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FLOW HARVESTING: A REVIEW OF POLICY AND POTENTIAL EFFECTS
FLOW HARVESTING: A REVIEW OF POLICY AND POTENTIAL EFFECTS

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EXECUTIVE SUMMARY

As demand for water increases in New Zealand, flow harvesting — abstracting water during periods of relatively high flow, generally into storage for later use — is increasingly being considered. Flow harvesting presents a possible solution to the common temporal mismatch between water availability and demand, an issue that is likely to increase with predicted climate change.

However, the effects of flow harvesting and storage provide new challenges for Regional Plans and the scientific methods used to set flow and water allocation limits, because of the potential to influence components of the flow regime other than low flows. Water allocation policy allowing for flow harvesting is termed ‘supplementary allocation’ in this report.

Environment Southland commissioned this report to review supplementary water allocation policy employed by other regional councils in New Zealand and potential effects of flow harvesting on the in-stream environment, as well as possible effects assessment methods.

Flow harvesting is likely to reduce mid-range flows\(^1\), with potential changes including altering flow variability, the magnitude, frequency, duration and timing (e.g. seasonality) of high and low flows. These changes have the potential to result in adverse effects on river morphology, sediment transport, periphyton, invertebrate production, freshwater fish and river bird populations and fish migration, as well as recreational river users and cultural values.

While there is insufficient ecological understanding to precisely quantify the likely ecological response of a given reduction in flow, the ecologically important flow components identified in this report, provides a starting point for assessing the likely significance of flow regime changes caused by supplementary allocation. Existing scientific knowledge provides useful rules-of-thumb regarding aspects of flow regimes that may need to be maintained. There are also several flow assessment tools that can be applied to provide more certainty around effects assessment, mainly on a case-specific basis.

A survey of regional councils and unitary authorities found that, the majority of councils have explicitly addressed the issue of flow harvesting or supplementary allocation in policy, with some (particularly the larger regional councils) having specified flow thresholds and/or allocation caps, while others have narrative clauses indicating the desire to support or promote water capture and storage. However, in many cases the policy remains relatively untested, so potential issues with implementation are yet to be revealed.

Those councils that have explicitly addressed supplementary (flow harvesting) in policy, tend to have a minimum flow threshold for abstraction and usually also either a cap on allocation or provision for flow sharing above this threshold. The most commonly used minimum flow for supplementary allocations, is the median flow.

\(^{1}\)Mid-range flows are between mean annual low flow and mean annual flood flow.
Several councils have policies that encourage off-season abstraction to storage during the winter, either explicitly or implicitly.

As with primary allocation, developing appropriate management objectives to reflect community aspirations is the critical first step in setting appropriate flow regimes. The level of investigation required for flow setting should be matched to the relative in-stream values and the level of abstraction pressure (i.e. the degree of hydrological alteration). Where abstraction pressure and/or in-stream values are low, simple rules-of-thumb may be adequate for flow setting, while in cases with high abstraction pressure and/or high in-stream values, more in-depth investigations are warranted.

With this in mind, I consider that policy providing for a tiered approach to supplementary allocation would be sensible, with the level of investigation depending on demand. This approach could specify a default minimum flow and supplementary allocation limit to provide protection for ecologically relevant components of the flow regime. However, it could also clearly indicate that more ambitious abstraction applications would be considered — provided that they include an appropriate level of effects assessment commensurate with a larger degree of hydrological alteration.

I consider that using the median flow as the minimum flow threshold for supplementary allocation is more appropriate than the mean flow, on the basis of current science, provided that other mechanisms, such as flow sharing or an allocation cap are also implemented to maintain higher ecologically relevant flow events (such as flushing flows). This flow threshold also has the advantage of increasing reliability of supply for abstractors.

Flow sharing has apparently presented compliance issues where there are multiple abstractions. Consequently, it may be worthwhile considering a simple cap on supplementary allocation, or perhaps a block by block flow sharing arrangement to avoid this problem.

Policy explicitly encouraging abstraction to storage during winter may also be worth considering, since demand and ecological flow requirements are likely to be lower then.

Supplementary allocation and water storage schemes may enable intensification of land use, with the potential for detrimental impacts on water quality. It would be prudent to bear these potential effects in mind, alongside the more direct in-stream impacts of supplementary allocation, when considering policy changes.
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1. INTRODUCTION

Although New Zealand is fortunate to have relatively abundant water resources, these are coming under increasing pressure. Until recently, minimum flows and allocation limits were generally considered sufficient planning mechanisms to protect environmental values for run-of-river water use in New Zealand (Snelder et al. 2013). However, as run-of-river allocation approaches regulated limits, water storage and flow harvesting (abstracting water during periods of relatively high flow, generally into storage for later use) is increasingly being considered (LAWF, 2010). Also, there is often a temporal mismatch between water availability and abstraction demands. The vast majority of water abstracted in New Zealand is used for irrigation (Rajanayaka et al. 2010), and demand tends to peak during summer dry periods. However, since much of the annual discharge occurs during relatively short periods of high flow, often during winter and spring, it is not available for abstraction when it is most required. This pattern may be exacerbated by climate change, with predicted increases in droughts and extreme rainfall events (Office of the Prime Minister’s Science Advisory Committee 2013). Flow harvesting and water storage offer a possible solution to this issue.

However, the effects of flow harvesting and storage provide new challenges for defining limits to water abstraction because of the potential to influence components of the flow regime other than low flows (Snelder et al. 2013). Consequently, regional plans and the scientific methods used to set limits will need to continue evolving to meet these challenges.

The terminology used around water allocation policy varies between regional councils. Water allocation policy allowing for flow harvesting has been variously termed supplementary allocation, secondary allocation, B or C block allocation, etc. The term supplementary allocation is used in this report.

Environment Southland recognises the need for information to underpin its policy on this component of water allocation for their region. They commissioned this report to review supplementary water allocation policy employed by other regional councils in New Zealand and potential effects of flow harvesting on the in-stream environment, as well as possible impact assessment methods.
2. POTENTIAL IN-STREAM EFFECTS OF FLOW HARVESTING

The potential effects of water abstraction for flow harvesting will depend largely on the flow range over which it occurs and the magnitude of abstraction, and the resulting degree of hydrological alteration (as discussed by Beca 2008). Flow harvesting is more likely to influence relatively high flows, although this depends on the policy governing allocation — as well as flood harvesting, flow could also be ‘harvested’ into storage during periods of moderate flows when water is not required for the intended use (e.g. into irrigation storage during winter). In any case, flow harvesting is likely to reduce mid-range flows to some extent. Snelder et al. (2011a) defined mid-range flows as the flows between mean annual low flow and mean annual flood flow. Potential changes to mid-range flows may include altering the variability of flows, the magnitude, frequency, duration and timing (e.g. seasonality) of high and low flows.

The following list provides a summary of recognised ecologically important components of the flow regime (based on Beca (2008):

1. Large floods, which are responsible for maintaining channel form and large scale sediment transport. Often referred to as channel forming flows. These are likely to be in the order of the mean annual maximum flow.
2. Smaller floods and freshes, which flush fine sediment, periphyton and other aquatic vegetation. Often referred to as flushing flows.
3. Low flows, the period of minimum wetted habitat availability, but also potentially of relatively high productivity in the remaining habitat.
4. Flow recessions, higher than usual flow in the few days following a flood may offer enhanced recreational opportunity, and increased wetted area during flow recession over longer periods (i.e. weeks) may enhance ecosystem productivity.
5. Flow variability, at a range of scales. From seasonal variability comprising the annual flow regime to small scale flow variations (which many people consider are an essential element of the regime that should be maintained, avoiding long periods of artificial “flat lining”). In some situations the timing of flow variability may be a critical factor, e.g. to provide a stimulus for fish migrations.

All of these functions and processes are performed by mid-range flows as defined by Snelder et al. (2011a). The ecologically relevant components of flow regimes most likely to be altered by supplementary allocation are channel-forming and flushing flows, in particular, through changes to the frequency, duration and magnitude of floods and freshes, as well as flow recessions that potentially support invertebrate production (in the low-to-median flow range) (Hayes 2009). Consequently, supplementary allocation has the potential to have significant physical and ecological effects in rivers. Water storage schemes (e.g. those involving damming and impoundment or large-scale diversion to an impoundment) have larger potential
effects on a river’s hydrology than usual ‘run of river’ abstraction (Beca 2008). Those involving damming in particular, can affect all of the ecologically important components of the flow regime, although it is difficult to conceive how large, channel forming flows are likely to be substantially altered by schemes that do not include large dams.

The nature of relationships between flow and ecological processes and functions are still not thoroughly understood. In particular, precise quantitative predictions of the consequences of flow changes are often not possible to inform ecological flow requirements (Poff & Zimmerman 2010). Consequently, it is not necessarily possible to prescribe requirements for mid-range flow regimes that will meet given management objectives (Snelder et al. 2011a). However, research over the past 30 years has improved our scientific understanding and the following sections draw on this to provide a summary of potential effects of reducing mid-range flows (note: this is not intended to be an exhaustive review of all potential effects, but rather to highlight key ecologically relevant flow regime components that may be effected by flow harvesting).

### 2.1. Morphological effects

While harvesting water into storage during high flow events has the advantage of reducing abstraction pressure during periods of low flow, it is the flood flows in particular that do the majority of the work of maintaining the channel’s morphology and substrate. High flow events keep the coarse sediment load moving downstream, flush fine sediment from pools, the stream margins, and from within the substrate, and can help control the encroachment of riparian vegetation (McKercher et al. 2005, Snelder et al. 2011a).

