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Water Management REPORT

# FUTURE FOCUSED FRESHWATER ACCOUNTING

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# EXECUTIVE SUMMARY

This report, and the resulting conclusions and recommendations, was commissioned by the Ministry for the Environment (MfE) to support potential improvements to freshwater accounting systems in New Zealand, with the aim of:

- providing high quality information for a wide range of local, regional and national needs; and
- increasing public trust and confidence in the environmental management system through increased transparency, completeness and consistency of information.

It focuses on the design, preparation and operation of freshwater quality and quantity accounting systems.

Freshwater accounting systems provide[1] measured and/or modelled data describing the quantity and quality of freshwater systems, and thus play a key role within a broader system of resource management by providing baseline information required for:

- setting target attribute states, environmental flows and levels, and limits;
- assessing whether a freshwater management unit (FMU) is, or is expected to be, over-allocated; and
- tracking over time the cumulative effects of activities (such as increases in discharges and changes in water and land use).

Regional authorities are required by the National Policy Statement for Freshwater Management 2020 (NPS-FM) to operate a freshwater quality and quantity accounting system for each of their defined FMUs.

Guidance for the design and operation of freshwater quality and quantity accounting systems was published in 2015[2] (the 2015 Guidelines). Regional authorities have implemented this guidance to varying degrees using a range of approaches.

The 2015 Guidelines are in large part still very relevant, but there have been several changes in context that indicate a need to revisit the design and operation of New Zealand's freshwater accounting systems. The most significant changes in context are due to the Essential Freshwater reforms in 2020, advances in environmental accounting methods and enabling technologies, and current and potential future legislative reforms affecting how water is governed, managed, and allocated. In particular, the NPS-FM (2020) directs regional authorities to give effect to Te Mana o te Wai (TMotW) and is more specific about the purpose and scope of freshwater accounting.

The freshwater accounting system principles in the 2015 Guidelines warrant updating to reflect changes in context outlined above, particularly in relation to TMotW and the need for greater transparency, completeness and consistency of information on water flows, levels and quality throughout New Zealand, and increased public access to this information.

For convenience, in this report we identify two primary ways in which information from freshwater accounting systems can be applied to meet the core purposes of freshwater accounting: Integrated Freshwater Accounting and Allocation Compliance Accounting.

**Integrated Freshwater Accounting** (IFA) reports quantify all water and contaminant stocks (masses) and flows within and between catchments, including all transfers of water and contaminants across the catchment boundary. IFA reporting aligns with the duty of regional authorities to monitor actual environmental outcomes and compare these to desired outcomes, standards and objectives, as set out in a number of regulations. Regional authorities have a duty to revise policies and plans in light of these comparisons.

The conceptual design of a framework for IFA systems described in this report is based on current approaches used in New Zealand and drawing from international examples.

[1] Clause 3.29, National Policy Statement for Freshwater Management 2020.
[2] Ministry for the Environment. 2015. A Guide to Freshwater Accounting under the National Policy Statement for Freshwater Management 2014. Wellington: Ministry for the Environment.

We draw an important distinction between a framework for presenting information in a standardised format and the methods (measurements and models) used to develop the information to be presented. We suggest that there should be a nationally consistent reporting framework that can be applied with a level of detail that is commensurate to the level of pressure on, and value of, the water resource in any particular part of the country.

Adopting a standardised, scalable structure for freshwater accounts produced under the NPS-FM (2020) will make it easier to compare across catchments and regions, and aggregate across scales to the national level.

The freshwater accounting framework is based on two types of tables: a Stock Account and a Flows Account.

A Stock Account provides a snapshot of water and contaminant mass for a specified point in time for the area for which the accounts are being produced. It is analogous to a balance sheet in financial reporting.

A Flows Account reports changes in water and contaminant mass over a specified time period by itemising the additions and removals of water and contaminant mass to/from the area for which the accounts are being produced. It is analogous to a cash flow statement in financial accounting.

We refer to the area for which freshwater accounts are being produced as an Input-Output Unit (IOU). It is a scalable, specific, real-world hydrological system that has been delineated for freshwater accounting purposes. The most readily identifiable IOU is a catchment. We suggest that a regional authority should create freshwater accounts for any sub-catchment IOU for which a specific environmental limit or water quality standard has been set (e.g., the capture zone for a public water supply bore).

Freshwater accounts can be produced in the recommended format using data from a combination of sources currently available – consent details, measurements, monitoring and modelling. There are several measurement and modelling methods available, some of which have been used to provide the data presented in the stocks and flows accounts in reports such as “Our Freshwater 2020”.

Ideally, we would like to have measurement and monitoring data to support every line-item in the freshwater accounts. However, due to technical and resourcing constraints the available spatial-temporal measured data is not in itself sufficient to complete freshwater accounts. Some forms of modelling are therefore essential to derive the spatial and temporal information required for freshwater accounting from the available measurements. Modelling, particularly complex physically-based modelling, comes with a specific set of challenges around data quality. Such models have inherent uncertainties due to simplifications in their structure, but are also generally processing multiple sources of data from measurements and monitoring, each with their own uncertainty.

The presence of uncertainty should be clearly recognised in both observational and modelled data and reported in any accounting system, and considered when freshwater accounting information is used in policy effectiveness reviews.

**Allocation Compliance Accounting** (ACA) is primarily concerned with assessing and reporting on compliance with allocation limits, which aligns with the duty of regional authorities to monitor compliance with consent conditions and their authority to enforce. Information from ACA reporting is an essential input to IFA and as such contributes to meeting the accounting and reporting requirements as set out in Sections 3:29 and 3:30 of the NPS-FM (2020).

ACA systems for water quantity are in operation in most regions in New Zealand, following the 2015 Guidelines. The transparency, technical robustness, completeness, effectiveness, relevance and adaptability of these systems could be increased by making changes to the design of consents and consents databases. Standardising the definition of specific fields in these databases would simplify automation of ACA and aggregation for analysis and reporting at multiple scales.

The table below summarises our recommendations for improving freshwater accounting to:

- provide higher quality information for a wide range of local, regional and national needs; and
- increase public trust and confidence in the environmental management system through increased transparency, completeness, accuracy and consistency of information.

| Recommendation | Principles to which these recommendations apply |
|---|---|
| **Recommendation 1**: Freshwater quality and quantity accounts should be presented in a standardised framework that is governed at the national level. This will likely require amendment of legislation and other regulatory instruments (primarily the NPS-FM 2020), alongside implementation support to regional authorities, including database and data management upgrades where needed. | Transparent<br>Integrated<br>Integrity |
| **Recommendation 2**: Different data sources (e.g., measurements and models) can be used to derive standard accounts, but these measurements and models should themselves have minimum standards to be fit-for-purpose. | Technically robust<br>Practical |
| **Recommendation 3:** Freshwater accounts under the NPS-FM (2020) should be standardised to include a Stock Account and a Flows Account. | Transparent<br>Integrated<br>Technically robust<br>Effective and relevant |
| **Recommendation 4:** Uncertainty should be quantified and reported for each line item in the Stock and Flows Accounts. The method for calculating uncertainty can vary depending on the line item and the type of data and models available, but clear guidelines should be produced to identify the accepted approaches for uncertainty quantification and reporting in freshwater accounting. | Transparent<br>Technically robust<br>Risk-based |
| **Recommendation 5:** Freshwater accounts must be produced for each FMU. | Transparent<br>Effective and relevant |
| **Recommendation 6:** Freshwater accounts should be produced for any sub-part(s) of an FMU for which specific environmental limits or targets have been defined. | Transparent<br>Effective and relevant<br>Adaptable |
| **Recommendation 7**: For each IOU defined for water quality accounting, water quantity accounts must also be produced. | Integrated |
| **Recommendation 8:** Freshwater accounts should be produced at least annually. The temporal resolution of water quantity accounts should be at least monthly. The temporal resolution of water quality accounts should be at least quarterly. For each, the temporal resolution can vary between different IOUs. | Timely |
| **Recommendation 9:** Freshwater accounts should produce forecasts as well as hindcasts, possibly with monthly or quarterly resolution, and looking forward and backwards in time, up to 12 months from present. | Effective and relevant |
| **Recommendation 10:** Regional authorities should retain the responsibility for operating freshwater accounting systems and producing account statements from them. Regional authorities should not delegate downward the requirement to publish freshwater accounts. | Practical<br>Transparent |
| **Recommendation 11**: Regional authorities should maintain oversight of freshwater accounting databases, with specified | Integrated<br>Practical |

| | |
|---|---|
| fields in consent database records consistently defined across all regional authorities to enable and substantially reduce the time and cost of aggregating data to catchment, regional and national scales and of undertaking robust analyses and reporting. | Transparent |
| **Recommendation 12:** MfE should coordinate the definition of specified fields to achieve the consistency required for robust regional and national-scale analysis and reporting (federation of regionally held databases). | Integrated<br>Practical<br>Transparent<br>Partnership |
| **Recommendation 13:** No change should be made to the statement of what is required for ACA reporting and the overall approach regional authorities are taking to provide the information required. | Practical<br>Transparent<br>Effective and relevant |
| **Recommendation 14:** Explicitly allocate flow-rate to the water body in addition to allocating water for taking. | Partnership<br>Effective and relevant<br>Transparent<br>Adaptable |
| **Recommendation 15:** Define water allocations by dividing the whole of the flow-rate or water level regime into reliability bands (as illustrated in Figure 6) and specifying the proportion of each band that is allocated:<br>(1) to remain in the water body;<br>(2) for meeting human health needs; and<br>(3) for meeting any other socio-economic purpose.<br>This is to ensure consistency with TMotW. | Partnership<br>Effective and relevant<br>Transparent<br>Adaptable |
| **Recommendation 16**: MfE and regional authorities should investigate consent design options that provide the data on diffuse discharges that the accounting system needs when there is more clarity around how the cumulative effects of contaminant discharges will be managed. | Integrated<br>Effective and relevant |
| **Recommendation 17:** The ease with which an ACA can be implemented should be considered by MfE as part of developing a feasible approach to managing diffuse contaminant discharges to waterways. | Practical |
| **Recommendation 18:** Take-and-use consents should be unbundled to create separate Allocation Consents, Water Take Structure Consents and Water Use Consents to simplify their management, increase transparency, and enable robust aggregation, analysis and reporting at catchment, regional and national scales. | Transparent<br>Technically robust<br>Practical<br>Timely<br>Effective and relevant<br>Adaptable |
| **Recommendation 19:** Water flowrates and volumes allocated to individuals should be recorded as time-seriesdatasets. | Adaptable<br>Technically robust<br>Practical<br>Transparent |
| **Recommendation 20:** A “Designated Discharge” consent type should be created to ensure that regional authorities receive all the information needed for automated water take compliance monitoring. | Transparent<br>Practical<br>Technically robust |

