RESOURCE MANAGEMENT GROUP

HAWKE'S BAY REGIONAL COUNCIL

SAFEGUARDING YOUR ENVIRONMENT + KAITIAKI TUKU IHO

Maraekakaho Stream Minimum Flow

Scientific Evidence

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Resource Management Group

Environmental Science Section

Maraekakaho Stream Minimum Flow

Scientific Evidence

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EXECUTIVE SUMMARY

As a result of the 2009 consents renewal process for the Ngaruroro Catchment, the consent hearing panel granted the applications in the Maraekakaho SMZ subject to a low flow of 90% of MALF over the hydrological year (i.e. a minimum flow of 120 L/s) for the following reasons:

a) this would provide a safer default minimum flow to protect the in-stream environment

b) changing from a weekly to monthly volume of take would also achieve a 7% reduction in volume which would address matters in Policy 39(c) of the RRMP.

Consent holders on the Maraekakaho appealed this decision on the basis that it would extend the irrigation ban days within the catchment and challenge the economic viability of their businesses.

In light of subsequent preliminary findings from the science programme in the Ngaruroro and Maraekakaho catchments, the MALF has been naturalised to a revised figure of 120.8 L/s. The new 90% MALF of 109 L/s is now recommended and supports the basis of the commissioner's decision.

This report summarises the Maraekakaho catchment and explains the science programme currently being undertaken to assess future water allocation scenarios and identifies preliminary results from recent investigations. Ban days have been calculated using the historical streamflow record for 100 L/s, 109 L/s and 120 L/s at Taits Road monitoring site.

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1.0 COMMISSIONER'S DECISION

The evidence provided identified that the Maraekakaho Stream Management Zone (SMZ) is significantly over-allocated according to Table 9 of Policy 74 of the RRMP. The methodology for setting minimum flows and allocations within this plan are now out of date. Scientific understanding and agreement in New Zealand has moved on since this plan was adopted.

Mr Johnson's evidence determined that 90% of non naturalised MALF measured over the hydrological year for the Maraekakaho Stream was 120 L/s. Mr Johnson confirmed that the Stream experienced drying between Tait Road and the confluence of the Ngaruroro River, and that abstraction had the potential to influence the duration/magnitude of drying of the Stream. Mr Johnson suggested that the ecological values of the Stream were not necessarily being protected by the current minimum flow (100 L/s), being well below 90% MALF.

The evidence identified that a significant number of lifestyle blocks had established in the Maraekakaho SMZ with permitted water takes and that the existing consents pre-dated the proliferation of permitted takes.

The Panel noted that converting the weekly volume into a monthly volume based on 4 times the weekly volume effectively gives a 7% claw-back in the total volume of water allocated.

The Panel also noted that when considering the applications, section 104(2A) must be taken into account, in terms of having regard to the value of the infrastructure investment of the existing consent holders.

The Panel found it appropriate that applications in the Maraekakaho SMZ be granted with a low flow of 90% of MALF over the hydrological year (i.e. a minimum flow of 120 L/s) for the following reasons:

a) this would provide a safer default minimum flow to protect the in-stream environment

b) changing from a weekly to monthly volume of take would also achieve a 7% reduction in volume which would address matters in Policy 39(c) of the RRMP.

2.0 CATCHMENT DESCRIPTION, HYDROLOGY STATISTICS AND ECOLOGICAL SUMMARY

The Maraekakaho Stream is approximately 24.3 km long and is fed by a catchment area of 122.4km^2. It joins the Ngaruroro River which is the second longest river in Hawke's Bay. The location of the Maraekakaho Stream catchment in the Ngaruroro River Catchment is shown in Figure 1 and a schematic layout of the Ngaruroro River in Figure 2.

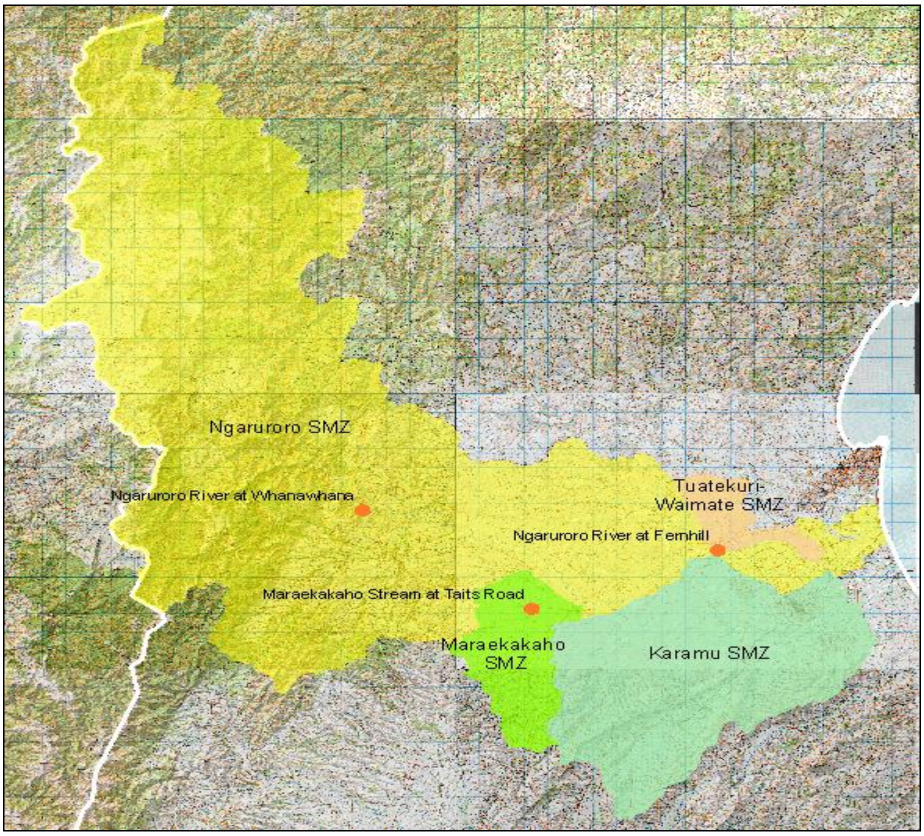

Figure 1: Ngaruroro River Catchment

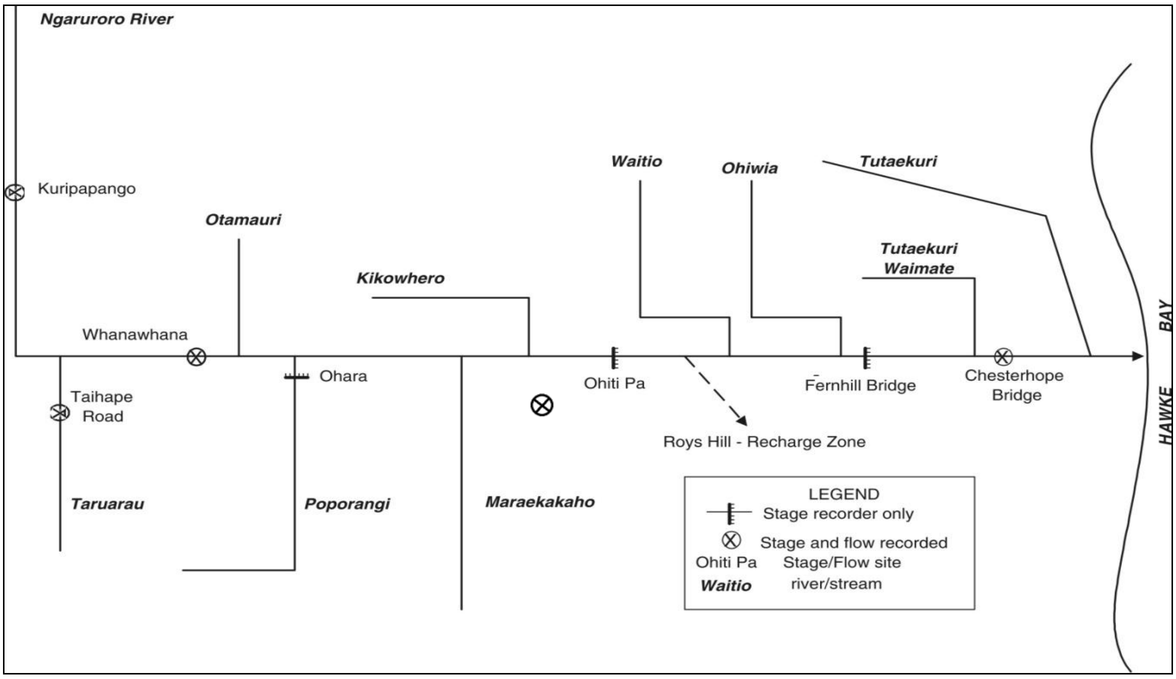

Figure 2: Schematic of the Ngaruroro River

The Maraekakaho Stream flows into the Ngaruroro River immediately north of the Maraekakaho Township. The Stream originates in the Raukawa region of Hawke's Bay (Stansfield, 2004). The Maraekakaho Stream follows a meandering course through pastoral farm land typically as a fourth order stream before converging with the Ngaruroro River as a fifth order stream at the confluence.

The geology of the Maraekakaho Stream catchment is similar to that of the Ngaruroro River catchment and consists of greywacke boulders, gravels and sands formed from Holocene and Pleistocene river terrace deposits derived from the Ngaruroro River. However the Maraekakaho Stream, like other nearby streams, is currently eroding into the deposited greywacke gravel terrace (erosional products from the Ruahine and Kaweka ranges) as a result of tectonic uplift of the Puketapu Fault Zone.

The Maraekakaho Stream is elevated along its entire course relative to the Ngaruroro River which means that groundwater flows from the Maraekakaho to the Ngaruroro River. Stream flow measurements indicate that the Maraekakaho Stream loses water to the groundwater before it reaches the confluence with the Ngaruroro River. Investigations undertaken by Rosen *et al.* (1995) indicated that 80 L/s is lost between Tait Road and the Maraekakaho Township. Piezometric contours based on Stream and well water levels taken between November 1993 and April 1994 indicate that groundwater is moving east towards the Ngaruroro River, away from the Maraekakaho Stream. On some occasions surface flow is completely lost (i.e. the riverbed is 'dry') between the Tait Road Bridge and Maraekakaho Road. It is thought that water lost from the Maraekakaho Stream seeps out of the active streambed, mixes with groundwater and travels underground, before emerging into the Ngaruroro River channel as springs.

A diurnal change of up to 30 L/s has been identified in the Maraekakaho Stream flow records. After preliminary investigations (see Attachment 1) it is concluded that this cycle is a natural phenomenon.

The Maraekakaho Stream is characteristic of a mildly enriched (moderate nutrients) slow moving water body. Water temperatures and dissolved oxygen concentrations from the stream indicate that environmental conditions for these variables would not cause mortality of native fish within the stream during summer months but would severely limit the suitability of the stream for trout. The absence of trout in electric fishing surveys undertaken in 2003, 2004 and 2006 supports this.

The Maraekakaho Stream catchment has been extensively cleared of indigenous vegetation. This includes the riparian zones (see Attachment 3). The lack of shading of the stream channel through the removal of indigenous stream side vegetation would result in increased water temperatures.

