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| **IN THE MATTER** | of the Resource Management Act 1991 |
| **AND** | |
| **IN THE MATTER** | of an application by Meridian Energy Limited for resource consents for the Mokihinui Hydro Project |

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**STATEMENT OF EVIDENCE OF IAN GEORGE JOWETT ON BEHALF OF MERIDIAN ENERGY LIMITED**

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## 1. QUALIFICATIONS AND EXPERIENCE

1.1 My full name is Ian George Jowett.

1.2 I have a Bachelor of Engineering degree from Canterbury University in 1968 and became a registered engineer in 1970. I am a member of the New Zealand Hydrological Society and the New Zealand Freshwater Sciences Society.

1.3 I am a scientist and was employed by the National Institute of Water and Atmospheric Research until my retirement on 31 October 2007. I have been engaged by Meridian Energy Limited as a private consultant to prepare this evidence.

1.4 Between 1969 and 1984, I worked on the investigation, operation and environmental impact of hydroelectric schemes, including the Mokihinui River. In 1984, I was employed by MAF Fisheries, now part of NIWA, and began research into the factors influencing the abundance and distribution of trout. As part of this study, I initiated the "100 rivers" survey and collected data on trout densities and comparable biological, hydrological, and chemical data for more than one hundred rivers.

1.5 From the "100 rivers" data, I developed models that predicted brown trout abundance from river characteristics. These results were published in the North American Journal of Fisheries Management (Jowett 1992).

1.6 For the past 22 years, I have carried out research to determine factors that influence the distribution and abundance of trout and native fish. I have authored or co-authored over thirty scientific publications on habitat and flow requirements of benthic invertebrates, brown trout and native fish.

1.7 I have carried out instream habitat surveys of more than 250 reaches and assessed minimum flow requirements for more than 50 rivers. For many of these, I have prepared reports and presented evidence to Regional Council and Environment Court hearings on the effect of flow on stream invertebrates, native fish and trout. I have presented evidence for Water Conservation Order hearings for the Mohaka, Buller and Rangitata rivers.

1.8 I have followed up on as many of my flow recommendations as possible by examining the biological consequences of flow changes, and found that in 6 out of 7 cases, the biological response was in accordance with predictions (Jowett & Biggs 2006; Richardson & Jowett 2006).

1.9 More generally, I have examined methods available for assessing flow requirements for rivers and their use in the flow management process. Results of this work have been incorporated into the Ministry for the Environment's "Flow guidelines for in-stream values" (MFE 1998) and into Environment Southland's Proposed Regional Fresh Water Plan for Southland following a review which I co-authored with Dr Hayes, Cawthron Institute, (Jowett & Hayes 2004). I have also been involved in the preparation of a proposed National Environmental Standard on methods for use in assessing flow regime requirements.

1.10 I have read the Code of Conduct for Expert Witnesses (Rule 330A, High Court Rules and Environment Court Practice Note) and I agree to comply with it. I have complied with it in the preparation of this statement of evidence.

1.11 I have been involved in the following work in relation to Meridian Energy Limited's (Meridian's) Mokihinui Hydro Project (MHP):

a. An instream habitat survey in April 2007*;*

b. A report on flow regime requirements (Jowett 2007)*;*

and I have prepared my statement of evidence in reliance on this work.

1.12 I have also reviewed:

a. The reports and statements of evidence of other experts giving evidence on behalf of Meridian relevant to my area of expertise, including:

   i. Mr Henderson, Dr Goring, Dr Hicks, Dr Kilroy, Dr Suren, Mr Bonnett, Dr Hayes, Mr Greenaway and Mr Watts;

b. Relevant submissions of others, namely Frida Inta for the Greens, Eugenie Sage, Forest & Bird, Fish & Game, and the NZ Federation of Freshwater Anglers.

## 2. SCOPE OF EVIDENCE

2.1 I have been asked by Meridian to prepare evidence in relation to the actual and potential effects of the MHP flow regime on the instream habitat of the Mokihinui River. This includes an assessment of:

a. flow regime requirements between the powerhouse and the SH 67 bridge, in particular the minimum flow, flow fluctuations and ramping rates, and

b. potential effects of the flow regime on water levels and river biota.

## 3. EXECUTIVE SUMMARY

3.1 The proposed hydro-electric power development would have sufficient storage to allow power station discharges to vary according to power demand with higher flows during the day (and in particular around the peak morning and evening periods) and lower flows at night. There would be two (approximately 60 cumecs) turbines and their combined maximum discharge would be 120 cumecs. A smaller turbine (around 19 cumecs) would be installed to generate with the minimum flow. This turbine would also be used at times when flows in excess of 120 cumecs would otherwise be spilt over the crest of the dam.

3.2 I examined flow regime requirements in the river between the powerhouse and the SH 67 bridge, below which water levels are affected by the tide.

3.3 I carried out an instream habitat survey and developed an instream habitat model to determine how the area of suitable habitat varied with flow for fish and benthic invertebrate species.

3.4 I found that a minimum flow of 16 cumecs (the mean annual low flow) would maintain near maximum habitat for native fish, many benthic invertebrate species, food production and adult and yearling brown trout. The flow would also limit the growth of long filamentous periphyton, which would also be kept in check by the frequent floods and freshes.

3.5 A flow change from minimum flow of 16 cumecs to the maximum turbine discharge of 120 cumecs would cause an average 0.64 m rise in water level above the SH 67 bridge.

3.6 The magnitude and timing of daily flow fluctuations would affect whitebaiting below the SH bridge. Although some combinations of flow and tide might improve whitebaiting, others will be detrimental. To avoid adverse effects, there will be no artificial flow fluctuations during the whitebait season from 01 September to 14 November. During this period, the dam will be operated so that the outflows will match the natural inflows coming into the lake as closely as practicably possible i.e., run of the river.

3.7 The natural rate of river rise during floods in the Mokihinui catchment is rapid changing by up to several hundred cumecs in a few hours. The rate of flow change under the MHP will not affect the stability and composition of river banks, and will be unlikely to cause stranding of people or livestock because of the relatively infrequent use of the river bed and lack of islands. However, because there is some recreational use of the river downstream of the proposed dam I recommended that warning signs should be erected to warn of sudden changes in water level, as described by Mr Watts. In addition, Mr Watts describes in his evidence how Meridian proposes to restrict the rate of change in flow to provide a safeguard for river users.

3.8 Daily flow fluctuations would reduce benthic invertebrate habitat and food production, but would not have any significant effect on native fish or trout habitat because they can move with changing flow and stranding is unlikely.

3.9 The potential effect of reduced invertebrate production on trout may be moderated by the availability of food sources other than invertebrates and a slight improvement in production resulting from less sediment transport. Anecdotal reports of “sea-run” brown trout, especially during the whitebait season, support this view. These “sea-run” trout probably live in the estuary where they develop a silvery coloration and feed largely on native fish.

3.10 There are benefits to both Meridian and local electricity consumers in fluctuating generation flows on a daily basis in order to follow electricity market demands, both nationally and regionally and there seems no compelling ecological or geomorphological reason to restrict flow fluctuations. However, a restriction on fluctuations during the whitebaiting season may be justified on recreational or amenity grounds.

3.11 Flow variability, including flushing flows and channel maintenance, is usually considered necessary to maintain aquatic ecosystems in good condition. Floods and freshes scour accumulated fine sediments and periphyton, leaving the clean substrates that are preferred by many benthic invertebrate and fish species. The proposed reservoir has relatively limited storage capacity and will not change the flood frequency distribution significantly. Thus, natural floods and freshes will still occur at frequent intervals and will be capable of maintaining clean river gravels and the present morphology.

