubt that such improvement could be effected by permitting catchment land-use to return to a more natural state. However, this is not a practical or realistic option and is not one that we advocate. We do suggest, however, that it would be prudent not to over-emphasize these relationships because it may raise expectations unrealistically.

Taranaki Regional Council (1999) developed other relationships between MCI and altitude for streams and rivers of different sources of flow (Table 2). These relationships described the existing average condition of streams. By definition, of course, some streams are better than average, but others are not, so these relationships provide a realistic target for the more polluted or degraded streams in order to improve them to average or better condition.

EQN6 updates EQN4 to enable MCI values to be predicted from site altitude for RPNP streams on the ring plain (Table 2). The r^2 value is lower for EQN6 than it was for EQN4 because more data are included and a greater amount of year-to-year variability is included.

Distance from the coast (EQN7) is not an especially useful variable for predicting stream health, but distance from source (EQN8) does appear promising with a logarithmic relationship (EQN10) a better visual fit to the data than a linear one. Restricting the linear relationship to rivers less than 35 km in length (EQN9) increased the percentage of variance in MCI explained by distance from source from 37% (EQN8) to over 50% (EQN9) (Table 2).

Comparisons of predictions from these equations with observed mean MCI values for the Kapuni, Patea, Waingongoro, and Stony Rivers revealed that EQN1A was the best predictor of MCI values within 10-15 km of source, but further downstream the logarithmic relationship (EQN10) performed best (most probably because distance from source is likely to be a better predictor of stream health than altitude as distance from the headwaters increases). For most rivers (except the Stony – which is unusually short and swift), the MCI-Altitude relationship (EQN6) provided estimates of MCI between EQN1A and EQN10. With isolated exceptions, the EQN6 and EQN10 regression lines lay within the range of observed MCI values for these rivers.

4.2 Ring plain streams with source of flow outside the National Park (RPOP)

Whereas all RPNP streams are hard-bottomed, there are both hard- and soft-bottomed RPOP streams. Very few HB RPOP streams have been sampled comprehensively down their lengths to enable derivation of relationships between MCI and site altitude (EQN12). The analogous relationship (EQN13) for SB RPOP streams was poor (explaining only 11% of the variance). The relationship derived when both HB and SB streams are included (EQN14) was almost identical to that for HB streams alone (*i.e.*, EQN12) due to the dominance of data from 'control' sites in HB RPOP stream in the dataset.

No SB RPOP streams have been sampled at enough sites at different altitudes for these equations to be tested on them. Relatively few HB RPOP streams have been sampled at multiple sites too, but for two that have (Huatoki Stream and Inaha Stream), EQN6 (which was developed for HB RPNP sites) fits observed MCI values much better than EQN12 or EQN14 (which were developed from data from RPOP streams).

Consequently, until suitable data are collected from RPOP streams, we recommend that EQN12 and EQN14 should not be used. Instead, EQN6 should be used to predict MCI for HB RPOP streams

4.3 River-specific relationships

For rivers with sufficient data and/or those that are atypical (*e.g.*, longer than the typical ring plain stream), river-specific relationships between MCI and altitude or distance from source can be developed (*e.g.*, EQN16 – EQN24, Table 2). Such relationships are almost certain to explain a greater proportion of the variance in MCI than generic relationships because they do not include between-river variability.

4.4 Overview of observed and expected average MCI values for the Taranaki ring plain

Figure 22 shows a map of the Taranaki ring plain overlaid with average MCI values in six stream/river health classes calculated from macroinvertebrate samples collected throughout the region (1980 to date). Highest average MCI values occur adjacent to the Egmont National Park boundary. Lowest average MCI values occur in some of the longer ringplain rivers in north and south Taranaki and in the lower reaches of streams west of Mt Taranaki.

Figure 23 shows average MCI values predicted from the MCI – site altitude regression equation (EQN6). Comparison of the two maps indicates where on the ring plain observed stream health is better, worse, or equal to that which is predicted by EQN6 (Figure 24).

