

**IN THE SPECIAL TRIBUNIAL**

In the matter of **THE RESOURCE MANAGEMENT ACT 1991**

And in the matter of **AN APPLICATION FOR A WATER CONSERVATION  
ORDER PURSUANT TO SECTION 201 OF THE ACT**

And in the matter of **THE PROPOSED NATIONAL WATER CONSERVATION  
(HURUNUI) ORDER APPLICATION**

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**STATEMENT OF EVIDENCE OF MAURICE JOHN DUNCAN**

**Dated 23 March 2009**

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**BUDDLE FINDLAY**  
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## **1.1 Introduction**

1.2 My name is Maurice John Duncan. I am a surface water hydrologist employed by the National Institute of Water and Atmospheric Research Ltd (NIWA) based in Christchurch.

1.3 The purpose of my evidence is to summarise hydrodynamic modelling and instream habitat assessment work I have done on the Hurunui River:

- (a) Establishing minimum flows for a number of instream uses.
- (b) Establishing how flow rates affect the periphyton types in the river.
- (c) Establishing the relationship between flow rates and the number and area of islands suitable for riverbed-nesting birds.
- (d) Establishing minimum flows for B Block allocations so the minimum flows enhance instream values.
- (e) Discuss the effect of a change in minimum flow from  $20 \text{ m}^3\text{s}^{-1}$  to  $40 \text{ m}^3\text{s}^{-1}$  during September to December on available physical habitat and habitat quality and the implications of the change on reliability of supply.

## **2. Background and qualifications**

2.1 I hold the qualification of Master of Agricultural Science in Agricultural Engineering from Lincoln University.

2.2 I am a member of the New Zealand Hydrological Society, the New Zealand Freshwater Sciences Society, the New Zealand Institute of Agricultural Science and the New Zealand Soil Science Society.

2.3 I have been employed by the National Institute of Water and Atmospheric Research and its predecessor organisations for 40 years. I am currently employed as a Senior Scientist in the field of surface water hydrology. My recent experience is with hydrodynamic modelling, the effects of hydrological flow regimes on instream values and the effects of land-use change on hydrology. I have modelled the Rangitata, Waimakariri, Hurunui and Waiau Rivers and I have derived relationships between flow and instream values for these rivers.

2.4 Before the Rakaia River Water Conservation Order hearing I co-authored a paper on the relationship between flow in the Rakaia River and the instream habitat for juvenile salmonids and native fish. (Glova and Duncan 1985). I also presented data on the Rakaia River water resources at the Rakaia River Water Conservation Order hearing.

2.5 I also have 15 years experience of on-farm irrigation scheduling.

2.6 I have read the Environment Court's "Code of Conduct for Expert Witnesses" and agree to abide by it.

### **3. The Hurunui River 2D hydrodynamic model.**

3.1 My evidence is a summary of a number of my reports prepared for Environment Canterbury (ECan) that are in the public domain.

### **4. The IFIM approach to setting minimum flows**

4.1 The minimum flows for the Hurunui River have been set primarily on the basis of methods based on the instream flow incremental methodology (IFIM). According to a review by the Environment Agency in the United Kingdom on river flow objectives, "Internationally, an IFIM-type approach is considered the most defensible method in existence" Dunbar et al. (1998).

4.2 Jowett et al. (2008) review six case studies involving trout, benthic invertebrate and indigenous fish communities where minimum flow and flow regime recommendations were made and implemented. In most of these cases minimum flows were increased based on IFIM analysis. As a result of the change in flows there were resulting increases in trout numbers, angling success, invertebrate numbers and favoured taxa.

4.3 Jowett et al. (2008) also document the relationship between adult trout biomass and various environmental variables. The quality of brown trout habitat at mean annual low flow was more closely related to trout numbers than the habitat available at higher flows. The quality of habitat for food production (benthic invertebrate habitat) at median flow was more closely related to trout numbers than the amount at either low or mean flow.

4.4 I conclude from this work that an IFIM approach to set minimum flows is sound and scientifically defensible.

4.5 Much of the IFIM based flow setting has been for small or single thread rivers where 1 dimensional (1D) modelling has been used. That is, the

modelling is based on the depths and velocities at representative river cross-sections that are extrapolated up and down the river. Where there is a high degree of hydrological alteration and medium or high significance of instream values or for hydraulically complex rivers, e.g., braided rivers 2D models are considered appropriate (MFE 2008, Beca 2008). Two-dimensional models predict the depth and depth averaged velocity for a large number of locations all over the model area. In the Hurunui River model a 1 metre square grid has been used. Two-dimensional models are explained in more detail later in my evidence.