Reducing flow, through water abstraction, decreases stream power and thus the ability of a stream to transport sediment downstream. Consequently, flow harvesting could reduce sediment transport, and potentially alter channel morphology. Gravel and sand may build up on the bed, particularly around the abstraction point, but also where tributary streams join the main channel further downstream (McKercher et al. 2005). This sediment accumulation may impact on in-stream habitat quality and availability. Aggradation of the stream bed adjacent to the abstraction point could present a problem for management of the associated intake structure (Snelder et al. 2011a), but could also increase the risk of flooding of surrounding land as the elevation difference between the streambed and the banks would be reduced (Young et al. 2004). Also, a reduction in sediment flow out of the river mouth may affect coastal erosion (McKercher et al. 2005).

Clausen and Plew (2004) attempted to calculate substrate mobilising flows for 40 New Zealand rivers and relate the results to the respective mean flows. Their results
indicate that flows of more than about ten times the mean flow, or 40% of the mean annual maximum flow, begin to move a substantial portion of the river bed. However, the authors caution that these results should be treated as first approximations only, and that field observations would improve the estimates.

A reduction in the frequency of bed moving floods may increase the likelihood of woody weed invasion of the riverbed. If floods return frequently enough, relative to the growth rate of woody plants (e.g. willows and broom), the flow has a good chance of clearing the immature vegetation from the banks or islands (McKercher et al. 2005). For example, in a normal year, approximately 70% of the Waimakariri River bed is disturbed sufficiently to remove vegetation, and within five years, the entire bed is disturbed (Snelder et al. 2011a). But if floods are reduced in size, the vegetation has a greater chance to establish and stabilise the substrate that it is growing on. Consecutive years with few floods increase the likelihood of partial invasion of the river bed by woody weeds (Snelder et al. 2011a). Over time it is likely that the flood channel may become choked, leading to narrowing of the channel.

By contrast with run of river abstractions, those involving dams are likely to starve the reaches below the impoundment of sediment (see Section 2.6).

2.2. Biological effects

2.2.1. Periphyton (and fine sediment) flushing

Periphyton forms the basis of stream food webs (along with terrestrial inputs of detritus) and can be likened to the grass in a farm or rangeland. However, during periods of stable flow periphyton can proliferate to nuisance levels. Excessive periphyton biomass can smother habitat, alter benthic invertebrate communities, produce adverse daily fluctuations in dissolved oxygen and pH, impede flows, block water intakes, as well as causing changes to water colour, odour, and making the substrate slippery, with detrimental impacts on aesthetics and human uses (Snelder et al. 2011a). Excessive growths of long filamentous algae, in particular, are generally considered to be detrimental to the invertebrate community and to river users.

Factors controlling periphyton cover and biomass on river beds include sunlight, nutrient concentration, temperature and flow history (i.e. the history of bed disturbance). Although temperature and nutrient concentration are flow-related to some extent, flushing of periphyton from the river bed is a key flow-related process, controlling periphyton cover and biomass (Biggs & Close 1989). Flushing flows can reset periphyton biomass to near zero. Flushing occurs by current drag (measured as bed shear stress), scouring and associated abrasion by mobilised sediment, as well as turning over of bed substrate (Biggs and Close 1989; (Biggs & Thomsen 1995). Flushing is initiated by mid-range flows, generally in the order of 3–6 times the median
flow (or 3–6 times the low flow in a highly regulated river) (Biggs & Close 1989; (Clausen & Biggs 1997). While flows in the high-range (i.e. greater than mean annual flood) also flush periphyton, they are not generally as important in controlling periphyton cover and biomass since they occur less often (Snelder et al. 2011a).

The period between flushing flows is referred to as the accrual period. Longer accrual periods are usually associated with greater periphyton biomass and cover. Flow harvesting has the potential to increase accrual periods by reducing the frequency and duration of flows sufficient to achieve appreciable flushing (Snelder et al. 2011a).

A reduction in mid-range flows may also favour periphyton proliferation through reduced velocities and suspended sediment load and higher water temperatures. Consequently, establishing the flows that flush the bed of periphyton is an important aspect of assessing the potential effects of changes in flow regimes. Research undertaken in New Zealand provides some useful guidance on flushing flow requirements.

Biggs and Close (1989) studied periphyton in relation to flows and nutrients. Their general conclusion was that flows of 5–6 times the preceding base flow were required to scour periphyton in alps-fed rivers. However, they also cited a study (Irvine & Henriques, 1984) in the Hawea River, where a flow change of only 1.8 times the preceding base flow caused major periphyton scouring. This was consistent with Biggs (1982) identifying flow thresholds for periphyton scour at 1.5 and ~5 times the preceding flow. Biggs and Close suggested that the first peak in periphyton flushing was associated with the tearing out of the surface mat and the second peak with the initiation of bed load movement and associated physical abrasion of tightly bound cells such as diatoms.

Clausen and Biggs (1997) studied the relationships between benthic biota and hydrological indices in New Zealand rivers. They found that the flood frequency statistic FRE3 (the annual number of flood peaks greater than three times the median flow), was the most useful overall (their emphasis) flow index in New Zealand streams. Periphyton biomass decreased with increasing FRE3, whereas invertebrate density peaked at values of FRE3 of 10–15 floods per year. However, it is important to remember that a flow of three times median is not a threshold above which periphyton or invertebrates do not survive.

These studies give an indication of the likely magnitude of flows required to achieve flushing of periphyton. While they provide useful rules-of-thumb, in cases where river specific flushing flow criteria are required, these can be explored either through modelling (i.e. flushing flow modelling) or empirical analysis.

River size is also pertinent to Clausen and Biggs’ (1997) findings (Snelder et al. 2011a). The rivers they focused on were mostly relatively small (median of the median
flows was 18 m$^3$/s) and were probably mostly single thread. Clausen and Biggs showed that the mean cross-section velocity of large rivers at median flow was higher than in small rivers, and that at three times the median flow it was much higher than in small rivers, indicating a much harsher environment for aquatic biota. This suggests that FRE3-based criteria should be applied cautiously in large rivers, where it is likely that flows smaller than three times median may be enough to flush periphyton.

### 2.2.2. Invertebrate production

Flushing flows and the duration of accrual periods between them are also pertinent to stream invertebrate communities (Scrimgeour & Winterbourn 1989). Macroinvertebrate production is important to the fish (and fisheries they support) and birds that prey on invertebrates, as it can help define the carrying capacity of a river or stream (i.e. the size of predator populations that can be sustained). As discussed above, periods of relatively low stable flows can increase the rate of sedimentation and increase the risk of periphyton proliferation. Periphyton proliferation and fine sediment deposition can affect the abundance and diversity of invertebrates (reviewed in Dewson et al. 2007) as well as invertebrate community structure (Quinn & Hickey 1990; Ryan 1991; Quinn et al. 1997).

Water abstraction can reduce the amount of wetted habitat available to invertebrates. Abstraction reduces the wetted channel width, and can alter habitat diversity and the suitability of remaining habitat for aquatic invertebrates (Stanley et al. 1997). However, the extent to which changes in habitat translate into changes in invertebrate production is largely mediated by processes of disturbance and re-colonisation (Olsen et al. 2013).

Disturbance plays a key role in determining invertebrate population dynamics in streams (Sagar 1986, Scrimgeour & Winterbourn, 1989, Suren & Jowett 2006). For example, Suren and Jowett (2006) found that while invertebrate communities in the Waipara River (Canterbury) were controlled by both floods and low flows, the relative effects of floods were greater than even extended periods of extreme low flow.

Sagar (1986) studied the effects of floods on the invertebrate fauna of the Rakaia River. Generally, there was an inverse relationship between invertebrate abundance and preceding flow. Invertebrate abundance decreased when mean daily flows where greater than ~2.5 the median flow at Rakaia Gorge, and lowest densities were recorded following floods in excess ~3.5 times the median flow at the Rakaia Gorge.

However, because they recolonise relatively rapidly, invertebrates may make productive use of extended flow recessions. New Zealand aquatic macroinvertebrates generally have asynchronous lifecycles (i.e. a range of different life stages are likely to be present at any given time), and may also have multiple cohorts per year. This means their populations are able to rebuild quickly (in the order of months) following
disturbance from floods and droughts. For instance, they may take as little as 15–30 days to fully colonise previously dry channels (or margins) (Sagar 1983). For this reason the median flow is often viewed as providing an approximation of the typical habitat conditions experienced, and able to be utilised, by benthic invertebrates (Jowett 1992).

Harvesting of freshes and floods may influence the frequency and effectiveness of population resetting events, while the truncation of flow recessions (by abstraction) may reduce productivity by prematurely reducing wetted area that would otherwise contribute to production (Olsen et al. 2013).

2.2.3. Fish habitat and migration

Habitat

Both low flow and high flow disturbance are potential limiting factors for freshwater fish. Research in New Zealand indicates that the mean annual low flow (MALF) and median flows are ecologically relevant flow statistics governing trout carrying capacity and stream productivity. Jowett (1990, 1992) found that the quality of in-stream habitat (HSI, Habitat Suitability Index predicted by hydraulic-habitat modelling) for adult brown trout at the MALF was correlated with adult brown trout abundance in New Zealand rivers. The adult brown trout habitat suitability criteria used in Jowett’s analysis were developed by (Hayes & Jowett 1994). The inference arising from Jowett’s research was that adult trout habitat about the MALF acts as a bottleneck to brown trout numbers. He also found that the quality of invertebrate food-producing habitat (HSI defined by Waters (1976) general invertebrate habitat suitability criteria) at the median flow was correlated with trout abundance ((Jowett 1990), 1992). These two habitat metrics are surrogate measures of space and food, which are considered to be primary factors regulating stream salmonid populations (Chapman 1966).

The reason why the MALF is a potential limiting factor for trout populations, is that it is the most commonly used flow statistic that is indicative of the average annual minimum living space for adult trout. Trout populations can be expected to be limited by annually occurring events because they reproduce only once per year and so are relatively slow to recover from abundance-limiting events. This contrasts with aquatic invertebrates which can recover much more rapidly from abundance-limiting events (such as flood disturbance). Other flow statistics that define, or are closely correlated with, average annual minimum flows should be similarly relevant as the MALF to adult trout abundance.