The macroinvertebrate community of the Maraekakaho Stream is characteristic of a stream with an impacted environment. The Stream experiences high summer temperatures of around 25 degrees Celsius that have the potential to limit macroinvertebrate diversity. It is suspected that water temperatures in the Maraekakaho Stream are typically too high for stoneflies and mayflies. Surveys undertaken on the Stream during December 2003 found these macro invertebrates to be absent. This was in contrast to nearby streams with lower water temperatures that had these groups present. Studies of the Karamu streams and the Maraekakaho Stream by the HBRC in December 2003 found the Maraekakaho Stream to have the highest stream temperatures of the six streams surveyed. Temperatures for the Maraekakaho Stream were found to be significantly lower than the critical or lethal temperatures of native fish known to be resident in the stream. However, midway temperatures in the Maraekakaho Stream were at or above lethal temperatures for rainbow and brown trout. Based on this information, it would be fair to say that water temperatures in the Maraekakaho Stream are unsuitable for trout over summer months. Trout have not been caught in electric fishing surveys in the upper catchment since 1986.

Five species of native fish have previously been found in the upper reaches of the Maraekakaho Stream showing stream conditions to be suitable for native fish.

A section of Stream in the lower catchment (up to approximately 500 m) is known to dry up in summer months when flows drop below ~200 L/s. It is considered that the timing of this drying would not impact unduly on upstream migrations of native fish which typically occur in late winter and spring, a time when this stream section experiences good surface flows. This is new information that was not part of the consent hearing process.

Over winter months, the Maraekakaho Stream provides spawning habitat for both brown and rainbow trout entering the stream from the Ngaruroro River. Analysis of historical Stream flows during the spawning season (July to October) shows fish passage through the lower section of the Maraekakaho Stream to be adequate during this period of the year (flows typically greater than 200 L/s).

Native fish monitoring in 2003 indicates that there is a higher diversity of native fish upstream of Tait Rd than what there is below and it is possible that this could be a result of the natural barrier (a dry reach) that exists between Tait Rd and Kereru Rd.

3.0 CALCULATION OF BAN DAYS AT DIFFERENT MINIMUM FLOWS

Collation of days less than 120 L/s, 109 L/s and 100 L/s for the 'irrigation season' (November to April) are summarised below. The flows are as measured at Taits Road and are actual ban days (not naturalised).

Ban Day Nov-Apr Summary	**Flow <120 L/s**	**Flow <109 L/s**	**Flow <100 L/s**
83 to 84	1	0	0
84 to 85	18	15	11
85 to 86	5	1	0
86 to 87	17	13	10
87 to 88	17	15	10
88 to 89	0	0	0
89 to 90	1	0	0
90 to 91	0	0	0
91 to 92	0	0	0
92 to 93	0	0	0
Recorder removed 5 January 1993			
94 to 95 *From Ban Record	18	18	18
98 to 99 *From Ban Record	6	6	6
02 to 03 *From Ban Record	30	30	30
Recorder installed 23 December 2003			
03 to 04	4	0	0
04 to 05	71	64	58
05 to 06	39	36	23
Recorder removed 21 April 2006			
Recorder installed 2 May 2007			
07 to 08	2	0	0
08 to 09	11	0	0
09 to 10	8	0	0
Total Nov-Apr Ban Days	248	198	166
Worst Recorded Year	71	64	58

The above table identifies that under the worst case scenario (2004/2005) over the recorded period of flow, the recommended 90% Naturalised MALF minimum flow of 109 L/s would produce seven more days of irrigation than under the 120 L/s minimum flow recommended in the hearing.

4.0 MALF NATURALISATION

Flow naturalisation involves adding all the various water abstractions that might affect the flow in a river back to the flow actually recorded. This produces an estimate of what the flow regime would have been, particularly the low flows, had the various consents for abstraction not been granted or exercised.

As a result of programmed work conducted since the consent hearings, the Maraekakaho Stream flow record has been naturalised. Measured flows have been naturalised two ways in order to form a comparison of worst case (all consented abstraction is taken at once) and actual take calculated from metered use records and calculated estimates used for periods prior to metered data. Recorded non naturalised MALF is also provided for reference.

The following describes the methods for deriving each set of statistics.

Flow Set 1: Recorded Flow - Using actual recorded stream flows from HBRC hydrometric stations (Tait Road 1983-1993, D/S Tait Road 2003-present), the 7-day moving average flow series has been produced and mean annual low flow calculated from those data.

Flow set 2: Recorded Flow + Consented Rate - A daily average flow series was calculated using the HBRC Hilltop database using recorded flows from HBRC hydrometric stations (Tait Road 1983-1993, D/S Tait Road 2003-present). Total consented rates of take were added for all surface water and stream-depleting groundwater takes. These data were added to the daily average flow series for all days between 1 November and 30 April. This process produced a synthetic flow series for further analysis.

The synthetic flow series was then analysed in Hilltop to produce 7-day moving average statistics and MALF.

Flow set 3: Recorded Flow + Estimated Actual Use - Estimated actual water use in the Maraekakaho Catchment was used as part of a flow naturalization process.

Average daily use (L/s) where available was obtained from metered data and added to the daily mean flows.

Where actual average daily use data was not available predating metered record, metered abstraction data and allocation volume was used to calculate percentage actual water use. For each metered abstraction per month of irrigation season (i.e. November to April) crop requirements were calculated within the Maraekakaho Catchment and then applied to the record where no actual metered data existed for consented takes back through the flow record for the duration of the individual consents.

The resultant synthetic flow series was analysed in Hilltop to produce 7-day moving average statistics and MALF for the period 1 November and 30 April.

Flow Scenario's (combined record)	Period	MALF	90% MALF
Recorded Daily Mean Flow	1/7/1983 0:00 to 12/05/10 0:00	112.4	101.2
Recorded Flow + Consented Rate	1/7/1983 0:00 to 12/05/10 0:00	135.9	122.3
Recorded Flow + Estimated Actual Use	1/7/1983 0:00 to 12/05/10 0:00	120.8	108.7

Part year 1983&2010 assessed as including minimum flow period
Combined record is using datasource daily mean flow

Assumptions and explanations

Gaps exist in recorded flow due to a variety of reasons, often related to physical damage or malfunction of water level measuring devices and electronic recorders. The gaps in the combined Maraekakaho flow record are as follows.

Gaps for site Maraekakaho Stream D/S Tait Rd [daily mean flow]. Data starts at 1-Jul-1983

Gap from 16-Jun-1984 00:00:00 to 13-Jul-1984	27.00 Days
Gap from 14-Aug-1984 00:00:00 to 8-Sep-1984	25.00 Days
Gap from 6-Nov-1984 00:00:00 to 16-Dec-1984	1.31 Months
Gap from 3-Aug-1985 00:00:00 to 21-Sep-1985	1.61 Months
Gap from 31-Mar-1986 00:00:00 to 18-Apr-1986	18.00 Days
Gap from 18-Jul-1986 00:00:00 to 16-Aug-1986	29.00 Days
Gap from 4-Mar-1988 00:00:00 to 2-Apr-1988	29.00 Days
Gap from 11-Apr-1988 00:00:00 to 4-May-1988	23.00 Days
Gap from 12-Nov-1990 00:00:00 to 29-Nov-1990	17.00 Days
Gap from 13-Dec-1990 00:00:00 to 6-Feb-1991	1.81 Months
Gap from 6-Jan-1993 00:00:00 to 24-Dec-2003	10.96 Years
Gap from 15-Feb-2004 00:00:00 to 19-Feb-2004	4.00 Days
Gap from 30-Jun-2004 00:00:00 to 30-Jul-2004	30.00 Days
Gap from 18-Aug-2004 00:00:00 to 29-Aug-2004	11.00 Days
Gap from 18-Jul-2005 00:00:00 to 3-Aug-2005	16.00 Days
Gap from 21-Apr-2006 00:00:00 to 3-May-2007	1.03 Years
Gap from 26-Jun-2007 00:00:00 to 1-Jul-2007	5.00 Days
Gap from 22-Feb-2010 00:00:00 to 5-Mar-2010	11.00 Days

Data ends at 12-May-2010 00:00:00

Each gap has been checked to determine if the lowest flow of the year was likely to be missing from the flow record. In the event that the lowest flow most likely occurred during a gap in record, that year was not analysed for low flow statistics.

The data indicated that it is acceptable to analyse all years on record with the exception of 1983 and the period 1993-2003. Flow monitoring started in July 1983, which is outside of the 1982/1983 low flow period, and the HBRC hydrometric station was inoperable between 1993-2003, so little or no flow data exist for these years.

It should be noted that the Tait's Road flow site was installed in July 1983 using a Foxboro Recorded and operated for ten years. This site was then disestablished. It was relocated upstream on 22 December 2003 (approximately 400m to an alternative recorder location, no significant inflows or outflows were identified between these two locations). After close to three years operation this site was destroyed in a flood on 21 April 2006 and the site was eventually reinstated to its former 2003 position on 29 June 2007.

Analysis of the statistics from the two sets of record (1983-1993 and 2003-2009) produce quite different mean minimum flows. It is considered that this may be due to the increase in accuracy of equipment and advances in measurement techniques. It may well also be due to a different climatic period. With these considerations it was decided that the conservative approach was to merge the record and analyse the full record and treat it as a record that takes into consideration any potential climatic deviation and natural variability of stream flow.

5.0 ECOLOGICAL EFFECT OF LOW FLOWS

The intermittent nature (cease to flow) of the lower section of the Maraekakaho Stream is not considered to significantly alter the integrity of the native fish community as upstream migration of juvenile native fish occurs at times when river flows are typically adequate to provide suitable upstream fish passage. Stream conditions in the upper catchment over summer months appear adequate to support most species of native fish.

Navigation of the lower section of the river by trout during the spawning season is not considered to be a problem as flows in the stream would be adequate to provide for upstream movement of the fish during the spawning period.

During summer months, a period of time when the lower section of the stream dries, fish passage requirements are minor for native fish species. The absence of trout in electric fishing surveys likely reflects the movements of adult fish downstream to the Ngaruroro River at the end of the spawning run and before stream conditions become too warm to accommodate trout.

In summary the Maraekakaho Stream is a warm stream with average ecosystem health when compared to streams of a similar REC type. Current instream conditions are not favourable for trout species where both temperature and preferred food sources are limiting in summer/low flow periods.

At present, the ecological health of the Maraekakaho Stream is compromised by high stream temperatures that appear greater than streams typical of the area. Efforts to increase riparian vegetation cover and remove stock from the Stream would help to offset effects of low flow periods by providing increased shading of the stream channel and improved water quality. This in turn would improve habitat suitability for macroinverebrates, native fish and trout. It must be noted that increased riparian study and exclusion of stock need to occur not only over the subject consent holders properties but would benefit the entire stream length.

6.0 RESEARCH PROGRAMME

Setting robust, scientifically defensible minimum flows based on physical habitat models requires a sound survey design and quality flow records. A critical part of minimum flow-setting methodology is the MALF. The preliminary naturalized MALF that has been developed for this report has been fast tracked from this science program in order to enable informed decisions to be made during negotiation using the most recent data available. This procedure has been peer reviewed by Opus.

