Environment Canterbury
Your regional council

6 July 2009 Ref : PL5C/00202

MEMORANDUM

FROM : **ADRIAN MEREDITH**

TO : **ANNA VELTMAN, MATTHEW MCCALLUM-CLARK**
cc

SUBJECT : **WAIMAKARIRI RIVER B BLOCK ALLOCATION / PLAN CHANGE**

The Waimakariri River is an important water resource close to Christchurch City. It is highly utilised as an irrigation water source, but also highly utilised recreational and ecological resource. Therefore there is tension between different water resource values. This necessitated the development of the Waimakariri River Regional Plan (WRRP 2004) to set in place a flow and water allocation management regime. However, since development, the potential abstractive requirements have increased beyond those anticipated. There is therefore a requirement to re-evaluate controls on abstraction from the higher flow bands. These are the ‘less reliable’ water blocks that are primarily identified for water storage uses, rather than continuous or routine ‘run-of-river’ use.

This memo further elaborates on and clarifies the powerpoint presentation material presented to the RPC meeting on Wednesday 10 June 2009. It is one of several technical memos that together represent the full integrated presentation and consideration of allocation regime options. This memo primarily discusses ecological flow requirements for the B block allocation options.

Introduction

Previous recent advice on flow regimes for setting ecological limits for B block allocations in the Waimakariri River has been based upon analysis and modelling by NIWA (Duncan and Bind 2008; Duncan 2008). These reports were based upon 2-D hydraulic models in a 1km x 3km reach at Crossbank (18 km from the Waimakariri River mouth), then extrapolated to the whole middle and lower reaches of the Waimakariri River. NIWA clarified that the ‘Crossbank reach’ is a location where the river changes from a degrading reach to an aggrading reach, (Griffiths 1979), and also that gravel grain size reduces downstream to Crossbank, and then linearly reduces at a much faster rate below Crossbank (Griffiths 1979). Coincident with the different grain sizes are different bed slopes with steeper slopes upstream and shallower slopes downstream. They therefore, were unsure whether or not the results of the modelling were transferrable either upstream or downstream of Crossbank. However, on the basis that the grain size, bed slope and braiding intensity are considered more or less in equilibrium throughout the river, they concluded that it was reasonable to apply the results of the studies to elsewhere in the river. The modelling is therefore extrapolated to the whole lower river, but there remains a level of uncertainty as to its broad applicability.

The resulting model data provided useful outputs for scenario testing and ultimately recommendations. However, the model outputs are largely without any monitoring verification of actual river bed behaviour. The only described follow up monitoring were opportunistic observations following a 500+ m^3/s flood. Therefore the predictions and scenarios, while based upon best available science and modelling capability, remain unverified.

I note that the NIWA national river water quality network (NRWQN) monitoring sites at Waimakariri Gorge (site CH3) and at the motorway bridge (site CH4) provide 20 years of monthly monitoring data that could be used to further consider the reliability of the modelled outputs. Neither Duncan and Bind (2008) nor Duncan (2008) considered or used this data in their analyses or discussed the advisability of using it. One reason for its omission may be due to variability of river reach characteristics. Crossbank is a highly braided reach while both CH3 and CH4 are physically constrained largely single channel reaches blow the gorge bridge, and within Wrights cut above the motorway bridge respectively. Despite this degree of site difference, the rationale for considering the river "to be in equilibrium" would suggest that this monitoring data is still useful for considering flow related water quality and habitat issues and outcomes that can then be related to models and scenarios. Furthermore, plan flow regimes are designed to equally manage the river over its entire lower length below Otarama Gorge, and so needs to be appropriate for managing effects in both constrained and highly braided reaches. It is therefore appropriate to consider and analyse the NIWA monitoring data to further verify flow regime scenarios.

This memo therefore starts from a position of accepting both the NIWA modelling outputs, and further hydrological assessments by ECan hydrologists (Leftley 2009), and assessing these against ecological sensitivities and ecological requirements of the river. As with the Duncan and Bind (2008) and Duncan (2008) assessments, this memo utilises existing ecological data and analysis that were presented by a wide range of parties to the Central Plains Water (CPW) Ltd consent application hearings in 2008.

Assessment criteria.

I consider that there are 3 ecological elements of Waimakariri River flow regimes that all need to be considered to ensure a flow regime sustainably addresses in-stream ecological and recreational requirements. These include low flow elements, flow variability elements, and consideration of beneficial flow ranges.

(a) low flow issues.

For the consideration of a B block allocation regime, the low or minimum flow requirements should not be a direct management issue, because B allocations commence well beyond the minimum flow. The minimum flow restrictions and duration of restrictions are most influenced by the A (and AA block) allocations. However, the degree to which the minimum flow is protective of overall river values is an issue of note for the whole integrated flow regime, if it is not close to an optimal flow. The many IFIM (In-stream Flow Incremental Methodology) WUA vs Flow curves presented by different parties to the Waimakariri River CPW hearings, show that unlike smaller rivers, the Waimakariri River does not have a definite optimal flow where habitat area either peaks or habitat gain tails off. Instead, it steadily increases throughout a wide flow range for most ecological components (Figure 1). In many rivers IFIM analysis is used to help set minimum flows relative to the flow that generates theoretical optimum habitat area for critical species, or at a percentage of modelled optimal habitat area (70%, 90% etc.). However, in the Waimakariri (at Crossbank) useable [habitat] area generally linearly increases throughout the low to medium flow range, so this cannot be done. This lack of a discernable pattern or peak is also true for many recreational use attributes (such as salmon angling) also presented in Figure 1.

Habitat quantity can therefore be considered to generally increase linearly with flow, and for many values to double in area, opportunity, or production, with a doubling of flow. Therefore, the minimum flow cannot be considered particularly protective of in-river values, and is generally more based upon hydrological statistics than specific ecological requirements. The existing minimum flow was originally set at a past calculated MALF(7d) (7-day mean annual low flow), but that is now approximately 90% of the currently calculated MALF(7d) statistic. The minimum flow was therefore more derived as a convenient hydrological statistic than an ecological flow, although there was some consideration of minimum water depths required to allow unrestricted salmon passage. Maintaining the river at the minimum flow (41 m^3/s), by allocating all flows above that, is therefore not explicitly maintaining a pre-determined ecological objective or outcome, and is not implicitly in any way beneficial to the river.

A common IFIM assumption is that useable habitat area within a river profile is limiting to populations, and that more habitat will equate to more ecological production or habitat use. This similarly remains untested for the Waimakariri River, but accepting the assumption is a sensible conservative management approach.

Consideration of the minimum flow illustrates that minimum flow controls alone (at the currently set minimum flow) are not particularly designed to protect and manage the many in stream values of the river. Consideration of other flow regime attributes that maintain flow variability and maintain flow frequencies within certain beneficial flow ranges are therefore equally as important, or more important protective components of a flow regime, in the face of high and increasing abstractive demand and requirements.

(b) Flow variability.

The Waimakariri River is a very dynamic river with a very ‘spikey’ hydrograph exhibiting a range of frequent freshes and floods of varying sizes. They range from small freshes (<100 m^3/s) to ecological resetting freshes (<400 m^3/s) through to channel forming floods (>500 m^3/s) (Figure 2.). The predicted function and behaviour of these freshes and floods were the subject of much of the NIWA modelling. Bed flushing effectiveness flow curves were derived by Duncan (2008) from these models. From these curves, certain flushing flow thresholds were recommended to maintain river bed characteristics or conditions. Superimposed on these original curves, are Duncan’s recommended fresh sizes for maintaining river function (Figure 3.). These show that recommendations were largely derived from arbitrary percentage levels of bed flushing derived from the model (50%, 60%, 70% etc.). None of these (other than the opportunistic flood observation (500+ m^3/s fresh ~ 90% flushing)) were verified as actually achieving these degrees of bed flushing. They are therefore useful benchmarks, but remain largely theoretical assessments.