## **5. The representativeness of the study reach**

- 5.1 The work I am going to refer to now is fully detailed in Duncan and Shankar (2004).
- 5.2 The critical reach for salmon passage is the reach between the State Highway 7 Bridge and the Pahau River confluence, because the greatest abstraction occurs upstream of this reach and this reach is more braided than further upstream and so likely to be shallower. The Pahau River adds up to  $4 \text{ m}^3\text{s}^{-1}$  during the irrigation season, so the reach downstream from there is less critical.
- 5.3 The reach chosen to be modelled was a 1.2 km long reach of the Hurunui River 1 km downstream of the State Highway 7 Bridge. To test whether the study reach was representative, braiding intensity and wetted width at a flow of about  $46 \text{ m}^3\text{s}^{-1}$  was measured on aerial photographs every 125 metres from State Highway 7 Bridge to the Lowry Peaks gorge (about 25 km). The total reach was divided into 10 sub-reaches and the study reach had a wetted width very close to the average for all reaches and close to the average number of braids.
- 5.4 A riffle depth survey to identify the critical (shallowest) riffle was carried out from the study reach to 17 m upstream. Flow on the day was gauged at  $13.5 \text{ m}^3\text{s}^{-1}$  and the shallowest riffle of the 36 measured was 0.25 m deep about 9 km upstream of the study reach.
- 5.5 Is the study reach long enough to adequately represent the river? Jowett et al. (2008) report flow vs weighted useable area (WUA, a measure of physical habitat) relationships for the Hurunui River where the study reach was divided in to 2, 3 and 4 reaches of equal length. While the WUA (for juvenile and adult brown trout) varied between sub-reaches when there

were 2 and 3 sub-reaches, the variation of habitat with flow was similar between each sub-reach and similar to the single full length reach. However, when the reach was divided into 4 reaches the differences between sub-reaches became more noticeable.

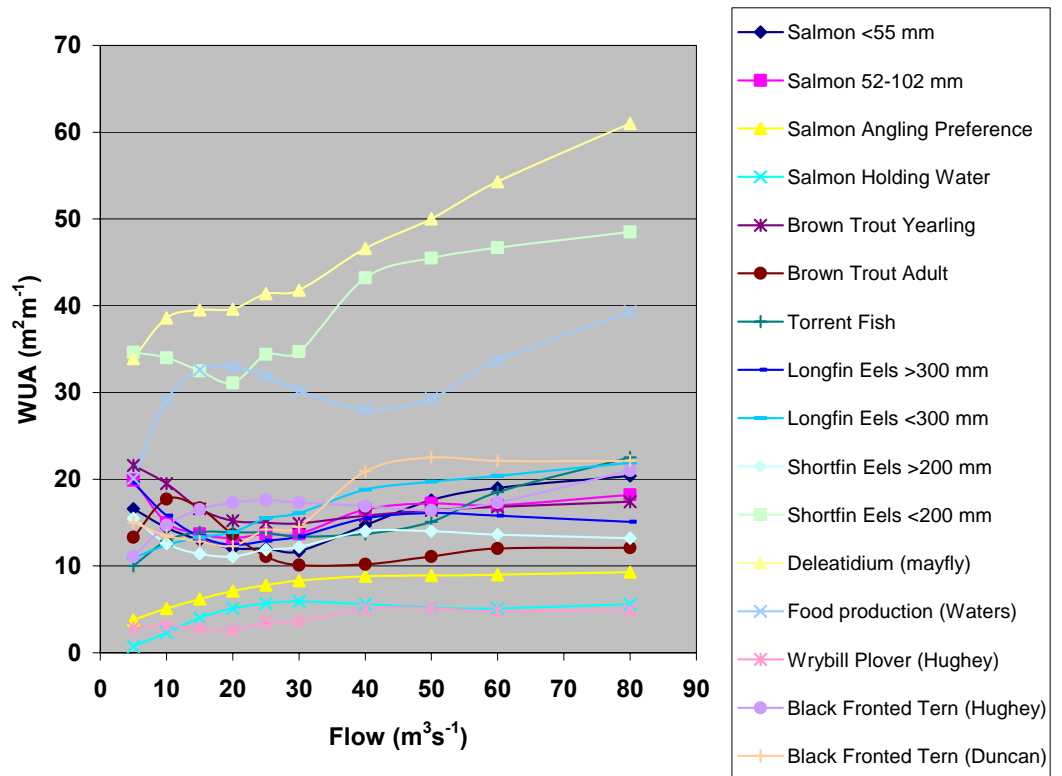
- 5.6 I conclude that the 2D model study reach is representative of most of the Amuri Plain reach of the Hurunui River and is long enough to provide a robust relationship between flow and physical habitat.

