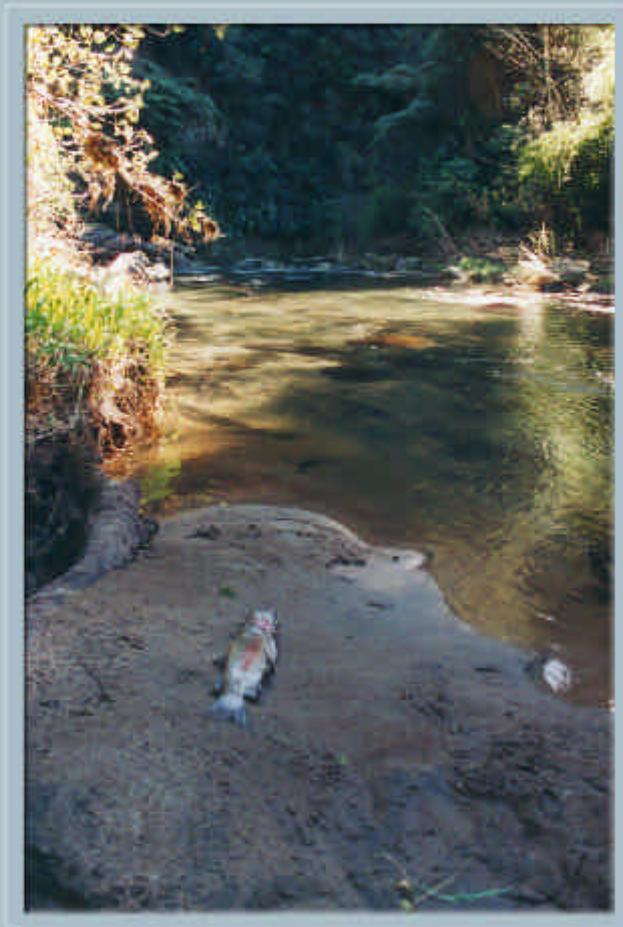


Instream Flow Requirements and Water Takes in the Bay of Plenty - A Discussion Document



Prepared by T K Wilding, Environmental Scientist

Environment B O P
Quay Street
P O Box 364
Whakatane
NEW ZEALAND

ISSN 1172 - 5850

Acknowledgements

Thanks to John McIntosh, Janine Barber, Mark Strinfellow, Ruth Feist, Stephen Park, Sean Hodges and Igor Drecki for their advice and assistance in producing this report.

I would also like to thank Kevin Collier and Ruth Berry for providing reference material.

Executive Summary

1.1 Introduction

There are difficulties in justifying the minimum flows that are presently derived using a ‘rule-of-thumb’ approach. Uncertainty surrounds the impact of this approach on aquatic ecosystems and the adequate provision of resources where demand is high. This project addresses instream ecological issues associated with surface water abstractions for irrigation, water supply and other out of stream uses. This is the first report produced and amounts to a literature review of the effects of abstraction and methods available for setting instream flow requirements.

The ecological effects of flow reduction are reviewed. Reduced water velocities can allow the accumulation of sediment and algae. Water takes reduce the dilution of downstream discharges and as a result, contaminants such as ammonia will have a greater impact. Oxygen concentration can drop as re-aeration is reduced and plant respiration increases.

The amount of suitable habitat for fish and invertebrates depends largely on depth and velocity as well as the area of wetted substrate. These factors are limited by the stream flow. Most often habitat is reduced with flow. It can be improved where natural velocities and depths are too great. Access to bank habitat, such as overhanging vegetation will depend on the maintenance of water levels.

Water temperature is increased by a reduction in water depth, potentially to levels that are intolerable for many stream inhabitants. Abstraction structures and insufficient flow may restrict fish passage.

1.2 Methods for Flow Determination and Case Studies

Methods available to establish the flow requirements of ecosystems are reviewed in an effort to identify those most appropriate for this study. Past application of these methods in New Zealand is reviewed.

The Ministry for the Environment has produced guidelines for assessing instream flow requirements and a summary of these guidelines is presented.

1.3 Recommended Options

Five options for determining flow requirements of stream ecosystems are presented and discussed. The recommended option is to adopt the “WAIORA” decision support system recently developed by NIWA and the Auckland Regional Council. The Waiora package predicts flow related changes in ammonia, temperature, habitat and oxygen. Further development and calibration of the Waiora methods is necessary before it can justifiably be applied to Bay of Plenty streams.

Contents

Executive Summary	i
1.1 Introduction.....	i
1.2 Methods for Flow Determination and Case Studies.....	i
1.3 Recommended Options	i
Chapter 1: Introduction	1
1.1 Background	1
1.2 Scope.....	1
1.3 Context	1
1.4 Environmental Effects of Flow Reduction.....	2
1.4.1 <i>Physical Effects</i>	2
1.4.2 <i>Ecological Effects</i>	3
Chapter 2: Methods for Flow Determination	5
2.1 Historic Flow Methods.....	5
2.2 Wetted Perimeter Method.....	5
2.3 Instream Flow Incremental Methodology (IFIM).....	6
2.4 Water Quality and Temperature	7
2.5 Effects Based Investigation	7
2.6 WAIORA (Water Allocation Impacts On River Attributes).....	7
Chapter 3: Flow Determination in New Zealand	11
3.1 Individual Catchment Studies	11
3.2 Regional Methods.....	12
Chapter 4: MfE Flow Guidelines for Instream Values	15

4.1	Purpose.....	15
4.2	MfE Guidelines	15
4.3	Limitations of the Guidelines.....	18
4.4	How useful are the guidelines?	19

Chapter 5: Recommendations for Setting Instream Flow Requirements for Bay of Plenty Streams..... 21

5.1	Options	21
5.2	Recommended Option: Regional Flow Modelling.....	22

References 25

Chapter 1: Introduction

1.1 Background

There are presently more than 300 approved surface water takes in the Bay of Plenty. Most are concentrated in the Western Bay (Figure 1). A total of 10 resource consent applications to abstract surface water were received in the last financial year. There are difficulties in justifying the minimum flows that are presently derived using a ‘rule-of-thumb’ approach. Uncertainty surrounds the impact of this approach on aquatic ecosystems and the adequate provision of resources where demand is high.

1.2 Scope

The effects of abstraction on aquatic ecosystems are reviewed. Methods available for determining instream flow requirements are presented along with examples of their use in New Zealand. This information is used to determine what are the most appropriate methods for determining instream flow requirements for the Bay of Plenty Region.

