DEVELOPING SOURCE WATER RISK MANAGEMENT PLANS: NATIONAL CASE STUDIES

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ABSTRACT

Source water risk management plans (SWRMPs) are comprehensive plans designed to help manage and protect the quality and quantity of drinking water at its source. The Water Services Act 2021 mandates the development and implementation of SWRMPs for all registered water suppliers in New Zealand.

While limited guidance exists for SWRMP development, Tonkin & Taylor Ltd has worked with clients to provide a robust and scalable methodology across varied water supplies and multiple regions, including Auckland, Canterbury, Wellington, and the Hawkes Bay. This paper outlines our process and methodology, which includes identification of potential contaminant sources (hazards), catchment risk assessments (CRA) and the development of source-specific SWRMPs. An overview of several case studies is also presented to illustrate the process and outcomes.

Before identification of potential hazards can be undertaken, we develop a source-specific conceptual hydro(geo)logical model to identify pathways for potential contaminants to enter the water source; either into an aquifer or directly into surface water. Using this understanding of the hydro(geo)logy of the source water, we delineate catchment areas for the water source, known as Source Water Risk Management Areas (SWRMA). These areas are defined using various analytical or numerical tools depending on data/model availability and water source characteristics.

Hazard data within the SWRMAs are assimilated into CRAs, which form an integral part of understanding the risks to a water source. These assessments comprise desk-based components and physical catchment surveys. CRAs rely on a detailed understanding of the historic, current and future activities in the source water catchments which could pose a risk to the source water quality from potentially contaminating activities. In addition, they incorporate publicly available data from climate change models, such as sea level rise and flooding events.

Once hazard data and hydro(geo)logical pathways have been assessed, each potential contaminant source is identified and rated based on a qualitative risk rating. Hazards are assigned a risk rating, based on a likelihood and consequence risk matrix, resulting in the development of a source-specific CRA for each water supply. These CRAs are then used in the creation of SWRMPs for each water supply, by reviewing the identified risks and developing management solutions for those risks in partnership with our clients and their stakeholders.

SWRMPs support the long-term, multi-barrier approach to understanding the health and well-being of the source water, acknowledging Te Mana o Te Wai. The

SWRMPs are dynamic documents that include proactive management strategies which can trigger specific actions once new risks are detected in the catchments, as evidenced by the devastation of the January 2023 Auckland floods and Cyclone Gabrielle. Furthermore, they play a crucial role in supporting Water Safety Plans.

KEYWORDS

Water Services Act 2021, Source Water Risk Management Plan, Catchment Risk Assessment

PRESENTER PROFILE

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INTRODUCTION

Reforms to drinking water regulations in New Zealand have led to an overall strengthening of drinking water requirements and responsibilities to manage source water catchments and risks to public health and the environment. These reforms have resulted in the establishment of a dedicated water regulator, Taumata Arowai, and a new regulatory framework which includes:

- Water Services Act 2021 (WSA).
- Drinking Water Standards for New Zealand 2022.
- Drinking Water Quality Assurance Rules 2022.

Rules within the WSA are based on a multi-barrier approach to risk management of drinking water, alongside an open exchange of information between local authorities, drinking water suppliers, stakeholders and Taumata Arowai. As part of the multi-barrier approach, the WSA (2021) requires all drinking water suppliers to “prepare and implement” source water risk management plans (SWRMP) that outline how risks to source water will be identified, managed and monitored. SWRMPs are to be included in supplier’s drinking water safety plans (DWSP), which must be lodged with Taumata Arowai.

Local authorities also have obligations under the WSA to contribute to SWRMPs by sharing information regarding risks to source water and taking appropriate actions to mitigate these risks on behalf of drinking water suppliers. These agreed actions are to be recorded within the SWRMP, and local authorities must assess the effectiveness of these actions to manage risks to source water in their region. In addition, SWRMPs should give effect to Te Mana o te Wai, making an understanding of the tikanga and mātauranga Māori essential and necessitating engagement with whānau, hapū and iwi Māori.

Source water catchments are dynamic and in response, risk management processes need to be able to adapt. SWRMPs should, therefore, be 'living' documents that are continually updated to:

- Capture emerging risks within source water catchments;
- Changes to stakeholder relationships and processes; and
- Changes to the regulatory landscape.

Management and monitoring approaches set out in SWRMPs should then be updated to reflect these ongoing changes within source water catchments.

This paper outlines the methodology we have undertaken, in collaboration with our clients, to help develop their SWRMPs across varied water supplies and multiple regions, including Auckland, Canterbury, Wellington, Waikato and the Hawkes Bay. We use examples from around New Zealand to illustrate the steps in our methodology.