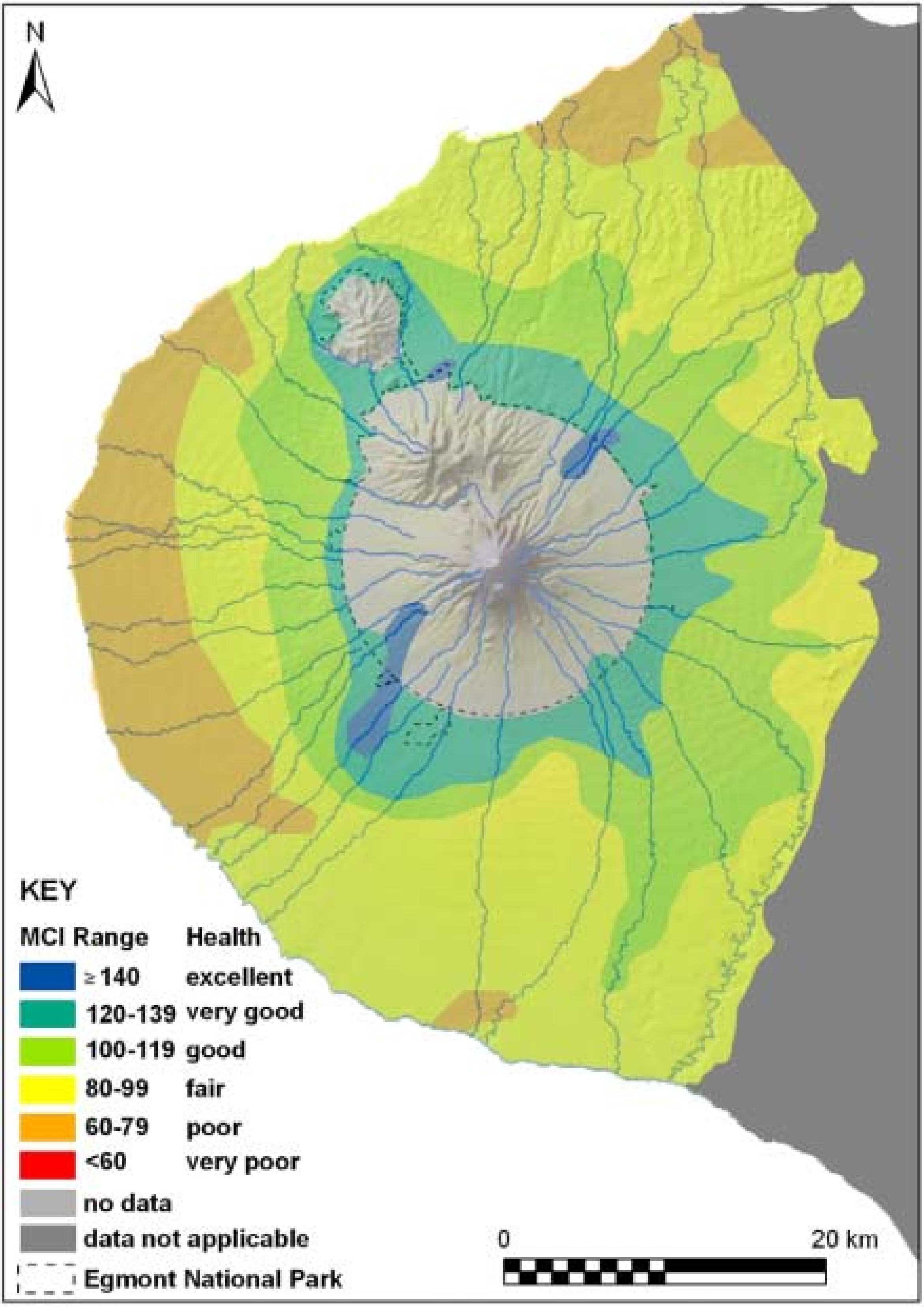

Figure 22 Map of the Taranaki ring plain showing stream/river health classes based on observed MCI values.