## **6. The 2D hydrodynamic model.**

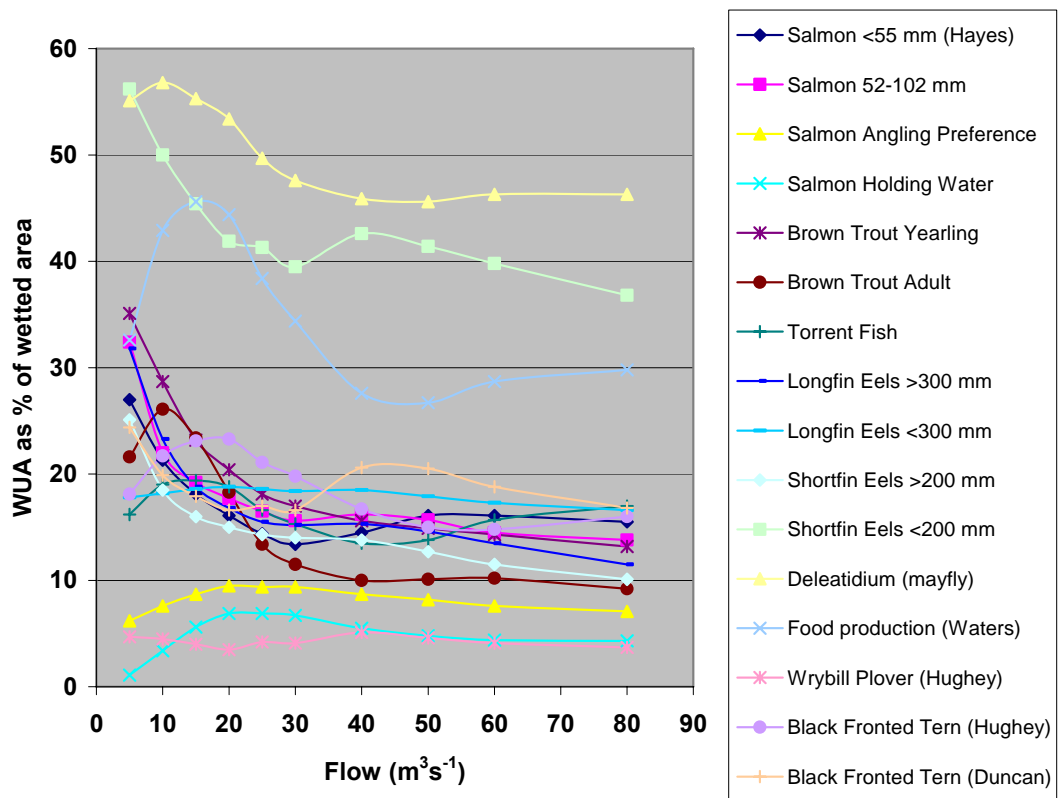
- 6.1 Two dimensional hydraulic models are the recommended method to be used in the assessment of ecological flow requirements where the degree of hydrological alteration is high the instream values are of medium or high significance or for hydraulically complex rivers, e.g., braided rivers (MFE 2008, Beca 2008).
- 6.2 A two dimensional (2D) model is one where the depth and average velocity of the water is predicted for each grid location in the model domain. For the Hurunui River there was a 1 metre square grid and the model domain is 1295 m by 604 m.
- 6.3 The topography for the 2D hydrodynamic model was prepared from a digital elevation model on based on vertical aerial photography of scale 1:4000. The topography of the wet bed was captured by wading shallow water with a pack mounted GPS. Where the water was too deep to wade the topography was measured from a jet boat or dinghy with GPS located echo-soundings.
- 6.4 A 1 m square grid for the 2-D hydrodynamic model was obtained by sampling a digital elevation model compiled from the topographic information. The model was run at 10 different flows from 5 to 80 m<sup>3</sup>s<sup>-1</sup>.
- 6.5 The modelled braiding patterns reflected the braiding patterns of vertical aerial photographs taken at 2 different flows. Comparisons of modelled and measured depths and velocities showed that depths were adequately modelled, but there was a tendency for cross-sectional variation in velocity to be smoothed.

## **7. The change of physical habitat with flow for fish and birds**

7.1 Weighted useable area (WUA) is a measure of potential physical habitat. Flow vs WUA plots for species/life stages and recreational pursuits were compiled from the depths and velocities produced by the model and habitat suitability curves available from the New Zealand and North American literature. The flow vs WUA plots are shown in Figure 1. Flow vs WUA/wetted width plots (WUA %), a measure of habitat quality, are shown in Figure 2.



**Figure 1. Composite of flow vs weighted useable area (WUA) for each species /life-stage.**



**Figure 2. Composite of flow vs weighted useable area (WUA %) for each species /life-stage.**

7.2 The optimum flow for each species/life stage was assessed. This was based on both the relationship between flow and WUA and flow vs WUA/wetted width. The latter is a measure of habitat quality. Also, habitat available at high flows is usually discounted as it is often transient due to flow variability, so cannot be fully used by periphyton and invertebrates because they do not have time to build up their biomass to exploit it. Table 1 shows optimum flow for each species/life stage based on both the flow vs WUA and flow vs WUA/wetted width curves.

**Table 1: Optimum flows derived from flow vs WUA curves.**

<b>Species/ life stage</b>	<b>Flow for maximum WUA (m<sup>3</sup>s<sup>-1</sup>)</b>	<b>Most efficient flow (m<sup>3</sup>s<sup>-1</sup>)</b>	<b>Optimum flow (m<sup>3</sup>s<sup>-1</sup>)</b>
Salmon <55 mm (Hayes)	50	5	<10
Salmon 52-102 mm (Hayes)	<5	5	<10
Salmon Angling Preference	80	15-40	>25
Salmon Holding Water (Raleigh)	30	20-30	>20
Brown Trout Yearling	<5	5	<10
Brown Trout Adult (Hayes & Jowett)	10	10-15	10-15
Torrent Fish	80	10-20	10-30
Longfin Eels >300 mm	<5	5	5-80*
Longfin Eels <300 mm	80	5-70	5-80*
Shortfin Eels >200 mm	<5	5	5-80*
Shortfin Eels <200 mm	80	5	5-80*
Deleatidium (mayfly) Jowett	80	5-25	10-30
Food production (Waters)	80	10-20	10-30
Wrybill Plover	40	5-10	40
Black Fronted Tern (Hughey)	80	10-25	15-40
Black Fronted Tern (Duncan)	50	5	>40*

\* Indicates that there was little response of WUA to flow

7.3 Table 2 suggests alternative monthly minimum flow regimes dependent upon different management objectives.

7.4 There is sufficient water depth (0.25 m) for adult salmon to traverse the study reach at 10 m<sup>3</sup>s<sup>-1</sup> and they could probably traverse the reach when the flow was 5 m<sup>3</sup>s<sup>-1</sup> but water depths in some riffles would be less than ideal. When the flow was 13.5 m<sup>3</sup>s<sup>-1</sup> all the riffles surveyed over a 17 km long reach were at least 0.25 m deep.