| | |
|---|---|
| **Recommendation 21:** Water supply entities should be required to provide, annually, water use profiles and a record of water supplied to each of their clients to enable compliance with reasonable use limits to be tested by the relevant regional authority. | Transparent<br>Practical<br>Technically robust |
| **Recommendation 22:** MfE should oversee the development of a nationally consistent digital water-body network "model" that uniquely labels each river reach and groundwater body, and their links to adjacent river reaches, adjacent groundwater bodies, and land parcels defined by the digital cadastral database, at a level of detail appropriate for catchment-scale application. | Transparent<br>Practical<br>Technically robust |
| **Recommendation 23:** Stream reaches and groundwater bodies should be labelled in a way that makes aggregation of water takes as simple as possible, particularly when aggregating upgradient from the coastline. | Practical |
| **Recommendation 24:** MfE should be given the responsibility for auditing freshwater accounting systems. The purpose of the audit is to test whether accounts have been prepared in accordance with agreed standards. | Transparent |
| **Recommendation 25:** Because different lines in the stock and flow accounts have different evidential bases, initial accounts should be created using the best available data and modelling for each line. | Practical<br>Adaptable |
| **Recommendation 26:** Where uncertainties detract from the integrity of the accounts, future work should prioritise identifying and eliminating critical data gaps and model limitations. | Adaptable |

## Next steps

Current work on reviewing and reforming resource management legislation, and on how to give effect to TMotW, may result in changed expectations of freshwater accounting. We suggest reviewing the recommendations made in this report in light of where relevant current processes and projects land.

IFA is not yet undertaken by regional authorities as a matter of routine. Information on the time and resource required to operationalise IFA is thus lacking. Carefully selected case studies would therefore be very valuable. The information obtained could then be used to help plan a progressive implementation and upskilling programme.

| | |
|---|---|
| **Recommendation 27:** MfE should develop, in partnership with mana whenua and regional authorities, a plan to progressively implement the Freshwater Accounting System (FWAS) at a rate that is consistent with resource management reform priorities and the availability of data, tools, expertise, and funding. | Partnership |
| **Recommendation 28:** Future work should be undertaken to evaluate the interface between the design and operation of FWAS and the wider aspects of TMotW and involvement of tangata whenua in water management in New Zealand. | Partnership |
| **Recommendation 29:** MfE should fund projects to test the feasibility of IFA in selected catchments or sub-catchments. These should be chosen to represent catchments ranging from those with little data through to those with substantial databases and those with low resource use pressure through to those under high pressure (over-allocated). | Partnership<br>Risk based<br>Practical<br>Technically robust |
| **Recommendation 30:** Future work should be undertaken to evaluate the interface between the design and operation of FWAS and any new legislation, especially the reform of New Zealand's resource management system. | Integrated |

# 1 INTRODUCTION

The requirement for regional authorities to operate a freshwater quality and quantity accounting system, for each of its defined freshwater management units (FMUs), has been a component of the National Policy Statement for Freshwater Management (NPS-FM) since 2014.

Freshwater Accounting Systems (FWAS) provide measured and/or modelled data describing the quantity and quality of freshwater systems, and as such play a key role within a broader system of resource management (Figure 1) to provide baseline information required for:

- setting target attribute states, environmental flows and levels, and limits;
- assessing whether a FMU is, or is expected to be, over-allocated; and
- tracking over time the cumulative effects of activities (such as increases in contaminant loads and changes in land use) (clause 3.29 (2) in NPS-FM (2020)).

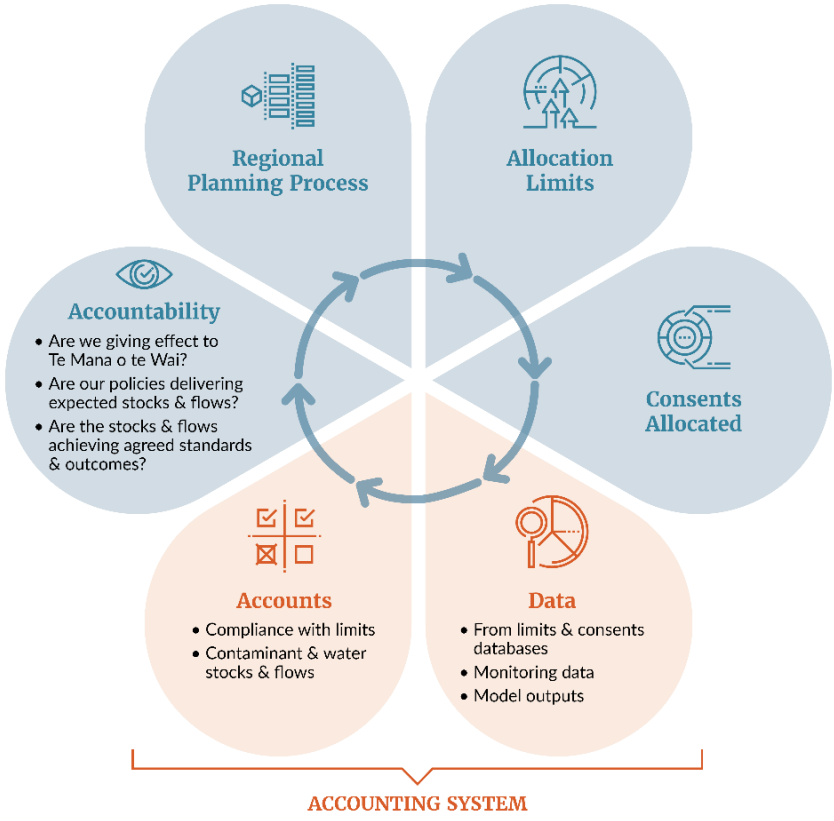


*Figure 1: Freshwater accounting systems sit within a broader system of resource management and accountability.*

The NPS-FM (2020) is specific about the information a FWAS must provide.

For freshwater quality accounting (clause 3.29 (5) in NPS-FM (2020)) the system must (where practicable) record, aggregate and regularly update, for each FMU, information on the measured, modelled, or estimated:

- loads and concentrations of relevant contaminants; and
- where a desired contaminant load has been set as part of a limit on resource use, or identified as necessary to achieve a target attribute state, the proportion of the contaminant load that has been allocated; and
- sources of relevant contaminants; and
- the amount of each contaminant attributable to each source.

For freshwater quantity accounting (clause 3.29 (6) in NPS-FM (2020)), the system must record, aggregate and regularly update, for each FMU, information on the measured, modelled, or estimated:

- the amount of freshwater taken;[3] and
- the proportion of freshwater taken by each major use category; and
- where a take limit has been set, the proportion of the take limit that is allocated.

As part of each review required by section 35(2A) of the Resource Management Act (RMA) every regional council must publish, at least every five years:

- a description of the environmental pressures on each FMU (such as water takes, sources of contaminants, or water body modification) as indicated by information from the freshwater accounting system. (Section 3.29 (2c in NPS-FM (2020))

For convenience, in this report we identify two primary ways in which information from freshwater accounting systems can be applied to meet some, or all, of the above-listed purposes, respectively: Allocation Compliance Accounting and Integrated Freshwater Accounting.

**Allocation Compliance Accounting** (ACA) is primarily concerned with assessing compliance with allocation limits, which aligns with the duty of regional authorities to monitor compliance with consent conditions and their authority to enforce. For example, for FMUs in which a maximum contaminant load or maximum total take has been identified, freshwater accounting by regional authorities can regularly report how much of the maximum load and take has been allocated and how much has been used. Of note is that an ACA system will not provide sufficient information to fully meet the above-listed accounting and reporting requirements as set out in clauses 3:29 and 3:30 of the NPS-FM (2020).

**Integrated Freshwater Accounting** (IFA) encompasses ACA reporting[4] but serves a significantly wider purpose. IFA reports quantify all water and contaminant flows within and between catchments, including all transfers of water and contaminants across the catchment boundary. Hence IFA reports provide:

- The baseline information on water quality and water flows and levels required for setting target states, environmental flows and levels, and limits.
- The baseline information required to assess whether an FMU is, or is likely to be, over-allocated.
- Information required to assess and track over time the cumulative effects of water takes, water uses and contaminant discharges.
- Information on water quality, and water flows and levels, that is fundamental to understanding why progress towards target states and environmental outcomes is being made, or not.

IFA reporting aligns with the duty of regional authorities to monitor actual environmental outcomes and compare these to desired outcomes, standards and objectives, as set out in a number of regulations: the NPS-FM (2020), regional policy statements, regional plans, and district plans, for example. Regional authorities have a duty to revise policies and plans in light of these comparisons. Accordingly,

[3] By “water taken” we mean any activity that changes the instantaneous flow rate. So-called ‘non-consumptive’ water takes can and do have significant effects on the flow regime and thus should be included in the freshwater accounts.
[4] Some of the data in ACA reports are key inputs to IFA

regularly prepared IFA reports, detailed to the level justified by local water quality and quantity issues, will help regional authorities and communities provide timely answers to questions such as:

- Why was river flow so low for so long this year – abstraction or normal climate variability? If abstraction, was it due to surface-water takes or groundwater takes?
- Why were Dissolved Inorganic Nitrogen (DIN) concentrations so much higher this year than last? What might need to change to avoid this happening again?
- Why was mahinga kai[5] so plentiful and such good quality last year? How do we keep this up?
- Are our water and land policies delivering the flow regimes and contaminant concentrations we should expect for a year like last year (considering the weather we experienced)?
- Why did my water supply dry up for a while last summer? How often is this likely to happen in future and what can I do about it?

