17 September 2021

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Dear Jason

DEFAULT MINIMUM FLOW AND ALLOCATION LIMITS FOR OTAGO

This memo uses some technical terms relating to river flow management. These definitions and concepts are summarised in Appendix 1.

Introduction

This advice letter is in response to a 27 April 2021 email request from Otago Regional Council (ORC) for a paired advice memo from Cawthron and NIWA on default minimum flow and primary allocation limits for use in the Regional Plan Water for Otago (RPW).

Following the request, John Hayes, Doug Booker, Shailesh Singh and Paul Franklin met on 4 June 2021 to discuss the default minimum flow and allocation limits that John recently presented to the Otago PC7 hearing, and how ORC might use region-wide low flow estimates from the hydrology models provided by NIWA to inform the setting of default limits on water resource use through specifying minimum flows and total allocations. We have given these matters further consideration since the meeting in the preparation of this advice letter.

Deployment of the default minimum flow and total allocation discussed below depends on the availability of summary flow statistics, in particular the naturalised MALF. One method for defining default minimum flow and total allocation across locations is to multiply the naturalised MALF by a specified percentage and, therefore, express these two components of water resource use limits in units of flow (m^3/s or L/s) at any location where naturalised MALF has been observed or modelled estimates are available.

Region-wide hydrological estimates represent summary flow statistics for all ungauged sites across catchments. These estimates can be complemented with observed river flow statistics calculated for gauged catchments to provide best estimates of naturalised MALF for calculating default water resource use limits over the regional river network. It should be noted that estimates of naturalised flow must correct for anthropogenic alterations to observed flows.

The purpose of minimum flow and allocation limits

Setting water resource use limits ensures that a predetermined level of alteration to flow regimes is not exceeded, while also clarifying the state of water availability for both present and potential users through comparison between the limits and present allocation. This type of comparison also allows assessment of which water bodies are under, fully, or over-allocated. These are important tasks to inform water resources planning. Information is available describing the various technical issues and considerations relating to water resource use limits (e.g. Booker 2018), potential methods that could be applied (e.g. Beca 2008), and how outcomes will depend on how limits are deployed (Booker et al. 2014). However, no official prescriptive guidelines are currently available describing how water resource use limits should be set. Furthermore, at the time of writing it is unclear how the concepts of adaptive management and Te Mana o te Wai (which mandates a precautionary approach to limit setting) introduced in the National Policy Statement for Freshwater Management 2020 (NPS-FM) should influence setting of water resource use limits.

Default minimum flow and allocation limits

For the purposes of this document, default water resource use limits are those to be set in the absence of detailed studies on flow-instream value responses and where current consented total allocation is low[1]. Default minimum flows and total allocations combine to serve several functions:

1. Protection against more than minor effects on instream values arising from future flow regime alterations in the absence of detailed studies on flow-instream value responses.
2. Provision of moderate support for out of stream values by allowing relatively low levels of water abstraction without significant consenting costs or risks to instream values.
3. Acting as a reference for assessing the degree of hydrological alteration that current consents or proposed water resource use limits represent, including an indication of the risk of more than minor effects on instream habitat, ecosystem health and other instream values in the absence of detailed studies on these responses.

The default minimum flow and total allocation proposed here are based on the values and risk-based framework commonly applied in New Zealand for assessing environmental flows (MFE 1998). The essence of the framework is that:

1. The lower the minimum flow, and / or greater the allocation rate, the greater the alteration to the natural river flow regime and, therefore, the greater the risk that instream habitat, ecosystem health, mahika kai, fishery amenity and other relevant instream values will be adversely affected.

[1] "Low allocation" systems fall within the default allocation parameters proposed in Table 1 (i.e. low allocation rates are ≤ 20% of 7-day MALF and ≤ 30% of 7-day MALF in surface water bodies with mean flows ≤ 5 > m^3/s, respectively (Table 1)).

2. The more significant the instream value, the more precautionary water resource use limits should be.

The default limits have been derived after having considered information from the following sources:

1. The 2008 proposed National Environmental Standard for Flows and Water Levels (NES) (MFE 2008).
2. The support document for the proposed NES on selection of methods to determine ecological flows (Beca 2008).
3. An international presumptive standard for environmental flow protection (Richter et al. 2012).
4. The National Policy Statement for Freshwater Management 2020 (NPS-FM), particularly the concept of Te Mana o te Wai and the ‘hierarchy of obligations’ that mandate a precautionary approach to setting limits because the first priority is to protect instream values.

2008 proposed NES

The 2008 proposed NES defined interim minimum flow and total allocations (to be applied where no limits had been set in regional plans) as percentages of naturalised 7-day MALF. The 2008 proposed NES recommended a default minimum flow of 90% of MALF, and a total allocation rate of 30% of MALF, for rivers with a mean flow of less than 5 m^3/s. For rivers with a mean flow greater than 5 m^3/s, it recommended a minimum flow limit of 80% of MALF and an allocation rate of 50% of MALF. These interim limits were proposed to be applied in locations where no limits had been stipulated in regional plans.