The NIWA NRWQN data can illustrate periods when there was a significant presence of detrimental black/brown algal mats in the Waimakariri River. The flow conditions preceding these incidences can be examined to verify which of these fresh thresholds may have been performing significant or effective flushing functions at the monitoring sites. There were in excess of 15 times in the existing record when significant black/brown mat (BM) presence was recorded. Conversely there were very few (<3) incidences where there was significant presence of long filamentous green algae recorded. These ‘naturally’ occurring records are useful in assessing the preceding flow conditions that allowed algal proliferations to occur (naturally). A flow regime can then be assessed by the degree to which they might further increase the flow regime elements that led to these incidences of detrimental algal growth.

This cursory examination indicates that Duncan’s lower fresh threshold (80 m^3/sec) freshes did not appear to have any significant influence on preventing mat formation, or ensuring mat removal from the two NIWA sampling sites. However, ~130 m^3/s freshes do appear to control mat presence or persistence (Figure 4). A conservative threshold may therefore be to manage or conserve freshes >130 m^3/s to achieve this function in the river. Furthermore, although only based upon monthly observations, there is an indication from this data that durations between freshes of the 3-4 week threshold described in the literature (i.e. Biggs et al. 2008) were too short for nuisance mat development, and that longer durations of 4-6 weeks are more important. It was also clear from NRWQN data that the detrimental black mats occur and develop at any time of the year, and frequently in autumn/winter/spring. Intervals between freshes therefore need to be managed where possible over the winter period as well as summer. Overall, this shows that flow regime controls should ideally aim to ensure fresh and flood events (>130 m^3/s) are maintained wherever possible at intervals of at least every 4-6 weeks all year round.

Earlier proposals by the NIWA reports suggested a suspension of any B block allocation gap (no gap) in the winter period (May to August) because:

- algal growths don't occur in winter (because of cold temperatures and flood frequency)
- higher base flows in winter
- a lack of significant values needing protection (birds, fish etc.)
- the A block was not allocated in winter and therefore its absence acted as a 22 m^3/s 'gap'.

However, these considerations are largely incorrect. As illustrated above; black algal mats are not strongly seasonal and do develop and occur in winter; winter can be a period of low stable flows; while high value communities (breeding birds, salmon fishery) are strongly seasonal, their habitat requirements can be influenced by preceding conditions in the late winter (K. Hughey, pers com.), and other ecological communities persist in the river all year round; and finally it cannot be assured or assumed that the A block will continue to only be a summer irrigation season allocation block.

It is therefore not appropriate to suspend any gap or flow sharing regime requirements for the winter period (May to August). They are equally required to manage a range of values and functions that can equally occur in the winter outside the summer irrigation season.

Other important water quality features of freshes, are specific water quality opportunities they provide to migratory biota. Most fish initiate or maintain migrations on flood or fresh conditions. In summer this is usually in response to water temperature limitations, with freshes causing significant reductions in mean daily and peak daily water temperature. In particular salmonid fish (salmon and trout) generally cease to be active above 19oC, yet summer low flow conditions can see river temperatures rise to beyond 22 to 23oC in December and January at the lower NIWA NRWQN site (CH4). Conversely, spot water temperatures recorded at Waimakariri Gorge (NIWA CH3) rarely exceed 16-18oC. The reaches between the gorge and SH1 are therefore becoming increasingly thermally blocked to fish migrations by solar heating of the river (particularly where flows are low and water is clear). Such solar heating is greatest at low and clear flows when the dark coloured gravel substrates absorb the greatest solar radiation and thermal mass of the river is lowest. Therefore regular freshes are important in providing opportunities for fish to disperse or migrate up the river from positions they might otherwise become 'thermally' trapped in (the lagoon, deep holes or lies, or discrete areas of upwelling cool groundwater). These opportunities should ideally also be provided at minimum frequencies (4-6 week intervals) to avoid fish losing condition while remaining blocked and not feeding for extended periods.

Decreased water clarity associated with freshes is another important attribute of freshes that can influence both migration initiation and success. These attributes are also utilised by salmon anglers to optimise angling success as well as being indexed to targeting these active migrations. Freshes therefore provide a wide range of 'functions' to the river such that they need to be protected or managed to ensure the integrity of existing values and overall river ecological resilience.

(c) Flow ranges.

Duncan (2008) summarised the accumulated CPWL evidence on preferred flow ranges for a range of values, into a single figure (Figure 5.). This largely showed that most values to be accessed or to function flows were required to be in the range 50-100 m^3/s, or secondarily up to 150 m^3/s. It is therefore preferable to maintain flows in these flow ranges as much as possible, or conversely avoiding reducing the frequency of 'opportunities' afforded by flows in these flow ranges. Recent consultation for this variation process on the possible flow regimes has further reiterated that for recreational use, flow ranges of 50-150 m^3/s are preferred in the Waimakariri River.

A corollary of this is that flows at or below 50 m^3/sec are not in the preferred range for most values and are generally NOT beneficial. This further illustrates that the minimum flow set for the Waimakariri River is not only low in terms of IFIM requirements (WUA vs Flow curves), but also in terms of preferred flows for beneficial uses. It is therefore important to identify the potential frequency (or increase in frequency) of flows falling below 50 m^3/s under any proposed regime. In some respects this also indicates that a more 'ideal' minimum flow would be of the order of 50 m^3/s rather than the existing 41 m^3/s.

Allocation regimes.

There are a very large number of possible flow regimes derived from different gap sizes, gap suspension periods, different B allocation block sizes, partial restrictions, and 1:1 environmental flow sharing. Each of these regimes will exhibit different patterns of restrictions, reliability of supply for abstracters, and exert different effects or benefits to in-stream values. Duncan (2008) and Duncan and Bind (2008) analysed the 40 year hydrological record of the Waimakariri River (1967-2007) to assist in determining allocation recommendations. This has also been conducted within ECan (Leftley 2009) to aid these discussions. Duncan (2008) considered several regimes with differing gap sizes and allocation block sizes, and Leftley (2009) analysed over 25 further scenarios, particularly additional ones including 1:1 environmental flow sharing of the B allocation block. While a large number of regimes were examined, to simplify the subsequent analysis, options were reduced to four allocation regimes that represented the options most frequently discussed or proposed, and therefore are most useful to portray a range of views. The four allocation regimes examined were; a B allocation gap of 30 m^3/s between the A and B allocation blocks, and B block allocations of 20 and 40 m^3/s respectively; and 1:1 environmental flow sharing from above the A block (from 63 m^3/s) and throughout the B block, and with B block allocations of 20 and 40 m^3/s respectively. Two reference regimes (natural flow and full A block allocation take only) were modelled as reference conditions.

Hydrological statistic analysis.

Hydrological statistics were generated for a range of hydrological metrics, for the river median flow condition from the 40 year flow record (1967-2007). That is, the statistics relate to the median flow year (the 50th percentile for the 40 years of record) and so would be 'worse' for 50% of years, and 'better' for 50 % of years. It is important to understand that the statistics generated therefore do not reflect a 'worst' case year (100%ile). As visible examples, three full year hydrographs are presented of the dry (1970/71), wet (1995/96) and average (1989/90) years. These were the years from the 40 year record that were generally agreed as representative of those (summer) condition years by submitters to the CPW hearings (Figures 6-8). These flow plots can be used to visualise features of whole year hydrographs such as (but not exclusively): periods of minimum flow, periods below 50 m^3/s flow, periods 50-100 m^3/s, periods 50-150 m^3/s, fresh frequency etc..

Flow variability statistics are summarised in Table 1. An additional statistic was also generated since the RPC presentation (number of days flow is recorded at less than 50 m^3/s at OHB) and is presented as Table 2.

The theoretical number of days at the minimum flow (41 m^3/s: 'flat-lining') in a median flow year is 52 days for all scenarios, and shows that flat-lining at the minimum flow is generated solely by full use of the A allocation block. Similarly, a number of days are flat-lined at 71 m^3/s and this is generated by full use of the B gap alone. Number of days at 71 m^3/s further increases at increasing sizes of the B block. While these are frequencies of ‘flat-lining’ for the median flow year condition, they would increase further in dryer years (as is visible in the dry year hydrograph (Figure 6 cf. Figure 8).