Another critical component of flow setting on the Maraekakaho is establishing the water quality and ecology (as described in Appendix 4). Although some prior research is available, a work programme is underway in order to enable more informed flow setting decisions and is set for completion prior to the 2015 consent renewal process.

7.0 CONCLUSION

It is considered a reduction of 11 L/s to the minimum flow would not have significant effect on the ecological health of the Maraekakaho Stream. The recommended figure of 109 L/s is still 90% MALF as requested by the hearings panel. This figure is also consistent with the National Environmental Standards (NES), which although has no statutory standing, is a suitable guideline representing the current approach within New Zealand. Based on the worst recorded year for accumulated ban days an 11 L/s drop in minimum flow would have provided a reduction of approximately seven ban days over the 2004/2005 low flow year.

At present, the ecological health of the Maraekakaho Stream is compromised by high stream temperatures that appear greater than streams typical of the area. Efforts to increase riparian vegetation and remove stock from the Stream would help to offset effects of lower flow by providing increased shading of the stream channel and improved water quality. This in turn would improve habitat suitability for macroinverebrates, native fish and trout.

In light of subsequent preliminary findings from the science programme in the Ngaruroro Catchment, the MALF has been naturalised to120.8 L/s. The revised 90% MALF to 109 L/s is recommended and supports the basis of the commissioner’s decision.

APPENDIX 1: DRYING AND DIURNAL FLUCTUATION OF THE MARAEKAKAHO STREAM

Drying of the lower reaches of the Maraekakaho Stream and diurnal fluctuations in flow present a challenge to water allocation in this catchment. Recent allocation pressure has necessitated targeted investigations to inform the processing of water use consents. The hydrology section was asked to compile information regarding the drying of the lower reaches and to provide an estimate of the potential number of drying days that may occur.

The location and aerial extent of drying has been documented using GPS in the lower Maraekakaho. The length of the dry reach has been related to flow measured at the HBRC hydrometric station at Tait Road. The available data show that drying can potentially occur at flows 200l/s or less. Flows less than 200 L/s occur over approximately 27% of the Maraekakaho flow record. If more detail is required as to the onset and duration of drying, additional field work will be necessary.

Diurnal streamflow fluctuation was also investigated to determine if pumping was a potential cause. HOBO pressure transducers were installed at multiple locations to determine if the diurnal flow pattern occurs throughout the Maraekakaho system. Results indicate that the diurnal pattern recorded at Tait Road is present at upstream and downstream sites. The cause of the fluctuation is unlikely to be pumping-induced.

Additional work is required to determine if the current minimum flow affords the intended protection of flows and habitat. This work is best coordinated as a joint effort between the hydrology and ecology teams.

Drying Reaches

A walking survey was conducted on the lower Maraekakaho on four occasions during low flow conditions to map the drying reach. The location and extent of the dry reach for each survey has been overlaid on aerial photographs (Figure 1).

Figure 1: GPS locations of the upstream and downstream extents of drying in the Maraekakaho Stream. A waypoint was marked at the point of lowest flow on 9/04/2010 as drying did not occur.

The flow at the Tait Road hydrometric station on 29 March 2010 was 207 L/s and the dry reach extended approximately 480 meters. The flow at Tait Road was 156 L/s on 16 April 2010 and the dry reach was approximately 360 meters long. Flow was continuous on 8 April 2010 with a corresponding flow at Tait Road of 213 l/s. On 9 April 2010, flow was approximately 5 l/s, with a corresponding flow at Tait Road of 188 L/s. An assumption was made that the conditions observed on 9 April were near the onset of drying, thus a dry-reach length of 0 meters was used for comparison to flow. These data were plotted to determine if a pattern or linear relationship was evident (Figure 2).

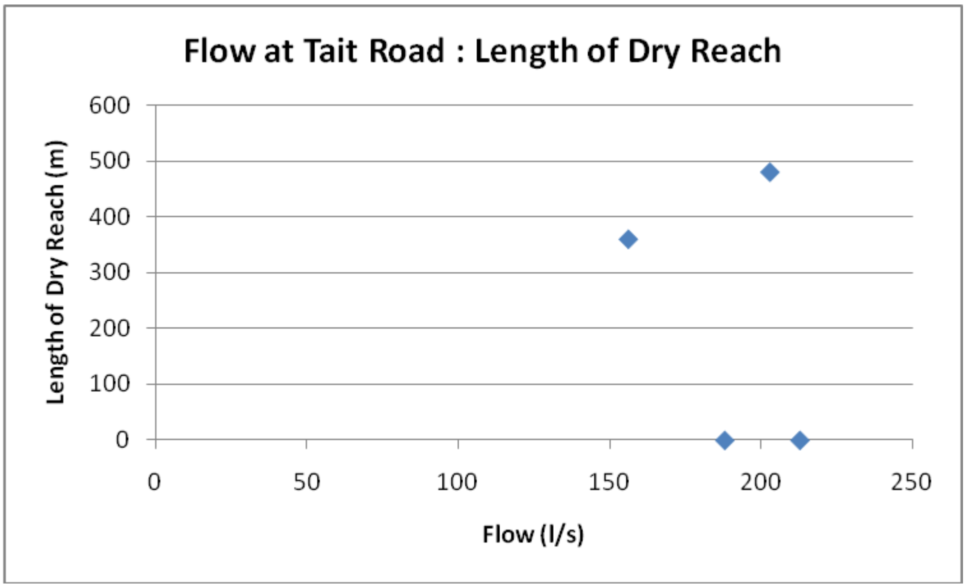

Figure 2: Comparison between length of drying reach and the flow recorded at Tait Road.

With this limited data set, it is not possible to determine a flow (at Tait Road) at which the lower Maraekakaho begins to dry. Additional observations of dry length shortly after to the onset of drying conditions would improve this relationship. It can, however, be said that drying of the lower Maraekakaho Stream can occur at flows 200 l/s or less.

Diurnal Fluctuation

Daily fluctuations in the flow of the lower Maraekakaho Stream have been frequently observed.

Water level data at the Tait Road hydrometric station show diurnal fluctuations of 10-15 mm. This occurs over much of the hydrograph except during flushing flow events where the diurnal pattern is masked by storm runoff. Hypotheses for the cause of the fluctuations have ranged from evapotranspiration to surface water pumping. Work was completed to isolate pumping as a potential cause.

Seven sites were chosen along the Maraekakaho Stream for installation of Hobo pressure transducers to measure water level in the stream and determine if the diurnal fluctuation occurs along the entire length (Figure 3). These sites are located at points along the stream above and below consented water takes to account for their potential influence on water levels.

Figure 3: Map of the Maraekakaho Stream catchment and locations of Hobo pressure transducer installations. Green dots mark the location of consented water takes.

A number of small rain events occurred during this investigation, which mask diurnal fluctuations in both Hobo data and the hydrometric station records. When two sets of data are compared, they show very similar responses to the same events and during recessions, indicating that the two are measuring the same instream conditions (Figures 4 and 5). A slight diurnal fluctuation during a recession can be seen between 24/10/2010 and 27/10/2010 in Figure 5. Both the hydrometric station and the Hobo pressure transducer record this pattern. Hobos 1-4 show nearly identical patterns as shown in Figure 4, as do Hobos 5-7 in Figure 5. This indicates that the fluctuations recorded by the Tait Road hydrometric station occur throughout the Maraekakaho catchment and represent conditions not influenced by pumping.

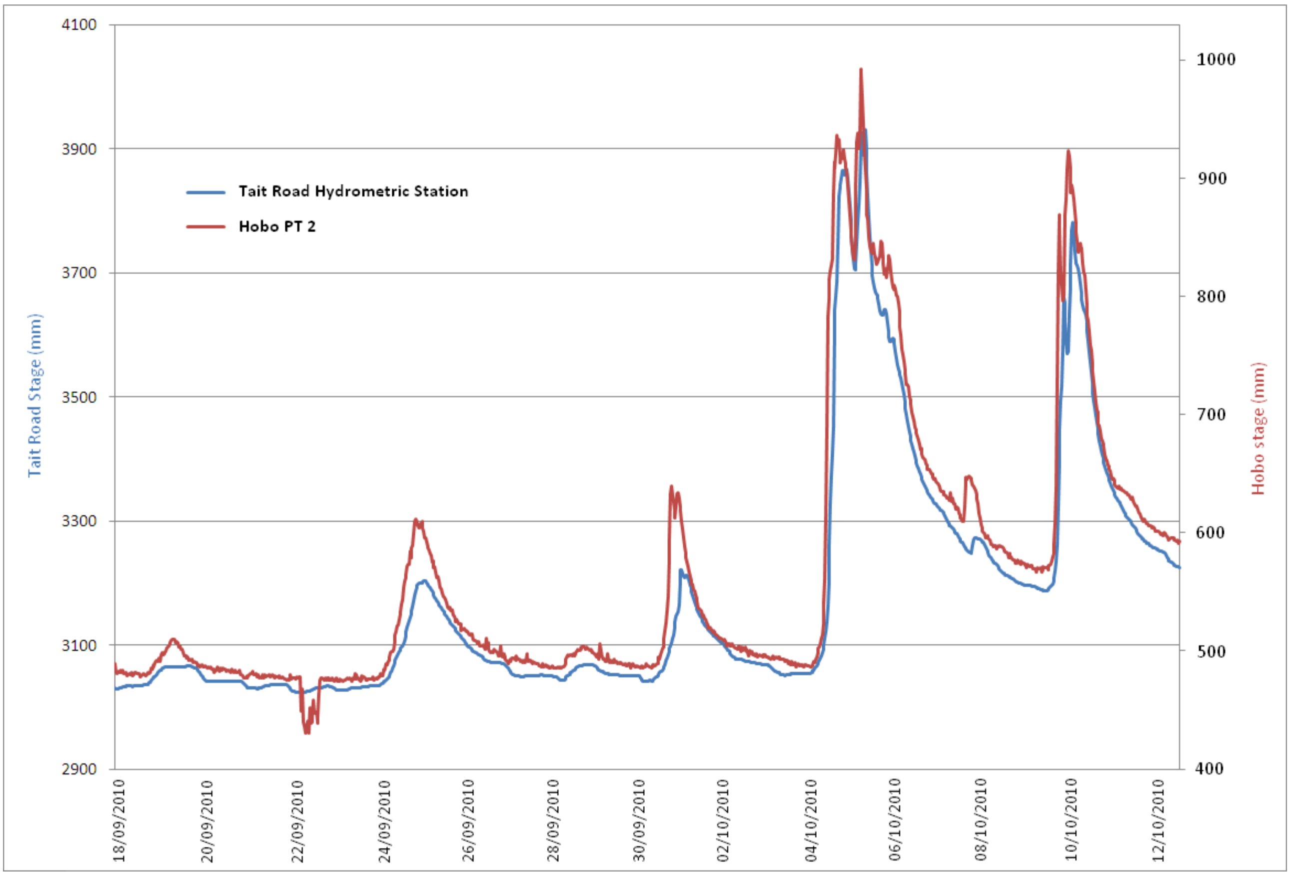

Figure 4: Comparison of water level measurements between the Tait Road hydrometric station and the number 2 Hobo pressure transducer. The sharp decrease in the Hobo data on 22/09/2010 is attributed to errors in barometric pressure correction and is not actual stream fluctuation.