The MALF is also relevant to native fish species with generation cycles longer than one year, at least in small rivers where the amount of suitable habitat declines at flows less than MALF. Research in the Waipara River, where native fish habitat is limited at low flow, showed that the detrimental effect on fish abundance increased with the duration and declining magnitude of low flow (Jowett et al. 2008). Research on the
Onekaka River in Golden Bay also showed that, when habitat availability was reduced by flow reduction, abundance of native fish species responded in accord with predicted changes in habitat availability in both direction and magnitude (Jowett et al. 2008).

The insights gained from this research provide a basis for identifying hydrological statistics that are ecologically relevant to fish populations. It seems reasonable that the MALF should be relevant to trout, and native fish species with generation cycles longer than one year, at least in situations where habitat declines as flow is drawn below the MALF. If the minimum flow restricts habitat for any species, there is potential for a detrimental effect on that population if abstraction draws flow below the MALF for extended periods of time (weeks to months).

While low flows potentially act as population ‘bottleneck’ events, fish populations can also be susceptible to flood disturbance. In New Zealand substantial reductions in trout abundance have been observed following floods (Jowett & Richardson 1989, Hayes 1995, Hayes et al. 2010, Young et al. 2010), whereas many native fish appear to have adaptive strategies making them more resilient to flood disturbance (e.g. McIntosh 2000, McEwan & Joy).

A recent analysis suggests that flow variability appears to be an important factor influencing community structure for both migratory and non-migratory fishes in New Zealand (Crow et al. 2013). While low flow was found to be an important explanatory variable for community structure, flow variability was substantially more important than the effects of low flow, particularly for non-migratory fishes (Crow et al. 2013). Flow variability has previously been found to be an important factor influencing distribution and abundance of rainbow trout in New Zealand (Jowett 1990; Jowett & Duncan 1990). Specifically, relatively stable flow regimes (such as experienced in lake fed rivers) were found to support higher rainbow trout biomass. In contrast to lake- and spring-fed rivers, rain-fed rivers with irregular rainfall, leading to infrequent floods separated by long flow recessions (i.e. highly variable flow), are generally associated with aquatic communities indicative of poor water quality and low velocity environments (Jowett and Duncan 1990). Rain-fed rivers with regular rainfall, supporting relatively high base flow, but frequent freshes (to provide flushing) generally tend to support ‘desirable’ aquatic communities. So while maintaining flow variability is often considered an important factor to take into account in setting allocation regimes, it is important to realise that increasing variability can actually be detrimental, while stabilising flows to some extent may result in more ‘desirable’ aquatic communities in some situations.

**Migration**

Many of New Zealand freshwater fishes have life histories that include at least one migratory phase. This group includes diadromous fish (e.g. eels, the whitebait species and salmon), which migrate between freshwater and the ocean as part of their normal
life cycle. The other group includes species that often make substantial migrations entirely within river systems, usually as part of a key life history event such as spawning, e.g. rainbow trout and brown trout — although in some rivers brown trout may also go to sea for various periods at various times in their life history. Aside from migrations associated with spawning and/or rearing, fish migrations occur for a variety of reasons, including re-colonising freshwater habitats, or to take advantage of feeding opportunities. The typical seasonality of migrations of New Zealand freshwater fishes is reasonably well known (Figure 1). Movement generally peaks over the warmer months (November–April), with the upstream migrations of lamprey and trout in winter being obvious exceptions.

![Figure 1](image.png)

**Figure 1.** Example of likely migratory timing (black bars) for a selection of freshwater fishes (taken from Snelder et al. 2011a). Progressive colonisation upstream is represented by green bars; dark green over the warmer periods when active upstream movement occurs, and light green for cooler periods when less movement occurs.

Most fish migrations tend to be associated with high flow events (Jellyman 2012), with increased flow either stimulating or enabling fish movement. For example, maturing eels tend to migrate downstream toward the sea during periods of high flow (Burnet 1969); (Boubee et al. 2001); Watene et al. 2003), and floods can stimulate the migration of whitebait from the sea into fresh water (McDowall & Eldon 1980). Therefore, flow harvesting has the potential to affect fish migration through the
damping or removal of high flow events that may otherwise have stimulated or assisted movement. Migrating fish may also be exposed to the risk of entrainment into water abstraction schemes as they move past the abstraction point if appropriate screening is not provided.

Unfortunately, the specifics of flow thresholds that may trigger fish migration are not well understood (Jellyman 2012), and are likely to vary between species, life history stages, and possibly between rivers. For example, relatively small increases in flow (about 2 to 3 times the preceding flow) can result in movements of juvenile and adult eels and lampreys, while flows of 10 times the preceding (or base flows) have been found to inhibit movement of adult lampreys (Jellyman et al. 2002), but not Chinook salmon (Glova et al. 1988). In addition, while increased flow appears to trigger migrations, it is often not possible to distinguish the influence of flow from correlated factors such as low air pressure, rainfall, and increased turbidity (Snelder et al. 2011a).

The timing of fish movement relative to flow peaks is also not well understood, at least in part due to the difficulties of monitoring fish movements during floods (Snelder et al. 2011a). Whether fish are more likely to move at the beginning of a flood, at its peak, during the recession, or throughout, is also likely to vary between species / life stages. For example, torrentfish are thought to migrate on receding flood flows (Davis et al. 1983), whereas migrations of adult lampreys commence at the beginning of floods (Kelso & Glova 1993).

Notwithstanding this uncertainty, it is likely that fish are stimulated to move by a change in flow relative to preceding flows, rather than by flows of a particular magnitude, with flows in the order of 2-4 times the median or preceding base flow being associated with movement of several species (Snelder et al. 2011a). On the other hand, there are instances where flows greater than a particular magnitude may be required to overcome a particular barrier to passage, such as to provide adequate depth for passage, or to maintain open passage to the sea through the river mouth. These issues would require assessment on a case by case basis. In any case, it is likely that a substantial reduction in the frequency of mid-range flow events could have negative impacts on fish movements.

2.3. Summary of ecological flow requirements

In summary, recognised ecologically important components of the flow regime include:

1. Large floods to maintain channel form, large scale sediment transport, and control encroachment of woody weeds. Likely to be in the order of the mean annual maximum flow, with flows of more than about ten times the mean flow or 40% of
the mean annual maximum flow beginning to move a substantial portion of the river bed (Clausen & Plew 2004).

2. Smaller floods and freshes (flushing flows) to flush fine sediment, periphyton and other aquatic vegetation. Usually about 3–6 times the median flow (or 3–6 times the low flow in a highly regulated river) (Biggs & Close 1989; Clausen & Biggs 1997).

3. Low flows, the period of minimum wetted habitat availability, the MALF is a potential limiting factor for trout populations and native fish species with generation cycles longer than one year, at least in small rivers where the amount of suitable habitat declines at flows less than MALF (Jowett 1990, 1992, Jowett et al. 2008).

4. Flow recessions, the median flow is often viewed as providing an approximation of the typical habitat conditions experienced, and able to be utilised, by benthic invertebrates (Jowett 1992), which in turn may help define carrying capacity for fish and birds populations that feed on invertebrates.

5. Flow variability, at a range of scales. It has been found to be an important predictor of fish community structure in New Zealand rivers (Crow et al. 2013), and may also provide a stimulus for fish migrations. Flows in the order of 2-4 times the median or preceding base flow have been associated with movement of several fish species in New Zealand (Snelder et al. 2011a).

The discussion above focuses on in-stream flow requirements. Consideration should also be given to whether hydrological alteration of rivers will affect connectivity of rivers with riparian wetlands, springs and groundwater (Beca 2008).

While there is insufficient ecological understanding to precisely quantify the likely ecological response of a given reduction in flow, the ecologically important flow components identified above provide a starting point for assessing the likely significance of flow regime changes caused by supplementary allocation. The research summarised provides rules-of-thumb that could be used to help develop supplementary allocation policy to avoid or mitigate potential adverse effects. For example, ensuring that supplementary allocation does not substantially alter the frequency and timing of flows 3-6 times the median flow, since flows of about this magnitude have been shown to have an important ecological function as flushing flows (Biggs & Close, 1989; Clausen & Biggs 1997). One rule applied by Hawke’s Bay Regional Council in assessing alternative supplementary allocation scenarios was that the average annual frequency of flows ≥ 3 times the median flow (the FRE3) should not be altered by more than 10% (Harkness & Forbes 2008, Waldron 2011).
2.4. Recreational effects

The science of in-stream flow assessment has focused mainly on ecological values. However, there is also some understanding of the flow needs of recreational values including fishing, boating and swimming. Flow recessions and moderately high flow events often provide opportunities for recreational river users. For example, for salmon angling the ‘catchability’ of adult salmon is related to specific flows that produce some turbidity through the entrainment of suspended sediment (Glova 1988); best flows for salmon angling are the first few days in a flow recession (i.e., following a flood) when the water clears just enough for an anglers to see their feet in about knee-deep water. There is also a widely held perception that trout are likely to feed more vigorously and therefore improve angling prospects following moderate flow events after periods of low flow. While minimum depth requirements for boating (e.g. kayaking and jet boating) may be provided over a relatively wide range of flows in many rivers, optimal flows that produce challenging and enjoyable flow features (such as waves and play holes) may be comparatively short lived since they often rely on a relatively narrow range of flows during high flow events.

However, the optimal flow ranges for recreational activities generally differ from river to river and therefore are likely to require definition on a case-by-case basis. While the most effective way to define these flow requirements is probably to question relevant recreational groups, there are also generic velocity and depth suitability criteria available for a range of recreational uses that would allow the relative suitability of various flow ranges to be modelled (e.g. Mosley 1983).