4. **THE PROPOSAL**

4.1 I confirm my evidence is based on the project proposal as described in the Assessment of Environmental Effects.

5. **METHODOLOGY**

5.1 The instream flow incremental methodology (IFIM; Bovee 1982) was chosen as the main tool for guiding the selection of an appropriate flow regime between the proposed dam and the tidal area of the Mokihinui River. IFIM provides an interdisciplinary framework that can be used in a holistic way to determine an appropriate flow regime by considering the effects of flow changes on instream values. IFIM is a means by which a range of biological information can be introduced into the flow assessment process. The method considers the amount of environmental change that accompanies a change in flow and considers all physical environmental changes including, physical habitat, water temperature, water quality, and river morphology.

5.2 The use of IFIM requires a high degree of knowledge about seasonal and life-stage requirements of species and inter-relationships of the various instream values or uses. My report (Jowett 2007) and this evidence only examine the effect of flow on instream physical habitat. I do not consider other issues, such as cultural or aesthetic values of river flows.

5.3 Other flow assessment frameworks are more closely aligned with the "natural flow paradigm" (Poff et al. 1997). The range of variability approach (RVA) and the associated indicators of hydrologic alteration (IHA) allow an appropriate range of variation, usually one standard deviation, in a set of 32 hydrologic parameters derived from the 'natural' flow record (Richter et al. 1997). The implicit assumption in this method is that the natural flow regime has intrinsic values or important ecological functions that will be maintained by retaining the key elements of the natural flow regime. Arthington et al. (1992) described a holistic method that considers not only the magnitude of low flows, but also the timing, duration and frequency of high flows. This concept was extended to the building block methodology (BBM), which “is essentially a prescriptive approach, designed to construct a flow regime for maintaining a river in a predetermined condition” (King et al. 2000). It is based on the concept that some flows within the complete hydrological regime are more important than others for the maintenance of the river ecosystem, and that these flows can be identified and described in terms of their magnitude, duration, timing, and frequency.

5.4 Obviously, maintaining the natural flow regime will maintain the hydrologic and hydraulic conditions necessary for sustaining natural ecosystems. However, if there is adequate knowledge of what ‘values’ need to be maintained in a waterway, and the hydraulic/flow variability requirements of the constituent taxa are also known, then provided the key value to be maintained is not simply the natural flow, regimes can be designed that target these requirements and thus optimise conditions for the ‘values’.

5.5 A process-based assessment of ecosystem requirements, such as I will describe, can achieve the best balance between resource use and sustaining ecosystem function and value as shown by examples where changes to natural flow regimes have maintained, or even improved, instream values in some New Zealand rivers (Jowett & Biggs 2006). Simple flow-based rules, such as those that might be developed under the natural flow paradigm, could be unnecessarily restrictive on multiple use of water in New Zealand whilst, at the same time, preclude the opportunity for enhancement of key ecosystem values in many waterways.

5.6 The ecological goal of habitat methods is to provide or retain a suitable physical environment for aquatic organisms that live in the river. The consequences of loss of habitat are well known; the environmental bottom line is that if there is no suitable habitat for a species it will cease to exist. Habitat methods tailor the flow assessment to the resource needs and can potentially result in improved allocation of resources.

Although it is essential to consider all aspects such as food, shelter, and living space (Orth 1987; Jowett 1995), appropriate habitat suitability curves are the key to the successful application of habitat based methods. The flow assessment considers physical habitat at a meso- to macro-habitat level rather than microhabitat. In this way, suitable average depths and velocities can be maintained in the main habitats, with a degree of habitat diversity that is generated by the morphology of the river, and is largely independent of flow.

5.7 The great strength of IFIM is that the physical habitat component quantifies the change of physical habitat caused by changes in flow, and this helps in the evaluation of alternative flow proposals. I do not know of any other method of flow assessment that could be used to evaluate the effects of flow changes on various aquatic organisms. Hydrologically based methods, such as the Range of Variability (RVA), simply assume that the natural flows are the flows to which the aquatic species have adapted and that any change from natural is detrimental. While I agree that maintaining natural flows will retain the existing ecosystem, I also believe that natural flow regimes can be substantially altered, while still retaining instream values. Case studies have shown that flow regime requirements determined using habitat analyses have generally achieved their objectives of sustaining or improving aquatic biota (Jowett & Biggs 2006; Richardson & Jowett 2006). The one case where response did not match predictions was in the Ohau River in the South Island where trout numbers and angler usage have remained low despite what is regarded as excellent angling water and trout habitat. The present low numbers of trout in this section of the Ohau River may be related to problems with recruitment and fish passage between Lake Ohau and the river, or simply a reluctance to move upstream from Lake Ruataniwha.

5.8 Traditionally, instream flow methods have been used to define a minimum flow. However, the current trend is away from methods that set one “minimum flow” towards methods that consider the whole flow regime.

5.9 The flow regime of a river is the pattern of flows through time. Some of the important elements of a flow regime are:

(i) the normal or modal flow – the flow that occurs most frequently

(ii) extreme flows – the magnitude of both high and low flows, and

(iii) the short - and long-term flow variability – where the short-term variability reflects the day-to-day flow fluctuations and the long-term variability reflects the seasonality or month-to-month variation.

5.10 The quality of the habitat provided by "normal" flows, as well as the magnitude and frequency of high and low flows, influences the abundance and species composition of aquatic ecosystems. Seasonal flow variation can also be important for some riverine ecosystems where life cycles of the species have evolved to fit the seasonal patterns in flow and water temperature.

5.11 The primary flow regime requirements are:

(i) Minimum flows to provide suitable habitat (both qualitatively and quantitatively) for a wide variety of species, life-stages and instream uses.

(ii) Flushing flows that remove excess accumulations of periphyton and fine sediment without significantly disturbing the bed sediments.

(iii) Occasional flood flows that re-work gravels, removing interstitial fine sediment deposits from the cobble/gravel bed matrix, removing terrestrial vegetation that has colonised the flood plain, and maintaining the natural character and morphology of the river.

5.12 The extent to which the amount of habitat for aquatic organisms can be maintained depends to some extent on each of these flow regime elements.

5.13 The key points concerning IFIM and flow management are:

(i) Habitat suitability criteria are a critical step in the process.

(ii) Environmental response to flow is incremental and aquatic communities will eventually decline as flows are reduced. Without water in a river, there would be no aquatic ecosystem or instream use. However, because of the degree of diversity in a river and flexibility of most aquatic organisms, there is probably no sharp cut-off that can be defined as the ‘minimum flow’.

(iii) It is unlikely that the state of knowledge of biological systems will ever reach the stage where the effect of flow changes on stream populations can be predicted with absolute certainty.

5.14 The procedure in an instream habitat analysis is to select appropriate habitat suitability curves or criteria (e.g., Figure 1) for each species or life stage considered to be of value within the river ecosystem, and then to model the effects of a range of flows on the selected habitat variables in relation to these criteria. The habitat suitability index (HSI) at each point is calculated as a joint function of depth, velocity and substrate type using the method shown in Figure 1. For example in Figure 1, at a given point in the river (representing an area of reasonably uniform depth and velocity) where the depth is 0.1 m, depth suitability is only 65% optimal, according to knowledge of the depth requirements of the fish. Similarly, the velocity recorded at the point is 0.25 m/s, which is optimal (suitability weighting of 1), and the substrate is fine gravel (sub-optimal, with a weighting of 0.4) and cobbles (optimal with a weighting of 1). Multiplying these weighting factors together gives a joint habitat suitability weighting of 0.455 for that point in the river for the selected fish species. If the depth had been 0.2 m and there had been no fine gravel, then that point in the river would have been optimal (i.e., 1 for depth × 1 for velocity × 1 for substrate = 1).