This is the first report produced towards a project aimed at providing the consents department with instream flow requirements based on ecological values. Other matters, including cultural, recreational and landscape values are outside the scope of this report, yet a framework for considering such issues on a case by case basis is presented. Recommendations are given for the best approach for establishing flow requirements, to be carried out in the next stage of this project.

1.3 Context

This project has been set up to address instream ecological issues associated with surface water abstractions for irrigation, water supply and other out of stream uses. While many reviews have focused on regulated waters where the construction of dams affects the entire flow regime (Kemper and Craig, 1987), the focus here is on abstractions only. Abstractions are expected to reduce the base flow especially during summer months. There is expected to be little effect on the magnitude or frequency of storm flows, which more typically results from damming of watercourses.

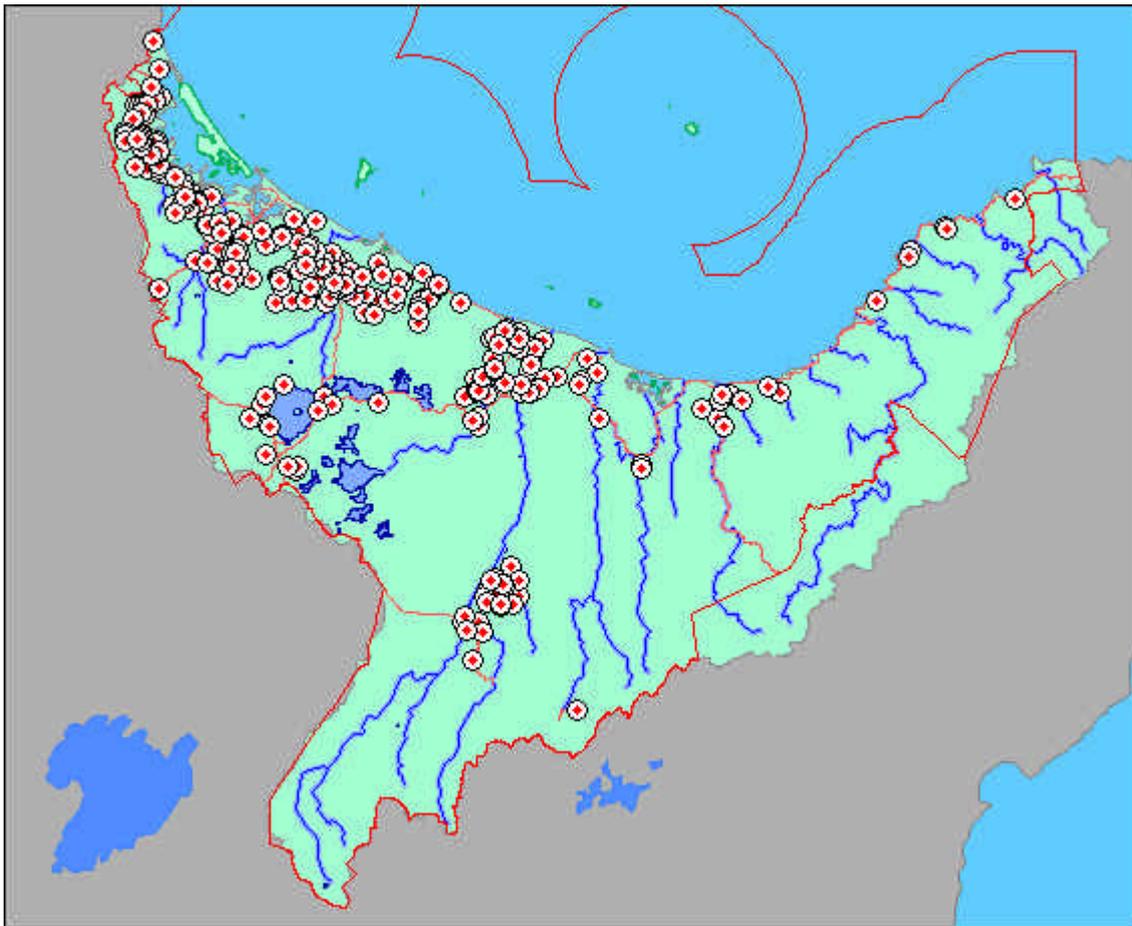


Figure 1 Resource consents within the Bay of Plenty Region for surface water abstraction (at 4 June 1998).

1.4 Environmental Effects of Flow Reduction

1.4.1 Physical Effects

Abstraction can affect the flow regime of a stream by reducing base flows, altering the timing of low flows and creating short term fluctuations in flow (Ward and Stanford 1987). Taking water for domestic water supplies and irrigation systems will extend the duration of low flow conditions. Short-term fluctuations in flow can result from taking water for irrigation at night-time only or daily fluctuations in water supply requirements.

Low water velocities can reduce scouring and as a result siltation can increase, smothering habitat (Jowett and Biggs 1997). Accumulation of sediment, combined with reduced flow can ultimately constrain the wetted channel and allow riparian vegetation or emergent vegetation to encroach further onto the streambed (MfE 1998b).

Shallow, slow flowing streams will reach higher temperatures and without sheltering vegetation can reach levels stressful to stream life (Wilcock et al. 1998).

Dilution of point discharges downstream of the abstraction, such as from dairy shed effluent, is reduced if stream flow is reduced (Collier 1993a). The resultant increased concentration of pollutants, (e.g. ammonia), may be harmful to aquatic life. Reduced velocities, increased temperatures and decreased dilution of pollutants can act together to significantly reduce oxygen levels (McBride and Nagels 1994).

1.4.2 Ecological Effects

Growth of aquatic weed and algae is often limited by sloughing and scouring in fast flowing streams (Jowett and Biggs 1997). Reduced low flows of extended duration can allow algae and aquatic weed growth to reach nuisance levels (Clausen and Biggs 1997). When these plants reach a large biomass, the shift from daytime photosynthesis to nighttime respiration can produce wide fluctuations in dissolved oxygen and pH (McBride and Nagels 1994). Higher pH increases the dissociation of ammonium to ammonia, increasing the toxicity to stream life.

The combined effect of nuisance algae and increased siltation as a result of reduced flow could smother benthic habitat. But this will only occur where flow has been reduced below the critical velocity necessary to scour algae and silt (MfE 1998a).