Some of the potential morphological and ecological changes discussed above also have the potential to influence recreational values. As mentioned above nuisance periphyton proliferation associated with a lack of flushing flows can impede flows, cause changes to water colour, odour, and make the substrate slippery, with detrimental impacts on aesthetics and recreational water users (Snelder et al. 2011a). Excessive growths of long filamentous algae, in particular, are generally considered to be detrimental to river users. Sedimentation due to reduced stream power during freshes has the potential to reduce swimming amenity, while morphological changes and encroachment of riparian vegetation may alter natural character values.

2.5. Effects on Māori cultural values²

In the traditional Māori worldview water is viewed as a taonga or treasure. It sustains life and is central to Māori life and wellbeing (Te Rūnanga o Ngāi Tahu 2001, Ngāi Tahu ki Murihiku 2008). There are several core Māori values and uses relating to the freshwater environment (Table 1) (Tipa 2011; ES & TAMI 2011b).

² This section was written by Dr. Jane Kitson, Kitson Consulting Ltd.
Table 1  
Core Ngāi Tahu whanui (general) values and uses relating to the freshwater environment (from Environment Southland and Te Ao Marama Incorporated 2011b).

<table>
<thead>
<tr>
<th>Core value</th>
<th>Description</th>
<th>Relationship to cultural use of freshwater environment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Whakapapa</strong></td>
<td>Whakapapa (genealogy) is about the relationships of all life forms to each other as well as the atua (gods). Whakapapa describes bonds, relationships, and connections. All things are linked by whakapapa.</td>
<td>Water has its own whakapapa and Māori link to this whakapapa. Whakapapa is also central to passing on kai gathering knowledge through the generations.</td>
</tr>
<tr>
<td><strong>Te Ao Māori</strong></td>
<td>The environment is viewed as a whole – not as divided parts.</td>
<td>This holistic view of the freshwater environment requires consideration of the whole catchment. A catchment constitutes soils, water, flora, fauna and the relationships between them.³</td>
</tr>
<tr>
<td><strong>Mauri</strong></td>
<td>Mauri is a central component of the Māori perspective on the environment. It can be defined as the life principle, life supporting capacity, or life force present in all things.</td>
<td>Protecting the mauri of a resource is the fundamental management principle for Māori. Māori treasure the mauri of freshwater and may experience cultural offence and distress when the mauri is degraded.</td>
</tr>
<tr>
<td><strong>Wairua</strong></td>
<td>Spiritual connection/wellbeing.</td>
<td>Ngāi Tahu, like other Māori, use different ways to feel spiritually connected with their takiwā. This spiritual connection can occur by gathering kai with whānau at a traditional fishing place that they know have been named by their tūpuna, and utilised by successive generations of their whānau; being able to contribute the kai that their takiwā is renowned for, to ceremonies. Being denied these opportunities can impact on spiritual wellbeing.</td>
</tr>
<tr>
<td><strong>Kaitiakitanga</strong></td>
<td>The exercise of guardianship by manawhenua of an area and resources in accordance to tikanga Māori (customs and rules).</td>
<td>Kaitiakitanga governs the way humans interact with the environment. The notions of sharing and maintaining balance with nature underpin cultural uses and practices. Balance requires respect to be shown when interacting with the environment; and use of the resource (within limits) afforded by healthy ecosystems. Māori continue to have a duty to protect the natural world.</td>
</tr>
<tr>
<td><strong>Tino Rangatiratanga</strong></td>
<td>Tino Rangatiratanga is the right to make decisions for your own people concerning the resources within your takiwā.</td>
<td>This means determining what, from a cultural perspective, represents satisfactory aquatic conditions and appropriate use.</td>
</tr>
<tr>
<td><strong>Mahinga kai</strong></td>
<td>Mahinga kai encompasses the resource harvested, the ability to access the resource, the site where gathering occurs, the act of</td>
<td>Mahinga kai is considered to be the principle ‘environmental indicator’ in natural systems. If mahinga kai is not present, or is unsafe to harvest, then, that natural system is under stress and requires remedial action. The state</td>
</tr>
</tbody>
</table>

³ This concept is also sometimes described as ki uta ki tai – from the mountains to the sea.
<table>
<thead>
<tr>
<th>Core value</th>
<th>Description</th>
<th>Relationship to cultural use of freshwater environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>gathering and using the</td>
<td>resource, and the good health of the resource.</td>
<td>of freshwater is important as a medium for sustaining and accessing mahinga kai. Ideally, streams will sustain healthy</td>
</tr>
<tr>
<td>Manaakitanga</td>
<td>The support, caring and hospitality shown to guests.</td>
<td>and diverse koiora/life.</td>
</tr>
<tr>
<td>Mātauranga Māori</td>
<td>Māori knowledge.</td>
<td>The ability to manaaki visitors by supplying kai sourced locally means that the activities of fishing, eeling and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>maintaining whānau and hapū ties and reinforces identity. Conversely the inability to manaaki guests and sustain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>whāungatanga can lead to cultural loss.</td>
</tr>
<tr>
<td>Te Reo</td>
<td>Language. Te Reo contains knowledge and is another expression of culture and</td>
<td>Stories, waiata and Te Reo that pertain to particular uses, and these uses sustain the culture. When a valued species</td>
</tr>
<tr>
<td></td>
<td>identity.</td>
<td>disappears from a local ecosystem or the activities associated with a species decrease, the associated Te Reo drops</td>
</tr>
<tr>
<td>Whānaungatanga</td>
<td>The interrelationship of Māori with their ancestors, their whānau, hapū and</td>
<td>Sustainable management seeks to sustain the health, wealth and well-being of the natural environment while sustaining</td>
</tr>
<tr>
<td></td>
<td>iwi as well as the natural resources within their tribal boundaries. This</td>
<td>communities dependent upon it. In a catchment it is water that makes and maintains connections between different</td>
</tr>
<tr>
<td></td>
<td>genealogical relationship is one of the foundations upon which the Māori</td>
<td>waterbodies and entities within a catchment.</td>
</tr>
<tr>
<td></td>
<td>culture is based.</td>
<td></td>
</tr>
</tbody>
</table>

In water management, a key Ngāi Tahu resource management principle is the maintenance and enhancement of mauri or life force / life principle (Te Runanga o Ngāi Tahu 2001, Ngāi Tahu ki Murihiku 2008). Promoting the mauri of a river will sustain healthy ecosystems, support a range of cultural uses (including mahinga kai, food gathering), and reinforce the cultural identity of the people (Tipa & Teirney 2003, Tipa 2010). While there are many intangible elements associated with the mauri of a waterbody, there are elements of physical ecosystem health which Ngāi Tahu use to reflect the state of mauri. These include aesthetic qualities, e.g. natural character, indigenous flora and fauna; life supporting capacity and ecosystem robustness; the continuity of flow of water (of high quality) from the mountain source of a river to the sea; fitness for cultural usage; and productive capacity.
Flow harvesting (and water storage) has the potential to degrade mauri and Māori cultural values and uses. Concerns over this have been expressed by Māori within the Ngai Tahu takiwa, area/region (Tipa 2013a, b) and by other iwi/hapu (Durette et al. 2009). Some examples of potential effects include:

- Reduction of mahinga kai, including access, disruption of fish movement and use of Mātauranga Māori (traditional knowledge) to guide harvests, e.g. kanakana / lamprey (Geotria australis) is an important traditional Māori fishery, with harvesting still practiced in locations on both North and South islands (Kitson et al. 2012). High flow events can act as a stimulus for lamprey migration, and have been used as an indicator of appropriate timing for cultural harvest. Flow harvesting has the potential to alter the frequency or magnitude of these events and thus the timing of migration and cultural harvest.

- Impairment of ngā mahi ahua o te awa (the working ability of a river) from ki uta ki tai (mountains to the sea); the ability of the river to carry nutrients and gravel to the coast, providing habitat, building coastline, building the plains, and providing floods to cleanse and rejuvenate the system (Tipa 2010). In the traditional Māori worldview floods are considered necessary natural processes (ES & TAMI 2011a). Concerns have been expressed about the impacts on the opening of river mouths and dependent features such as wetlands and springs (TRONT 1991, Tipa 2010).

- The potential for unnatural mixing of waters between waterbodies (depending on the configuration of the scheme) can lead to changes in the mauri of a freshwater body and estuary (TRONT 1991, NTkM 2008).

- The potential to exacerbate impacts on cultural values from primary allocation, especially given that existing minimum flows are not considered adequate to maintain the mauri of some water bodies (TRONT 1991; Tipa 2011; Tipa and Associates 2013a,b)

- Degrading of wahi tapu (sacred places) and wahi taonga (treasured resources) and the meaning of wahi ingoa (place names), for example through loss of flow characteristics, flooding of areas to construct storage ponds, or by drying of streams or wetlands. Changes of this nature can result in a loss of active associations and cultural relationships with the area (TRONT 2001, Tipa 2010; Tipa 2013a).

- The potential for water to be used inefficiently with water storage schemes (Durette et al. 2009) and to exacerbate water quality decline through enabling further intensification of land use and reducing frequency and magnitude of flushing flows.

- The potential to further commoditise water through water trading and create further disparity of water allocation to iwi / hapu. Iwi / hapu rights and interests as per the Treaty of Waitangi must be recognised and provided for with respect to water allocation from freshwater resources (NTkM 2008; LaWF 2012).
However, there are some potential opportunities for restoration of, and access to, some mahinga kai through creation of water storage reservoirs (Durette et al. 2009) (e.g. by providing an opportunity for harvest of koura).