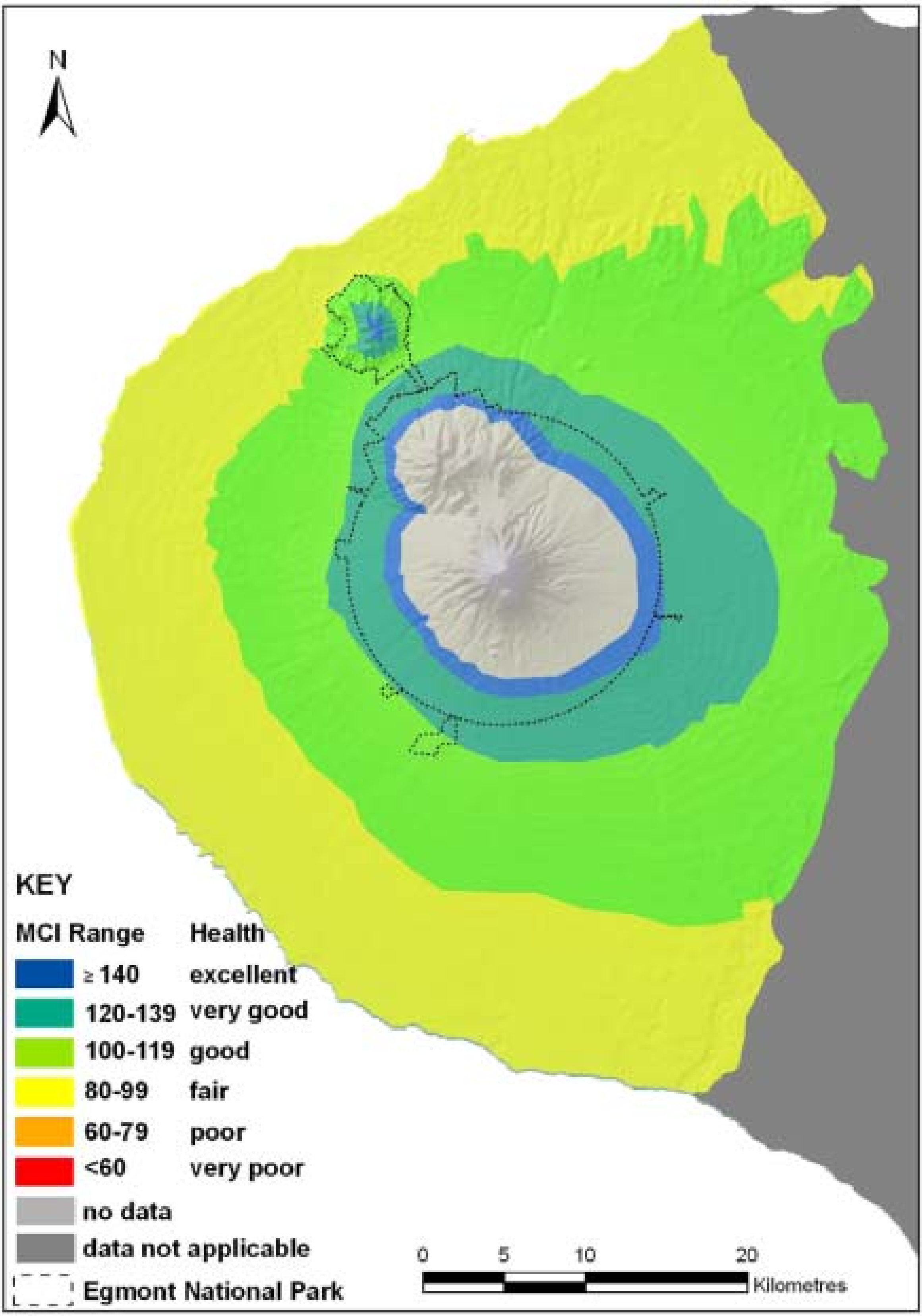

Figure 23 Map of the Taranaki ring plain showing stream/river health classes predicted from the MCI – site altitude relationship (EQN6).