The supporting document for the NES (Beca 2008) includes tables 1 and 2 (reproduced in Appendix 2), which were intended to guide the selection of methods for assessing ecological flow requirements; the approach required application of more complex methods, offering greater certainty in determining effects, where instream values were greater, and/or the degree of hydrological alteration was larger. The guidance in the tables is, therefore, also relevant to assessing the risk of deleterious effects on instream values resulting from flow alteration. Hence, the tables are relevant for informing environmentally conservative minimum flow and allocation limits.

However, it should be noted that the 2008 proposed NES interim limits did not align directly with the guidance for selection of methods (Beca 2008), which advised that “Abstraction of more than 40% of naturalised 7-d MALF, or any flow alteration using impoundments, would be considered a high degree of hydrological alteration, irrespective of region or source of flow”. The supporting document further advised that a total allocation of 20–30% of MALF could be considered a high degree of hydrological alteration in rivers and streams with mean flow less than 5 m^3/s, depending on the instream values and baseflow characteristics.

As part of the framework for guiding selection of methods for assessing ecological flow requirements, , table 1 in Appendix 2 presents an assessment of the likely risk of deleterious effects on instream habitat according to the fish species and life-stages present and the naturalised mean streamflow. Risk of deleterious effect is related to stream size; the smaller the mean flow, the greater the risk presented by the same flow alteration when defined as a percentage of MALF. Furthermore, risk is related to our understanding of habitat preferences. Fish species and sizes that demonstrate a preference for deeper and/or faster water are considered more vulnerable across a broader range of river sizes relative to those species with a preference for shallower and/or slower water. For example, large (adult) trout, which prefer deep, fast water, are more at risk in medium to small rivers than small fish. Finally, risk of deleterious effects on instream habitat is also related to the conservation status of the instream values; rare and/or threatened species should be afforded a higher level of protection in maintaining habitat and flows because they have greater risk of extirpation than more common, widespread species.

Appendix 2's table 2 is the second step in the framework for guiding selection of methods for assessing ecological flow requirements. It categorises the degree of hydrological alteration arising from total allocation (specified in terms of percentage of naturalised MALF) relative to the risk of deleterious instream effects (i.e. Appendix 2, table 1) and stream baseflow characteristics.

Richter et al.'s (2012) presumptive flow standard

Richter et al.'s (2012) presumptive flow standard was derived by expert judgement based on a review of international scientific research. The standard of Richter et al. (2012 p. 1318) states that:

- 'A high level of ecological protection will be provided when daily flow alterations are no greater than 10%; a high level of protection means that the natural structure and function of the riverine ecosystem will be maintained with minimal changes.'
- 'A moderate level of protection is provided when flows are altered by 11–20%; a moderate level of protection means that there may be measurable changes in structure and minimal changes in ecosystem functions.'
- 'Alterations greater than 20% will likely result in moderate to major changes in natural structure and ecosystem functions, with greater risk associated with greater levels of alteration in daily flows.'

'Structure' in this context could refer to flow-related habitat, species composition and abundance of instream communities.

Deployment of the presumptive flow standard entails setting the allowable rate of water take for a given day as a percentage (e.g. 10%) of naturalised flow for that day. The allowable rate of take reduces as naturalised flow reduces. This concept is applied consistently across the entire flow range. At extremely low flows, some (very small) take is allowable. At higher flows, more take (much more than 10% of MALF) is allowable. There is no concept of a minimum flow below which no take is allowable in the presumptive flow standard method.

Assessing the 2008 proposed NES interim limits alongside the presumptive flow standard

The presumptive flow standard is not directly comparable with methods that utilise a minimum flow and total allocation such as the 2008 proposed NES. When compared to the 2008 proposed NES for small streams (minimum flow is 90% of MALF, total allocation is 30% of MALF), the presumptive flow standard (e.g. 10% of naturalised flow for each day) would allow more permissive rates of take at higher flows, equivalent rates of take at MALF, and less permissive rates of take at lower flows above the minimum flow. In this example comparison, the rate of take allowed by the two methods would be equivalent only on days when 10% of naturalised flow is equal to 30% of MALF. The methods also differ in that the presumptive flow standard allows some level of flow alteration under all flow conditions, whereas no abstraction would occur when natural flows are below the minimum flow under the 2008 proposed NES. Figure 2 of Richter et al. (2012) is insightful in showing this point.

Although the percentage values applied in these two methods are not directly comparable, both methods are intended to set default environmental flows to secure low risk (or high protection) to instream values in the absence of more detailed studies. It is, therefore, insightful to consider the presumptive flow standard when proposing default minimum flows and total allocations.