APPROACH

Effective source water risk management depends on a comprehensive understanding of the drinking water catchment, targeted management initiatives, and efficient interaction and communication among stakeholders. As such, the key components of effective drinking water source management include:

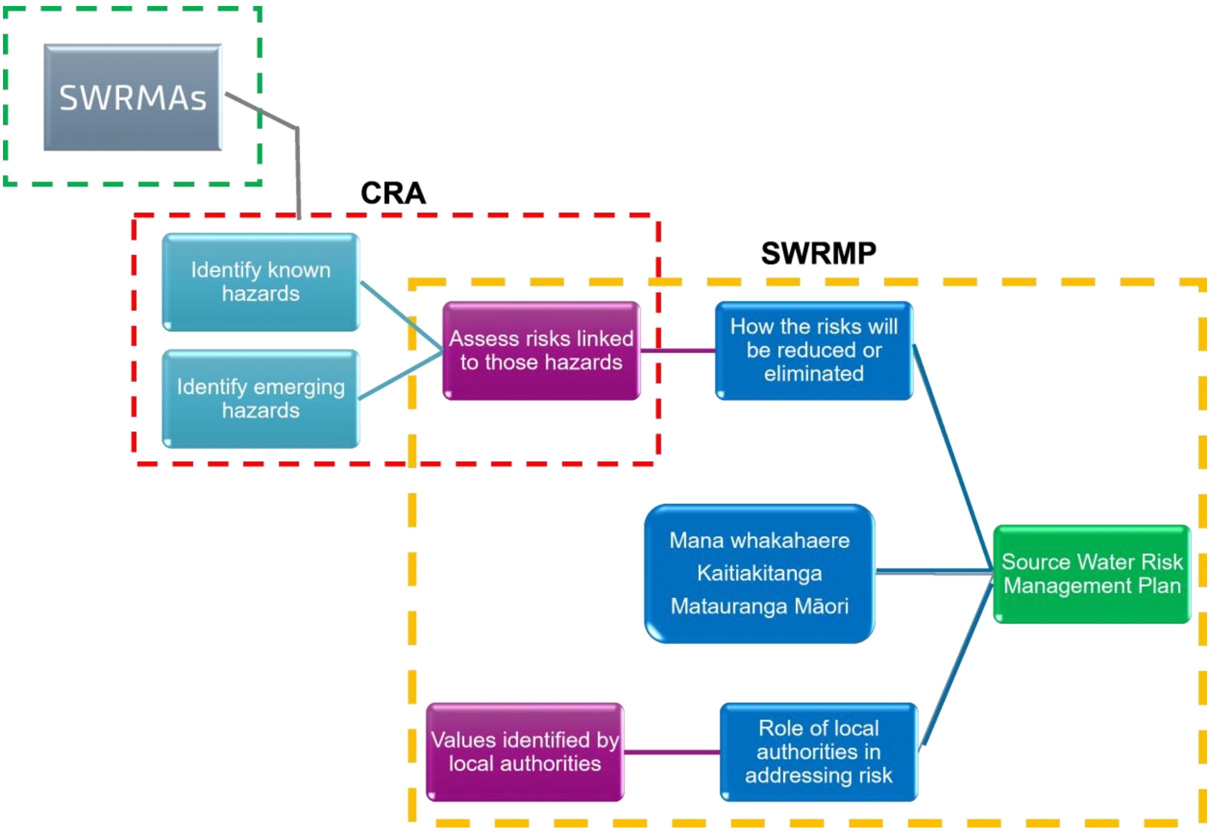
- Defining drinking water source areas (Source Water Risk Management Areas) and understanding how water moves through the source area to the intake location.
- An understanding of key contaminant sources (hazards) and potential pathways for contaminants to compromise source water quality, along with a mechanism to be alerted when new risks emerge and information is updated.
- Identification of the various regulators and stakeholders who have a role or mandate to manage sources of drinking water, defining the roles/responsibilities of those parties and how they interact with one another.
- Monitoring of source water quality (regional and local scale) as a means of 'early warning' of potential water quality risks.
- Implementing targeted management initiatives to address specific risks to source water quality, which should include continuous improvement planning.

The first crucial step in source water risk management is understanding where the source water comes from and how it flows overland and/or through the sub-surface to the water supply bore or intake location. This necessitates an understanding of the hydrology, geology and hydrogeology within a catchment and the development of a conceptual hydro(geo)logical model. Without this fundamental knowledge of the entire source water hydro(geo)logical system, drinking water source areas may be delineated incorrectly and/or potential pathways between a source of contamination and the source water could be missed.