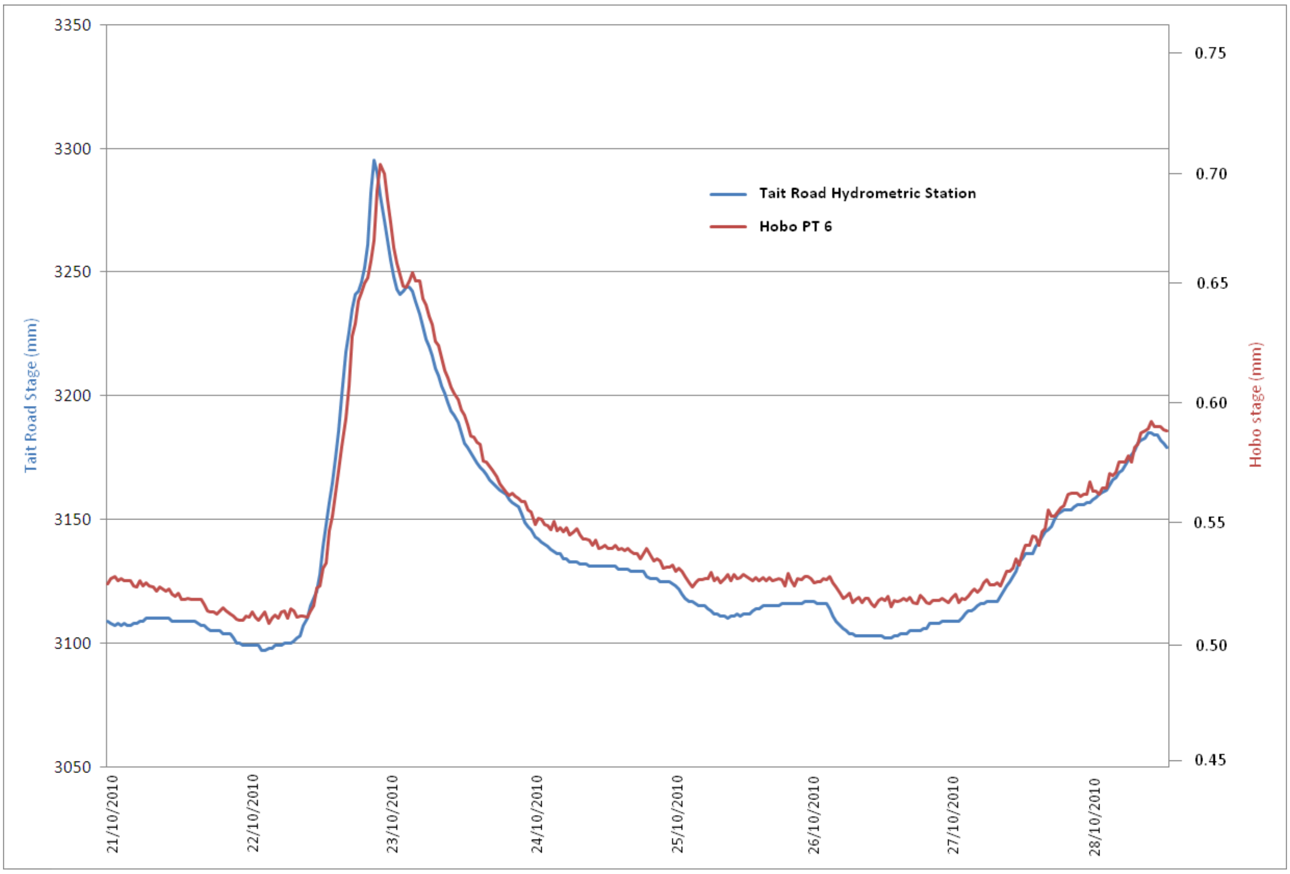

Figure 5: Comparison of water level measurements between the Tait Road hydrometric station and the number 6 Hobo pressure transducer.

Conclusions and Recommendations

The drying of the lower Maraekakaho Stream is a common occurrence. Current data show that drying in the Maraekakaho can potentially occur at flows 200l/s or less. Using the 7-day moving average flow distribution, flows less than 200 l/s occur over approximately 27% of the flow record.

It is likely that multiple factors influence drying, including river flow, evapotranspiration, water abstraction, and water table fluctuation. More data are required to determine the primary cause and it's magnitude of influence. If more detail is required as to the onset and duration of drying, additional field work will be necessary.

It is recommended that future efforts focus on determining the frequency and duration of drying and relate this to the flow at Tait Road. A full survey of instream fauna will also prove useful to determine the sensitivity of those species to drying events. This will be valuable for minimum flow assessment.

The diurnal fluctuation observed at the Tait Road hydrometric station appears to be present throughout the Maraekakaho stream. This includes the upper reaches above all consented water takes. It is unlikely that water abstraction is the cause of the dirunal streamflow pattern.

APPENDIX 2: OPUS PER REVIEW OF NATURALISED MALF OF THE MARAEKAKAHO STREAM

15 July 2010

Mr Rob Christie
Consents Manager
Hawkes Bay Regional Council
159 Dalton Street
Private Bag 6006
NAPIER 4142

Dear Rob,

Re: *Naturalised MALF of the Maraekakaho Stream*

Introduction

Many streams and rivers now have highly modified flow regimes as a result of various human impacts; including dams, abstractions, and discharges. To assist with catchment management and water allocation decisions it is often necessary to derive a naturalised flow regime, i.e. what the flow regime would be without any human impacts.

With regard to the Maraekakaho catchment, flow naturalisation involves adding all the various water abstractions that might affect the flow in a river back to the flow actually recorded. This produces an estimate of what the flow regime would have been, particularly the low flows, had the various consents for abstraction not been granted or exercised.

The derivation of an accurate naturalised flow record requires high quality information on:

- The actual flow in the river;
- The flow variability over time, including the effects of any cyclic behaviour or longer term trends that might affect the representativeness of the flow record under consideration; and
- The volume and timing of all abstractions.

While in general the first constraint can be met with current flow monitoring and gauging techniques, this may not be the case when using older information. The resolution of both the amount of flow, and its variability over time, is significantly greater using modern techniques than in the past. This may affect the accuracy of any statistics derived from the analysis of older records. The flow record should also be of sufficient length that it includes the effects of any cyclic or longer term variability within the flow regime.

Information regarding the volume and timing of abstractions is usually the major constraint affecting the accuracy of naturalised flow records. This is because, at the present time, there is usually little precise data relating to the actual volume and timing of water abstracted from the river. Consents usually provide information relating to: the maximum abstraction rate; the total volume able to be abstracted; and the duration of the irrigation season. They do not, however, always require metering of the abstraction. This is particularly the case with older consents.

The above constraints must be recognised when reviewing the accuracy of any naturalised flow record derived for the Maraekakaho Stream.

Information reviewed

To assist with undertaking a review of the derivation of a naturalised flow record for the Maraekakaho Stream, I used the following materials:

- The hydrometric flow information relating to the Maraekakaho catchment;
- Literature relating to low flow analysis for both gauged and ungauged catchments;
- *Ngaruroro River Flow Naturalisation.* A report prepared for Hawkes Bay Regional Council by MWH, 15 March 2010;
- A brief methodology of the revised naturalisation approach taken by Ms Kim Coulson, HBRC;
- Various Excel spreadsheets containing the steps and associated calculations to derive the naturalised flow records for Maraekakaho Stream; and
- The resulting naturalised flow series.

I have also had a number of telephone discussions with Kim Coulson HBRC to clarify particular issues and processes. It should be noted that I was not provided with the actual abstraction consent database. I was therefore not able to check that the consented abstraction volumes used in the analysis, and the date at which they took effect, are correct. However, I am assuming that this is the case. I have no reason to believe otherwise.

While I have randomly checked the various spreadsheet calculations, I have not confirmed all the data transfers to Hilltop. However, this process is straightforward and any errors would be immediately obvious. Given the results, it can be assumed that the data transfer and conversion protocols were correctly used.

Maraekakaho hydrometric data

Flow data

Flow data have been collected from the Maraekakaho catchment since 30 June 1983. However, although the present site was initially established in 1983 there is a 14.3 year gap in the record between 6 January 1993 and 1 May 2007. Some of this missing flow data can be obtained from a second site located just upstream. Data from this site are available between 22 December 2003 and 21 April 2006.

The flow record used in the analysis has therefore been formed by combining the records from two sites on Maraekakaho Stream. Graphing the merged flow series shows no apparent change in the flow regime over the period of merged record. It is possible that the effect of any slight difference between the sites would be mitigated by the use of daily averages, rather than instantaneous flows, in the analysis.

Even after merging to the two flow sites there is still a long period of missing record. Given the constraints of missing record, low flow analysis can be most reliably undertaken using data from 1984-1992, 2004-2005, 2008-2009, i.e. only 13 years in total. This has the potential to affect the reliability and robustness of low flow analysis. There are four additional years where periods of flow data are missing, but it has been assessed by HBRC that the low flow period has still been captured in the record. The inclusion of these years increases the flow record duration to 17 years. The consequences of using a relatively short record are compounded if the flow regime is subject to any cyclic behaviour or trends. This is discussed later in this review.

Some justification should be provided in the final report regarding the appropriateness of combining these two records into a single flow series for the stream. This discussion should also include any potential effects of using a combined flow series on the results and conclusions.

Reliability of ratings

Since the flow data used in this analysis are derived from measuring the water level, the quality and reliability of the rating curve used can have a significant effect on the accuracy of low flow estimates.

The flow monitoring sites on the Maraekakaho River have both been subject to natural rather than artificial control. Because the river flows across a gravel bed, and between gravel banks, the cross section tends to be relatively unstable. Consequently, the cross-sectional area often changes during flood events. This will lead to a change in the rating (i.e. the relationship between water level and flow). There are at least 17 shifts in the rating over the length of record (Figure 1). While rating shifts are most likely to occur during, and immediately following, flood events unless they are corrected rapidly any shift has the potential to affect the reliability of low flow estimates.