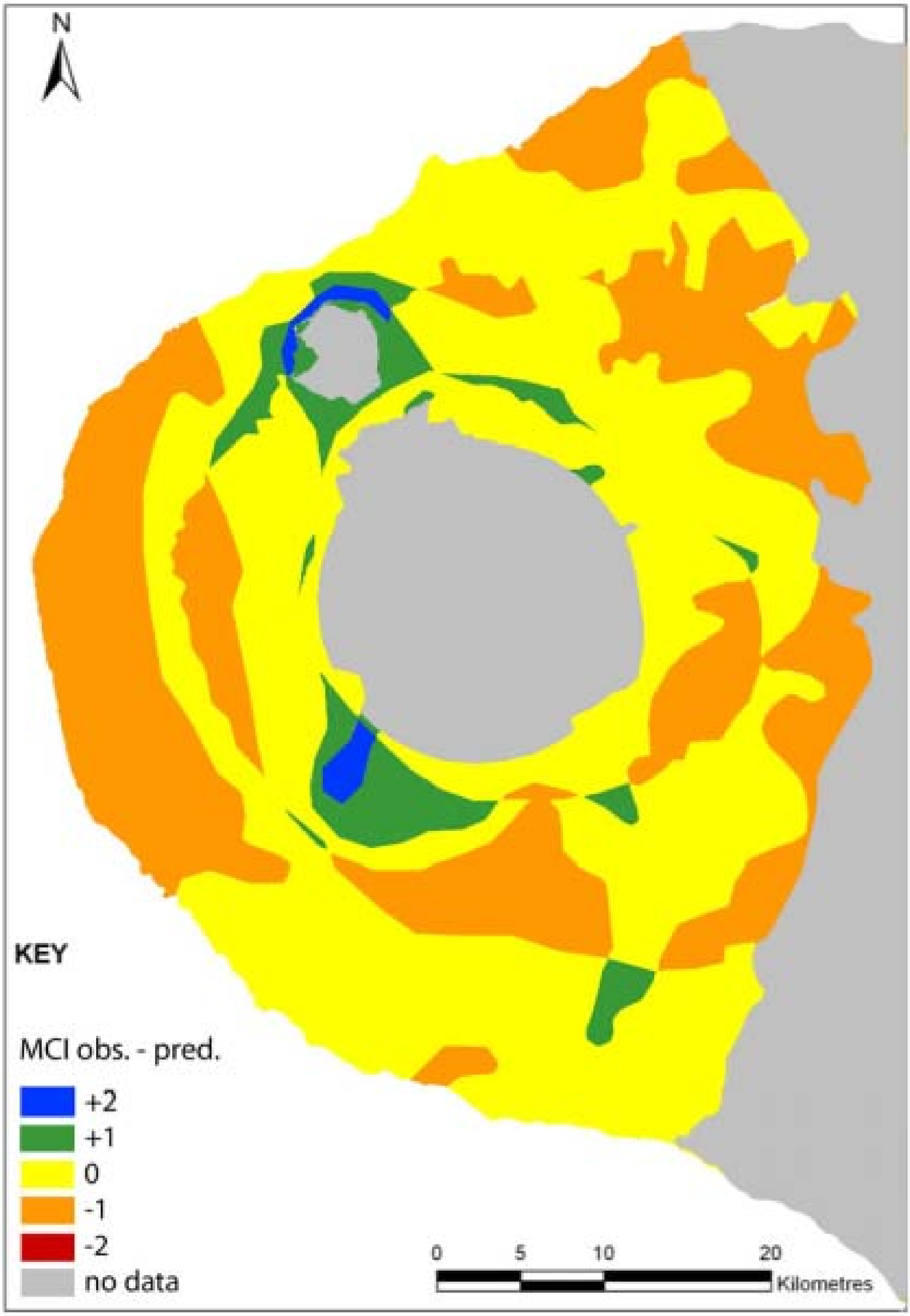

Figure 24 Map of Taranaki ring plain showing the differences between observed (Figure 22) and predicted (Figure 23) MCI values. In the key '0' means that observed and predicted stream health classes were the same, and '+2' means that the observed quality class was two classes higher than predicted (*e.g.*, Excellent vs good).

Table 3 Percentage area of Taranaki ring plain (for which data are available – see Figure 22) where observed MCI values are within six stream health classes.

MCI range	Interpretation	% of ring plain area
>140	Excellent	1.5
120 π 139	Very Good	12.1
100 π 119	Good	24.7
80 π99	Fair	47.0
60 π 79	Poor	14.7
<60	Very Poor	0.0

Measurement of the areas in different stream health classes using Adobe Photoshop CS3's area measurement tool suggests that streams on 47% of the ringplain are in fair condition, and 38.3% are good, very good, or excellent. MCI values suggest that streams are in poor health on only 14.7 of the ringplain. There are no ringplain streams in very poor health (Figure 22, Table 3).

Table 4 Percentage area of Taranaki ring plain (for which data are available – see Figure 24) where observed MCI values are greater than, equal to, or less than predicted by the MCI – Altitude regression (EQN6).

MCI obs. – pred.	Interpretation	% of ring plain area
+2	Observed MCI two health classes higher than predicted	0.8
+1	Observed MCI one health class higher than predicted	5.7
0	Observed MCI equals predicted	58.8
π1	Observed MCI one health class lower than predicted	34.7
π2	Observed MCI two health classes lower than predicted	0.0

Figure 24 was created by overlaying Figures 22 and 23 in Adobe Photoshop CS3. Areas on the ring plain where observed and predicted MCI values matched were coloured yellow, and areas where observed and predicted MCI differed were coloured according to the key on Figure 24. The areas of each colour on the map were measured using Photoshop's measurement area tool.

Examination of Figure 24 and the associated table of percentages (Table 4) reveal that approximately 65.3% of the area of the Taranaki ring plain shown on the map meets or exceeds the stream health predicted by the MCI – altitude relationship (EQN6). These areas are shown in yellow, green and blue on Figure 24. The remaining 34.7% (shown in orange) falls just one health class below predicted.

Given the intensity of land-use on the Taranaki ring plain, we believe that the existing state whereby streams in over 65% of the area meet or exceed the average predicted stream health (as indicated by the MCI) is a good result. Given that all the remaining area falls only one health class below predicted, we believe that there is considerable potential to improve stream health particularly in areas of the western ring plain.

5 FUTURE DIRECTIONS

The equations that we have developed provide water managers with simple-to-apply tools for estimating average stream health in Taranaki ring plain streams from site altitude (EQN6) or distance from source (EQN10). Analogous relationships developed for specific catchments tend to explain even more variance (60-80%) than the more generalised relationships (50-55%).

Dr John Leathwick (NIWA, Hamilton, pers. comm.) is planning to publish (and make freely available to end-users) a GIS-based multivariate model that predicts MCI values for any stream reach in New Zealand. When we commenced the development of our simple predictive relationships, we envisaged a second stage that linked our relationships to REC river classes. Given Leathwick's REC-based predictive model, this will no longer be necessary.

Some might argue that Leathwick's complex multivariate model has rendered our more simple approach obsolete. We disagree. In fact, because we have each used different approaches to predict MCI values for ring plain streams we expect that the similarity in outputs will not only serve to confirm the utility of our simple approach, but also confirm that the more complex procedures used by Leathwick (which may not be so easily understood by end-users) have produced sensible results. Furthermore, the relationships we have derived enable MCI to be predicted given a site altitude (which is easy to obtain from a map or GPS in the field) or a distance from source.

At this stage, insufficient data are available for SB streams on the ring plain and for most RPOP streams to enable generic or catchment-specific equations to be developed for predicting MCI from site altitude or distance from source. This same data scarcity must also affect the multivariate model produced by Leathwick. TRC could consider identifying sites down the length of RPOP and SB streams on the ring plain that could be sampled to enable such relationships to be developed in future.

Finally, the identification of areas of Taranaki where MCI values appear to be below average (Figure 24) may provide the impetus for TRC to investigate why this might be the case, identify the likely cause(s), and consider whether there are practical and cost-effective steps that can be taken to improve stream health in those areas.