Reduced flows are likely to reduce the area of wetted streambed with a corresponding reduction in available habitat for fish and macroinvertebrates. Less flow also means reduced water velocities and depth. Both are important determinants of fish, invertebrate and plant life communities (Clausen and Biggs 1997). Short-term fluctuations in flow may occur too quickly for invertebrates or fish to avoid being left high and dry. The sudden drop in water level (drawdown) can also promote invertebrate drift (Collier 1993a). (Invertebrate drift describes invertebrates breaking free of the substrate to be carried down stream).

Overhanging banks and vegetation provide places necessary for fishes to live and hide (Hicks and Barrier 1996). These areas will not be available if the water level is excessively reduced. Aquatic weeds may be ideal habitat for some species or smother suitable habitat for others. Where water velocities are sufficiently high to limit the growth of macrophytes, abstractions will allow their spread. In shallower streams, reduced flow may leave weed beds exposed.

As discussed earlier, reduced flows can affect water quality. Macroinvertebrates and fish have limited tolerance of increased water temperatures and reduced water quality (Richardson 1997, Hickey and Vickers 1994, Dean and Richardson 1999, Quinn et al. 1994). In addition, more stable flows or extended low flow conditions will allow some species to proliferate, particularly those that benefit from increased algal biomass (Quinn and Hickey 1990).

Abstraction structures such as weirs can act as barriers to fish migration, limiting access of species such as inanga to suitable habitat. Fish may be drawn into pump intakes if screens are inadequate or velocities too high (Mitchell and Williamson 1995). Fish passage can also be restricted when shallow reaches dry up or river mouth closure occurs.

In some instances reduced flow can actually improve habitat suitability. Water depths and velocities exceed habitat preferences for many species in deep, fast flowing rivers.

Chapter 2: Methods for Flow Determination

Historically a wide range of methods have been used for allocating water resources. Choosing a method most appropriate for use in the Bay of Plenty necessitates a review of those in common use, in particular their benefits and limitations.

2.1 Historic Flow Methods

One of the most widely used methods for setting minimum flows is the Tennant method and its derivations (Jowett 1996a). This method is based on a study of 11 streams in Montana. Tennant found that 10% of the mean flow provided for the short-term survival of aquatic life, 30% provided satisfactory habitat for a baseflow regime and greater than 60% provided optimum flows for most forms of aquatic life (Jowett 1996a). The Tennant method can be used to generate valid instream flow recommendations where competition for water is minimal (Estes and Osborn 1986). However, these authors recommend that the percentages of mean flow recommended by Tennant should not be taken as having universal application. Other workers have found the remaining flow necessary to support stream life varies depending on what species are present and existing habitat conditions, including the size of the stream (Jowett 1993a, 1993b).

Where as the Tennant method is based originally on habitat measurements, other historic flow methods rely on the assumption that stream flows within the historic flow range will provide for stream animals because they have survived these conditions in the past. This might prescribe, for example, the 7-day, one in ten-year low flow (Q7-10). Such methods have been likened to prescribing a person's all-time worst health condition, as a recommended level for a portion of his future well being (Tennant 1976, cited in Jowett 1996a). How long these low flow conditions persist naturally is not taken into consideration. Advantages of such methods over more complex habitat methods include retaining the natural character of larger rivers and minimum flows are easily established.

2.2 Wetted Perimeter Method

Picture a stream with a reasonably flat bed and steep banks. Intuitively there will be little reduction in habitat with flow, at least until the streambed becomes exposed, after which point habitat is lost more rapidly. The flow at which this occurs is referred to as the inflexion point. Prescribing the minimum flow based on this point of inflexion is termed wetted perimeter method. Streams with more V shaped channels are not likely to show this point of inflexion.

The wetted perimeter method assumes the majority of habitat will be retained if the streambed is kept wet. This fails to consider the importance of water velocity and depth to most aquatic species and assumes that bank habitat, such as overhanging vegetation and emergent macrophytes, is not important. This may not be the case for many Bay of Plenty streams where the streambed is sand or pumice. Here many fish and macroinvertebrates depend largely on the stable substrate associated with bank vegetation and snags.

Orth and Maughan (1982) achieved similar flow recommendations from the wetted perimeter method as for IFIM. However, a study of Northland streams recommended against using the wetted perimeter method, as points of inflexion could not be identified (Collier 1993c).

2.3 Instream Flow Incremental Methodology (IFIM)

The aim of this method is to describe how instream habitat changes with flow. The method assumes instream habitat can be adequately described in terms of depth, substrate and velocity. IFIM is probably the most difficult and time consuming to implement but is the only method that actually measures habitat.

Scott and Shirvell (1985) reviewed this method and its use in New Zealand. This paper highlighted the fact that IFIM was intended to include water quality and temperature modelling, while only the habitat component (PHABSIM) is used in New Zealand (Note: more recent models incorporate temperature). IFIM also fails to consider the importance of instream cover. Reportedly, in 74% of evaluations there was no relationship found between Weighted Usable Area and standing crop of trout (weighted usable area is the area of suitable habitat as measured by IFIM).

Other limitations of the method are presented in the MfE flow guidelines (MfE 1998a). The model will not work well in very turbulent streams. Current meters are often too large for use in small streams. There is debate over the validity of native fish preference curves and it is suggested that these be used with caution.

Advantages of the method include the ability to evaluate flows for specific target species, such as brown trout, banded kokopu, invertebrates, etc. It is also the only method that recognises the 'natural' flow in a stream is not necessarily optimal for the target species. This has the potential to allow a greater proportion of water to be abstracted.

It is also the only method that recognises the percentage flow allocation will vary with stream size. For small streams under low flow conditions, the remnant flow is far more critical to stream life than in larger rivers. Many reviews have failed to consider this because, in the past only larger rivers have been evaluated, reflecting the importance of such rivers to communities rather than the scale of ecological vulnerability to abstraction. It also reflects the need for historical flow data, which is generally only available for larger streams and rivers.

2.4 Water Quality and Temperature

NIWA investigated the effects of flow reduction on water quality in developing a low flow allocation policy for Northland streams. This involved determining the dilution of dairy shed effluent necessary to meet water quality criteria (Collier 1993b). Dissolved oxygen was also modelled using daily minimum dissolved oxygen criteria. It was found that one in five year low flows provided sufficient oxygen concentrations for Northland streams (McBride and Nagels 1994).