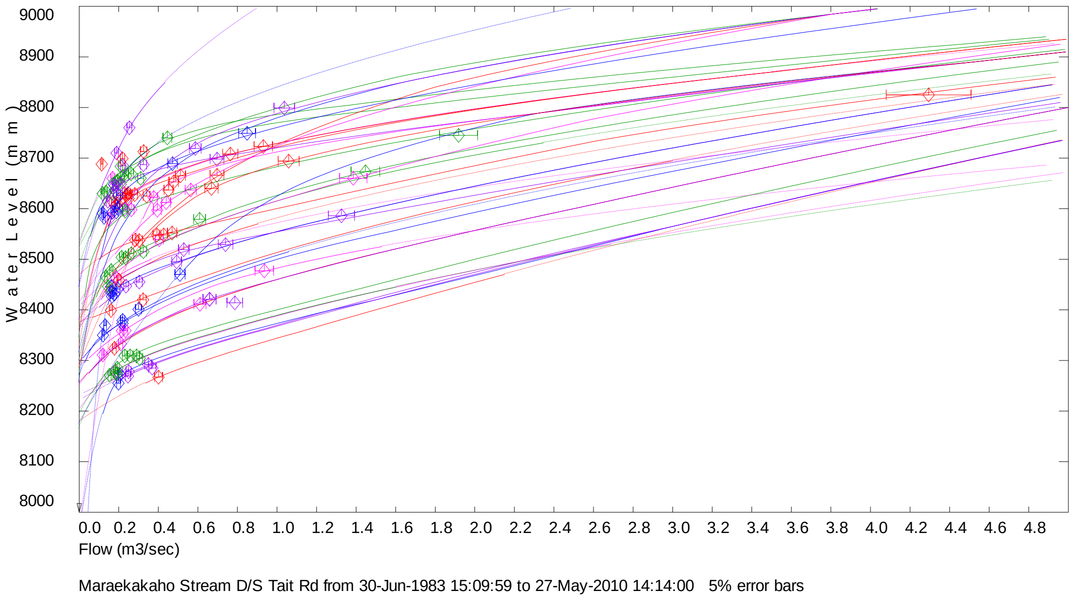

Figure 1: **Low flow gauging and ratings for the Maraekakaho River.**

Obviously the accuracy of the rating curve for predicting low flows depends on the data from which the rating curve was derived. This is directly affected by the number of low flow gauging that define the shape of the rating curve. At low flows relatively small changes in water level can result in large changes in estimated flow.

A review of the gauging data for the Maraekakaho D/S Taits shows that the lowest flow gauged was 88 l/s, and in fact there is only one gauging below 100 l/s. There are 87 gaugings between 100 and 200 l/s. There is also a gauging of 66 l/s at the other flow site measured in January 2005, but the distribution of gaugings at both sites is similar. This would indicate that while there may be some uncertainty associated with the very low flows confidence increases rapidly with increasing flows.

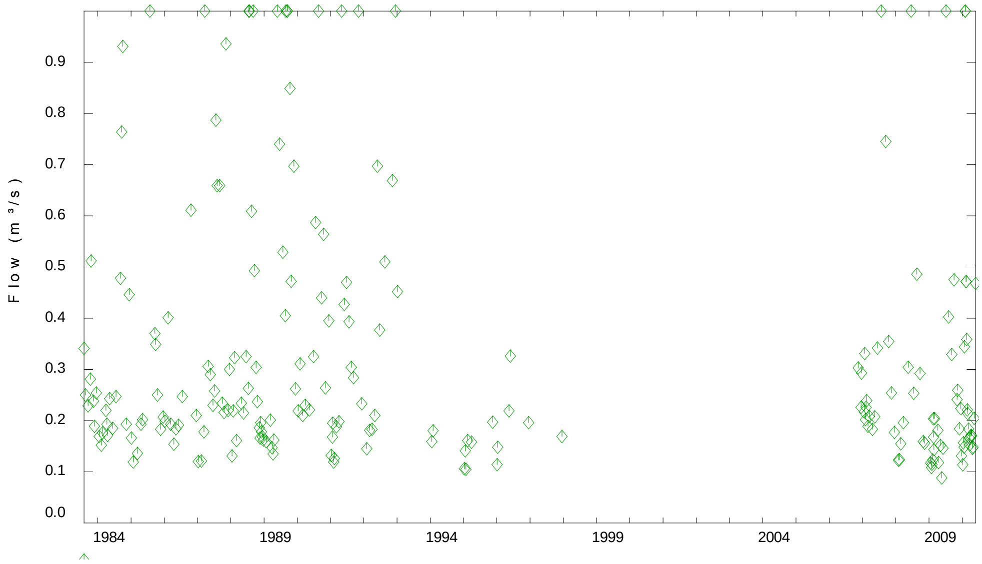

Figure 2: Gauged flows for the Maraekakaho River.

The stability of the cross section and ratings, and the reliability of low flow gauging, can also be assessed with reference to a bedplot, i.e. the difference between the measured and predicted water levels using the rating at each gauging (Figure 3). It is apparent that the ratings at this site are in general very good, and are adjusted appropriately. The variability is usually within ±10 mm. However, there is still a difference between the measured and predicted levels and this will translate to an 'uncertainty' in low flow estimates. This is not surprising given that even using best practice during a stream gauging the measured flow will only be within ±8% of the actual flow. At low flows in shallow gravel-bed channels this error is likely to be significantly higher. This means that there is an uncertainty associated with the low flow estimates based on the rating curves. This error must be recognised when reviewing the results of any statistical analysis, and any derived MALF.

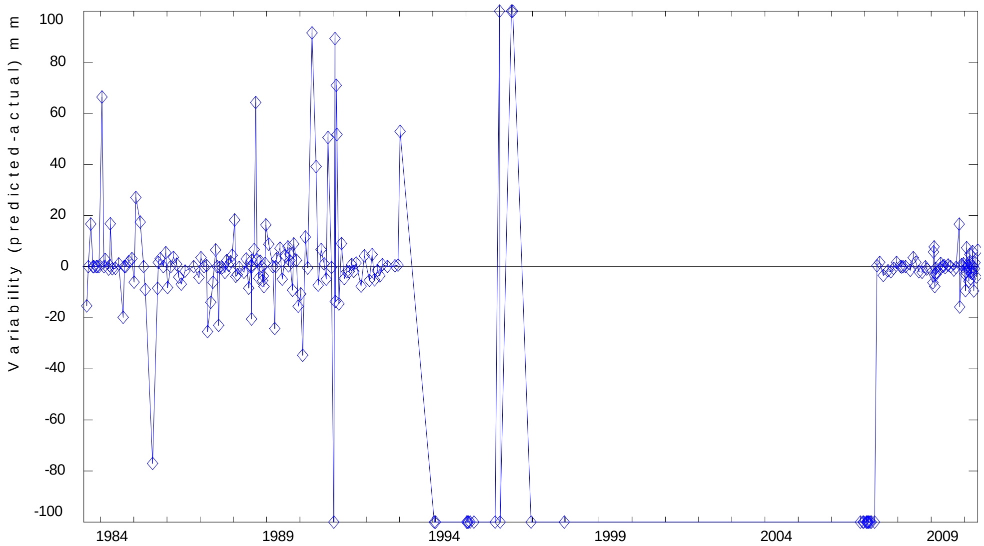

Figure 3: Bedplot for the Maraekakaho River.

Conclusions

It would appear that the flow data for the Maraekakaho is of generally high quality although there is likely to be increased uncertainty regarding the low flow regime. This is typical of the flow records for all small gravel-bed rivers, subject to high flow variability, and with only natural flow control.

These limitations of the flow record must be considered when reviewing the accuracy and reliability of a naturalised flow regime.

Methodology

The methodology adopted by HBRC for to produce a naturalised flow record for the Maraekakaho catchment is summarised below (Table 1). The various steps, and all calculations, were clearly explained and presented in an Excel spreadsheet supplied for review.

Table 1: Methodology used to derive the naturalised flow series.

All consents relevant to the analysis of flow records from 1983-2010 were sourced from HBRC's 'Daisy' database. Daisy records appear to start 1985.

Metered water use data available from 2004 to 2010 were sourced from WaterMeter.hts (HBRC's Hilltop database)

Where only meter reading information stored, volumes were calculated

Volumes were then expressed as Average Daily Usage in l/s

As the volumes are weekly readings, these were imported into Hilltop so that daily data could be exported. These were then added to the daily mean flows

Daily mean flows in l/s were compiled from the combined flows for Maraekakaho

Daily mean flows were exported to Excel and the actual water use from the meter data was added. The total flows were then imported back into Hilltop

Average crop usage assessments were derived from the metered data - monthly (Pcal from Hilltop), percent of allocation was calculated. Average daily use l/s compared to total consented rate l/s to derive percentage of use

Crop types were then averaged. (MWH data were used to validate)

Averages were used to assess usage for periods of early, expired, or without metered data (1983-1993)

The crop averages were applied to the consent abstractions

The calculated l/s were then added to the daily mean flows using date filtering (gaps removed, later put back in once in Hilltop), Daily mean flows in l/s plus usage between 1983-1993 were exported from Hilltop

This data was added to the Hilltop file with all ready calculated 04-2010 actual water usage

Used Psummary to collate MALF's

MALF summary provided of assessed (naturalised) and actual recorded flows

Review comments

I would make the following comments regarding the naturalised flow record, and its derivation:

1. The method used to derive the naturalised flow series appears to be logical and realistic given the constraints of the available water usage data and flow series. The process described in Table 1 has been followed, and all the various calculations appear to have been correctly applied.

2. The daily average flows all appear to have been calculated correctly from midnight to midnight. The use of a 7-day moving average to determine the ALF is the standard approach, as is taking the mean of all the ALFs to determine the MALF. It should be pointed out that in this case the MALF is actually the 7-day MALF. This is the usual MALF index used in New Zealand, although some regional councils (e.g. Horizons) use a 1-day MALF.

3. The present methodology appears to capture the seasonal variability of water usage. Consequently, the difference between the naturalised and actual ALFs varies each year, largely as a function of irrigation demand which is climatically driven (Figure 4).

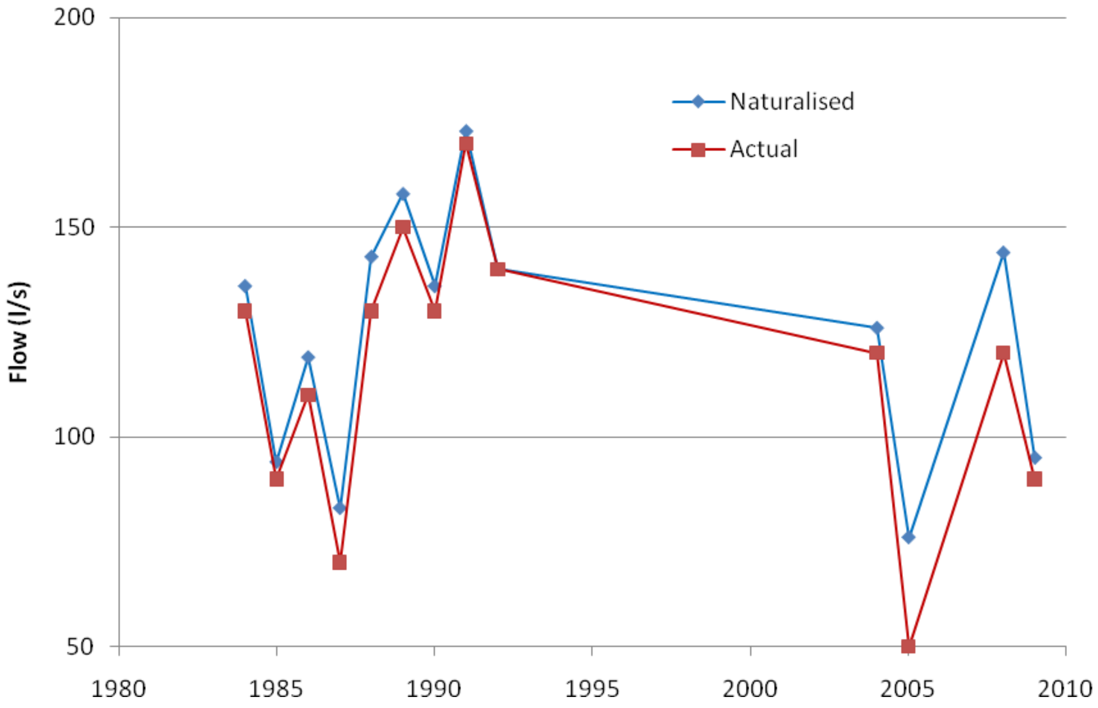

Figure 4: ALFs for each full year of available record from the Maraekakaho River.