The methodology we have followed in the development of source-specific SWRMPs is illustrated in Figure 1 and includes the following steps:

- Creation of a detailed (dependent on data availability) conceptual hydro(geo)logical model for the drinking water source under consideration.
- Delineation of Source Water Risk Management Areas (SWRMAs) following Ministry for the Environment (MfE) guidance (PDP, 2018).
- Undertaking a catchment risk assessment (CRA).
- Development of a source-specific SWRMP, in collaboration with our clients and their stakeholders, to manage and monitor identified risks to the drinking water supply.

Figure 1: Flow diagram of the Source Water Risk Management process – CRA process in red-dashed box, SWRMP process in orange-dashed box.



METHODOLOGY

In this section we describe each step in our methodology, along with examples from water sources across New Zealand. We have assisted a number of drinking water suppliers in their source water risk management process, across a range of water sources and catchments. These sources include deep confined groundwater for Waimakariri District Council and Hastings District Council, shallow groundwater and conjunctive supplies (groundwater and surface water combined) for Wellington Water and Watercare, and surface water supplies for Watercare and Matamata Piako District Council. Some of the source water catchments have included large urban centres, while others encompass predominantly rural and/or back country land.

CONCEPTUAL MODEL

Development of a detailed conceptual hydro(geo)logical model constitutes one of the most important steps in source water risk management. This model forms the foundation for all other facets of the risk management process, encompassing the selection of an appropriate method for establishing SWRMAs, assessing the vulnerability of the source water to land use activities, and identifying potential pathways through which contamination could reach the source water.

To construct a conceptual model, we collate and analyse publicly available data (geology, pumping tests, hydrogeology reports, well logs, etc.), as well as monitoring data provided by the drinking water supplier (groundwater levels, pumping tests, water flows, water quality, water age, etc.). This process allows us to ascertain the hydro(geo)logical characteristics of the drinking water source. The conceptual model should:

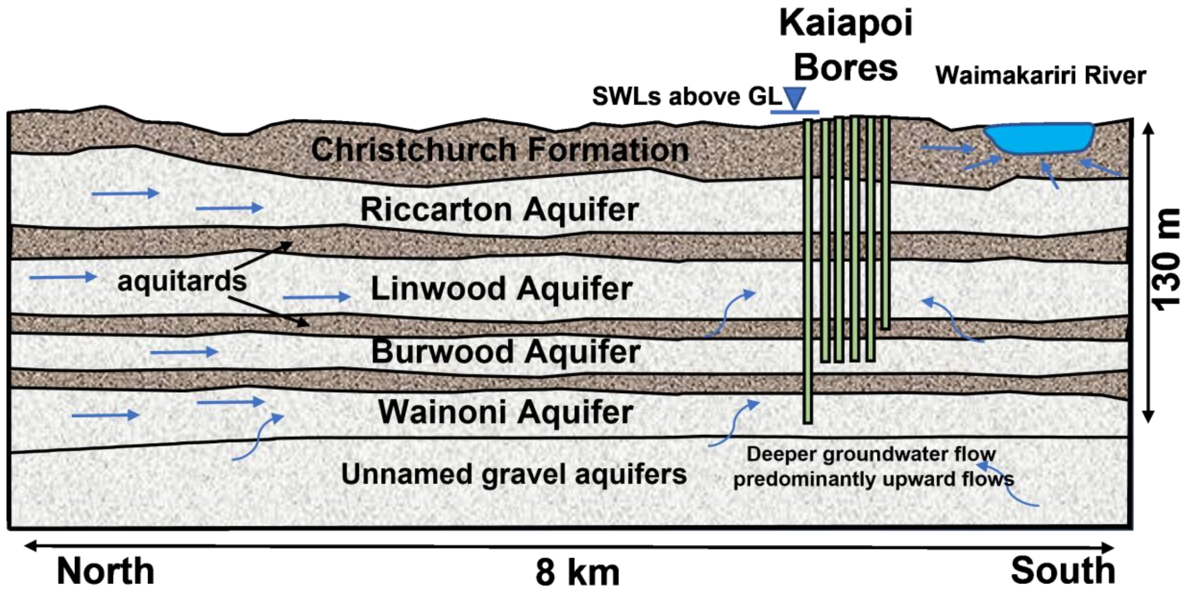
- Infer how the source water moves through the sub-surface and/or overland.
- Understand flow directions and rates, assess heterogeneity and define aquifer parameters.
- Assess raw water quality trends and source water age.
- Identify potential connections (pathways) between land/surface water and groundwater.

The information above, contained in the conceptual model, contributes to the delineation of SWRMAs and the overall understanding of risks to the source water quality.

Waimakariri District Council (WDC) operate and maintain twelve major water supplies across the Waimakariri District. In our work with WDC, we developed source-specific conceptual hydrogeological models for each water supply. We used schematic geological cross sections to illustrate our understanding of the source water hydrology/hydrogeology.