In the Auckland region, a water supply dam on the Mangatangi Stream produces a residual-flow equivalent to the 1:20 year low flow. Daytime temperatures in the stream were found to exceed 26°C during summer. Habitat, dissolved oxygen and temperature were investigated to see how these changed with flow (McBride *et al.* 1994). Using mathematical modelling, the effects of increased water temperature were found to be restricting biological communities more so than dissolved oxygen and habitat. In order to reduce daytime temperatures, planting of riparian vegetation was advocated as a means of minimising the effects of the water take.

2.5 Effects Based Investigation

Many streams in the Bay of Plenty are already subject to approved abstractions. The opportunity therefore exists to determine suitable flow regimes based on the observed effects of different levels of abstraction. This has the potential to integrate all of the effects of reduced flow including increased water temperature, nuisance algae, water quality and reduced habitat.

The main problem lies with measuring this effect. The level of impact may require intensive sampling to provide adequate detection limits. There is a lack of defensible and rigorous sampling methods available for quantifying effects on communities inhabiting fine substrate and aquatic weed. However, the methods described in previous sections are of equally debatable relevance to such habitat. Measuring the spatial extent of any impact is important given the likely contraction of habitat area and may require the use of wetted perimeter methods or alike. Factoring out the effects of land use will be difficult. Such an approach is dependent on the occurrence of low flow conditions of sufficient duration. In Northland significant effects on macroinvertebrates were only observed after 2 months of stable low flows (Collier 1994a). Although theoretically the simplest and most defensible approach, in practice it may be difficult to get a meaningful result.

2.6 WAIORA (Water Allocation Impacts On River Attributes)

Waiora is a decision support system designed to provide guidance on whether a proposed low flow could have adverse impacts on instream ecological values (Kingsland and Collier 1997, McBride *et al.* 1998). It has been developed by NIWA for the Auckland Regional Council. The name WAIORA is an acronym for Water Allocation Impacts On River Attributes. It is also the Maori word to describe water that is sacred and fit for human consumption.

This is a computer-modelling package for quantifying changes with flow of dissolved oxygen, total ammonia, water temperature and habitat. Waiora uses simplified numerical models with the intention of predicting relative amounts of change associated with flow scenarios rather than

predicting absolute changes. The main advantage of this approach is to simplify data collection and analysis over conventional modelling techniques, e.g. IFIM - Rhyhabsim. The basic layout is a Windows package.

Waiora is still in prototype form undergoing testing by several independent organisations. A final version is due to be made available to all regional councils by July 1999. The following is a summary of the modelling components of Waiora taken from draft reports.

Stream Width, Velocity and Depth – Habitat

Ian Jowett, who developed the Rhyhabsim model on which this is based, developed the simplified model for Waiora. For Rhyhabsim velocity, depth and width are measured at a multitude of sites to represent riffle, run and pool habitat. The change in total suitable habitat with flow can then be modelled. Ian Jowett demonstrates in the technical report that measuring habitat in runs alone provides a good estimate of the change in habitat in all three habitats (McBride *et al.* 1998).

The results of Rhyhabsim are interpreted in terms of changes in weighted usable area (suitable habitat) with flow. This requires the input of species preference curves. From what I can gather, Waiora makes no estimate of weighted usable area. Instead guidelines are used; for example, the flow should not decrease velocity below 0.3m/s. These guidelines can however be based on species preference curves.

Temperature Modelling

The simpler Edinger equation has been used in place of the more “cumberson” STREAMLINE model. Kit Rutherford compares the two models in the technical report (McBride *et al.* 1998). From the user manual, the inputs appear to include daily air temperature, solar radiation and stream shading (Kingsland and Collier 1997). I gather stream depth also factors into the equation. In conversation with Kevin Collier, it was recommended data loggers be used to validate the model for the intended area of application.

Oxygen Modelling

This model has been developed by Graham McBride (McBride *et al.* 1998), and is based on the model of Chapra and Di Toro (1991). Three basic processes explain the stream dissolved oxygen patterns: natural physical re-aeration, plant photosynthesis and plant/bacterial respiration. Data inputs include the daily average stream temperature (presumably derived from the temperature modelling), stream depth and velocity (from the habitat modelling), respiration and photosynthesis rates (McBride *et al.* 1998). The latter two figures can be estimated based on stream type or calculated from datasonde information.

Total Ammonia Concentrations

Also developed by Graham McBride, this model calculates the reduced dilution of point discharges associated with abstractions (McBride et al. 1998). Obviously it helps to know what point discharges occur below an abstraction and stream ammonia concentrations prior to the point of abstraction. Instream ammonia decay is allowed for and pH is measured to determine dissociation of the toxic form, (NH₄ to NH₃).

How useful is Waiora?

This package caters specifically for the needs of water managers and would prove most useful in helping Environment B·O·P fulfil its functions. It is probably the most comprehensive decision support system produced to date that targets water abstraction. Having said that, Waiora is intended as a first cut approach only. Simplified models have been used presumably in an effort to minimise the cost of data collection and analysis. In conjunction with the Auckland Regional Council, NIWA are hoping to go through the process of validating the models and tailoring them specifically to Auckland conditions.

Chapter 3: Flow Determination in New Zealand

3.1 Individual Catchment Studies

Scott and Shirvell (1985) reviewed methods used for determining minimum flows in New Zealand. The following case studies are taken from this paper.

For the Tongariro River (Taupo) a minimum flow was agreed upon which approximated the summer baseflow conditions. It was assumed this flow would provide for juvenile and adult trout.

The Opihi River is a typical example of the drought prone Canterbury Plains where abstraction requirements are high. An irrigation scheme developed in 1936 saw the stream dry up during low flow periods. Concern from anglers saw a flow-sharing scheme introduced. Zero flows were still possible, however a one in seven day nil abstraction was enforced. Flow allocation has since been reviewed again as the fishery continued to decline.

A proposal to divert 47% of the low flow from Deep Stream (Otago) for hydroelectricity production and water supply was challenged by fisheries interests. A compromise of 37% was agreed to.

An irrigation scheme planned for the Taieri River set a minimum flow of 10% of the mean annual discharge with no consideration of fisheries values. This has since been reviewed.