4. Usage of water for irrigation purposes increases during drier years. Consequently the difference between the ALF for the naturalised and actual records is greater during dry years than wet years. That is, the naturalised flow record would appear to reflect the expected changes in irrigation demand. The difference between the naturalised and actual flow records over recent years likely reflects increased water usage. This is consistent with the consent information available.

5. Two difficulties with the naturalisation of the flow record, and the determination of an appropriate MALF, are the relatively short hydrometric record and the numerous gaps. The inclusion of only years with almost complete flow records limits the analysis to 13 years; HBRC have used 17 years. The use of 13 years provides a conservative assessment, but it removes the subjectivity of including other years which may or may not contain the lowest seasonal flows. The use of such a short record makes it difficult to determine whether any cyclic behaviour or trends are present in the data, and the degree to which these might affect the derived MALFs.

6. A high degree of variability is displayed over the two periods of flow record. This is problematic when attempting to derive an appropriate MALF for use in water management. Statistical summaries suggest that the two periods are actually quite different, particularly with regard to the low flows. For example, the first period from 1984-92 has a naturalised MALF of 126 l/s (the Median ALF was 136 l/s). From 2004 to 2009 the naturalised MALF was only 110 l/s (the Median ALF was also 110 l/s). The second period of flow data would therefore appear to reflect lower flow conditions, however, this second period is very short with two of the four years being significantly drier than average.

7. There are a number of years where periods of flow data are missing, but it has been assessed by HBRC that the low flow period has still been captured in the record. When these years (i.e. 4 extra years) are included in the analysis the long term MALF reduces to 121 l/s. This lower MALF is likely to better reflect the nature of the flow regime despite the subjectivity involved. This is because it increases the length of record, and includes a number of additional low flow periods. Had lower flows been recorded over the period of missing record, the resulting MALF would have been even lower. It could therefore be argued that a MALF of 121 l/s is still slightly conservative.

8. My concern over this apparent significant difference over the two periods of record is whether it is a function of the accuracy of flow measurement, or climatic variability. If it is caused by climatic variability, this would act as a significant constraint on the usefulness of a single MALF, whether actual or naturalised, derived from the entire period of record. Such an 'average' would mask the actual natural variability of flow. Such a value might also be too high for the past few years, although realistic over the longer term.

9. Climatic oscillations have the potential to bias any runoff record used in analysis. This is not a major issue with long-term records that include a number of both El Niño and La Niña phases. The effects of both phases are apparent in a long record and will therefore be included in the results of any statistical analysis. However, when a runoff record coincides largely with one or other of the phases, the flow record may be biased. The record may reflect either decreased (El Niño) or increased rainfall and consequently runoff (La Niña).

10. Assuming that the flow record is representative of the natural variability of stream flow, and the total range of flow variability has been captured in the record, then the MALF might be an appropriate index. I would, however, direct attention to the high degree of variability in the specific annual low flows (ALFs). Over the actual recorded flows these range from 50-170 l/s, with a mean (MALF) of 115 l/s.

11. Given the variability in ALFs, and the apparent differences between the two periods of record, the naturalised MALF derived from all 13 years of record i.e., 125 l/s (or from 17 years 121 l/s) would provide the most appropriate index. It should be noted that the MALF from 1984-1992 (i.e. 126 l/s) is almost identical to that including the additional years from 2004-2005 and 2008-2009 (i.e. 125 l/s). The reverse is not the case. Consideration of just the four years from 2004-2005 and 2008-2009 would produce a MALF (i.e. 110 l/s) that would be lower than the longer term average.

12. The methodology adopted to naturalise the flow regime is a standard approach. All the various steps appear to have been applied in the appropriate and correct manner. The naturalised flow record derived for the Maraekakaho Stream therefore reflects good practice.

13. Based on the analysis provided, and the 13 years for which almost complete data exists, the actual MALF is 115 l/s while the naturalised MALF is 125 l/s. This is

significantly higher than provided in a previous analysis, but reflects the more appropriate and discriminant use of the actual water usage information.

Validation of the MALF

Although the MALF derived above is based on the instrumental record, adjusted for the effects of water abstraction, it is important that it be validated if possible. There are generally two approaches for establishing a MALF for an ungauged catchment:

1. Correlation of concurrent gaugings with an adjacent gauged catchment, and then translation and scaling of the various flow statistics.

2. Regional low flow modelling based on rainfall and catchment parameters.

Both these approaches are subject to significant errors, up to ±40% in some situations. Therefore the MALF based on the instrumental and abstraction records for the Maraekakaho is likely to be significantly more accurate.

The only way to independently validate the MALF derived in this study is to compare it to that obtained from a regional low flow analysis. Hutchinson (1990) developed a method for estimating specific 7-day mean annual low flows (MALF) for catchments that are ungauged, or have records which are inadequate for reliable flow frequency analysis. New Zealand was divided into 11 regions, and a regression equation for estimating the specific MALF developed. However, Hawkes Bay (including the Maraekakaho) was lumped in to a Central Region that also included all of the Waikato Basin and the Central Plateau. The standard error of prediction for 9 out of 10 catchments was 40% or less for all regions, and less than 30% for nine of the eleven regions. The errors of this approach are therefore likely to be significantly higher than using the instrumental record.

A regional low flow estimation approach was developed further by Pearson (1995). The annual minimum low flow series from nearly 500 catchments were used to investigate the regional patterns and frequency of low flows in New Zealand. Maps of the logarithm of MALF demonstrate broad regional patterns and suggest estimation of this statistic from interpolated contour maps may be worthwhile for many regions. Catchment characteristics (rainfall, soil porosity, vegetation, slope, elevation, hydrogeology) can be used to explain the regional variations. Using the maps provided by Pearson (1995) indicate a specific MALF for the Maraekakaho of approximately 1 l/s/km^2. Assuming a catchment area above the Tait Road gauging site of 97.7 km^2 (i.e., from the Index to hydrological recording sites) would yield a MALF of 98 l/s. This is approximately 20% less than that estimated from the instrumental record. Using the catchment area from the River Environment Classification (REC), i.e. 102 km^2 would yield a MALF of approximately102 l/s.

Additional flow modelling of a range of statistics has subsequently been undertaken by NIWA. These results are now provided as information layers attached to the River Environment Classification. The MALF estimated for the Maraekakaho catchment in the vicinity of the Tait Road gauging station is 95.5 l/s. Again, this is less that determined from the actual instrumental record or the naturalised flow regime.

The above review would suggest that the MALF derived from the naturalised flow is likely to be realistic. While higher than that derived from regional estimation techniques, a MALF of 121 l/s (or 125 l/s) is considered to be more accurate and better reflect the flow regime.

Conclusions

I have reviewed the materials supplied relating to the derivation of a naturalised flow regime for the Maraekakaho Stream, and the MALF of the resulting record. I would conclude that:

1. The methodology used is appropriate given the constraints relating to available data for this catchment.

2. This methodology is a significant improvement over that reviewed previously for this catchment. The current approach ‘captures’ the weekly, seasonal, and annual variability of irrigation demand and consequently the effect of water abstraction and usage on streamflow.

3. The methodology has been applied correctly, and each step appears logical and consistent.

4. The naturalised flow record is likely to realistic of natural flow variability.

5. There is a high degree of annual variability in the 7-day low flows (i.e., ALFs) and this is compounded by the relatively short flow record available for analysis. There are only 13 years with most complete flow information.

6. There appears to be a significant difference between flows during the first part of the combined record (i.e., up to 1992) and that since 2004. This may reflect cyclic flow behaviour as a result of climatic oscillations. The available record is too short to confirm this with any confidence.

7. The most appropriate naturalised MALF to use for water resource management is likely to be that obtained from using the complete flow record. Such a value, however, does not reflect the natural variability in ALFs that can be experienced from year to year.

8. There are a number of years where periods of flow data are missing but it has been assessed by HBRC that the low flow period has still been captured in the record. When these years (i.e., 4 extra years) are included in the analysis the long term MALF is 121l/s. Using only 13 years of record gives a MALF of 125l/s. The lower MALF is likely to better reflect the nature of the flow regime despite the subjectivity involved. This is because it increases the length of record, and includes a number of additional low flow periods. Had lower flows been recorded over the period of missing record the MALF would have been even lower. It could therefore be argued that a MALF of 121l/s is still slightly conservative.

9. A MALF of 121 (or 125l/s if only 13 years are considered) is within the range of flows where the measurement error is likely to be relatively low, and reliability of the ratings high. That is, the value is likely to be reasonably robust, given the high degree of annual variability. It must also be remembered that the accuracy of the gaugings and ratings on which the flow data are based are only accurate to ±8%.

10. Although the MALF determined in this manner is higher than that from regional analyses, these have associated error of up to 40%. They are also likely to be biased by abstraction rates since they are not based on naturalised records. That is, they reflect the actual flow record where flows are lower than would naturally have occurred.

References

Hutchinson, P.D. 1990: Regression estimation of low flow in New Zealand. Publication 22, Hydrology Centre, DSIR, Christchurch.

Pearson, C.P. 1995: Regional frequency analysis of low flows in New Zealand rivers. *Journal of hydrology (NZ) 33*(2): 94-122.

If you have any questions or require any clarification please do not hesitate to give me a call.

Kindest regards

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APPENDIX 3: LANDCOVER OF THE MARAEKAKAHO RIVER CATCHMENT

By looking at the land cover of the catchment an assumption can be made on the level of protection of native vegetation within the catchment. By applying a buffer to the streams we can determine the level of protection for aquatic species. A large buffer of indigenous forest provides excellent habitat for fish and invertebrate species as well as providing a pivotal function of temperature control in turn improving the biochemical conditions of the stream and improving in-stream values.

The Maraekakaho River catchment covers a land area of 12241.28Ha. The catchment is dominated by high producing exotic grassland (93.34%) with small fragments of remnant indigenous forest (0.19%) and broadleaved indigenous hardwoods (1.26%) within the headwaters of the Yarrow and Ettrick waters. A small proportion of afforestation (0.97%), imaged and non- imaged[1], is also present within the catchment (Table 1).

