BEFORE THE INDEPENDENT COMMISSIONERS

UNDER	the Resource Management Act 1991
AND	
IN THE MATTER	of the proposed Canterbury Land and Water Regional Plan

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STATEMENT OF EVIDENCE OF MAURICE JOHN DUNCAN
ON BEHALF OF NGĀ RŪNANGA OF CANTERBURY, TE RŪNANGA O NGĀI TAHU AND NGĀI TAHU PROPERTY LIMITED

4 February 2013

ANDERSON LLOYD
LAWYERS
CHRISTCHURCH

Solicitor: J M Crawford/ B McAuley

18a Birmingham Drive
Middleton
PO Box 13831
CHRISTCHURCH 8141
Tel 03 379 0037
Fax 03 379 0039

1. INTRODUCTION

1.1 My name is Maurice John Duncan.

1.2 I am currently employed by the National Institute of Water and Atmospheric Research (NIWA) as a hydrological scientist.

Qualifications and Experience

1.3 I have an M .Ag. Sc. in Agricultural Engineering from Lincoln College. I have worked for NIWA and its predecessor organisations for 43 years. I have been building and running two–dimensional hydrodynamic models since 1995 and have modelled many of the large braided rivers in Canterbury primarily to understand relationships between flow and instream physical habitat. This work also included recommending minimum flows and surface water allocations. I have written reports reviewing allocation plans for the Waimakariri and Hurunui Rivers. I have also modelled the conditions when sediment transport is likely to occur for some of the rivers. My first experience in developing relationships between flow and instream habitat was for the Rakaia River in 1985. Since then I have presented evidence at a number hearings, including Environment Court hearings, on instream habitat based on hydrodynamic models and on river hydrology.

1.4 I am familiar with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note and I agree to comply with the Code. This evidence is within my area of expertise except where I state that I am relying on information provided by another party. I have not knowingly omitted to consider material facts known to me that might alter or detract from the opinions expressed.

Scope of Evidence

1.5 I have been asked by Ngāi Tahu to prepare evidence in relation to:

a. The types of rivers found in Canterbury.

b. The need to retain the natural character of braided rivers.

c. Managing water abstraction.

d. How allocation regimes, allocation blocks and gaps work.

e. The need for partial restrictions on abstraction.

f. The need for flow variability.

g. Stream depleting groundwater and surface water allocation.

h. Different types of surface water abstraction.

1.6 In preparing this evidence I have reviewed:

a. The proposed Canterbury Land and Water Regional Plan (pLWRP).

b. Measures, R., Hicks, D.M. 2011. Geomorphic effects on the Hurunui River of the Waitohi Water Storage Scheme. NIWA Client Report. CHC2011-112.38 p.

c. Snelder, T., Biggs, B., Weatherhead, M. 2004 (updated 2010. New Zealand River Environment Classification User Guide. Ministry for the Environment. 144 p.

Summary of Findings

1.7 Canterbury has many unique and fine examples of relatively unmodified braided rivers that would completely lose their character and function if they were dammed. The policies and rules in the pLWRP need to be amended to prohibit the damming of braided river main stems and tributaries that contribute significant amounts of sediment, so the natural character, and geomorphological and ecological functions of these braided rivers can be retained.

1.8 As well as having a minimum flow to maintain ecological and amenity values, gravel bed rivers need variable flow regimes including flows to flush periphyton and silt if the rivers are to carry out their ecological and morphological functions , including keeping river mouths open.

1.9 In my opinion, partial restrictions on abstractions are a practical and useful way of managing residual flows.

1.10 Surface water and stream depleting groundwater access the same pool of water and hence need to be managed together.

1.11 There are different sorts of surface water take that have different effects residual flows, and these different effects also need to be taken into account when setting minimum flows and allocation blocks.