**Table 2: Alternative minimum flow regimes. The reason for the level of the minimum flow is given in brackets.**

Month	Minimum flows to protect-life supporting capacity and passage for salmon, kayaking and jet-boating (m <sup>3</sup> s <sup>-1</sup> )	Minimum flows if in addition to column 1, the	
		objective is to maintain good protection from predators for birds nesting on islands (m <sup>3</sup> s <sup>-1</sup> )	Minimum flows if in addition to column 1 the objective is to protect salmon angling amenity (m <sup>3</sup> s <sup>-1</sup> )
Jan	15 (boats)	20 (birds)	20 (salmon angling)
Feb	15 (boats)	15 (boats)	20 (salmon angling)
Mar	15 (boats)	15 (boats)	20 (salmon angling)
Apr	15 (boats)	15 (boats)	20 (salmon angling)
May	10 (salmon passage)	10 (salmon passage)	10 (salmon passage)
Jun	10 (life support)	10 (life support)	10 (life support)
Jul	10 (life support)	10 (life support)	10 (life support)
Aug	10 (life support)	10 (life support)	10 (life support)
Sep	15 (boats)	20 (birds)	15 (boats)
Oct	15 (boats)	20 (birds)	15 (boats)
Nov	15 (boats)	20 (birds)	15 (boats)
Dec	15 (boats)	20 (birds)	20 (salmon angling)

7.5 Both canoes and jet boats should be able to traverse the river when it is flowing at 10 m<sup>3</sup>s<sup>-1</sup>, but jet boat drivers would require a high degree of skill to avoid the cobbles that protrude from the bed and present a shallower passage for navigation than the modelled depths. At a flow of 15 m<sup>3</sup>s<sup>-1</sup> minimum thalweg depths exceed 0.3 m and should allow trouble free passage for kayakers and jet-boaters with average ability. However, kayakers may prefer higher flows because their paddles usually go into the water further than is required to float the kayak.

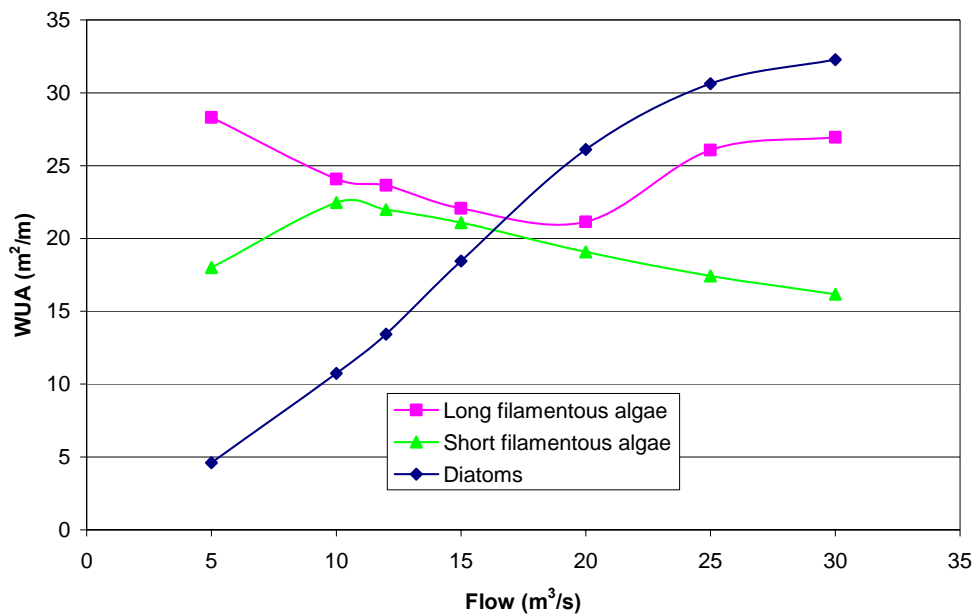
## 8. The change of physical habitat with flow for periphyton

8.1 The work I refer to is detailed in Duncan (2007).

8.2 In 2005, Environment Canterbury (ECan), in the process of considering a flow regime for the Hurunui River, became interested in the potential effects on long filamentous algae of predicted increased inflows of high nutrient water from intensive irrigated agriculture of the Amuri Plain to the Hurunui River.

8.3 I used output from the 2-D hydrodynamic model to develop the responses of long filamentous algae, short filamentous algae and diatoms to different flows. An extra model run was carried out to predict depths and velocities for a flow of  $12 \text{ m}^3\text{s}^{-1}$ .

8.4 The WUA response to increases in flow varies with the type of algae. WUA for filamentous algae tends to decrease as flow increases but tends to increase with for diatoms as is shown in Figure 3. The increase in WUA for long filamentous algae at flows greater than  $20 \text{ m}^3\text{s}^{-1}$  is because there is more slow flowing edge habitat as the number of braids increases as flow increases.



**Figure 3:** WUA for three types of periphyton at flows between  $5\text{-}30 \text{ m}^3/\text{s}$  in the Hurunui River predicted from a 2-D hydrodynamic model.