## 1.1 Purpose of this report

Guidance (Ministry for the Environment 2015) for the design and operation of freshwater quality and quantity accounting systems was published in 2015 ("the 2015 Guidelines"), which regional authorities have implemented using a range of approaches (Rouse et al. 2013).

Subsequent reports have identified the need for greater consistency, completeness and coverage of freshwater datasets, including information from freshwater quality and quantity accounting systems (Ministry for the Environment and StatsNZ 2017, 2019; Parliamentary Commissioner for the Environment 2019; 2020).

This report, and the resulting conclusions and recommendations, has been commissioned by the Ministry for the Environment (MfE) to support potential updates to freshwater accounting systems in New Zealand to more fully meet the requirements of clause 39 of the NPS-FM 2020. Achieving this is key to:

- providing high quality information for a wide range of local, regional and national needs; and
- increasing public trust and confidence in the environmental management system through increased transparency, completeness and consistency of information.

This report focuses on the design, preparation and operation of freshwater quality and quantity accounting systems, as indicated in Figure 1. The re-design of freshwater accounting for New Zealand was required to be future focussed, not limited by what is currently feasible given current legislation, and tools for acquiring data through measurement and modelling. The design needed to be flexible enough to work under the wide range in data availability and quality across New Zealand and, ideally, to accommodate the range of potential outcomes from current Government reviews. Some aspects of the design and recommendations were therefore likely to be aspirational, others pragmatic changes to current practice.

Minimal consideration is given to the role of freshwater accounting systems within the broader resource management system, though we acknowledge this is an important aspect that must be addressed through further work (see section *Next Steps*).

Attention is given to freshwater accounting for contaminant concentrations and loads, and water flows and levels, which are the main types of freshwater accounting presently being undertaken in New Zealand. However, in thinking about the flexibility an accounting system framework will need to accommodate future resource management policy, we have been conscious of the fact that the range of attributes an accounting system reports on may change over time.

[5] Mahinga kai means food and other natural resources, and the areas they are sourced from.

# 2 CONTEXT FOR FRESHWATER ACCOUNTING

The 2015 Guidelines are still very relevant, but there have been several changes in context that indicate a need to revisit the design and operation of New Zealand's freshwater accounting systems (**Table 1**).

## 2.1 Te Mana o te Wai

Te Mana o te Wai (TMotW) is a concept and framework derived from te ao Māori, recognising freshwater as a natural resource whose health is intrinsic to the social, cultural, economic and environmental wellbeing of communities (Ministry for the Environment 2019, 2020). The concept was first introduced into policy in the NPS-FM (2014), with greater direction for its implementation provided in the NPS-FM (2017).

The NPS-FM (2020) advances a more definitive structure to the TMotW framework giving greater clarity on its implementation throughout freshwater management in New Zealand. Fundamentally, the NPS-FM (2020) sets a new hierarchy of obligations in freshwater management that prioritises:

- first, the health and well-being of water bodies and freshwater ecosystems;
- second, the health needs of people (such as drinking water); then
- third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

The TMotW framework as articulated in the NPS-FM (2020) also includes six principles for greater inclusion of tangata whenua and other New Zealanders in the management of freshwater. Of particular note is the principle of *mana whakahaere*, which recognises the power, authority and obligations of tangata whenua to be decision makers in the management of freshwater.

To uphold TMotW, the NPS-FM (2020) also sets clear requirements for regional authorities to:

- set long-term (intergenerational) visions for freshwater that are informed by aspirations of tangata whenua and communities for what the waterbodies should look like in the future, factoring in an understanding of current pressures and the respective water body's history;
- report on progress towards the long-term visions; and
- investigate options for tangata whenua involvement such as joint management agreements, and publicly report on decisions around whether to use these options.

The NPS-FM (2020) also provides a clarified and more integrated definition of ecosystem health as comprised of water quantity, water quality, habitat, aquatic life and ecological processes, which must all be managed holistically.

Giving full effect to the concept and framework of TMotW, as mandated in the NPS-FM (2020), will require wide-ranging research that may lead to expanding the scope of New Zealand's freshwater accounting systems and tools. However, this report limits its scope to understanding the freshwater accounting requirements that arise with the new hierarchy of obligations under TMotW and the holistic assessment of ecosystem health as defined in the NPS-FM (2020).

Wider consideration of the freshwater management requirements arising from the newly defined hierarchy of obligations and six key principles under TMotW, including *mana whakahaere,* requires further targeted research by experts in te ao Māori and mātauranga. Implementation of freshwater management requirements revealed by this research is likely to impact the scope of freshwater accounting systems. It is therefore important that this research is undertaken urgently and, following this, that the recommendations in this report are reviewed and, where necessary, adjusted to align with the wider FWAS (See section *Next Steps*).

## 2.2 Current and potential future legislative reforms

There are legislative reforms underway, notably of the replacement of the Resource Management Act (1991), that may introduce wide-ranging changes to spatial management and the ways resources are managed, governed and allocated (NZ Labour Party 2020; Resource Management Review Panel 2020).

Other potential legislative changes may occur soon, such as in the Environmental Reporting Act (Parliamentary Commission for the Environment 2019), which may alter the purpose of environmental reporting and/or the roles, responsibilities and resourcing of organisations involved.

Freshwater quality and quantity accounting systems must be designed to operate optimally within the current legislative context but also be adaptable to new requirements that may come out of current and potential future legislative reviews (see section *Next Steps*).

## 2.3 Advances in environmental accounting methods

Recent advances in environmental accounting methods are described in **Appendix A**. Of note, the United Nations internationally accepted statistical standard System of Environmental-Economic Accounting (SEEA) and the SEEA-compliant Australian Water Accounting System (AWAS) have demonstrated the practical and real-world application of accounting approaches that are standardised yet flexible and scalable to suit differences in the availability and quality of data for the areas and metrics being reported upon.

There have also been many technological advances in freshwater quality monitoring and modelling since 2014, and further future advances are anticipated, all which make near-real time measurement of water flows, water takes and uses, and contaminant discharges and fluxes more feasible (**Appendix B**). These new techniques may be adopted to different degrees or over different time horizons by different regional authorities. Thus, freshwater accounting systems must evolve and cater for different types of data, data collection methods, accuracy and resolution as these new technological approaches are taken up variably through time across New Zealand.

***Table 1: Changes in context since 2014 that indicate a need to revisit the design and operation of New Zealand's freshwater accounting systems.***

| Change since 2014 | Relevance to freshwater accounting system design |
|---|---|
| Crown-Māori relationships | Evolving across a wide range of Crown-Māori relations, including rights and interests in water, including Waitangi Tribunal findings (WAI 2358). |
| Essential Freshwater reforms 2020 | Under the NPS-FM (2020), accounting systems now need to provide greater support for upholding TMotW, including through a three-tier hierarchy of water use/allocation. |
| | The National Environmental Standards for Freshwater (NES-FW) 2020 introduces requirements for farm plans, improved regulations for reporting of water takes, potential controls on source water protection and wastewater discharges, etc. |
| | Under the Resource Management (Measurement and Reporting of Water Takes) Amendment Regulations 2020, use of telemetry for reporting water use data is now required for all takes >5 l/s. |
| Current and potential future legislative reforms | Reform of the resource management system may introduce wide-ranging potential changes to the way(s) resource(s) are managed, governed and allocated. |
| | Potential reform of the Environmental Reporting Act 2015 (ERA) may alter the purpose of environmental reporting and the roles, responsibilities and resourcing of organisations involved. |

| Change since 2014 | Relevance to freshwater accounting system design |
|---|---|
| Advances in environmental accounting methods | The international System of Environmental-Economic Accounting (SEEA) and the Australian Water Accounting System (AWAS) have made significant advances in accounting design and implementation, which can inform the updates of a NZ freshwater accounting system. |
| | Increasing emphasis on accounting for Greenhouse Gas (GHG) emissions and legislated requirement for targets for reduction; recognition that GHG emissions interface with a wide range of sectors and activities, including water and land use. |
| | Technological advances in sensor design, reduction in costs, improvements in data storage and transfer protocols now make near-real time measurement and modelling of water flows, water takes and uses, and contaminant discharges and fluxes more feasible than in the past. |

# 3 PRINCIPLES FOR FRESHWATER ACCOUTING

The principles in the 2015 Guidelines are still relevant but some warrant updating to reflect changes in context outlined above.

*Table 2: Changes in freshwater account systems Principles due to changes in resource management policy since 2014.*

| Principle and Description from 2015 Guidance | | Updates to 2015 Guidance needed given the context changes since 2014 |
|---|---|---|
| Partnership | • Accounting systems should be developed, and information collected in partnership with stakeholders, Māori and the community. This will help to ensure that the accounts produced are well understood and accepted. It will also help to minimise duplication of resources and ensure that appropriate aggregation is used to protect individual and commercial privacy. | Accounting systems need to be appropriate for use from different cultural perspectives and world views, as well as across agencies, especially to uphold the newly refined aspects and introduced principles for TMotW in the NPS-FM (2020). |
| Effective and relevant | • Accounting systems should be fit for purpose, allowing for multiple uses in regional freshwater management.<br>• Accounting systems should produce meaningful information that is accurate, appropriate to the spatial scale of the issues and useful to the intended end users.<br>• Accounting systems should be cost-effective. | • Needs to provide information that is part of demonstrating the extent to which TMotW is being given effect. |
| Timely | • Accounting systems should allow a regional authority to produce regular accounts in a suitable form for water quantity and water quality for FMUs, where freshwater objectives and limits are being set or reviewed.<br>• Accounting systems should allow regional authorities to collect and analyse information at frequencies | • Accounting systems and compliance may need to operate at many spatial and temporal scales, not just annual reporting for each FMU. It is likely that reporting at a greater temporal resolution may itself require data collected at smaller time steps. For instance, monthly reporting may require daily data. |