The following example illustrates the differences in hydrological alteration that would occur by the deployment of the proposed NES limits, Richter et al.'s (2012) presumptive standard, and default limits we are proposing for Otago (Table 1). The Cardrona at Mt Barker is a relatively small stream in upland Otago with a MALF of 0.9 m^3/s and a mean flow of 3.1 m^3/s. February has generally been the month with lowest observed flows at this site. Figure 1 shows observed flows for Cardrona at Mt Barker in the form of the flow duration curve (FDC) calculated over the entire flow record and for February only. Figure 1 also shows FDCs that would result from deployment of the NES for small rivers (minimum flow is 90% of MALF, total allocation is 30% of MALF) and the presumptive flow standard (e.g. 10% of naturalised flow for each day). The figure demonstrates various scenarios of allowable rates of abstraction, and therefore flow alteration, over the range of observed flows at this example site. Figure 1 shows that deployment of the NES for small rivers would preserve the lowest 4% of all-time daily flows but would allow more permissive rates of take between the 4th and 53rd percentiles of all-time daily flows when compared to the presumptive standard regardless of month. The differences in rates of take allowable under the NES for small rivers and the presumptive standard are greater for the February FDC than the all-time FDC. Deployment of the NES for small rivers would allow more permissive rates of take for longer periods compared with those allowed by the presumptive standard during February.

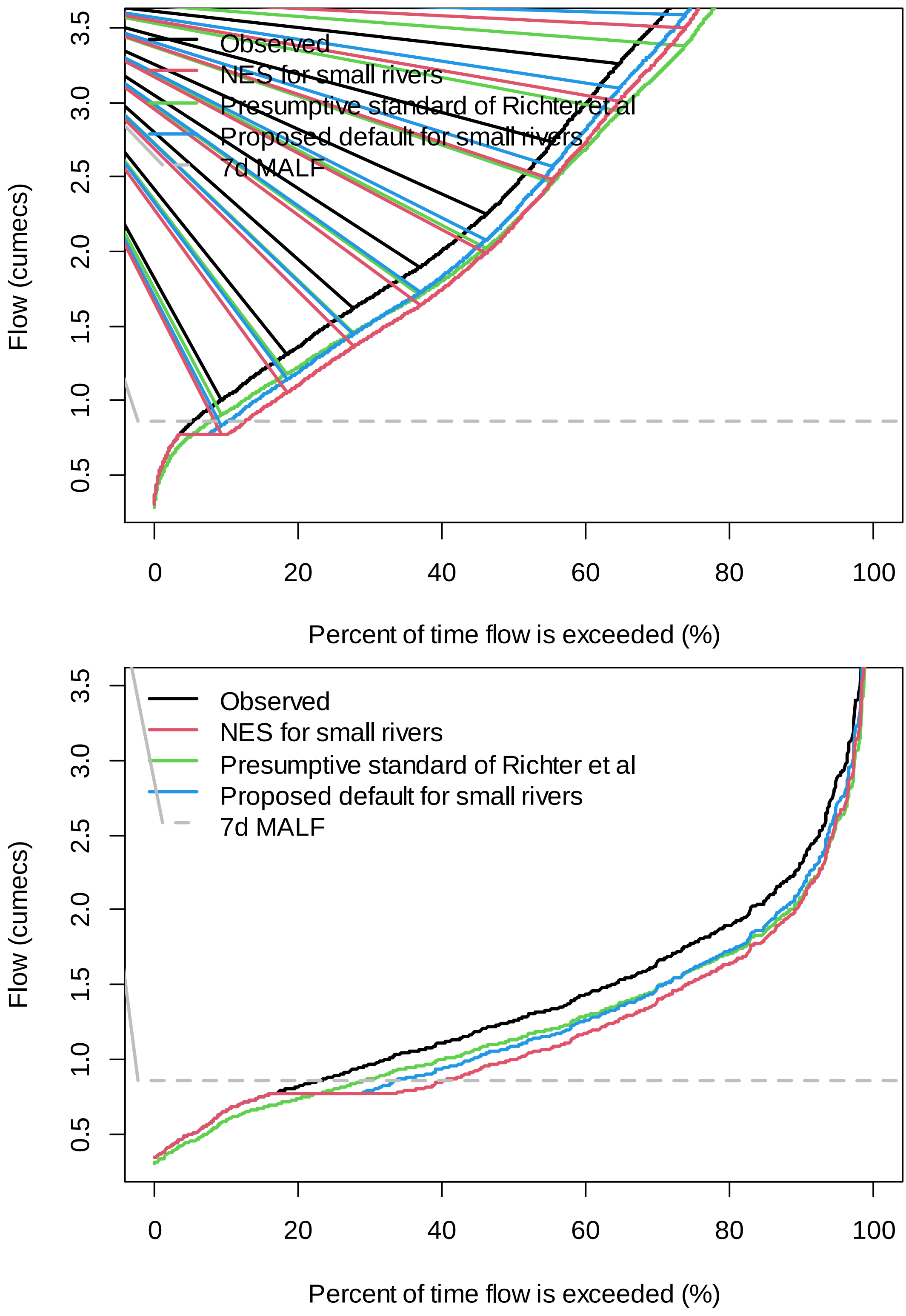

Figure 1. Observed and altered flow duration curves from the Cardrona at Mt Barker (1978-2020). Top is all-time daily flows regardless of month. Bottom is February-only daily flows. 'Proposed default' refers to the default minimum flow and allocation limits for Otago proposed in Table 1.