More enlightening as to the effect on lower flows of the river is the theoretical number of days flows would be less than 50 m^3/s (Table 2.). This shows that the number of low flow days below 50 m^3/s increases from 18 days (naturally) to 100 days as a result of the full use of the A allocation block alone. There is no further increase in number of (<50 m^3/s) low flow days as a result of B allocation blocks if there is a 30 m^3/s allocation gap present. However 1:1 flow sharing from the beginning of the B block would generate a further additional 31 days per year (131 days total) with river flows at <50 m^3/s in a median flow year. Table 2. also shows that there is significant variation year to year in this statistic with the river showing up to 252 days at <50 m^3/s with an allocation gap, and up to 278 days below 50 m^3/s with 1:1 flow sharing in an extremely dry year (1969/70). This shows the potential for dry years to generate detrimental flow regimes, and increased incidence of these detrimental low flows in the river (<50 m^3/s) as a result of 1:1 flow sharing B allocation regimes.

Flow regimes are therefore not only designed to manage the effects of the modelled median flow year condition (~average year), but even more importantly to minimise the critical effects in low flow years.

The further three statistics in Table 1 relate to length of ‘accrual periods’ between fresh peaks (periods of time available for unrestricted algal growth), and number of fresh peaks. The maximum length of time between 130 m^3/s freshes in a median flow year is 57 days, and this increases to 68 days as a result of full use of the A block allocation. Further increased durations are 2 and 14 days respectively for B blocks of 20 and 40 m^3/s respectively, irrespective of whether the regime is based upon a gap regime or 1:1 flow sharing. These increased durations are problematical as they greatly exceed the 3-4 or 4-6 weeks (28-42 days) threshold for excessive algal growths suggested by both Biggs et al. (2008) and our observations from NRWQN data respectively. This would suggest that under fully utilised A allocation blocks we should routinely see some periods of nuisance growths in median flow years, only a small further increase (2 days) as a result of a B block of 20 m^3/s but a much larger increase in duration and prevalence (14 days) as a result of bigger B block allocations. The effects would be exacerbated to a greater extent in dryer years. This illustrates that under a highly utilised allocation regime we could expect to see and receive complaints about nuisance algal mat growths much more frequently and to a greater degree in the river. This would be a direct visible measure of ecological sustainability.

The B block allocation regimes have a less dramatic effect on larger bed moving freshes (3x median flow (284 m^3/s)) reducing their incidence (natural median 10 times per year) by two and three peaks for the two block sizes respectively, and increasing the maximum number of days between these size freshes by 25 and 32 days respectively. Again, these decreased number of peaks and increase duration between peaks would lead to less healthy river bed communities under B block allocation regimes, especially at lower flow times. Again, in dryer years the reduction in size or loss of these larger freshes may be of even greater significance.

The effect on increased accrual (algal growth) period and reduced fresh frequency is exacerbated by all of the different B block allocation regimes, but may be additionally addressed by a specific rule to protect the integrity of particular freshes after a specified inter-fresh period has been exceeded. This is intuitively needed in addition to the other flow management components. This was promoted as a component of the original overall draft plan change, and is further discussed in more detail later in this memo.

The other major hydrological statistics table (Table 3.) describes numbers of days, and numbers of consecutive days in beneficial flow ranges. Under a natural flow regime the Waimakariri River in median flow year condition has 166 days (45% of the year) in the beneficial flow range of 50-100 m^3/s. This high percentage shows why the Waimakariri River is generally so productive, and so highly regarded for recreational and ecological activities. Almost half of the days in a year provide an opportunity for utilising recreational, sporting or ecological values. However, if the A allocation block is fully utilised, this reduces by 33 days, to 133 days. The fully utilised B block allocations with a gap, increase the number of beneficial days back to close to natural levels (for a 20 m^3/s block) or exceed it (40 m^3/s block). These additional 'opportunities' are generated solely by allocations drawing fresh flows down into the optimal range, while the gap prevents lower flow days being drawn down into sub-optimal < 50 m^3/sec flows . Beneficial flow day opportunities afforded by 1:1 flow regimes are much less than 'natural' or 'gap' regimes because more days (30+) are drawn down below 50 m^3/s into detrimental 'low flow' conditions. This is one of the biggest detriments of the 1:1 flow regimes modelled. The effect is also further exacerbated in successively dryer years as successively more days are drawn into < 50 m^3/s flows (Table 2).

Patterns are similar, but benefits are less for the widened flow range of 50-150 m^3/s, and 1:1 flow sharing regimes continue to be detrimental to generating optimal flow opportunities. The maximum number of successive days within optimum flow ranges (days of continuous opportunity) shows a similar pattern with gap regimes improving windows of instream use opportunities relative to the A block alone, but 1:1 flow sharing regimes being more detrimental than the A block alone.

Overall, the statistical assessments show that B block allocations can be acceptable for maintaining flow range opportunities at median flow years if associated with a B block gap, but not if associated with 1:1 flow sharing. This is because maintaining flows in a beneficial flow range is an interplay between drawing higher flow days down into the beneficial range, but not drawing useable lower flow days down into the < 50 m^3/s sub-optimal flow range.

Flood or Fresh rules

A final issue worthy of consideration, is managing flow variability effects via a specific flood or fresh protection rule. That is, a rule that identifies the onset of a significant fresh and imposes restrictions on takes to allow the fresh to pass through the river for a period without abstraction. The fresh is therefore allowed to exert its beneficial 'flushing' effects functions, unhindered by abstractions.

The plan review council agenda paper (15 April 2009) discussed and proposed a flood protection rule. This rule sought to achieve protection of freshes after either an interfresh period of 21 days, or if detrimental algal growths were identified.

A specified 21 day period is appropriate (despite being considerably shorter than the 4-6 weeks discussed previously) as a trigger because a flood or fresh will generally occur some considerable time after trigger conditions are generated, and the fresh is designed to 'prevent' rather than 'treat' nuisance growth conditions. Freshes that need to be protected are those that generate in-river flows with a peak at or over 130 m^3/s.

The problem with such rules is ensuring they can respond in a timely manner to a rising hydrograph and trigger cessation of abstractions before the fresh has peaked. An example of a moderate fresh is shown in Figure 9. This 140 m^3/s fresh had a rising limb of less than one day. Therefore, timely trigger responses to such a rising hydrograph would need to be between instantaneous to over a small number of hours (not a daily trigger).

From the peak there was a duration of 5 and 8 days of B block allocation abstractable water (for B Gap and 1:1 regimes respectively) and a total of 12 days until flows again fell below 50 m^3/s. A flood/fresh protection rule protecting 12 or 24 hours of the fresh are therefore still leaving a significant abstractable volume on the descending limb.

To be effective such **rules would need to apply to both A and B allocation blocks** and be triggered in real time (such as from Otarama or further upstream (Esk River recorder?)) to effectively allow the flood peak to be identified and protected. Such a regime is not possible with the current recording site measures (daily flow record and daily irrigation restrictions posted to a website from OHB) but is likely to become viable over time with telemetry of data and more sophisticated management of abstractions. Conversely it may be possible or effective to manage such a regime via ‘audited self monitoring’ by major abstractors detecting and responding to such rising limbs at their intake points.

Overall, more consideration needs to be given to effective development of such a rule, but it intuitively is a very effective means of managing the flood and fresh requirements of the river, and overall functional resilience of the ecology of the river. From considering the relative responses to flow variability protection in Table 1, it can also be deduced that such a rule would also directly address the advisability of a small (20 m^3/s) B allocation block **without** explicit fresh protection, or advisability of a large (40 m^3/s) B allocation block **with** explicit fresh protection.

A final consideration is whether an explicit fresh protection rule may be considered additional to or replaces the other flow regime rules. Implementing a fresh protection rule alone would potentially make more water available for allocation with less potential restriction. However, this is not being promoted or suggested, as fresh protection only addresses one area of flow requirement discussed earlier (i.e. it does not address the issues of beneficial flow bands, flat lining, frequency of suboptimal flows (<50 m^3/s) etc.). Clearly, a fresh protection rule must be considered as only one element of the flow regime rules giving rise to a sustainable flow regime.

Conclusion.