A schematic cross section of the Kaiapoi source water is shown in Figure 2. Groundwater is abstracted from deep confined aquifers that have old groundwater ages (greater than 100 years (mean residence time)) and flowing artesian conditions. Based on these source water characteristics, including multiple confining units in the thick overlying vertical geological sequence, we assessed the vulnerability of the Kaiapoi source water to surface contamination to be low. Historical raw water quality results were also analysed, which indicated no long-term or acute contamination.

Figure 2: Schematic geological cross section for the Kaiapoi drinking water supply.



SOURCE WATER RISK MANAGEMENT AREAS

Delineating Source Water Risk Management Areas (SWRMAs) (previously called Source Protection Zones or SPZ) generally constitutes the second step in our source water risk management process. SWRMAs are intended to define the source water catchment and are a key regulatory tool for managing potential risks to drinking water quality, by creating areas where specific rules and guidelines can be established for activities that may pose a risk to a drinking water source.

When generating SWRMAs, we follow the MfE guidance (PDP, 2018), which is based on best practice both within New Zealand and internationally. The guidelines recommend that three areas be delineated around each water supply, comprising:

- **SWRMA1** - an immediate 5 m protection area around the wellhead for groundwater sources and a 30 m protection area for conjunctive sources, to prevent direct contamination of the water source.
- **SWRMA2** - an intermediate protection area to reduce microbial contamination risks, based on a 1-year groundwater travel time and/or an 8 hour surface water travel time to the water supply bore/intake.
- **SWRMA3** - a catchment area based on the entire up-gradient area of the source water catchment, to ensure long-term protection of the water source.

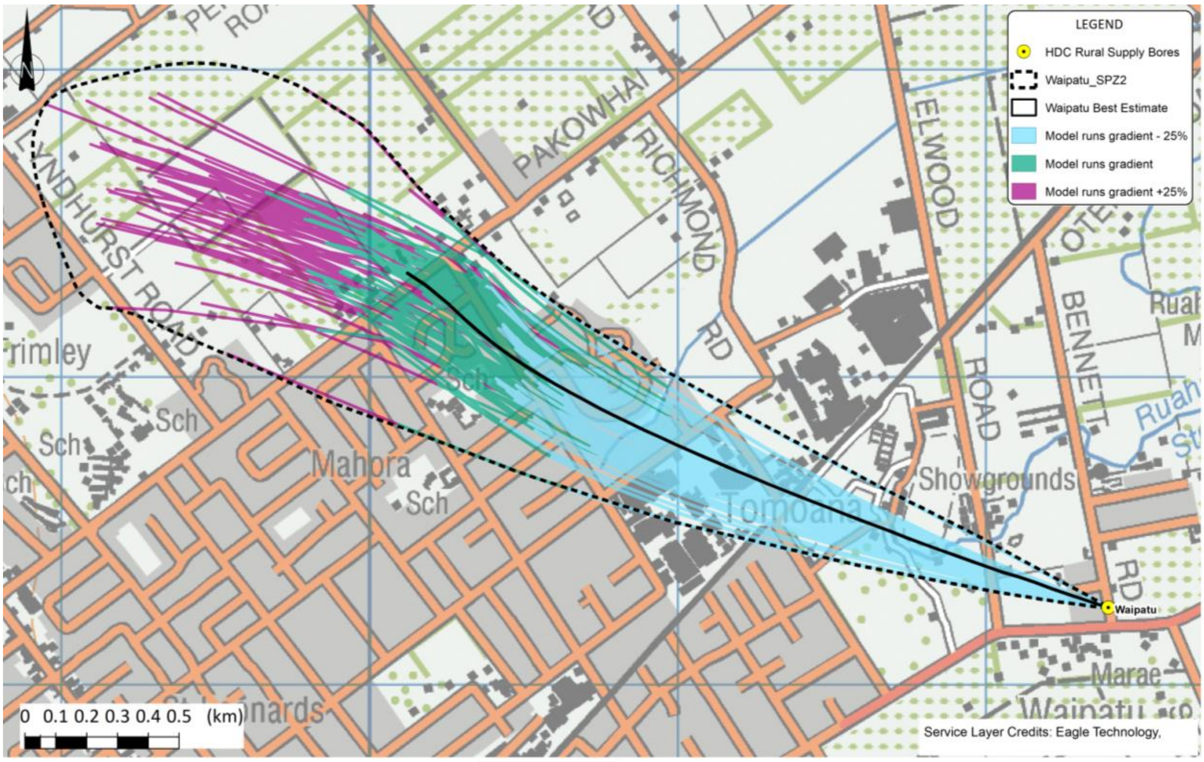
Both modelling and generic methodologies can be employed to define SWRMAs. The approach adopted should be based on the hydro(geo)logical conceptual model, which provides an understanding of the complexity of the source water hydrological system. Without a comprehensive understanding of the entire source water system, the resulting SWRMAs could prove to be inaccurate. This could lead to incorrect areas being assessed in the CRA process, causing the wrong hazards to be identified, and rules and regulations being applied to the wrong areas.