Compared to Richter et al.'s (2012) presumptive standard, the NES limits for allocation of up to 30% and 50% of naturalised 7-d MALF in rivers with mean flow less than and greater than 5 m³/s, respectively, seem insufficiently precautionary. This is particularly the case when naturalised flow is between the minimum flow and the minimum flow plus the total allocation. There are two reasons for this situation. First, the NES limits allow a greater proportion of river flow to be abstracted for a greater proportion of the time at lower flows (but not at flows lower than the minimum flow). Second, the presumptive standard ensures some flow variability at lower flows, whereas the NES limits may result in "flat lining" of river flow at lower flows because, in theory, the same flow would be experienced for all days on which naturalised flow is between the minimum flow and the minimum flow plus the total allocation. See Figure 1 for an example of flat lining. In our opinion, allocation limits of 20% and 30% of MALF for rivers with mean flow less than and greater than 5 m³/s, respectively, are more appropriate to give effect to Te Mana o te Wai by securing low risk (or high protection) to instream values.

All-time and February-only FDCs resulting from an allocation limit of 20% of MALF are shown by the blue line in Figure 1 for the Cardrona at Mt Barker. An allocation limit of 20% of MALF produces an altered FDC that more closely matches the presumptive standard than an allocation limit of 30% of MALF for flows in this example of a small river site (mean flow less than 5 m³/s).

The importance of Te Mana o te Wai within the 2020 NPS-FM

A factsheet published by MfE and MPI (MfE/MPI 2020) states that:

- "Te Mana o te Wai refers to the vital importance of water. When managing freshwater, it ensures the health and well-being of the water is protected and human health needs are provided for before enabling other uses of water."
- "Te Mana o te Wai must inform how the NPS-FM 2020 is implemented by imposing a hierarchy of obligations. This hierarchy means prioritising the health and well-being of water first. The second priority is the health needs of people (such as drinking water) and the third is the ability of people and communities to provide for their social, economic, and cultural well-being. The hierarchy does not mean, however, that in every case the water needs to be restored to a pristine or prehuman contact state before the other needs in the hierarchy can be addressed."

Other excerpts from the 2020 NPS-FM relevant to Te Mana o te Wai, and setting environmental flow and take limits, are listed in Appendix 3.

Default minimum flow and allocation limits proposed for Otago

Table 1 summarises the default minimum flow and allocation limits that we propose for Otago. The limits are based on percentage of naturalised 7-d MALF. The table is derived from Hayes' (2021) evidence presented to the Otago PC7 hearing, but revised to be read as minimum flow limits for ceasing consented water takes and primary allocation limits not to be exceeded. Furthermore, for simplicity, the table does not distinguish between perennial and intermittently flowing rivers, as did Hayes' (2021) version. We are satisfied that the default limits for perennial rivers will also provide precautionary limits for permanently flowing segments of intermittent rivers, and that the method of calculation of the limits for such reaches, based on percentage of MALF, is practical. NIWA's hydrology models can predict MALFs for such segments, and ground truthing gaugings can improve the accuracy of MALF estimates.

Table 1. Proposed default minimum flow and primary allocation limits, expressed as % of naturalised 7-d mean annual low flow (MALF), for maintaining flow regimes that present a low risk of more than minor effects on ecosystem health and wellbeing of Otago's streams/rivers, including their instream habitat, life-supporting capacity, mahika kai and fisheries amenity.

Limit	**Surface water body with mean flow ≤ 5 m^3/s**	**Surface water body with mean flow > 5 m^3/s**
Minimum flow	90% of naturalised 7-day MALF	80% of naturalised 7-day MALF
Allocation rate	20% of naturalised 7-day MALF	30% of naturalised 7-day MALF

The proposed limits can serve two functions: 1) for efficiently setting default allocation rates and minimum flows to avoid more than minor ecological effects, and 2) for defining a gateway/threshold for more than minor effects. In respect of the latter, if allocation rate exceeds, and/or the minimum flow is less than, the limits in Table 1, ecological effects are likely to be more than minor. Nevertheless, it is possible that the instream values and freshwater management objectives could be met with alternative allocation rates and minimum flows to those in Table 1, but more information would be needed to assess ecological effects to support that outcome (e.g. hydraulic-habitat modelling, invertebrate drift versus flow relationship, and other methods listed in Beca (2008)).