Māori recognise there are economic and water security benefits from flood harvesting (Durette et al 2009; TRONT 2001). However, there is a call for a precautionary approach in implementing such programmes and a real need for participation and resourcing of mana whenua (customary territorial rights) in assessment of pros and cons of such proposals in whanau takiwa. Participatory methodologies to assess flow regimes suitable for cultural values are available and in use in several regions, including Canterbury, Northland, Wellington, Gisborne (e.g. Tipa & Associates 2013a, b; Tipa & Nelson 2012; Royal 2011; Durette 2010; Tipa & Severne 2010), and these methods would be directly transferable to Southland.

2.6. Dams versus off-river storage

The potential effects of flow harvesting are likely to depend to some extent on the location of water storage. Intuitively, off-river storage is likely to have less adverse effects relative to large in-river dams (Young et al. 2004), especially with regard to hydrological alteration, fish passage and sediment transport/morphological impacts. Dams capture sediment, blocking sediment transport, with the result that downstream reaches can become sediment starved (Young et al. 2004). As well as potential morphological changes downstream, impairment of sediment transport is likely to alter habitat quality below the dam, and alter the magnitude of flows required to provide flushing — as the substrate coarsens and becomes armoured. Dams also have the potential to influence water quality downstream (e.g. releasing cooler water in summer and warmer water in winter, and lower dissolved oxygen concentrations, depending on where in the reservoir water column water is released). Dams obstruct migrating fish; while fish passage facilities can be provided, passage success tends to decline with increasing dam height.

On the other hand, water storage schemes with in-river dams, which stabilise flows, may also offer ecological benefits. As discussed above, benthic invertebrate and trout abundance are both reduced by floods, so capture of potentially damaging high flows by storage may result in productivity gains and may also offer the opportunity to augment minimum flows. Potential issues with nuisance periphyton growths, may be managed with releases of flushing flows (Clausen & Plew, 2004; Jowett & Biggs 2006). This type of flow stabilisation is probably only possible with dams, since off-stream storage schemes are unlikely to be capable of capturing large flood flows. Release of flushing flows from off-river storage is also likely to present more logistical difficulties than those from a dam.
In practice, some of the potential effects identified in the sections above may not be fully realised, particularly in schemes with off-river storage, because of practical constraints on exercising water abstraction consents at high flows. For example, it may be impractical or uneconomic to construct intakes large enough to accommodate rare large flow events, or abstracting during periods of very high flow may have to be avoided due to excessive sediment load, etc.

However, as stated by Beca (2008), “The frequency of flushing flows may also be affected if the capacity of the diversion is sufficiently large (e.g. > 1.5 times the mean flow)” p10, and this would also apply to the cumulative effect of multiple smaller diversions. Consequently, a cap on allocation or a flow sharing rule is sensible, at least as a default position, to ensure adverse effects are avoided (see Section 6).
3. POTENTIAL ECOLOGICAL FLOW ASSESSMENT METHODS

While the ecologically relevant flow thresholds discussed above provide useful rules-of-thumb regarding features of flow regimes that may need to be maintained, there are also several flow assessment tools that can be applied to provide more certainty around effects assessment, mainly on a case-specific basis.

The NIWA report “Waiau River mid-range flows evaluation” (Snelder et al. 2011a) provides a good example of how existing science and flow assessment methods can be applied to evaluate the potential effects of supplementary allocation in a given river. This report was produced to provide Environment Canterbury with information on the probable consequences of various allocation scenarios for the Waiau River. It involved:

- a hydrological analysis (comparing a broad array of hydrological statistics under a range of allocation scenarios with the natural regime)
- modelling of physical variables (such as degree of bed movement, flushing and bedload transport).

Hydrological and physical data from these first two assessments in combination with empirical ecological information was used to assess the likely effects of the proposed allocation scenarios on:

- woody weed encroachment
- bed morphology
- the prevalence of nuisance periphyton proliferation
- fish migration cues.

While Snelder et al. (2011a) selected and calculated their own array of hydrological statistics for their assessment; there are hydrological assessment tools available that can be used to perform similar analyses. The Range of Variability Approach (RVA; Richter et al. 1997), based on Indicators of Hydrologic Alteration, (Richter et al. 1996) provides an alternative hydrological assessment tool, which has been used by Hawke’s Bay Regional Council in assessing their supplementary allocation scenarios. The approach allows the user to prescribe an acceptable level of change to any component of the flow regime, based on the ‘natural’ range of variation in the set of 32 hydrologic parameters derived from the ‘natural’ flow record (Richter et al., 1997). This level of change is usually taken to be one standard deviation, but could be some other multiple of the standard deviation, or a certain inter-percentile range. The RVA was proposed in response to perceived lack of adequate knowledge regarding how changes to flow regimes will impact ecosystems (Richter et al., 1997). Its development was closely aligned with the “natural flow paradigm” ((Poff et al. 1997)),

with the implicit assumption that the natural flow regime has intrinsic values or important ecological functions that will be maintained only by retaining all elements of the flow regime within their natural range. Although the biological relevance of all of the hydrological parameters used has not been established, and may be of questionable relevance in New Zealand (Jowett & Biggs 2008), it does provide an approach for assessing the degree of hydrological alteration of given abstraction scenarios on a range of components of the flow regime.

Hawke's Bay Regional Council application of RVA is informative. Three key points were that:

6. The method relies heavily on having adequate hydrological records (Richter et al., 1996) recommend a minimum of 20 years, although these could be synthesised for sites with shorter records).

7. The lack of a maximum allocation limit can, at least theoretically, cause substantial hydrological changes (if allocation is fully exercised).

8. Deciding how much change is acceptable remains a key issue (this is still up to the user to specify and remains a policy issue, balancing risk of potential adverse effects with values of and abstractive water use).

The National Institute of Water and Atmospheric research (NIWA) have recently developed two flow assessment tools to assist with allocation planning. These modelling tools have been applied in Canterbury, Northland and Auckland regions. The Environmental Flows Strategic Allocation Platform (EFSAP) allows water allocation scenarios to be simulated and compared at a catchment or regional scale (Snelder et al. 2011b, Franklin et al. 2012). Using the spatial framework of the River Environment Classification (REC), EFSAP simulates changes in predicted physical habitat (based on generalised habitat models), reliability of supply for water abstractors, and flow duration curves. The model requires hydrological data inputs, which have been predicted for ungauged sites across New Zealand (Booker & Woods 2012). The EFSAP allows these hydrological predictions to be compared with results from flow records, where available. For catchment-specific applications simulations can take account of the cumulative effects of abstraction down the catchment. However, since the modelling is based around changes in flow duration curves it is not suitable for predicting changes in the frequency of flushing flows of a particular magnitude (e.g. FRE3).

However, this can be done using NIWA’s Cumulative Hydrological Effects Simulator (CHES) software (Diettrich 2012). This software is also GIS based and as its name suggests is intended for simulating the cumulative hydrological effects of abstraction scenarios at a catchment scale, but it also has the ability to transform these into predictions of environmental effects. It can incorporate user specified abstraction and storage options. For each channel segment in the river network of interest CHES
calculates a suite of statistics (e.g. mean flow, minimum flow, MALF, and FRE3) from hydrographs generated for specified abstraction scenarios. Reliability of supply for any existing and/or proposed abstraction is also calculated. Time series generated can also be used by other linked applications such as those for periphyton growths, fish species habitat estimation and fish passage estimation. Results can be visualised in GIS, allowing relative effects of different water-use scenarios to be compared for values of interest, and reaches where environmental bottom-lines or objectives would not be met to be easily identified. The user interface is designed to assist the objectives-based water-management framework recently proposed by Ministry for the Environment (pers. comm. Murray Hicks, NIWA).

In-stream habitat modelling (e.g. RHYHABSIM) can also be applied to assess likely changes to habitat quality and availability associated with given supplementary allocation regimes on a reach by reach basis. Predictions can be made of changes in habitat for periphyton and benthic invertebrates over the flow range affected by supplementary allocation.

Cawthron has recently developed a model, in collaboration with NIWA, to simulate the effects of flow alteration on benthic invertebrate habitat productivity (Olsen et al. 2013, Hayes et al. in review). The Benthic Invertebrate Time Series Habitat Simulation model (BITHABSIM) builds on existing hydraulic-habitat and bed disturbance models, to simulate the amount of benthic invertebrate habitat that is likely to contribute to invertebrate production, taking account of the following: (i) changes in habitat suitability that occur in response to variations in flow; (ii) the disturbance effects of high-flow and drying events that reset invertebrate densities and; (iii) the population recovery (or accrual) rates and times following such events. By incorporating the processes of resetting by disturbance and recovery this modelling approach is intended to improve the biological realism of assessments of effects of flow change on benthic invertebrates over the entire hydrograph. It has recently been tested on the Rainy River, in the Motueka Catchment, Nelson and shown to make better predictions of the response of invertebrate abundance to flow variation than traditional hydraulic-habitat modelling (Hayes et al. in review).

Flow requirements for fish passage can also be modelled with the same hydraulic models used for habitat modelling. There are reasonably well established fish passage depth criteria for salmonids, to allow flow requirements for fish passage to be predicted. However, passage depth criteria for native fish are less well established.

As discussed in Beca (2008) the level of investigation required should be matched to the relative in-stream values and the level of abstraction pressure (i.e. the degree of hydrological alteration). In cases with high abstraction pressure and/or high in-stream values, more in-depth investigation, including habitat modelling and flushing flow analysis, is warranted.
4. SUPPLEMENTARY ALLOCATION POLICY IN NEW ZEALAND

To help provide useful information for policy development to Environment Southland, I conducted a survey of the other regional councils and unitary authorities, seeking insights from their experience with supplementary allocation policy. A contact at each Council was sent an e-mail with the same five questions regarding their experiences with policy in this area (Appendix 1). Responses were received from all of the councils and information gleaned from these responses, and from relevant planning documents, is summarised in the following section.

The majority of councils have explicitly addressed the issue of flow harvesting or supplementary allocation in policy, with some (particularly the larger regional councils) having specified flow thresholds and/or allocation caps, while others have narrative clauses indicating the desire to support or promote water capture and storage. However, in many cases the policy remains relatively untested, so potential issues with implementation are yet to be revealed.