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7 GLOSSARY

A	Altitude (m above mean sea level)
AUSRIVAS	Australian River Assessment Scheme
BEAST	Benthic Assessment of Sediment
ca.	About or approximately
D_c	Distance from coast (by river) in kilometres
D_s	Distance from source (by river) in kilometres. The source is defined as either the National Park boundary, the edge of the native bush line, or Carrington Road depending on the river concerned.
EQN	Equation
HB	Hard-bottomed or stony (referring to the nature of the streambed).
km	kilometre
LOWESS	Locally weighted scatterplot smoothing. At technique for fitting a trend line to a scatterplot (X-Y graph).
m	metre
MCI	Macroinvertebrate Community Index
p	Probability of differences being due to chance. Usual interpretation: $p = 0.01$ or less: difference is almost certainly significant $p = 0.05$ or less: difference is probably significant $p > 0.05$: significant difference is not proven
QMCI	Quantitative Macroinvertebrate Community Index
r^2	The square of the correlation coefficient (which is a measure of the degree of closeness of a linear relationship between two variables X and Y. r^2 may be described as the estimated proportion of the variance of Y that can be attributed to its linear regression on X.
RIVPACS	River Invertebrate Prediction and Classification System
RPNP	Taranaki ring plain streams with source of flow within Egmont National Park
RPOP	Taranaki ring plain streams with source of flow downstream of Egmont National Park
SB	Soft-bottomed or sandy/muddy (referring to the nature of the streambed)
SEM	State of the Environment Monitoring
SQMCI	Semi-quantitative Macroinvertebrate Community Index
TRC	Taranaki Regional Council

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Appendix 1 Tolerance values used by TRC for calculation of the MCI (with those for the MCI listed by Stark & Maxted (2007) for comparison). TRC has assigned tolerance values, or modified tolerance values for the highlighted taxa. Only taxa present in the data analysed for this report are included here.

	TRC	MCI		TRC	MCI		TRC	MCI
Coelenterata	3	3	**Plecoptera**			**Trichoptera** (cont.)		
Nematoda	3	3	*Acroperla*	5	5	*Neurochorema*	6	6
Nemertea	3	3	*Austroperla*	9	9	*Oecetis*	6	6
Nematomorpha	3	3	*Megaleptoperla*	9	9	Oeconesidae	5	9
Oligochaeta	1	1	*Spaniocerca*	8	8	*Olinga*	9	9
Polychaeta	3		*Spaniocercoides*	8	8	*Orthopsyche*	9	9
Hirudinea	3	3	*Stenoperla*	10	10	*Oxyethira*	2	2
Flatworms	3	3	*Taraperla*	10	7	*Paroxyethira*	2	2
Rhabdocoela	3		*Zelandobius*	5	5	*Plectrocnemia*	8	8
Mollusca			*Zelandoperla*	8	10	*Polyplectropus*	6	8
Amphibola	3	π	**Odonata**			*Psilochorema*	6	8
Ferrissia	3	3	*Aeshna*	5	5	*Pycnocentrella*	9	9
Gyraulus	3	3	*Antipodochlora*	5	6	*Pycnocentria*	7	7
Hyridella	3	3	*Austrolestes*	4	6	*Pycnocentrodes*	5	5
Latia	5	3	*Hemicordulia*	5	5	*Tiphobiosis*	6	6
Lymnaeidae	3	3	*Ischnura*	4	π	*Triplectides*	5	5
Melanopsis	3	3	*Procordulia*	5	6	*Zelolessica*	7	10
Physastra	5	5	*Xanthocnemis*	4	5	**Diptera**		
Physella	3	3	**Coleoptera**			*Aphrophila*	5	5
Potamopyrgus	4	4	Dytiscidae	5	5	*Austrosimulium*	3	3
Sphaeriidae	3	3	Elmidae	6	6	Ceratopogonidae	3	3
Crustacea			Hydraenidae	8	8	*Chironomus*	1	1
Amphipoda	5	5	Hydrophilidae	5	5	*Corynoneura*	3	2
Cladocera	5	5	Ptilodactylidae	8	8	Culicidae	3	3
Copepoda	5	5	Scirtidae	8	8	Empididae	3	3
Helice	3	π	Staphylinidae	5	5	Ephydridae	4	4
Isopoda	5	5	**Hemiptera**			Eriopterini	5	9
Mysidaceae	5	π	*Anisops*	5	5	*Harrisius*	6	6
Ostracoda	1	3	*Microvelia*	3	5	Hexatomini	5	5
Paranephrops	5	5	*Saldula*	5	5	*Limonia*	6	6
Paranthura	5	π	*Sigara*	3	5	*Maoridiamesa*	3	3
Paratya	3	5	**Neuroptera**			Muscidae	3	3
Tanaidacea	3	4	*Kempynus*	8	5	*Nothodixa*	4	4
Ephemeroptera			**Megaloptera**			Orthocladiinae	2	2
Acanthophlebia	9	7	*Archichauliodes*	7	7	*Paradixa*	4	4
Ameletopsis	10	10	**Lepidoptera**			*Paralimnophila*	6	6
Arachnocolus	8	8	*Hygraula*	4	4	*Pedicia*	6	π
Atalophlebioides	9	7	**Trichoptera**			Podonominae	8	8
Austroclima	7	9	*Alloecentrella*	8	9	*Polypedilum*	3	3
Coloburiscus	7	9	*Aoteapsyche*	4	4	Psychodidae	1	1
Deleatidium	8	8	*Beraeoptera*	8	8	Sciomyzidae	3	3
Ichthybotus	8	8	*Confluens*	5	5	Stratiomyidae	5	5
Mauiulus	5	5	*Costachorema*	7	7	Tabanidae	3	3
Neozephlebia	7	7	Ecnomidae	6	8	Tanyderidae	4	4
Nesameletus	9	9	*Helicopsyche*	10	10	Tanypodinae	5	5
Oniscigaster	10	10	*Hudsonema*	6	6	Tanytarsini	3	3
Rallidens	9	9	*Hydrobiosella*	9	9	Tipulidae	5	5
Zephlebia	7	7	*Hydrobiosis*	5	5	*Zelandotipula*	6	6
			Hydrochorema	9	9	**Acarina**	5	5