For Hastings District Council's small community water supplies, we used a combination of geospatial analysis, groundwater flow modelling and surface water velocity modelling to delineate the SWRMAs (the source water varies between each supply and includes groundwater and conjunctive sources). Among these small community supplies is the Waipatu drinking water supply, which includes a single production bore drawing groundwater from a confined aquifer.

To derive the SWRMAs for this water supply, we used the GNS capture zone delineation toolkit (Toews & Gusyev, 2013), which utilises the uniform flow equation for capture zone boundaries (Bear & Jacobs, 1965). We varied model parameters to account for the inherent uncertainty in the measurement of aquifer parameters and interpreted hydrogeological conditions, consistent with the MfE guidance (PDP, 2018). Figures 3a and 3b depict the results of the groundwater modelling used to delineate the SWRMA2 (SPZ2) for the Waipatu water supply. The pathlines from each sensitivity run are illustrated in each figure and the final SWRMA2 encompasses all groundwater pathlines derived from the multiple sensitivity models (Figure 3b).

Figure 3a: SWRMA2 (SPZ2) for the Waipatu drinking water supply. Pathlines from the aquifer parameter sensitivity modelling runs for porosity and hydraulic conductivity.

Figure 3b: SWRMA2 (SPZ2) for the Waipatu drinking water supply. Pathlines from the aquifer parameter sensitivity modelling runs for hydraulic gradient and variable flow paths.



CATCHMENT RISK ASSESSMENT

A catchment risk assessment (CRA) addresses clauses (a) and (b) in Section 43 (2) of the WSA. A CRA comprises the collation and identification of hazards that relate to the source water within the SWRMAs, including emerging or potential hazards, and an assessment of risks associated with those hazards. All hazards are identified irrespective of the resulting risk.

A significant challenge with this part of the methodology is making sure that all relevant data is acquired and reviewed. This requires robust management of collated data and a systematic review process. We have used GIS to manage the large volume of data needed to identify potential hazards, including having editable layers to document observations as data is reviewed.

Identification of potential hazards and pathways

Typically, we undertake desktop reviews of various data sources and site walkovers to identify any potential hazards. The information collated includes (but is not limited to):

- Land use mapping.
- Historical and present-day aerial imagery.
- Discharge and land use consents.
- Bores/wells databases.

- Land Use Registers or Hazardous Activities and Industries List (HAIL) sites.
- Wastewater and stormwater infrastructure.
- Observations and photos from site walkovers.
- Source water quality.
- Information from the drinking water supplier and stakeholders, where possible.

In addition, information relating to natural hazards, such as flooding and earthquakes, are also considered because these may increase the likelihood of a hazard reaching the source water (potential pathways). CRAs should be regularly updated, since land use activities within many source water catchments are continually changing and advances are being made in prediction modelling of natural hazards (e.g., updated flooding scenarios due to climate change).

For Wellington Water, we undertook CRAs for a total of eight drinking water supplies. Figure 3 includes maps of current land use in SWRMA2 and SWRMA3 for the source water which supplies the Wairarapa towns of Featherston and Greytown (referred to as the Waiohine water supply). Figure 4 includes primary land use maps from the LUCAS NZ Land Use Map (Ministry for the Environment, 2020), which show that the predominant land use in SWRMA2 is grazing for dry stock and dairy (grassland, both high and low producing). SWRMA3 encompasses the upper catchment of the Waiohine River, which comprises mostly natural forest. This water supply is modelled as conjunctive, since it is inferred that the unconfined aquifer targeted by the water supply bores (Woodside supply bores) is in hydraulic connection with the river. The aquifer system is predominantly recharged from surface water from the river and rainfall over the alluvial flood plain of the Waiohine River.

Potential contaminating rural activities associated with grazed farmland in SWRMA2 include:

- Application of chemicals, such as application of fertilisers and pesticides.
- Stock grazing and associated activities, such as storage of silage for feed, and discharge and storage of dairy effluent.
- Bulk fuel and chemical storage on rural properties, which can be a source of contaminants such as fuel, diesel, pesticides and fertilisers.