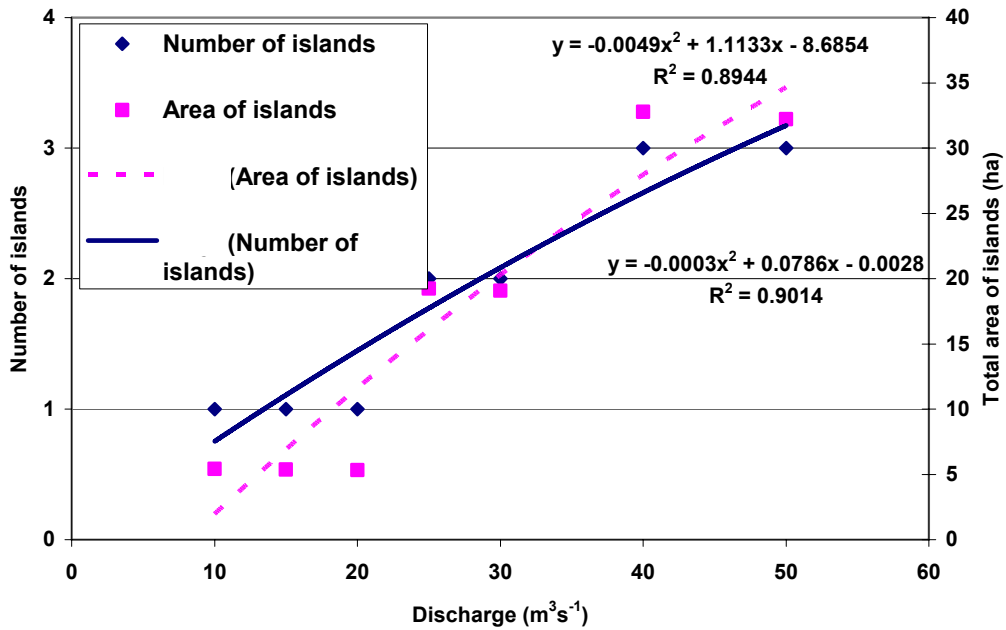
8.5 Maps of WUA show that long filamentous algae habitat is confined to edge habitat of the main stem and minor side braids. Thus it would appear that the flow conditions for the main stem are too vigorous to sustain long filamentous algae.

8.6 There is potential for a dominance shift from filamentous algae to diatoms at flows greater than  $20 \text{ m}^3/\text{s}$ .

8.7 The response of the filamentous algae to flow increases also indicates that they are vulnerable to increases in flow. So if the flow regime included flushing flows they should be successful in the removal of filamentous algae should they become a nuisance.

## **9. The change in the number of islands suitable for riverbed-nesting birds with flow**

- 9.1 The work I am going to refer to now is fully detailed in Duncan (2008) and Duncan et al. (2008).
- 9.2 Research by Boffa Miskell and Urtica Consulting (2007) suggested that provided riverbed-nesting bird mammalian predator populations were under pressure from trapping, the mere presence of water was sufficient to deter them from crossing channels to predate on eggs and chicks regardless of the swimming ability of the predators.
- 9.3 NIWA was contracted by Environment Canterbury to explore the relationship between flow and the number of islands capable of supporting riverbed-nesting birds.
- 9.4 We used the 2D hydrodynamic modelling data that I have referred to earlier in my evidence to explore the relationship between river discharge and the number and area of islands large enough to support nesting.
- 9.5 Over the range of flows from  $10 \text{ m}^3\text{s}^{-1}$  to  $50 \text{ m}^3\text{s}^{-1}$  there is a positive, more or less linear, relationship between the number and areas of islands large enough for nesting (Figure 4). If the relationship was taken higher flows I would expect the relationship to be parabolic like that for the Waimakariri River (Duncan et al. 2008).
- 9.6 The study shows that flows in the range  $30 \text{ m}^3\text{s}^{-1}$ –  $40 \text{ m}^3\text{s}^{-1}$  provide the optimum number and area of islands, and there is a significant reduction in the area and number of islands at flows less than  $25 \text{ m}^3\text{s}^{-1}$ .
- 9.7 The study could be potentially biased by the limited extent of the reach and its braid configuration even though the reach has been shown to be typical.



**Figure 4:** The relationship between flow and the number of islands and their combined area for the modelled reach downstream of the State Highway 7 Bridge.