Appendix 2 Distances from source for Taranaki ringplain stream sites.

SiteCode	River$	Site$	Distance from Source (km)
CLD000175	Cold Stream	u/s Cold Creek W.S. scheme intake	1.3
KAI000250	Kaiauaia Stream	End of Hill Rd	3.38
KAI000499	Kaiauaia Stream	Alfred Rd Bridge	9.33
KHH000350	Kaihihi Stream	u/s Okato dairy Factory Weir	12.69
KHH000380	Kaihihi Stream	SH.45 (500m d/s Okato dairy factory)	12.98
KHI000245	Kahouri Stream	4km u/s SH3	5.18
KHI000250	Kahouri Stream	3.2km u/s SH3	6.05
KHI000260	Kahouri Stream	2 km u/s SH3	7.55
KHI000290	Kahouri Stream	Monmouth Rd lower bridge	8.68
KHI000457	Kahouri Stream	u/s new Stratford CC Power Station	14.93
KHI000460	Kahouri Stream	10m u/s Stratford sewage outfall	15.8
KNN000195	Konini Stream	100m u/s Barclay Rd bridge.	1.95
KPA000250	Kapoaiaia Stream	Wiremu Rd	5.65
KPA000700	Kapoaiaia Stream	Wataroa Rd	13.48
KPA000850	Kapoaiaia Stream	Approx. 2km d/s of SH45	22.68
KPA000950	Kapoaiaia Stream	Cape Egmont	25.22
KPK000250	Kaupokonui River	Opunake Rd	3.3
KPK000475	Kaupokonui River	Approx 300m u/s Kaponga	7.89
KPK000500	Kaupokonui River	u/s Kaponga oxidation ponds	9.16
KPK000550	Kaupokonui River	1km d/s Kaponga oxidation pond discharge	10.62
KPK000560	Kaupokonui River	1.3Km d/s Kaponga Ox/pond	10.96
KPK000655	Kaupokonui River	1km u/s of railway bridge	14.18
KPK000657	Kaupokonui River	Lactose Northern Farm upstream boundary	14.81
KPK000880	Kaupokonui River	Upper Glenn Rd	25.85
KPK000900	Kaupokonui River	SH45	27.21
KPK000990	Kaupokonui River	near mouth	31.08
KPN000125	Kapuni Stream	Approx 0.6km inside Nat Park	π0.7
KPN000150	Kapuni Stream	Opunake Rd	3.24
KPN000175	Kapuni Stream	Upper Palmer Rd	7.46
KPN000210	Kapuni Stream	Eltham Rd	10.93
KPN000275	Kapuni Stream	120m d/s Hawera WTP intake	16.89
KPN000280	Kapuni Stream	250m u/s water treatment plant	17.79
KPN000328	Kapuni Stream	Lower Palmer Rd	20.85
KPN000330	Kapuni Stream	Imm. u/s confl. u/n trib.	20.95
KPN000360	Kapuni Stream	Kokiri Rd	23.53
KPN000400	Kapuni Stream	Normanby Rd	27.02
KPN000450	Kapuni Stream	SH45	30.72
KRI000150	Kiri Stream	Carrington Rd	π0.25
KTK000150	Katikara Stream	Carrington Rd	0.04
KTK000220	Katikara Stream	SH45	12.55
KTK000248	Katikara Stream	Beach	18.05
MGE000200	Mangorei Stream	Upper Mangorei Rd	7.05
MGE000970	Mangorei Stream	SH3	21.55
MGN000115	Manganui River	10m u/s of unnamed trib (ex York Rd quarry extension)	0.62
MGN000130	Manganui River	U/s of York Rd Quarry	0.83
MGN000150	Manganui River	~3km u/s SH3	5.73
MGN000160	Manganui River	York Rd	5.34
MGN000185	Manganui River	1km u/s SH3 (off Denbigh Rd)	7.47
MGN000195	Manganui River	SH3	8.71
MGN000200	Manganui River	100m d/s SH3 bridge	9.02
MGN000215	Manganui River	10 m u/s of Te Popo S. confl.	11.92
MGN000280	Manganui River	Croydon Rd	18.79
MGN000300	Manganui River	u/s of Tariki Rd (approx 400m)	22.01
MGN000427	Manganui River	Bristol Rd	37.85
MGN000430	Manganui River	Everett Park (u/s Kurapete S.)	38.8
MGN000435	Manganui River	Everett Park (d/s Kurapete S.)	39.27
MGW000249	Mangawarawara Stream	Immed. u/s of Kaiauai Stream confl.	11.73
MHM000300	Mangahume Stream	Wiremu Rd	4.45
MHM000650	Mangahume Stream	Eltham Rd	12.29
MHM000970	Mangahume Stream	SH45	19.65
MKW000200	Maketawa Stream	opposite Denby Rd	2.25
MKW000250	Maketawa Stream	SH3	9.06
MKW000300	Maketawa Stream	Tarata Rd	15.54
MKW000370	Maketawa Stream	100m u/s of confl. of Manganui R	18.04
MTI000075	Mangatokiiti Stream	Opunake Rd	4.72