| | | |
|---|---|---|
| | that are relevant to the intended management use (e.g., seasonally, to be relevant to ecological systems and variability in flows; daily, if data will be used for operational water take and/or restriction management). | • Accounting systems may have to accommodate dynamic allocation mechanisms, for example, daily irrigation scheduling. |
| Transparent | • The purpose of the accounting system should be clearly stated.<br>• Accounting information should be generated and easily accessible by water users, Māori and the community.<br>• Methods used for accounting should be clearly documented, so that calculations are repeatable. | • Increasing focus on use of limits and targets in resource allocation means that freshwater accounting systems will need greater transparency, auditability, and a means of depicting risk that a limit or target will or will not be met.<br>• Accounting system will become an integral and key part of a wider system for resource management, including governance, and audit, in addition to the accounting itself (Figure 1).<br>• To be comparable, meaningful, and auditable within and across regions and for national reporting, the presentation of accounts should be standardised. |
| Practical | • Accounting systems should allow for regional authorities to collate information from various existing systems or models (e.g., consents databases, monitoring databases).<br>• Accounting systems should be future-proofed, so they remain practical, capable of being replicated, understood, and upgraded over time. | • Automation of accounting systems and compliance reporting aspects is highly likely to be necessary to deliver on Transparency principles. |
| Technically robust | • Accounting systems should use good practice methods based on relevant science.<br>• Accounting systems should allow comparison between years (or reporting periods) and with other FMUs.<br>• Any errors and uncertainties of methods used should be clearly documented.<br>• Quality assurance steps should be documented, | • Mass balance must be displayed in water and contaminant accounts – total inputs must match the sum of the total outputs and the change in stock.<br>• Although accounting systems should be standardised, different data sources (e.g., models) can be used to derive accounts.<br>• These methods should be fit-for-purpose and meet |

| | | |
|---|---|---|
| | and methods for handling any data issues that may come to light outlined. | minimum standards for use.<br>• Model ensembles may be required for interpolation and forecasting. |
| Risk-based | • Accounting systems should allow for accounts to be generated using methods appropriate to the scale and significance of issues in a FMU.<br>• Identification of relevant contaminant sources should be linked to risks faced in a FMU. | • Risk-based assessments need to be depicted as clearly linked to quantitative accounts and a robust technical assessment of accounting uncertainty, especially for forecasts.<br>• Risk and uncertainty need to be tied to a hierarchy of obligations for freshwater management under TMotW. |
| Integrated | • Where appropriate, the system should allow for the consideration and combined reporting of, for example, surface water and groundwater interactions or discharges to different receiving waters, such as estuaries. | • Greater emphasis on IFA reporting for the entire water or contaminant mass, rather than just ACA reporting on the allocatable fraction, to support freshwater management under the hierarchy of obligations for TMotW.<br>• Freshwater accounting should be compatible with other environmental accounting at an appropriate scale. For example, accounts that can link to national Greenhouse Gas accounts. |
| Adaptable | • Accounting systems should accommodate different methods appropriate to the scale and significance of the issues in different FMUs.<br>• The systems should allow for improvements in methods and the accuracy of measurements, estimates and/or modelling results with time. | • Accounting systems need to be future-proofed and recognise that the roles of Māori in the management and governance of natural resources will continue to evolve. |

**Recommendation 1**: Freshwater quality and quantity accounts should be presented in a standardised framework that is governed at the national level. This will likely require amendment of legislation and regulatory instruments (primarily the NPS-FM (2020)) to achieve this, alongside implementation support to regional authorities, including database and data management upgrades where needed.

**Recommendation 2:** Different data sources (e.g., measurements and models) can be used to derive standard accounts, but these measurements and models should themselves have minimum standards to be fit-for-purpose.

# 4 CONCEPTUAL DESIGN FOR FRESHWATER ACCOUNTING

This section provides a high-level overview of the conceptual design of a framework for IFA systems based on current approaches used in New Zealand and international examples drawn from the Australian Water Account Standards (AWAS) (Water Accounting Standards Board 2014) and the water module of the UN SEEA framework (2012).

We draw an important distinction between a framework for presenting information in a standardised format and the methods used to develop the information to be presented.

We suggest that there should be a consistent reporting framework that can be applied with a level of detail that is commensurate to the level of pressure on, and value of, the water resource in any particular part of the country.

We are not suggesting that the same detailed model be applied everywhere in the country to develop the information needed to populate the framework.

The framework puts into practice the key principles described in the previous section to enable a standardised, scalable framework for freshwater accounting in New Zealand. Adopting a standardised, scalable structure for freshwater accounts produced under the NPSFM will make it easier to compare across catchments and regions, and aggregate across scales to national level.

## 4.1 Basic structure of the freshwater accounts

The freshwater accounting framework is based on two types of tables: a Stock Account and a Flows Account. The Stock Account and Flows Account are both required when reporting on freshwater quantity, and when reporting on freshwater quality. A key aspect of this framework is that the line items in the accounting statements remain the same, but allow for differences in the spatial scale, temporal resolution, time interval, etc.

A **Stock Account** provides a snapshot of water mass, for a freshwater quantity account, or contaminant mass, for a freshwater quality account, for a specified point in time and for the area for which the accounts are being produced. The Stock Account is similar to the AWAS Statement of Water Assets and Water Liabilities and is analogous to a balance sheet in financial reporting. At minimum, the Stock Account would include three line-items as shown in Figure 2.

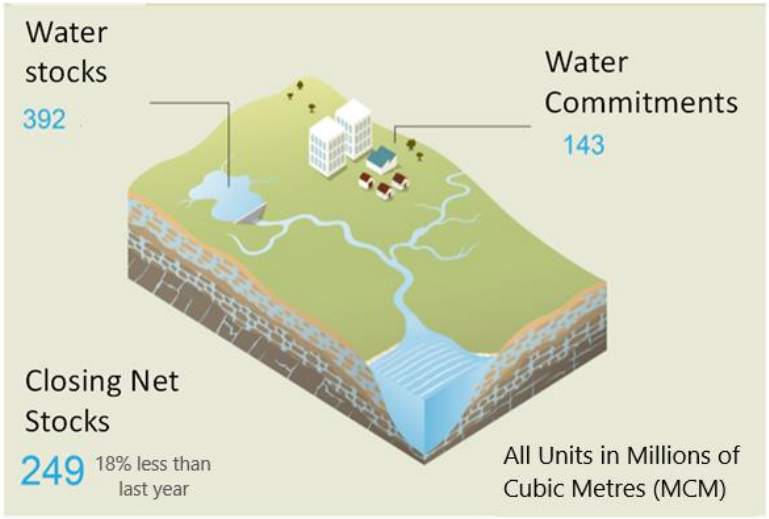


*Figure 2: Example of key line items to be included in a water quantity Stock Account (based on an example from http://www.bom.gov.au/water/nwa).*

*Table 3: Overview of Stocks Account*

| Line-Item | Description |
|---|---|
| Total stocks | Total mass of water or contaminant within the domain of interest. Total stocks should account for the entire known mass of water or contaminant, not just the fraction that has been allocated or may be suitable for abstraction or discharge. |
| Commitments | A commitment is a consented or permitted right to add or remove a mass of water or contaminant to/from a water body in the future. Commitments can be positive or negative.<br><br>For water quantity, a positive commitment could represent a right to transfer water into the waterbody in the future, for example from another catchment. A negative water quantity commitment could represent the right to abstract water in the future.<br><br>For water quality, a positive (increasing) commitment could represent a right to discharge an amount of contaminant into the water body in the future. A negative (decreasing) commitment could indicate a right or agreement to remove an amount of contaminant in the future, for example during environmental remediation.<br><br>The Stock Account would only record the commitments that exist at the start date of the reporting period and are expected to be exercised by the end date of the reporting period. For example, if the reporting period is one year, the Stock Account would only record the future discharges and removals of water and contaminants that are consented or permitted to occur within that water body and within that one year. |
| Net Stocks | Total Stocks minus sum of Commitments. |

A **Flows Account** depicts changes in water or contaminant mass over a specified time period. It itemises the additions and removals of water or contaminant mass to area of interest over a specified time window, including opening and closing Stocks over the same period, and is analogous to a cash flow statement in financial accounting.

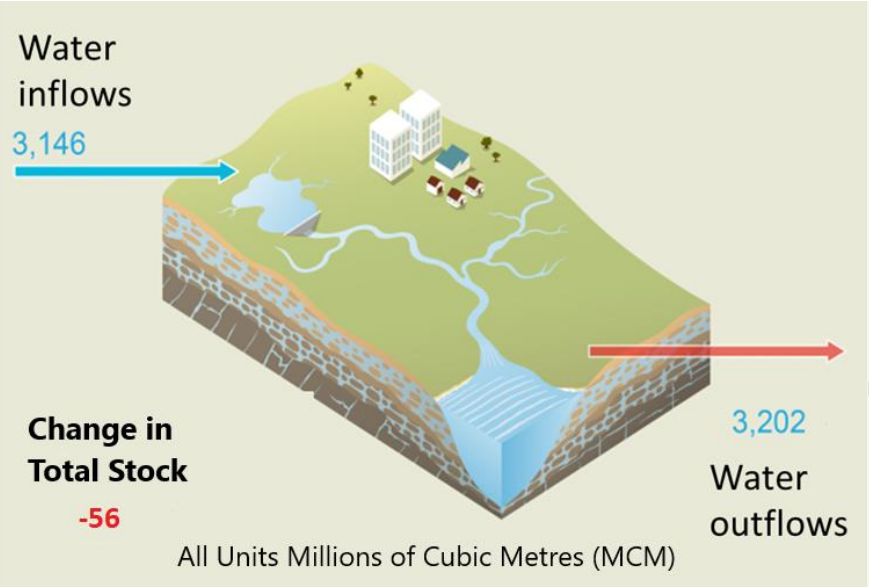


*Figure 3: Example of a water quantity Flows Account (based on an example from http://www.bom.gov.au/water/nwa). Note that individual inflow line items have been aggregated and shown above as total inflows. Similarly outflow line items.*

The Stock Account and the Flows Account for a particular catchment or area could be used, for example, to present information from three scenarios in a standard format: 1) reference state (no water takes, no increase in contaminant loads); 2) with measured and estimated water takes and estimated contaminant loads, and 3) assuming all consented takes and contaminant loads are fully exercised, plus estimated takes and loads from activities not requiring consents.

From these scenarios the regional authority could assess:

- The extent to which changes in water quality, flows and levels may have contributed to a reduction in Te Mana o te Wai (relative to the reference state) and the extent to which these changes were driven by variations in climate (for example) and by within-catchment anthropogenic activity.
- Whether the water bodies would have been “over stressed” if all of the consented allocations had been fully utilised.