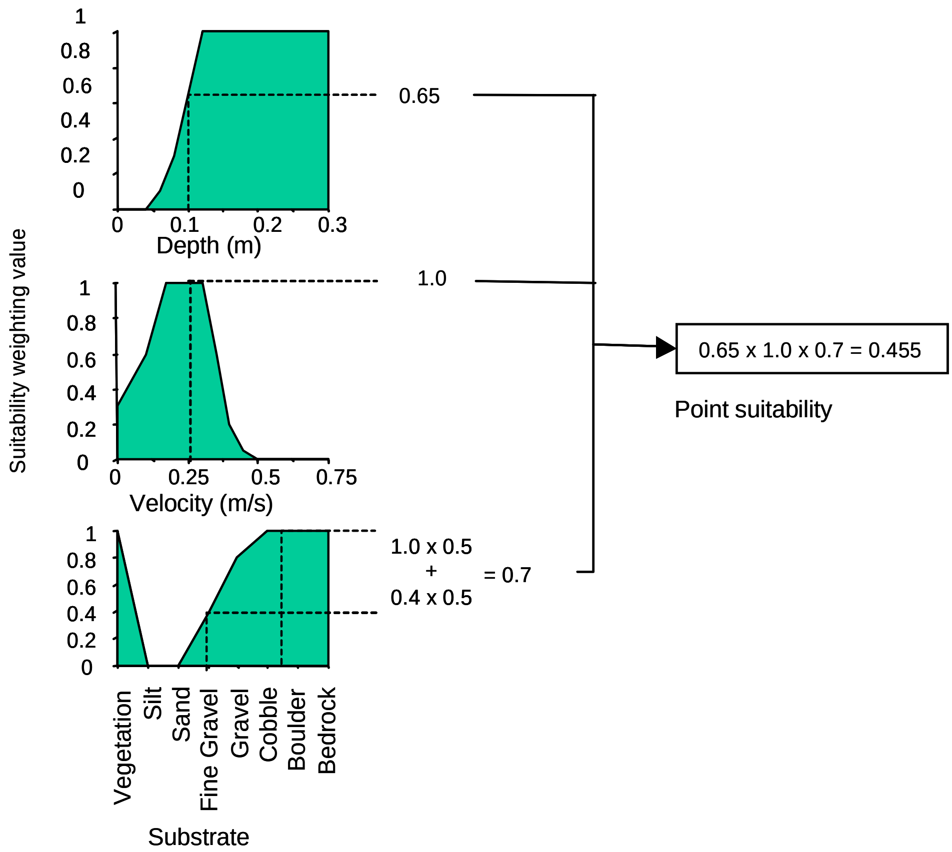


**Figure 1**: Calculation of habitat suitability for a fish species at a point with a depth of 0.1 m, velocity of 0.25 m/s, and substrate comprising 50% fine gravel and 50% cobble. The individual suitability weighting values for depth (0.65), velocity (1.0), and substrate (0.7) are multiplied together to give a combined point suitability of 0.455.

5.15 The weighted usable area (WUA) is the sum of the habitat suitability values (HSI) across each cross-section, weighted by the proportion of the habitat type which each cross-section represented in the river. This is a measure of total area of suitable physical habitat for the given species at the given flow. The process is repeated for a series of flows. WUA is then plotted as a function of flow. Variations in the amount of suitable habitat (i.e., WUA) with flow are then used to assess the effect of different flows for each species.

5.16 Various approaches to setting levels of protection provided by a minimum flow have been used, from maintaining a maximum amount of habitat, a percentage of habitat at median flow, or using a breakpoint (or “inflection point”) on the habitat/flow relationship (Jowett 1997). The latter is possibly the most common procedure used for assessing minimum flow requirements using habitat methods. While there is no percentage or absolute value associated with a breakpoint, it is a point of diminishing return, where proportionately more habitat is lost with decreasing the flow than is gained by increasing the flow.

5.17 Habitat methods can also incorporate other flow regime requirements, such as seasonal variation and flow fluctuations. Flow fluctuations are an important component of the habitat of most naturally flowing streams. Large fluctuations remove excess accumulations of silt and accumulated organic matter (e.g., from algal slimes) and rejuvenate stream habitats. Frequent fluctuations disrupt aquatic communities, whereas extended periods without a flow disturbance usually result in a shift in benthic community composition such as a reduction in diversity, and an increase in biomass of a few species within plant and animal communities.

5.18 An instream habitat flow assessment for a particular river has three important steps:

(i) Survey and hydraulic modelling;

(ii) Selection of habitat suitability criteria and calculation of WUA/flow relationships; and finally

(iii) Evaluation of the effects of the flow regime on aquatic organisms.

5.19 The instream habitat survey was carried out over 3.6 km of river above the SH 67 bridge. The length of each habitat type present in the reach was recorded and then cross-section locations were randomly selected in each habitat type (Figure 2). Cross-sections were located in runs and riffles, but not in the riffle/rapids because we could not survey these either by wading or jetboat. Pools were not surveyed because they were rare and pools have little influence on habitat/flow relationships because the deep water and low velocity characteristics do not vary with flow significantly.

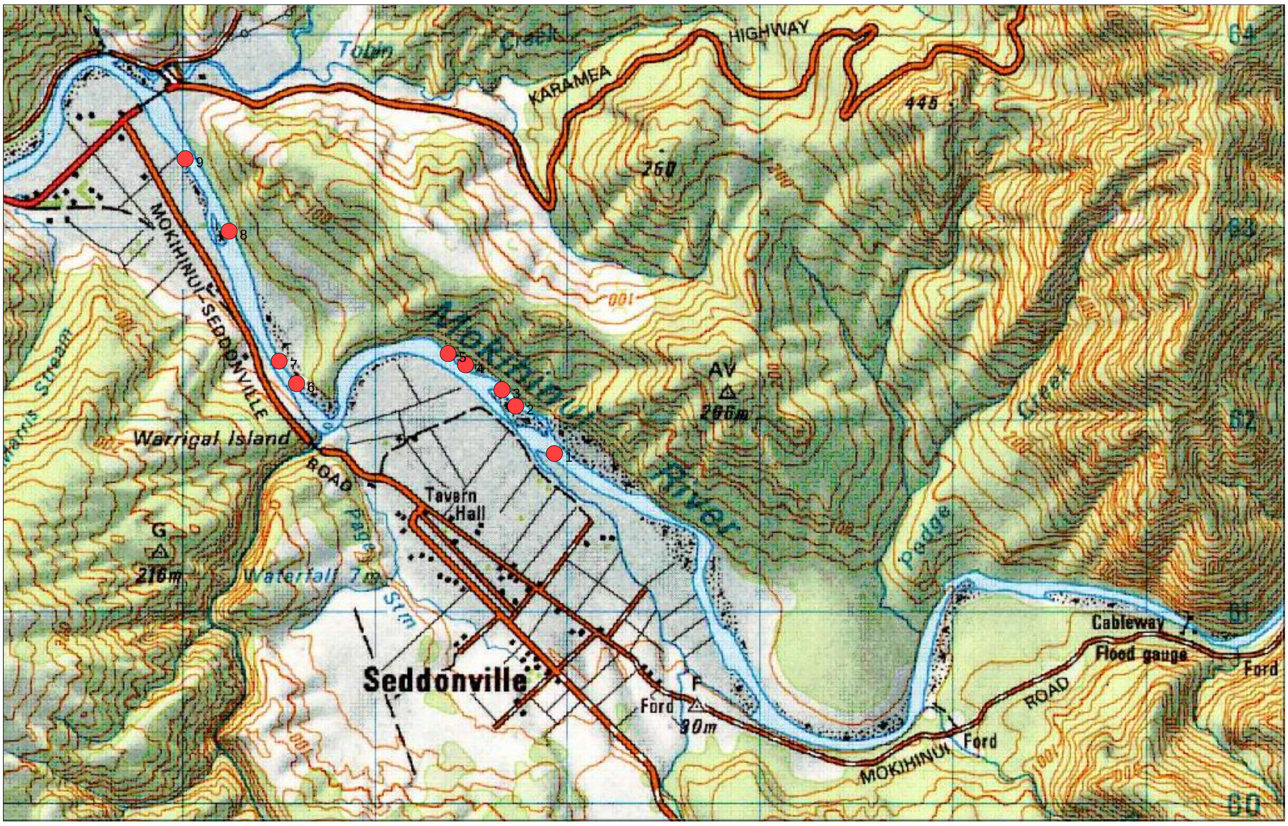


**Figure 2:** Location of cross-sections on the Mokihinui River.

5.20 The survey of cross-sections was carried out on 24 April 2007 when the flow was 17.9 cumecs. At each cross-section, water velocities, depths, and substrate composition were recorded at a spacing that varied with the uniformity of the cross-section. The water level was also measured and referenced against a temporary staff gauge.