2. RIVER TYPES IN CANTERBURY

2.1 There are four predominant river types in Canterbury according to the river environment classification. They are described below:

a. Glacial Mountain- and Mountain-fed rivers. These rivers are sustained by frequent North West storms in the headwaters, snow and glacier melt and groundwater stored in gravel filled glacial valleys in the high country. Their flows are characterised by frequent floods and freshes that peak in late spring, relatively sustained low flows with low flow periods in late summer and mid-winter when it snows and headwater streams freeze, e.g., the Rakaia River. These rivers are often turbid and have a high sediment load. The frequent floods, large sediment load and river steepness result in braided rivers.

b. Hill-fed rivers. These rivers have lower specific yields than Mountain-fed rivers and are characterised by having floods in late winter and early spring, and long periods of low flows in summer when evapotranspiration exceeds rainfall across their headwaters and in autumn before soil water stores are replenished, e.g., the Selwyn River.

c. Spring-fed streams. The characteristics of spring-fed stream are relatively high and sustained flows with little flow variability and a low sediment load, e.g., Avon River. In Canterbury most spring-fed streams arise in the lower plains where groundwater reaches the surface. The minimum flow and allocation need to be carefully set as many lowland spring-fed streams have already had their flows reduced by groundwater abstraction, so the minimum flow and allocation need to reflect the natural flows rather than current flows.

d. Lake-fed streams have similar characteristics to spring-fed streams with perhaps a little more flow variability depending on where they are.

2.2 Rivers of each flow type have characteristic flora and fauna, and need different rules for minimum flows and allocations.

3. BRAIDED RIVERS

3.1 Most Glacial Mountain and Mountain-fed rivers in Canterbury are braided rivers. Unmodified braided rivers have a special character and are defined in the pLWRP as "any river with multiple successively divergent and re-joining channels separated by gravel islands". What this definition is not specific about, and should be specific about, is that gravel islands should be predominantly bare of vegetation. The sparsely vegetated bare nature of gravel islands is a key feature of the natural character of braided rivers. Some of the smaller braided and gravel-bed rivers are hill-fed.

3.2 The conditions associated with braided channel formation include:

a. An abundant supply of sediment;

b. High stream gradient;

c. Rapid and frequent variations in water discharge, and

d. Erodible banks.

3.3 This combination of conditions is rare worldwide and braided river are mostly confined to Alaska, Canada, the Himalayas and the South Island of New Zealand. Accordingly, the braided rivers of Canterbury are geomorphologically and ecologically unique. The benthic invertebrate *Dealeatidium* is specially adapted to these braided rivers and can rapidly recolonise, from refugia, new channels that are formed after floods. Common bullies have high reproduction rates and replace fish that might be flushed away. Both have the ability to burrow into the gravels to escape the effects of floods.

3.4 The Rakaia River is a good example of a braided river. The value of retaining the natural character of the Rakaia River has been recognised in the Rakaia Water Conservation Order by prohibiting the damming of the main stem of the river.

3.5 While many braided rivers are Glacial Mountain- and Mountain-fed it is not the source of flow that makes them unique, but their braided nature.

3.6 Braided rivers maintain their natural character by having frequent channel forming floods and an abundant sediment supply. The sediment supply may come from tributaries as well as the main stem and where there is a significant contribution of sediment from the tributary, the flow regime of the tributary also needs to be maintained to continue the sediment supply so the main stem can maintain its natural character.

3.7 Without floods with sufficient power to move the bed, vegetation invades the bed and strengthens the banks. This tends to reduce the number of channels, which become narrower and deeper than those of a braided river with a natural flow regime. Main stem dams reduce the size and frequency of floods and trap the gravel supply resulting in coarsening of the river bed downstream of the dam. These two factors reduce the mobility of the bed leading to the formation of more stable channels that allow woody species to invade the former braided bed.

3.8 The upper photograph in Figure 1 shows the braided character of the Rakaia River bed with its multiple channels and bare, sparsely vegetated gravel bed. This is in sharp contrast with the lower photograph in Figure 1 that shows the vegetated bed and relatively few channels in the Waitaki River downstream of the Waitaki Dam.

3.9 The invasion by woody species of gravel river beds downstream of dams also occurs on smaller gravel bed rivers and Figure 2 shows woody species on the former bare gravel Opuha River bed, downstream of the Opuha Dam.

3.10 A further effect of damming the main stems of braided rivers is the reduction of sediment supply to the coast. This will change the semi-equilibrium at the coast and lead, in the medium to long term, to erosion of the coast or an increase in the rate of erosion of already eroding coasts, such as the coast of the Canterbury Bight.