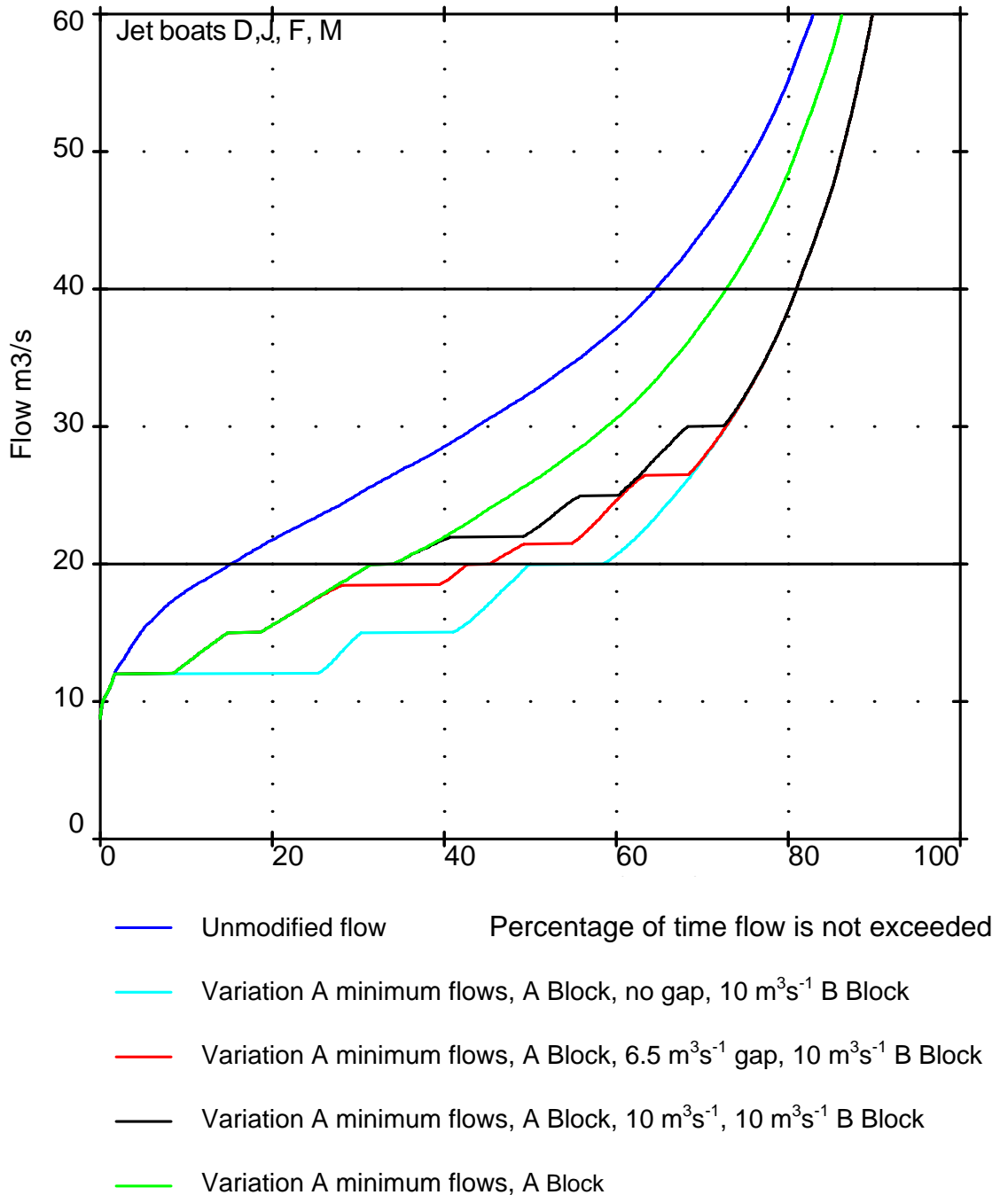
## 10. Hurunui River B Block allocation

- 10.1 Environment Canterbury asked me to assess, for the Hurunui River, the environmental effects of different sizes of B allocation blocks and sizes of flow gaps between the A and B Blocks as part of their review of the minimum flows required by the proposed Natural Resources Regional Plan (NRRP) Policy WQN5.
- 10.2 The A allocation block for the Hurunui River is fully allocated and there are potential applications for a greater allocation from the river. Thus there is a need to explore the effect of various sizes of B/C Block allocations and the sizes of flow gaps between the A and B/C Blocks on environmental values and volumes and reliability of supply of abstractions.
- 10.3 I reviewed community interests on environmental effects of further abstraction allocations and determined that the critical issue was the need to have flows in the range 25-40 m<sup>3</sup>s<sup>-1</sup> during September to December for riverbed nesting bird breeding and to have flows in the range 15-40 m<sup>3</sup>s<sup>-1</sup> during December to May for salmon passage and angling. However, given the small amount of salmon angling away from the river mouth it could be argued that it is unnecessary to provide for this activity. If flows were sufficient for these activities then there would be sufficient flow for kayaks

and jet boats, benthic invertebrates, trout and native fish. I also considered other issues, such as flow regimes to flush periphyton and fine sediment and to need preserve bedload transport and channel forming capacity.

- 10.4 Any flow regime needs to include provision for short term suspension of abstractions to enhance the flushing effects of freshes should algal biomass build up to nuisance levels.
- 10.5 Any allocation regime needs to set limits on the total take to avoid exploitation of the resource for unforeseen uses, e.g., off river storage.
- 10.6 The effects of allocation mechanisms such as abstraction limits, flow sharing and gaps between allocation blocks, on the critical values were discussed and explored. Abstraction limits and gaps between allocation blocks appear to be the most useful mechanism for preserving environmental values.
- 10.7 Flow gaps between the A and B allocation Blocks are a powerful and valuable tool for providing for instream values. That is, separate minimum flows are set for each allocation block. When flows are between the B Block minimum and the B Block minimum plus the B Block allocation, flows are flat lined at the B Block minimum flow. If the B Block minimum flow is set at a flow that provides for a particular value, e.g., salmon passage, then conditions for that value are enhanced. For some values, the combination of the B Block minimum and the B Block allocation could maintain the flow in the favourable range for the value for longer than would occur naturally.
- 10.8 A consequence of providing flow gaps between allocation blocks is to reduce the volume and reliability of supply of takes higher than the B Block minimum flow.
- 10.9 This size of any gap between the A and B Blocks depends on the A Block minimum flow, the size of the A Block allocation and the instream value of interest. Gap sizes can be varied with time to accommodate any changes with time in those variables.
- 10.10 These concepts are probably more easily understood by considering the example shown in Figure 5. In this example it is assumed that people will boat the river during December to March and that a suitable flow range for boating is 20-40 m<sup>3</sup>s<sup>-1</sup>. This flow range is between the two horizontal black lines shown in Figure 5. It can be seen that the option with a 10 m<sup>3</sup>s<sup>-1</sup> gap (the black curve) has more time between the horizontal black lines than the

other options. In this case the gap size could be revised down to about 8  $\text{m}^3\text{s}^{-1}$  and still have the same time in the preferred band. The object of the revision would be to increase the volume and reliability of the B Block abstraction without compromising the time the river was suitable for boating.