5.21 In order to establish a relationship between water level and flow at each cross-section, water level was measured on the temporary gauges at two other flows; on 9 May 2007 when the river flow was 45.5 cumecs and on 30 May 2007 when the flow was 42 cumecs.

5.22 I developed an instream habitat model and relationships between habitat and flow by:

(i) Developing stage-discharge relationships for each cross-section using a least squares fit to the logarithms of the measured flows and stages (water levels) including an estimated stage at zero flow.

(ii) Calculating water depths and velocities at each measurement point across each cross-section for a range of simulated flows, and evaluating habitat suitability (HSI) at each measurement point from habitat suitability curves for each fish species.

(iii) Calculating weighted usable area (WUA) over a range of flows.

(iv) Finally, I plotted WUA against flow for each species and used these curves to assess the effect of the minimum flow on instream habitat.

5.23 I also calculated the water level, velocity and width over the range of flow fluctuations. These were used to assess the potential effects of flow fluctuations on river biota.

5.24 I consider the approach taken represents best practice in the application of IFIM as a tool to assist in setting an appropriate flow regime to protect important instream values.

## 6. EXISTING ENVIRONMENT

### Physical characteristics

6.1 The Mokihinui River flows generally westward from the Kahurangi National Park to the sea west of Seddonville. In the upper catchment, the North and South Branches join just before the river flows westward through a gorge to the proposed dam site at the end of the gorge. Below the gorge, the river opens out into a wide flood plain and in normal flows there are exposed boulders and gravel along much of the river. The river distance from the gorge to the SH 67 bridge is approximately 8 km and it is a further 3.6 km to the sea. The tidal influence extends from the mouth to just below the SH 67 bridge.

6.2 Between the gorge and the SH bridge, the river comprises long runs and occasional pools between riffles or rapids. I investigated this area from jet boat, and on foot in some areas. Overall, I found that 84% of the river was run, 6% riffle, 4% riffle/rapid and 6% pool. The river is constrained by a bedrock outcrop at the Chasm Stream confluence, where the river narrows with several very deep pools. About 1.5 km above the Chasm, there were several wide and shallow riffles that prevented the jetboat from travelling further upstream. There is no change in the river gradient between here and the gorge, as described by Dr Hicks, and no significant change in flow, geology or river morphology, so that the surveyed reach will be representative of the section of river between the dam and the SH bridge.

6.3 At the survey flow of 17.9 cumecs, the average river width, depth and velocity was 50.2 m, 0.95 m, and 0.43 m/s, respectively. The substrate comprised a mixture of boulders, cobbles, and gravel (38%, 38% and 19%, respectively), with some bedrock outcrops (3%) where the river flowed against the true right bank and small pockets of fine gravel and sand behind boulders.

6.4 A change in flow of 10 cumecs from 10 to 20 cumecs increased the average width, depth, and velocity by 4 m, 0.11 m, and 0.15 m/s, respectively. A flow change from 10 cumecs to 20 cumecs increased the water level by about 0.17 m.

**Fish**

6.5 New Zealand native fish can be classified as either diadromous (migrating to and from the sea as a necessary part of their life cycle) or non-diadromous (spending their whole life in fresh water). Diadromy has a strong influence on fish distribution, with high fish diversity in rivers at low elevations, and low diversity at inland sites.

6.6 The New Zealand Freshwater Fish Database (NZFFD) contains 40 records of fish in the Mokihinui catchment. NIWA carried out additional electric fishing, trapping and spotlighting to improve the knowledge of the distribution and abundance of fish throughout the catchment. Torrentfish, bluegill bully, redfin bully, common bully, longfin eel, shortfin eel, inanga, koaro, shortjaw kokopu, giant kokopu, lamprey and brown trout are present in the lower catchment. Mr Bonnett and Dr Jellyman discuss these surveys in more detail in their evidence.

6.7 The three bully species, torrentfish, longfin eel and brown trout are commonly found in the main river below the gorge. The other species are only found in low numbers with the whitebait species except inanga (giant kokopu, shortjaw kokopu, koaro) moving through the river to tributaries (Bonnett et al. 2007). Inanga form a part of the whitebait catch and Bonnett et al. (2007) found adult inanga in low numbers in the lower reaches of the river, and little suitable inanga spawning habitat.

6.8 I used native fish habitat suitability criteria derived from Jowett and Richardson (1995) to calculate instream habitat. These criteria are widely accepted as being appropriate for native fish.

6.9 Bluegill bullies and torrentfish are found in high velocity water, whereas the other species are usually along the shallow and slow flowing margins of large rivers. As would be expected for these habitat preferences, the amount of habitat for common bully, redfin bully and longfin eel increased as flows reduced, with suitable habitat available along the margins at all flows considered. Near maximum habitat for the fast-water species (bluegill bullies and torrentfish) was provided by flows of 27.5 and 30 cumecs, respectively (Figure 3).

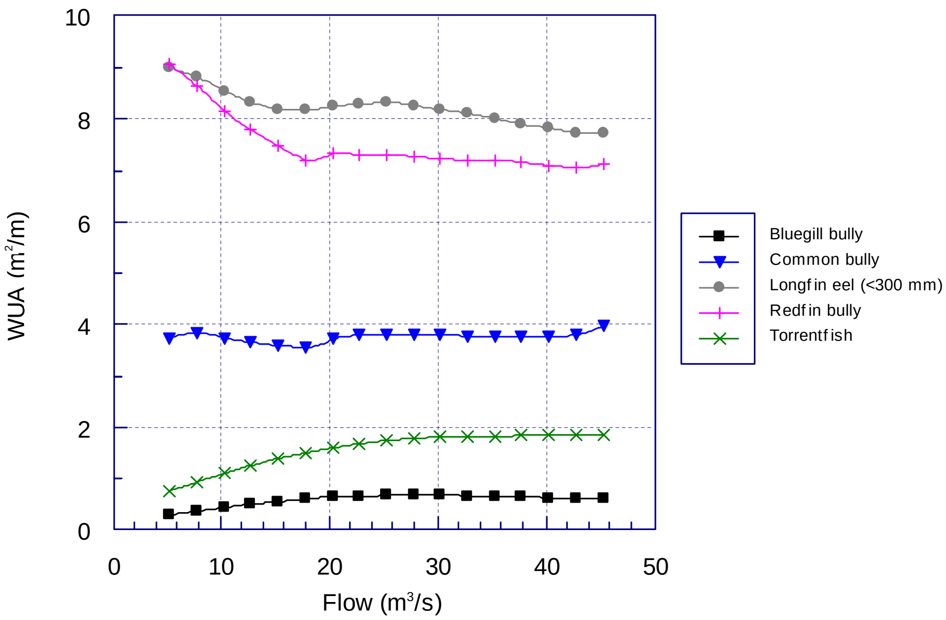


**Figure 3**: Variation of weighted usable area (WUA $m^2$/m) with flow for bluegill bully, redfin bully, common bully, torrent fish and small longfin eels in the Mokihinui River.

6.10 A study of brown trout in New Zealand (Jowett 1992) suggested that brown trout abundance is closely linked to the availability of instream habitat and food. I used habitat suitability curves for adult brown trout feeding (Hayes & Jowett 1994), juvenile brown trout rearing (Raleigh et al. 1986), and benthic invertebrate production (Waters 1976). These criteria are widely accepted as being the most appropriate for New Zealand trout.