*Table 4: Overview of Flows Account*

| Line Item | Description |
|---|---|
| Opening Total Stocks | Total mass of water or contaminant within the domain of interest at the start of the reporting period. |
| Inflows | Itemised inflows of water or contaminant into the domain of interest over the duration of the reporting period. For water quantity accounting, this would include typical water budget terms such as precipitation, inter-basin inward transfers, return flows following water use, etc. For contaminant accounting, the listed inflows could include anthropogenic discharges into waterways as well as additions through natural processes such as atmospheric deposition, geochemical weathering, etc. If accounts are being prepared for a domain that represents just part of an FMU (e.g. just an aquifer), then the listed water and contaminant inflows would also include inward transfers from other parts of the FMU (e.g. from surface water). |
| Outflows | Itemised outflows of water or contaminant from the domain of interest over the duration of the reporting period. For water quantity accounting, this would include typical water budget items such as evapotranspiration, water abstractions and inter-basin outward transfers, etc. For contaminant accounting, listed outflows would include natural processes such as contaminant transformations (e.g. denitrification) and export or transport into neighbouring FMUs, along with anthropogenic processes such as removal during environmental restoration. |
| Change in Total Stocks | Opening Total Stocks plus Inflows minus Outflows. This is equivalent to the change in actual storage of water or contaminant mass within the domain of interest over the reporting period. |
| Closing Total Stocks | Total mass of water or contaminant within the domain of interest at the end of the reporting period, which is equivalent to Opening Total Stocks minus Change in Total Stocks over the reporting period. |
| Commitment Changes | Changes in consented or permitted rights to add or remove water or contaminant over the reporting period. These could be positive or negative and would be itemised separately. Decreases in commitments may arise from a consent-holder notifying forfeiture of some of their allocation to take water or discharge contaminants, or from the regulator applying restrictions that deliver the same result. Increases in commitments may arise from easing of restrictions or issuing of more consents to take water or discharge contaminants. |
| Change in net stocks | Change in stocks plus/minus change in commitments over the reporting period. |

### 4.1.1 Uncertainty in Accounts

All data used to compile freshwater accounts will be uncertain, whether obtained by measurement or modelling. The degree of uncertainty will most likely vary between line items in the accounts.

The NPS-FM (2020) requires that decisions be based on the best information available at the time, with preference given to information that provides the greatest level of certainty. Furthermore, uncertain information must be interpreted and used in the way that will give best effect to the NPS-FM 2020 (Clause 1.6).

To comply with the NPS-FM (2020), the uncertainty associated with each line item of a set of freshwater accounts must be stated. Expressing the degree of uncertainty in quantitative terms alongside the line-item value it relates to should be very influential in determining how best to give effect to the NPS-FM (2020). For example, a very high degree of uncertainty in a line-item value that is a very small proportion of a flows account may be unimportant compared to the significance of a small degree of uncertainty in a line item that is a large proportion of a flows account.

Quantification of uncertainty in each reported line item in each Stock Account and each Flows Account is essential.

The uncertainties reported within the line items in the Stock and Flows Accounts can be used to quantify how close or far the system is from being overallocated or exceeding a defined environmental limit. The approach for calculating uncertainty will depend on the line item to which it applies, and the number and type of data and/or models available for its measurement. It may be acceptable and appropriate to base the accounting on sparse, limited datasets or models with relatively large uncertainties if the catchment isn't under significant resource pressure, i.e. is far from being overallocated. In contrast, more robust datasets and models that allow for tighter quantification of uncertainty may be necessary for catchments that are under significant pressure and/or close to their allocation limits.

**Recommendation 3:** Freshwater accounts should be standardised to include a Stock Account and a Flows Account.

**Recommendation 4:** Uncertainty should be quantified and reported for each line item in the Stock and Flows Accounts. The method for calculating uncertainty can vary depending on the line item and the type of data and models available, but clear guidelines should be produced to identify the accepted approaches for uncertainty quantification and reporting in freshwater accounting.

## 4.2 Spatial scale for freshwater accounting

We define the term **Input-Output Unit** (IOU) as a scalable, specific, real-world hydrological system that has been delineated for freshwater accounting purposes, i.e., containing at least one of the following: lake, wetland, groundwater, river/stream, estuary, constructed water infrastructure.

At the coarsest scale, an IOU would equate to an entire FMU. This is because the NPS-FM (2020) requires regional authorities to operate freshwater accounting systems for each of their defined FMUs. This requirement was first introduced in the NPS-FM (2014).

At finer scales, we suggest that a regional authority should create freshwater quality or quantity accounts for any sub-catchment or sub-part of an FMU for which a specific environmental limit or target has been set. For example, a regional authority might have different limits for allocation of groundwater vs. surface water within a single FMU, and so different IOUs with separate accounting statements should be produced for each (Figure 4). An IOU might also be developed for the catchment of a specific spring, river reach, lake, etc. or wherever water quality or quantity limits exist. Accounting at these 'sub-FMU' scales would be used to demonstrate that water quantity/quality has been 'maintained or improved' relative to relevant set limits and targets, as required by the NPS-FM.

Wherever there is an IOU that has been defined for freshwater quality accounting, then corresponding freshwater quantity accounts should also be produced for that IOU. This is because water quality measurements can be reported in units of mass, concentration and/or load, and conversion between these units requires information on water mass and fluxes for the same location and time interval.

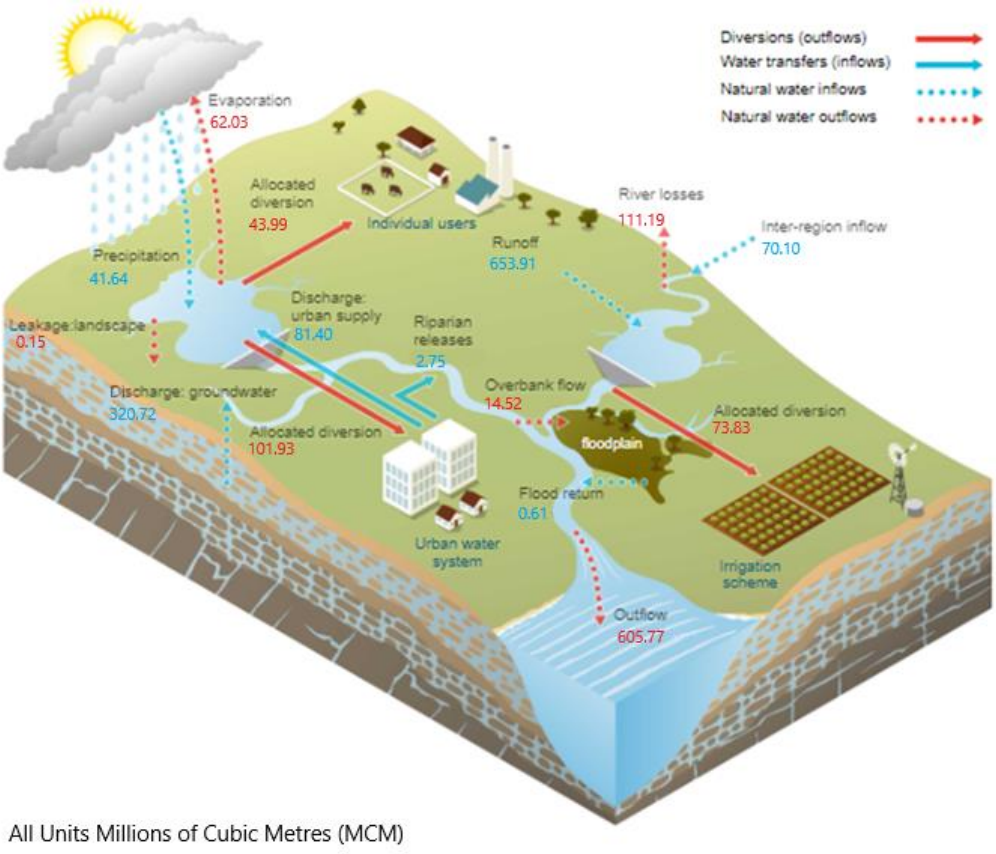


*Figure 4: Example of Flows Account showing individual inflow and outflow line items (based on an example from http://www.bom.gov.au/water/nwa).*

**Recommendation 5**: Freshwater accounts must be produced for each FMU.

**Recommendation 6**: Freshwater accounts should be produced for any sub-part(s) of an FMU for which specific environmental limits or targets have been defined.

**Recommendation 7:** For each IOU defined for water quality accounting, water quantity accounts must also be produced.

## 4.3 Time interval and temporal resolution for freshwater accounting

At minimum, freshwater accounts should be produced annually and cover the period of one hydrological year. This time interval corresponds with the frequency at which regional authorities must report (Clause 3.30 (1) in NPS-FM (2020)) and corresponds with normal freshwater accounting practices overseas such as the AWAS.

We note that it may be necessary to publish (i.e., produce) freshwater accounts at greater than annual frequency for some IOUs, for example if a particular catchment experiences seasonal or sub-seasonal risks of over-allocation. Generating frequent or even near-real-time updates for freshwater accounting is not presently possible with sufficient resolution and accuracy for all parts of New Zealand. However, significant advances are being made for telemetered data collection, automated quality control checking, and rapid assimilation into models, all of which can support the more frequent generation of

freshwater accounting information in the future. We note that even where near-real-time updating of freshwater accounting information is possible, it is likely that the reporting period would continue to cover one hydrological year.

The temporal resolution of the accounting is different from the reporting interval or period of time covered by the accounts. For example, accounts covering one hydrological year might be produced annually, but the information contained within the accounts might have a seasonal, monthly or even weekly temporal resolution.

Freshwater accounting as recommended in this report will likely require a finer temporal resolution than employed in other countries. Overseas, it is common for freshwater accounts to have a yearly temporal resolution, corresponding the same interval at which the accounts are updated. However, New Zealand has smaller and steeper catchments with less storage, and higher average precipitation and contaminant leaching rates than many overseas countries that have implemented standardised freshwater accounting systems. Thus, on average, the fluxes of water and nitrogen (an exemplar contaminant) are higher and catchment residence times are shorter in New Zealand compared to overseas, indicating a need for relatively high temporal resolution (McDowell et al. 2021).