Scott and Shirvell (1985) present 12 cases where IFIM has been used in developing minimum flows. For the Rakaia River it was concluded that significant flow reductions would have no affect on the fisheries based on IFIM studies. Habitat requirements of juvenile trout were apparently not addressed by the IFIM approach (more recent IFIM models include juvenile trout flow preferences). In the end, flows required for angler access and fish-ability were used to determine the minimum flow set for the Rakaia.

There have been significant developments in the determination of flow requirements since the 1985 review by Scott and Shirvell. With the introduction of the Resource Management Act (1991), the need to consider environmental effects of reduced flow on all streams is becoming more widely recognised. Also, IFIM has been extended to include the habitat requirements of several native fish and macroinvertebrate species.

Recommendations for the minimum flow of the Kakanui River, North Otago, were developed using the IFIM approach (Jowett 1994). The river was first electro-fished to identify target

species. Each species was found to have individual flow preferences. Fast water fishes, such as blue gilled bully and torrent fish, were found to prefer higher flows. Habitat suitable for longfin and shortfin eels, upland bully, common river galaxias and redfin bully showed little variation with flow. Common bully preferred flow conditions close to the existing low flow. The minimum flow recommended by the report was equivalent to the preferred flow of common bully, which was considered to maintain acceptable habitat for native fish. In cases such as this a trade-off is necessary given the variability in flow preferences between species.

A proposal to abstract water from the Waitakere River for the irrigation of a golf course was assessed using IFIM (Hicks and McCullough 1998). Habitat modelling was completed for the 8 species of native fish identified from the river. Because of the significant inflow from tributaries within 1 km downstream, the reduction in habitat area was deemed acceptable. Thermal modelling indicated negligible changes in maximum water temperature.

Lynch and Weber (1992) proposed an economic approach to resolving conflicts in water use for the Ashburton River (Canterbury). Instream values were estimated by a telephone survey that asked ratepayers and visitors what they were willing to pay for a 50% increase in minimum flow of the river. The potential value of water to farmers for irrigation purposes was estimated using a mathematical model. There seems to be little discussion of setting minimum flows in the report. The main thrust is in developing a transferable water permit system that reflects the values to respective users. Those who stand to gain the most will pay more to hold a larger share of the water. There appears to be no recognition of intrinsic stream values or problems associated with transferring water permits upstream where available flows are less.

The Department of Conservation commissioned a survey of the Waitahanui Stream (Bay of Plenty) to benchmark fisheries abundance and diversity prior to the onset of major abstractions (Mitchell and Williamson 1995). In comparison, monitoring of the Takahue River in Northland was proposed to monitor the ongoing effects of abstraction over a five-year period, in addition to documenting pre-existing fish communities (Charles Mitchell & Associates 1994). The importance of monitoring the effects of reduced flows regardless of how the minimum flow was determined is made clear from these reports.

3.2 Regional Methods

A regional approach to flow management is used where individual investigations cannot be justified, which is often the case in small streams or where the cumulative effects of several small abstractions are the primary concern. Regional methods are a relatively recent approach reflecting an increasing awareness of ecological issues in streams of all sizes. Many regional councils, including Environment B·O·P, employ variants of the historic flow methods on a regional scale; the minimum flow is set as a proportion of the low flow (see section 0).

A regional approach to surface water allocation was taken in Northland and considered the potential and observed effects on water quality, habitat and macroinvertebrates (Collier 1994b). Classification of Northland waterways allowed the identification of ecoregions as a first step (Collier 1993d). Recommendations from this study included:

- Flow allocations should be dependent on ecological “value”, (low, medium or high);

- Flow sharing above the one in five year low flow;
- A maximum duration of reduced flow (e.g. 2 months);
- The use of IFIM in “high value” streams where competition for water is high.

Regional methods based on the IFIM were used to develop instream flow requirements for Wellington and Taranaki Regional Councils (Jowett 1993a, 1993b). Habitat preferences of brown trout and food producing habitat (macroinvertebrates) were used. No justification is given for the choice of target species, however the report suggests that in providing for food producing habitat, native fish will also be provided for.

Several rivers and streams in each region were assessed in producing the model, which sets a minimum flow depending on the size of the river only. This minimum flow is intended to retain a set proportion of suitable habitat and limit the amount of flow modification to any river. The model acknowledges the greater effect of reduced flow on smaller streams in allowing more water to be taken from larger rivers. Using multiple streams in developing such a model will also average out any site anomalies.

Chapter 4: MfE Flow Guidelines for Instream Values

The Ministry for the Environment (MfE) has developed these guidelines with the assistance of an advisory group and in consultation with external organisations. There are two volumes, totalling more than 300 pages (MfE 1998a & 1998b). The second volume provides technical background to the first. The following is a brief summary of relevant sections.

4.1 Purpose

The guidelines have three stated purposes:

- To provide a consistent framework for determining flow requirements. This does not mean that the same method should be used throughout the country. Rather the most appropriate methods should be selected for a particular location.
- To provide an up-to-date summary of the effects of altering flow regimes and available methods for defining flow regimes.
- To assist water managers increase their understanding of the methods for setting flow regimes, their use and limitations.

4.2 MfE Guidelines

The approach used in the guidelines is summarised in Figure 2, (taken from the guidelines). The following is an explanation of each text box.

Identify out-of-stream values of water resource

Not addressed in the guidelines.

Identify and assess the significance of instream values.

Instream values are expected to fall into four categories (in accordance with Part II of the RM Act): ecological, landscape, recreation and Maori. All are dealt with in the guidelines. This project concentrates only on ecological issues.

The guidelines identify three main aspects to ecological values:

- Fish passage. If abstraction causes shallow areas to dry up, the life cycle of migratory fish especially can be interrupted.

- Habitat, in terms of food producing areas, water quality and space to live.
- Breeding areas including riparian vegetation.

The only help the guidelines offer in actually identifying ecological values is to identify possible sources of information (Fish and Game, DoC, regional and district councils, Iwi).

Identify instream values that are to be sustained

Target species may be chosen or the freshwater community as a whole. This is particularly important where conflicts arise, for example, trout and torrent fish may prefer higher flows than galaxiids. Water managers need to establish the relative significance of instream values and the acceptable level of risk that these values will not be sustained.

Determine the instream management objective

This involves defining the level of protection afforded to the instream values that are to be sustained. Options include optimising habitat for a target species, maintaining existing habitat, provide a percentage reduction in habitat, etc. The identification of an instream management objective appears to be central to the guidelines. Clarification of the objectives right from the start simplifies the choice of methods and flow requirements decision.