This memo has considered a range of flow regime requirements necessary to ensure ecological and recreational values are provided for in managing allocations of water for abstraction. The high use and wide range of values of the Waimakariri River for both in-river and out-of-river uses means there is considerable tension between the two groups of uses. The separation of the flow regime into different functional elements has allowed more in depth consideration of flow regime requirements and a more detailed analysis against the 40 year hydrological record of the Waimakariri River. It has also allowed more detailed assessment of a wide range of possible managed flow regimes and analysis of them against the functional flow elements.

An overall analysis shows a pattern of B block regimes with a significant gap between the A and B blocks being most beneficial to managing effects on river ecological and recreational values. Conversely, a 1:1 environmental flow sharing regime is least limiting to abstractive out of river users, but least beneficial to maintaining in-river values. B block allocation size is a further consideration with benefits and detriments of smaller or larger block sizes. On the 4 assessed flow regimes alone, the 30 Gap/20 Block regime appears to be the most beneficial for sustainably protecting in-river values. However, if explicit protection of critical freshes can be effected by a smart fresh protection rule, then the 30 Gap/40 Block regime could be recommended. Neither of the 1:1 flow sharing regimes could be recommended on the basis of their sustainable management of ecological or recreational in-river values.

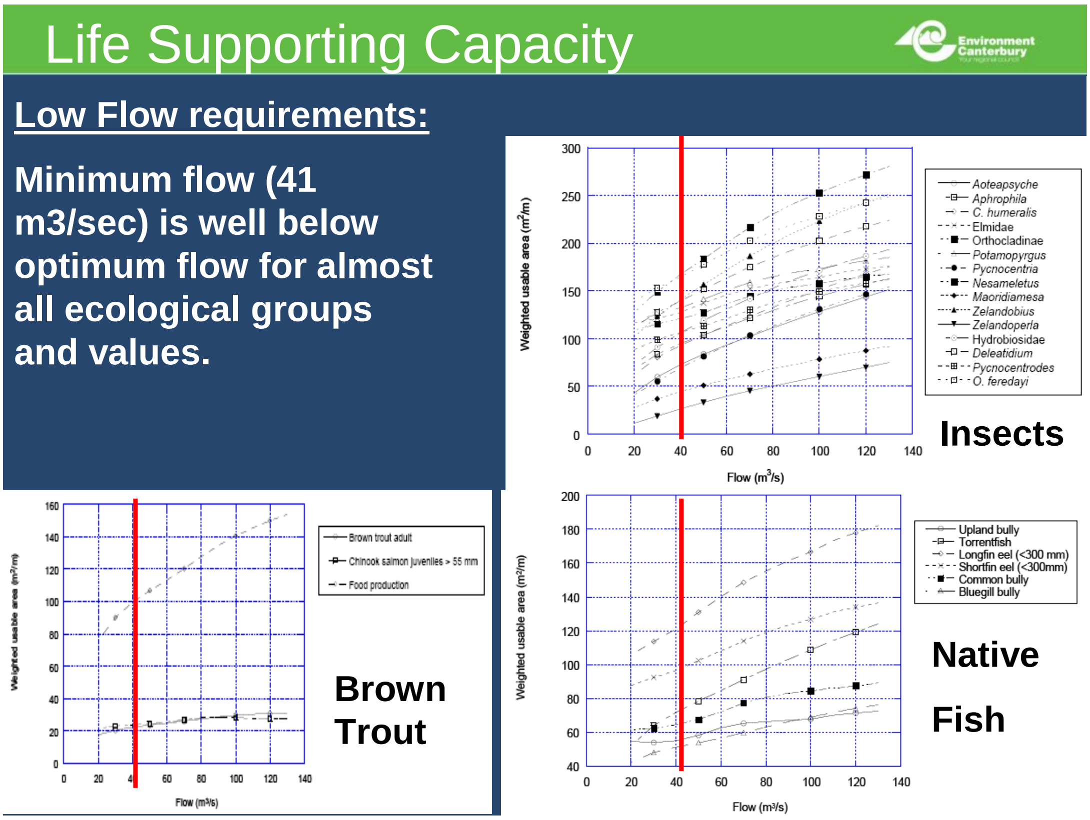
References cited

Biggs, B.J.F., Ibbitt, R.P., and Jowett, I.G. 2008: Determination of flow regimes for protection of in-river values in New Zealand: an overview. *Ecohydrology and Hydrobiology*: 8(1): 17-29.

Duncan, M. 2008: Waimakariri River: B/C Block allocation Review. Environment Canterbury Technical Report R08/67. 32pp.

Duncan, M, and Bind, J. 2008: Waimakariri River bed sediment movement for ecological resetting. Environment Canterbury Technical Report R08/94. 32pp.

Figure 1. Selected IFIM WUA vs Flow curves presented in evidence at CPWL hearings for the Waimakariri River at Crossbank.



Life Supporting Capacity

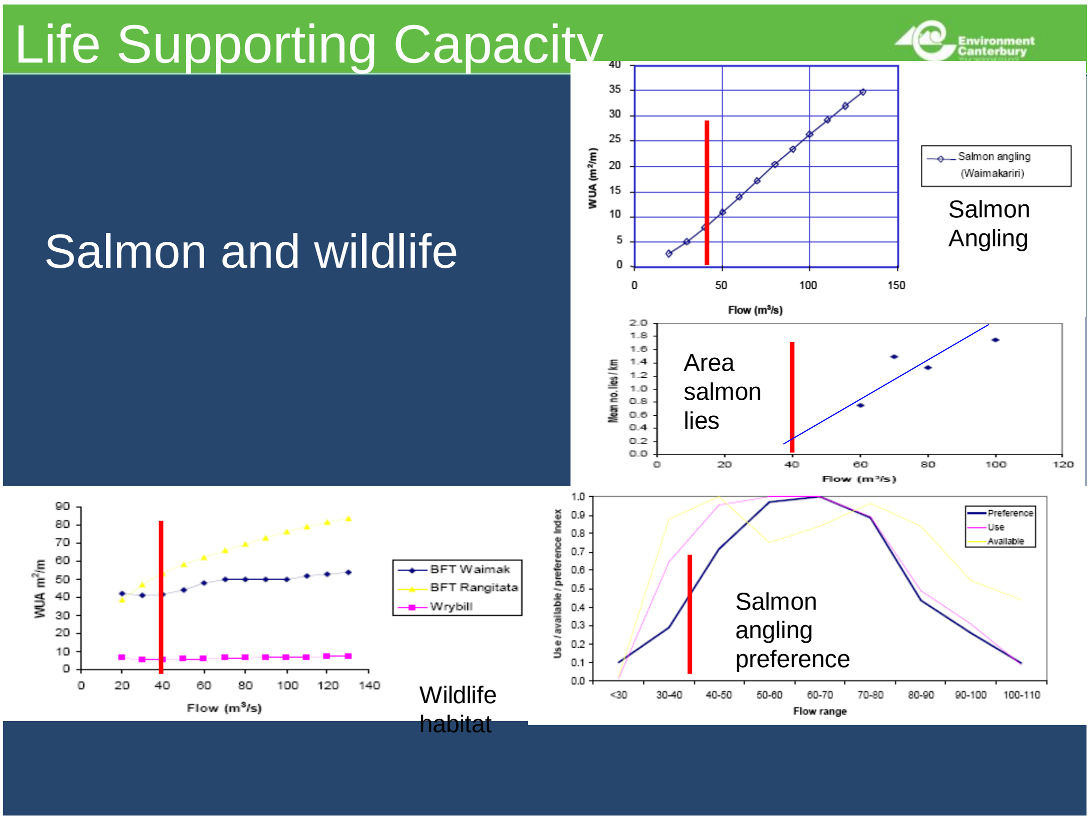
Low Flow requirements:

Minimum flow (41 m3/sec) is well below optimum flow for almost all ecological groups and values.