**Figure 5:** Flow duration curves for the unmodified flow, an A Block allocation of  $6.2 \text{ m}^3\text{s}^{-1}$  and a B Block allocation of  $10 \text{ m}^3\text{s}^{-1}$  with gaps of 0, 6.5 and  $10 \text{ m}^3\text{s}^{-1}$  between the A and B Blocks for September to December (1957-2007). The optimum flows for jet boats and kayaks are assumed to be those between the two horizontal black lines. Variation A minimum flows are a possible set of minimum flows.

## 11. Comments on the proposals for a Water Conservation Order

### 11.1 Change in minimum flows for 1 September to 31 December

- (a) I understand that the proposals for the WCO include a change in the minimum flow for September to December from 20 m<sup>3</sup>s<sup>-1</sup> to 40 m<sup>3</sup>s<sup>-1</sup>. This section examines the effect on instream values and reliability of supply for abstractors of this proposed change.
- (b) If the minimum flow for this period was changed from 20 m<sup>3</sup>s<sup>-1</sup> to 40 m<sup>3</sup>s<sup>-1</sup> then the physical habitat would change as is indicated in Table 3. There would be large increases in the physical habitat for most species/life stages, much less for brown trout adults and food production as assessed by Water's suitability index and little effect for brown trout yearlings, torrentfish and black-fronted terns. There would also be an increase in the area of islands suitable for riverbed nesting birds of islands greater than 2 hectares from ~5 hectares at 20 m<sup>3</sup>s<sup>-1</sup> to ~32.5 ha at 40 m<sup>3</sup>s<sup>-1</sup>. However, the change in habitat suitability index (HIS)(WUA/wetted width), a measure of habitat quality, decreases for all species/life-stages except for wrybill and fish-feeding black-fronted terns.

**Table 3: Percentage change in availability of physical habitat and habitat suitability index at the minimum flow if the minimum flow was changed from 20 m<sup>3</sup>s<sup>-1</sup> to 40 m<sup>3</sup>s<sup>-1</sup>.**

Species/ life stage	Δ WUA %	Δ HIS %
Salmon <55 mm (Hayes)	23	-10
Salmon 52-102 mm (Hayes)	25	-8
Brown Trout Yearling	4	-24
Brown Trout Adult (Hayes & Jowett)	-25	-45
Torrent Fish	-1	-28
Longfin eels >300 mm	25	-9
Longfin eels <300 mm	35	-2
Shortfin eels >200 mm	26	-8
Shortfin eels <200 mm	39	2
Deleatidium (mayfly) (Jowett)	18	-14
Food production (Waters)	-15	-38
Wrybill Plover (Hughey)	96	46
Black-Fronted Tern (Hughey)	-2	-28
Black-Fronted Tern (Duncan)	70	24

- (c) Accompanying any increase in the minimum flow is a reduction in the reliability of supply for abstractors. Table 4 shows the extent of the

reduction in reliability of supply. For an allocation of  $6.7 \text{ m}^3\text{s}^{-1}$  where the minimum flow is  $20 \text{ m}^3\text{s}^{-1}$  the full allocation can be taken 86-95% of the time, depending on the month, whereas if the minimum flow was  $40 \text{ m}^3\text{s}^{-1}$  the full allocation could only be taken 42-69% of the time, with the lowest reliability of supply in December when irrigation demand is close to its peak. For September to December period as a whole, for an allocation of  $6.7 \text{ m}^3\text{s}^{-1}$ , where the minimum flow is  $20 \text{ m}^3\text{s}^{-1}$ , the full allocation can be taken 91% of the time, whereas if the minimum flow was  $40 \text{ m}^3\text{s}^{-1}$  the full allocation could only be taken 57% of the time. The viability of irrigation would come into question at the low reliability of supply associated with a minimum flow of  $40 \text{ m}^3\text{s}^{-1}$ .

**Table 4: Average reliability of supply for A Block allocations for minimum flows of  $20 \text{ m}^3\text{s}^{-1}$  and  $40 \text{ m}^3\text{s}^{-1}$ .**

Take month	A Block Allocation $\text{m}^3\text{s}^{-1}$	20 $\text{m}^3\text{s}^{-1}$ minimum	20 $\text{m}^3\text{s}^{-1}$ minimum	40 $\text{m}^3\text{s}^{-1}$ minimum	40 $\text{m}^3\text{s}^{-1}$ minimum
		Start take reliability % of time	Full take reliability % of time	Start take reliability % of time	Full take reliability % of time
August	6.7, 15	98	87, 65	55	43, 31
September	6.7, 15	99	92, 73	64	54, 43
October	6.7	99	95	77	69
November	6.7	99	94	74	62
December	6.7	97	86	55	42
Sept-Dec	6.7	99	91	67	57