Thus, we recommend that the temporal resolution of the accounts, at least initially, should coincide with common data collection intervals in New Zealand, which are typically at least monthly for water flows and at least quarterly for water quality. As noted above, with automated data collection, telemetry and modelling becoming more common, in the future it will likely be possible to have finer temporal resolution in the accounting statements in the future, corresponding with a suitable frequency for their updates as may be possible with near real-time measurements and modelling.

Note however that the temporal resolution required for freshwater quantity accounting may differ to that required for freshwater quality accounting, and in either case should be selected based on the temporal resolution of appropriate data and models, and to suit the degree of pressure the resource is under and thus the risks it faces. The temporal resolution of freshwater quality accounts also needs to suit the effects basis of whatever contaminants are being reported upon, in order to ensure that any key processes that affect the fate or transport of the contaminant are sufficiently temporally resolved.

The temporal resolution can vary between different IOUs, reflecting difference in pressure and risk.

**Forecasting**, as well as reporting in arears (**hindcasting**), should be included in freshwater accounting under the NPS-FM (2020) (**Figure 5**). This is because one purpose of freshwater accounting is to assess whether a FMU (or IOU) is, *or is expected to be*, overallocated. Assessing possible future overallocation therefore necessitates forecasting, with the uncertainties reported in the accounting statements used to evaluate the likelihood of overallocation. Furthermore, forecasting the cumulative effects of activities will aid in the management of some activities not immediately observable in some IOUs because of lag times.

Ideally, forecasts will cover twelve months looking forward from the date the forecast is made. A twelve-month forecast incorporates four full seasons (i.e. spring, summer, autumn, winter) and therefore takes account of seasonal changes that may influence water or contaminant stocks and flows, such as periods of high or low rainfall, high or low water use, or high or low contaminant discharges that are important for sustainable allocation and management. We acknowledge that, at present, inclusion of twelve-month forecasts in freshwater accounting is an aspirational target.

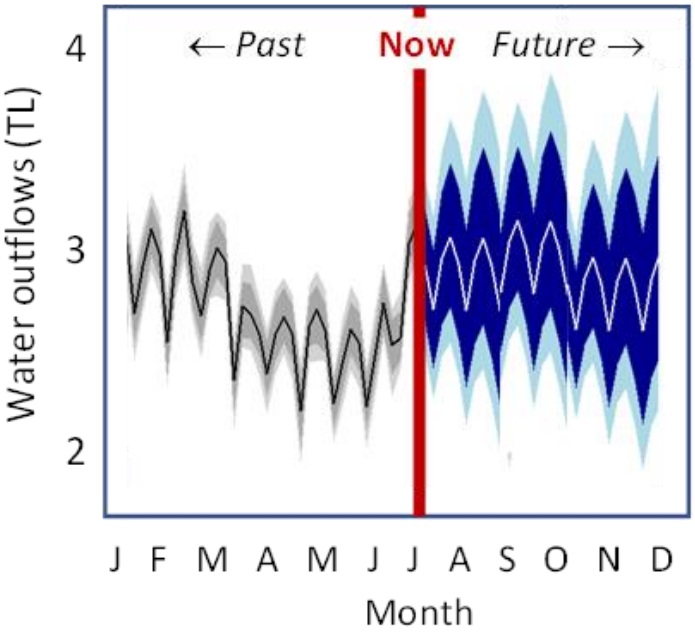


*Figure 5: Illustration of how forecasting, with associated uncertainties could be incorporated into a freshwater quantity accounts.*

**Recommendation 8**: Freshwater accounts should be produced at least annually. The temporal resolution of water quantity accounts should be at least monthly. The temporal resolutions of water quality accounts should be at least quarterly. For each, the temporal resolution can vary between different IOUs.

**Recommendation 9**: Freshwater accounts should produce forecasts as well as hindcasts, possibly with monthly or quarterly resolution, and looking forward and backwards in time, up to 12 months from present.

## 4.4 Responsibility for producing freshwater accounting statements

Responsibility for operation of freshwater accounting systems is assigned to regional authorities under the NPS-FM (2020). This responsibility has been in place and assigned to regional authorities in previous versions of the NPS-FM.

**Recommendation 10:** Regional authorities should retain the responsibility for operating freshwater accounting systems and producing account statements from them. Regional authorities should not delegate downward the requirement to publish freshwater accounts.

# 5 IMPLEMENTATION OF FRESHWATER ACCOUNTING

How allocation limits are defined or specified in regional plans lays the foundations for a freshwater accounting system, whether it is allocation of contaminant discharge load as a mass or as a risk, or allocation of water flowrate or volume (level).

A specific individual's share of the maximum allocatable amount (contaminant mass or loss-rate, water volume or flow-rate) is specified in consents granted to them or authorised through a Plan rule.

The design of the system of consents required to manage the use of water and land within set limits is key to meeting a number of the Principles listed in Section 3.

Regional variation in the availability of data and models, and the design of databases, particularly the specifications for records in consents databases, mean that aggregation of data within, across and between regions is a high-cost, manual process. Lack of consistency also increases uncertainties derived from aggregated data, whether aggregated to regional scale or national scale.

This section outlines recommended changes to the way allocation limits are specified in regional plans and to the design of consents and the associated databases, with the aim of reducing the cost of FWA implementation and increasing the utility, completeness, accuracy, and consistency of FWA outputs across spatial scales.

## 5.1 Federated databases

The wide variation between catchments and regions and the importance of maintaining local knowledge of people and place justifies continuation of the current practice of regional authorities building, operating and maintaining the core datasets required for freshwater accounting.

To enable automated aggregation of data and reduce uncertainty in indices derived from aggregated data it is necessary to adopt and implement standardised definitions for selected fields in consent database records (i.e., adopt a national standard). Not all fields need be standardised – standardisation of all fields would unduly limit a council's ability to tailor consents databases to meet regional needs.

If national standards for critical elements of consents databases are adopted, the most efficient way of implementing them may be for MfE to obtain a copy of all existing water take and use consents and translate them from their current design to the agreed format on a like-for-like basis. A process for doing the translation should be developed alongside the development of the national standard. It is expected that the translation process would involve review and sign-off by consent holders.

**Recommendation 11:** Regional authorities should maintain oversight of freshwater accounting databases, with specified fields in consent database records consistently defined across all regional authorities to enable and substantially reduce the time and cost of aggregating data to catchment, regional and national scales and of undertaking robust analyses and reporting.

**Recommendation 12:** MfE should coordinate the definition of specified fields to achieve the consistency required for robust regional and national-scale analysis and reporting (federation of regionally held databases).

## 5.2 Implementing ACA

Basic ACA reporting for water quantity is implemented by linking three databases – a consents database, a water-meter time-series database and a time-series database of water flow-rates and levels. This enables regional authorities to test for compliance by comparing:

- The total flowrate allocated for taking from a water body with the total allocatable flow-rate (the allocation limit) for that water body.
- The sum of the water meter data from all take structures on a water body that are operated by an individual to the flowrate allocated to that individual for taking from that water body.
- The total flow volume supplied to a property, net of changes in the volume of water stored in reservoirs on the property, with the reasonable use limit for that property.

This approach to compliance monitoring is still fit for purpose.

**Recommendation 13:** No change should be made to the statement of what is required for ACA reporting and the overall approach regional authorities are taking to provide the information required.

## 5.3 Defining allocation limits

How we define what is being allocated lays the foundations for a freshwater accounting system, whether it is allocation of contaminant discharge load as a mass or as a risk, or allocation of water flow-rate or volume (level). How consents are designed and recorded has a major impact on whether the Principles listed in Section 3 and met.

### 5.3.1 Limits on the alteration of water flows/levels

Building on current practice, and in accord with the hierarchy of obligations under TMotW (see Section 2), flowrates should be allocated across the whole flow regime, not just the part intended for abstraction. This holistic approach to allocation allows explicit reporting of the amount of water allocated to remain in the river, for the river, across the whole flow regime.

A practical way to do this is to divide the flow-duration curve into reliability bands and specify the proportion of each band that is allocated to:

1. Stay in the river or aquifer,
2. Be available for taking to meet human health needs,
3. Be available for taking or using in some other way to meet socio-economic needs (Figure 6, next page).

This method for specifying allocations is a simple way to give practical effect to TMotW's hierarchy of obligations and lays the foundations for broadening the scope of freshwater accounting to include reporting on the health of the freshwater system.

Under current practice water is specifically allocated for abstraction only. While, by implication, water not allocated for abstraction is there for the water body, the focus of allocation has been on abstraction. TMotW requires a broader view and the allocation approach above provides a mechanism for this.

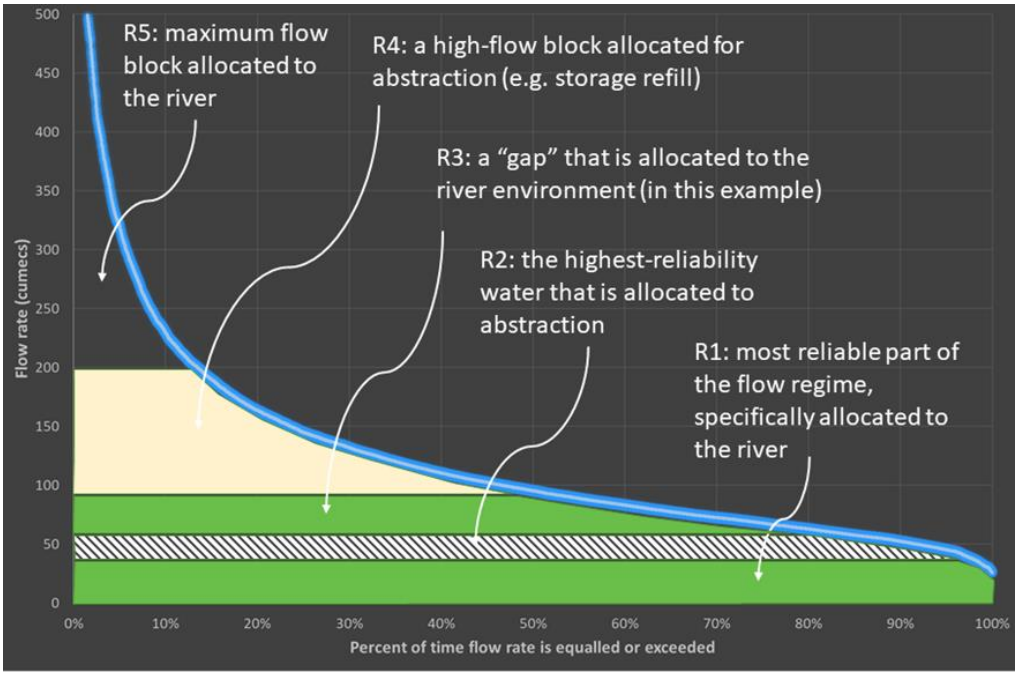


*Figure 6: An example showing the division of the whole of a river's flow regime into reliability bands.*

**Recommendation 14:** Explicitly allocate flowrate to the water body in addition to allocating water for taking.

**Recommendation 15:** Define water allocations by dividing the whole of the flowrate or water level regime into reliability bands (as illustrated in Figure 6) and specifying the proportion of each band that is allocated:

1. to remain in the water body;
2. for meeting human health needs; and
3. for meeting any other socio-economic purpose.