Minimum flow and allocation limits set as proportions of historical flow statistics, such as the default limits proposed here, assume spatially consistent reductions in habitat or ecological responses with flow reduction. However, flow-related habitat and ecological–flow relationships are known to respond non-linearly to flow, and to vary in space. This results in default minimum flow and allocation limits delivering different habitat and ecological protection levels in different rivers and for different species/size classes (Snelder et al. 2011; Booker et al. 2014). On the other hand, they are simpler to apply than more complex methods of assessing environmental flows and setting limits, and some guidance exists on percentage flow alteration limits likely to pose low risk of adverse ecological effects (e.g. the 2008 proposed NES and Richter et al.'s (2012) presumptive standard).

Potential improvements to the default minimum flow and allocation limits

If ORC wished to apply limits that accounted for non-linear responses of channel geometry (e.g. wetted width) and generalised habitat (Booker 2016) to flow alteration, then NIWA's recently developed eFlows Explorer webtool (https://shiny.niwa.co.nz/eflowsexplorer/) would allow exploration of this option. The app is intended to aid understanding of how minimum flow and total allocation can be set, by demonstrating how they interact with reliability of water supply and an example environmental outcome represented by total area of aquatic habitat (wetted width at minimum flow) or availability of habitat for a chosen fish species. The eFlows Explorer uses the National Digital River Network as a spatial framework and can make predictions for all ungauged segments of that network.

Setting limits based on generalised habitat modelling (i.e. a method that can be implemented in the eFlows Explorer) represents a more complex method than application of default limits based on percentage of MALF (or other hydrological statistics) owing to the challenge of deciding which species/life-stages to model and how to balance trade-offs between outcomes for different values (e.g. different species and/or reliability of supply). Moreover, habitat–flow relationships cannot be used to set the allocation limit, although the effect of the allocation rate on duration of habitat below habitat thresholds can be examined. There is no guidance available that would allow setting a default allocation limit based on availability of suitable physical habitat.

Alternatively, information obtained from the eFlows Explorer (or similar) would be useful for assessing the effects of the default minimum flow and allocation limits based on percentage of naturalised MALF, proposed in Table 1, on wetted width, instream habitat, and reliability of water supply to abstractors over streams in Otago. Information obtained from estimated flow duration curves available from the eFlows Explorer webtool (or similar) would also allow assessment of the relationship between reliability of water supply and combinations of minimum flow and total allocations.

Regional hydrology model

A regional hydrological and statistical model was developed by NIWA (Singh et al. 2021) to provide Otago Regional Council with estimates of fundamental hydrological statistics and daily flow time-series for all streams of Strahler order 3 or higher (covering the whole Otago region). The hydrological statistics provided include 1 in 5-year low flow, 7-day mean annual low flow, mean flow, median flow, proportion of flow in February (driest month) and frequency of events exceeding three times the median flow.

The hydrological statistics for 59 gauging sites (out of 250 sites) that met selection criteria on record completeness and minimal upstream abstraction, damming or diversion (see Singh et al. 2021 for details) were calculated using observed data. Data from the 59 sites were then used to estimate naturalised hydrological statistics for all streams in the region of Strahler order 3 or higher. It should be noted that the 59 gauging sites that met selection criteria did not represent an unbiased sample of river locations due to the influence of current water use, and the requirement of channel stability for accurate ratings, on the siting of gauging stations.

NIWA compared the predictive ability of three methods for estimating the hydrological statistics across the ORC region: Method (1) Random forest regression, Method (2) a 'Bias-corrected TopNet' hydrological model, and Method (3) the Booker and Woods (2014) national predictions as extracted from 'New Zealand (NZ) River Maps'. We found that no one method outperformed the others for all statistics. For example, Bias-corrected TopNet estimates of hydrological statistics produced the best correspondence between observed and calculated values of mean and median flow, whereas the Random forest regression method produced the best correspondence between observed and calculated values for 7-day MALF, 1 in 5-year low flow, frequency of events exceeding three times the median flow and proportion of flow in February. We recommend using the best of the three methods identified in Singh et al. (2021) for estimating each of the hydrological statistics, along with their uncertainties, to assist with the process of setting limits.

We note that hydrological statistics and daily flow time-series are not currently available for small streams (Strahler order 2 or 1) since predictions for these streams were not required by ORC for Singh et al.'s (2021) report. As with any hydrological estimates for ungauged sites, there are mathematical uncertainties associated with naturalised MALF estimates. These uncertainties varied across sites (Figure 2). The models tended to overestimate in small catchments and underestimated in large catchments. Factors contributing to these uncertainties include: 1) quantification of the true catchment area (particularly difficult for small catchments), 2) inputs to the model (e.g. spatial distribution of precipitation) and 3) measured flow data (especially to differences in record duration). These uncertainties should be considered when applying the estimates for any water allocation management purposes.