Insects

Brown Trout

Native Fish



Life Supporting Capacity

Salmon and wildlife

Salmon Angling

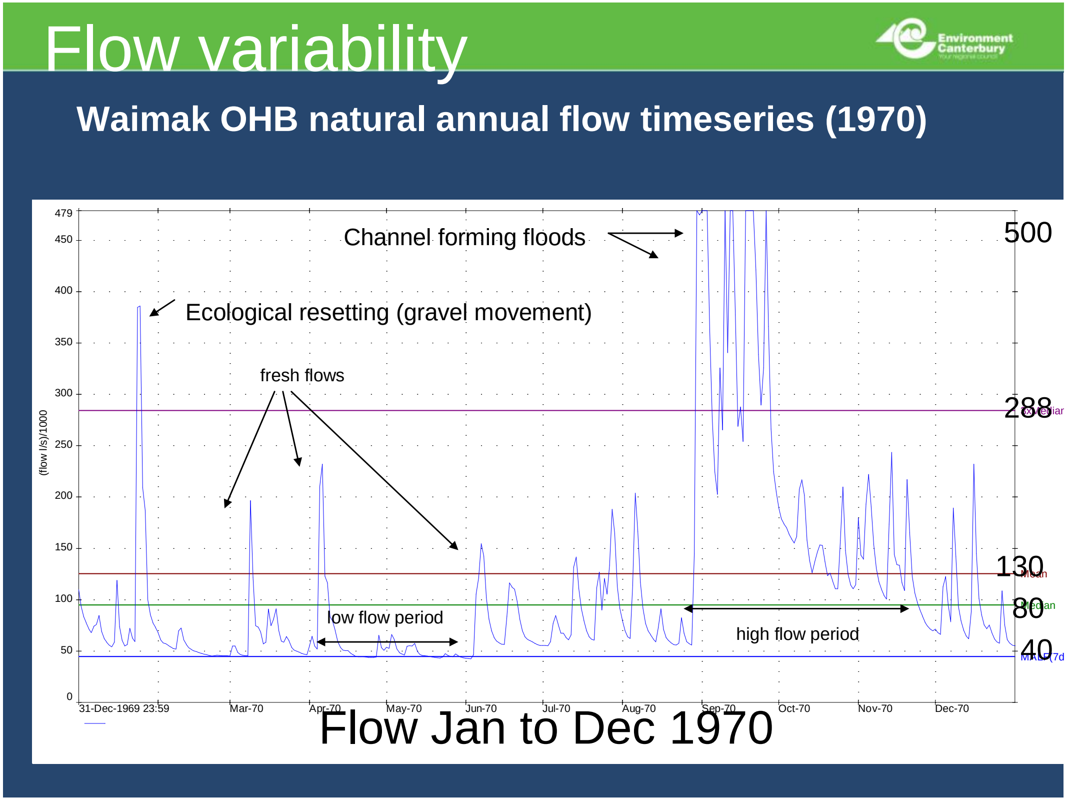
Area salmon lies

Wildlife habitat

Salmon angling preference

(From evidence of Hayes, and Olsen (Cawthron Institute)).

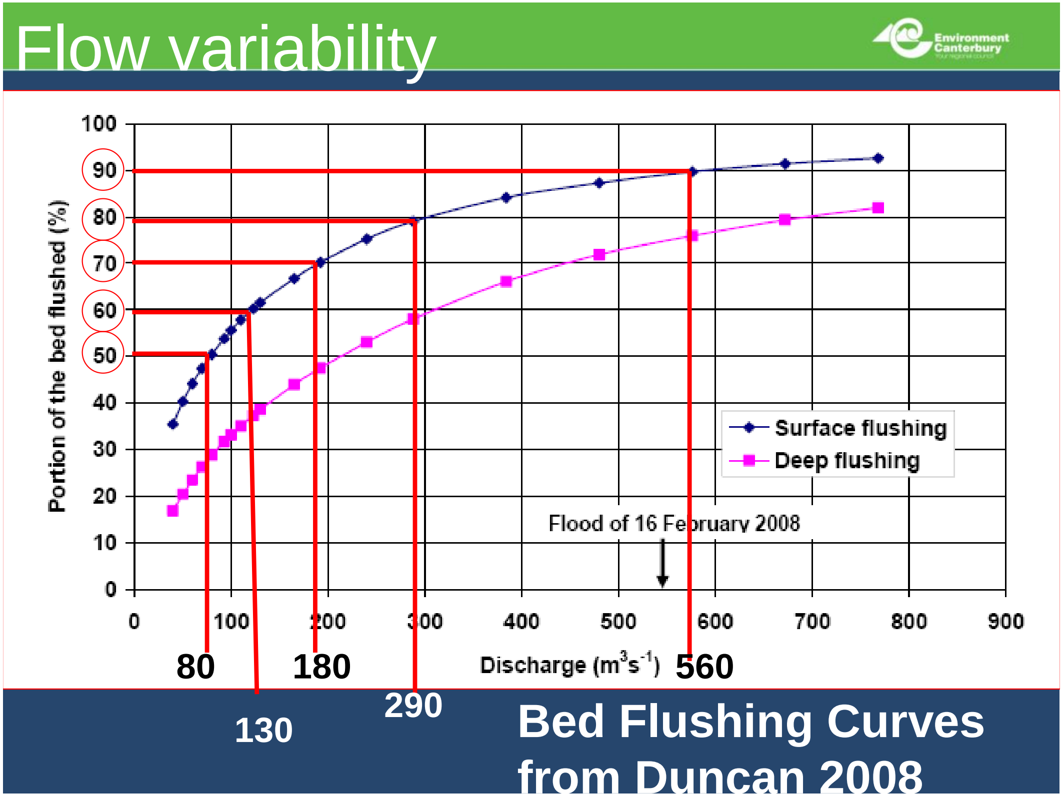
Figure 2 Annual hydrograph of Waimakariri River indicating typical flood and fresh sizes/types.



Flow variability

Waimak OHB natural annual flow timeseries (1970)

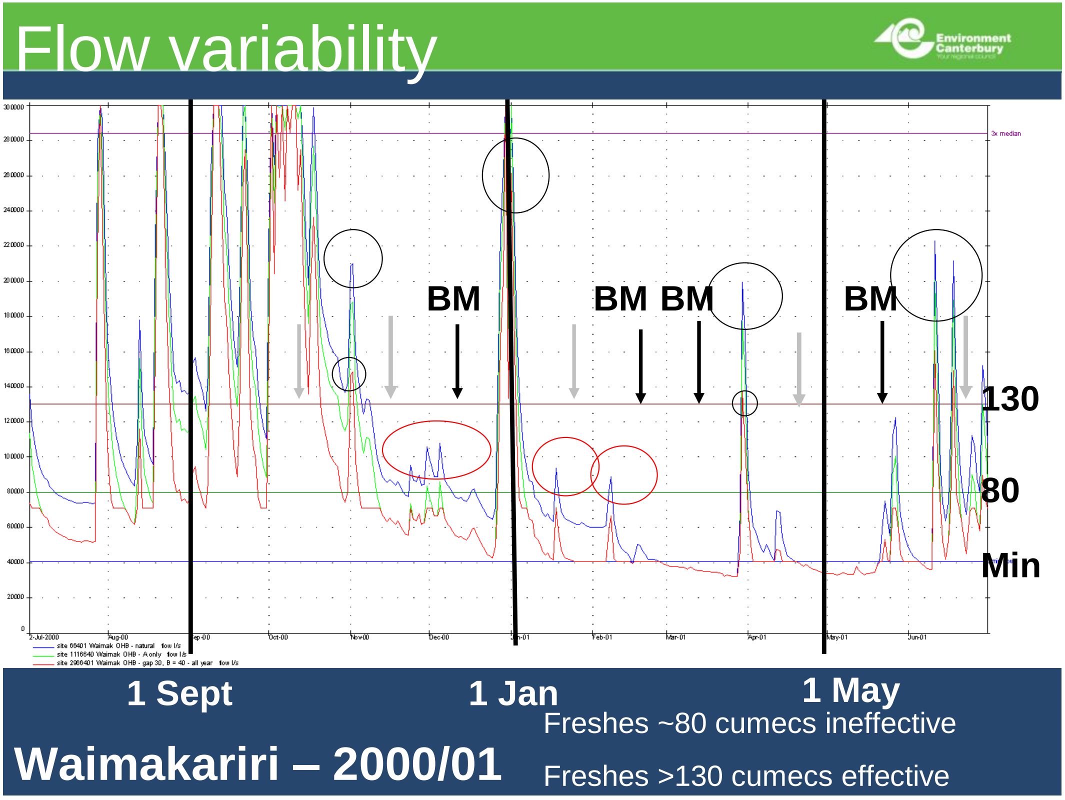
Figure 3 Modelled bed flushing versus flow curves from Duncan and Bind (2008) with superimposed fresh and flood size criteria.