6.11 The maximum area of suitable habitat for yearling brown trout occurred at a flow of 10 cumecs (Figure 4). However, the amount of habitat for adult brown trout was greatest at a flow of 30 cumecs and the area of food producing habitat increased with flow up to 45 cumecs at least. The average habitat suitability index began to decline sharply when flows fell below 15–17.5 cumecs (Figure 5), indicating a decline in trout habitat quality when flows fall below about 15 cumecs.

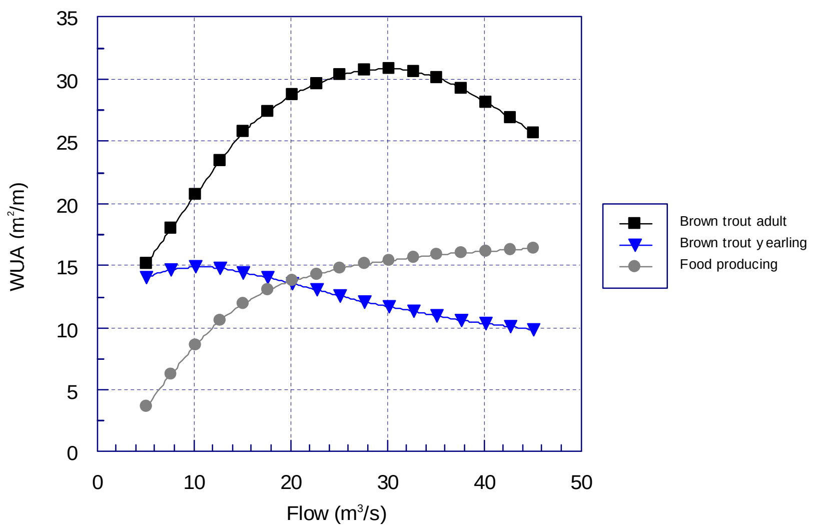


**Figure 4**: Variation of weighted usable area (WUA $m^2$/m) with flow for adult and juvenile brown trout and food production in the Mokihinui River.

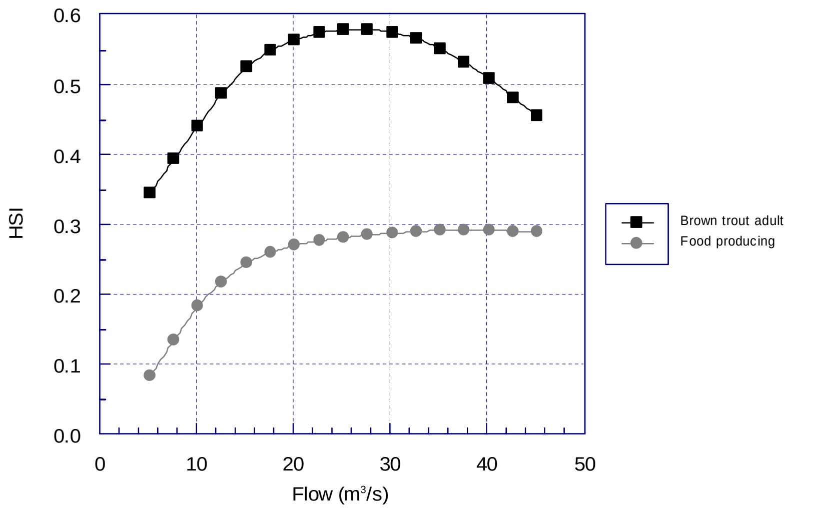


**Figure 5**: Variation of average habitat suitability (HSI) with flow for adult brown trout and food production in the Mokihinui River.

**Benthic invertebrates and periphyton**

6.12 Benthic invertebrates have been sampled in the Mokihinui River at 4 locations below the gorge (Suren et al. 2007). The dominant (>2%) species were *Deleatidium* (39%), *Eukiefferiella* (27%), *Tanytarsus* (6%), *Zelandoperla decorata* (5%), *Beraeoptera roria* (4%), *Helicopsyche* (2%). The average abundance was slightly low with an average density of 1637 per $m^2$ (median density in New Zealand is 2784 per $m^2$, Scarsbrook et al. 2000), but other measures of invertebrate "quality" were high with an average MCI of 113 and 55% EPT. A flood a few days before sampling may have affected invertebrate abundance, but Suren et al. (2007) considered that the effect was probably small. Periphyton biomass (10-50 mg/m$^2$ chlorophyll a) was higher below the gorge than above (Suren et al. 2007). The frequency of floods and the erosive effect of bedload probably result in low periphyton biomass.

6.13 Although the Mokihinui River is similar in size and substrate characteristics to the rivers used by Jowett et al. (1991) to develop the benthic invertebrate habitat suitability curves, curves were not available for all of the common species found in the Mokihinui. However, a comparison of benthic invertebrate densities and water velocity in the Mokihinui indicated that the preferred velocity for the most common benthic invertebrate species was in the range 0.3-0.6 m/s (Suren et al. 2007), and this is consistent with the velocities in the food production and invertebrate suitability curves that I used.

6.14 I calculated the variation in area of suitable habitat (WUA) with flow for eight benthic invertebrate taxa. For most invertebrate species, the area of suitable habitat increased with flow up to 15 cumecs, and then increased more slowly. For the species with the greatest areas of available habitat (*Deleatidium*, *Pycnocentrodes*, *Aphrophila*, Hydrobiosidae and *C. humeralis*), near maximum habitat was provided by flows of 20–30 cumecs (Figure 6).

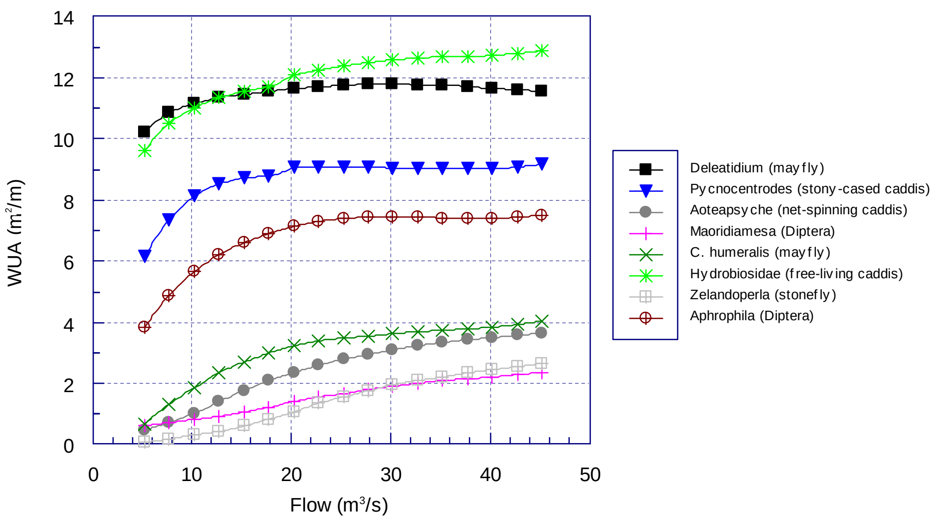

**Figure 6**: Variation of weighted usable area (WUA $m^2/m$) with flow for benthic invertebrate taxa in the Mokihinui River.

6.15 Periphyton habitat suitability criteria were based on unpublished NIWA data. A reduction in flow reduces water velocities and this favours the growth of long filamentous algae rather than the growth of diatoms (Figure 7). This can result in a change in the invertebrate community composition. The proportion of the river wetted area that provided suitable habitat for the growth of long filamentous algae began to increase sharply as the flow decreased below about 12.5 cumecs.