Identify the critical parameters

There are three components to a flow regime requirement for ecological values:

- Flow variability;
- A minimum flow for water quality;
- A minimum flow for habitat requirements.

There may be one parameter that is critical to sustaining the instream management objective. For example water temperature may limit the target species before habitat does. The guideline provides simple tests to determine which of the three components could be limiting. For example, the tests for where the flow requirement should consider habitat requirements are - will average velocity be less than 0.3 m/s?; will depths in pools be less than 0.4m? and so on. Such tests are likely to prove very useful.

Apply technical assessment methods

The instream management objective and the identification of the critical parameters will influence the choice of methods. Popular methods are comprehensively reviewed and the reader made aware of assumptions and shortcomings.

Flow regime requirements

The following aspects need to be considered when setting instream flow requirements and management objectives:

- Remedial and mitigation measures; using means other than flows to achieve an instream management objective, e.g. riparian vegetation.
- The scale and magnitude of a potential effect. The area of habitat affected and to what extent it will be affected.
- Reversibility issues; e.g. a hydro dam is more difficult to remove than an abstraction, is the habitat of an endangered species to be reduced.

MONITOR: Does the flow regime requirement meet the Instream Management Objective?

The interaction of flow and physical conditions with the ecological response to changes in these is complex and impossible to predict with certainty. Most prediction of effects will have wide error boundaries. Where possible, allowances should be made in setting flow regime requirements to fine-tune the consent conditions to more accurately attain the designated instream management objectives in the context of local natural phenomena. Monitoring therefore seeks to provide information that can help refine the assessment of the flow regime requirement.

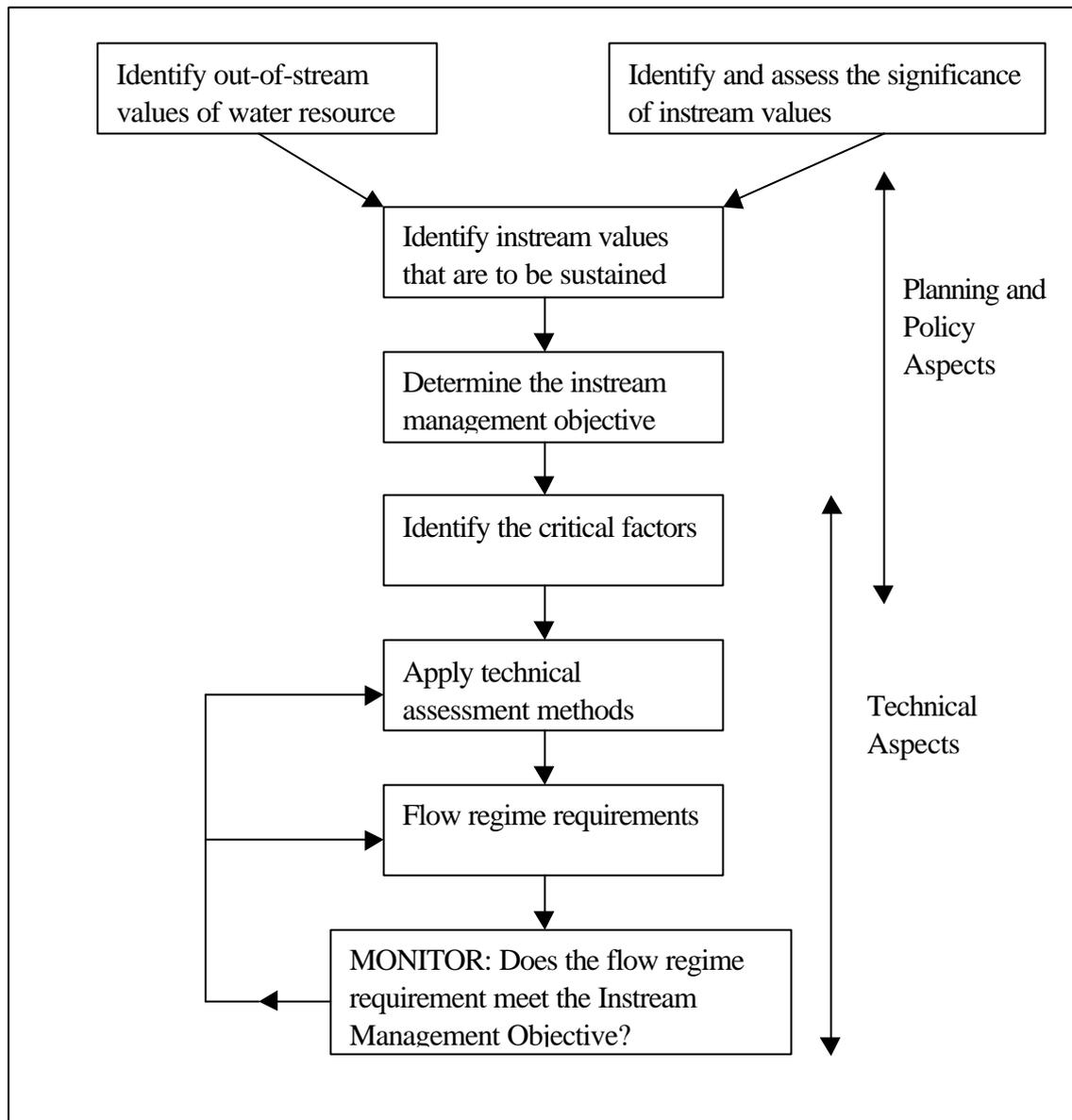


Figure 2 Summary of approach to managing instream values taken in the Flow Guidelines for Instream Values (MFE 1998a).

4.3 Limitations of the Guidelines

The following limitations are as described in the guidelines.

- They only cover instream values. Out-of-stream values and how to allocate water is not addressed. It is recommended that conflict resolution between out-of-stream and instream values is addressed on a case by case basis.
- Methods do not presently exist for prescribing flow variability.
- They do not adequately cover small streams. Most of the research on the effects of flow regimes has been undertaken on larger rivers. Small streams can have very high ecological value. The use of rule of thumb methods in these streams is suggested.

- The guidelines are not intended to identify flow as an issue.
- Although the ecotype or ecoregion approach is advocated, this approach is not described.