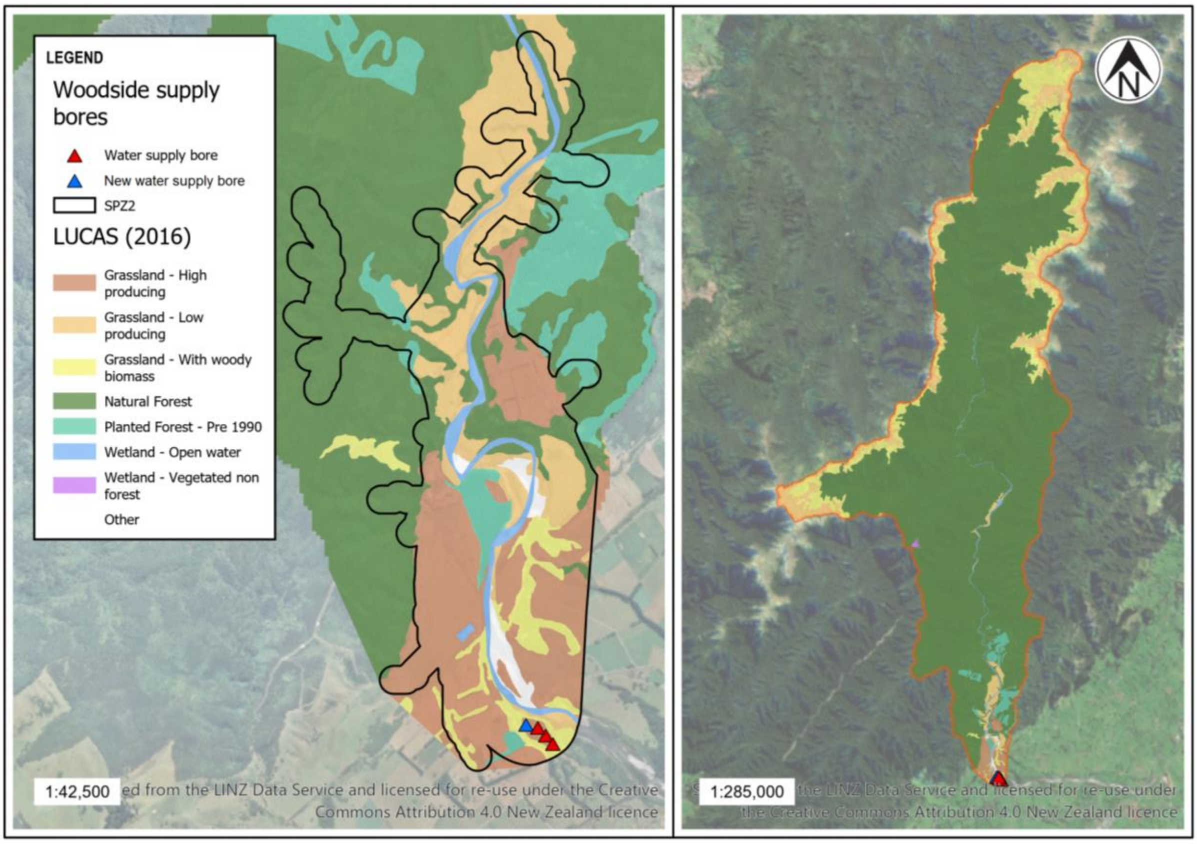
Potential pathways associated with this conjunctive source were assessed as:

- Direct recharge from the Waiohine River, especially when river levels are elevated, which can increase the hydraulic gradient between the river and groundwater system. This in turn can increase the rate of recharge of surface water to groundwater, increasing contaminant loadings to the source aquifer.
- Direct recharge into the underlying aquifer across the land surface, particularly during rain events when recharge may be increased.

- Surface water run off entering the river during rain events and subsequently reaching the hydraulically connected aquifer.

- Direct contamination through the water supply bores themselves and/or privately owned bores, due to surface water inundation (flooding of the Waiohine River) of the bores and ingress through casing or headworks defects.

Figure 4: LUCAS (2016) maps for the land use within SWRMA2 (SPZ2) and SWRMA3 for the Waiohine water supply, Wairarapa.



Source-based qualitative risk rating

For a risk to exist, a contaminant source (hazard) and a pathway to the source water must be present, either through surface flow or subsurface flow as groundwater. As summarised in the section above, part of our CRA work is to identify potential hazards and pathways within SWRMAs. Most of our clients have multiple drinking water supplies, with different source water catchments, serving a variety of populations. We have endeavoured to rationalise identified hazards to ensure consistency across numerous supplies and reviewers, and to reduce individual bias during the risk assessment process.

For each hazard identified, we determine a qualitative risk rating. This rating considers the potential harm (consequence) if a population is exposed, weighted against the likelihood of contamination entering the source. A level of uncertainty exists in anticipating the likelihood of an event occurring and also the consequences should it occur. We typically adopt drinking water suppliers' individual risk frameworks for assigning these risk ratings, otherwise we use the framework described in the Ministry of Health DWSP Handbook (2019).