The overprediction of MALF for small catchments will result in more precautionary (i.e. higher) minimum flow limits, but also less precautionary (i.e. greater) allocation.

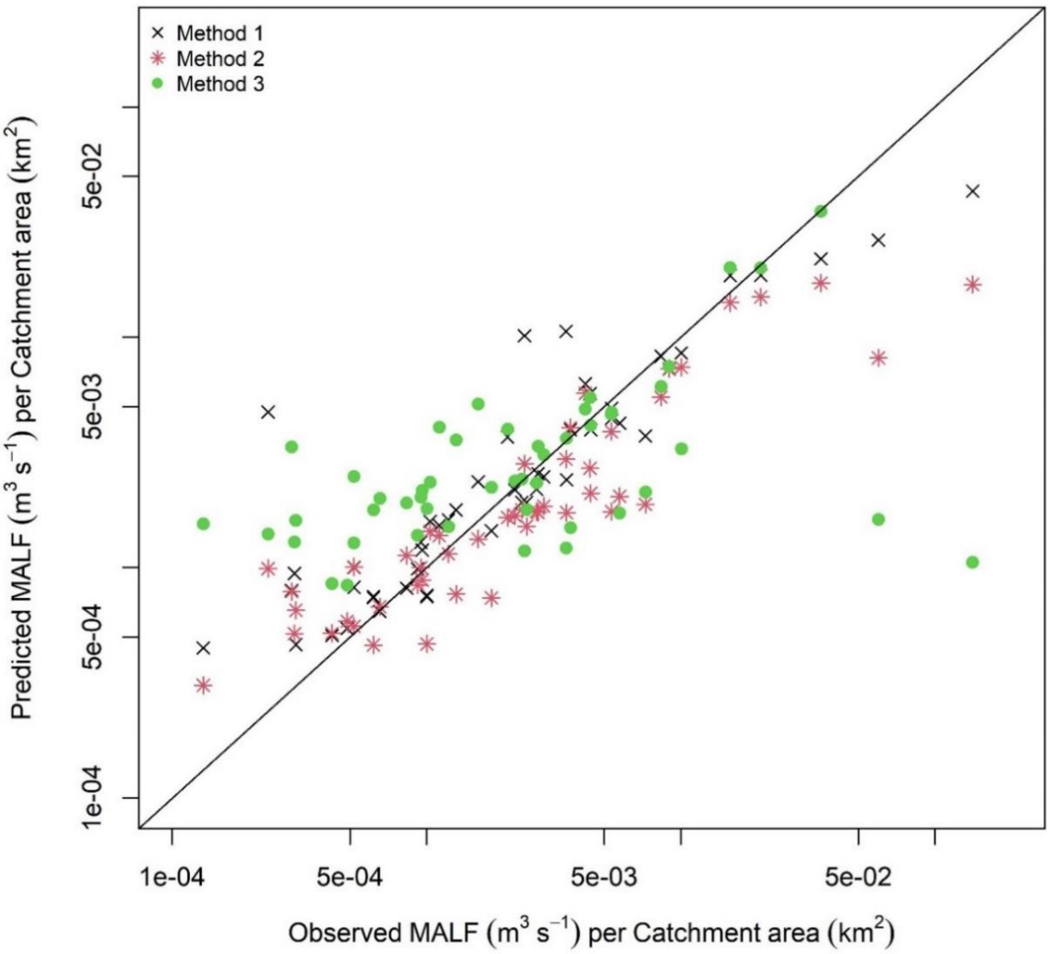

Figure 2. Observed vs Predicted specific MALF calculated from various methods for observed Otago sites with abstraction % < 30.

Implementing the default minimum flow and allocation limits with flow estimates from the regional hydrology model

Our judgement is that the default minimum flow and primary allocation limits proposed here are environmentally conservative whilst allowing for modest levels of water abstraction. The limits:

- Give effect to the NPS-FM directive of Te Mana o te Wai to put the health and wellbeing of waterbodies above other needs.
- Take account of uncertainty in naturalised 7-d MALF estimates and the need to reduce the risk of over allocation in the event that the MALF has been overestimated. Minimum flows can later be revised, and total allocation rates revised upward, if MALFs are found to be underestimated. However, it is much more difficult to claw back water for rivers after flow has been overallocated through the consenting process.