4.4 **How useful are the guidelines?**

A standardised framework for determining instream flow requirements has been created; this is significant in itself. In the past many conflicts have arisen simply from the failure to identify all instream values. The guidelines achieve their intended purpose (section 4.1 of this report). They will ensure consistency in the approach people take and increase awareness of the issues and methods associated with flow regime assessment. Water managers will be better placed to deal with abstractions and affected instream values.

The guidelines provide useful advice but leave a lot for water managers to work through. It does not strongly promote ecotyping or regional approaches because of the lack of research to date. At the same time additional complex issues are put forward for water managers to deal with. For this reason I believe that inappropriate rule of thumb methods will continue to be applied particularly to small streams where public interest is not as high.

Chapter 5: Recommendations for Setting Instream Flow Requirements for Bay of Plenty Streams

5.1 Options

Option 1: No Action

Continue to use current rule of thumb approach: do not exceed 30% of Q total flow allocation, restrict individual takes to 5%.

For many stream types, these figures may in fact adequately provide for instream values, however we have no data to back this up. This would result in ongoing justification problems with regard to ecological integrity. Obviously the cheapest option.

Option 2: Conservative Approach

Reduce permissible abstraction levels to a more conservative level. For example, do not exceed 10% total flow allocation and no takes allowable from streams below a certain size.

It is likely that ecological values would be provided for while eliminating the need for detailed ecological investigations. Tried and tested methods could be adopted as they become available. This approach may impose undue hardship on resource users and it would be difficult to provide justification for revoking consents from existing users.

Option 3: Case by Case Approach

Require that each consent applicant complete an assessment of ecological effects, following the MfE flow guidelines (Chapter 4:). Taking this approach, the best methods could be used in each case, but would be left open to interpretation. The cost to resource users is likely to be prohibitive in most cases. It may not effectively consider cumulative effects.

Option 4: Monitoring Approach

The existing rule of thumb allocation system would be critically evaluated in a monitoring or assessment of ecological effects type approach (see section 2.5). The effects of reduced flow on stream biota and water quality could be assessed directly rather than attempting a predictive approach. Changes could then be made where the current system was deemed inappropriate.

This approach would be ecologically defensible and rely on established monitoring techniques. The problem is that these effects may only occur once every five years and after an extended

low flow period. The monitoring would therefore be left to chance and would be difficult to plan and budget for. Measuring any effects with certainty may prove difficult. Detailed studies may be required with large sample sizes. Confounding land use effects could prove difficult to factor out. If no effect is found, how do we justify setting minimum flows below that assessed? Generalising to an ecoregion or stream type would be forward where few or no authorised abstractions exist to evaluate.

Option 5: Regional Flow Modelling

The Waiora decision support system (see section 2.6) would be adapted for use in the Bay of Plenty and applied within the framework of the MfE Guidelines (Chapter 4:). Water quality and macroinvertebrate data collected during the recent dry summer would be used together with dataloggers in validating the Waiora models.

The key mechanisms by which reduced flows have an impact on ecosystems would be addressed by this approach, including dissolved oxygen, habitat, temperature and ammonia. Certainly more factors would be considered than typically have been in the past. Climatic factors are less crucial in the success of this approach (cf. Option 4).

After the monitoring approach, this is probably the next most intensive in terms of staff resources and cost. Setting minimum flows may still be difficult or arbitrary. For example, where habitat is reduced proportionally with flow and no inflexion points exist, how does one set a minimum flow? Outside assistance from organisations such as NIWA may be needed in adapting Waiora to the Bay of Plenty region. This is a relatively untested approach and there are many unknowns. It is however derived from tested models.

5.2 Recommended Option: Regional Flow Modelling

As stated in Option 5, the Waiora decision support system would be adapted for use in the Bay of Plenty and applied within the framework recommended by the MfE flow guidelines (see Figure 2). Identification of management objectives would be supported by the recent report on ecological values of Bay of Plenty streams (Williams 1999). For example, if a stream provides habitat for important native species, the management objective may be to maintain habitat for freshwater fish, or, not allow stream temperatures to exceed 20°C.

The next step would be to identify stream types or perhaps ecoregions. (This may need refinement through the course of the project.) Within each stream type there may be some factors that do not require consideration. The MfE guidelines provide tests, for example, nuisance algae growth can be a problem where: depth is reduced below 0.6m; velocity below 0.7m/s; low flows are constant for more than five weeks; the substrate is predominantly gravel or cobble (MfE 1998a).

At this stage Waiora appears to be the most promising technical assessment method because of the simple generic approach taken. It contains basic models that are likely to require calibration for conditions in the Bay of Plenty. For instance, dataloggers and water quality data will enable us to test and adjust the predictions of dissolved oxygen models. Macroinvertebrate data from last summer and perhaps the more complex IFIM approach (section 2.3) could be

used in validating the simplified habitat modelling used in Waiora. Guidelines and standards that are used in Waiora to determine minimum flows will require clear rationale.

Output and Application

The final output might be a regional model, such as an equation for each ecoregion into which only the stream size is required to determine a minimum flow (see Taranaki and Wellington examples, section 3.2). Alternatively Waiora may be implemented for use on a catchment by catchment approach, as the need permits. The most practical approach might not be apparent however, till well into the project.

A catchment approach is preferable in setting minimum flows because flow requirements downstream may limit the allowable take in the headwaters. At this point it is worth distinguishing instream flow requirements from water allocation policy. Once the requirements of stream ecosystems are determined, for example, in the form of a minimum flow, the question still remains as to how the available water is allocated to individual users. It is not the intention of this project to come up with allocation methods. Relevant plans are currently being developed (Water & Land Plan, Heritage Strategy), so it would be premature to say how this project could tie in with these documents.

If time permits, mitigation options will be investigated, e.g. water harvesting (storing flood flows in dams), riparian planting, pumping regimes, seasonal restrictions.

Follow-up monitoring will be necessary to confirm instream management objectives are being met. Provision for changes to the maximum allowable take will therefore need to be set in consent conditions. The effect of abstraction on wetlands has received little attention. The lack of information describing the effects of abstractions on receiving wetlands may necessitate a conservative approach where significant wetlands are at risk.

Participation by other staff would be required in setting management objectives. Staff would need to be trained in carrying out minimum flow assessments and help would be required during the initial validation of the model.