The risk rankings, from very low to extreme, allows for risk management actions to be prioritised for those hazards most likely to cause harm. Typically, the final source-based qualitative risk rating of potential hazards is for the unmitigated case. Some drinking water suppliers have requested a mitigated risk assessment based on current monitoring and controls in their DWSPs. Depending on the controls and monitoring, the unmitigated risk can be lowered.

In the case of the Waiohine water supply, one of the potential pathways identified within SWRMA2 is flooding of the Waiohine River. The Greater Wellington Regional Council (GRWC) (2023) flood hazard mapping indicates that the Woodside supply bores are at risk of direct inundation with a 1% Annual Exceedance Probability. The flood mapping also predicts that most of the valley floor within the source catchment is sensitive to flooding. Flood waters can mobilise contaminant sources, which for rural activities associated with grazed farmland includes pathogens.

Given livestock can introduce pathogens into the source water catchment, flood waters as a potential contaminant hazard were assigned a consequence rating of 'Substantial' (Catastrophic). However, the likelihood of contaminants reaching the water source received a rating of 'Rare' since flooding of the Waiohine River, and therefore inundation of the bores, is expected to occur, on average, every 100 years according to the GWRC information. Based on these assigned consequence and likelihood ratings, flood waters within the source water catchment resulted in an unmitigated risk rating of 'Moderate'.

SOURCE WATER RISK MANAGEMENT PLAN

Working SWRMP

Risk management involves implementing controls (referred to as solutions) aimed at reducing or eliminating the risks identified during the CRA. These management solutions focus on the prioritized risks identified in the CRAs and are documented within the SWRMP. The solutions are tailored to the level of risk, recognizing the need to balance comprehensive risk management or elimination, with maintaining an adequate supply of drinking water, preventing significant economic impacts, and ensuring recognition of cultural and social requirements.

To address prioritized risks, the solutions developed in collaboration with the drinking water supplier are designed to target specific risks or to encompass broader approaches that might help manage 'unknown risks'. We have categorized solutions into two groups: operational and non-operational, as described below:

- *Operational solutions:* Primarily encompassing day-to-day risk management of identified hazards. These solutions form the core of the management approach. Solutions can either be preventive, aiming to stop contaminants from entering the source, or mitigative, aimed at minimizing consequences if contamination does reach the water source.

- *Non-operational solutions:* This category encompasses a range of activities that aid continual risk reduction in the source catchment or reduce uncertainties, thus refining risk assessments. These solutions may involve one-time efforts, ongoing engagement, research/review initiatives, or regulatory/policy actions, often shared in responsibility with local authorities.

Examples of operational solutions include increasing setbacks from intake locations, strengthening existing fencing, raising boreheads above modelled flood levels, regular raw water quality testing, and increased water quality monitoring frequency for pathogens and other sentinel contaminants during flood events.

Examples of non-operational solutions include research to improve characterisation of a hazard, enhanced GIS mapping, ongoing natural hazard and climate change predictions, risk communication to the community, engagement with community water groups, and establishing mechanisms to obtain information on all non-compliances from regional council for discharge consents within the SWRMA.

We assisted in the development of a SWRMP for a water supply that takes water from a confined aquifer within a SWRMA2 covering residential, commercial and industrial land uses. While the aquifer is categorized as confined, the hydrogeological characteristics of the aquitard vary spatially, and the layer is deemed 'leaky'. As a result, the aquifer is vulnerable to surface contamination because contaminants can migrate through the unsaturated zone into the source water wherever the aquitard is 'leaky'.

The wastewater network within SWRMA1 and SWRMA2 received the highest risk rating: 'Extreme'. Table 1 presents a small sub-set of potential operational and non-operational solutions to manage and monitor the risks related to the wastewater network, after consultation with stakeholders.

Table 1: Example of proposed operational and non-operational solutions documented in a SWRMP.

Operational Solutions	Non-Operational Solutions
Existing • Regular raw water quality testing from the bores, including pathogens and chemical determinands. • Online water quality monitoring for turbidity, electrical conductivity, temperature and pH as proxies for a change in water quality that may indicate a wastewater influence. • Condition assessment and renewal programmes for wastewater infrastructure.	**Existing** • Implementation of regional plan rules, which regulate discharges relating to wastewater.
Potential additional measures • Prioritise wastewater infrastructure condition assessment (within SWRMA1). • Review of raw water quality sampling suites to include wastewater indicators such as brighteners and whiteners. • Regular sampling of wastewater quality (quarterly) to determine typical contaminant	**Potential additional measures** *Research / review* • Quantitative assessment of potential cumulative impact of numerous leaking wastewater connections within SWRMA1 using an available hydrogeological numerical model.