The regional hydrology model estimates of naturalised MALF can have a high level of uncertainty for individual sites—in the order of ± 30%. This level of uncertainty exceeds the differences in levels of flow alteration allowed by the default limits for rivers less than and greater than 5 m^3/s (i.e., up to 10% of naturalised 7-d MALF difference in minimum flow and allocation limits) (Table 1). How should this certainty mismatch between MALF estimates from the regional hydrology model and the default limits be reconciled? The rationale we favour blends pragmatism with environmental conservatism. Minimum flow and allocation limits need to be set for the RPW, and they need to be tailored to the importance and flow sensitivity of instream values, which is related to stream size. This means a 'one size fits all' approach to limits setting is inappropriate; limits should be more environmentally conservative for small rivers. This justifies the different limits we have proposed for rivers with mean flow less than and greater than 5 m^3/s. To give effect to Te Mana o te Wai, minimum flow and allocation limits should be environmentally conservative. This is particularly important in order to reduce the risk of inadvertent over-allocation with default limits based on naturalised MALFs estimated from the regional hydrology model, where the MALF estimates have a high degree of uncertainty. If the uncertainty in available MALF estimates is taken as justification to infer that there is no difference between limits that differ by 10% of MALF, or that limits could be more permissible than those we propose, this increases the risk of unintended overallocation and greater potential for adverse effects on instream values. To avoid this, and to proceed pragmatically, limits should simply be based on the best available estimates of naturalised MALF, including those from the Otago regional hydrology model or better estimates from flow recorders and flow naturalisation methods where such data exist. Limits can be revised in future as more flow data are gathered and naturalised MALF estimates become more accurate.

The default minimum flow and allocation limits ought to apply to the minimum flow for a river segment of management interest and to the cumulative allocation. Takes should be managed such that the percentage protection afforded by the minimum flow at the reference flow recorder is also provided elsewhere throughout the catchment. This avoids flow being drawn very low in upstream parts of a management segment, but not breaching the minimum flow limit at the downstream recorder due to flow accretion from tributaries and groundwater. This requires freshwater management units defined for the purpose of flow management to be relatively fine-grained (i.e. applied at the tributary or tributary segment scale and mainstem segment scale) or application of methods that explicitly account for spatial variability when applications for new consents are considered through calculation of actual total allocation and comparison with plan limit total allocation.

The NPS-FM 2020 requires that the best available information be used to inform decision making and that decisions should not be delayed due to uncertainty about the information available. The proposed approach is consistent with this mandate, but we also note the requirement to "take all practicable steps to reduce uncertainty" in the absence of complete and scientifically robust data. To this end we also recommend establishment of an environmental flows monitoring and evaluation framework alongside deployment of the proposed default limits to enable future adaptive management and revision of limits as knowledge increases.

Yours sincerely

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Appendix 1. Terms and definitions.

Term	Definition
MALF	The mean of an annual series of flow minima after having applied a 7-day running mean to a daily river flow time-series.
Naturalised flow	An estimation of river flow that would have been observed under the present landcover but in the absence of abstractions or diversions of either groundwater or surface water.
Environmental flow	River flows that will result in a river flow regime able to support in-stream values.
Minimum flow	Water abstractions must be restricted during times of low flow such that flow is not artificially drawn below the minimum flow. All associated water abstractions must cease when river flow is below the minimum flow.
Total allocation (also known as allocation limit)	The sum of all instantaneous allowable rates of abstraction that are associated with a catchment or management zone.
Water resource use limits	For the purposes of this letter "water resource use limits" are defined as the combination of minimum flow and total allocation. These two limits together control the maximum potential impact of consented consumptive water abstractions on naturalised river flow time-series. It should be noted that, for broader purposes, "water resource use limits" can include additional elements such as specific requirements for flushing flows or seasonal patterns.
Default limits	Water resource use limits to be applied in situations where local studies on impacts of water abstraction on instream values have not been applied and where current consented total allocation is less than our proposed default total allocation.
Instream values	Environmental values of streams/rivers, particularly those influenced by river flows and flow regimes, including: ecological status or health, cultural values, fishery values and aesthetic values. In-stream values may be identified by the local authority, iwi, freshwater management zone-committee, or national legislation via the National Policy Statement for Freshwater Management.

Appendix 2

Table A1. Assessment of risk of deleterious effects on instream habitat according to fish species present and natural mean stream flow (and generic application to other values/management objectives°). The data in the column for 'Salmonid spawning and rearing, torrentfish, bluegill bully', may be generically applied to invertebrates and riverine bird feeding (e.g., wading birds, blue duck, black fronted tern). Table reproduced from Beca (2008).

Mean flow (m^3/s)	Inanga*, upland bully, Crans bully, banded kopopu*	Roundhead galaxias, flathead galaxias, lowland longjaw galaxias, redfin bully*, common bully*	Salmonid spawning and rearing, torrentfish*, bluegill bully*	Adult trout+
<0.25	High	High	High	High
< 0.75	Moderate	High	High	High
< 5.0	Low	Moderate	High	High
< 15.0	Low	Low	Moderate	High
15–20	Low	Low	Low	Moderate
> 20	Low	Low	Low	Low

* Access to and from the sea is necessary
\+ Access to spawning and rearing areas is necessary
° Actual degree of impact will depend on the degree of hydrological alteration whether or not the level of risk is high or low

Table 2. Relationship between degree of hydrological alteration and total abstraction expressed as percentage of 7-day mean annual low flow for various risk classifications (Appendix Table 1) based on stream size (baseflow[1] and species composition. Table reproduced from Beca (2008).