References

- Charles Mitchell & Associates. 1994: Monitoring impacts of water abstraction from the Takahue River. Conservation advisory notes No. 52. Department of Conservation. Wellington.
- Clausen, B.; Biggs, B.J.F. 1997: Relationships between benthic biota and hydrological indices in New Zealand streams. *Freshwater Biology* 38: 327-342.
- Collier, K.J. 1993a: A review of the environmental effects of flow regulation and approaches to flow management: implications for northland. Consultancy Report No. NRC 101/2. NIWA, Hamilton.
- Collier, K.J. 1993b: Flows required to maintain sufficient dilution for water quality standards. Consultancy Report No. NRC 101/3. NIWA, Hamilton.
- Collier, K.J. 1993c: Analysis of low flow inflection points for some Northland rivers. Consultancy Report No. NRC 101/4. NIWA, Hamilton.
- Collier, K.J. 1993d: Bioassessment and classification of Northland rivers. Consultancy Report No. NRC 101. NIWA, Hamilton.
- Collier, K.J. 1994a: Summer bioassessment of some Northland rivers and interim recommendations for flow management. Consultancy Report No. NRC 101/5. NIWA, Hamilton.
- Collier, K.J. 1994b: Low flow allocation options for Northland. Consultancy Report No. NRC 101/6. NIWA, Hamilton.
- Dean, T.L.; Richardson, J. 1999: Responses of seven species of native freshwater fish and shrimp to low levels of dissolved oxygen. *New Zealand Journal of Marine and Freshwater Research* 33: 99-106.
- Estes, C.C.; Osborn, J.F. 1986: Review and analysis of methods for quantifying instream flow requirements. *Water Resources Bulletin* 22: 389-398.
- Hickey, C.W.; Vickers, M.L. 1994: Toxicity of ammonia to nine native New Zealand invertebrate species. *Archives of Environmental Contamination and Toxicology* 26: 292-298.
- Hicks, B.J.; Barrier, R.F.G. 1996: Habitat requirements of black mudfish (*Neochanna diversus*) in the Waikato region, North Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 30: 135-151.

- Hicks, B.J.; McCullough, C.D. 1998: The impact of the irrigation abstraction for the Waitakere Golf Course on the Waitakere River. Unpub. report. Department of Biological Sciences, University of Waikato. Hamilton.
- Jowett, I.G. 1993a: Minimum flow assessments for instream habitat in Wellington rivers. NZ Freshwater Miscellaneous Report No. 63. NIWA, Christchurch.
- Jowett, I.G. 1993b: Report on minimum flow requirements for instream habitat in Taranaki rivers. NZ Freshwater Miscellaneous Report No. 75. NIWA, Christchurch.
- Jowett, I.G. 1994: Native fish and minimum flows in the Kakanui River. Conservation Advisory Notes No. 88. Department of Conservation. Wellington.
- Jowett, I.G. 1996a: Instream flow methods and minimum flow requirements. Course instruction manual. NIWA.
- Jowett, I.G. 1996b: RHYHABSIM: River Hydraulics and Habitat Simulation. Course notes for survey and analysis of instream habitat. NIWA, Hamilton.
- Jowett, I.G.; Biggs, B.J.F. 1997: Flood and velocity effects on periphyton and silt accumulation in two New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research* 31: 287-300.
- Kemper, B.; Craig, J.F. (Ed.) 1987: Regulated Streams - Advances in Ecology. Plenum Press, New York.
- Kingsland, S.; Collier, K.J. 1997: WAIORA User Guide: Version 1.0: Prototype. NIWA Client Report No. ARC70214/2. NIWA, Hamilton.
- McBride, G.B.; Cooke, A.B.; Cooper, A.B.; Smith, C.M. 1994: Optimising habitat in a stream impounded for water supply. *In* Restoration of Aquatic Habitats. Selected papers from the second day of the Limnological Society 1993 Annual Conference. Department of Conservation. p111-123.
- McBride, G.B.; Nagels J.W. 1994: Analysis of continuous diurnal dissolved oxygen measurements in eleven Northland streams. Consultancy Report No. NRC004/1. NIWA, Hamilton.
- McBride, G.B.; Jowett, I.G.; Rutherford, K.C.; Pearson, C. 1998: Water allocation impacts on river attributes: technical report on modelling. NIWA Client Report: ARC70214/1. NIWA, Hamilton.
- Ministry for the Environment 1998a: Flow Guidelines for Instream Values – Volume A. Ministry for the Environment, Wellington.
- Ministry for the Environment 1998b: Flow Guidelines for Instream Values – Volume B: Technical Background. Ministry for the Environment, Wellington.
- Mitchell, C.P.; Williamson G.M. 1995: A fisheries survey of the Waitahanui Stream and discussion of the likely impacts of cumulative water abstractions. Charles Mitchell & Associates. Rotorua.

- Orth, D.J.; Maughan, O.E. 1982: Evaluation of the incremental methodology for recommending instream flows for fishes. *Transactions of the American Fisheries Society* 111: 413-445.
- Quinn, J.M.; Hickey, C.W. 1990: Magnitude of effects of substrate particle size, recent flooding, and catchment development on benthic invertebrates in 88 New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research* 24: 411-427.
- Quinn, J.M.; Steele, G.L.; Hickey, C.W.; Vickers, M.L. 1994: Upper thermal tolerances of twelve New Zealand stream invertebrate species. *New Zealand Journal of Marine and Freshwater Research* 28: 391-397.
- Richardson, J. 1997: Acute ammonia toxicity for eight New Zealand indigenous freshwater species. *New Zealand Journal of Marine and Freshwater Research* 31: 185-190.
- Scott, D.; Shirvell, C.S. 1987: A critique of the IFIM and observations on flow determination in New Zealand. In: Kemper, B.; Craig, J.F. (Ed.). *Regulated Streams - Advances in Ecology*. Plenum Press, New York.
- Ward, J.V.; Stanford, J.A. 1987: The ecology of regulated streams: past accomplishments and directions for future research. In: Kemper, B.; Craig, J.F. (Ed.). *Regulated Streams - Advances in Ecology*. Plenum Press, New York.
- Wilcock, R.J.; Nagels, J.W.; McBride, G.B.; Collier, K.J.; Wilson, B.T.; Huser, B.A. 1998: Characterisation of lowland streams using a single-station diurnal curve analysis model with continuous monitoring data for dissolved oxygen and temperature. *New Zealand Journal of Marine and Freshwater Research* 32: 67-79.
- Williams, S. 1999: Ecological values of freshwater bodies in the Bay of Plenty region. Consultant report to Environment B·O·P.