4.1. Northland Regional Council

Northland Regional Council currently does not have anything specific in its plans regarding supplementary allocation. However, it does have a general policy drafted in the proposed Regional Policy Statement to “Recognise and promote the benefits of water harvesting, storage, and conservation measures.” (Policy 4.4.4)

This policy has been drafted in recognition that water harvesting, storage, and conservation measures are likely to become increasingly important in Northland as demand for water increases and the local climate changes with longer dry spells and more frequent high intensity rain events. The explanation of this policy also recognises that water storage potentially has other benefits beyond efficient water use, such as “buffering storm flows, recharging aquifers, creating habitat for ecological values, and improving recreational opportunities”.

The value of flow harvesting is also recognised in the explanation for Policy 4.4.2 “Efficient allocation and use of water”, with the statement, “Security and reliability of supply can be increased by harvesting and storing water for distribution and use during shortages.”

4.2. Auckland Council

The existing Regional Plan, which continues to apply until a new Unitary Plan is developed, contains policy and rules that favour abstraction of water to storage during the winter months (May to October inclusive, Policy 6.4.15) and off stream water
storage over new dams. However, uptake is apparently very low (pers. comm. Naveen Kumar, Auckland Council).

Providing for additional abstraction at higher flows is recognised as a way to address the trade-off between increased availability and reduced access [security of supply] (Explanation of Policies 6.4.19, 6.4.20 and 6.4.21), with additional allocation potentially available to existing users to supplement their take allowed at lower flows, or by new users, or both.

Rule 6.4.43 states that “off stream damming of water shall be preferred to the damming of permanent rivers or streams”, and taking water from an off-stream dam is a permitted activity (subject to certain conditions), whereas water takes from existing on-stream dams are a controlled activity.

4.3. Waikato Regional Council

The Waikato Regional Plan (through Variation No. 6) provides for surface water harvesting of up to 10% of the river’s flow at times when the flow is greater than the median flow immediately upstream of the point of the take, except upstream of Karapiro Dam (Waikato-Regional-Plan, 3-Water-Module, 33-Water-Takes, 333-Policies, Policy 2 d). This supplementary allocation is in addition to two allocation bands with greater security of supply.

Waikato Regional Council have 1) a ‘primary’ allocation band, for which abstraction is restricted when flow reaches the minimum flow, 2) a ‘secondary’ allocation band, which has lower security of supply than the primary allocation band, and 3) a ‘flow harvesting’ band, which allows abstraction of a proportion of flow at relatively high flows (above the median; generally into storage for later use) (Waikato Regional Plan, 3-Water-Module, 33-Water-Takes, 333-Policies, Policy 2).

The first two allocation bands tended to be the key focus of stakeholders and Waikato Regional Council during the recent plan variation hearing process (pers. comm. Ed Brown, Waikato Regional Council). The provision for flow harvesting is new to the Plan, introduced through this variation. The old allocation rules generally resulted in creep over the core allocation limits, rather than utilising higher flows. However, under the new rules this creep cannot occur and there will now be greater need for supplementary allocation. As yet there has been little demand for flow harvesting allocation since it was introduced last year, so the test will come in time. The supplementary / flow harvesting allocation was set at what was seen to be a safe level based on rules of thumb to ensure maintenance of flushing flows etc. (pers. comm. Ed Brown).
4.4. Bay of Plenty Regional Council

The operative Regional Water and Land Plan provides for water harvesting during periods of high flow by allowing for short duration takes in addition to the abstraction in the primary allocation band (Regional Water and Land Plan Table 13 – Water Allocation Methodology Policy (b)). Under the methods of implementation the Plan states that Council will “Promote and encourage the use of water management methods to reduce surface water abstraction during low flow, particularly in catchments under water abstraction pressure, and to buffer sensitive streams. Such methods include:
(a) Collection of rainwater.
(b) Water harvesting and peak flow collection and storage” (Method 158).

However, guidance is not given on how these activities should be managed (pers. comm. Jo Noble, Bay of Plenty Regional Council).

Consents have been sought under the Plan for applications to take peak or high flows from fully-allocated streams (i.e. ‘high-flow allocation’) and for on-stream storage ponds/damming headwater streams (pers. comm. Jo Noble). The latter raised the potential issue of pulses of warmed water being discharged downstream from the storage ponds, which was addressed through consent conditions regarding planting around ponds to provide shade and monitoring of discharges from the ponds into downstream waterways.

The Council is in the process of reviewing the water allocation framework in the Plan (pers. comm. Jo Noble). The requirements for accurate monitoring and the possible need to automate takes, to ensure that water is taken only over the consented range, has been identified as an issue that will need to be addressed. However, since the incursion of the kiwifruit vine disease Psa (Pseudomonas syringae pv. actinidiae) into the region in 2010, the pressure on water resources has reduced, and water allocation has not been seen as such a high priority.

4.5. Hawke’s Bay Regional Council

The operative Regional Resource Management Plan (2006) provides for water to be allocated above the core allocatable volume (in Policy 39(d)), subject to a ‘substantially higher’ minimum flow. While this policy does not specify any particular allocation volume or higher minimum flow limit, information to justify these are required on a case by case basis, to be provided by the applicant. However, the recently notified Plan Change 6 for the Tukituki River Catchment does set abstraction limits and minimum flows for takes during periods of relatively high flow (Policy TT10). This Policy provides for abstraction at flows above the median flow, with cumulative abstraction for these takes capped at approximately 10% of the median flow (specified
for three locations). However, Community Irrigation Schemes involving storage of water behind in-stream dams are excluded from these restrictions.

Under the notified Plan Change 6 minimum flow limits for core allocation have been increased, with a consequent reduction in security of supply. However, providing for water harvesting to supplement existing supplies is an important element of the policy approach (pers. comm. Helen Codlin, Hawke’s Bay Regional Council).

Hawke’s Bay Regional Council evidently put substantial effort into exploring the implications of different flow harvesting/ supplementary allocation scenarios. They commissioned a series of reports, including Harkness and Forbes (2008), Harkness (2010), and Waldron (2011), which expanded on the previous two reports. Various allocation and flow sharing options were considered in these reports. Ultimately, an allocation limit of approximately 10% of the median flow was adopted to maintained flow variability, rather than flow sharing. This approach was taken under the rationale that being specific about allocation volumes and minimum flows ought to provide more certainty for irrigators, as well as consent officers (see Section 4.14). It was also seen as having the additional advantage that the assessment of effects is done only once through the planning process (pers comm. Helen Codlin). However, it is recognised that that site specific consideration of the effects of flow harvesting may still be required, even for those within the high flow allocation limit. There would still need to be a good understanding of the local hydrological system, since high flow minimum flows have been specified for only three sites (pers comm. Helen Codlin).

The Proposed Change 6 is currently going through the Plan change process, so it remains to be seen how it will ultimately be implemented. Some stakeholder groups representing horticultural and agricultural water users made submissions suggesting changes to make more water available such as, “graduated allocation limits for levels of high flow abstraction” (presumably allowing for more abstraction as flows increase), or including a B block allocation (perhaps similar to the system in some Canterbury Rivers, or Waikato Regional Council’s “secondary allocation band”).

4.6. Gisborne District Council

Gisborne District Council does not have any specific supplementary allocation or flow sharing policies, since it does not currently have a water management plan or a chapter in the Combined Regional Land and District Plan regarding water allocation. Consequently, consent applications are dealt with on a case-by-case basis, with all applications being treated as discretionary consents under Section 14 of the RMA.

Consents that incorporate storage and ‘off-season’ abstraction are encouraged and consent conditions stating that the storage needs to be full before the irrigation
season (often 30 October) have been issued, with the consent holder having to provide verification (pers. comm. Dennis Crone, Gisborne District Council).

4.7. Horizons Regional Council

Horizon’s One Plan provides for supplementary allocation in addition to the core (primary) allocation (Policy 6–18). It provides for abstraction of up to a total of 10% of the flow in the river during periods when flows are greater than the median flow (Policy 6-18 (a)). It also provides for alternative supplementary allocation scenarios in circumstances where it will not: increase the frequency and duration of minimum flows, lead to a significant departure from the natural flow regime (including the magnitude of the median flow and the frequency of flushing flows), cause any more than minor adverse effects on the surface water management values of the water body or its bed, limit the ability of anyone to take water under a core allocation, or derogate from water allocated to hydroelectric generation (Policy 6–18 (b)).

These provisions were designed to maintain ecologically relevant components of flow regimes that supplementary allocation potentially affects, including “channel-forming and flushing floods, and flow recessions that support invertebrate production — in the low-to-median flow range. The default supplementary abstraction of 10% above the median is above this ecologically sensitive range and is small enough not to noticeably affect the frequency and duration of floods” (Hayes 2009). Provisions under Policy 6-18 (b) signal that more ambitious supplementary allocation applications should specifically address effects on frequency and duration of low flows, flushing flow and in-stream values.

No consents have yet been applied for under this policy (pers. comm. Clare Barton, Horizons Regional Council).