3.11 Flood flows are also required to maintain or cause river mouth openings to allow the migration of diadromous fish and to reduce flooding in hāpua.

Figure 1 Illustration of the effect of damming a braided river with the unmodified Rakaia River at the top and the Waitaki River downstream of the dam below.

Figure 2. The Opuha River downstream of the dam showing the invasion of the river bed by woody vegetation.

3.12 The preservation of the natural character of braided rivers requires the pLWRP to prohibit the damming of the main stem of braided rivers and to ensure that any diversion to out-of-river storage maintains most of the natural flood peaks and volumes. It is my opinion that the wording of Policies 4.41 and 4.43 of the pLWRP is not strong enough to prohibit the damming of the main stems of braided rivers and the wording needs to be amended to prohibit the damming of the main stems of the major braided rivers and their major gravel contributing tributaries where it is not already proscribed in Water Conservation Orders or Regional Plans.

4. MANAGING SURFACE WATER ABSTRACTION

4.1 This section of my evidence is about what flow and allocation regimes are and the key fundamental things that need to be managed and protected as part of setting environmental flow and allocation regimes.

4.2 Flow and allocation regimes usually consist of:

a. A minimum flow. Abstractions are not allowed to cause the river to flow at less than the minimum flow.

b. Allocation blocks. These provide for blocks of flow that can be abstracted when river flows are greater than the minimum flow, e.g., if the minimum flow was 15 m^3/s and the A Block was 6.2 m^3/s, then when the river flow was more than 21.2 m^3/s, the full 6.2 m^3/s could be abstracted. A Block flow is the most reliable and B and C, etc. blocks become increasingly unreliable.

c. Flow gaps. These are flow ranges between allocation blocks where the water must remain in the river. Following the example from the previous bullet point, if there were a 5 m^3/s gap between A and B Blocks then any B Block abstraction would be prohibited once the flow reduced to 26.2 m^3/s (15+6.2+5 = 26.2). The purposes of gaps will be explained later.

d. The flow regime may also include flows to flush periphyton and silt from gravel river beds. Flushing flows are explained in more detail later in my evidence.

e. There may be other rules to help maintain flow variability to ensure the river continues to carry out its ecological and morphological functions.

4.3 Figure 3 shows a hydrograph, and two allocation blocks with a gap between them. With this example no water could be abstracted from early February to mid-April as the flow is less than the minimum flow for the A Block. The full A Block allocation could be taken in the first 3 weeks of January, from mid-April to early July and from early August until the end of December. The B Block allocation could be taken for similar, but shorter periods. Note that real examples of flow allocations can have the minimum flow and allocations varying with time.