### 5.3.2 Contaminant discharge limits - for contaminants for which it is practical to set limits.

In relation to diffuse discharges from land-use there are three primary 'control items' – outputs (contaminant discharge to waterways), stocks (mass of contaminant stored in a part of the hydrologic system such as soil), and contaminant inputs. The ease with which each can be measured, modelled or deemed varies and this significantly affects the design and implementation of an ACA system.

We expect that regardless of which of the 'control items' are used to manage diffuse discharges from land-use the approach to ACA reporting for contaminants will mirror that for water quantity.

However, we acknowledge that because of the Overseer™ review (Science Advisory Panel 2021) and Government's response (MfE and MPI (2021)) to it, there is uncertainty about how New Zealand will approach managing diffuse discharge of contaminants to achieve specified water quality standards, and how such discharges will be quantified for management purposes (measurement, modelling or deemed values / lookup tables).

**Recommendation 16**: MfE and regional authorities should investigate consent design options that provide the data on diffuse discharges that the accounting system needs when there is more clarity around how the cumulative effects of contaminant discharges will be managed.

**Recommendation 17**: The ease with which an ACA can be implemented should be considered by MfE as part of developing a feasible approach to managing diffuse contaminant discharges to waterways.

## 5.4 Design of consents and consent databases

The design of resource consents and resource consent databases is critical to being able to obtain the data needed for robust, routine freshwater accounting at multiple scales.

Current designs of consents relating to water quantity have generally served us well during the period of perceived unlimited water availability. As the cumulative effects on a water body of water takes have increased, consent conditions have been put in place to control these effects. The often ad hoc nature of these consent conditions is generating cases which are problematic to manage, from an accounting and accountability (compliance monitoring) perspective.

Current water take consent design is generally based on the assumption that water allocation (to each consented water take) is static. In practice water allocations to individuals are dynamic – they change over time for a variety of reasons (**Table 5**). Unless a record is kept of each individual's actual allocation, as it varies throughout the year, it is not possible to check whether a water take is compliant.

*Table 5: Selected examples of how actual allocations change during the year, drawn from recent resource consenting and compliance accounting experience*

| Case | Description |
|---|---|
| 1 | A consent condition specifies that the maximum rate at which water may be taken is tied to a river flowrate or groundwater level monitoring station. If the flowrate is less than a specified cease-take flowrate the maximum rate of water take is zero. If the flow is greater than the cease-take flowrate plus the allocation limit then water may be taken at the maximum consented flowrate – the actual allocation equals the maximum consented flow rate. Between these bounds the actual allocation is pro-rata reduced.<br><br>In this example it is not difficult for the actual allocation to be calculated "after the event" or "on-the-fly" provided the monitoring station flowrate or groundwater level data is stored in a time-series database (which it almost always is), thus avoiding the need to store actual allocation for each consented water take. This is current practice. |
| 2 | A water user group arranges short-term transfer of water allocations between consent holders. It's not unusual for restrictions on water takes (i.e. reducing actual allocations) determined as in case 1 to be impractical to work with. Irrigation systems, for example, are designed to operate efficiently at a particular flow rate. To overcome this water-user groups are used by some regional authorities as a means of reducing the total take from a river to achieve the restriction required by rostering the flow available for taking. For example, even though each person is entitled to take water under a reduced actual allocation, one person's actual allocation is transferred in whole or in part to another's for one day and vice versa the following day so that each can operate their irrigation system at its design flow-rate when their turn comes. In this case each person's actual allocation varies from day-to-day (e.g. oscillates between zero allocation and full allocation) while river flows remain low enough to require water takes to be restricted. |
| 3 | Designated discharges. In this case person A has a consent that allows them to discharge water into a river upstream of the council's river flow monitoring site. Person B has a consent to take water, subject to a condition that restricts their actual allocation based on river flow at the monitoring site. The Council's regional plan allows Person B to take water discharged by Person A even when the river flow is less than the cease-take-flow providing Person A is discharging water from |

| Case | Description |
|---|---|
| | storage for Person B. Person's A and B have a side-contract that formally sets out when a discharge designated for taking by Person B can occur. Compliance accounting will show that Person B is taking water at a higher rate than allowed unless the Council has a record of when the designated discharges occurred and what the flowrate was. |
| 4 | The rate at which water is taken via each of several take structures (wells or river intakes) that are taking water from the same aquifer or river changes without changing the total allocation. In other words, the proportion of the total allocation that is taken via each take structure changes over time. This arises when, for example, the pump in one well fails and needs to be replaced. Often there is capacity in the other pumped wells to make up a significant part of the difference. But to use this capacity without creating non-compliance, some or all of the dysfunctional well's allocation needs to be transferred to the functional well(s). It also arises when there is slow deterioration in take structure performance, eventually reaching the point where the full allocation can no longer be taken. Usually an extra intake structure is added to augment the original one(s). If each structure has an allocation then some of the original total allocation needs to be transferred to the new structure and periodically adjusted as the performance of each individual structure changes. At present this case is usually handled by varying the relevant consents to take water. In most cases this is a time consuming manual process. Until it is complete, compliance accounting will show periods of non-compliance. |
| 5 | Peer-to-peer short term transfer of allocation. This is a generalised version of case 2 above – generalised in the sense that the circumstances under which short term transfers are sensible and practical extend well beyond the water user group case. |

Key points to be taken from these examples are:

- The actual allocation from a water body to a person or entity is best recorded as a time-series dataset. Recording it as such using existing database tools for storing time-series data would enable automated, frequent compliance accounting and make provision for a wide range of allocation/re-allocation methods.
- It is often necessary for a person to use multiple water take structures to take their full allocation from a water body. This is particularly so for groundwater takes. The number and location of the intake structures used to take an allocation can change, often at short notice and temporarily.
- Short term peer-to-peer transfer of allocations do occur and are likely to need to occur more often in response to more frequent short-term reductions in allocations or in order to derive greater value from water taken.

ACA reporting that does not generate false-positive and false-negative results and is future-proofed with regard to allocation/re-allocation methods needs to be based on consent designs and associated databases that are able to handle these cases, in addition to those successfully handled by current consent designs and database systems.

However, at present it appears that changes in actual allocation in all but the first case in **Table 3** are recorded manually, which necessitates manual compliance accounting and thus limits the frequency with which this occurs, and its integrity if information is lost.

To simplify the management of consents and the implementation of freshwater accounting, we recommend changes be made to the design of consents which, in turn, would require changes to the structure and contents of consents databases.

## 5.5 Unbundling consents

The main suggested change from the consent design and database structures in use in 2013 is the unbundling of consents to "take and use water" into an Allocation Consent, a Water Take Structure Consent and a Water Use Consent, each of which serves a different purpose as summarised below and illustrated in more detail in **Appendix C**.

- The primary purpose of the **Allocation Consent** is to manage the cumulative effects of all water taken from a water body and provide fair access to the water made available for taking. The scope of the conditions in an allocation consent is limited to these matters. Allocations to individuals should be recorded as time-series, with a time-step of between 1 day and 1 year.
- The primary purpose of the **Water Take Structure Consent** is to manage the localised (near-field) effects on the water source and other water takes of the operation of an intake structure, and to apply conditions such as requiring water metering on all takes and fish screens on river intakes. The scope of the conditions in the take structure consent is limited to these site-specific matters. Changes to these site-specific consents are not likely to be required very often and can be achieved through existing consent variation processes.
- The primary purposes of the **Water Use Consent** are to manage the effects of using water, such as increasing drainage, and to apply the 'reasonable and efficient use' requirement of the RMA. The scope of the conditions in the water use consent is limited to these matters. Changes to these property-specific consents are not likely to be required very often and can be achieved through existing consent variation processes.

Consideration should be given to separately consenting contaminant discharge allocation, point source contaminant discharges and land use (diffuse discharges).

To address the situation of Case 3 in **Table 3**, a **Designated Discharge consent** should be created with a condition that requires the council to be informed of the flowrate of a discharge to a natural waterway that is designated for taking by a specific person downstream, each day that the discharge occurs. This is to fill a gap in the current consents design that results in false positives (non-compliance events).

To enable regional authorities to monitor compliance with reasonable water use limits (where these are set), a condition should be added to a water supply infrastructure owner's consent to take water that requires them to submit water delivery data to the council by 30 June each year to fill a gap in council's data on the total amount of water supplied to a property each hydrological year. This requirement would only apply to water deliveries that would, if they were a stand-alone consented water take, be required to be metered under the Measuring and Reporting of Water Takes Regulations.

**Recommendation 18:** Take-and-use consents should be unbundled to create separate Allocation Consents, Water Take Structure Consents and Water Use Consents to simplify their management, increase transparency, and enable robust aggregation, analysis and reporting at catchment, regional and national scales.

**Recommendation 19:** Water flowrates and volumes allocated to individuals should be recorded as time-series datasets.

**Recommendation 20:** Create a "Designated Discharge" consent type to ensure that regional authorities receive all the information needed for automated water take compliance monitoring.

**Recommendation 21:** Water supply entities should be required to provide annually a record of water supplied to each of their clients to enable compliance with reasonable use limits to be tested.