4.8. Taranaki Regional Council

The current Regional Freshwater Plan provides for flow harvesting in Policy 6.1.7, which states that, “Water harvesting, including the use of storage reservoirs or impoundments to store water at times of high river flow, or the collection or storage of rainwater, will be encouraged, provided adverse effects can be avoided, remedied or mitigated”. Apparently, there has been little demand for water harvesting consents in the Taranaki Region to date (pers. comm. Bart Jansa, Taranaki Regional Council). Taranaki Regional Council are currently preparing for a review of the Regional Freshwater Plan, so it remains to be seen how this issue will be addressed in future policy.
4.9. Greater Wellington Regional Council

The existing Regional Freshwater Plan (made operative in 1998) provides for the harvest of water at high flows (Policy 6.2.1. Clause 3), with supplementary allocation being additional to the core allocation. Supplementary flow thresholds \((i.e.\) minimum flows\) are stipulated for large, named rivers, but there is no 'catch-all' policy to cover all non-listed waterways. The thresholds vary between rivers with respect to their flow exceedence percentiles from around the median flow in some rivers to lower flows in other cases \((e.g.\) around 85th percentile in the Tauherenikau River\). It is not clear how these thresholds were derived. However, at the time that the existing Regional Freshwater Plan was developed there was little, if any, interest in the less secure, higher flow water for abstraction (including flow harvesting), so the derivation of supplementary flow thresholds probably did not warrant substantial analysis \(\text{pers. comm. Mike Thompson, Greater Wellington Regional Council}\). There is currently no specified limit to the amount of water that can be taken above the supplementary flow thresholds in the existing Plan, although in the explanation of Policy 6.2.1. Council states that it retains the discretion to place a maximum limit on the supplementary allocation allowed, or to allocate only a proportion of the water available.

Greater Wellington Regional Council is currently working toward a review of the Regional Freshwater Plan and is proposing a new set of supplementary flow policies. There is now much greater interest in flow harvesting (primarily in the Wairarapa) and hence a need to ensure a more robust approach to setting supplementary flows \(\text{pers. comm. Mike Thompson}\). It appears that some existing supplementary flow thresholds may be too low to offer sufficient protection for in-stream values, especially given the lack of an associated allocation limit. Greater Wellington Regional Council intends to provide greater consistency and transparency in supplementary flow policy in the next plan.

At this stage, the proposed new policy is intended to provide for 1 to 1 flow sharing at flows above median flow, so long as the frequency and magnitude of flushing flows three times the median flow are preserved. The conceptual underpinning of this policy was developed through an expert panel convened by Greater Wellington Regional Council. The primary intent is to recognise the importance of flushing flows in many of the region’s rivers (nuisance periphyton blooms are already relatively common) and focus the policy on a known relationship between flow and consequence \((i.e.\) periphyton flushing\). The policy also ensures that a proportion of flow is left in the river, through the 1:1 flow sharing rule. The choice of median flow as the minimum flow for supplementary allocation was based on essentially the same rationale as used by Horizons Regional Council \(\text{see Section 4.7}\), and this trigger level has been used in several other regions.

The main limitation of the new policy is that it is still fairly arbitrary and offers no explicit protection for any other in-stream values \(\text{including recreational}\) that rely on
flow variation and the maintenance of mid- to high range flows (pers. comm. Mike Thompson). However, this was a deliberate decision made on the basis that not enough is known about flow requirements to construct a more sophisticated (but manageable) policy that applies at a regional scale. This issue will probably need to be worked through in more detail during the Plan consultation process, along with whether it may be desirable to have a less prescriptive level for flushing flows (to allow greater discretion on a consent by consent basis), and/or additional allocation bands (pers. comm. Mike Thompson).

4.10. Marlborough District Council

The Wairau / Awatere Resource Management Plan includes policy to “… encourage water storage in water short areas, for use during low flow and level periods, by exempting water retained in storage from any conditions on use, and when flows are high allowing water to be drawn off for storage purposes” (Wairau / Awatere Resource Management Plan Volume 1 Objectives and Policies, 6.4.1, Policy 1.3).

The Plan provides for a three tiered system of water allocation, conceptually similar to that provided for in the Waikato Regional Plan. Three classes of water permit are provided, with Class A having the highest security of supply, Class B has lower security of supply and may be allocated only after all Class A water has been allocated. Flow harvesting is provided for through Class C permits. Rule 27.1.1.2.4 states that “Class C water permits are only available at flows above the flow that is exceeded 80% of the time. There is no upper limit on Class C permits. Class C water permits may only be drawn to supply a storage reservoir, or recharge groundwater or generate electricity”. In addition to the specified flow threshold the Plan provides for a flow sharing arrangement with 67% of the flow above the threshold flow available for abstraction and 33% to be left for in-stream users. If Class A and B water permits are not being fully exercised, this flow will be left for in-stream uses and is not available for Class C water permit (Rule 27.1.1.2.6).

The Marlborough Sounds Resource Management Plan also has policy to “encourage, and where appropriate require, adequate water storage facilities in areas affected by seasonal water shortages, while avoiding, remedying or mitigating adverse environmental effects” (3.2.5 Objectives and Policies, Policy 1.5). However, since water demand is lower in this part of the District this policy has not really been required (pers. comm. Rachel Anderson, Marlborough District Council).

Marlborough District Council’s Plans are currently under review and it is using working groups and direct consultation with relevant environmental and recreational organisations to identify any issues with the existing policies. The new Plan is intended to cover the entire District and is likely to more closely resemble the Wairau / Awatere Resource Management Plan with respect to water allocation policy.
(pers. comm. Rachel Anderson). The practicality of implementing the current flow sharing and flow rationing provisions in the Plan has been raised as an issue the Council will aim to resolve through the Plan review.

4.11. Nelson City Council

The Nelson Resource Management Plan does not explicitly address supplementary water allocation. Nelson does not have a large agricultural demand for irrigation so there are only a few consented private takes (e.g. for irrigating golf courses, school playing fields, etc.) aside from the municipal water supply schemes (pers. comm. Paul Fischer, Nelson City Council), all of which are treated as primary allocation.

4.12. Tasman District Council

Supplementary water allocation and flow harvesting are not explicitly addressed by Tasman District Council’s Resource Management Plan. The Plan specifies allocation limits on a catchment by catchment basis, but these limits apply only from November to April, inclusive (pers. comm. Joseph Thomas, Tasman District Council). While applications for takes above the summertime allocation limit are treated as ‘non-complying’, applications for takes during winter would be treated as a ‘restricted discretionary activity’ (pers. comm. Joseph Thomas). This implicitly favours off-season abstraction, potentially into storage, during the winter months.

4.13. West Coast Regional Council

West Coast Regional Council have not yet explicitly addressed supplementary allocation and flow harvesting in policy, due to relatively low demand and relatively high availability of water resources on the West Coast.


The predominant allocation framework used by Environment Canterbury has changed over time (pers. comm. Andrew Parrish, Environment Canterbury). A 1:1 flow sharing approach has been employed, predominantly in earlier cases, such as the 1980 Hurunui Flow Management Plan, the Rakaia and the Rangitata Water Conservation Orders (WCO) – Generally drafted before 2000 (with the exception of the Rangitata WCO). A perceived disadvantage of this approach has been that abstractors have often found it difficult to comply with in situations where there are multiple abstractors (pers. comm. Andrew Parrish).

More recently a system of allocation blocks was adopted, generally with an A and B block and sometimes also a C block, with progressively reducing reliability of supply
between successive blocks. The C block, in particular, provides “for takes at higher
flows to help facilitate off-river water harvesting” (NRRP page 5–265). Often gaps
were included between the allocation blocks, and substantial effort was expended in
some cases on analyzing alternative scenarios of allocation block and gaps sizes (e.g.
for the Hurunui — Duncan (2009), for the Waimakariri — Duncan (2008)). Historically
there was no gap between allocation blocks and no cap on B block allocation.

However, a cap on abstraction has been found to be crucial to avoid over allocation
(pers. comm. Andrew Parrish). The system of allocation blocks and gaps was
generally employed in water allocation regimes drafted following the notification of the
Natural Resources Regional Plan, in the period (2004–2009) (e.g. Waimakariri River
Regional Plan, Pareora River Environmental Flow and Water Allocation Regional
Plan, Waipara River Environmental Flow and Water Allocation Regional Plan). This
system has been criticized by some for being excessively restrictive in reducing
reliability of supply for water users in the B and C (pers. comm. Andrew Parrish).

Most recently, in the Hurunui and Waiau River Regional Plan (Drafted 2011) there has
been a move away from gaps between allocation blocks, replaced with contiguous
allocation blocks with no gap, but accompanied by a strong policy framework
specifying maintenance of flow variability. This came about because the efficacy of
gaps between allocation blocks for maintaining in-stream values in these alpine
sourced rivers was successfully challenged in the hearing of the Proposed Hurunui
and Waiau River Regional Plan4, with the proviso that adequate flow variability and
sufficiently high minimum flows were retained to maintain in-stream values. Policy
setting out values that must be protected before the C Block can be allocated was
strengthened in this Plan.

This Plan is significant, since it is the first prepared to align with the vision and
principles of the Canterbury Water Management Strategy. It has been developed by
Environment Canterbury to give effect to recommendations prepared by the zone
committee. One potential disadvantage of this approach is that some control is
divested from the policy makers to the consent application process and conceivably
decision makers could allocate all of the C Block which would result in the river being
flat lined for long periods (pers. comm. Andrew Parrish). No projects have been
developed under this framework at this stage, so it is not yet clear how effective the
approach will be. However, the first consent application has just been granted5, and
the commissioners decided that a 1:1 flow sharing approach will be required for C

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4 Hearing Commissioner Recommendations to the Proposed Hurunui and Waiau River Regional Plan and
Proposed Plan Change 3 to the Canterbury Natural Resources Regional Plan. Commissioners: Hon Peter
Salmon QC (Chair), Rauru Kirikiri, Robert van Voorhuyzen. (Released 27 April 2013).
(accessed 2 August 2013).

5 Report and Decision of Hearing Commissioners: Paul Rogers, Andrew Fenemor, Terry Scott. In the Matter of
nine resource consent applications filed by Hurunui Water Project Limited (the Applicant) in relation to the
Hurunui Water Project Waitohi Irrigation and Hydro Scheme (Released 5 August 2013).
2013).
Block abstraction during summer (November to April inclusive) “to provide adequate flows and flow variability for native fish and salmonids, and for their migration, and for braided river birds” (paragraph 10.170), along with additional cessations of abstraction to allow for flushing flows and for recreational boating under certain conditions (paragraphs 10.171 and 10.179, respectively).