SiteCode	River$	Site$	Distance from Source (km)
MTK000048	Mangatoki Stream	200m u/s Upper Palmer Rd	2.18
MTK000050	Mangatoki Stream	Upper Palmer Rd	2.39
MTK000067	Mangatoki Stream	Immed. u/s of Inaha WTP backwash discharge trib.	4.51
MTK000234	Mangatoki Stream	160m u/s of pipeline crossing	10.67
MTK000235	Mangatoki Stream	100m u/s pipeline crossing	10.59
MTK000240	Mangatoki Stream	Eltham Rd	11.76
MTK000250	Mangatoki Stream	Hastings Rd	14.96
MTK000265	Mangatoki Stream	500m u/s Skeet Rd	20.76
MTK000267	Mangatoki Stream	350m u/s Skeet Rd Bridge	20.88
NGN000200	Ngatoronui Stream	SH3	11.46
NGT000104	Ngatoro Stream	50m u/s NPDC intake weir.	0.88
NGT000165	Ngatoro Stream	300m u/s bridge to Ngatoroπ1	4.59
NGT000167	Ngatoro Stream	20m u/s Ngatoro P.S.1 discharge	4.93
NGT000182	Ngatoro Stream	50m u/s of unnamed trib. confl.	6.2
NGT000185	Ngatoro Stream	50m u/s NPDC WTP backwash discharge	6.69
NGT000193	Ngatoro Stream	Near Bedford Rd Bridge	7.1
NGT000300	Ngatoro Stream	SH3	11.18
NGT000330	Ngatoro Stream	Junction Rd	15.48
OAN000250	Oaonui Stream	Wiremu Rd	6
OAN000278	Oaonui Stream	50m u/s of water intake weir	10.06
OKR000150	Oakura River	Carrington Rd	0
OKR000475	Oakura River	SH45	18.76
OTK000200	Otakeho Stream	Opunake Rd	2.97
OTK000400	Otakeho Stream	Skeet Rd	13.04
OTK000402	Otakeho Stream	50m d/s Skeet Rd	13.24
OTK000900	Otakeho Stream	SH45 ("old" bridge)	23.27
PAT000200	Patea River	Barclay Rd	1.94
PAT000225	Patea River	Cardiff Rd bridge	6.19
PAT000285	Patea River	Regan St Walkway d/s Mangarangi S	10.32
PAT000287	Patea River	Brecon Rd Bridge	10.79
PAT000300	Patea River	50m u/s swimming pool intake	11.41
PAT000310	Patea River	adj.Reg.Cncl.HQ.,Cloton Rd	12.51
PAT000313	Patea River	adj centre old Celia St.,tip	12.74
PAT000315	Patea River	Swansea Rd	12.91
PAT000357	Patea River	100m d/s CCPS discharge	17.41
PAT000360	Patea River	Skinner Rd	19.2
PAT000372	Patea River	1 km. u/s confl. with Ngaere S	22.88
PAT000374	Patea River	200m u/s Ngaere S. confluence	23.79
PAT000375	Patea River	50m u/s Ngaere Stm confl.	23.89
PAT000385	Patea River	30m u/s drains below Ngaere#1	24.5
PAT000397	Patea River	Hungers Rd	28.48
PAT000400	Patea River	500 m d/s Toko S. confluence.	35.17
PAT000430	Patea River	Raupuha Rd	42.08
PIK000110	Piakau Stream	Upper Durham Rd	2.47
PIK000200	Piakau Stream	SH3	9.73
PKS000198	Piakau Stream South	200m u/s SH3	8.58
PNH000200	Punehu Stream	Wiremu Rd	4.36
PNH000210	Punehu Stream	Opunake Rd	6.22
PNH000800	Punehu Stream	500m d/s Mangapapa S. confl.	15.99
PNH000900	Punehu Stream	SH45	20.93
STY000260	Stony River	near end of Saunders Rd	1.63
STY000280	Stony River	Wiremu Rd	5.29
STY000300	Stony River	Mangatete Rd	7.31
STY000400	Stony River	SH45	12.45
THN000200	Te Henui Stream	Baker Rd bridge	11.2
THN000395	Te Henui Stream	Junction Rd bridge	19.25
THN000496	Te Henui Stream	Adjacent to East End Bowling Club	23.99
TMR000150	Timaru Stream	Carrington Rd	π0.82
TMR000375	Timaru Stream	SH45	10.94
TPP000170	Te Popo Stream	SH3 Midhirst	10.35
WAA000050	Waiaua River	Brames Falls Track	π4.36
WAA000150	Waiaua River: trib.	National Park boundary	π0.23
WAA000200	Waiaua River	Wiremu Rd	5.57
WAA000395	Waiaua River	50m u/s Opunake water supply intake	11.63
WAA000447	Waiaua River	SH45	18.59
WGA000080	Waiongana Stream	Ngatoro Track	π2.92
WGA000120	Waiongana Stream	adj. Egmont Road	2.93
WGA000150	Waiongana Stream	Bedford Rd	7.56