LANDCOVER TYPE	***HECTARES***	***% OF CATCHMENT LAND COVER***
Afforestation (imaged, post LCDB 1)	116.17	0.95
Afforestation (not imaged)	2.22	0.02
Broadleaved Indigenous Hardwoods	154.39	1.26
Deciduous Hardwoods	62.80	0.51
Forest Harvested	25.19	0.21
Gorse and Broom	1.48	0.01
Grey Scrub	14.96	0.12
High Producing Exotic Grassland	11425.95	93.34
Indigenous Forest	23.32	0.19
Lake and Pond	1.63	0.01
Major Shelterbelts	35.12	0.29
Manuka and or Kanuka	55.00	0.45
Mixed Exotic Shrubland	1.54	0.01
Orchard and Other Perennial Crops	27.17	0.22
Other Exotic Forest	47.55	0.39
Pine Forest - Closed Canopy	84.98	0.69
Pine Forest - Open Canopy	101.07	0.83
Short-rotation Cropland	13.29	0.11
Vineyard	47.43	0.39
Grand Total	12241.28	100.00

Table 1: Landcover of the Maraekakaho River catchment

By applying a buffer of 30m around the stream network (REC); the level of protection afforded to the river from surface run off of nutrients and sediments can be determined. This analysis also gives an idea of the level of stream shading from riparian vegetation that may be present. Table 2 shows that there is very little riparian protection on the rivers and streams (1st to 5th order) within the Maraekakaho catchment. The main proportion of riparian land cover is high producing exotic grassland (82.98%). The small fragmented remnants of indigenous hardwoods provide a good level of riparian protection within the Yarrow Stream headwaters. This indicates there is potential for high quality habitat for native galaxiid species in the Yarrow Stream headwaters, providing there are no passage barriers for diadromous species and permanent water in this stream. It is important to note that there has

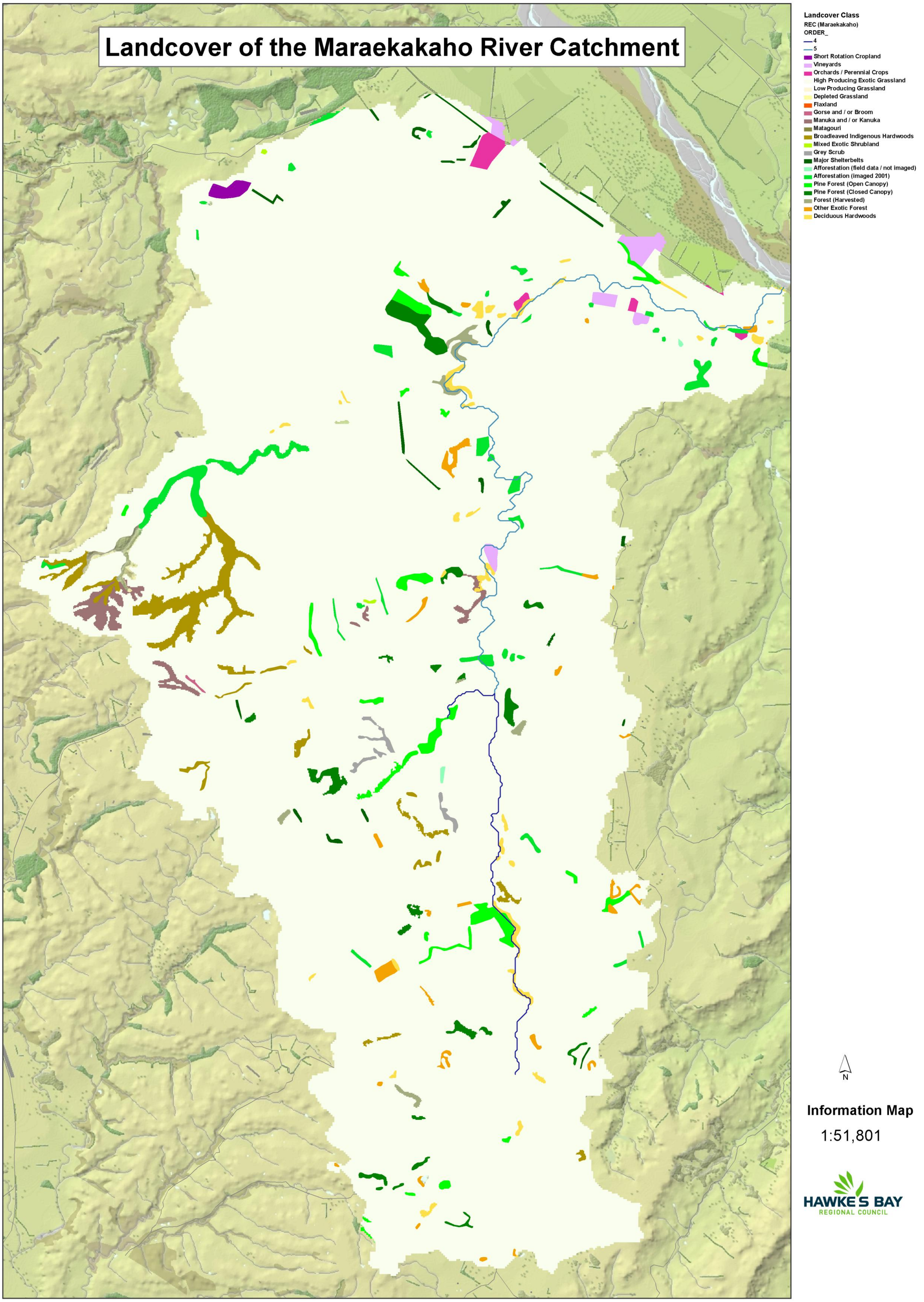
[1] Imaged post LCDB1 relates to landcover classes imaged after LCDB1, non imaged relates to landcover not picked up by the satellite imagery but identified during field truthing excercises.

been some fish surveys of the Yarrow Stream which have found populations of both crans bully and dwarf galaxiid. These species are both non migratory and can form self sustaining populations. The dwarf galaxiid population is under pressure from the land practices within the catchment and distribution has been fragmented within these small pockets of indigenous riparian cover.

LANDCOVER TYPE	***HECTARES***	***% RIPARIAN COVER***
Afforestation (imaged, post LCDB 1)	32.79	2.67
Afforestation (not imaged)	1.45	0.12
Broadleaved Indigenous Hardwoods	47.68	3.89
Deciduous Hardwoods	25.18	2.05
Forest Harvested	9.60	0.78
Gorse and Broom	0.07	0.01
Grey Scrub	6.38	0.52
High Producing Exotic Grassland	1017.26	82.98
Indigenous Forest	8.56	0.70
Lake and Pond	0.06	0.00
Major Shelterbelts	2.95	0.24
Manuka and or Kanuka	8.63	0.70
Mixed Exotic Shrubland	0.18	0.01
Orchard and Other Perennial Crops	3.26	0.27
Other Exotic Forest	5.87	0.48
Pine Forest - Closed Canopy	26.63	2.17
Pine Forest - Open Canopy	25.23	2.06
Vineyard	4.13	0.34
Grand Total	1225.90	100.00

Table 2: Riparian cover of the Maraekakaho River catchment

The following map shows what is known about the landcover of the Maraekakaho River catchment and includes 4^{th} and 5^{th} order river sections. Figure 1 describes the system for determining stream order by the river environments classification (REC) geodatabase.



Landcover of the Maraekakaho River Catchment
Landcover Class
REC (Maraekakaho)
ORDER_
4
5
Short Rotation Cropland
Vineyards
Orchards / Perennial Crops
High Producing Exotic Grassland
Low Producing Grassland
Depleted Grassland
Flaxland
Gorse and / or Broom
Manuka and / or Kanuka
Matagouri
Broadleaved Indigenous Hardwoods
Mixed Exotic Shrubland
Grey Scrub
Major Shelterbelts
Afforestation (field data / not imaged)
Afforestation (imaged 2001)
Pine Forest (Open Canopy)
Pine Forest (Closed Canopy)
Forest (Harvested)
Other Exotic Forest
Deciduous Hardwoods
N
Information Map
1:51,801
HAWKE'S BAY
REGIONAL COUNCIL

By selecting and analysing the riparian vegetation of specific river orders (REC) we can separate and determine the level of protection, or conversely the potential pressures, on smaller streams as well as major rivers within the catchment. This information is displayed in Tables 3 and 4.

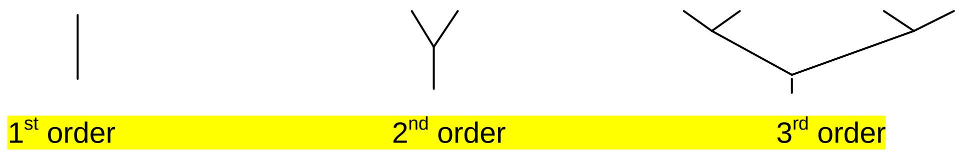


Figure 1: Diagram of the 1st to 3rd order rivers as described in the river environments classification (R.E.C)