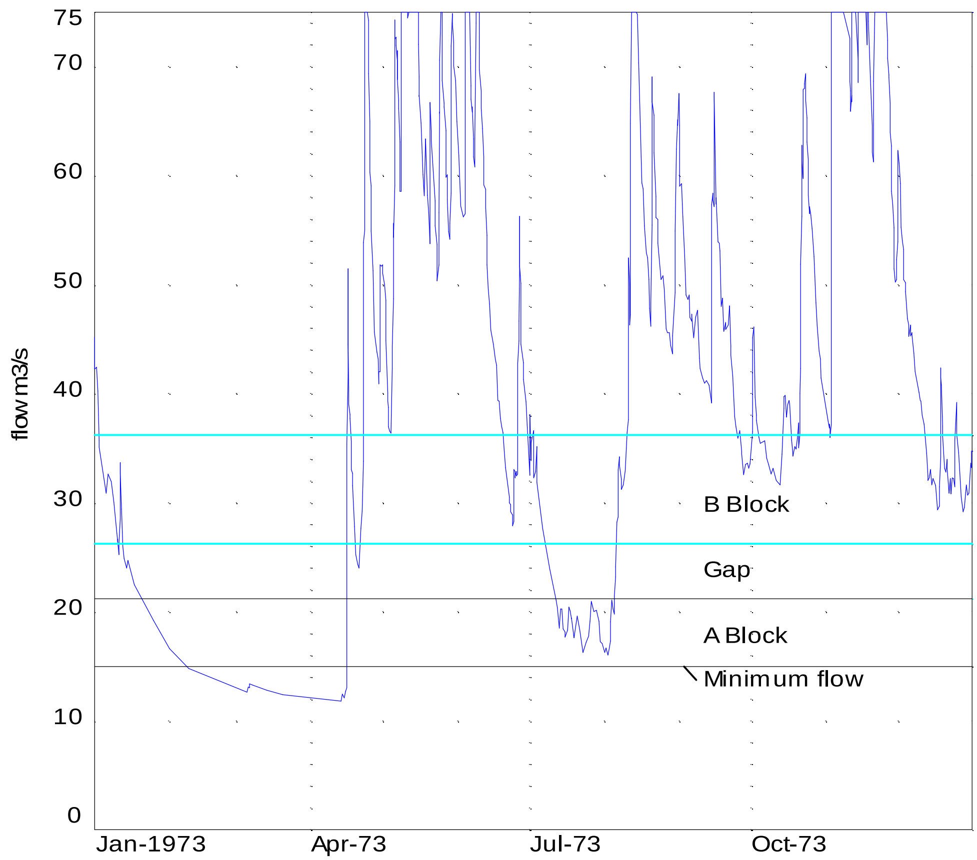

Figure 3. A hydrograph showing the relation between minimum flows, allocation blocks and gaps.

4.4 Minimum flows are flows set primarily to preserve the life supporting capacity of rivers, and if appropriate, to provide enough depth and width of water for adult salmon, jet boat and kayak passage. No abstraction is allowed to cause the flow to fall below the minimum flow set in a plan, except for stock water, municipal supply and fire fighting.

4.5 To decide the minimum flow for life supporting capacity requires knowledge of the fish that inhabit the river and NIWA's fish data base is usually the first resource consulted. If there are any rare and endangered species, then the minimum flow needs to provide good habitat for them. The water depth and velocity requirements are known for most of New Zealand's freshwater fish and benthic invertebrate species and for different types of periphyton. The larger rivers in Canterbury have been modelled, so that the distribution of depths and velocities are known for a range of flows. These two pieces of information are combined to result in a relationship, which can be shown in a graph, between flow rate and the amount of physical habitat available for each fish and invertebrate species and type of periphyton. These graphs show for each species the optimum flow rate and the flow at which habitat starts to reduce rapidly as flows decline.

4.6 To determine the minimum flow for fish, a list is made of the flow at which, say, 80% of the habitat is available for the fish species known to inhabit the river. From this list a compromise minimum flow is set that suits most species. Commonly, the fish that requires most flow is brown trout and it is often assumed that if the flow is sufficient to provide for, say 80% of the physical habitat required by adult brown trout, then it is sufficient for most species. Other considerations are:

a. The requirements for rare and endangered species.

b. Passage depths for salmon, jet boats and kayaks.

c. Flows sufficient to discourage growth of long filamentous algae to prevent nuisance growths and encourage the growth of diatoms that are the preferred food for invertebrates favoured by fish.

4.7 Figure 4 shows an idealised relationship between flow and physical habitat. It shows the optimum flow, 80% of the optimum and the fast decrease in physical habitat at flows that provide less than 80% of the optimum habitat. Physical habitat is often referred to as “weighted useable area”.