Flow variability

Bed Flushing Curves from Duncan 2008

Figure 4. Hydrograph (2000/01) from Waimakariri River indication presence of Black Mats (black arrows) and absence of mats (grey arrows) in NIWA NRWQN monitoring. Circled freshes and floods discussed in text.



Flow variability

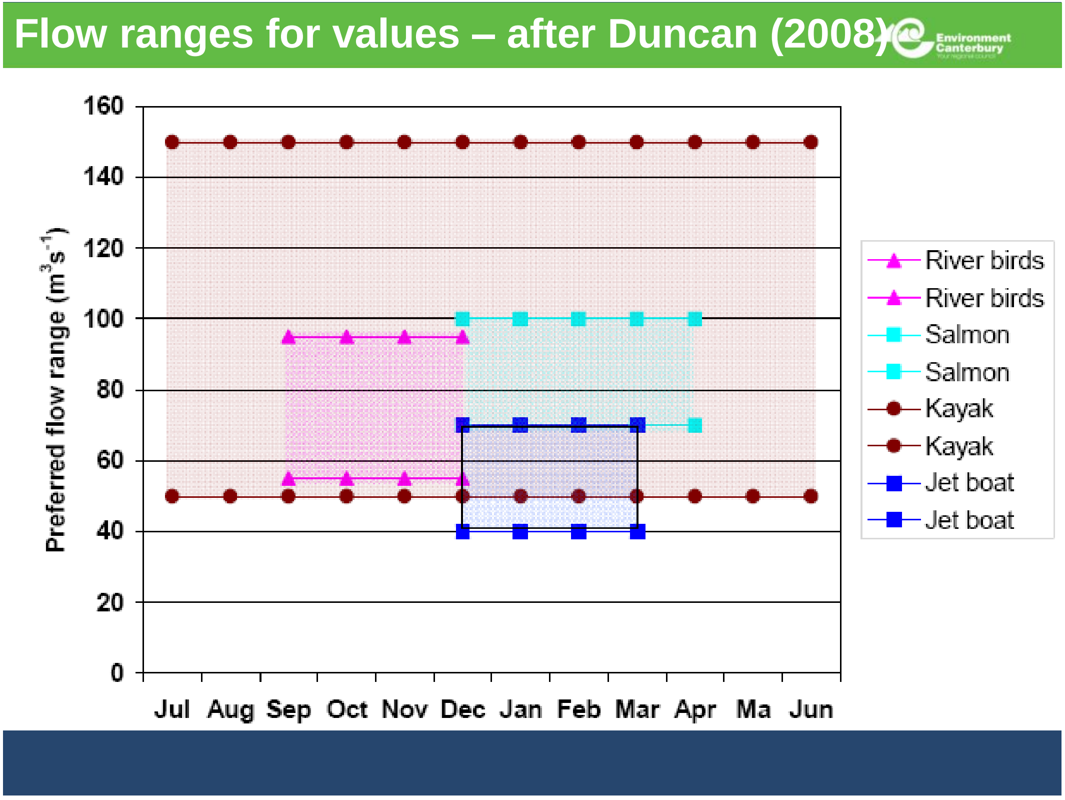
1 Sept
1 Jan
1 May

Waimakariri – 2000/01

Freshes ~80 cumecs ineffective

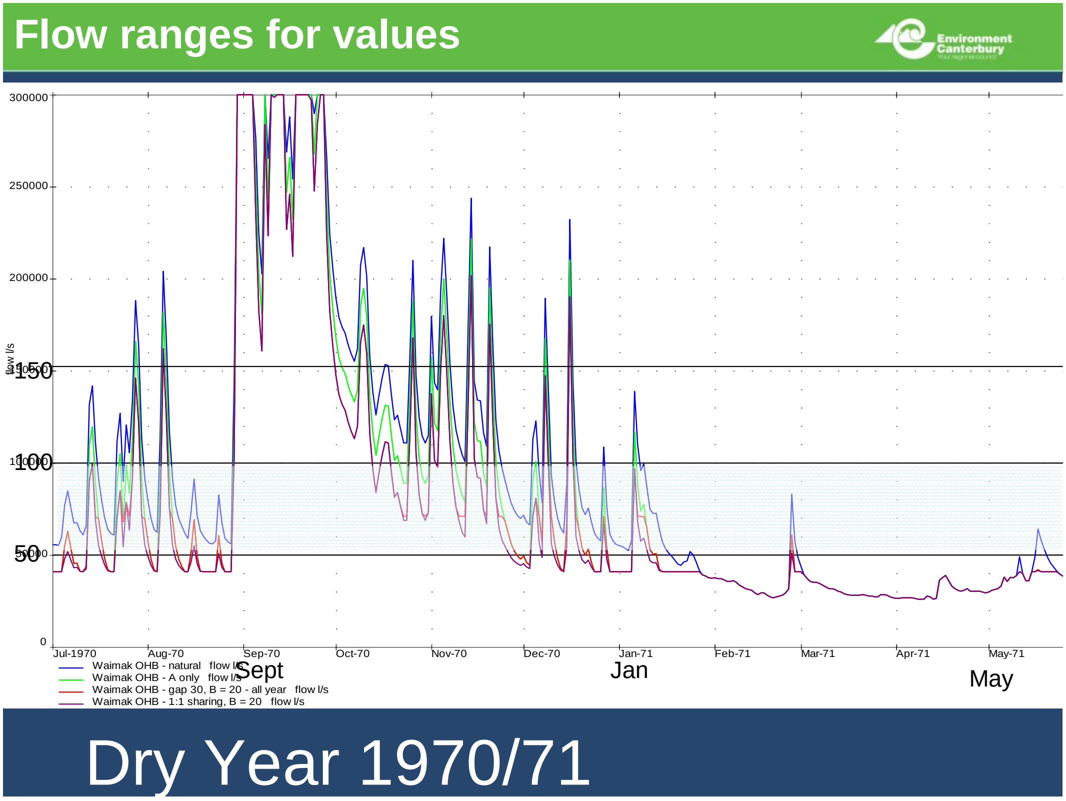
Freshes >130 cumecs effective

Figure 5. Schematic presentation of preferred flow ranges for four ecological and recreational values (after Duncan 2008).



Flow ranges for values – after Duncan (2008)

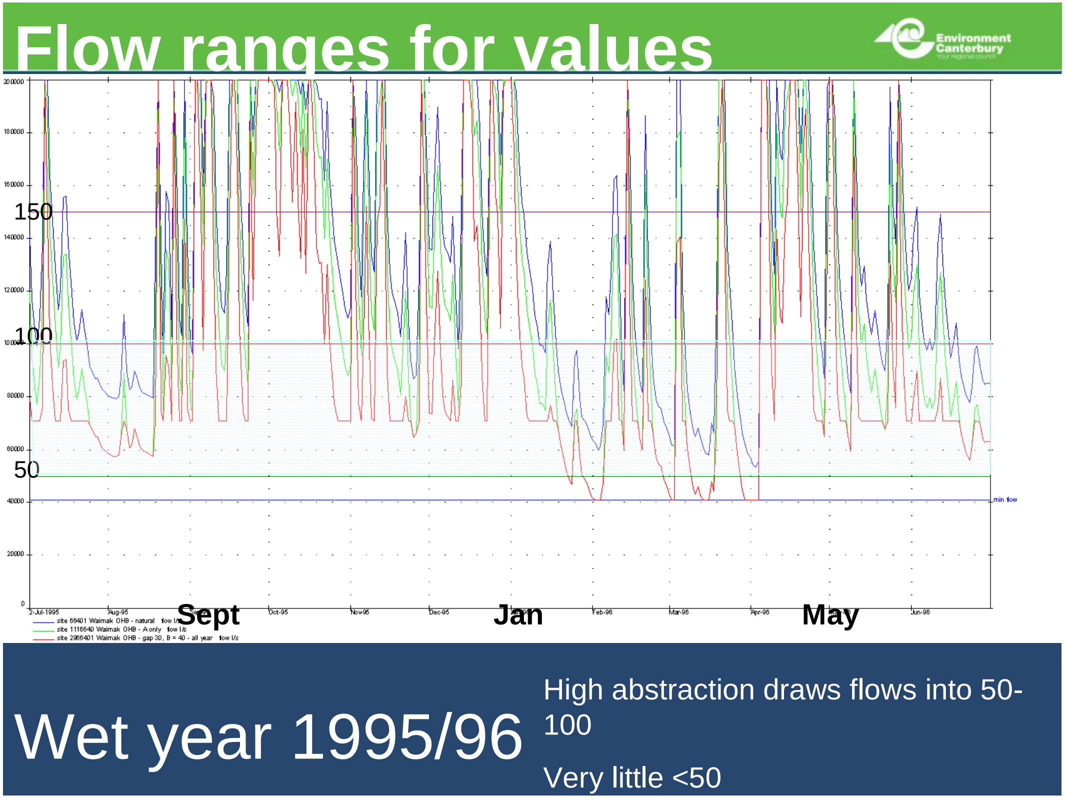
Figure 6. Annual hydrograph for the Waimakariri River for the year generally considered to represent a "dry [summer] flow year".