Risk of deleterious effect						Degree* of hydrological alteration
Low risk and high baseflow	Low risk and low baseflow	Moderate risk and high baseflow	Moderate risk and low baseflow	High risk and high baseflow	High risk and low baseflow	
<20%	<15%	<15%	<10%	<15%	<10%	Low
20–40%	15–30%	15–30%	10–25%	15–30%	10–20%	Medium
>40%	>30%	>30%	>25%	> 30%	>20%	High

[1] A high baseflow river is one where the low flows are relatively high compared to the mean flow, such as in rivers with frequent freshes, rivers with their sources in hilly or mountainous areas or rivers fed from lakes, or springs. A low baseflow river is one where the low flows are very much lower than the mean flow, such as occurs in rain-fed rivers in areas that are not subject to orographic rainfall. Many of the rivers under abstraction pressure in the dry country of Otago will be of this character.

Appendix 3

Concept of Te Mana o te Wai taken from the 2020 NPS-FM

(5) There is a hierarchy of obligations in Te Mana o te Wai that prioritises:

(a) first, the health and well-being of water bodies and freshwater ecosystems

(b) second, the health needs of people (such as drinking water)

(c) third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

Other relevant part of the 2020 NPS-FM

3.16 Setting environmental flows and levels

(1) Every regional council must include rules in its regional plan(s) that set environmental flows and levels for each FMU, and may set different flows and levels for different parts of an FMU.

(2) Environmental flows and levels:

(a) must be set at a level that achieves the environmental outcomes for the values relating to the FMU or relevant part of the FMU and all relevant long-term visions; but

(b) may be set and adapted over time to take a phased approach to achieving those environmental outcomes and long-term visions.

(3) Environmental flows and levels must be expressed in terms of the water level and flow rate, and may include variability of flow (as appropriate to the water body) at which:

(a) for flows and levels in rivers, any taking, damming, diversion, or discharge of water meets the environmental outcomes for the river, any connected water body, and receiving environments

(b) for levels of lakes, any taking, damming, diversion or discharge of water meets the environmental outcomes for the lake, any connected water body, and receiving environments

(c) for levels of groundwater, any taking, damming, or diversion of water meets the environmental outcomes for the groundwater, any connected water body, and receiving environments.

(4) When setting environmental flows and levels, every regional council must:

(a) have regard to the foreseeable impacts of climate change; and

(b) use the best information available at the time; and

(c) take into account results or information from freshwater accounting systems.

3.17 Identifying take limits

(1) In order to meet environmental flows and levels, every regional council:

(a) must identify take limits for each FMU; and

(b) must include the take limits as rules in its regional plan(s); and

(c) must state in its regional plan(s) whether (and if so, when and which) existing water permits will be reviewed to comply with environmental flows and levels; and

(d) may impose conditions on resource consents.

(2) Take limits must be expressed as a total volume, a total rate, or both a total volume and a total rate, at which water may be:

(a) taken or diverted from an FMU or part of an FMU; or

(b) dammed in an FMU or part of an FMU.

(3) Where a regional plan or any resource consent allows the taking, damming, diversion or discharge of water, the plan or resource consent must identify the flows and levels at which:

(a) the allowed taking, damming, or diversion will be restricted or no longer allowed; or

(b) a discharge will be required.

(4) Take limits must be identified that:

(a) provide for flow or level variability that meets the needs of the relevant water body and connected water bodies, and their associated ecosystems; and

(b) safeguard ecosystem health from the effects of the take limit on the frequency and duration of lowered flows or levels; and

(c) provide for the life cycle needs of aquatic life; and

(d) take into account the environmental outcomes applying to relevant water bodies and any connected water bodies (such as aquifers and downstream surface water bodies), whether in the same or another region.

3.18 Monitoring

(1) Every regional council must establish methods for monitoring progress towards achieving target attributes states and environmental outcomes.

(2) The methods must include measures of:

(a) mātauranga Māori; and

(b) the health of indigenous flora and fauna.

(3) Monitoring methods must recognise the importance of long-term trends, and the relationship between results and their contribution to evaluating progress towards achieving long-term visions and environmental outcomes for FMUs and parts of FMUs.

3.28 Water allocation

(1) Every regional council must make or change its regional plan(s) to include criteria for:

(a) deciding applications to approve transfers of water take permits; and

(b) deciding how to improve and maximise the efficient allocation of water (which includes economic, technical, and dynamic efficiency).

(2) Every regional council must include methods in its regional plan(s) to encourage the efficient use of water.