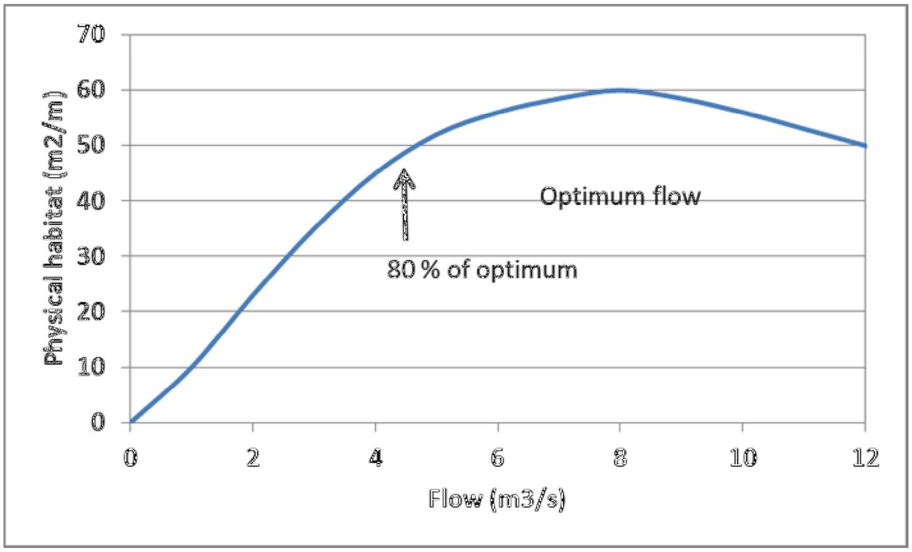

Figure 4. An idealised flow vs physical habitat relationship

4.8 While minimum flows might provide for adult salmon, jet boat and kayak passage, they are often much less than the preferred flows for salmon angling and boating. In rivers where these activities are popular, the flow regime may have to provide for those requirements by providing a flow gap between allocation blocks or flow sharing when the river flows are in the appropriate range, as has happened with the Central Plains Water consents. I will explore this concept later in my evidence.

4.9 In very large rivers, e.g., the Clutha River, the optimum flow for fish can be much less than the natural low flow and issues such as natural character and visual amenity are considered when setting the minimum flow.

4.10 In small rivers the preferred minimum flow can be greater than the mean annual low flow or the 7-day mean annual low flow and in those cases, the minimum flow should be set at the value of the 7-day mean annual low flow. In the case of adult brown trout there is a relationship between their biomass and the amount of habitat available at the mean annual low flow, so setting a minimum flow at a higher level may not result in environmental benefits and would reduce abstraction opportunities.

4.11 In some small rivers the minimum flow may be set to ensure that abstraction does not cause flow to stop, e.g., the Lower Conway River.

5. HOW ALLOCATION REGIMES, ALLOCATION BLOCKS AND GAPS WORK

5.1 Allocation regimes start with a minimum flow that dictates that flows should not fall below the minimum because of abstraction. Above the minimum flow sits the A allocation and above that B and C etc. allocation blocks. There may or may not be flow gaps between the allocation blocks. The flow regime of a river with abstraction allocations may also include the requirement to cease taking water, or delay the resumption of a restricted take, until a flushing flow has passed.

5.2 A flow gap is where the minimum flow for a B Block allocation is more than the sum of the minimum flow and the A Block allocation. Similar explanations would apply to gaps between B and C Blocks etc.

5.3 Gaps have been used for several functions:

a. To make allowance for over allocation of a block, e.g., if the sum of the A Block consents to take is greater than the A Block allocation by, say 1.5 m^3/s then there may be gap between the A and B Blocks of, say 2 m^3/s.

b. To ensure that the continuity of supply of water to A Block consent holders is not compromised by the takes of B Block holders, e.g., if both blocks were being abstracted and that caused the minimum flow to be approached or breached, then consent holders from both blocks should stop taking. However, if there were a 2 m^3/s gap, then the B Block holders would need to stop taking or have their takes restricted when the flow were 2 m^3/s above the minimum flow, thus ensuring the A Block holders' security of supply.

c. To maintain environmental or recreational flows, e.g., it may be that the ideal flow for nesting for river-bed nesting birds and/or salmon angling and/or jet boating preference, etc. is the sum of the minimum flow and A Block allocation and ideal conditions remain for the next 15 m^3/s. In this case there might be a gap of 15 m^3/s between the two blocks.

5.4 Figure 5 shows flow duration curves for a river for a number of allocation options. It shows that if there is a gap of 6.5 m^3/s or 10 m^3/s between the A and B Blocks (black and red lines) the flow is in the ideal range for river nesting birds (between the horizontal black lines) for longer than if there were no gap (light blue line).