4.15. Otago Regional Council

Otago Regional Council’s Water Plan refers to two categories of supplementary allocation. The first category provides for abstraction with lower security of supply than the primary allocation block, so could be considered similar to the “secondary” allocation band in the Waikato Regional Plan or B Class water permits in Marlborough. This category provides for block by block 1:1 flow sharing above the primary allocation block, up to the mean flow (Policy 6.4.9), with the increments for each allocation block defined based on the MALF of the river. The flow sharing requirements can be relaxed, or removed, in circumstances where the proposed abstraction is expected to have no effect on in-stream values, flows at other specified locations, or any other water users (e.g. an ephemeral creek that is normally not connected to another water body and has no in-stream values (pers. comm. Matt Dale, Otago Regional Council).

The second category of supplementary allocation is essentially a flood harvesting policy, intended for storage, which allows for abstraction when the flow is above the natural mean flow, with no allocation cap (Policy 6.4.10). This policy is based on the assumption that “At such times, water is sufficiently abundant so that taking will have no more than minor effect on in-stream values or other takes” (Policy 6.4.10 Explanation). Although large on-river dams can theoretically lead to flat-lining of the hydrograph at the mean flow, the Council can include addition consent conditions to deal with that issue (pers. comm. Matt Dale).

These policies have remained largely unchanged since they were implemented in 1998, and have apparently worked well so far, although they have not yet been used for any large scale in-river storage and consumptive use (pers. comm. Matt Dale). An additional clause was added in the last plan change; it provides for supplementary allocation and associated minimum flows (of the type described in the first category above) to be specified in a Schedule to the Plan (Policy 6.4.9 (c)). This clause allows Council to use broader policy and public consultation, through a fully publicly notified process, to set allocation limits and minimum flows in specific cases (usually as part of a primary minimum flow consultation process). This also allows for any relevant values or flow assessment methods to be taken into account (pers. comm. Matt Dale).
4.16. Environment Southland

The Regional Water Plan for Southland currently provides for both primary and supplementary allocation (under Policy 15: Surface Water Abstraction, Damming, Diversion and Use Clause (g)). The minimum flow for supplementary allocation is the natural mean flow, with no cap on allocation or flow sharing rule specified. The Plan explains that this allocation provides access to water at higher flows and allows water harvesting. It is assumed that “At higher flows, water is sufficiently abundant that abstraction, damming, diversion and use is unlikely to have more than minor effects on in-stream values or other users” (p35). However, it is recognised that flow variability is part of the natural character of rivers and flood flows are important for natural ecosystem function, and that these matters should be addressed in consent conditions.

Consents have been granted under this existing policy, for a few relatively small scale storage schemes, with no apparent problems (pers comm. Lawrence Kees, Environment Southland). However, with increasing abstraction demand in the Southland region there are likely to be greater numbers of applications for supplementary takes and potentially for larger schemes in the future.
5. SUMMARY OF POLICIES

The majority of Councils that have explicitly addressed supplementary (flow harvesting) in policy tend to have a minimum flow threshold for abstraction and usually also either a cap on allocation or provision for flow sharing above this threshold. The most commonly used minimum flow for supplementary allocations is the median flow. As discussed above, the median flow is often viewed as providing an approximation of the typical habitat conditions experienced during flow recessions, and able to be utilised, by benthic invertebrates, which in turn may help define carrying capacity for fish and birds populations that feed on invertebrates.

Current policy of Environment Southland and Otago Regional Council uses the mean flow as the flow threshold for supplementary (flow harvesting) abstraction, with no cap on allocation. This is based on the assumption that “At higher flows, water is sufficiently abundant that abstraction, damming, diversion and use is unlikely to have more than minor effects on in-stream values or other users”. While this is probably true for relatively small takes, there remains the risk that large scale schemes, or the cumulative effect of a large number of small abstractions, may influence the frequency and effectiveness of channel forming and flushing flows. As discuss above this could lead to loss of natural character and nuisance periphyton proliferation with potential adverse effects on in-stream values and water users (both recreation users and water abstractors).

Using the median flow, rather than the mean flow as the minimum flow threshold for supplementary allocation provides greater reliability of supply for abstractors, since the median flow is exceeded more of the time (Waldron 2011).

With regard to flow sharing, two Councils that have had flow sharing policies in place for some time (Environment Canterbury and Marlborough District Council) expressed concern about the workability of this approach. It was considered difficult for abstractors to ensure compliance where there are multiple abstractions (pers. comm. Andrew Parrish, ECan). Compliance may require real time information on river flow and abstraction rate (including the individual shares of the total volume available for abstraction to be calculated and adjusted in real time) and, possibly automated, incremental control over intakes.

Several councils have policies that encourage off-season abstraction to storage during the winter, either explicitly or implicitly. This concept has merit, since demand for other uses is often lower during this period and reduced flows during winter may be less likely to have adverse ecological effects because growth rates and energetic demands of aquatic organisms tend to be temperature dependent, although food availability may also be lower during winter.
6. RECOMMENDATIONS

As with primary allocation, developing appropriate management objectives to reflect community aspirations is the critical first step in setting appropriate flow regimes (Ministry for the Environment Flow Guidelines 1998, Jowett & Hayes 2004, Biggs et al. 2008). Developing appropriate management objectives should involve the identification of in-stream and out-of-stream values, and deciding on in-stream values that are to be maintained. This provides the basis for assessing the likely flow regime requirements to achieve the desired management objectives. However, in the absence of specific management objectives, the recommendations below are intended to avoid more than minor adverse ecological effects associated with altering the ecologically relevant flows identified in Section 2.3. Cultural and recreational values in particular may have case-specific requirements.

As discussed by Beca (2008) and Jowett and Hayes (2004) the level of investigation required for flow setting should be matched to the relative in-stream values and the level of abstraction pressure (i.e. the degree of hydrological alteration). Where abstraction pressure and/or in-stream values are low simple rules-of-thumb may be adequate for flow setting, while in cases with high abstraction pressure and/or high in-stream values, more in-depth investigation are likely to be warranted, including habitat modelling and flushing flow analysis.

With this in mind, I consider that policy providing for a tiered approach to supplementary allocation would be sensible, with the level of investigation depending on demand. This would be comparable with Environment Southland's primary allocation policy (Appendix I to the Regional Water Plan for Southland, based on recommendations from Jowett and Hayes 2004). I consider that something similar to the supplementary allocation policy in Horizons Regional Council's One Plan is appropriate. This policy specified a default minimum flow and allocation limit, to provide protection for ecologically relevant components of the flow regime, but also included a clear indication that more ambitious applications would be considered — subject to an appropriate level of effects assessment, commensurate with the larger degree of hydrological alteration (as discussed by Beca et al. 2008).

Using the median flow as the minimum threshold for supplementary abstraction (as in the One Plan) aims to maintain flow recessions that support invertebrate production — in the low to-median flow range (Hayes 2009). As mentioned above, the median flow has also been used in this role by several other Councils. The mean flow (as currently used in Environment Southland's policy) is more environmentally conservative, but is more restrictive on water users — in that it provides lower reliability of supply for abstraction. I consider that using the median flow threshold is more appropriate, on the basis of current science, provided that other mechanisms, such as flow sharing or an allocation cap are also implemented to maintain higher ecologically relevant flow events (such as flushing flows). Explicitly specifying the
degree to which flushing flows are to be maintained may also be worthwhile (similar to the likely intent of Greater Wellington Regional Council’s upcoming policy change proposal).

Flow sharing apparently presents compliance issues where there are multiple abstractions (pers. comm. Andrew Parrish, ECAn). It may be worthwhile considering opting for a simple cap on supplementary allocation or perhaps a block by block flow sharing arrangement (as used by Otago Regional Council for their lower flow supplementary allocation) to avoid this problem.

Another point worth considering is whether policy should explicitly encourage abstraction to storage during winter, when demand and ecological flow requirements are likely to be lower. Such policy could include a higher allocation cap during winter or a flow sharing regime with a greater proportion of flow available for abstraction.

As mentioned in Section 2.5, supplementary allocation and water storage schemes may enable intensification of land-use, with the potential for detrimental impacts on water quality. It would be prudent to bear these potential effects in mind, along-side the more direct in-stream impacts of supplementary allocation when considering policy changes.

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Thanks to Doug Booker and Murray Hicks (NIWA) for information and advice on the CHES and EFSAP modelling tools described in Section 0.
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Office of the Prime Minister's Science Advisory Committee 2013 New Zealand's changing climate and oceans: The impact of human activity and implications for the future. An assessment of the current state of scientific knowledge by the...


9. APPENDIX

Appendix 1. E-mail sent to regional council and unitary authority contacts to survey experiences with supplementary allocation policy.

Hi _____,

I am currently working on a report for Environment Southland reviewing supplementary (flow harvesting) water allocation policies employed by other Regional Councils, as well as looking at how ecological and recreational values dependent on mid to high range flows may be impacted by supplementary allocation. Your answers to the following questions would be greatly appreciated, along with any general comments or suggestions you may have to add.

1) What (if any) supplementary allocation and/or flow sharing policies have _____ employed (including both past and present policies)?

2) If previous policies have been abandoned or adapted, what prompted this (i.e. what aspects of the policies were problematic/ didn’t work)?

3) How were these perceived problems addressed in the new policy?

4) Can you see any fish hooks/ problems in your current supplementary allocation policy?

5) Do you have any general comments to make on supplementary allocation policy and/or potential environmental or recreational impacts of supplementary allocation?

Thank you very much for your time and input. I understand the Environment Southland are likely to make the report I am working on available on their website, so hopefully, the final report will also be helpful to you with future allocation policy development.

Regards,

Joe Hay
Freshwater Biologist