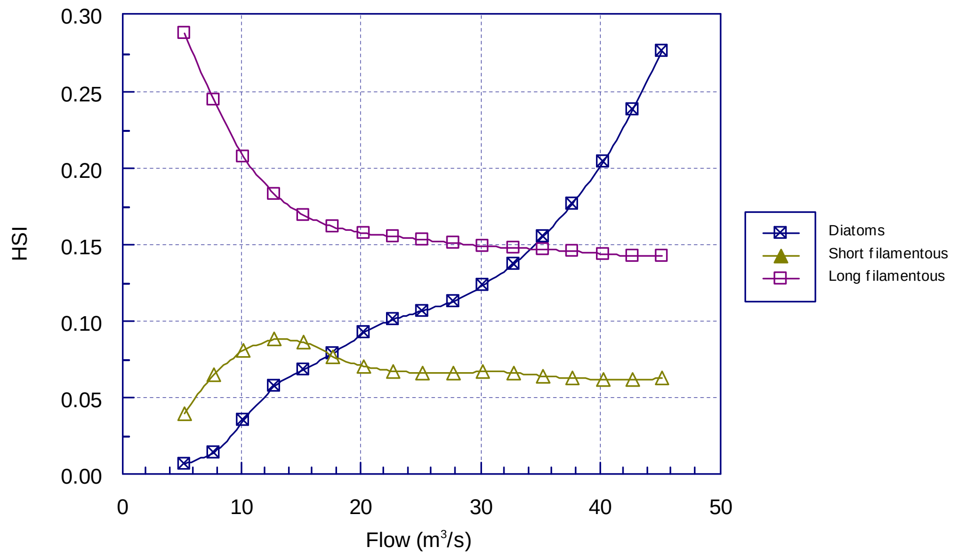


**Figure 7**: Variation with flow of the proportion of wetted river area (HSI) providing suitable periphyton habitat in the Mokihinui River.

## 7. ACTUAL AND POTENTIAL EFFECTS OF MHP ON INSTREAM HABITAT

7.1 The selection of appropriate flow regime requirements is a matter of judgement, where the habitat requirements and perceived values of the different species must be considered. Any potential effects on the aquatic environment need to be weighed against the benefits derived from flow fluctuations for power generation. Flow regime recommendations are necessarily a compromise between species, and are usually made to prevent a sharp decline in habitat for most species or to retain a percentage of the maximum habitat, thus aiming to retain some habitat for all species that make up the aquatic community.

7.2 The proposed power station would have two main turbines capable of a combined maximum discharge of 120 cumecs. Mr Henderson and Mr Watts describe the river flows and generation patterns in their evidence. Generally, when the inflows to the lake are high, the generators would run continuously with any excess water discharged over the spillway. When inflows are low, minimum flows would be generated. Maximum flow fluctuations between the proposed minimum flow of 16 cumecs and the maximum machine discharge of 120 cumecs would occur with intermediate inflows. The natural flow regime of the Mokihinui is characterised by frequent floods and this would be substantially unchanged by power development because the limited storage capacity of the lake created by the dam will be unable to regulate the volume of water associated with a flood, as described by Mr Henderson.

**Minimum flow**

7.3 I consider the habitat requirements of most aquatic species present in the river when assessing the effects of a minimum flow. I usually select minimum flows so that they prevent a serious decline in habitat. This is the breakpoint or flow below which habitat declines sharply. If the flow is likely to be at that minimum frequently, I usually recommend flows closer to the optimum.

7.4 Low flows can limit the amount of available habitat and it is often assumed that frequently occurring low flows will limit fish populations. The mean annual low flow has been used as a measure of frequently occurring low flows for long-lived fish species (e.g., Jowett 1992). Other studies have also shown that flood flows can limit trout populations, with minor floods during incubation or rearing causing high mortality (Hayes 1995; Nehring and Miller 1987) and large floods causing devastation (Jowett and Richardson 1989).

7.5 The relationships between WUA and flow in the Mokihinui River show that the mean annual low flow (MALF) of 16 cumecs provides near maximum habitat for the fast water species, torrentfish and bluegill bully, and this flow will also provide habitat along the margins for the fish species that prefer lower water velocities. The MALF also provides near maximum habitat for adult brown trout, yearling trout, food production and benthic invertebrates. The proportion of river suitable for the growth of long filamentous algae also begins to increase sharply as flows fall below the MALF.

7.6 Overall, the MALF and proposed minimum flow of 16 cumecs appears to provide excellent quality habitat for the aquatic species examined.

**Effect of flow fluctuations on water level**

7.7 The water level at each cross-section was calculated for flows of 16 cumecs to 120 cumecs, and then averaged over all cross-sections to an arbitrary datum of 0 m at 16 cumecs (Table 1). This table shows, for example, that a flow change from 16 to 45 cumecs would result in a water level increase of 0.30 m and a velocity increase from 0.37 to 0.72 m/s. A flow change from the proposed minimum flow of 16 cumecs to the proposed maximum generation flow of 120 cumecs would result in the water level rising by 0.64 m, with a larger rise where the river is confined, such as at the Chasm Stream confluence, and a smaller rise (about 0.2-0.3 m) near the State Highway bridge.

Table 1: Average water level above an arbitrary datum of 0 m at 16 cumecs for flows of 16 to 120 cumecs.

| Flow (cumecs) | Water level (m) |
|---|---|
| 16 | 0.00 |
| 25 | 0.12 |
| 35 | 0.22 |
| 45 | 0.30 |
| 55 | 0.36 |
| 65 | 0.42 |
| 75 | 0.47 |
| 85 | 0.51 |
| 95 | 0.55 |
| 105 | 0.59 |
| 120 | 0.64 |

**Effect of flow fluctuations on biota**

7.8 Flow fluctuation is the term used to describe flow variations that result from controlled flows. The rate at which controlled flows are changed is known as the ramping rate.

7.9 The Mokihinui River experiences frequent and rapid flow variation as a result of its exposure to prevailing westerly winds and high rainfall frequency as discussed in the evidence of Mr Henderson. Boulders form the dominant substrate in the lower part of the river and there is a wide channel. Artificial flow fluctuations will probably have less impact on West Coast rivers that experience frequent flow variations than on rivers with more stable flow regimes. At low flows, low velocity runs are the dominant type of habitat and these provide shelter for adult trout.

7.10 I have recently reviewed the available information on short-term flow fluctuations and the considerations that should be given to flow fluctuations with respect to aquatic ecosystem and biodiversity values.

7.11 Flow fluctuations cause changes in water depth and velocity and these can have physical and biological effects, the magnitude of which will depend primarily on the extremes of the hydraulic conditions relative to normal hydraulic conditions.

7.12 My review of international literature showed that the effects of artificial flow fluctuations on aquatic ecology can be variable and probably depend on the magnitude of fluctuations and associated hydraulic conditions. The most frequently reported effects are on benthic invertebrate drift and density, juvenile salmonid stranding, and juvenile salmonid displacement. The fluctuating flows also result in a varial zone, the area intermittently inundated by flow fluctuations as I describe later, and that this will reduce the overall benthic productivity of the river, but not necessarily the density of organisms outside of the varial zone.

7.13 There is limited New Zealand research on the effects of artificial flow fluctuations, but measurements of the biotic condition of rivers with frequent flow fluctuations suggest that flow fluctuations less than twice the mean flow maintain good invertebrate densities providing the minimum flow maintains good habitat. Fish surveys below the Waitaki Dam indicated that there were high densities of native fish, trout and benthic invertebrates despite large flow fluctuations (Jowett 2006).

7.14 Flow fluctuations reduce invertebrate habitat and this may affect trout, but not native fish. Jowett (1992) showed that benthic invertebrate density was the single most important factor affecting brown trout density. Jowett et al. (1996) showed that juvenile brown trout density was related to benthic invertebrate density, but failed to find any such relationship for native fish. Presumably, this was because native fish can be sustained in less productive streams than trout and do not require the high benthic invertebrate densities that trout seem to prefer.