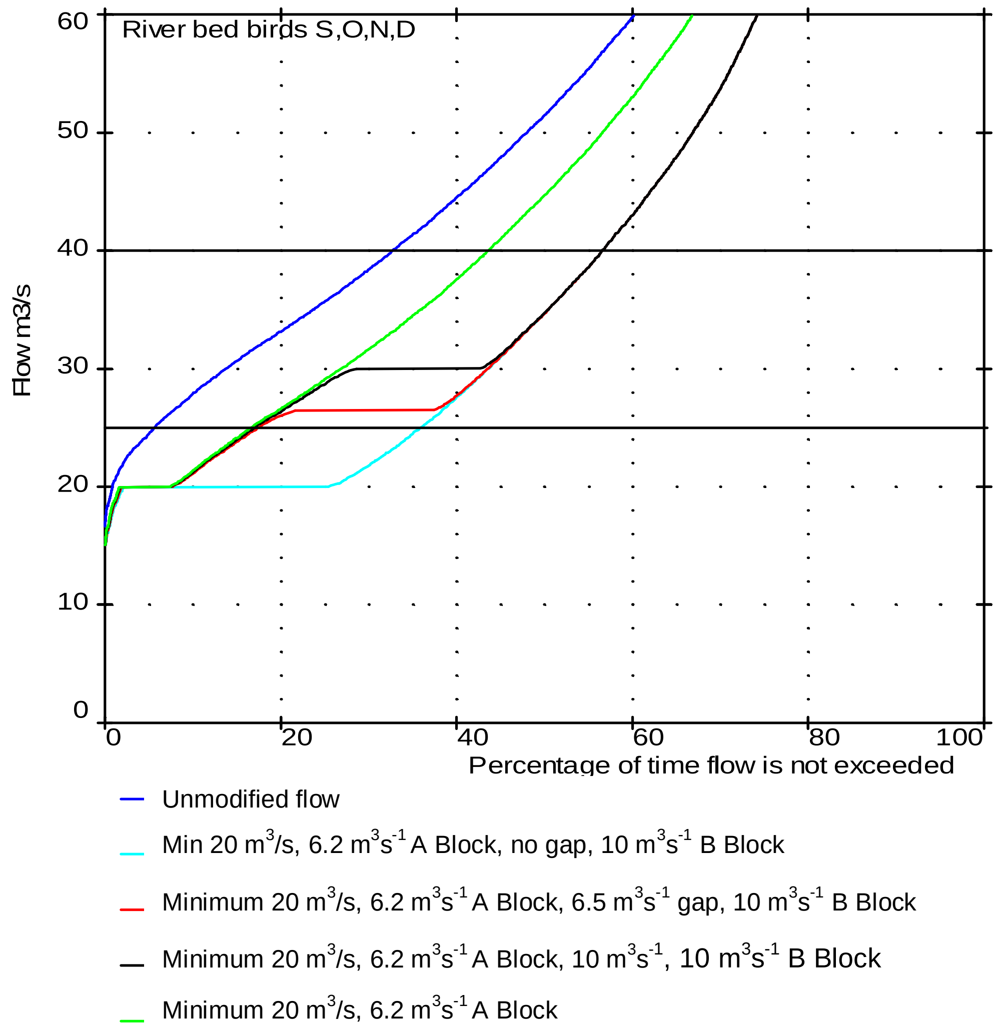

Figure 5: Flow duration curves for the unmodified flow, and for allocation options with a common minimum flow of 20 m^3/s, an A Block allocation of 6.2 m^3s^{-1} and B Block takes of 10 m^3s^{-1} with gaps of 0, 6.5 and 10 m^3s^{-1} between the A and B Blocks for September to December (1957-2007). The optimum flows for river bed nesting birds are those between the two horizontal black lines.

Allocation Blocks

5.5 Allocation block designation is supposed to indicate a particular reliability of supply. A Block water is the most reliable, with B and C Blocks being increasingly unreliable.

5.6 In practice there is a difference in reliability of supply between A Blocks from different rivers. Initially A Block designation indicated a supply so reliable that a farmer could rely upon the water supply without the need for water storage. On some schemes, such as the Waimakariri Irrigation Company scheme, A Block water is so unreliable that farmers are building on-farm storage and the Company is considering a large storage reservoir. Ideally A Block and other Block allocations could be altered to reflect a Canterbury-wide uniform reliability of supply without disrupting the actual supply that farmers receive.