SiteCode	River$	Site$	Distance from Source (km)
WGA000170	Waiongana Stream	~2km u/s SH3	9.19
WGA000175	Waiongana Stream	Junction Rd	10.91
WGA000260	Waiongana Stream	SH3a	16.13
WGA000290	Waiongana Stream	100m u/s NPDC water supply weir	20.07
WGA000360	Waiongana Stream	Manutahi Rd	23.69
WGA000450	Waiongana Stream	Devon Rd	31.24
WGA000485	Waiongana Stream	850m u/s coast (LB)	34.59
WGA000486	Waiongana Stream	850m u/s coast (RB)	34.5
WGA000489	Waiongana Stream	750m u/s coast (LB)	34.81
WGA000490	Waiongana Stream	750m u/s coast (RB)	34.72
WGA000494	Waiongana Stream	500m u/s coast (RB)	35.08
WGA000495	Waiongana Stream	500m u/s coast (LB)	35.01
WGG000115	Waingongoro River	900m d/s National Park	0.73
WGG000150	Waingongoro River	Opunake Rd	7.16
WGG000175	Waingongoro River	75m d/s tributary confl.	8.7
WGG000250	Waingongoro River	Finnerty Rd	14.1
WGG000375	Waingongoro River	Imm. u/s of Tuikonga S. confl.	17.91
WGG000377	Waingongoro River	Cornwall Rd	18
WGG000490	Waingongoro River	end of Clifford Rd	20.45
WGG000495	Waingongoro River	800m u/s Eltham Rd. bridge	22.27
WGG000500	Waingongoro River	Eltham Rd	22.99
WGG000502	Waingongoro River	100 m d/s Eltham Rd, 30m u/s Riverlands	23.34
WGG000505	Waingongoro River	Riverlands' river weir	23.55
WGG000507	Waingongoro River	Imm. d/s weir	23.67
WGG000665	Waingongoro River	Stuart Rd	29.57
WGG000680	Waingongoro River	Skeet Rd bridge	35.77
WGG000778	Waingongoro River	300m u/s Mawhitiwhiti Rd	46.53
WGG000780	Waingongoro River	Mawhitiwhiti Rd	46.82
WGG000818	Waingongoro River	End of Burgon Rd	56.37
WGG000895	Waingongoro River	SH45	62.95
WGG000995	Waingongoro River	Ohawe Beach	66.62
WKH000100	Waiwakaiho River	National Park	π0.2
WKH000185	Waiwakaiho River	Upper Alfred Rd. track	2.34
WKH000300	Waiwakaiho River	50m u/s of KaimiroπO well site discharge	6.3
WKH000475	Waiwakaiho River	~700m u/s confl. of Kaiauai S.	8.92
WKH000485	Waiwakaiho River	100m d/s of Kaiaua Stream confl.	10.32
WKH000500	Waiwakaiho River	SH3	10.62
WKH000520	Waiwakaiho River	50m u/strm NPE intake gates	12.06
WKH000673	Waiwakaiho River	Meeting of Waters'	18.12
WKH000675	Waiwakaiho River	Approx 100m d/s Mtg of Waters	18.21
WKH000687	Waiwakaiho River	Burgess Park.	18.99
WKH000720	Waiwakaiho River	Balsom Park, Highlands	21.39
WKH000800	Waiwakaiho River	Merrilands Domain.	23.65
WKH000860	Waiwakaiho River	60m u/s Rimu St Landfill	25.21
WKH000920	Waiwakaiho River	Constance St (NePl)	26.6
WMK000100	Waimoku Stream	Lucy's Gully	π0.48
WMK000170	Waimoku Stream	Approx. 1.5km d/s SH45	2.08
WMK000298	Waimoku Stream	Beach	4.03
WPK000085	Waipuku Stream	Near start of York Rd. track (Egmont Nat. Pk.)	0
WRA000140	Wairau Stream	Oakura water supply intake	0.07
WRA000160	Wairau Stream	250m u/s SH45	1.39
WRA000298	Wairau Stream	Oakura Beach	3.27
WRE000150	Warea River	Wiremu Rd	5.2
WRE000450	Warea River	SH45	19.38
WWN000200	Waiweranui Stream	Wiremu Rd	5.18
WWN000600	Waiweranui Stream	end of Ruakere Rd	12.65
WWN000900	Waiweranui Stream	SH45	15.45