- (d) The start take reliability of supply also indicates how reliable the instream environment would be for the instream values such a riverbed nesting birds. For example, during December flows would be above  $40 \text{ m}^3\text{s}^{-1}$  for only 55% of the time and so the physical habitat and number of islands available at that flow would be unavailable for 45% of the time. It is open to question as to whether the river bed nesting birds (or other instream values) would be able to use all the habitat available at  $40 \text{ m}^3\text{s}^{-1}$  given that the flow will be variable.
- (e) To explore why the reliability of supply for a minimum flow of  $40 \text{ m}^3\text{s}^{-1}$  is so low it is helpful to compare the minimum flow and allocation regimes proposed for the Hurunui with those for other large Canterbury Rivers and the proposed National Environmental Standards (NES) (MfE 2008). Table 5 allows those comparisons. For the Hurunui River the minimum flow as a percentage of the 7-day MALF is 84.7% for a minimum flow of  $15 \text{ m}^3\text{s}^{-1}$ , 123% for a minimum flow of  $20 \text{ m}^3\text{s}^{-1}$  and

245% for a minimum flow of 40.  $\text{m}^3\text{s}^{-1}$ . The 84.7% value is higher than for other rivers apart from the larger Waimakariri and Rakaia Rivers and the 123% value is higher than those for all the other rivers except for the Rakaia in some months and the 245% value is much higher than for other rivers. This indicates that even with a minimum flow of 15-20  $\text{m}^3\text{s}^{-1}$  more protection is being given to the instream values than for most other comparable rivers in Canterbury. The A block allocation as a percentage of the 7-day MALF is lower than for most other Canterbury Rivers. The NES suggest that for rivers with mean flows greater than 5  $\text{m}^3\text{s}^{-1}$  a minimum flow of 80% of MALF and an allocation limit of 50% of MALF. The minimum flow of 15  $\text{m}^3\text{s}^{-1}$  is 84.7 % of the MALF and exceeds the standard as does the A Block allocation that is less than 50% of MALF. These indexes for the Hurunui River indicate a high level of protection for instream values and a relatively low level of allocation of the resource.

**Table 5: The minimum flow and A block allocation as a percentage of the 7-day MALF for large Canterbury Rivers for September to December (base data from Morgan et al 2002).**

River	Minimum flow	A Block	MALF	Minimum	Allocation
	Sept -Dec $\text{m}^3\text{s}^{-1}$	allocation $\text{m}^3\text{s}^{-1}$	$\text{m}^3\text{s}^{-1}$	as % of 7d MALF	as % of 7d MALF
Waiau	25	14	31	81	45
Waimakariri	41	22	41	100	54
Ashburton	5-8	14.5	13.5	37-59	107
Rakaia - Sept	90	70	87	103	80
Rakaia - Oct	106	70	87	122	80
Rakaia - Nov	129	70	87	148	80
Rakaia - Dec	139	70	87	160	80
Rangitata	20	32	38	53	84
Waitaki	80	43	196	41	22
Hurunui	15	6.7	16.3	84.7	41
Hurunui	20	6.7	16.3	123	41
Hurunui	40	6.7	16.3	245	41

## 12. Summary

12.1 I have justified the use of IFIM principles for setting minimum flows on the basis of the successful application of flow regimes based on flows set by IFIM.

- 12.2 A 2D hydraulic model was used to predict depths and velocities as recommended by the proposed national environmental standard (MfE 2008) for rivers like the Hurunui. I have shown that the 2D model reach is representative of the critical Amuri Plains reach of the Hurunui River and that the model reach is long enough to robustly represent the flow vs WUA properties of that reach.
- 12.3 I have used the model output of depths and velocities with habitat suitability indices to generate relationships between flow and WUA and WUA/wetted width. These relationships were interpreted to provide optimum flow rates for a wide range of riverine species and life-stages.
- 12.4 Those optimum flow rates were used to prescribe alternative monthly minimum flows depending on the instream values most valued by the community. The principle being that the species with the highest flow requirements dictates the minimum flow.
- 12.5 Further use was made of the modelling data to explore the relationships between flow and periphyton type with the outcome that the favoured diatoms would probably dominate at flows greater than  $20 \text{ m}^3\text{s}^{-1}$ .
- 12.6 The modelling data was also used to determine relationship between flow and the number and area of islands suitable for riverbed-nesting birds with the result that over flow range 5 to  $50 \text{ m}^3\text{s}^{-1}$  the number and area of islands increased as flows increased over that range.
- 12.7 Flow gaps between A and B allocation blocks are equivalent to minimum flows for the B Block allocation. They can be manipulated to ensure that any flat-lining associated with the B Block abstraction can be at a level that leaves residual flows that enhance critical instream values.
- 12.8 Increasing the minimum flow for September to December from 20 to  $40 \text{ m}^3\text{s}^{-1}$  would increase the amount of physical habitat for most species/life-stages, albeit at the cost of a lower quality habitat. It would also decrease the reliability of supply of allocated water to a level where the viability of irrigated agriculture would be challenged. How useful the increased physical habitat would be if the minimum flow was increased as proposed is open to question.
- 12.9 A comparison of proposed minimum flows for September to December shows that in relation to other large Canterbury rivers the even a minimum flow of  $20 \text{ m}^3\text{s}^{-1}$  is high in relation to the 7-day MALF and the amount of the

A Block allocation in relation to the 7-day MALF is lower than for other Canterbury rivers. Both these indexes indicate a relatively high level of protection for instream values.

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