5.7 B Block allocations commonly require some storage for the water supply to be reliable enough for farmers to invest in irrigation infrastructure.

5.8 C Block allocations almost definitely need storage for the water supply to be reliable enough for farmers to invest in irrigation infrastructure.

5.9 However, the allocation of water into blocks in different rivers and schemes appears to be ad hoc and there does not appear to be any commonality between schemes apart from the relative reliability of the allocation blocks within a scheme.

6. THE NEED FOR PARTIAL RESTRICTIONS FOR ABSTRACTIONS

6.1 When flow falls to the minimum flow because of abstraction, the abstraction should cease. If it doesn't, the flow in the river will be drawn down below the minimum flow with associated effects on ecology and other instream values. If the abstraction ceases, this will cause the river flow to increase, and allow abstraction to recommence. However if the total allocation were put into effect, the river flow would then drop below the minimum flow again.

6.2 The way to avoid this effect is to have partial restrictions, e.g., when the sum of the flow plus abstraction is approaching the minimum flow, then the abstraction can be restricted to say 75% of the allocation. This maintains the flow above the minimum flow and allows some abstraction to continue. A win-win situation. If the river flow continues to decline, then further restrictions can be introduced.

6.3 The same arguments apply to the need for partial restrictions for B and C, etc. blocks.

6.4 An issue when abstractions are restricted is having sufficient water to operate an irrigation system. This issue is commonly overcome by having a local water users group decide who gets the water and when. This usually allows the irrigator to get the required amount to operate the irrigation system but makes it available to each farmer for a shorter time than normal.

7. THE NEED FOR FLOW VARIABILITY

7.1 Braided rivers and other gravel bedded rivers need flow variability to carry out their hydrological, biological and geomorphic functions. Essentially, flows need to increase periodically to:

a. Flush periphyton and silt draped over the gravel to reduce nuisance growths of periphyton and to provide a suitable environment for diatoms and preferred invertebrates to thrive.

b. Move bed load and form new channels to keep the bed free from vegetation so the rivers retain their natural character, and provide a good environment for river bed nesting birds.

c. Move bed load to the coast to maintain the coastal sediment budget and prevent accelerated coastal erosion.

d. Maintain or cause river mouth openings to allow the migration of diadromous fish and to reduce flooding in hāpua.

e. Provide flow, turbidity or temperature signals to initiate the migration of fish.

7.2 The sorts of flows required to carry out these functions are freshes and floods. The freshes need daily flood peaks at least as big as twice the median flow in our large braided rivers and three times the median flow in small rivers. Flows of these sizes are required at least once every 3 to 6 weeks to flush periphyton, provide signals for fish migration, and open, or keep open, hāpua.

7.3 At least once per year a flood of the order of, or greater than, the mean annual flood is required to maintain river character, and to transport gravel to nourish the coast.

7.4 The need for flushing flows often occurs following a period of low flows or flat-lining when abstractions will have ceased or will have been restricted. A good management option for flushing when a fresh occurs after a period of low flows is to continue the restriction for 24 hours to allow the fresh to do its work. Guidance for a change of restriction conditions is usually updated on the ECan website every 24 hours, so in some cases allowing a fresh to continue will mean in practical terms that there is no increase in restriction duration if abstractors vary their abstraction in accordance with the ECan website.

7.5 To allow annual, or greater, floods to carry out their functions requires the prohibition of dams on main stems and tributaries contributing significant amounts of flow or bed load. Abstractions to off-stream storages are not usually a big issue as long as the abstractions are small in relation to flood size, and abstractions often cease during floods in any case to reduce sedimentation issues with the infrastructure.

8. DIFFERENT TYPES OF SURFACE WATER ABSTRACTION

8.1 Different sorts of surface water takes can result in different residual flows and therefore the effect on the instream environment, amenity and visual appearance. There may be a need to reconsider the minimum flow, allocation block size and flow regime management depending on the type of surface water take.

8.2 The different types of surface water takes are:

a. Run of river takes.

b. Takes to storage.

c. Double consented takes.