7.15 Trout are adaptable and feed on a variety of food sources, and drift-feeding on invertebrates is not the only method of feeding. In pools, they also browse on insects on the stream bed and prey on smaller fish. Flow fluctuations could provide drift-feeding habitat at the high flows and pool habitat for resting, browsing or predation at low flows.

7.16 During the instream habitat survey of the Patea River, I observed that there were good native fish and trout populations despite average daily flow fluctuations from 2 to 22 cumecs and maximum fluctuations of up to 50 cumecs. I attributed the good quality of the habitat and fish population to the low gradient which resulted in deep wide runs and pools at low flows and low hydraulic stresses during flow fluctuations.

7.17 The habitat loss caused by flow fluctuations depends on the degree of flow fluctuation and habitat preferences of the species. The loss can be evaluated for different fluctuating flow scenarios. The assumption is that if there were no fluctuations the flow would be relatively steady at some flow (“baseflow”). Flows also fluctuate naturally and this leads to some natural habitat ‘loss’ compared to a steady flow.

7.18 I assumed that a daily flow fluctuation of 30 cumecs from the minimum flow of 16 cumecs to the median flow of 46 cumecs would be a reasonable scenario to examine for biological effects. Fluctuations below the median flow were used because these were considered to be the most biologically productive because low flows persist for longer than higher flows that are caused by freshes.

7.19 I compared habitat with flow fluctuation to the habitat at a steady flow of 31 cumecs. I assumed that the invertebrates were not affected by increases in water depth, but would be affected if velocities were too high or low or if the bed were exposed.

7.20 I found that fluctuation results in a reduction of 20–60% of potential invertebrate habitat, depending on the species (Figure 8). Part of the reduction in habitat is because there is 8% less wetted area at 16 cumecs than at 31 cumecs (Figure 6). This is the effective varial zone that would be colonised under steady flow. The greatest reduction occurred for *Zelandoperla*, *C. humeralis* and *Aoteapsyche* because these species are found in relatively high water velocities and there is little high velocity habitat at the low flow. There was a lower reduction (20%) for *Deleatidium* and Hydrobiosidae. A flow fluctuation between 16 and 46 cumecs changes the river average width by 7 m.

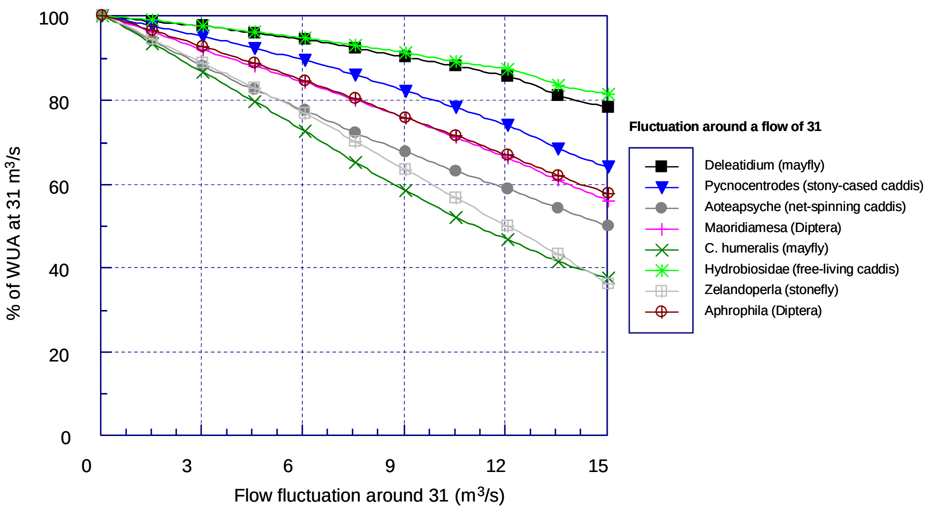


Figure 8: Percentage of habitat retained with flow fluctuations from a minimum flow of 16 cumecs to the median flow of 46 cumecs around a flow of 31 cumecs.

7.21 Habitat loss can also be compared to the habitat available at the mean annual minimum flow (16 cumecs), assuming that there are daily flow variations above this. A 30 cumecs flow variation up to the median flow (46 cumecs) was evaluated (Figure 9). This flow fluctuation resulted in 10% or less habitat loss for most species and a loss of just under 20% for *Pycnocentrodes*.

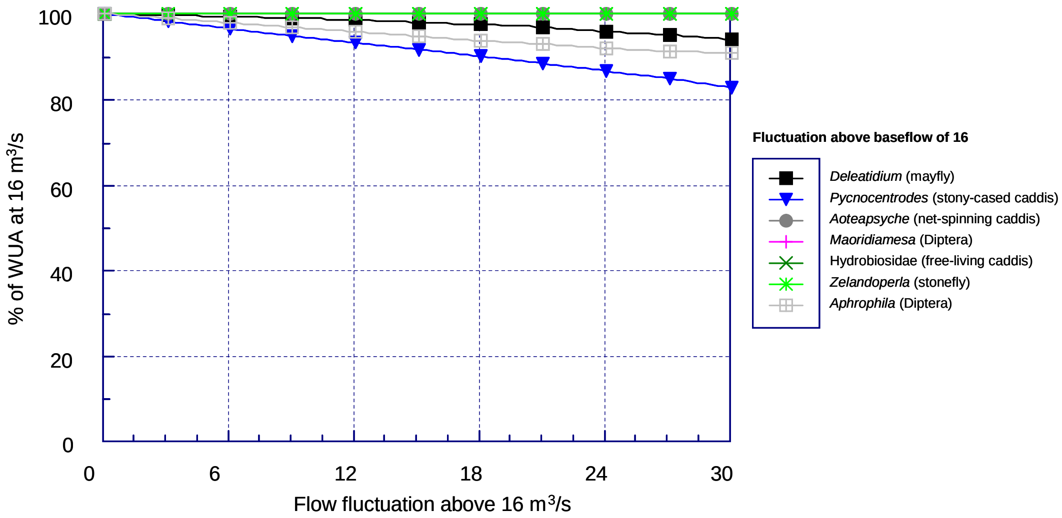


Figure 9: Percentage of habitat retained with flow fluctuations from a minimum flow of 16 cumecs to the median flow of 46 cumecs above a flow of 16 cumecs.

7.22 Flow variations greater than those modelled would increase habitat loss. However, the reduction in invertebrate production may not have a detrimental effect on native fish and trout. This issue is discussed in more detail in the evidence of Mr Bonnett and Dr Hayes.

**Whitebaiting**

7.23 The magnitude and timing of daily flow fluctuations would affect whitebaiting below the SH bridge. Whitebaiters catch whitebait when the combination of tide and river flow encourages whitebait to swim upstream close to the banks. Whitebait are believed to move upstream mainly during the day and fishing is restricted by legislation to daylight hours. Most whitebait are caught on a rising tide during the day. If the flow fluctuation peak flow overwhelms the incoming tidal current, whitebait will not be able to swim against the current. If the flow fluctuation minimum is too low, whitebait may be able to swim in the centre of the river and would avoid the whitebaiter's nets. Although some combinations of flow and tide might improve whitebaiting, others will be detrimental.

7.24 Because there is no clear method of avoiding any detrimental effects, any potential adverse effects of whitebait migrating behaviour and whitebaiting will be avoided by ensuring that flow fluctuations remain as natural as practicable during the whitebait season from 01 September to 14 November. During this period, Meridian intends that the outflow from the lake matches inflows as closely as practicable. In effect, the flows will be similar to those that would be experienced naturally without a dam. Mr Watts describes how this will be achieved in the operation of the dam.

**Ramping rates**

7.25 Ramping rates are often restricted for public safety and to prevent bank erosion, but do not appear to affect fish stranding. Observations of the effect of a sudden flow change below the Waitaki Power stations indicated that fish did not become stranded by a sudden reduction in flow, although they can become isolated in pockets of water (Strickland et al. 2002).