Operational Solutions	Non-Operational Solutions
profile, then regularly reviewing and updating raw water quality sampling suites to ensure the raw water quality monitoring includes key contaminants present within the wastewater.	• Quantitative risk assessment (contaminant fate and transport) of a discharge event from constructed overflows at pump stations into significant surface water bodies using the numerical model. *Regulatory / policy* • Pending results from the hydrogeological numerical model assessment above, explore options for increased regulation of wastewater connections with local council. *Engagement* • Communicate with regional council Freshwater team on outcomes of the numerical modelling for significant surface water bodies and coordinate risk management approach. *Enhancement of Te Mana o Te Wai* • Support the Mana Whenua target attribute state for important surface water bodies, where all known point sources of pollution have been identified and remedied, and a full review of all discharge and water take resource consents is performed. • Proactively act on recommendations in the Mana Whenua implementation programme to develop a strategy / plan (by 2023), within the wastewater network resource consents, to contribute to achieving an *E. coli* B rating in surface water bodies' catchments.

Ongoing monitoring and review of the SWRMP

SWRMPs are dynamic and evolving documents that must be updated with national policy changes and should be adaptive to emerging risks, natural hazards and ongoing engagement with whānau, hapū and iwi Māori to achieve enhancement of Te Mana O Te Wai. The documents must also accommodate shifts in circumstances that might amplify or possibly mitigate identified risks, as well as changes to management solutions should their ineffectiveness be demonstrated. Consequently, a consistent process of regular monitoring and review becomes essential in ongoing risk management decisions and updates to SWRMPs.

Regular monitoring and analysis of data trends provide insights into whether the current management solutions specified in a SWRMP are effectively reducing the identified risks to source water quality. The following sources of information are suggested for monitoring:

- Trends in regular and periodic raw water testing.

- Tracking trends in regional council surface water and groundwater quality monitoring.

- Monitoring the number of consents and the stringency of conditions aimed at protecting source water quality, particularly where SWRMP solutions have influenced these conditions.

- Observing the management or remediation of any hazard sites named in the SWRMP.

- Reviewing reports from strategic plan implementation and key performance indicators.

Scheduled and event-based updates to CRAs are also crucial. The Auckland floods in January 2023 and Cyclone Gabriele in February 2023 underscore the importance of event-based risk assessments, which may lead to revisions of CRAs and consequently, SWRMPs. These natural disasters should trigger actions outlined in current SWRMPs for such events, including heightened raw water quality monitoring, alarms for submerged bore chambers, and established communication protocols. The effectiveness of these measures needs to be assessed, and SWRMPs should be updated if any process/equipment failures are identified or if improvements need to be made to processes.

Furthermore, site investigations, or review of high-definition satellite images/drone images, will provide details regarding whether bores and intakes were inundated by flood waters. We have been undertaking a review of satellite images for our ongoing CRA work and updating risk ratings and rankings based on whether water intakes were flooded during Cyclone Gabrielle.

The outcomes of such work might involve examining the integrity of bores and potentially raising or relocating infrastructure above the new flood level (if modelling suggests that these types of events will become more frequent due to climate change). All of these new measures must be documented within SWRMPs.

We suggest that updates to SWRMPs (and CRAs) be tracked through version numbers, with additional context added where there are significant departures from the previous risk management approach. Updated SWRMPs should be communicated to all stakeholders, including Taumata Arowai.

CONCLUSIONS

Under the Water Services Act 2021, all registered water suppliers are mandated to produce Source Water Risk Management Plans (SWRMPs). These plans require comprehensive assessments of the drinking water source, including the creation of hydro(geo)logical conceptual models, the delineation of management areas, and catchment risk assessments (CRAs).

This paper outlines our methodology for the development of SWRMPS, in collaboration with our clients. We have identified crucial steps in our methodology that ensure the resulting SWRMPs effectively mitigate risks to the source water. These include:

- Establishing a robust and accurate source-specific hydro(geo)logical conceptual model; to understand how contaminants at the surface could migrate to the source water (pathway).

- Using this hydro(geo)logical conceptual model to inform the derivation of SWRMAs. Otherwise, the resulting areas may be incorrect, leading to the identification of erroneous hazards.

- Employing GIS technology to manage the extensive data required during hazard identification; facilitating a systematic review process that reduces the chance of overlooking hazards.

- Making sure management solutions are not generic; our methodology emphasises determining targeted and customised management solutions specific to the source water under investigation.

Just as SWMRPs are designed to be 'living' documents, so too is our methodology. Our approach will continually be updated to accommodate changes in legislation, guidelines, and emerging data, ensuring the ongoing effectiveness of our methodology.

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