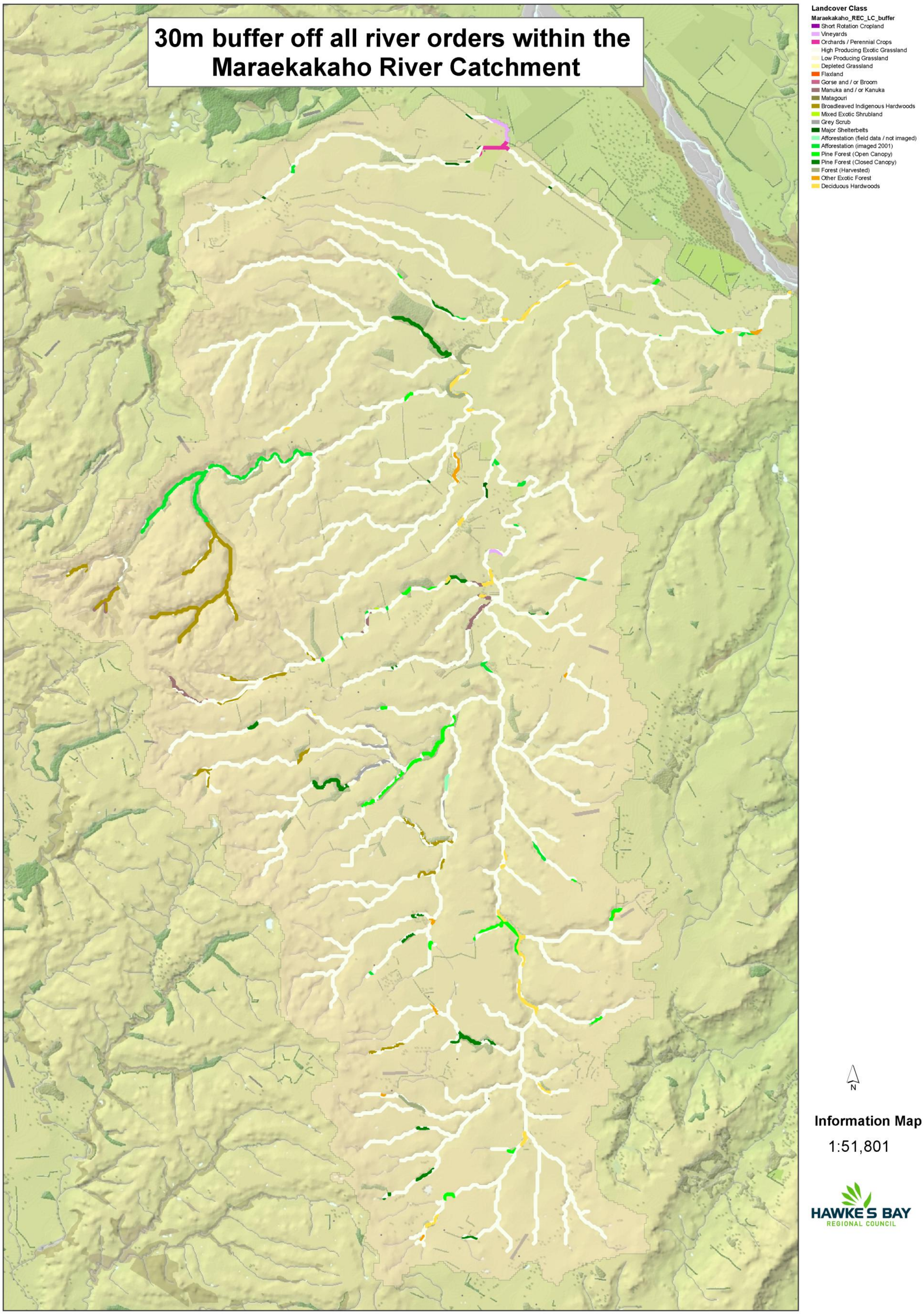
LANDCOVER CLASS	*HECTARES*	*% RIPARIAN COVER (1st-3rd order)*
Afforestation (imaged, post LCDB 1)	28.99	2.67
Afforestation (not imaged)	1.45	0.13
Broadleaved Indigenous Hardwoods	47.68	4.39
Deciduous Hardwoods	11.00	1.01
Forest Harvested	4.96	0.46
Gorse and Broom	0.07	0.01
Grey Scrub	6.38	0.59
High Producing Exotic Grassland	906.53	83.38
Indigenous Forest	8.56	0.79
Lake and Pond	0.06	0.01
Major Shelterbelts	2.95	0.27
Manuka and or Kanuka	8.45	0.78
Mixed Exotic Shrubland	0.18	0.02
Orchard and Other Perennial Crops	3.26	0.30
Other Exotic Forest	4.90	0.45
Pine Forest - Closed Canopy	26.63	2.45
Pine Forest - Open Canopy	22.19	2.04
Vineyard	2.98	0.27
Grand Total	1087.22	100.00

Table 3: Riparian cover for 1st to 3rd order streams within the Maraekakaho river catchment

LANDCOVER CLASS	*HECTARES*	*% RIPARIAN COVER (4th & 5th order)*
Afforestation (imaged, post LCDB 1)	4.16	2.78
Deciduous Hardwoods	15.31	10.21
Forest Harvested	5.32	3.55
High Producing Exotic Grassland	119.30	79.60
Manuka and or Kanuka	0.26	0.17
Other Exotic Forest	0.98	0.65
Pine Forest - Open Canopy	3.40	2.27
Vineyard	1.15	0.77
Grand Total	149.87	100.00

Table 4: Riparian cover of the 4th and 5th order stream sections within the Maraekakaho River catchment

Riparian cover present on all rivers and streams within the Maraekakaho River catchment



APPENDIX 4: THE SCIENCE BEHIND SETTING ECOLOGICAL FLOWS

An integral component of managing surface water resources is determining the flows needed to sustain instream values. Defining “ecological flows” often forms the foundation for environmental flow management investigations.

Matters in Part II of the RMA that relate directly to ecological values are:

- Section 5(2)(b): The life-supporting capacity of water and ecosystems
- Section 6(c): Significant habitats of fauna
- Section 7(d): Intrinsic values of ecosystem
- Section 7(f): Maintenance and enhancement of the quality of the environment
- Section 7(h): The protection of the habitat of trout and salmon.

An ecological flow, or water level, is defined as “the flow and water level required to provide for the ecological integrity of the vegetation and fauna present within the waterbody and its margin” (Ministry for the Environment National Environment Standard “Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels”, 2008).

The ecological function of a water body must always be provided for when setting environmental flow management objectives. Other factors that may be taken into account in environmental flow management to meet community expectations are tangata whenua, cultural, recreational and landscape values.

In defining ecological flows for a water body, there is a requirement for robust scientific methodology that assesses the ‘needs of freshwater ecosystems’ over a range of flow and seasonal conditions.

An important aspect of ecological flows is that they quantify the amount of water available for allocation and also address requirements for both high and low flows/water levels throughout the year. The amount of water that can be allocated (allocation limit), and the manner in which it is used or regulated, determines the degree of hydrological alteration (the degree to which the natural hydrological regime could be potentially modified) and in turn will determine the technical methods to be used.

Minimum flows support protection for the ecological values of rivers and streams. The purpose of an allocation limit is to limit the impact of abstraction on these ecological values. Without an allocation limit the potential exists for the flow to be at or near the minimum flow for extended periods of time. This results in ‘flat lining’ and reduces the natural flow variability essential for ecological health and function.

Setting a minimum flow and allocation limit together ensures a reasonable amount of water is allocated to users while maintaining the required ecological function of the river or stream.

A range of different methods and techniques have been used by regional councils for determining flow requirements for river systems, and there has been little consistency between councils.

Ministry for the Environment (MfE) have published two key documents to aid in establishing flows needed to sustain ecological values:

- Flow Guidelines for Instream Values (1998)
- Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Level (2008)

Both documents bring together and summarise all scientific methods appropriate for New Zealand surface waters to determine ecological flows and provide a decision-making framework to select an appropriate method.

The first step in the process is to identify and assess the significance of ecological values such as species and habitats. This is commonly called the “instream management objective”.

A decision must be made regarding which ecological values are to be sustained; maintaining the status quo (provides all existing ecological values with existing levels of protection) or protecting targeted biota (reduce flow conditions for a specific targeted ecological value).

The flow regime that supports the ecological values that are to be sustained needs to be determined:

- Minimum flows - for water quality and habitat
- Flow duration and magnitude
- Flow variability – frequency of low flows, frequency of freshes
- Seasonal requirements

The critical parameters to sustain ecological values are the minimum flow as well as flow variability.

Flow variability needs to be considered to assess the effect of increases in duration and frequency of low flows. Also the frequency and magnitude of freshes needs to be considered as freshes are essential to the "flushing" of river systems.

The minimum flow is often the most important part of assessing flow regime requirements for ecological values. Minimum flows can be an ecological "bottleneck" and can strongly influence the nature of the ecological values in a river.

Water quality needs to be considered when water temperature may increase due to reduction in flow, point source discharges, or non-point source discharges, which influence the ecological functioning of the river. Minimum flows can be set to achieve certain water quality standards given adequate information to model hydraulic conditions of the stream and resulting levels of dissolved oxygen and temperature.

Habitat is usually the critical aspect to consider when developing flow regime requirements. Changes to a river's natural flow regime have the potential to negatively impact habitat and population structures of instream fauna by reducing habitat diversity.

Commonly used technical methods for setting flow regimes include:

- Historic flow methods
- Hydraulic methods
- Physical habitat modelling (e.g. RHYHABSIM)
- Water quality modelling
- Regional methods

Historic methods are based on flow records and are the easiest to apply. They are generally desktop rules-of-thumbs based in a proportion of a flow statistic to specify a minimum flow, e.g. abstraction ceased when natural flows fall below 80% of the MALF.

Physical habitat models predict how the waterbody changes incrementally with flow changes and are most suited to evaluating effects of changes to the natural flow regime. They can be used to assess the available instream habitat for a targeted ecological species at different minimum flows, assuming that an ecological community can be sustained provided there is sufficient habitat. Minimum flows are therefore specified by available habitat for targeted species. RHYHABSIM is a physical habitat modelling program that has been commonly used throughout New Zealand.

Water quality modelling estimates the likely impacts of change to flow regimes on parameters such as water temperatures and dissolved oxygen.

Regional methods are an extension of the other methods and aim to set minimum flows for several rivers in a region based on predetermined levels of habitat availability or water quality criteria.

The decision as to which method to use to assess the ecological flow requirements of a river or stream depends on:

- The values to be managed (e.g. native fish, invertebrates) and critical factors affecting those values (such as spawning habitat, food habitat, cover, water quality etc). Gauging the significance of these values requires stakeholder input (e.g. Iwi, DOC, Fish and Game, interested public).
- The degree to which abstraction will affect components of the hydrological regimes such as the duration of low flows, and the magnitude and frequency of higher flows or freshes.

The Ministry for the Environment (MfE) has published a draft National Environment Standard (NES) "Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels". Table 1, sourced from the draft NES, details the decision-making framework to select a methodology appropriate to the significance of instream values and the potential for hydrological alteration.

While the NES is only proposed much of the science collated within the supporting document represents the most up to date evidence on ecological flow setting currently available in New Zealand.

Table 1 Methods used in the assessment of ecological flow requirements

Degree of hydrological alteration	Significance of instream values		
	Low	Medium	High
Low	Historical flow method Expert panel	Historical flow method Expert panel	Generalised habitat models 1D hydraulic habitat model Connectivity/fish passage Flow duration analysis
Medium	Historical flow method Expert panel Generalised habitat models	Generalised habitat models 1D hydraulic habitat model Connectivity/fish passage	1D hydraulic habitat model 2D hydraulic habitat model Dissolved oxygen model Temperature models Suspended sediment Fish bioenergetics model Groundwater model Seston flux Connectivity/fish passage Flow variability analysis
High	Generalised habitat models 1D Hydraulic habitat model Connectivity/fish passage Periphyton biomass model	Entrainment model 1D Hydraulic habitat model 2D Hydraulic habitat model Bank stability Dissolved oxygen model Temperature models Suspended sediment Fish bioenergetics model Inundation modelling Groundwater model Seston flux Connectivity/fish passage Periphyton biomass model	Entrainment model 1D Hydraulic habitat model 2D Hydraulic habitat model Bank stability Dissolved oxygen model Temperature models Suspended sediment Fish bioenergetics model Inundation modelling Groundwater model Seston flux Connectivity/fish passage Periphyton biomass model Flow variabiity analysis

One or more of the methods listed within each cell of the Table should be used to assess ecological flow requirements for the given combination of degrees of hydrological alteration and significance of instream values. In situations with high instream values, two or more methods from each cell should be used, because the risks to stream ecology of making an incorrect ecological flow decision are greater.

A number of differing methods have been applied to New Zealand waterbodies to decide on appropriate ecological flows, minimum flows and allocation limits.

Defining an ecological flow involves determining the significance of ecological values within the waterbody and then deciding which ecological values are to be sustained.

The two MfE documents “Flow Guidelines for Instream Values” and “Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels” detail the appropriate scientific methods to determine the flow regime that will sustain the ecological values.

While scientific evidence is essential for deciding an ecological flow within a waterway, the RMA also requires a balancing of this scientific information with social, economic and cultural evidence. Hence, while the RMA requires ‘environmental bottom lines’ are protected, it is acknowledged that ‘optimal’ protection of instream values can often not be achieved when social and economic considerations are taken into account.