7.26 Some flow attenuation will occur, as river storage reduces the rate of change of flow. However, because the distance between the dam and the sea is relatively short, any effective flow attenuation will probably be small. However, stage attenuation will occur as the river increases in width. This is discussed further in the evidence of Dr Goring.

7.27 Public safety may be more of an issue than biological effects. Upstream of the SH 67 bridge a flow change of 10 cumecs would cause a water level change of 0.04–0.14 m depending on the flow at the time. Fluctuations from a minimum of 16 cumecs to 60 cumecs would cause a level rise of 0.4 m, and fluctuation from 16 cumecs to maximum discharge of 120 cumecs would cause a rise of 0.64 m.

7.28 Mr Watts describes in his evidence the procedure that Meridian proposes for restricting ramping rates. He proposes that in Summer flows can double and then be held constant for 45 minutes for flows of up to 32 cumecs and for 30 minutes for flows up to 120 cumecs. Thus, flows could increase from the minimum of 16 cumecs to 32 cumecs and then be held at 32 cumecs for 45 minutes before any further increase. Mr Watts shows an example of how flows could be increased in stages from

16 to 120 cumecs. Table 1 in my evidence shows the average level changes that would accompany these flow changes in the instream habitat survey reach and Dr Goring presents water level changes for individual cross-sections. The proposed summer ramping rates will cause the water level in the instream habitat survey reach to increase by up to 0.23 m in 45 minutes at flows of up to 32 cumecs and by about 0.23 m in 30 minutes for higher flows.

7.29 Mr Watts suggests winter ramping rates that allow the flow to change by 175%, with the flow being held constant for 45 minutes before any further increase. This could result in changes from 16 to 44 cumecs, followed by a further increase from 44 to 120 cumecs after 45 minutes, as shown in Mr Watts' evidence. The proposed ramping rate would increase water levels in the instream habitat survey reach by 0.29 m and 0.35 m per 45 minutes, respectively.

7.30 These are average water level changes. There will be larger rises where the river is confined and smaller rises where it is wider and Dr Goring presents level changes at individual cross-sections. The effect of flow changes will be much less noticeable below the SH67 bridge due to dissipation of water level rise with a widened river channel and the tidal influence on water levels.

7.31 Signage, as described in Mr Watts' evidence, will be erected to indicate that potential rises of up to 0.64m could occur.

7.32 As described in the evidence of Mr Henderson, for the summer ramping rate of rise is exceeded in 35%, 42% or 48% of events. That is, one third to one half of events in the river have rates of rise larger than the proposed summer rate. For the winter rate (equivalent to 139 cumecs/hr), this rate of rise is exceeded in 25%, 30% or 35% of events. That is, one quarter to one third of events in the river have rates of rise larger than the proposed winter rate.

**Bank erosion, floods and sediment transport**

7.33 Potential bank erosion caused by artificial flow fluctuations will not be a problem below the dam because the river flows in a wide flood channel armoured by boulders and cobbles.

7.34 The relatively small lake area and storage range of the proposed dam means that flood magnitudes will be substantially unmodified and that the frequency of floods and freshes will be similar to the present situation as described in the evidence of Mr Henderson. During these floods and freshes, the rates of change of flow and water level are high. Thus, there should be no requirement for flushing flows or channel maintenance flows.

7.35 Dr Hicks describes how the dam will retain sediment and thus reduce the supply of sediment in the river down stream. This will remove finer sediment from the surface armour, so that on average, and over a long time, the substrate will be coarser, more uniform, and more stable than the existing bed surface. The coarsening will be most noticeable on flood berms where fine sediments are presently deposited by floods. In the main channel, the most noticeable effect will be the absence of small pockets of fine sediment within or behind larger boulders and cobbles. However, the substrate will be primarily boulders and cobbles, as it is now, but possibly with less gravel. From a biological point of view, any change in substrate composition will have a minor beneficial effect on habitat quality because fish and benthic invertebrate species prefer coarse substrate.

7.36 The river appears to transport large quantities of sand derived from the erosion of granite in the catchment. This would have a negative effect on benthic invertebrates. The percentage of sand on the river bed was a negative factor in the model of abundance that I developed (Jowett 1992). I considered that the presence of sand probably reduced the invertebrate food supply for trout. The construction of a reservoir would trap sand and fine gravel coming from the upper part of the catchment, and this is likely to have a beneficial effect on benthic invertebrate production and trout density below the dam.

7.37 The creation of a reservoir could promote the growth of large plankton that when carried downstream as organic seston provides a source of food for benthic invertebrates. However, the residence time in the lake will be small and the downstream effect of increased supply of organic seston on benthic invertebrate density is debatable. Although this is a potentially beneficial effect, I do not think it is likely to be a significant effect.

**Summary**

7.38 In summary, the proposed minimum flow of 16 cumecs will provide excellent quality habitat for the aquatic species examined. However, the proposed daily flow fluctuations will reduce benthic invertebrate production and total numbers because benthic invertebrates will not be able to colonise the area that is alternatively wetted and dried by the flow fluctuations (the varial zone).

7.39 The effect of reduced invertebrate production on trout is uncertain because any reduction in invertebrate density would be moderated by the degree to which other food sources are available, the improvement in production resulting from less sediment transport, and whether there is sufficient recruitment to sustain high trout numbers.

## 8. ISSUES RAISED BY SUBMISSIONS

8.1 Ms Inta raises the issue of the effect of reduced benthic invertebrates on long-tailed bats. Long-tailed bats are present in the Mokihinui gorge. They feed exclusively on flying insects caught on the wing. Their natural habitat is indigenous forest, but they have adapted to modified habitats in many parts of the North Island especially pine forest. They roost in a wide variety of cavities, usually in trees but also caves. They would not be affected by a reduction in benthic invertebrate production in the river below the dam because they do not appear to live below the gorge and because their numbers are so low that they are unlikely to be limited by benthic invertebrate densities.

8.2 The NZ Federation of Freshwater Anglers claim that the Mokihinui is a well known sea run brown trout fishery, although Dr Hayes failed to find any evidence of extensive movement between the headwaters and downstream reaches. Sea run trout are usually estuarine and native fish are a large component of their diet. They will not be affected by the reduction in benthic invertebrate biomass.

## 9. CONCLUSION

9.1 The river below the proposed dam contains a diverse fish community, as would be expected at a low elevation site close to the sea. A minimum flow of 16 cumecs (the mean annual low flow) will maintain near maximum habitat for native fish, many benthic invertebrate species, food production and adult and yearling brown trout. This flow would also limit the growth of long filamentous periphyton, which would also be kept in check by the frequent floods and freshes.

9.2 Daily flow fluctuations below the proposed dam would reduce benthic invertebrate habitat and food production, but would not have any significant effect on native fish or trout habitat because they can move with changing flow and stranding is unlikely. The reduction in food production could have a minor effect on the trout population, but alternative food sources, such as forage fish, are available and may compensate for any reduction in benthic invertebrates.

9.3 The magnitude and timing of daily flow fluctuations might affect whitebaiting below the SH bridge. The extent to which this would be beneficial, detrimental, or neutral to whitebaiters is unknown and because of this run of the river flows are recommended during the whitebait season to avoid adverse effects on whitebaiters.

9.4 Flow variability, including flushing flows and channel maintenance flows, is usually considered necessary to maintain aquatic ecosystems in good condition by scouring accumulated fine sediments and periphyton. Natural floods and freshes will still occur at frequent intervals and will be capable of maintaining clean river gravels and the present morphology.

9.5 In my opinion, the proposed minimum flow will provide near optimum habitat and considering the natural frequency of flow variations and the effects of daily flow fluctuations, there seems no compelling ecological or geomorphological reason to restrict flow fluctuations or ramping rates except during the whitebaiting season. However, as described by Mr Watts, Meridian proposes to restrict ramping rates to safeguard river users.

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