Flow ranges for values

Dry Year 1970/71

Figure 7. Annual hydrograph for the Waimakariri River for the year generally considered to represent a "wet [summer] flow year".



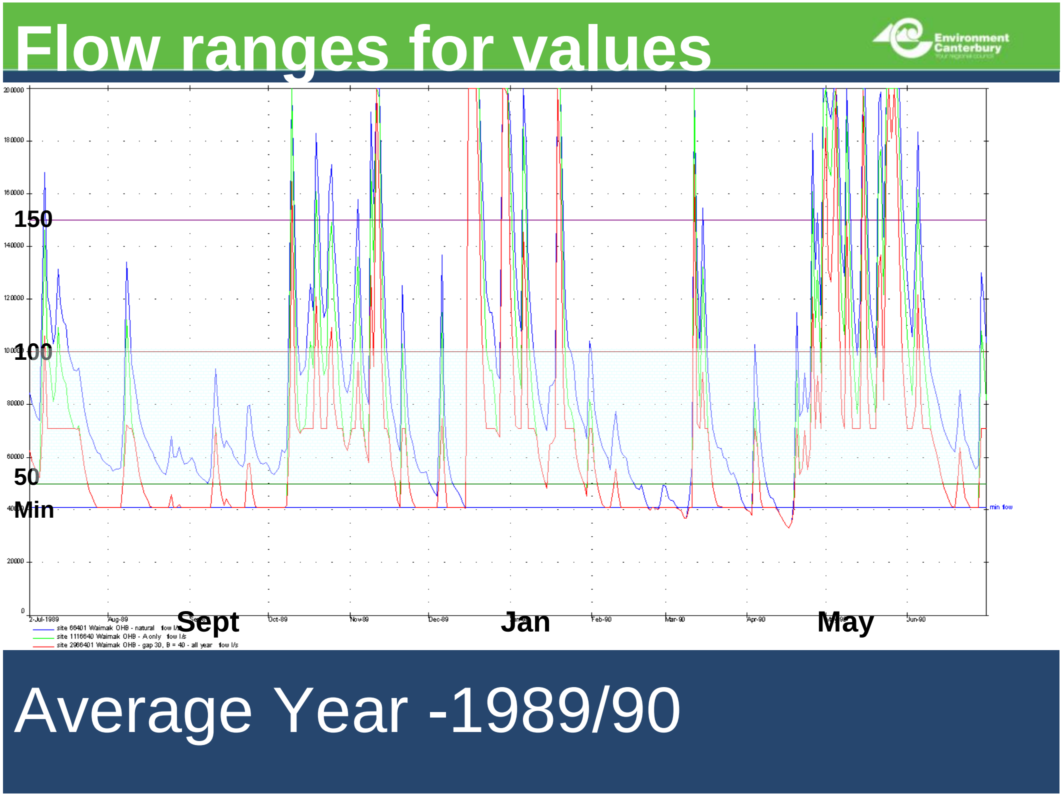
Flow ranges for values

Wet year 1995/96

High abstraction draws flows into 50-100

Very little <50

Figure 8. Annual hydrograph for the Waimakariri River for the year generally considered to represent an "average [summer] flow year".



Flow ranges for values

Average Year -1989/90

Figure 9. Hydrograph of a random 140 m3/sec fresh (January 5 1971), to illustrate features of the flow characteristics a 'typical' fresh flow.

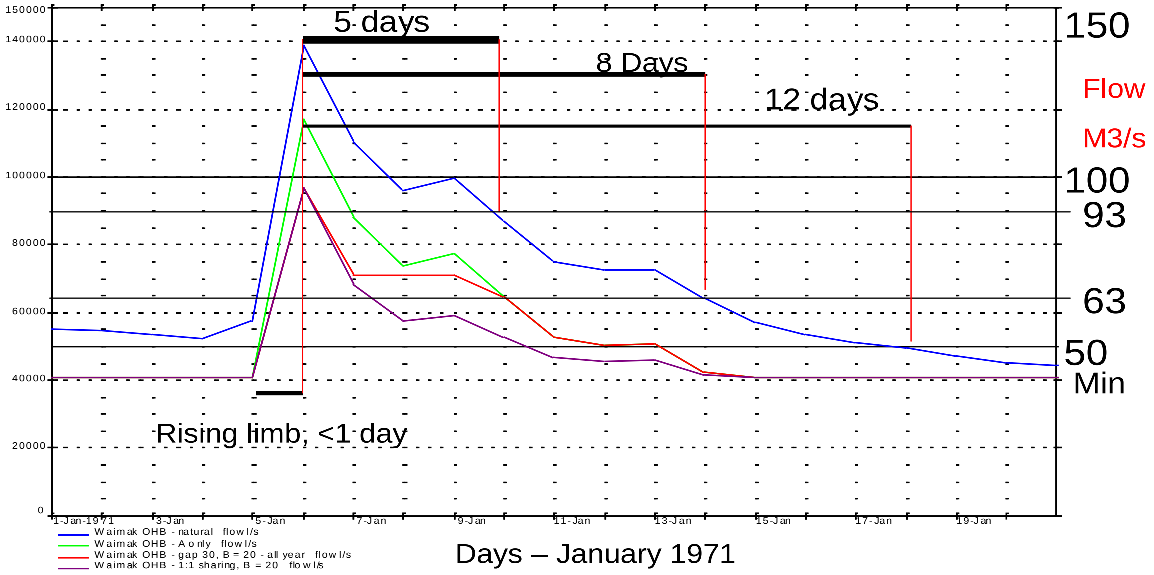
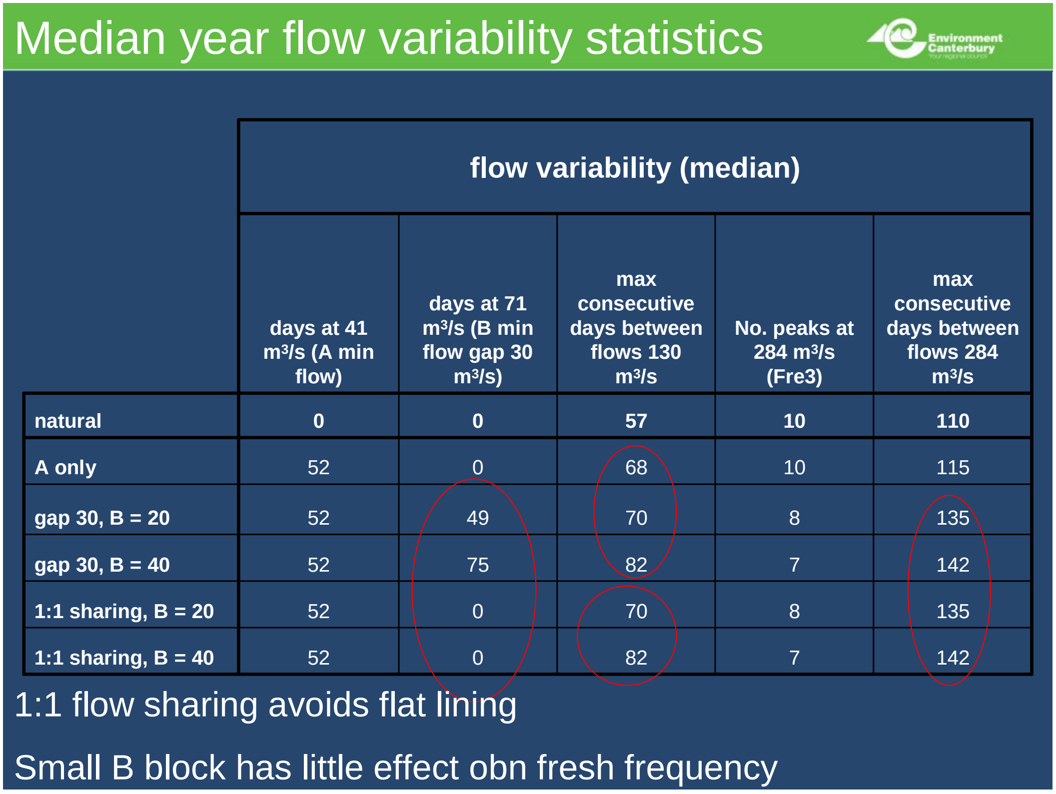