8.3 Run of river takes only take water when irrigation is required. Thus, at the beginning and end of the irrigation season and after rain, water may not be taken and if crops are being irrigated the demand and take will reduce in summer and autumn as crops ripen. No water will be taken in winter. Commonly only about half the allocated water is taken. This has positive effects for instream values, amenity and appearance. If minimum flows and allocations have been made taking these effects into account, then they may have to be changed if the nature of the take changes.

8.4 Takes to storage, including those that take to storage when irrigation water is not required, have quite different effects on the river compared with run of river schemes. These sorts of take can take at the maximum allowable rate until the storage is full. Thus they will reduce the residual flow more, and over a longer time period, than run of river takes. If the total take is dominated by such takes then it can result in long periods of flat lining of the hydrograph at the minimum flow. This lack of flow variability is bad as it allows periphyton to accumulate to nuisance proportions, for gravels to be smothered in silt, for hāpua to close or elongate and prevents fish receiving signals to migrate. Special conditions need to be attached to such consents to allow for flushing flows.

8.5 Of particular concern is the conversion over time of run of river consents to take to storage. What I have in mind is the change in practice in the Waimakariri Irrigation Scheme where many on-farm storages are being, or have recently been, constructed that are being filled during shoulder seasons and after rainfall, when normally water would be left in the river. Further, it is likely that the Scheme consent will, or has been, varied to allow takes to storage in the winter. As far as I am aware the consent has not been altered to allow for flushing flows if the take results in long periods of flat lining.

8.6 Double consented takes. These are defined as takes where if the primary consent holder is temporarily not exercising their full take, then the secondary consent holder has the right to take the balance of the take not being exercised by the primary consent holder. I understand this sort of situation potentially exists on the Rakaia River.

8.7 The effect of double consenting is for a previous run of river take to have the effect of a take to storage. Thus if the allocation regime assumed the takes were run of river and allowed larger allocation block or lower minimum flow assuming that a proportion would not be taken, then when double consenting is granted the allocation regime and minimum flow would need to be revised to have the same effect on the river as the original consent.

9. STREAM DEPLETING GROUNDWATER TAKES AND SURFACE WATER ALLOCATION

9.1 This section is about the need to include effects of stream-depleting groundwater takes in setting flow allocations rather than just considering surface water takes.

9.2 Much of the Canterbury Plains and inter-montayne basins are composed of sands and gravels that have relatively high hydraulic conductivity. This means there is a relatively good hydraulic connection between many Canterbury rivers and their floodplains. Thus water flows between the river and the groundwater beneath the floodplains and vice versa.

9.3 Accordingly, in terms of effects on the surface water (rivers) there is very little difference between abstracting water directly from the river and from a groundwater well on the floodplain. These wells are known as stream depleting groundwater takes. The main difference between a surface water take and stream depleting groundwater take is that the surface water take will affect the river flow instantaneously, whereas there may be a time lag with the groundwater take. The greater the distance between the river and the groundwater take, the longer the time lag.

9.4 Because there is no real difference in the effect on the river whether it is a surface water or groundwater take, when allocating and managing surface water, both types of take need to be considered as having the same effect, i.e., surface water depleting groundwater takes need to be considered as part of the surface water take. When restrictions are in force, or takes stopped because the minimum flow has been reached, the restrictions or cessations need to apply to the surface water depleting groundwater takes as well as the surface water takes.

10. CONCLUSION

10.1 In my opinion, the wording in policies 4.41 and 4.43 needs to be much stronger so that it is clear that there shall be no damming of the main stem of any braided river or significant tributary. Clear policy direction is required to ensure the unique character of Canterbury's predominantly relatively unmodified braided rivers is retained and they continue their geomorphic and ecological functions.

10.2 As well as having a minimum flow to maintain ecological and amenity values, gravel bed rivers need variable flow regimes including flows to flush periphyton and silt, if the rivers are to carry out their ecological, societal, cultural, economic and geomorphological functions.

10.3 Partial restrictions on abstractions are a practical and useful way of managing residual flows.

10.4 There are different sorts of surface water take that have different effects on residual flows and these effects need to be taken into account when setting minimum flows and allocation blocks.

10.5 Surface water and stream depleting groundwater access the same pool of water and need to be managed together.

Maurice John Duncan

4 February 2013