## 5.6 Spatial referencing of consents

The cumulative effects of all water inputs (precipitation, transfers, etc.), takes, discharges and contaminant discharges (point and diffuse) are calculated by applying a conservation of mass model of water flows and contaminant transport to a digital representation of flow paths and storages in an IOU.

At present the location of a consented activity that affects water quality, flows or levels is specified in a consent by map grid reference and/or an area identified on a map. To estimate the cumulative effects of water takes it is generally necessary to assume that the stream reach first affected by a water take is the reach closest to the grid coordinates of the take structure or, in the case of a groundwater take, the stream reaches within a specified radius of the take. This assumption is incorrect for many groundwater takes. The stream-depletion effects of groundwater takes can be some distance downstream of the reaches closest to the bore.

To enable automation of water and contaminant accounting at multiple scales and to improve robustness and accuracy, a significant change to current methods for specifying location is necessary. The more robust way of enabling aggregation of water takes to assess cumulative effects is to include in the Water Take Structure consent the name (a unique identity) of the most upstream reach affected by a water take. “Take structure” includes tube wells for taking groundwater.

In order to efficiently aggregate contaminant discharges, particularly diffuse discharges, to subcatchment and catchment scale it is essential to have a robust digital description of the area from which contaminants are discharged and the water body which first receives the contaminant.

A robust way of specifying the area from which contaminants are discharged by a land-use activity is to list the relevant land parcels and their unique identity, as specified in the New Zealand Digital Cadastral Database.

To uniquely identify the river/stream reach that first receives a contaminant discharge one would use the unique stream identifier. To uniquely identify the groundwater body that first receives a contaminant discharge we need a groundwater body identification schema equivalent to a digital river network schema. It’s important to note that the scope of this is to identify all groundwater bodies, not just aquifers.

In order to route flow and the effects of water takes and contaminant discharges through a catchment for the purposes of compiling stocks and flows accounts, for example, we need to know the connections between stream reaches, between groundwater bodies and pathways between stream reaches and groundwater bodies.

This labelling schema is key to enabling automated freshwater accounting, especially IFA reporting.

**Recommendation 22:** MfE oversee the development of a nationally consistent digital water-body network “model” that uniquely labels each river reach and groundwater body, and their links to adjacent river reaches, adjacent groundwater bodies, and land parcels defined by the digital cadastral database, at a level of detail appropriate for catchment-scale application.

**Recommendation 23:** Stream reaches and groundwater bodies should be labelled in a way that makes aggregation of water takes as simple as possible, particularly when aggregating upgradient from the coastline.

If “Reach 0” for every river/stream was the terminal reach, for example the reach that discharges into the sea, it would be much easier to identify sea-draining catchments than it is at present from the REC database.

## 5.7 Audit of freshwater accounts and accounting systems.

The purpose of the audit process is to test whether accounts have been prepared in accordance with accepted standards and that they are fit for purpose.

The Ministry for the Environment has responsibility for preparing national-scale state of the environment reports. Outputs of a freshwater accounting system should be key data sources for this reporting. Working with the data is an ideal way to identify issues. It seems sensible that MfE be given responsibility for auditing freshwater accounting systems.

**Recommendation 24:** MfE should be given the responsibility for auditing freshwater accounting systems. The purpose of the audit is to test whether accounts have been prepared in accordance with agreed standards.

# 6 AVAILABILITY OF DATA AND MODELS FOR FRESHWATER ACCOUNTING

Freshwater accounts can be produced in the format recommended above using data from a combination of sources currently available – measurements, monitoring and modelling. There are several measurement and modelling methods available (see **Appendix B**), some of which have been used to provide the data presented in the stocks and flows accounts in reports such as "Our Freshwater 2020" (Ministry for the Environment and StatsNZ 2020).

Ideally, we would like to have measurement and monitoring data to support every line-item in the freshwater accounts. However, due to resource constraints, limitations in available measurement techniques, issues in the differing spatial scales (point, plot, census district, catchment, etc) that various data relate to, and our very limited ability to "measure" subsurface stocks and flows, the available spatial-temporal measured data is not in itself sufficient to complete IFA. The availability of monitoring data for the water flows element of ACA is steadily increasing due to the water metering regulations but data for permitted activity water uses currently must be estimated (modelled). Compliance monitoring for diffuse contaminant discharges currently is heavily reliant on modelling.

Some forms of modelling are therefore essential to derive the spatial and temporal information required for freshwater accounting from the available measurements. In addition, although one key purpose of the accounts is to track "progress to date" to identify trends, changes, and compliance issues, there is also an important role for the accounts to support analysis of different scenarios. Modelling is a necessary part of this. Scenario analyses could assume that future climate will mimic the past, in terms of variability, or projected future climate. As we cannot measure those potential futures until we meet one, far less measured data is available for populating the accounts and additional modelling techniques are thus required to produce projected-future freshwater accounts.

A description of methods available for obtaining data for freshwater accounting through measurement, monitoring and modelling is presented in **Appendix B**. Methods specific to each element of the Water Stock, Water Flows, Contaminant Stock and Contaminant Flows accounts that make up a Freshwater Accounting System are provided. Those included are only a subset of those available. They are presented to demonstrate that practical methods are now available for obtaining the data required. The availability of data, time and skills in a region may dictate that methods other than those listed in **Appendix B** be used. **Tables 6** and **7** below provide an assessment of the availability of methods for obtaining data by measurement and modelling and the likely quality of these data.

Modelling, particularly complex physically-based modelling, comes with a specific set of challenges around data quality. Such models have inherent uncertainties due to simplifications in their structure but are also generally processing multiple sources of data from measurements and monitoring, each with their own uncertainty.

*Table 6: The authors' assessment of the availability of methods for obtaining data for Stock Accounts*

| | | Quantity Data | Quantity Models | Contaminant Data | Contaminant Models |
|---|---|---|---|---|---|
| Inflows | Precipitation /atmospheric deposition | | | | |
| | via rivers | | | | |
| | via groundwater | | | | |
| | via transfers | | | | |
| Outflows | Evapotranspiration /volatilisation | | | | |
| | via rivers | | | | |
| | via groundwater | | | | |
| | via transfers | | | | |

*Table 7: The authors' assessment of the availability of methods for obtaining data for Flows Accounts*

| | | Quantity Data | Quantity Models | Contaminant Data | Contaminant Models |
|---|---|---|---|---|---|
| Inflows | Precipitation /atmospheric deposition | | | | |
| | via rivers | | | | |
| | via groundwater | | | | |
| | via transfers | | | | |
| Outflows | Evapotranspiration /volatilisation | | | | |
| | via rivers | | | | |
| | via groundwater | | | | |
| | via transfers | | | | |

*Table 8: Key for Tables 6 and 7*

| | |
|---|---|
| | Data records generally reasonably sufficient without requiring models (if carrying out hindcast accounts. |
| | Good or reasonable quality (often point) data is available, but modelling required for spatial or temporal interpolation and infilling purposes. |
| | Data is available but may be particularly uncertain and/or rely on remote sensed or very spatially and temporarily sparse measurements. |
| | Models are available to allow forecasting. |
| | Models that are suitable for interpolation or use process and mass balance principles to calculate account items exist. |
| | Models exist but are often highly uncertain and significant further work recommended to improve them to be better fit for purpose in informing policies and decisions. |

The presence of uncertainty should be clearly recognised and considered in any accounting process, particularly where local scale policy decisions may draw on information from the accounts or the models used in their generation. A first check is sensibility, that the model is being applied in appropriate conditions for the context the model has been developed and tested in, and that output results look physically and otherwise realistic. Sensitivity and uncertainty analyses are strongly encouraged to understand the range of uncertainty surrounding output predictions. An overview of model types and methods for sensitivity and uncertainty analyses is provided in **Appendix D**.

One of the first steps in sense-checking water and contaminant flows in an IOU should be to complete the mass-balance – that is, a flows account. If a mass balance cannot be calculated it is questionable whether the function of the IOU (catchment, sub-catchment, etc.) is understood well enough, quantitatively, to meet the reporting requirements of Clause 3:30 of the NPS-FM (2020).

The nature and quality of data currently able to be obtained will limit the spatial scale and temporal resolution at which freshwater accounts can be prepared at present. This is okay – there is value in making best practical use of what is currently available, learning what the biggest sources of uncertainty are, and improving over time.

**Recommendation 25:** Because different lines in the stock and flow accounts have different evidential bases, initial work should be created using the best available data and modelling

**Recommendation 26:** Where uncertainties detract from the integrity of the accounts, future work should prioritise identifying and eliminating critical data gaps and model limitations

# 7 NEXT STEPS

## 7.1 Progressive implementation of the FWAS

While ACA can be implemented relatively quickly, IFA is likely to take longer (though for some catchments it could be relatively quick). It is suggested that each region choose a few representative FMUs initially and use them to gain experience in implementing IFA.

**Recommendation 27:** MfE should develop, in partnership with mana whenua and regional authorities, a plan to progressively implement the FWAS at a rate that is consistent with resource management reform priorities and the availability of data, tools and funding.

## 7.2 Te Mana o te Wai

There are several work streams actively exploring and planning how to give effect to TMotW, including aspects of freshwater accounting. As this work comes to completion it would be wise to review the recommendations in this report for consistency with where these work streams land.

**Recommendation 28:** Future work should be undertaken to evaluate the interface between the design and operation of freshwater accounting systems and the wider aspects of TMotW and involvement of tangata whenua in current and water management in New Zealand.

## 7.3 Test Cases - IFA

Implementation of the IFA recommendations in this report will be less daunting when more information is available regarding the methods and resources required to implement IFA. Test cases which document the technical and resource requirements of IFA and illustrate the benefits to regional authorities and the community of preparing these accounts will help provide this information.

**Recommendation 29:** MfE should fund projects to test the feasibility of IFA in selected catchments or sub-catchments. These should be chosen to represent catchments ranging from those with little data and low resource use pressure through to those with substantial databases and well-developed modelling tools.

## 7.4 Implications of current or future legislative changes

Current legislative changes may impact the relevance of some of the recommendations in this report. It would be wise to review the recommendations when the results of current legislative overhauls become clear.

**Recommendation 30:** Future work should be undertaken to evaluate the interface between the design and operation of freshwater accounting systems and any new legislation, especially the current overhaul of the RMA 1991.

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