Table 1. Hydrological statistics representing flow variability features, modelled for the Waimakariri River median flow year condition.



Median year flow variability statistics

	flow variability (median)				
	days at 41 m^3/s (A min flow)	**days at 71 m^3/s (B min flow gap 30 m^3/s)**	**max consecutive days between flows 130 m^3/s**	**No. peaks at 284 m^3/s (Fre3)**	**max consecutive days between flows 284 m^3/s**
natural	**0**	**0**	**57**	**10**	**110**
A only	52	0	68	10	115
gap 30, B = 20	52	49	70	8	135
gap 30, B = 40	52	75	82	7	142
1:1 sharing, B = 20	52	0	70	8	135
1:1 sharing, B = 40	52	0	82	7	142

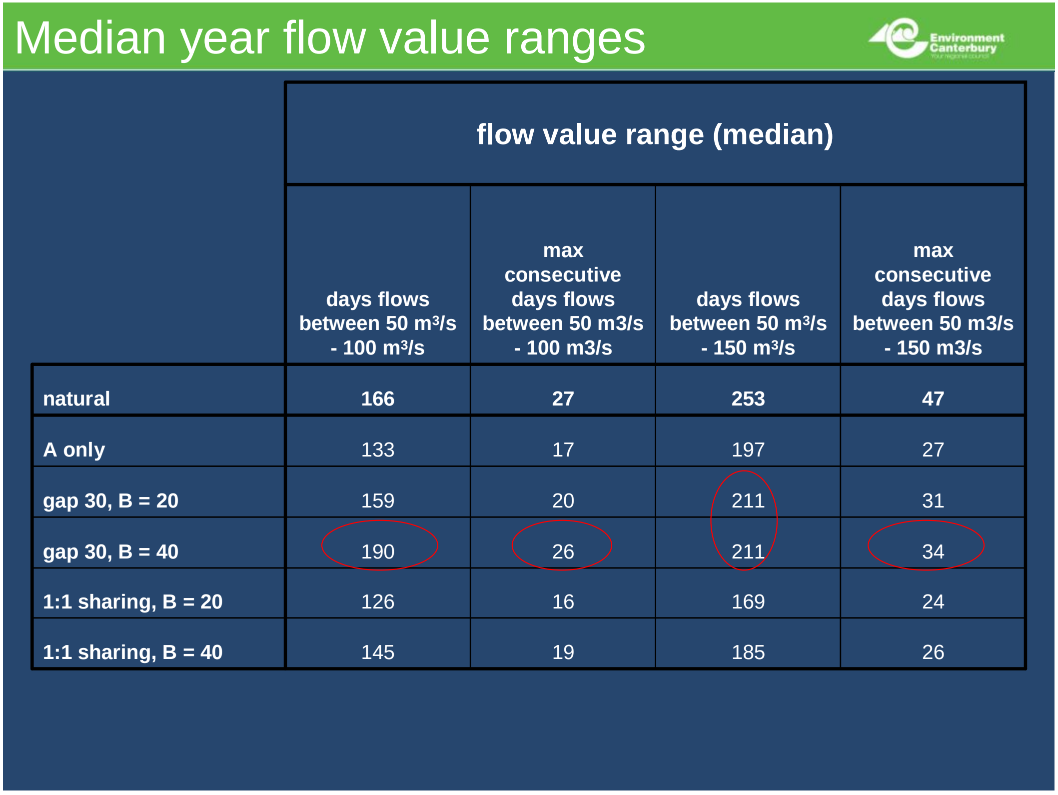
1:1 flow sharing avoids flat lining

Small B block has little effect obn fresh frequency

Table 2. Modelled number of days Waimakariri River flow would be below 50 m3/s for individual years and median flow condition for 7 flow regimes.

Number of days river flow is below 50 m3/s							
YEAR	natural	recorded	A only	gap 30, B = 20	gap 30, B = 40	1:1 flow sharing, B = 20	1:1 flow sharing, B = 40
	66401	166401	1116640	2866401	2966401	3366401	3466401
67/68	9	29	76	76	76	97	97
68/69	59	94	181	181	181	200	200
69/70	78	116	252	252	252	278	278
70/71	129	141	200	200	200	217	217
71/72	82	109	167	167	167	203	203
72/73	79	91	143	143	143	174	174
73/74	29	50	157	157	157	204	204
74/75	0	0	37	37	37	80	80
75/76	21	34	96	96	96	122	122
76/77	0	10	76	76	76	114	114
77/78	52	65	157	157	157	195	195
78/79	0	0	32	32	32	68	68
79/80	0	0	16	16	16	43	43
80/81	16	24	92	92	92	125	125
81/82	46	66	133	133	133	162	162
82/83	32	46	85	85	85	110	110
83/84	8	23	87	87	87	122	122
84/85	74	100	157	157	157	177	177
85/86	5	11	89	89	89	123	123
86/87	0	0	27	27	27	57	57
87/88	36	53	135	135	135	171	171
88/89	21	38	100	100	100	126	126
89/90	46	70	165	165	165	197	197
90/91	17	26	97	97	97	120	120
91/92	84	112	158	158	158	174	174
92/93	4	4	76	76	76	86	86
93/94	13	33	133	133	133	179	179
94/95	0	21	35	35	35	58	58
95/96	0	2	31	31	31	51	51
96/97	4	5	39	39	39	91	91
97/98	0	0	105	105	105	157	157
98/99	22	43	113	113	113	154	154
99/00	0	12	68	68	68	131	131
00/01	96	104	144	144	144	184	184
01/02	36	59	142	142	142	172	172
02/03	18	34	82	82	82	119	119
03/04	9	14	54	54	54	86	86
04/05	7	27	121	121	121	157	157
05/06	57	112	202	202	202	244	244
min	0	0	16	16	16	43	43
median	**18**	**34**	**100**	**100**	**100**	**131**	**131**
average	30	46	109	109	109	142	142
max	129	141	252	252	252	278	278

Table 3 Hydrological statistics representing flow range features, modelled for the Waimakariri River median flow year condition.



Median year flow value ranges

	flow value range (median)			
	days flows between 50 m³/s - 100 m³/s	max consecutive days flows between 50 m3/s - 100 m3/s	days flows between 50 m³/s - 150 m³/s	max consecutive days flows between 50 m3/s - 150 m3/s
natural	**166**	**27**	**253**	**47**
A only	133	17	197	27
gap 30, B = 20	159	20	211	31
gap 30, B = 40	190	26	211	34
1:1 sharing, B = 20	126	16	169	24
1:1 sharing, B = 40	145	19	185	26